Executive Summary

1 The Need to Change the Concept of Water-related Disaster Prevention

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Frequent seismic and volcanic activities cause intense geomorphic changes in Japan, while the low-pressure systems of typhoons and weather fronts cause heavy rainfall and storm surges. These make Japan physically vulnerable to water-related disasters.

From the beginning of modern era in the history of Japan, structural measures such as dams, levees, breakwaters and coastal revetments have been adopted to cope with water-related disasters based on the data and experiences of past events. In the mean time, small and medium-scale flood disasters have been decreased. However, these measures also led properties and population concentrated in floodplains along large rivers and coastal areas that had been originally at a high risk and vulnerable to water-related disasters. This means new risk of an unexpected disaster due to possibility of an abnormal phenomenon that exceeds the design criteria of the prevention measures. Moreover, changing the natural circulation systems and water-nature interaction due to structural measures will continue to worsen environmental degradation of coastal area and river ecosystem as well as their natural sceneries. It also should be taken into account that flood disaster prevention measures in a particular area may intensified disaster damages or related impacts in other areas.

More and more there is increasing discussion that climate change due to global warming will increase the frequency of heavy rains and more sever tropical cyclones due to future abnormal weather. Considering all the above, existing disaster prevention reliant upon structural measures to protect areas against water-related disasters has limit in terms of response ability for external force, economic cost and environmental impact. The abundance of daily life, preservation/restoration of the natural environment, and disaster prevention at abnormal conditions should be treated all in an integrated manner. We need to make efforts toward changing our concept of disaster prevention to utilize natural systems for example terrain and also keep water-nature circulation to deal with huge water-related disasters at a local community in a basin-wide scope.

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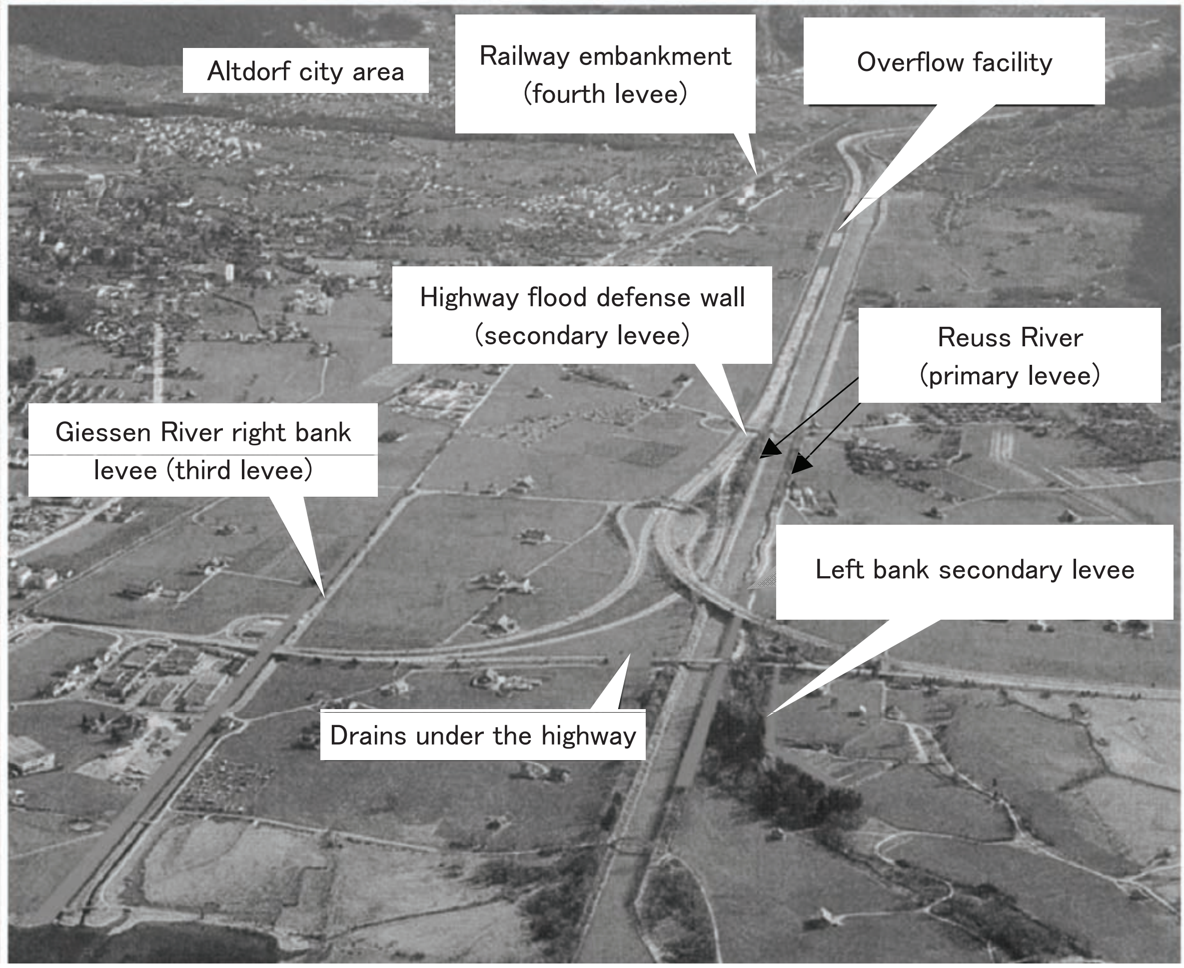

Figure : Multistage Flood Control in Switzerland's Reuss River

Compiled by the Science and Technology Foresight Center, based on Reference #26

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The Need to Change the Concept of Water-related Disaster Prevention

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1 Introduction

This paper introduce recent trends in water-related disaster prevention technologies with focus on floods and storm surges and discuss why Japan needs to change its approach for water-related disaster prevention.

We have to be aware that the high-density land use on vulnerable areas has served to increase the risk of water-related disasters. Fragile geographical features are distributed throughout Japan's steep terrain as a result of frequent seismic and volcanic activities. Furthermore, the country possesses conditions that allow for the occurrence of a wide variety of water-related disasters in each and every region. Included among these are the low-pressure systems of typhoons and weather fronts that cause heavy rainfall and storm surges. To support the industrial expansion and sudden population increase during Japan's rapid economic growth period, public infrastructure was put in place, and disaster prevention measures undertaken to suppress the threat of water-related disasters with structural measures. These measures resulted in a decrease of small and medium-scale disasters such as floods. On the other hand, they also led to the urbanization of river floodplains, coastal depressions, steep slopes, cliffs and other places that had originally been considered dangerous.

In September 2011, strong Typhoon No. 12 landed in Shikoku and caused extended bouts of rainfall everywhere from Shikoku to Hokkaido. Total rainfall exceeded 1,800 mm in the Kinki region, with record-setting rainfall observed in various areas throughout the country.[1] This intensive rainfall caused landslides and bank overtopping. Houses and railways has been damaged and 94 people lost their life or missing.[2]

In Thailand, the Chao Phraya River flooded from an extended periods of heavy rain. In addition to over 600 dead and missing, many industrial complexes were inundated, negatively impacting supply chains in ways that caused serious economic turmoil throughout the world.[3] The damage it caused to Japan's economy has been a cause for concern when compared with that from the Great East Japan Earthquake.

Although mother of nature bestows our daily life with rich blessings, it could be a major threat and bear down on us at the time of natural disasters in a society. There are increasing concerns that the climate change due to global warming will lead to an abnormal weather in the future. To this end, the idea of using levee lines and other stationary disaster prevention measures have reached their limit, and more new disaster prevention and damage reduction technologies are expected to enable regional communities coping water-related disasters. The 4th Science and Technology Basic Plan aims for the realization of sustainable nature-friendly and recycling-oriented societies as well as enrichment of people's lives. To achieve this, it calls for measures that will make public infrastructure more environment friendly, including "initiatives aimed at the creation of cities and regions that adapt to climate change and large scale natural disasters, preservation of natural environments and biodiversity, maintenance of the natural cycles of forests, natural disaster reduction, and sustainable cyclic food production."

