Study on a New Concept of Flood Management beyond Watershed Scale

March 2020

MA DONGLAI

Study on a New Concept of Flood Management beyond Watershed Scale

Graduate School of Systems and Information Engineering
University of Tsukuba

March 2020

MA DONGLAI

Abstract

In recent years, flood has become the most frequent natural disaster as a consequence of global climate change and frequent extreme rainfall across the world. Intergovernmental Panel on Climate Change (IPCC) pointed out that localized torrential rain is becoming more intensely and frequently in mid-latitude areas during the 5th assessment report. Though the construction of flood disaster-resistant infrastructure is an effective measure for reducing the vulnerability of flood risk from the 9th of Sustainable Development Goals (SDGs) of the United Nations, Raising standards again and again becomes impossible, which the one important reason is that today's Japan is facing serious local financial problems. The latest flood management concepts emphasize integrated watershed management including structural measures using some new materials and nonstructural measures with computer science to solve urban waterlogging problems. Compared with urban waterlogging problems, flood water from the river is more destructive. Regional historical factors such as new paddy development (polder) and urbanization which have changed the river channel and original landform, leading to a change of the watershed patterns, this has intensified regional flood risks.

This dissertation suggests a new concept of the flood management beyond watershed scale according to the analysis of 2015 flood disaster of Kantou-Tohoku Heavy Rain in Kinu River watershed, which the contents are consist of levee breach position, water level, road heights, encroachment in the flood plain, and regional population change. The suggestion mainly uses road-farmland as a temporary detention basin to divert floodwater from dangerous rivers (Kinu River) to the bordering watershed whose river (Kokai River) is safe. Moreover, 2D shallow water equations have been selected to simulate the flood water movement. At the same time, suitable lowlands areas where flood water can drain naturally are proposed, with benefit and cost calculation, and landscape comparison. In addition, other available areas of Japan not limited in Kinu River Watershed and Kokai River Watershed are analyzed and extracted. Lastly, we discussed the development operating mechanism of flood plain according to comparing several ever frequently flooded countries, gave the suggestions and draw further research

The dissertation is consisting of 8 chapters.

Chapter 1 describes the flood threats and damage in recent years and the coming flood-relevant problems in the future under global climate change, and then we stated the intention of the study. Both flood management of Japan and other countries and have been introduced. In the end, we draw the flow chart of the study.

Chapter 2 did a very succinct description of the spatial transition of flood management scale, issued what future flood management will be, and this is the fundamental idea of the proposed method.

Chapter 3 is the overview of the study area; we introduced the study area – Kinu river watershed and Kokai River watershed (KK watershed), flood plain, Kinu River and Kokai River respectively. And we did the analysis of watershed transition, flood history, and limitation of local management. The reason for selection on KK watershed is that flood hazard appears to be increasing in this region. Although structural measures of river improvements such as raising levee and enlargement of river channel width has been done to increase floodwater drainage capacity. Moreover, the land area of the flood plain is slowly disappearing in Japan, whether biodiversity or flood detention, it should be significant research.

In this chapter, we conclude the result of the dissertation which has mainly provided future flood risk management based on past flood control systems and current land use considering not only in KK watershed of 2015KTHR but also the whole of Japan. Summary findings are described as follows:

Chapter 4 mainly analyzed the flood of 2015 Kantou-Tohoku Heavy Rain. A new finding of the levee breach position was obtained firstly. Although we have not proved that the levee break is directly related to its location. We will further explore and study it in future research. The committee of inquiry of Kinu River made the decision according to several times discussion, which is a quick recovery of the river levee breach point. Many examples like the Hakojima retarding basin project after the 1986 flood, Iowa floodway construction after flood in the USA. Learning from the disaster and upgrading from disaster to adapt to the future of climate change.

Then we did the analysis factor of water, road distribution on flood, land use change, population change and regional development of the study area, the result that flood damage was inevitability, road-farmland played some roles in floods, resident land encroachments in the floodplain, flood accelerated the speed of population moving out, spillover happened in the study area seriously, a negative sprawl of region was accelerating were carried out respectively.

Chapter 5, we used the 2D hydrodynamic model to simulate the flooding process with the case studies to show land use characteristics combined with the flooding calculation results in the study area, calculated the loss of inundated houses and farmland. We could infer that merely raised roads could benefit people in a certain area; it should combine the land use and actual situation. According to the inundation navigation issued by MLIT, an expectation of that the wherever a river levee breach happens, floodwaters would reach the DID of Joso, where is the most important area of a city, especially specific public infrastructures such as commerce, education, medical and manufacturing, but are also the basic guarantee for human life sandwiched by the two big rivers. Four tentative options using raised road-farmland according to geographic, land use and escape time analysis were listed and calculated for their benefit and cost as far as possible within the scope of the study roughly, although it conflicts with the land use and economic environment, it is beneficial in long term. Comparing to the Kinu River Project or the Kokai River Project, this proposal suggestion would be lower cost and do little impact on the landscape. However, this needs designated drainage and a social agreement, letting the floodwater flow into this area, so the determining factors are relocating the residents and land use regulation.

Flood management beyond watershed scale differs from the existing concepts of flood management, but they do have something in common, aiming at reducing flood loss resulting from a certain flood by blocking and transporting floodwaters in low vitality, low assets and low population area. It reconnected the watersheds to share the flood risk to benefit most of the residents living in the floodplain, which appropriate land use practice is a key to reduce the flood risk. Land-use pattern changes due to agriculture and industrial development over the last century were accompanied by both straightening of the rivers and loss of river space which led to an increase of urban flood risk. It is difficult to change in nowadays society. Similarly, raising roads and affirming high flood risk areas will decrease the risk of an uncertain levee breach. When the linear pattern of roads is raised, inundation will be confined. The relationship between house damage and inundation depth can also be conducted, while the intangible loss such as quality of life is usually impossible to estimate.

If the plan would pass, both the Kinu River and Kokai River would be reconnected to share the flood risk and stopped fighting alone to benefit more of the residents living in the floodplain sandwiched by two the rivers. The proposal suggestion could also provide advice for decision-makers and river managers. This suggested plan would also restrict the deregulated development, prompt people moving out of high flood disaster risk areas independently, and land use may align with the concept of a compact city in a sustainable urban plan viewpoint.

