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Lessons learned from mega-disasters and future policy development on water-related disaster management in Japan

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Abstract

Japanese disaster management approaches have been enhanced and strengthened through repeated experiences of disasters in the past. The report presents lessons learned from the Great East Japan Earthquake and Tsunami, a disaster caused by a low-probability but extremely large hazard, and introduces the distinct features of Japanese water-related disaster management, including those enhanced and strengthened based on the recent lessons. Finally, drawing from Japan's experiences, messages to be sent to the world from the water-related disaster community are proposed.

Keywords: Disaster prevention; Great East Japan Earthquake and Tsunami; Japan; Mega-disaster; Policy development; Structural measures; Water-related disaster management system

1. Introduction

Japan's topography and climate give rise to certain challenges. The steeply mountainous nature of most the country's territory leads to concentration of population and industry on limited, narrow alluvial plains, and the typhoons and weather fronts make torrential rain a frequent occurrence. Japan has in consequence experienced floods and numerous other water-related disasters. In these circumstances, it has been the continuous implementation of water-related disaster management measures corresponding to society's needs that has supported Japan's continued development and establishment of its social stability.

Water-related disaster management in Japan has developed through the implementation of measures based on the principle of preventing the recurrence of disasters and leaving a more disaster-resilient nation to posterity, learning lessons from repeated experiences of disasters. One distinctive feature of Japan's approach to managing water-related disasters is that it deploys an appropriate combination of

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hard (structural) and soft (non-structural) measures at all stages of disaster management (pre-disaster, emergency response, and post-disaster reconstruction and recovery). Another feature of the approach is that it does not largely rely on disaster response after the event; rather, it places emphasis on well-planned implementation of preventive measures at the pre-disaster stage. Both the legal framework and the technologies underpin water-related disaster management in Japan, which has undergone continual improvement as a result of numerous experiences of disaster.

During the Great East Japan Earthquake and Tsunami, Japan's territory was subjected to low-probability but extremely large hazards: the great seismic motion and the tsunami. While this disaster demonstrated that Japan's disaster management measures had been effective to a certain extent, it also brought us a lesson in that we had not adequately prepared for a situation in which the extent of the hazards greatly exceeded the design capacity of coastal levees and other structures. Learning from the lessons, understanding the importance of the 'assumption of hazards of any possible magnitude', new water-related disaster management approaches are being introduced in Japan. Thus, Japan is continuing on the same road that it has followed in the past, the road of learning from previous disasters and upgrading its disaster management capability.

The generating mechanisms of meteorologically or hydrologically induced water-related disasters are different from those of earthquakes and tsunamis. However, the issues and the countermeasures drawn from the Great East Japan Earthquake and Tsunami have enough generality and can be applied to other water-related disasters including hydrological and meteorological ones. Accordingly, in this study, the Great East Japan Earthquake and Tsunami and the lessons learned are described first. The distinctive features of Japan's approach to water-related disaster management, which has been enhanced through repeated experiences of disasters in the past, including those from the earthquake and tsunami, will be systematically presented together with details of the legal framework and the technologies that underpin the approaches. Our world is now facing the risks of both climate change and mega-earthquakes. Given this situation, we believe that, by sharing our experiences with other countries, Japan can make a major contribution to improving the world's disaster management capability.

2. The Great East Japan Earthquake and Tsunami and the lessons learned

2.1. A brief account of the earthquake

On 11 March 2011, a 9.0 magnitude earthquake occurred in the Pacific Ocean off the coast of Tohoku, causing major seismic motion across a large area of Japan. Approximately 30 minutes after the earthquake, a giant tsunami struck a 650-km stretch of the Tohoku coastline, inundating an area of over 500 km^2.

The tsunami left about 20,000 people dead or missing, and caused the total collapse of about 130,000 buildings, the partial collapse of about another 260,000 buildings, and damage to about 730,000 more buildings. The damage from the disaster was immense, with up to about 470,000 people evacuated, while the economic losses amounted to 16.9 trillion yen.

The distinctive features of the Great East Japan Earthquake and Tsunami were the low probability but massive scale of the earthquake and the coincidence of the tsunami hazard with the seismic vibration. The earthquake and tsunami resulted in damage to an extremely large area and caused extensive knock-on effects including power outages, nuclear accidents, and repercussions for industry worldwide through the supply chain. For details of the Great East Japan Earthquake and Tsunami and lessons learned, refer to Ranghieri & Ishiwatari (2014).

2.2. Lessons from the Great East Japan Earthquake and Tsunami

The lessons learned from the Great East Japan Earthquake and Tsunami are described below.

1. Measures developed after the Great Hanshin-Awaji Earthquake (1995), including the earthquake-proofing of buildings and infrastructure, were effective against large seismic motion to a certain extent.

In January 1995, Japan was hit by the Great Hanshin-Awaji Earthquake, which left about 6,500 people dead or missing. The majority of the victims of this earthquake died when buildings constructed according to the old (pre-1981) earthquake-resistance standards collapsed, followed by a lesser number of those who died in the fires that broke out after the collapse. In addition, sections of the elevated Kobe expressway, the region's arterial road, buckled or collapsed. In response to the lessons learned from this disaster, Japan has carried out a systematic program to promote earthquake-proofing in buildings and seismic reinforcement of the country's elevated roads. Consequently, the buildings that collapsed during the Great East Japan Earthquake and Tsunami were mainly structures built according to the old earthquake-resistance standards. Despite the extremely large seismic motion, the majority of buildings having undergone adequate seismic reinforcement escaped damage. Also, bridges that had been seismically reinforced did not collapse or sustain other serious damage, which made it possible for these to be used as escape and relief routes as the authorities were able to bring them back into service soon after the earthquake (see Figure 1).