2 The Vulnerability of Japanese Territory against Water-related Disasters

2-1 Changes in the Relationship between Local Communities and Water-Related Disaster Prevention

(1) Development of disaster prevention projects and the concentration of populations and property on floodplains

Since the Meiji period (1866-1912), Japan had the ability to establish nationwide regulations and actively incorporated flood control measures that utilize Western technology to channelize rivers into structures that allow floods to flow more easily. However, immediately following its defeat at the end of the World War II in 1945, deforestation due to overharvesting of mountain forests and inadequate maintenance of levees left again the country extremely vulnerable to water-related disasters. With the frequent occurrence of disasters like Typhoon Kathleen (1947) resulting over thousand deaths, Japanese at the time had no greater desire than the construction of rivers capable of withstanding water-related disasters. In the aftermath of the typhoon, river levees were strengthened to make rivers safer, and the country worked hard to level mountainous areas and construct erosion controls.

On the other hand, floodplains and other low-lying land originally thought to be at risk of water-related disasters have been rapidly urbanized to support the sudden sharp population increase and economic growth following World War II. Measures to strengthen disaster-prevention structures like erosion controls, dams, levees, coastal revetments and slopes stabilizing were either systematically implemented or included as part of the reconstruction efforts following disasters. These disaster prevention facilities also helped support efficient land use and resulted in a dramatic decrease in death tolls due to medium and small-scale water-related disasters. Ironically, this use of structures to forcefully prevent disasters not only led to additional population increases and asset accumulation in areas originally considered dangerous, but also declined disaster prevention awareness among the general public. Currently, approximately 50% of Japan's population and 75% of its assets reside on the floodplains that comprise roughly 10% of the country. For this reason, an abnormal situation that exceeds the scale assumed for a facility's design could potentially result in unprecedented damage to these areas.

There is a need for us to shift our attention to the growing risks due to both social and living environmental changes. Though construction of flood control facilities has led to a decline in the inundated land area, the total amount of water-related disaster, as well as the damage per unit area has increased annually. In addition, new types of urban damage have emerged, including the inundation of underground space and the expansion of dense urban zones standing at sea level due to land subsidence caused by the pumping of groundwater.[4]

In the past, if heavy flooding exceeded the capacity of levees, self-defense flood prevention systems and traditional damage control measures, which were based on each region's natural environment, social characteristics, and long years of disaster experience, functioned by using the land to save human life. For example secondary levee lines or ditches dug into levees to divert flood water away the flooded areas and also riverside forests that existed to reduce damage from flooding. Nowadays, however, construction of disaster prevention facilities and also increasingly sophisticated land use have reached the point where it is now impossible to perform cross-sectional check and set up a management systems for each organization. The result is that there is no regulatory system for efficient land use, and construction can now be built near slopes, beaches, mountain stream outlets and other vulnerable places where people traditionally did not live.

The preparedness of flood control facilities on Japan's rivers is still only 60% of the current target to prepare against floods occurring on medium or small-sized rivers once every 5-10 years (5-10 year return period of floods) and 30-40 year for floods on large rivers.[5]

(2) Environmental Impact

A variety of environmental impacts have been observed as the result of large-scale disaster measures.

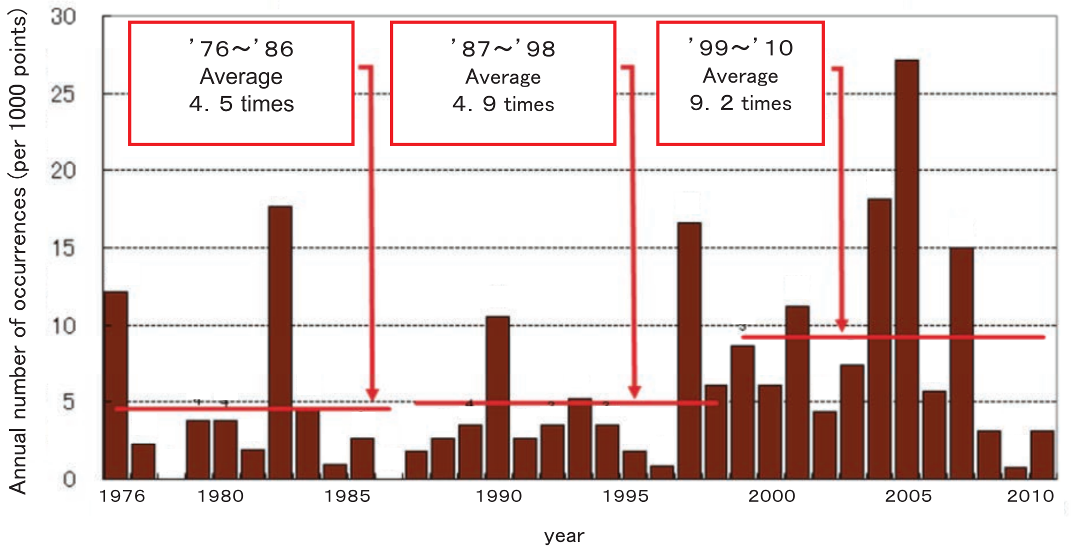
We need to pay attention to the construction of dams and dikes as an erosion control in mountainous areas. It has prevented fishes from swimming upstream to spawn. The less amount of sediment transported by river flow also has led to a loss in active river dynamism in some part of Japan. This has had a number of negative impacts, including the degradation of plant and animal habitats due to downstream river beds becoming course/fixed, the erosion of levees, bridge piers that is also affected by regulations on the extraction of gravel resources from dry riverbeds, and the deterioration of water quality due to the eutrophication of reservoirs and prolonged periods of muddy water in rivers following floods.[6]

In the flood plain, rivers have been straightened and riverbeds have been dug. The result has been a decrease in the dampness of riversides and a loss of naturally rich waterfront environments that serve as controls against overtopping, water quality maintenance, ground water recharge, habitats for plants and animals and recreational areas. Additionally, in dense urban areas, waterfront scenery has deteriorated due to the construction of vertical concrete revetments and the concealment of rivers with culverts.

In estuaries and coastal areas, the development of afforestation/flood control projects has been accompanied by a decline in sand supply, while the construction of large coastal structures like breakwaters has been inhibiting sediment continuity toward the coast. As a result, the erosion of tidal flats and gravel beaches has continued. This not only decreases disaster prevention's ability to attenuate high waves, but also causes a decline in available environments for ocean water purification operations and the raising of juvenile fish.[6] There are concerns that combatting coastline erosion with makeshift man-made structures is actually accelerating the erosion of neighboring beaches. Nearly 9,500 km of Japan's 35,000 km coastline is equipped with coastal protection facilities. Although these facilities protect human life and property from storm surges, this increase in artificial beaches is seriously damaging Japan natural landscapes. The burden of maintaining/improving such huge artificial structures will fall on the local governments in the future that preserve the coastline.

2-2 The Frequency of Abnormal Weather in Recent Years

From extremely heavy rainfall that continues for long periods of time, the occurrence of abnormal rainfall has been increasingly confirmed in recent years. According to statistics compiled by the Japanese Meteorological Agency, frequency of extremely heavy rainfall with intensity of 50 mm per hour or more has increased by a factor of about 1.5 over the past 30 years.[7] Additionally, heavy daily rainfall of over 400 mm per day has increased by a factor of two (see Figure 1).[8] As it will be discussed in a following chapter, future climate change due to global warming will cause more sever tropical cyclones, and sea levels rise will lead to an increase in wave height. Thus climate change also increasing fears that water-related disasters will continue to expand in magnitude.[5]



※In order to avoid in fact the differences between observation area points by year, the number of occurrences are converted to 1000 per point.