The Chapter 6 is mainly the analysis of DEM, rivers longer than 50km were extracted, calculation of natural lowland with different buffer distances that intersected multiple watershed boundaries was made, the lowland areas containing more than 2 river watersheds are considered suitable, the result is that there are many areas in Japan that are suitable for beyond watershed-scale management flood. In some of which, countermeasures have been made. Each region has its own characteristics decision-makers and how to select the prevention measures for flood damage may show more or fewer differences. In addition to KK watershed, there are many areas available for our approach - flood management beyond watershed scale; although different buffer threshold might get different results and so-called flood management beyond watershed scale would depend on size and characteristics of river watersheds. However, we have to mention that our study revealed our proposal idea in parallel river water systems will be more efficient to the original one – in the confluence area. With the continuous updating and improvement of Remote Sensing data, DEM data and hydrological information extraction technology in the future, watershed-related research such as flood prevention for the regional sustainable development would be more accurate. Besides, according to the distributions urban area, decision-makers and river administrative department could quickly respond and find where is vulnerable to be protected with the relationship between upstream, downstream and successive watershed conditions

Chapter 7 discussed the operating mechanism of flood plain according to comparing with several ever frequently flooded countries and gave suggestions. All stakeholders' interests should be considered especially in a huge project like changing the river channel, which means vulnerable areas need special treatment. As mentioned, the flood plain is usually a conflict area to develop no matter what country it is. The national government has an important role to coordinate geographically adjacent watersheds, they should be responsible to "share the challenge" and local governments of the related areas should make appropriate land-use plans to reduce long-term risks. If not, loss of life and flood will continue to worsen in future floods.

Chapter 8 gave a brief conclusion of the concept, which was calculated to the KK watershed using the road-farmland rearrangement to determine the flood storage areas and resident area. The results were validated against data from historical floods. The road-farmland could also reduce the risk of uncertain levee breach and unstoppable flood. If a flood comes, reserve farmland will make the flood damage controllable, fixed and minimized (Hirao, T., 2000). Also, the landscape would do less impact on the local people's lives, production of agriculture and industry. Our proposed approach is not a modern technology methodology, but it does rethink the theory of current flood management, with the emergence of more and more advanced materials, the human should have nothing to fear to meet the future of rapid climate change.

Acknowledge

Time flies, five years of doctoral study are coming to an end. I was fortunate to have received the careful guidance and help from everyone in the lab.

I would express my heartfelt thanks to my academic advisor Professor Osawa Yoshiaki who has taught me not only cultivated scientific research skills but also the way of thinking and how to be a doctor, which is an encouragement for me to write my dissertation. He also gave me many chances to learn that I have never experienced Japanese culture and events during my Ph.D. period.

I would thank co-advisor Professor Ishii Norimitsu, in the process of writing the dissertation; Professor Ishii has been giving me selfless help. He helped me to find the problems in the dissertation and face up to it and guided me tirelessly to revise the dissertation.

Mr. Suzuki Tsutomu is also my co-advisor and he is very kind, he always encouraged me and gave me suggestions when I am confused. He is also the key to why I choose this research topic. I had a good time that I spent with his students Dr. Hasekawa doing the flood fieldwork.

I would also like to thank Professor Fujikawa Masaki, my co-advisor, Professor Kawashima Hiroichi, committee member, I appreciate their guidance and comments they gave me from different viewpoints that enabled my study to be plenitude.

Besides, I would thank Dr. Yoshikawa Seiko from the National Agriculture and Food Research Organization of Japan; she does much invisible help me to finish this dissertation.

I would also thank the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) of Japan who has offered me a 3 years scholarship as the financial support.

Sometimes, I always feel helpless in a foreign country. Thanks to my classmates in the lab and friends around me. When I am frustrated, they give me encouragement. When I am alone, they stay with me. I wish our friendship would last forever.

At last, I want to thank my family for living both in China and Japan, my wife and my daughter.

Everyone again, thank you for encouraging me all the way in the past five years, thank you

for your help and support, thank you for your care and love for me, thank you sincerely!

Appendix

List of some names of place and river are not shown on maps in the dissertation

Place name	River name	Japanese name	Prefecture
Ichikawa City	Mama River	真間川	Chiba Prefecture
Mabi Town	Oda River	小田川	Okayama Prefecture
	Ishikari River	石狩川	Hokkaido
	Chitose River	千歳川	Hokkaido
	Hakkenbori River	八間堀川	Ibaraki Prefecture
	Biwa Lake	琵琶湖	Shiga Prefecture
	Kisosansen	木曽三川	Nobi Plain
	Hakojima retarding basin	母子島遊水地	

Table of content

Table of Tables

1. Introduction

1.1 Background

In recent years, flood has become the most frequent natural disaster (Figure 1-1) as a consequence of global climate change and frequent extreme rainfall across the world (Wilby, R.L., Keenan, R., 2012; Kundzewicz et al., 2010). Intergovernmental Panel on Climate Change (IPCC) pointed out that localized torrential rain is becoming more intensely and frequently in mid-latitude areas during the 5th assessment report (IPCC, 2013). Especially in Asia, floods are reportedly the most severe (Figure 1-2). Dams, dikes, and levees are the structures which are often used to control floodwater and reduce flood risk in the past decades (Kamada, S., 1989; Tanabe, T., Okuma, T., 2001; Nakajima, H., Ohgushi, K., 2013), once failures of these flood control structures happens, it will cause huge loss of economy and life due to population concentration and the frequency of extreme rainfall in Japan (Duan, W et al., 2014).

Though the construction of flood disaster-resistant infrastructure is an effective measure for reducing the vulnerability of flood risk from the 9th of Sustainable Development Goals (SDGs) of the United Nations, Raising standards again and again becomes impossible, which the one important reason is that today's Japan is facing serious local financial problems (Uda N., 2015); the nation cannot pay enough local expenditure. Regional developments have traditionally relied on structures such as river levee or an upstream dam, as flood control methods to mitigate flood hazards, but these kinds of approaches have been criticized for decreasing riverine ecosystems, biodiversity and increasing long-term flood risk (Pedroli, B., et al., 2002; Rohde, S., et al., 2006, Chen, Y.R., et al., 2011.). Especially in Japan, there are lots of earthquakes happening every day that may destroy some vulnerable flood control facilities at any time.