A distinctive feature of disaster management in Japan, the systematic implementation of preventive measures in the pre-disaster phase, can be considered a success. Continuous investment in such measures can consequently be regarded as essential.

2. Preparedness for a tsunami that greatly exceeded the design capacity of the defense structures was not sufficient. It is important to mitigate human and economic losses by assuming possible hazards of maximum scales and deploying 'multi-layered protection', combining structural and non-structural measures.

Fig. 1. Effect of seismic reinforcement of bridges after the Great Hanshin-Awaji Earthquake.

Since the height of the tsunami that struck the coastal area during the Great East Japan Earthquake and Tsunami greatly exceeded the design height of the defense structures, the tsunami overtopped coastal levees, and inundated a large area inland. Although levees and other facilities in some areas did retard the advancing tsunami and reduce the extent and depth of inundation, many of them collapsed after they were overtopped. Advancing at high speed, the waters of the tsunami inundated inland areas to a great depth within a short time, and swept away numerous buildings and other property, causing extensive damage and claiming many lives.

As we reflect on these events, it is recognized all the more clearly that 'hazards can be of any possible size', thereby highlighting the importance of implementing all possible measures to 'protect lives whatever it takes' even if a tsunami of the maximum-possible scale occurs. Accordingly, policy was developed for tsunami protection measures, applicable also to reconstruction and recovery work after the Great East Japan Earthquake and Tsunami (see Figure 2). As referred to in Section 3.4.2.1 (ii), the Act on Regional Development for Tsunami Disaster Prevention became law in December 2011 to actually implement this policy. The policy aims to promote tsunami countermeasures of 'multi-layered protection', which is to flexibly apply structural and non-structural measures in comprehensive regional development. Against comparatively frequent tsunamis with certain scales, structures such as coastal levees will be developed to protect lives and assets, and to conserve national land. Against tsunamis with maximum scales that would cause devastating damage, although the frequency of occurrence is quite low, non-structural measures will be applied in addition to the structural measures for mitigation of damage. Taking into account the characteristics of each region, existing public and private facilities are fully utilized in the application of measures. Under the said concept, the Act on Regional Development for Tsunami Disaster Prevention became law in December 2011. In the development of coastal levees, to cope with tsunamis of a greater scale than the defense-design height, technological development will be promoted to make structures resiliently continue to exert their effects even after being overtopped. This example of the new policy development illustrates a distinctive feature of disaster management in Japan: the strategy of continuous improvement of both a legal framework (Tsunami Disaster Management and Regional Development Act) and technologies (technological development of resilient coastal levee structures) in response to the lessons learned from previous disasters.

3. An extensive transportation network provided alternative routes for rescue activities and transportation of relief goods, and road embankments were effective in preventing tsunami propagation further inland. It is important to incorporate or mainstream disaster risk reduction in every social system.

In the extensively damaged coastal areas, many roads including arterial routes were cut off by piles of debris or structural damage. Keeping routes to the coast open for rescue and relief operations was a matter of life and death. Accordingly, in the aftermath of the disaster, the Tohoku Regional Bureau of the Ministry of Land, Infrastructure, Transport and Tourism immediately began clearing roads that run from longitudinal roads, which pass through inland areas where damage was less severe, to the coastal regions. Eleven routes had been cleared within one day after the disaster and fifteen routes within four days after it, providing access for ambulances and police, the Self-Defense Force and other emergency-service vehicles. For details of this operation, refer to Tohoku Regional Bureau, Ministry of Land, Infrastructure, Transport and Tourism (2014).

The Sanriku Expressway, which runs along the coast of Tohoku region, was planned to run through a hilly area in view of the effects of the tsunami. As a result, it functioned as an evacuation area for neighboring residents and as a road for emergency transport as an alternative to the damaged Route 45, which