Figure 1 : Annual number of occurrences of daily precipitation over 400mm

Compiled by the Science and Technology Foresight Center, based on Reference #8

3 The Trend toward Nature- friendly Disaster Prevention Technologies

3-1 Changing Perceptions of Disaster Prevention and Reduction

Conventional water-related disaster prevention measures are designed based on the past experiences of damage scale. Disaster prevention facilities are planned to prevent flooding up to that scale of damage. Japan's decreasing birthrate and aging population has been increasing the cost of social security. The prolong national debt of Japan and its local governments, coupled with increases in the administrative expenses necessary to maintain social capital stocks up to now, are gradually chipping away at the amount of funding available for construction.[9]

We also need to concern that the abnormal weather caused by global warming is increasing severity of typhoons and increasing rainfall beyond that of conventional rates. In recent years, there has been greater recognition that the perceptions that have persisted up to now regarding the ability of disaster prevention facilities to prevent flooding in the event of abnormal phenomena that are extremely rare has reached their limit in terms of response ability, economic cost and environmental impact. Accordingly, a gradual shift toward land development that is extremely flexible in the face of water-related disasters and takes into account the total package of regional livelihood and environmental preservation and restoration is taking place, as can be seen in the enactment of the National Spatial Planning Act and in revisions to the Urban Green Space Conservation Act. This shift reflects the dawn of an era where the preservation of vitality and living assistance for local residents, the improvement of regional and river basin environments, and the preservation/enhancement of biodiversity through the symbiosis of people and nature are all in demand (see Table 1). In the future, it will be increasingly important to introduce flood damage reduction methods that enable best use of entire regions and basins and as well as preserve and/or restore the environment. Concerns have been raised that water-related disasters will increase in severity due to the emergence of stronger tropical cyclones brought on by the climate change as well as surging tidal waves as sea levels.

3-2 Trends in Research and Investigation that are Reflecting Changes in Perspectives

3-2-1 Investigations on Predictions of Abnormally Catastrophic Events and Damage Estimation

(1) Investigations of Abnormally Catastrophic Events Prediction

1) Abnormal Rainfall

Based on the average scenario (A1B scenario) indicated in the Intergovernmental Panel on Climate Change Assessment Report 4 (IPCC-AR4), in 100 years from now, the highest precipitation in a year comes to 1.1-1.5 times higher than that in 2009 in Japan. It has been estimated that this change in precipitation will cause devastating floods that currently occur once every 200 years to occur once every 90-145 years and floods that currently occur once every 100 years to occur once every 25-90 years.[5]

2) Rising Sea Levels

The risk of disasters due to storm surges and beach erosion will continue to rise as wind gusts increase and sea levels rise due to the drop in atmospheric pressure that will occur as typhoons intensify.[5] Predictions indicate that the frequency of extremely strong tropical cyclones with peak wind speeds in excess of 45 m/second will continue to increase from here on out.10 If sea level rises 59 cm in the future, the total land area and the populations of areas at sea level in Tokyo, Osaka and Nagoya are estimated to increase by approximately 50%.[11]

3) Regional Water-related Disasters

Researchers recognized that our ancestors could manage both benefits and threat of rivers. In the Shinano River drainage system and Chikuma River basin in Nagano Prefecture, for example, researchers with backgrounds in archeology, geology, river engineering and other fields collaborated on research into the changes of the rivers and levees that have occurred since the Jomon period (10,000 B.C.-300 B.C.) Based on data from historical excavations and numerical analysis of floods in each of the areas, the researchers came to understand that our ancestors leaned from traces of past flooding. Our ancestors cleverly used the range of flooding, the scale of river flow rates and slightly elevated land such as natural

Table 1 : The Implementation Status of Laws and Plans Concerned with Environmental Preservation/Restoration or Comprehensive Disaster Prevention in Regions/River Basins

Laws/Plans	Contents
National Spatial Planning Act (National Plan/2008)	The objective of this act is to "form a country that is strong and flexible against disasters" in the face of the ever increasing risks of global warming. It views the future, full-scale depopulation of Japan and the resulting surplus of land as a good opportunity to reconstruct Japan's structural make-up and make it stronger against disasters. A number of organizations, including green earth communities, individuals, NPOs, corporations, educational institutions, and administrations, will work together to develop regions in way that both maintains their vitality and supports the livelihoods of area residents
Urban Green Space Conservation Act (Revised/2008) A basic plan to encourage greening and the preservation of green spaces.	The Urban Green Space Conservation Act is illustrated as a strategic program concerned with greening and the preservation of green spaces in cities, towns, and villages based on a number of functions, including "environmental preservation through urban greenery," "recreation," "protection through firebreak belts, emergency evacuation, and flood regulation/ retardation," and "landscape structure."
Basic Act on Biodiversity (2008)	In National Biodiversity Strategy 2010, the enrichment of biodiversity beyond current levels and the realization of greater symbiosis between people and nature on both national and regional levels are mid-range goals to be achieved by 2050.
The Third Basic Environment Plan (2006)	Put in place as a political program that prioritizes "efforts to ensure a healthy water cycle in terms of environmental protection," this plan points out the need for river basins to be considered in their entirety. The plan establishes "water quality," "water volume," "aquatic life," and "waterfronts" as four areas to be targeted.
Flood Control Act (Revised/2005)	Municipalities are obliged to designate areas along large rivers and major small/medium rivers that are hypothesized to be susceptible to flooding and inform citizens about communication methods for flood forecasts, shelters, and other information by means of hazard maps, etc.
Act on Countermeasures against Flood Damage of Specified Rivers Running Across Cities (2003)	This act was created to combat urban flooding stemming from considerable urbanization. It establishes flood control measures that seek to improve the preservative and water retarding abilities of entire river basins by servicing existing rivers and drainage systems, increasing the permeability of road surfaces and residential areas, and establishing regulating ponds in developing areas.
Act on the Promotion of Nature Restoration (2002)	This act aims to restore the natural environments of rivers, wetlands, tidal flats, seaweed beds, woodlands, rural mountains, rural lands, forests, and other areas lost due to past projects or human activity. Based on the previous promotion act, it promotes initiatives in 22 areas across the country (as of March 2011), including restoration of the meandering rivers of Kushiro Marsh.

Created by the Science and Technology Foresight Center

levees along rivers to extract benefits from rivers, avoid the threat of flooding and ultimately, find a wisdom way to survive.[12]

4) Combined Disasters Involving Earthquakes and Floods

There is a need to develop explanations and verification methods for the specific mechanisms behind the phenomenon of levee liquefaction.[13] The Koto Delta area in Tokyo, for example, is soft ground that sits right at sea level. If the ground were to liquefy during an earthquake and a flood or storm surge were to occur after the levees take damage, great harm could potentially be inflicted upon the elderly and other vulnerable individuals due to extensive flooding in dense urban areas.

(2) Flood Damage Estimation

1) Simulations of Flood Damage in the Metropolitan Area

Simulations results have been predicted a huge flood damages in Tokyo. If the Tone River were to burst open in an area similar to the one that did due to Typhoon Kathleen in 1947, estimates show that flooding would reach Tokyo in 48 hours and that Edogawa, Katsushika and other wards in Tokyo would remain flooded for over 14 continues days. Damage estimates are approximately 2,600 dead, 860,000 homes flooded and serious damage to lifelines over a wide area. If the Arakawa River that flows through Tokyo and Saitama Prefecture were to burst open near Shimo in Tokyo's Kita Ward, 110 km^2 of Arakawa, Itabashi, Taito, Chuo and other wards in Tokyo would be flooded, and the death toll would rise to approximately 2,000. If flooding were to reach the subway lines, it is estimated that 17 of 22 lines and 97 of 130 stations would be inundated 72 hours after levees are broken.[14]

2) Storm Surge Disasters

In a simulation of storm surges and high waves in Ise Bay based on the terms of the medium-scale scenario laid out in the aforementioned IPCC-AR4, it is estimated that, due to the enormity of typhoons 100 years from now, Chubu International Airport will be flooded by storm surges reaching as high as 6.9 m. This figure greatly exceeds the 3.5 m storm surges observed in the Port of Nagoya during Ise Bay Typhoon in 1959, which is thought to have been the worst disaster of its kind up to this point.

3-2-2 Flood Mitigation in Flood Plains

1) Disaster Management Plans for Flood Plains and their Evaluation.

Disaster management plans are increasingly emphasizing how safe flood sites are in terms of both human loss and properties damage. Rather than follow the conventional wisdom of placing the focus of disaster prevention and management on how safe flood control facilities are. For example, development is underway on a model that would quantitatively evaluate the effectiveness of disaster management plans and cover measures taken at flood plains as well as at river basin dams and levees. Because much time is required to actually implement measures, this model also takes implementation sequence into consideration.[16]

2) Retarding and Retention of Floods Flow.