The latest flood management concepts so-called integrated watershed management includes structural measures using some new materials and nonstructural measures with computer science to solve urban waterlogging problems (Schneidergruber, M., et al., 2004); Mama River watershed is one of the areas which came up with integrated watershed management with high urbanization (Takano. K.,1983). Compared with urban waterlogging problems, flood water from the river is more destructive. Regional historical factors such as new paddy development (polder) and urbanization which have changed the river channel and original landform, leading variations in the flow direction, sediment production and even the watershed patterns, have intensified regional flood risks. These polders are disorderly distributed in back swamp and lowlands, which are usually planned as urbanization control areas. Moreover, floods are major drivers of soil erosion, pollutant, agrochemicals pesticides, and other sources. Floods-related problems and unreasonable land use directly restrict local sustainability development.

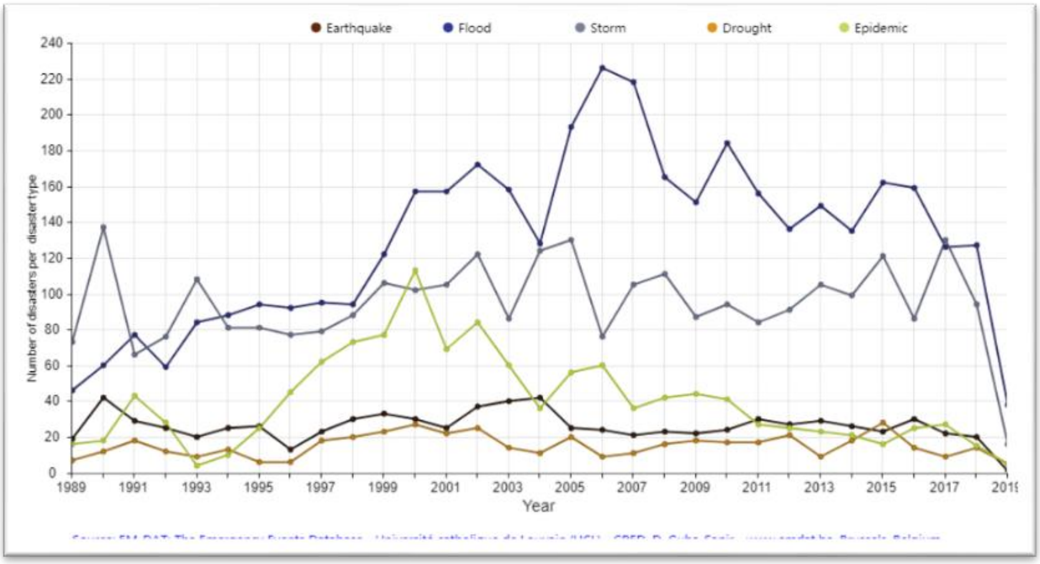


Figure 1-1 Number of natural disasters across the world from 1989-2015

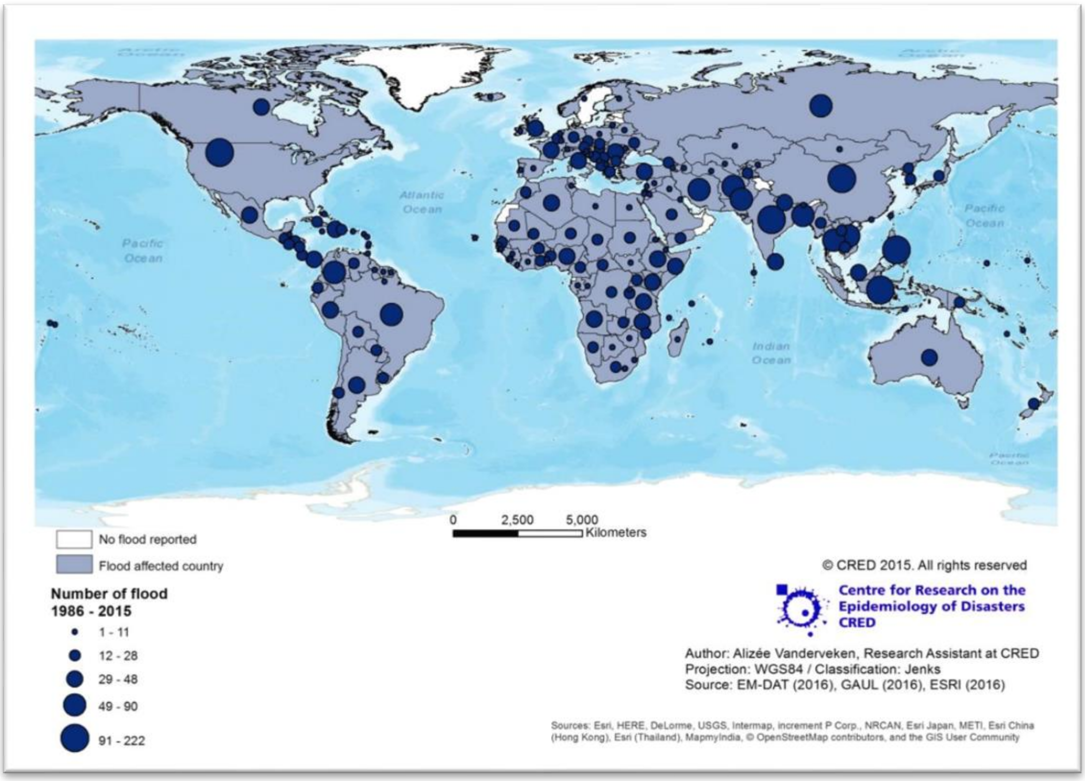


Figure 1-2 Distribution of flood disasters across the world

1.2 Flood management in Japan

1.2.1 Main factors of frequent flood disasters in Japan

Several factors are well known of frequent flood disasters in Japan, described as follows:

(1) High precipitation

The annual average rainfall of the whole of Japan is approximately 1,700 mm, much higher than the world average of 970 mm (Inoue, K., 2007).

(2) Steep elevation

Japan is a narrow island country with steep mountains in the center part making the rivers flow into the sea shortly and steeply and watershed areas small. Thus, floods usually start and end quickly (Inoue, K., 2007).

(3) Social conditions

Another important is a social condition, owing to the natural conditions above, which 50% of the nation’s population and 75% of the nation assets are concentrated on 10% of the lands (Ueda, T. 2003), which are usually considered suitable for development.