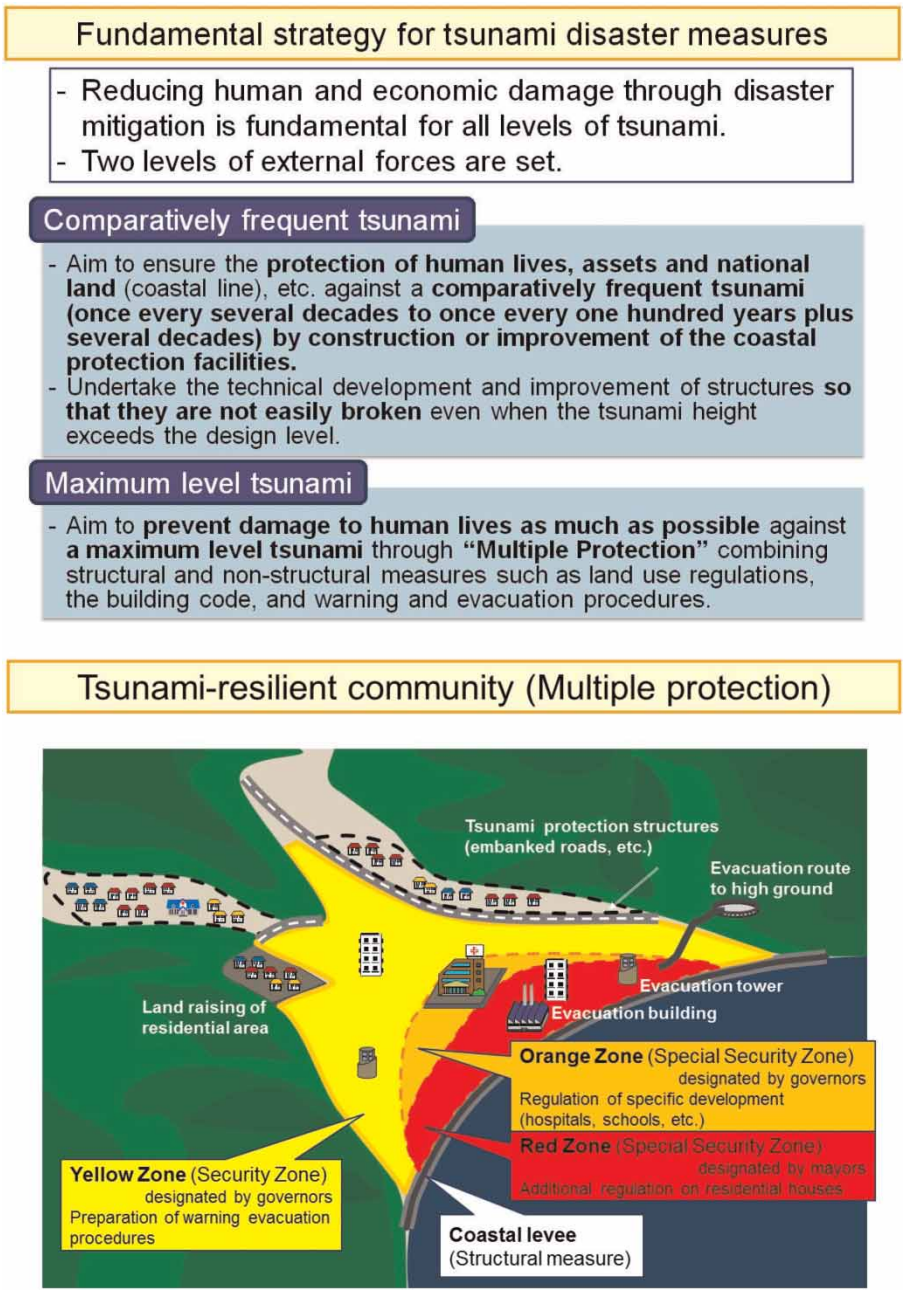

Fig. 2. New policy development for tsunami prevention measures.

runs along the coast. The East Sendai Expressway, built on an embankment 7–10 m above its surroundings, obstructed the flow of the tsunami, which had traveled almost 4 km inland across the Sendai Plain, thus functioning as a barrier to the advancing tsunami water and debris. Furthermore, local residents were able to escape onto the embankment (see Figure 3).

Fig. 3. An expressway functioned as a tsunami barrier and an evacuation site.

These examples show that expressways developed to secure alternative routes support rescue and relief operations and recovery activities after disasters, and that road embankments work as barriers to limit the inundation area. The aforementioned cases demonstrate the importance of incorporating the perspective of disaster management not only in the defense structures, such as coastal levees, which are developed for the purpose of disaster management, but also in all of society's systems.

4. Records of past disasters and the provision of adequate hazard information to the public in advance supported appropriate evacuation behavior. It is important to collect and pass on disaster records to others, and to apply technologies and other scientific expertise, including those of inundation prediction, in providing disaster protection structures or when pursuing urban development.

The region damaged by the tsunami in the Great East Japan Earthquake and Tsunami had been recurrently hit by the same phenomenon, with the frequency of once every few decades. This means that knowledge of the threat posed by tsunamis had been passed down from generation to generation, and that local people were well aware of the significance of preparing for disasters. There are stone markers scattered all over the region, commemorating the damage incurred by past tsunamis or showing the height that they reached. Without doubt, these played a part in keeping residents aware of the importance of preparing for the tsunamis that occur once every few decades.

In Kamaishi City, where the tsunami claimed about 1,000 victims out of a population of about 40,000, elementary and junior high-school students had been taking part in repeated evacuation drills and disaster-education activities using tsunami hazard maps. As a result, the death toll for elementary

and junior high-school children was comparatively low, with five fatalities out of approximately 2,900 children in these age groups. The death rate was about five percent of that of the whole city.

Conversely, the occurrence of the gigantic tsunami and the consequent extensive damage revealed the limit of disaster countermeasures excessively dependent on structure development, even though the structures such as coastal levees are effective against tsunamis that do not exceed the defense-design height. It cannot be denied that the existence of such structures gave people a false sense of security due to the inadequate communication about the risks. Also, the tsunami hazard maps made no reference to a low-frequency mega-tsunami, which occurred on this occasion, and in many places, the actual inundation area was far greater than the area shown on the map. As a result, evacuation behavior may not have been based on an accurate understanding of the local risks arising from the disaster.

There are limitations in *ex-ante* risk assessment technologies. It is important to develop techniques to enable assessment that is based on more diverse multiple scenarios, by collecting a wider range of data, including the analyses of historical documents, and so on. Moreover, the success of the evacuation in Kamaishi City proved awareness-raising, education and evacuation drills used in normal times to be effective. Knowledge-sharing on initiatives that enable effective use of hazard maps is as important as that of producing the hazard maps. Adequately assessing the risks and accurately informing local residents about these risks are indispensable for appropriate evacuation behavior and the development of a community's disaster-resilience. When 'multi-layered protection' based on the 'assumption that the hazards can be of any possible size' is being developed for future tsunami protection, initiatives for the aforementioned purposes must be stepped up. In tandem with improvements in the accuracy of flood prediction and other technologies, there must be more consistent application of the technological knowledge to assess the risks and provide disaster-risk management in an effective manner. For this purpose, it is important to make and pass on to others, not only the accurate records of the inundated area and its depth, and so on, but also detailed records of the activities of residents and relevant administrative bodies.