The scale assumed for agricultural drainage pumps installed in a paddy fields is generally set for ten-year floods. However, facilities at river drainage sites are designed for 100 to 200-year floods and indicate the water retention/retarding in basins by retaining flood water on rice fields when the inflow exceeds the capacity of agricultural drainage pumps. Considering this, the possibility of using paddy fields for flood control in a variety of land for different flood scales has been investigated.[17]

3) Guidelines for Water-related Disaster Risk Management

The World Federation of Engineering Organizations (WFEO) has been systemically compiled accumulated lessons learned and experiences in water-related disasters around the world due to floods, storm surges, etc. When managing risks of a hazard, it is necessary to apply a method that is inexpensive and sustainable. The applied method also should be able to operate using simple techniques that minimize the impact of risk management on natural environments and landscapes.

It is necessary to improve the function of disaster prevention facilities so that they can be used for a variety of purposes, even under normal circumstances. It is also necessary to proactively utilize nature's inherent water retarding and flood retention capacities. Additionally, managing floodplains on a basin-wide scale, regulating land use in compliance with the degree of danger involved, suppressing and guiding the flow of floods, and defending focal points are all necessary as well. Attention is also being given to the modern implications of traditional Japanese techniques like overflow levees and ring levees.[18]

3-2-3 Examples of Measures Utilizing Research Results

(1) Creating Water Retardation Capacities through the Restoration of River Wetlands[19]

In a combined flood control and environmental restoration effort, Saga Prefecture authorities implemented the Matsuura River Azame-no-se Natural Restoration Project in accordance with the Law for the Promotion of Environment Restoration. This project was launched in 2002 to “restore the flood plain wetlands that once existed in the Matsuura River basin” and to “restore the relationship between humans and other living things.”(See Figure 2)

Citizens, NPOs, scholars, the Ministry of Land, Infrastructure, Transport and Tourism, and the municipality of Ochicho organized the Azame-no-se Investigative Commission and settled on a project plan. Scholars provided research results on flood behavior, wetland ecosystems and landscapes. The approximately 6 hectares of Azame-no-se acquired by the country for flood control measures were dug down to depths normal for the Matsuura River and the area's wetlands were restored. Creating floodplain forests alongside the river, wetland vegetation was restored using the site's soil seed bank and living/spawning environments for insects, fish and other living things were added along with flood shelters. The site was also provided with the ability to allow floodwaters in and regulate river flow rate as a retarding basin. Wetlands are maintained and the flood pattern that had persisted up until now has been restored because the ground is low.

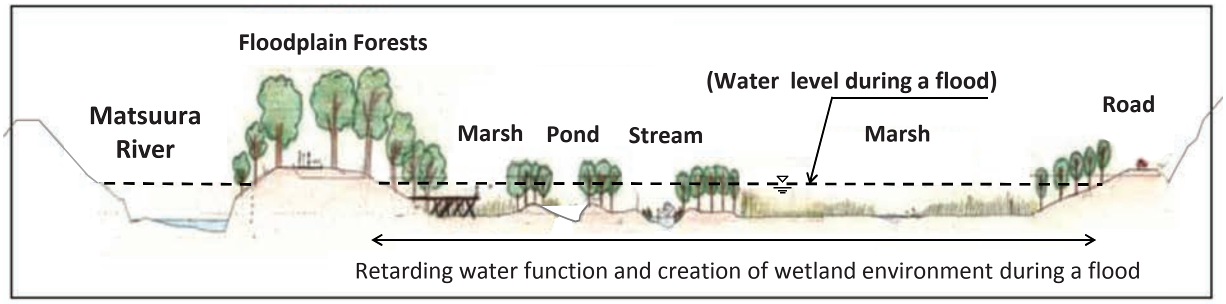


Figure 2 : Restoration of Wetlands with Water Retarding Abilities in Saga Prefecture's Matsuura River (cross-section view)

Compiled by the Science and Technology Foresight Center, based on Reference #19.

(2) Ensuring Disaster Prevention Capacities while Restoring and Preserving Fisheries and Other Coastal Environments through Artificial Reef Restoration.

A beach restoring plan was carried out in Aomori prefecture, in which seaside habitats, coastal erosion and disaster prevention are considered together. The rocky beach areas on the Kinoppe Coast of Aomori Prefecture's Shimokita Peninsula, which is defined by the Tsugaru Strait, were rich in nature, inhabited by a variety of creatures, and a thriving coastal fishery up until 1955. With the construction of a fishing harbor and a variety of coastal protection structures, the rocky beaches were lost and fish catches declined. Local citizens dug up pictures from around 1955 and, hoping something could be done to restore the once thriving beach, held a social gathering attended by citizens, NPOs, coastal specialists, and administrations from both Aomori Prefecture and Ohata town to seriously discuss the issue. Utilizing the experience of people living in the region, specialists presented research results on seaside habitats and coastal erosion and with each side in agreement, plans were finalized for a rocky beach restoration project that would also function as disaster prevention. Based on this plan, the blocks that formed the sloping revetments protecting the coastline were demolished/removed and diverted for use on an offshore foundation mound. Large stones were then placed irregularly on top of an artificial reef, which was completed in 2003 (see Figure 3).[20]

Reconstruction of existing revetments that takes environmental restoration into consideration was unprecedented in terms of coastal projects at the time. However, the project has been realized thanks to the enthusiasm and cooperation of all involved parties. By effectively neutralizing waves and suppressing the flow rate of coastal currents, the sandy areas of beach expanded and the scenery of the rocky beach of the past was restored, with seaweed (rock laver) and abalone becoming available for harvesting. In January 2004 and October 2006, unusually low atmospheric pressure generated high waves that severely damaged structures like the fish harbor's concrete-block breakwaters and detached breakwaters. Despite this, the artificial reef demonstrated the ability to neutralize waves.

Artificial reefs are soft coastal public works technology that will change over time. People in

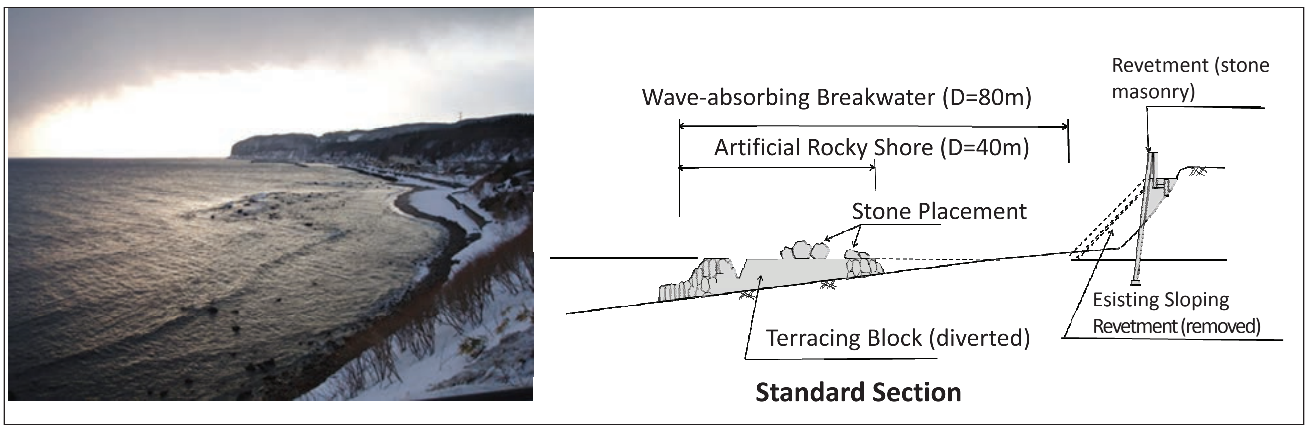


Figure 3 : Restoration of Revetments with Disaster Prevention Abilities on the Kinoppu Coast
(Artificial rocky shore is the central and slightly offshore parts of the photograph that are dotted with rocks)

Compiled by the Science and Technology Foresight Center based on Reference #20 the region have been conducting independent and continuous monitoring of the reef to ascertain its effects in terms of terrain alteration, wave attenuation, and habitat.

In addition, whenever disaster prevention revetments are installed in the Nakatsu Tidal Flat of Oita Prefecture, they are not placed at conventional sites such as at water's edge, but rather, are pushed back toward the vicinity of communities. This is conducted in collaboration with individuals who possess knowledge of or have experience with ecosystems and coastal disaster prevention in order to satisfy the demand of local residents that the tidal flat be protected. Preservation of natural tidal flats and their rich ecosystems, as well as the small sand dunes behind them, wetlands, and maritime forests, maintains their natural wave attenuation capabilities. These coupled with the placement of small levees, also helps protecting local communities.[21]

(3) Environment-friendly Disaster Prevention Technologies Applied to Basins Utilizing Existing Infrastructure and Facilities.