1.2.2 Flood management in Japan

The Japanese government and researchers have been working on flood management all the time. In ancient times, people used the experiences and local knowledge of flood characteristics to control local floods (Ueda, T. 2003). Most flood managements were focused on structural methods such as excavating canal and constructing river levees to prevent flood disasters. For example, the Horie canal in Nanba, which was used to divert the flood water from Kawauchi Lake; and the Bunroku Levee, which was designed and constructed to block the floodwater from Yodo River. Systematic and scientific flood management works began in the Meiji period. They were led by the government, recommended by researchers and supported by the public until nowadays. Furthermore, with the rapid development of computer information science, non-structure methods such as a flood model to simulating a flood or a flood hazard map showing the dangerous area, and a rational land use regulation. According to the main contents of flood management, the structural method can be roughly divided into the following four types:

(1) Flood control construction management around rivers

The Japanese government had basically completed the flood control measure constructions for rivers by about 1930. Flood control measures around rivers can be divided into two types according to the flood control theory, Low Water Level flood management in the past and High Water Level flood management currently. Low Water Level flood management was designed to ensure the maximum flow of the river by broadening the river channel, dredging the bed, and constructing the super levee. But only the Low Water Level flood measures were not enough to prevent flooding by practice. High water level flood management who is mainly based on straightening the river channel and constructing high levees has become a major flood management measure (Kundzewicz, Z.W., Takeuchi, K., 1999). The shape of a river channel is one of the major factors affecting the speed of flooding. The discharge capacity of a straight river is faster than a winding river. It indicated that river straightening can increase floodwater discharge speed and reduce sedimentation (Ueda, T. 2003). With the rapid economic growth of Japan during the 1950s-1970s, more and more continuous river levees were constructed to impound floodwater and reduce flooding, and this method is proved as a very efficient to reduce the flood risk during the past decades. As a consequence, the sediment was brought by the rainstorms accumulated in rivers and raised river beds. The standards of river levees have to be increased continuously to cope with the elevated bed and global climate change, standards of river levees were calculated by using the historical maximum watershed rainfall and river water level. Although these constructions around rivers are the most immediate and effective flood control measures, they also have some drawbacks. For example, straightening the channel destroyed the river ecosystem and rising the river levee became continuously and decrease of landscape, moreover, this method is not 100% safe as there is always exceed design rainfall coming.

(2) Green flood control management

Flood control constructions can not only completely prevent flooding, but these construction activities also damage riverside environments and ecosystems. In the 1980s, people gradually realized the importance of the ecological environment. Those constructions at the expense of destroying the environment were replaced by the concept of Green flood control. Forests and grasslands can store and intercept surface water. Green flood control management refers to use the functions of forest and grassland to control flood. It also can improve the ecological environment (Calder, I.R., 2007), and gradually evolved into a municipal landscaping facility to provide service for the public. But this method can only mitigate flood risk in the short term, considering with the soil water saturation, the effectiveness will be limited if the rainfall lasts for more than one week.

(3) Super embankments

Floods are huge hazards to densely populated cities. In 1987, the Ministry of Construction’s River Council proposed Protection Policies to defense extreme floods from urban areas to improve the flood control capacity, among which super embankment is a practical method for urban flood management. An ordinary embankment is 20-50 meters in width and 10-50 meters taller than the surrounding houses and buildings, but there is a risk of the breach (Hamaguchi, T. et al., 1986). If the ordinary embankment fails in flooding, the house and building near the river levee will be risky of being washed away. Super embankments have a width of about 200-300 meters and raise the ground level around rivers (Kundzewicz, Z.W., Takeuchi, K., 1999; Knight, D., Shamseldin, A., 2005). Then more and more new towns were developed on them. Comparing with ordinary embankments, Super embankments work better on flood control. They protect people and property from flooding by raising the ground level around rivers and reducing embankment failure risk. Current super embankments were implemented at the 6 largest rivers, including the Ara River, the Yamato River, the Tone River, the Yodo River, the Tama River, and the Edo River. However, a project of the super embankment is very difficult to execute. The construction is not only very expensive but also requires the support of cooperation among the government, local offices and residents.

(4) Integrate flood management

Since watershed science was rapidly developed with computer technology, flood management is becoming an issue everywhere of the entire watershed not limited to the riverside area. Especially in urban areas, beyond the basic sever system, integrate flood management was suggested in the 1980s, a typical example was the flood management of Mama River Watershed in Ichikawa City (Takano. K., 1983).

1.3 Flood management across the world

Different countries differ in flood management methods according to the adopted flood control strategies on its natural geographic characters. Here we list some countries with their flood management.

Flood management in China is mainly depending on the dams and reservoirs which are designed to plan and construct flood storage and detention areas, because of its broad land, but it is regulated for how and when to use the flood detention recently. Moreover, the construction of a super dam such as the Three George Project in the Yangtze River is very efficient on flood preventing, bus also criticized for other impacts. Some researchers discussed the project did direct impact on the 2008 Wenchuan Earthquake; many environmental and ecological issues were dressed and need to be improved in the future (Hayashi, S., et al., 2008). Moreover, lots of floodways and flood retention areas for flood mitigation are still retained.

The Netherlands has the 40% of the land area below the sea level, what they concerned is more likely tsunami, thus a strategy of ring levee and double levee was made (Brouwer, R., Van Ek, R., 2004), moreover, their standards for flood control are very high such as those for city and the seawall can defense against 10000 years flood and 4000-10000 years flood respectively. Furthermore, their river way was designed to defend from a 1250 years return period flood. However, the high standard flood control projects are still facing the failure risk and tremendous pressure caused by extreme weather events (Van Stokkom, H.T., 2002.).

Germany, the whole country was run by Elbe River, flowing from the Czech Republic, controlled flooding using a system of retention area on the middle reaches of the Elbe River to be an effective method. The flood control system consists of 6 polders and the floodplain of a tributary, total volume amounts to approximately 250 million m^3 (Saskia, F., et al. 2005).

France has implemented the natural disaster risk disclosure system since the 1980s, it clearly defines that a levee and civil engineering construction in the flood plains cannot affect the flood detention effect and the expansion from the city to the flood risk areas is strictly controlled, based on the basic structure methods (Tu, M., et al., 2005).