Passing on knowledge of relatively low-frequency disasters such as the tsunami is not an easy task. However, various initiatives are under way in the affected areas to collect, store and pass on records of disasters.

As stated above, many lessons have been learned from the Great East Japan Earthquake and Tsunami. Recovery and reconstruction are being progressed, with a view to develop safer regions for posterity, making use of the lessons learned from the disaster.

Japan has only just begun the process of improving its disaster management in response to the lessons learned from the Great East Japan Earthquake and Tsunami. The evaluation of the results of this process will be a task for posterity. In any case, Japan should continue on the road of continuously improving its legal framework and technologies in the light of past experiences of disaster.

3. Japan's water-related disaster management system: learning lessons from numerous and diverse disasters

3.1. Overview of Japan's water-related disaster management system

The previous section reviewed the lessons learned from the Great East Japan Earthquake and Tsunami and described how disaster management in Japan is being enhanced in response to these lessons. As stated in that section, disaster management in Japan has been strengthened in the light of repeated

experience of earthquakes, mega-water disasters and other events. Indeed, it can be said that disaster management in Japan has been shaped by a process of continuous improvement. Here, we outline the special features of disaster management in Japan, in particular water-related disaster management, and how this has been shaped by the country's extensive experience of disasters.

Since one distinctive feature of Japan's water-related disaster management system is that it deploys an appropriate combination of structural and non-structural measures at all stages of disaster management (pre-disaster preparedness, emergency response and post-disaster recovery and reconstruction), we will describe here measures for each phase in chronological order. Also, since disaster management in Japan has, in the light of repeated experiences of disaster, been supported by continuous improvement of its legal framework and technologies, the major aspects of this framework and the most important of these technologies are described below.

3.2. Pre-disaster

3.2.1. Well-planned investment in disaster management measures in the pre-disaster phase. On the basis of assessment of potential damage, disaster management plans are made and measures are consistently implemented in the pre-disaster phase. These measures form a multiple defense, appropriately combining structural and non-structural components. The measures include construction of embankments and other river improvements; preparation and publication of hazard maps to provide guidance on safe land use and to facilitate flood response measures by residents, businesses and other entities; construction of systems for early warning based on flood forecasts and other information; evacuation and disaster response training and drills; and so forth.

3.2.1.1. Legal framework

(i) The River Law provides for the establishment of a flood-control system (under long-term 'fundamental river management policies' and 'river improvement plans'). The purpose of the River Law is 'to contribute to land conservation and development, and thereby maintain public safety and promote public welfare by administering rivers comprehensively to prevent occurrence of damage due to floods, tsunamis, storm surges, etc., ensure appropriate river use, maintain the normal functions of the river water, and improve and conserve the fluvial environment'. The river administrator designated under this law (for example, the Ministry of Land, Infrastructure, Transport and Tourism in the case of class A rivers) is authorized to draw up long-term 'fundamental river management policies' and short- and medium-term 'river improvement plans', and to carry out river improvement based on these plans. Generally, river improvement plans are drawn up after consideration of the views of academic experts, local residents and local mayors. The fact that these plans are both based on the law and drafted with consideration for local opinion ensures proper implementation of the measures that these plans provide for.

(ii) The Flood Fighting Law provides for the support of initiatives by local communities against floods. The River Law mainly provides for long-term structural measures. In contrast, the Flood Fighting Law provides for non-structural measures including actions by flood fighting organizations; transmission of flood forecasting information to local residents by administrative agencies; provision of risk information through the designation of areas prone to flooding and publication of flood hazard maps; promotion of the participation of residents' and businesses' flood fighting activities;

and implementation of other necessary measures. The River Law and the Flood Fighting Law operate in tandem to promote integrated structural and non-structural measures.

3.2.1.2. Disaster management technology

(i) Run-off and inundation prediction technologies are used for analyzing cost-effectiveness of investments at the pre-disaster stage, risk assessment, and so on. Whenever plans for river improvement are being prepared, water levels and river discharges for floods are calculated using run-off and hydraulic analysis based on observed values of accumulated precipitation and river discharge. In the assessment process for flood control projects, areas susceptible to inundation are identified by flood inundation analyses, and the benefits resulting from flood control measures are evaluated. In addition, flood inundation analysis technologies are used to identify the possible impacts of inundation (inundation damage risk assessment) and so forth. In recent years, in order to adequately comprehend flood disaster risks, quantitative assessment of damage categories that were not conventionally assessed due to difficulties in monetization has been introduced in the assessment process for flood control projects. Human damage, impairment of social function, and cascading economic impacts are among the newly introduced damage categories (see Figure 4).

Use of the above-named analytical technologies facilitates efficient and effective project planning and implementation through quantitative assessment of the effectiveness of flood control measures.