1) Sediment Transport System Improvements combined Forest Preservation with Dam Modification

A plan which seeks to simultaneously achieve continuous hydroelectric power generation, water damage prevention upstream of the dam, restoration of downstream riverbed environments, and the prevention of coastal erosion has been carried out in Miyazki prefecture.[22] A total collapse across the slopes of the basin Mimigawa River was caused by a typhoon in 2005 and led to a huge influx of sediment into the dams. This influx in turn caused riverbeds upstream of the dams to rise, resulting in flood damage to the area as well as a great deal of damage to the power plants. In response, river administrator, regional representatives, local governments, dam employers, and individuals with relevant knowledge/experience collaborated to control sediment runoff through forest conservation and significantly remodel the dams and in 2009, began creating a system that would allow sediment to continuously flow downriver from the dam into the foreseeable future. Experienced and knowledgeable individuals, in addition to presenting a variety of research results pertaining to forest conservation, river engineering, coastal engineering, ecosystem preservation/restoration, and other fields, took on leadership roles in a variety of investigative commissions.

2) Synthetic Use of Existing Dams through Dam Restructuring Project

Specialists are currently investigating ways to maintain flood control capacity, ways to ensure continuous removal of sediment, downstream waterways and sediment drainage, and changes to natural ocean environments in Shizuoka prefecture.[23] A large amount of sediment is accumulated at the Sakuma Dam on Shizuoka Prefecture's Tenryu River, and a direct consequence of this accumulation has been the progression of severe erosion at Enshunada coast. Carrying out permanent measures aimed at draining accumulated sediment from the Sakuma Dam, which is used exclusively for hydropower and irrigation, while also secure the dam's flood control capacity. The dam restructuring project has exercised since 2009 to find ways to integrate other features. These include the improvement of downstream flood control safety, the preservation of future power generation, and coastal erosion controls.

Additionally, research is being conducted into how to improve the performance of existing dams by using them more effectively. Efforts are being made to improve the flood control capabilities of dams while paying close attention to the runoff characteristics in dam basins in order to release water from the reservoir before flood inflow. The advancement of research such as this will allow the flood control capacity of dams that are up to now empty in the rainy season to be more effectively used at normal times for hydropower generation, water supply, and environmental discharge.[24]

3) The Recovery of Sediment Transport Continuity in Coastal Areas

At the Fukude fishing port near the mouth of Shizuoka Prefecture's Tenryu River, a plan has been in place since 2007 to recover sediment transport continuity along coastlines by constructing a permanent sand bypass system using pipes to control coastal erosion and preserve the port's functionality.[25]

3-3 Trends in other Countries

3-3-1 Examples of Multi-stage Flood Control[26]

In Europe and the United States, it has widely accepted the limits of structural measures with respect to their cost and also in terms of environmental impacts. Therefore, there has been debate over which combination of structural and non-structural measures—such as those that deal with land use planning or building code—is the best when it comes to the institutionalization of a variety of disaster management systems. In Japan, which land use is sophisticated in floodplains, it is thought that consultation should occur after investigating disaster management for future societies that can co-exist with nature, even if those techniques are difficult to implement. For example, on the Reuss River, which pours into Lake Lucerne in Switzerland and is a tributary of the Rhine, a degree of flood control safety has been established in accordance with land use and multi-stage flood measures that utilize river levees, roads, and other structures are in effect. (See figure 4) Their purpose is to provide water-related disaster protection to Altdorf, the capital of the Swiss Canton of URI. It is located near the convergence point of the Reuss River and Lake Lucerne. The levees on the Reuss River are the first line of flood protection and flood water with the return period of more than 50 years may overflow them. If a flood with return period of more than 50-year happened, floodwaters are allowed to overflow and traffic will be restricted in the parallel highway beforehand of overflow. The height of the highway's flood protection wall allows it to handle floods as large as 250-year floods and is the second line of flood protection. In the event that the flooding exceeded that of a 250-year return period, the floodwaters would be stored in the agricultural land between the highway and the adjacent Giessen River. The Giessen River levees are in place to be the Reuss River's third line of protection. If faced