After the severe flood in 1993, the United States revised the national flood plain management comprehensive plan which takes the sustainable development of the economy and ecological environment in the long term as a task of flood management. The plan focuses on the quality of flood control constructions especially levees and doesn’t ask for higher flood control standards, which is quite different from the Japanese flood strategy. The Iowa State Government purchased and demolished houses in the 100-year flood plain after the 2008 flooding to completely restore the function of the flood plain where the areas are being used as community parks (The Daily Iowan). Recently low impact development (LID) and best management practices (BMPs) become research hotspots to solve urban flooding as integrated flood management.

It can be concluded that flood management methods are divided into two major types, the ones that focus on engineering flood control measures and the others that combine engineering flood prevention measures with non-engineering measures, they are usually made by designed heavy rain, with the uncertain climate change in the future, it is necessary to consider more methods to reduce flood damage. For the flood control technology, it does not need advance technology but respect to nature itself to find effective methods to reduce flood risk.

1.4 Research intention

Simply strengthen flood protection standards seem to be no longer popular and unrealistic because of insufficient funds in Japan. In addition, only using the river levee to control floodwater is proved to be impossible. Flood management should consider leaving sufficient room for future floodwater from an overall perspective of sustainable development. In addition, the local government is paying more attention to the problem of livelihood issues rather than flood management. Therefore, flexibility and alternative should be a basic requirement for future flood management, which is an extremely important but usually neglected factor of flood management. This study takes the 2015 Kantou-Tohoku Heavy Rain (2015 KTHR) in Japan as an example and analyzes characteristics of flood management strategies, land use patterns, and population characteristics in the flood plain systematically. We discussed the floodwater behavior, suggest the land use pattern and remap the flood hazard zone. The Ph.D. thesis aims to answer the following research questions:

(1) The cause of the 2015 KTHR flood that Ministry of Land, Infrastructure, Transport and Tourism (MLIT) did not find out.

(2) Suppose a new concept of flexibility method from the 2015 KTHR and how should the performance and applicability of using these facilities as temporary floodways be evaluated?

(3) How to minimize loss when meeting a huge disaster that could not stop?

2. Concept of flood management – beyond watershed scale

2.1 Flood management transition

It has been a long time ago the flood management was simply floodwater mitigation to protect the target area. In the 20th century, industrialization became popular, flood management gradually becomes the combination of flood mitigation and water use, as several times the amount of water consumption than before. Immediately thereafter, the emphasis was placed on issues of water quality and the environment. Currently, flood management is becoming integrated in U.S. Japan, Europe, and Australia all over the world (Heidari, A., 2009), it is not only structures of flood control method based on the traditional idea in riverside area, but also small-scale rainwater storage and promotion of infiltration projects in the landside area, in addition, unstructured flood control methods such as computer predictions is developing. Kinds of effort have been made, but there is still a lack of countermeasures of coping with floods that exceed the design of the current flood control system. So it is crucial to find a method that would flood management be in the future (Figure 2-1).

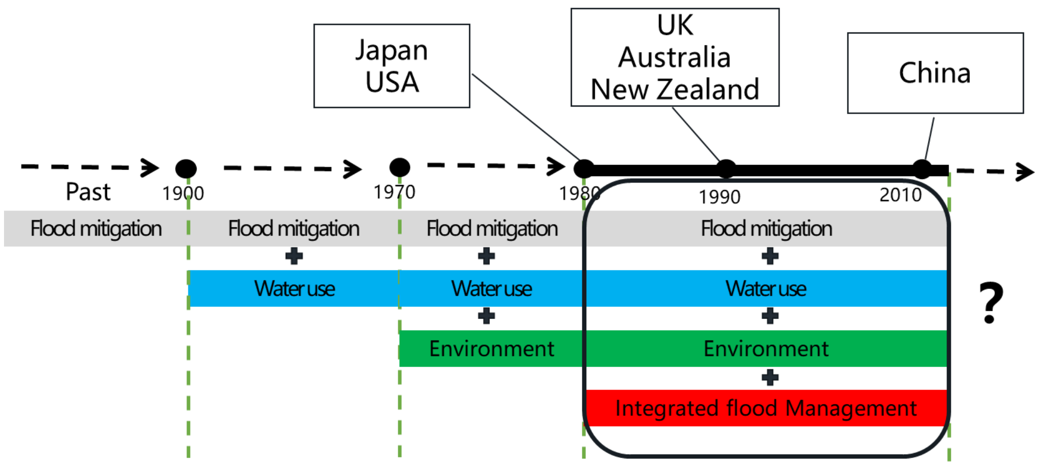


Figure 2-1 Flood management transition

2.2 Spatial scale shift

In this section, we summarized the spatial scale shift of flood management for a better understanding of the flood management transition (Figure 2-2). Water is the basis of life, the wise ancients usually lived nearby a river, but rivers without any control often brought floods, so they started to control a river from flooding a certain area, gradually this area formed a city. People started to control not only the section where they are closed but also the river upstream, as time passes flood management transformed as a whole watershed scale till nowadays. This study would like to suggest a new concept of flood management beyond a watershed scale in the future.

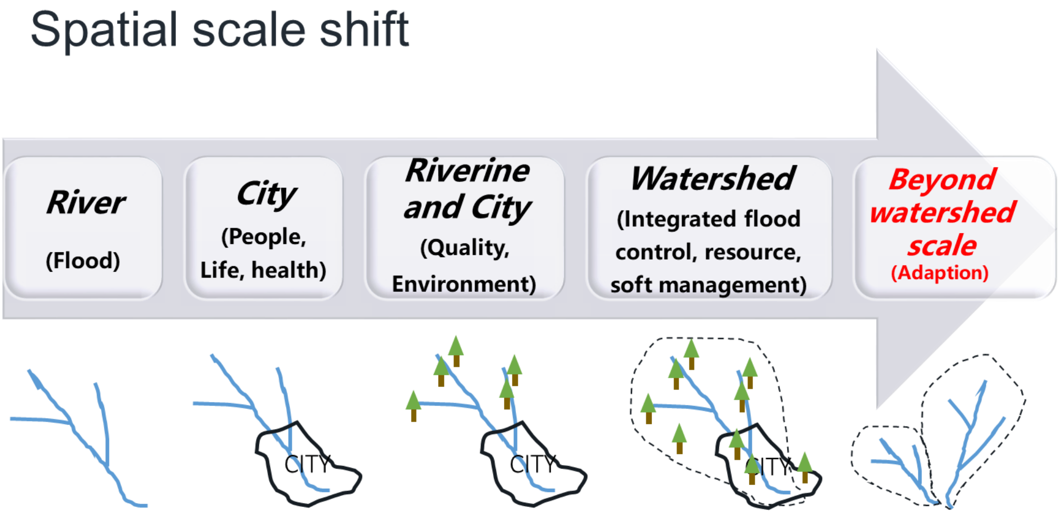


Figure 2-2 Spatial scale shift of a flood management

2.3 New concept of flood management – beyond watershed scale

Rivers that catch water in their basin while flowing are greatly affected by the topography. It can be understood as a flood sharing in the multi-watersheds, similar but the different concepts (Huang, G.W.; Isobe, M., 2005) exists throughout the world such as a retarding basin and drainage floodway. These methods focused on restoring the capacity of rivers to accommodate more floodwaters, but not to share flood risk from the perspective of multi-watersheds.