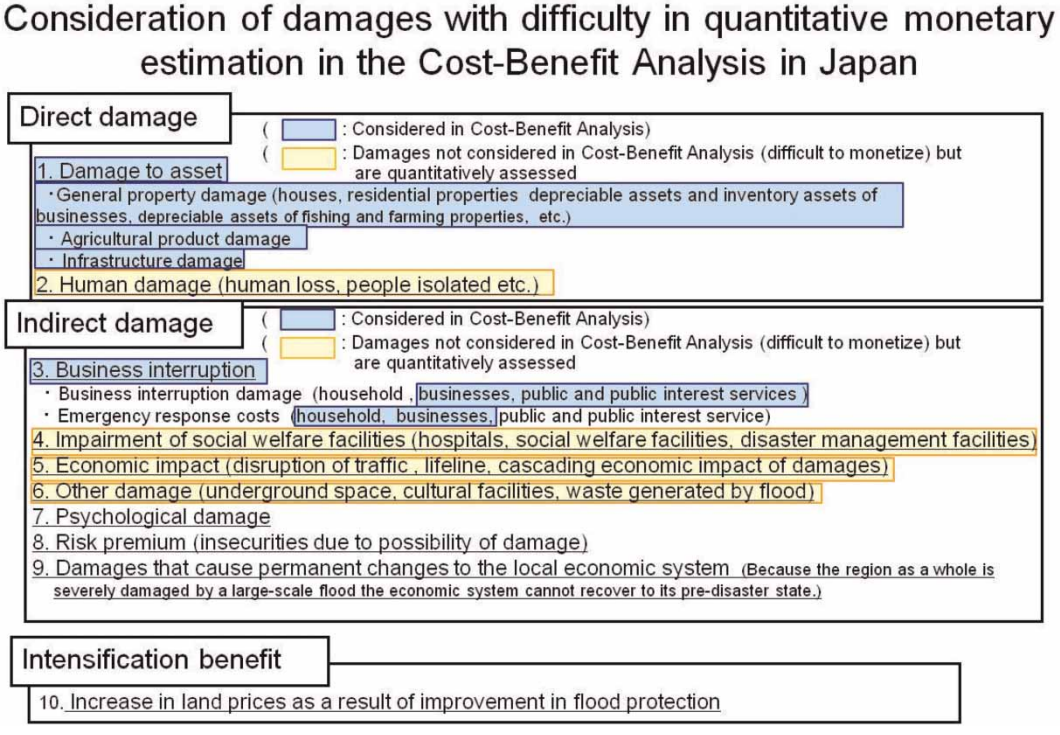

Fig. 4. Newly introduced damage categories in the assessment of flood control projects.

3.3. Emergency response

3.3.1. Appropriate infrastructure operation and other emergency responses. Emergency responses include the appropriate operation of dams, sluice gates and other types of infrastructure based on rainfall and water level information; the provision of flood and other relevant information to assist flood fighting activities and the evacuation of residents; rapid removal of flood water using drain pump vehicles; and other measures as appropriate.

3.3.1.1. Legal framework

(i) The river management framework secures responsible local offices for river maintenance and management. The existence of designated 'public facility administrators' is an important feature of Japan's public infrastructure management system. In the case of a river, the River Law designates a 'river administrator', such as the Minister of Land, Infrastructure, Transport and Tourism for class A rivers. In normal circumstances, the river administrator is responsible for river-related studies and planning; river patrols; maintenance and management of dams, sluice gates and other types of infrastructure; construction work on embankments and other defense structures; and conservation and improvement of the fluvial environment. During flood events, the administrator is responsible for tasks including monitoring precipitation and water levels; providing flood forecasts and other relevant information; operating dams, sluice gates and other types of infrastructure; ensuring rapid removal of flood water using drain pump vehicles and other methods; and post-disaster surveys. Making a single entity responsible for infrastructure management during both normal circumstances and flood events fosters the accumulation of knowledge and experience relating to rivers and river basins, and the development of a sense of responsibility, thus facilitating appropriate responses to an emergency.

3.3.1.2. Disaster management technology

(i) Forecasting and warning technology enables infrastructure management based on hydrological forecasting, assisted by real-time data transmission systems and radar technology. Japan frequently experiences heavy rain events during typhoons or in the rainy seasons, and riverbank steep slopes cause quick flood run-off. For these reasons, it is important to accurately monitor such hydrological and hydraulic information as precipitation, river discharge and water level without delay, provide relevant information to the authorities and residents concerned, and operate dams, sluice gates and other types of infrastructure appropriately using the information. Also, to enable successful evacuation by residents, accurately predicting water levels is essential. The response to rapidly occurring emergencies on Japan's rivers is facilitated by the deployment of real-time data transmission systems of precipitation and water level data, the deployment of radar systems for precise monitoring of precipitation distribution, and forecasting and warning technologies that utilize these observed data.

3.4. Post-disaster response

3.4.1. Surveying, analyzing and recording damage. Surveys, analyses and records of damage are used for rapid planning of recovery and reconstruction. After a flood event, river administrators must survey and collect such information as flood high-water marks (maximum river water levels during a flood), flood inundation area, and incurred damage. The results of surveys are used for improving the analytical methods that are essential in river improvement planning and so forth. They are also reflected in the

improvement of plans for river improvement works and maintenance. Data regarding flood damage are indispensable for promoting public understanding of the need for flood control measures.

3.4.1.1. Legal framework

(i) The water disaster statistical survey system is an important data-compiling system. Under the Statistics Act, since 1961, surveys of damage to personal or business property, rivers, roads, or other public infrastructure, transport, telecommunications, or other public services from floods, inundation by insufficient drainage, storm surges, or debris flows have been carried out with the aim of compiling basic data required for the implementation of various flood control policies. It has become an institutionalized procedure that the municipal governments conduct surveys and reports on damage to personal and business property, and the prefectural governments conduct surveys and reports on damage to public infrastructure (see Figure 5). These surveys and reports help to build up reliable and consistent records of water-related disaster damage.

3.4.2. Recovery and reconstruction for future damage reduction. Preventing recurrence of disaster is a priority when rebuilding damaged infrastructure. Reconstruction in disaster-stricken regions provides these areas with greater reduction of disaster risks.