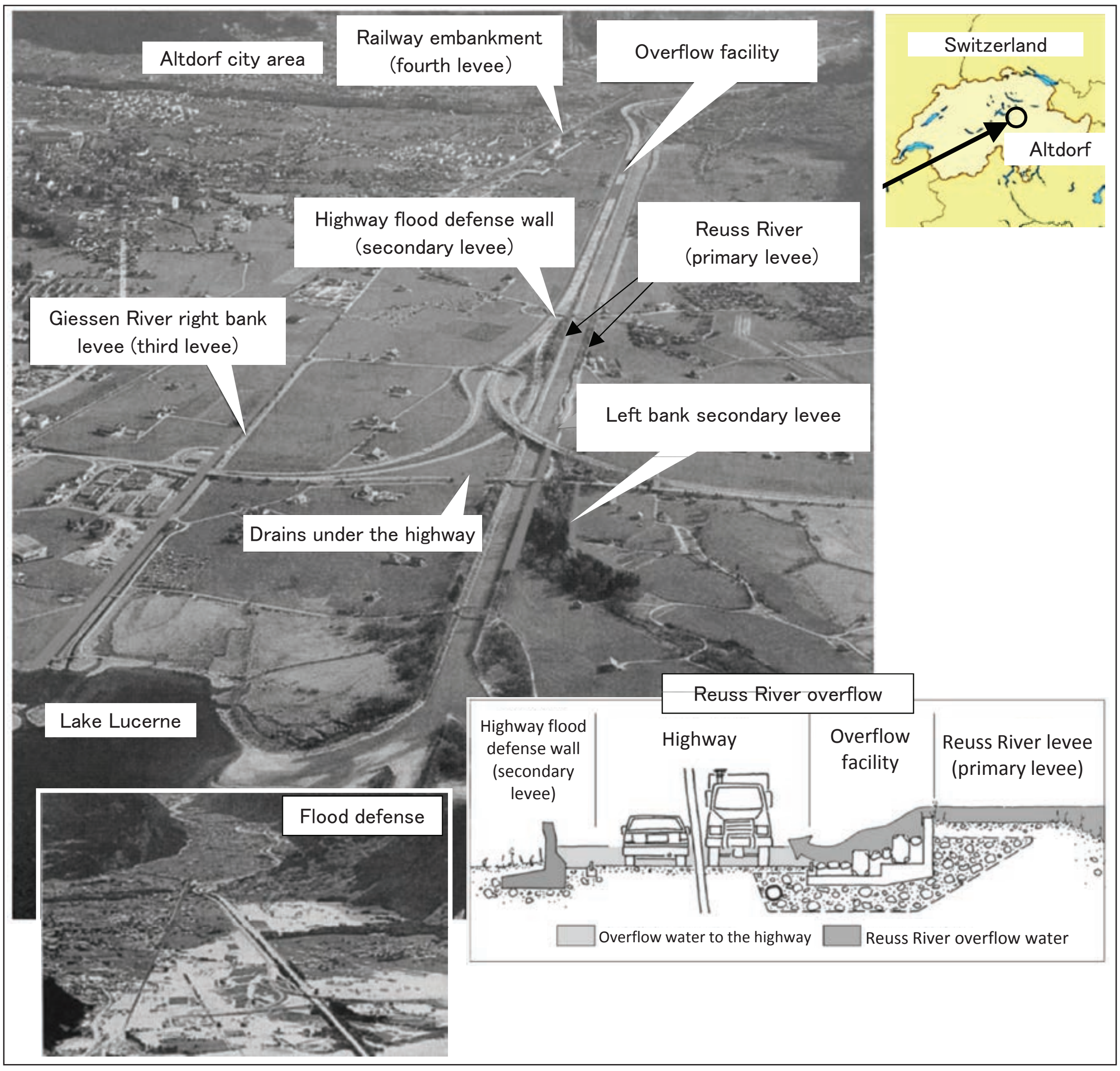


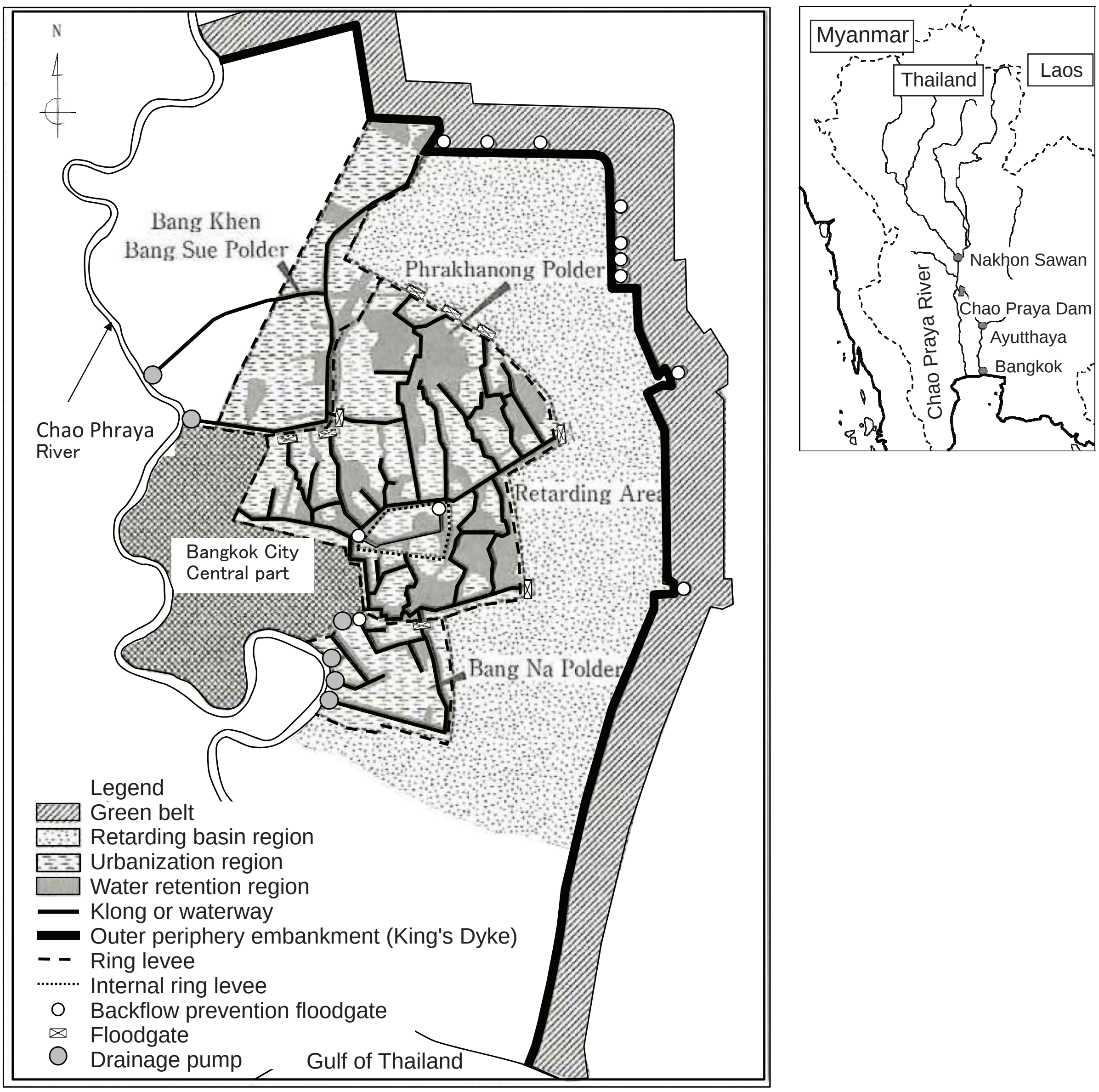
Figure 4 : Multistage Flood Control in Switzerland's Reuss River

Compiled by the Science and Technology Foresight Center, based on Reference #26.

with an even stronger 1000-year flood, the series of railroad embankment would protect the most densely populated areas of Altdorf.

3-3-2 Thailand's Comprehensive Flood Control Measures and Flooding in the Chao Phraya River

The frequent flood of Chao Phraya River of Bangkok is serious problem. Bangkok, the capital of Thailand, is located in the lower basin of the Chao Phraya River, which takes up a total area of 163,000km^2. In recent years, population and economic growth have led to the urbanization of the flood-heavy lowlands. Additionally, land subsidence has been caused suddenly by the excessive pumping of groundwater, and the frequent occurrence of water damage from flooding on the Chao Phraya River is now a serious problem. In 1983, the Bangkok Metropolitan Administration settled on the "Master Plan on Flood Protection/Drainage Project in Eastern Suburban-Bangkok." (see Figure 5).[27] The plan protected



Structural support	• Installation of outer periphery embankment prevent flood inflow from the northeast (Kings Dyke) and a floodgate to the waterway
	• Installation of drainage pump for rain water to drain into the Chao Phraya River and the canal leading to it
	• Levees to prevent flooding from the Chao Phraya River and installation of a floodgate to the waterway
Non-structural support	• Paddy fields outside of the King's Dyke as a greenbelt areas to ensure conservation and water retarding functions
	• Area between the urban areas and the King's Dyke is a preserved as a water retarding basin area
	• Specified in a water retention region that is relatively low and also in an urbanized area (Development cannot occur in the region without permission from the government)
	• Guidance/regulation of urbanization
	• Installation of flood information systems for rivers and flood response centers

Figure 5 : Flood Control Measures in Eastern Suburban-Bangkok, Thailand

Compiled by the Science and Technology Foresight Center, based on Reference #27.

central Bangkok from flooding from the northeast and allowed the water to flow east by creating the King's Dyke, an external levee that surrounded Bangkok from north to east, and by making the exterior into a green belt.

In addition, a second levee was established within the King's Dyke and land use regulations were incorporated to preserve the space between two levees as a flood retarding basin. Furthermore, drainage pumps and sluice gates were added to provide internal drainage within Bangkok. The low-lying city areas in risk of inundation are registered as water retention areas. A governmental permission is required to do any development in the area. However, it has been said that the political chaos that following the military coup in 2006 and the stresses on land use and rapid urbanization prevented implementation from proceeding as planned.[27]

In autumn of 2011, a large-scale flood damage happened in this area. Between May and October of 2011, the Chao Phraya River Basin experienced rainfall that was 143% of the average of the past 21 years. In early September, the Chao Phraya River's flow rate exceeded flow capacity, overtopping began between Nakhon Sawan and Ayutthaya, and from mid to late September, the left bank levee between the Chao Phraya Dam and Ayutthaya broke in eight places. It has been observed that this break down led to an influx of over 5 billion m^3 of water (1/4 of total flooding) into the left bank floodplains. Floodwaters reached an industrial park outside of Ayuthaya in early October, two weeks after breaking through the levee, and then flow further downstream, inundating seven industrial parks and the capital of Bangkok. 804 companies (approximately 449 of which were Japanese) damaged.[3] It has been estimated that, nationwide, approximately 5.05 million people living in approximately 1.88 million households were affected. The dead and missing currently stand at 609 as of November 2011, and the total area of agricultural land damage has reached 170,000km^2 (virtually the same size as the Kanto Plain area).[28] It is anticipated that detailed investigation will be undertaken into the functional and practical problems of disaster management infrastructure, systems and application of land use regulations needed to manage floodplains, disaster management information, plans for warnings and evacuations, and a system able to support it all.

Populations are now concentrated due to the rapid urbanization of floodplains, and as a result of that, there have cases of increased damage all across Asia. Besides flooding, storm surges were caused by Cyclone Sidr in Bangladesh in 2007 resulted over 4,000 dead or missing,[29] Cyclone Nargis in Myanmar in 2008 also resulted over 70,000 dead or missing.[30] Instruction based on investigations into these disasters will need to be used in order to help future disasters management.