In contrast, the merit of this proposal could be expected:

(1) Reduce the risk of levee breach and make the random damage become controllable (same as a retarding basin). As detailed previously, flood retarding basins can reduce the river water level downstream which can reduce flood damage particularly for more exceed flood events. While appropriate planning decisions need to make to avoid project failure, if not, it can cause catastrophic downstream damages.

(2) Connect two watersheds to share the flood risk, flexibility for flood mitigation of both

rivers. This kind of flood retarding basin generally occupies large areas of land. As a result particularly in urban areas, large areas of land need to be purchased or insured which would cause the relocation and disruption of local community members and equality issues of individual members.

(3) Reduce the flood loss if there is a river breach.

2.4 Research flow chart

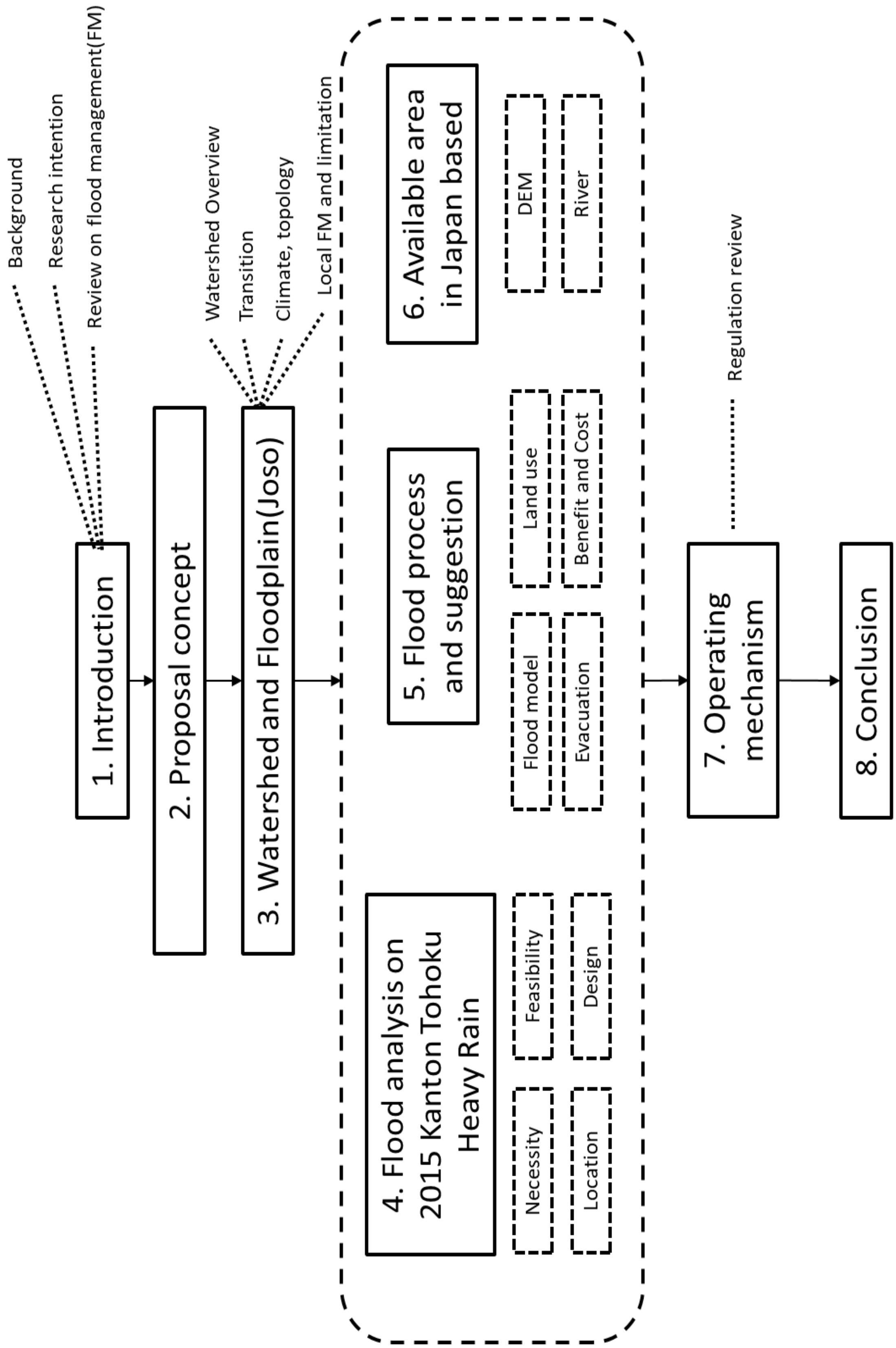


Figure 2-3 Research flow chart

3. Overview of research area

3.1 Watershed and formation

Watershed refers to a land area that collects rainfall and snowmelt to rivers, and eventually to outflow points such as confluence or ends in the sea. While some watersheds of tributary are relatively small, mainstreams usually encompass vast areas and contain various water receiving bodies such as rivers, lakes, reservoirs and underlying groundwater.

Flood plain refers to a lowland area where the river waters overflow from the river channel during flooding (almost synonymous with alluvial plains). Usually, it extends from the river bank to the base of the valley walls. The meander erodes its sideways day and night as it travels downstream. The river breaks its banks when floodwater comes, which leaves behind layers of alluvium. This unconsolidated alluvium that floodwater brought gradually build up the flood plain. Alluvium usually contains sand, gravel, loam, silt, and clay which are important aquifers for the environmental development of the flood plain.