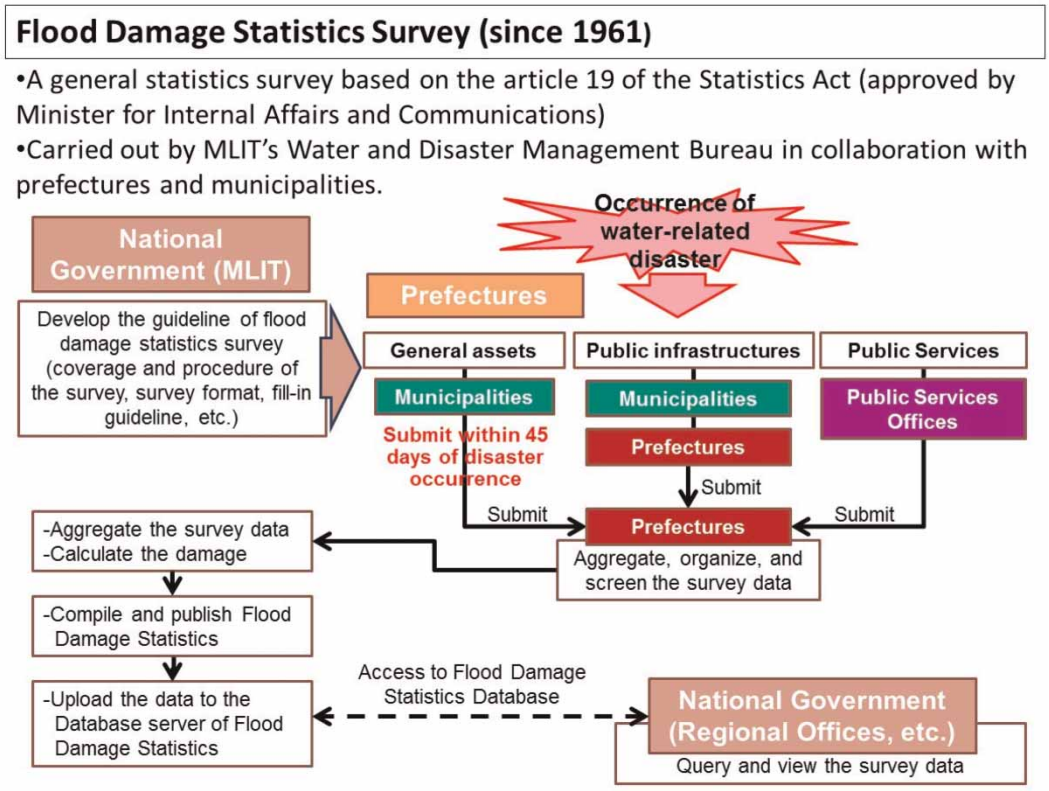

Fig. 5. Flood damage statistics survey since 1961.

3.4.2.1. Legal framework

(i) The first significant component of the legal framework is the post-disaster recovery projects system. Prompt and sound recovery of public infrastructure damaged in natural disasters is important for securing social welfare. However, the cost of rebuilding public infrastructure can burden local public bodies with impulsive and heavy spending. To address this issue, Japan has set up a system for recovery projects aimed at various kinds of public infrastructure, under which central government increases its share of these expenditures depending on the local public body's financial situation. Unlike as for other public works projects, funds are made available rapidly, in accordance with the project's urgent needs for recovery, and damage assessments for the purpose of determining the projects are carried out as soon as local public bodies are ready. The local public body can start reconstruction work immediately after a disaster before completion of the damage assessment. Furthermore, if restoring infrastructure to its pre-disaster condition is inappropriate or significantly difficult, then the reconstruction may include qualitative improvements in position, configuration, materials, dimension, and so forth. For example, a winding road that was washed away due to a sediment disaster may be replaced by another road built on a new route, such as a tunnel connecting both ends of the damaged section. Under this system, post-disaster recovery in Japan can take into account prevention of disaster recurrence.

(ii) The other significant component of the legal framework is the Act on Regional Development for Tsunami Disaster Prevention. As recovery continues in areas that suffered major damage during the Great East Japan Earthquake and Tsunami, regional development must promote resilience to tsunami disasters that may occur in the future. There was a need to establish a general system, covering the whole of Japan, that would be capable of preventing or mitigating any future tsunami disasters. In response to this need, the Act on Regional Development for Tsunami Disaster Prevention became law in December 2011. In accordance with this act, 'regional development for tsunami disaster prevention' is being promoted through a principle of 'multi-layered protection' combining structural and non-structural measures. The act authorizes prefectural governors to determine and announce the possible extent of tsunami inundation (including the areas thought to be at risk of flooding in the event of a tsunami and the estimated depth to which they would be flooded). Using these projections, municipalities can develop regional development plans in such a way as to promote integrated tsunami disaster prevention, and implement various measures such as setting up warning and evacuation systems for residents, and applying restrictions on development and buildings' construction.

4. Conclusion

Japan has experienced numerous disasters due to its challenging topography, and to its climate. Experiencing such disasters has enabled the country to improve its disaster management capability.

As the disaster risks from climate change and mega-earthquakes increase, the sharing of Japan's experiences of disaster with the world should contribute to enhancing the world's ability to address and manage disasters. In the light of its experiences, it would be appropriate for Japan to send the following message to the world.

(i) Strengthening disaster management investment for 'disaster prevention'

At present, most countries can hardly be said to be making sufficient investment in disaster prevention. In most countries, disaster management has remained at the stage of emergency response and relief

during disaster events. However, disasters do not only claim many human lives. By destroying buildings and other property, they also sweep away the economic development gains so far achieved. In the developing countries, eradicating poverty is a priority task. It is necessary to understand that disaster prevention is important for laying the foundations of growth and protecting the fruits of development. Japan's experience of achieving economic development under challenging topographical and climatic conditions demonstrates that disaster prevention measures make economic sense, given the costs resulting from disaster damage.