3-3-3 Institutionalization and Implementation of Floodplain Management

(1) France's System

The basic idea behind flood defense in France is "local control." Straightening rivers and protecting them with continuous levees is not a good idea as they raises flood levels in downstream, and increasing water damage risk. The preservation of as many natural flood retarding basins as possible prevents the increase of flood flow, and the institutionalized way of thinking in France is that areas that possess important hinterlands should be protected by local levees. In regard to flood damage reduction measures for floodplains and measures against excess flooding, France provides effective information on flood forecasting and defines the areas that are at risk of inundation. It also prohibits all construction within those at-risk areas (flood retarding basins).[31]

(2) The United Kingdom's System

In the UK, serious consideration is given to protections against storm surges that cause severe damage by rapidly raising water level. With the exception of the Thames Barrier (protective wall), which was built in the downstream areas of London to protect against 1000-year storm surges, using embankments to defend against flooding has not been the norm in recent years. Instead, progress has been made with non-structural measures, such as regulating limited development in floodplains along waterways. Intended for the benefit of safe water environments as well as the users of those environments and all related agencies, progress has also been made on the establishment of the water drainage unit from the "River Basin Management Plan." Consideration for the environment has become prerequisite for all urban planning in UK flood control projects, and flood control projects themselves are often found to a part of environmental conservation projects. The contents of the flood defense in these plans include regulations for floodplain development, investigations into the degree of safety basins offer against floods, flood forecasting and warnings, and maintenance management of flood control facilities. Project plans emphasize land use assessments and the development of flood defense strategies, as well as guidelines development based on those assessments.[31]

(3) Germany's System

In Germany, land use planning is believed to be the foundation of the country's floodplain management. In addition to specifying floodplains, construction and land use within them is regulated. For example, constructor of structures like oil tanks and power facilities are asked to choose construction methods that ensure safety against floods. In addition to the inspection and repair of deteriorated levees, the establishment of areas that will allow water to overflow through changes to the form of land use, the restoration of wetland environments with water retarding capabilities, and other measures are taken across the whole of river basins in a comprehensive manner.[31]

In the case of the Elbe River, approximately double the size of the area damaged by flooding in 2002 has been designated for water retarding basins and flood control plans have been established to protect major cities.[31]

(4) The Netherlands' System

With 27% of the country's territory below sea level and 60% of the country's population residing in those areas, the Netherlands have undertaken protection measures that use large-scale embankments to counter the enormous threat of damage from storm surges. Flood control projects are implemented incorporating the perspectives of scenery, nature, and culture in accordance with LNC policy. The country does not have a special system in place to deal with floodplain management, but the city of Amsterdam is situated on slightly elevated land like hills and sand dunes that serve as natural levees and make it difficult for storm surges to land a direct hit. The coastal areas and deltas that are vulnerable to extreme damage from storm surges are lightly populated and no large cities exist there. In regard to river floods, the protection level of upstream areas is low. However, flooding that occurs in upstream agricultural area will not reach the larger cities downstream.[31]

(5) The United States' System

In response to the heavy flooding that occurred in Missouri River in 1993 and damaged 37,000 homes, the U.S. federal government has greatly shifted its river management policies. With dams and levees judged to be weak against the power of stronger rivers, a buyout system was introduced that allows the government to buy property and houses at-risk areas in order to create a buffer zone in times of flooding. Additionally, if a house is built on an area at risk of flooding from a 100-year or 500-year flood, building regulations that take waterproofing into account are applied, and flood insurance (with rates determined in accordance with the area's degree of danger) is mandatory. This limits the number of residences at-high risk areas and reduces the risk of flood damage.[31]

4 Constructing Disaster Prevention for a New Era in Japan

4-1 Problems with Japan's Water-Related Disaster Prevention Measures

In Japan, population and property are concentrated on low-lying lands like coastlines, floodplains of large rivers, and other areas that are naturally susceptible to the threats of nature, because water-related disaster prevention and regional plans are carried out separately. Additionally, a number of established underground facilities, industrial facilities, and other facilities are susceptible to secondary disasters.

Based on many years of experience with disasters and working off of the presumption of water-related disasters that regions had been hit by, the Japan of the past specified land use in an attempt to reduce damage. In order to protect higher priority areas, water retarding basins and overflow levees were established to guide floods elsewhere. Meanwhile, traditional countermeasures like ring levees and Elevated housing for flood prevention (Mizuya), as well as regional flood prevention organizations, served to protect settlements and houses from floods (see Table 2). However, from the Meiji era (1868-1912), disaster prevention became a field of specialized expertise within the administration and progress was made on the development of disaster prevention facilities that would serve as a line of defense for regions. Also, as land use in regional planning grew increasingly sophisticated, the preparedness of local residents to deal personally with water-related disasters waned and systems/ideas for how to deal with the risk management of disaster prevention/reduction that were based on wisdom and mutual understanding disappeared or at least were severely weakened, bringing us to the present. For this reason, there is almost no research dealing with land use as the essence of flood control.[27] If a disaster prevention facility degrades or is damaged, or if an external force generated by an abnormal phenomenon exceeds the assumed scale for that facility's design, it would give rise to new risks of large-scale disaster.

Additionally, degradation of river and coastal habits for plants and animals, landscapes, and other environments is taking place. This is a result of changes to the natural cycles of water and materials brought on by the reshaping of nature that accompanies large-scale installation of infrastructure and facilities. Furthermore, negative links have been observed, including disaster prevention measures that unintentionally promote the occurrence of disasters in other areas. As was mentioned in section 2-2, there is a growing fear that abnormal weather will occur due to global warming and that habitats of ecosystems will continue to deteriorate from now into the future.

4-2 Problems to be solved

4-2-1 Clarification of Problems Facing Regional Disaster Prevention and the Environment

Japan is long from north to south and differs greatly in terrain/geological features, weather, and other natural conditions depending on the region. There are also a variety of regional conditions for land use. Naturally, the variety, scale, and likelihood of the natural disasters in Japan are also different depending on region.

In recent years, hazard maps have been under development to help share risk information about a variety of disasters, including the range of floods and debris flows. Nevertheless, the target range of the scale of external force assumed in the risk information is imprecise. Because natural phenomena are complex and the time scale of occurrence of large-scale disasters is long, an adequate amount of quantitative data on the geological features of regions, long-term rainfall, and other information has not been organized/accumulated.[32] In addition, both sediment discharges and damage to facilities due to earthquakes/volcanic activity and complex disasters such as torrential rainfall or storm surges caused by typhoons or weather fronts/low atmospheric pressure have yet to be targets for study. There are a variety of challenges when it comes to dealing with the uncertainty of disaster causes. In the future, it will first be necessary for research to use data from folklore and ancient documents to gain a long-term understanding of disaster history, nature-friendly land use, living culture, environment changes, and other information as it applies to each and every region. Also, it will be necessary for us to combine the scientific expertise of meteorology, topographical geology, and civil engineering with expertise from the past and clarify the issues surrounding regional mechanisms for disasters and disaster prevention/environment.

Table 2 : Examples of Traditional Water-related Disaster Prevention Countermeasures

Name	Structure/Function
Discontinuous Levees (Kasumitei)	Discontinuous levees have an opening. During a flood, the flow amount of mainstream goes out from an opening in order to decrease downstream. The floodwater is promptly discharged with the decreasing mainstream water level.
Overflow Levee (Nogosi)	An embankment which is partially lower than a normal embankment. A certain amount over the mainstream water level is allowed to overflow, which reduces the mainstream water level.
Protection Forest	A forest zone prevents the spread of sediment and driftwood along with weakening the energy of the water flow against flooding. Protection forest from tide is established along the coastline, anti-debris forest protection is in the mountains and protection forest from flood is along the river.
Setback Levee	An embankment has been constructed on the protected inland behind the primary embankment, and if this embankment collapses it prevents the spread of flood inundation. This secondary levees is also referred to as a two line embankment.
Ring Levee	There is an embankment that has been constructed around the periphery of the village, and this embankment defends the houses and the life from flooding.
Elevated housing for flood preventation (Mizuya, Mizutsuka)	The type of houses(Mizuya) built on a high embankment prepare against internal and external flooding in a flood prone zone. Mizutsuka is able to provide shelter for a long period of time and are stockpiled with wells, food and bedding. A boat is also available as a means of transportation during a flood.