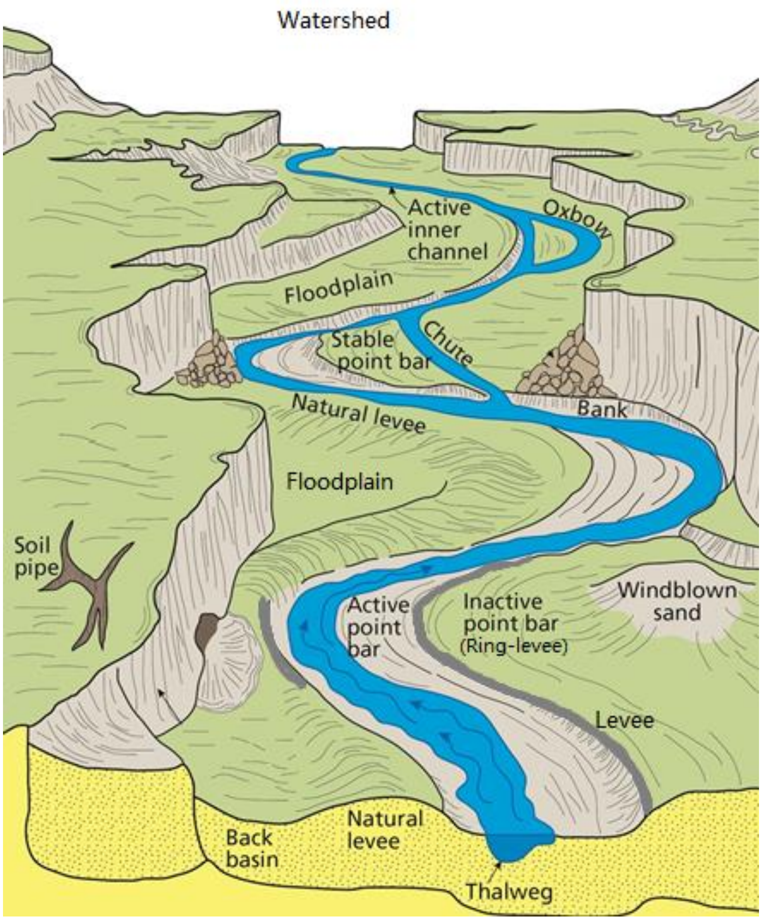


Figure 3-1 Image of a watershed (Source: Trista L. Thornberry-Ehrlich, Colorado State University, edited by author)

The formation of a floodplain is marked by an active inner channel and is occasionally completely covered with water such as oxbow, stable point bar, and back swamp. When the river channel has been stopped or entirely diverted for no matter natural reason or human reason, the floodplain would become an area of great fertility that is suitable for farming, it usually formed downstream, which is flat and has a slow angle from the side towards the center.

The floodplain is the natural area where the river dissipates its energy. Floodplain usually forms from meanders which could slow down the main river water flow, and when the main river channel is out of its capacity, the river water would spill over to the floodplain and temporarily stored.

For flood management, the upstream of the watershed, there is usually a mountainous zone, where is crucial as the flood water control starts. There are always dams constructed. Levees are set up in midstream or downstream of the watershed because they are usually considered vulnerable.

Large scale artificial canalization of the river does a major impact on flooding. A new flood plain will be formed. Land development in the flood plain is a relatively sensitive issue nowadays. The encroachments of flood plain by residents have caused many river terraces of the flood plain to be reclaimed into farmland, especially in Asia, where rice is the staple food. Large areas of cultivated land are arranged along the river banks and levees. As the uncertainty of a levee breach, highly-concentrated residents will more be exposed to a flood.

3.2 Kinu River and Kokai River watershed

Kinu River and Kokai River (KK) watershed (Figure 3-2) is the largest sub-watershed of the Tone river basin. There are 24 municipalities in the KK watershed, in Ibaraki prefecture and Tochigi prefecture, Japan.

3.2.1 Kinu River

Kinu River started from the Kinunuma pond, which located on the boundary of Tochigi prefecture and Gunma prefecture, flows down the canyon (Kawaji hot spring area in Nikko City, Tochigi Prefecture) to the east, and then goes through flood plain (Shimotsuma, Joso, and Ryugasaki, Ibaraki Prefecture) part with several tributaries joint, ends into the Tone River (largest basin in Japan) at Moriya, Ibaraki Prefecture.