(ii) Appropriately combining structural and non-structural measures

Early warning systems, disaster education, and other non-structural measures are effective in protecting human life when disasters occur. However, the evacuation action, the primary non-structural measure, cannot by itself protect property from disasters. This means that the development gains may be lost in disasters, which would result in delaying the achievement of the international goal of eradicating poverty.

Structural measures are effective not only against disasters that are within the design capacity of defense structures, but also, to a certain extent, against disasters exceeding this design capacity (see Figure 6). Furthermore, even when a disaster exceeds the design capacity of defense structures, an appropriate combination of structural and non-structural measures can minimize damage. In response to the lessons

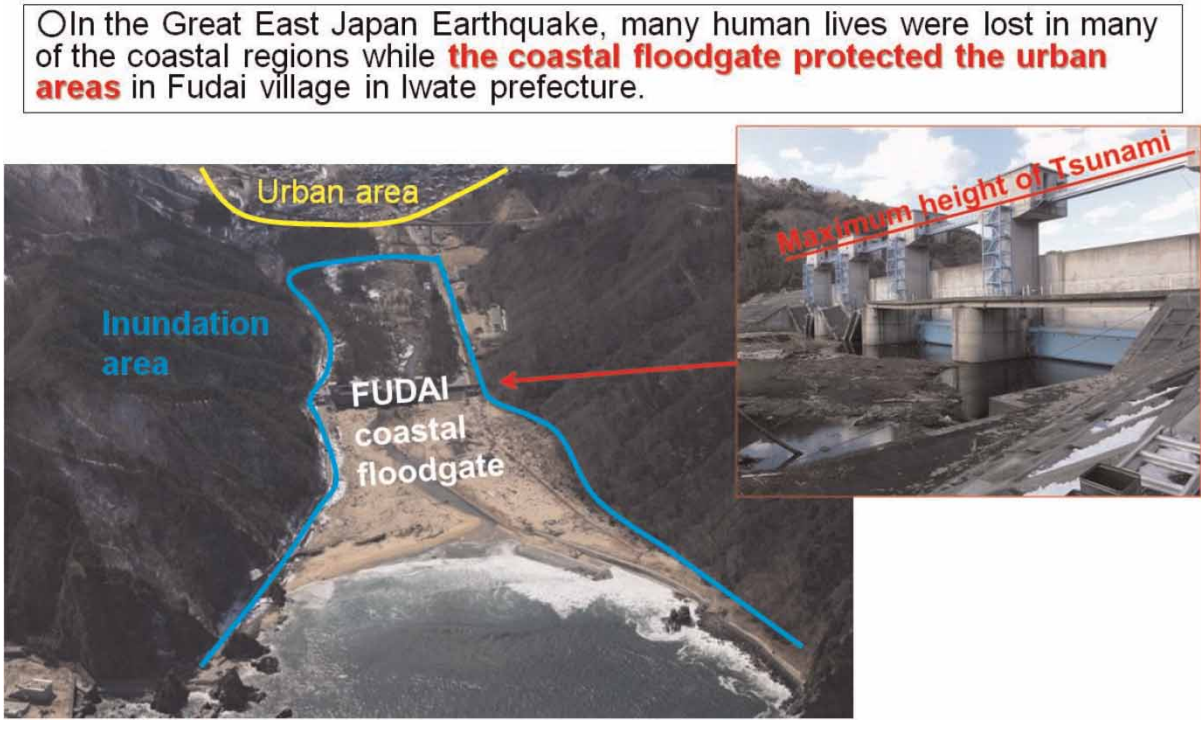

Fig. 6. An example of structural measures that provided protection against a tsunami that exceeded the defense-design capacity.

learned from the Great East Japan Earthquake and Tsunami, Japan is implementing both structural and non-structural measures as it pursues regional development for tsunami disaster prevention. Structural measures may be more expensive than non-structural measures, but, with the prevention of damage from future disasters in mind, an appropriate combination of both kinds of measure seems to be a wise investment.

(iii) Incorporating disaster management in all sectors

Building a disaster-resilient society cannot be achieved by projects with a 'disaster management' label alone. Disaster management needs to be incorporated into projects within other sectors also. During the Great East Japan Earthquake and Tsunami, the redundancy built into the road network, or the function of the road network to enable provision of alternative routes when there is disruption on some roads, clearly played a decisive role in rescue and relief efforts in the disaster aftermath. Moreover, road embankments acted as secondary levees. Although the focus in road development is on increasing the convenience of travel and providing an economic stimulus, we should be fully aware of the role that roads play when a disaster occurs. Having evaluated this role, we should seek to maximize all the benefits of road development including its disaster mitigation function. In many countries, budget limitations make it difficult to accord higher priority to investment in disaster management infrastructure. However, consideration of disaster management issues when investing in projects of any sector will enable efficient and effective enhancement of the disaster response capability of these countries.

(iv) Reconstruction and recovery planning for damage reduction

Japan's examples present good cases of transforming a disaster into an opportunity to leave a more disaster-resilient region to posterity, that is, the budget system allowing recovery to begin immediately after a disaster occurrence, and the reconstruction and recovery efforts designed to reduce the risk of disaster recurrence currently under way in the region affected by the Great East Japan Earthquake and Tsunami. Disasters catch the world's attention, and thus enable affected regions to receive a great deal of support. However, merely rebuilding the damaged infrastructure without implementing adequate measures during reconstruction and recovery efforts cannot reduce possible loss of life and property if another disaster happens. Disaster should not be treated as a transitory experience. In the long term, repeated efforts to prevent such an experience from recurring will build a disaster-resilient nation (see Figure 7).