Created by the Science and Technology Foresight Center

4-2-2 Construction of Disaster Prevention Technologies Integrated with Regional Livelihood and Land Use

(1) Changes in Concept toward the Co-existence of Nature and Disaster Prevention Technologies

The primary disaster prevention measures of river managers, coastal managers, and other disaster prevention department authorities up until now has depended on the extent to which protective facilities can handle their attempts to contain design floods in water ways with dams or levees before discharging them toward the sea and to protect coastlines with revetments. However, as was previously mentioned, there are limits to the extent of which these strategies can be used for future disaster prevention. In order to make future efforts toward a sustainable coexistence between Japanese regional communities and nature, as well as to integrate livelihoods with disaster prevention/reduction, big changes in the concept toward disaster prevention will need to occur. Namely, the thinking behind disaster prevention attempts that rely on the strength of structures to counter the energy generated by disasters will need to be revised. Facilities will need to nullify all harm from frequently occurring external forces, while human life will need to be protected from external forces that are exceedingly rare. To achieve this, a move toward a more flexible approach to controlling the size and varieties of damage throughout the entirety of an area or basin is necessary, as is an acceptable degree of structural damage or temporary loss of functionality. This kind of thinking is rather similar to the approach that Japan had been adopting as its ultimate crisis management techniques to protect regional communities from water-related disasters prior to modern times. For example, once when there was a large-scale flood, floodwaters flowed over or broke through the levees and damage was dramatically spread over a wide area. Because the place where the levee would be compromised had been determined ahead of time, however, the surrounding areas were allowed to flood and the damage was localized. In the future, places such as these will be clearly established. In ordinary circumstances, they will be areas that are naturally restored to be wetlands or fields or places that are used for food production, recreation, or sightseeing. In times of distress, however, they will be used to prevent catastrophic disasters. At the same time, preferential treatment in terms of compensation and taxation will come into effect when disaster strikes. As for conditions for land use or evacuation, continuous changes will need to be made with regard to mechanism creation under the assumption that floods will occur.

With a variety of land use and facility development already in place, abandoning these designs to start anew will by no means be easy. However, if considered in terms of Japan's declining birthrate/aging population, Japan will need to change its long-term perspective on how to prevent disasters. The nation make the move toward the construction of a low carbon society with a reduced population. More specifically, Japan will need to introduce multistage disaster control technologies that include reviews of land use in accordance with the scale of catastrophic disaster events. In order to achieve this, evaluations of the flood control capabilities of forests and fields during abnormal weather, the human and material damage that accompanies flooding, the indirect ripple effect of damage, and environmental impact will all be necessary. Also, the technology used for disaster prevention/reduction measures needs to be durable in the face of devastating phenomena, and the entire system from hardware to software needs to be linked reliably. Finally, consensus methodologies need to be crafted in each region.

It is necessary to enhance areas of research that will allow for more comprehensive regional planning. In particular, regional topography, living environments rooted in history, energy, resources for food, economy, and culture could all be merged with disaster prevention in these plans. With regard to the necessity of isolating disaster chains in urban systems and improving redundancy, for example, there is a need for approaches that considers surplus space from the perspective of environmental disaster prevention as well as research approach that adopts a basin-wide scheme.

It is also necessary to establish regional disaster prevention cultures that include educational instruction and disaster prediction/evacuation systems utilizing a variety of data on weather/flow rates to allow for precision evacuation prior to disasters. With all of these ideas, the collaborative support of experts in disaster prevention, environment, social sciences, and numerous other fields will be required.

(2) Challenges in Research on Effective Use of Existing Infrastructure and Facilities

Considering the future increases to the cost of social security, the effective use of existing infrastructure and facilities is an important challenge facing Japan. Beyond simply maintaining the functionality that has persisted up to now, it is vital to capitalize on the many years of operational experience of these facilities and to reconstruct them from a longevity standpoint. This means reconstructing them to be utilized in a more comprehensive manner that will benefit the nature-friendly societies of the future or perhaps help in the creation of regions that are strong against disasters.

Dams, in addition to being able to use stored water for hydraulic energy and a variety of other uses, are able to temporarily dissuade floods and sediment runoff in times of abnormal rainfall and prevent disasters downstream. On the other hand, large amounts of sediment accumulation in the reservoirs forces the dams unable to operate sustainably. Depending on the characteristics of the basin or the facilities used, large amount of sediment is captured and deposited in dam resevoir, changing the water quality or hydrological regime downstream and impacting the environments of flora and fauna as well as the terrain of rivers and coasts. In order to use dams more effectively and more continuously, downstream hydrological regimes and sediment discharge from dams need to be improved. Comprehensive research that takes into consideration of the safety based on local characteristics, the continuous use of resources, and the preservation/restoration of the natural environments is necessary to overcome this challenge, which extends far beyond mere expertise in mountains, rivers or oceans.[6]

Although levees are indispensable when it comes to protecting their surroundings from flooding, construction and improvements to them have taken place in various periods, and they have also been installed over old riverved. Consequently, the structures and materials from which were made lack uniformity, and the protective strength of many of these levees remains uncertain. An accurate evaluation of facility vulnerability is the first thing that needs to be done. Research and development is then necessary to develop inspection/diagnosis technologies for precision maintenance, reinforcement technologies that utilize durable materials/structures to defend collapse by overflow during heavy flooding, and reinforcement technologies harmonize to the restoration of rivers and surrounding environments.

On sandy beaches, numerous tetrapod breakwaters and detached breakwaters have been installed to combat coastal erosion, which is a result of the blockage of drift sand toward the coast caused by coastal structures and a reduction in sediment supply from rivers. However, there are many cases where erosion prevention facilities are nothing more than a basic block. In addition to appropriate sediment supply from rivers, technical solutions conducive to environmental restoration, such as shore reclamation techniques using sand bypasses and the concentration of fishing ports, need to be proposed.

4-2-3 Promotion of Problem-Solving Research through Pilot Projects

Efforts to prevent water-related disasters and restore environments are a complex intermingling of independent natural and social conditions. In addition to investigations into systems and unique technologies by Japan and its local authorities, the accumulation of practical studies that endeavor to place focus on individual regions is also necessary. It is believed that, by clarifying environmental and disaster prevention issues from a regional/basin-wide perspective and discussing each and every path/route of study to solve problems, scientific knowledge will accumulate and will emerge new problem solving technologies and institutional solutions. However, it is impossible to conduct research on every single local area. It is necessary for regions and individuals knowledgeable/experienced in a variety of fields to work closely in order to bring together the wisdom of Japan and conduct project research targeting pilot sites.

5 Final Remarks

We believe studying disaster prevention wisdom from the past and establishing a new era of disaster prevention technologies will contribute to cope with tragic and repeated disasters happened in a region. The “best policy” for the Yellow River continues to be a topic of debate. The river flow and large amounts of sediment caused damage to people living in the alluvial fan. Political dynasties from every period have tried to combat the Yellow River’s behavior in a variety of different ways, such as diverting the river into tributaries to ease its force or heightening levees to raise the flow strength of the river to flush the sediment. The best policy was said to be reading into the tendency of nature by observing the direction in which the stream leaned, then moving the people from that area, tearing down artificial structures in advance, and letting the stream go where it may. At the same time, plains were developed and simple improvements were made.[33] Ideas such as these are thought highly suggestive in terms of regional disaster prevention that is in harmony with nature.

Japan has been blessed with the ability to enjoy rich and plentiful nature that changes with each distinct season thanks in part to large-scale earthquakes, volcanic activity, typhoons, low atmospheric pressure, winter snowfall, and other changes in the natural environment. However, when there is an abnormality, nature suddenly changes, and the weather goes crazy as if to attack us. The Japanese people who inhabited a country such as this must have originally included preparedness and provisions for disasters as part of their daily life. 100 years have passed since modern technology was introduced in the Meiji era, and we are now faced with new challenges. Once more, we need to start at the beginning, correctly understand the nature of each region, and from a comprehensive and long-term perspective, use human intelligence and science to clear a new path that allows us to live in the harmony with nature.

Furthermore, if we shift our attention to the world, we see that over half of the world's natural disaster casualties are a result of floods. Also, 90% of the world's water-related disaster victims are in Asia. Asian countries are a growth center for the world economy. By inspecting disaster prevention measures from the past and establishing a new era of disaster prevention technologies for societies that will coexist with nature, we can make international contributions to countries that have been repeatedly plagued by tragic disasters through the development of infrastructure in countries all across Asia.

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