(v) Assessing and recording damage

In many countries, there is still no system in place for continuous and consistent collection of disaster-related records and statistics. In Japan, there is a long-established system for collecting statistics on disasters including water-related disasters (see Figure 8). This is useful not only for assessing the effectiveness of disaster management measures and setting priorities; it also fosters understanding of the necessity for such measures and facilitates the securing of budgets and other resources, allowing these measures to be fully implemented. It is essential for every country in the world to have systems for continuous recording of disasters and collection of relevant statistics, so that the justification for

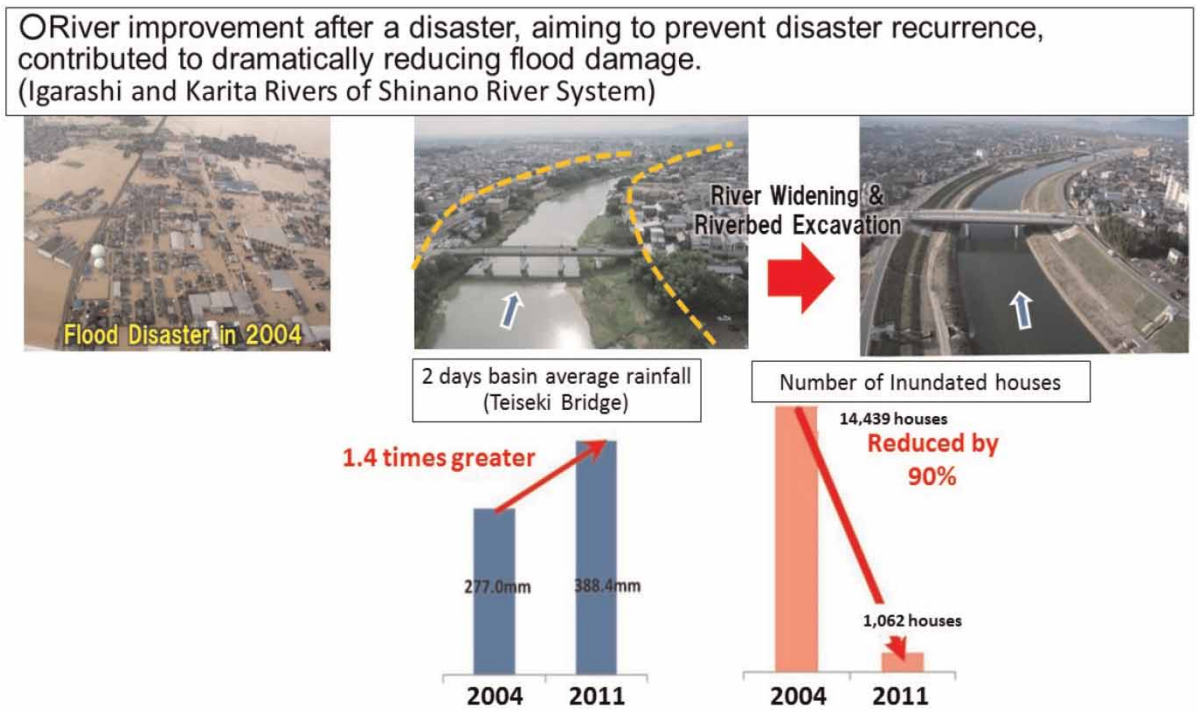

Fig. 7. An example of recovery and reconstruction works that prevented the recurrence of disaster.

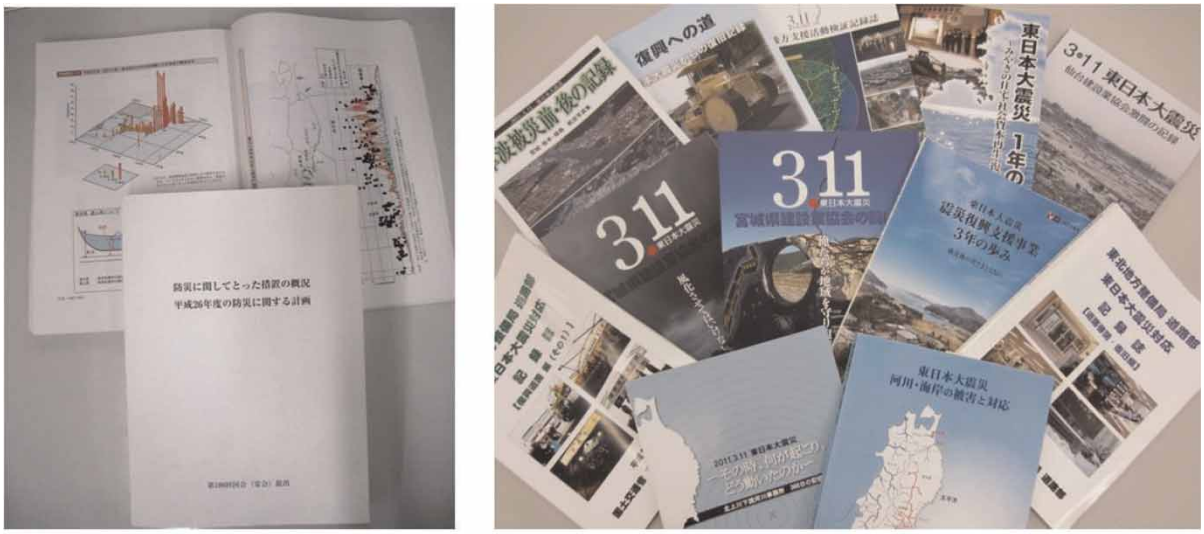

Fig. 8. Efforts to collect disaster-related records and statistics.

investing in disaster management can be adequately explained, and systems to enable implementation of the necessary measures created. It is vital that such initiatives are promoted worldwide.

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