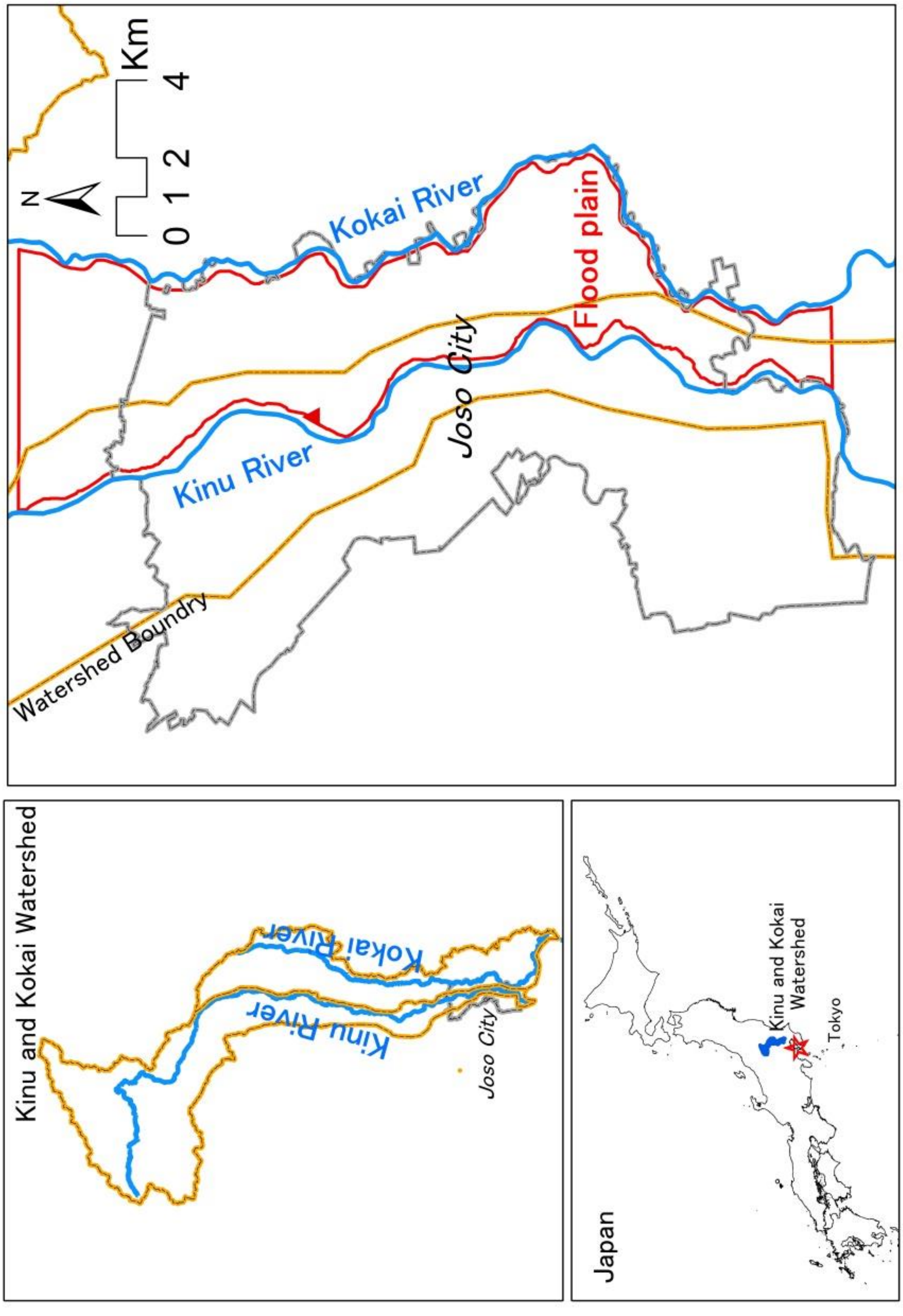


Figure 3-2 Location of KK watershed and study area

The main river channel of the Kinu River is 176.7km, the total tributaries channel length is 859.8km, the watershed area is 1760.6km^2, which the mountain area is 1105.4 km^2, and flat area is 607.6 km^2. The population is approximately five hundred and fifty thousand.

2.2.2 Topography

There is a series of steep mountains ranging from 500m to 2,500m above the sea level in upstream of Kinu River watershed, where is very susceptible to rainfall. And the downstream is quite flat where suffers from flood frequently as the consequence.

3.2.3 Climate

The temperature of the upstream is about 4 ℃ - 6 ℃ lower than midstream and downstream because it is located at a higher altitude and much north. Annual rainfall is between 1,800mm and 2,000mm.

3.2.4 History flood

This watershed has been flooded many times in history since its formation. The annual report usually includes numbers of injured and dead; damaged houses; the number of assets, public loss such as gas, agriculture, and the inundation area by the Ministry of Land, Infrastructure, Transport and Tourism of Japan after World War II. However, the quality of life of the affected population has never been recorded. Besides, local municipalities have also kept statistical flood loss. Table 3-1 listed the recent brief information on flood disasters of the Kinu River.

Table 3-1 History flood of Kinu River

Date	Reason	Site	The damage
1935.9	Heavy rain / typhoon	Ibaraki Prefectural	Inundated house: 739 Inundation area: 1300 ha
1938.8	Heavy rain / typhoon	Mitsukaido, Ibaraki Prefecture	Inundation area approximately: 4000ha
1947.9	Heavy rain / typhoon	All municipalities along the river	Complete destroyed houses: 5,736 Half destroyed houses: 7645 Inundated house: 303,160 Inundation area:176789ha
1948.9	Heavy rain / typhoon	-	Inundation area: 200ha
1949.8	Heavy rain / typhoon	Utsunomiya, Tochigi Prefecture	Complete destroyed houses: 2 Half destroyed houses: 170 Inundated house: 230 Inundation area: 4500 ha
1998.9	Heavy rain / typhoon	Utsunomiya, Shioya, Tochigi Prefecture	Inundated house above floor level: 27 Inundated house below floor level: 170 Inundation area: 200 ha
2002.7	Heavy rain / typhoon	Joso	-
2011.9	Heavy rain / typhoon	Ibaraki Prefecture Yuki, Joso City, etc.	Inundated house above floor level: 5 Inundated house below floor level: 13 Inundation area: 30ha
2015.9	Heavy rain / typhoon	Joso City, Shimotsuma City, Yuki City, Chikusei City, Ibaraki Prefecture	Dead and missing: 14 Complete destroyed houses: 1703 Half destroyed houses: 3574 Inundated house above floor level: 2523 Inundated house above floor level: 13259

3.3 Kokai River watershed

3.3.1 River Water System

The Kokai River originates from Nasu Kashiyama City, Tochigi Prefecture, and joins the Tone River mainstream in Tone Town, Ibaraki Prefecture. This river is comparatively gentle quite different from the Kinu River. The main channel is 111.8km, the total channel is 474.5 km and the watershed area is 1,043.3km^2.

3.3.2 Climate

In the Kokai River watershed, the annual average precipitation is 1000-1300mm, barely snowfall in winter.

3.3.3 Topography

In the Kokai River watershed, flat land accounts for more than 80%, and the mountainous area is only 10%. The altitude of the water source is low, and the slope of the riverbed is slight.

3.3.4 History flood

This watershed has also been flooded many times as its slow discharge. Table3-2 listed the recent flood disasters and brief information.

Table 3-2 History flood of Kokai River

Date	Reason	Affected Area	Disaster Loss
1927.9	Heavy rain / typhoon	Mitsukaido, Ibaraki Prefecture	Inundated house both above and below floor level: 289
1935.9	Heavy rain / typhoon	Ibaraki Prefecture	Complete damage house:109, Inundated house both above and below floor level: 2950
1938.7	Heavy rain / typhoon	Moka, Tochigi Riverine cities of Ibaraki	Dead and missing：9 Inundated house above floor level: 2863 Inundated house below floor level: 5787
1938.9	Heavy rain / typhoon	Sekijo, Akino, Ibaraki	Complete damage house: 9 Inundated house both above and below floor level :416
1950.8	Heavy rain / typhoon	Torite, Fujishiro Ibaraki	Dead and missing: 3 Complete damage house: 1874 Inundated house both above and below floor level: 5468
1981.8	Heavy rain / typhoon	Riverine cities of Ibaraki	Inundated house above floor level: 1580 Inundated house below floor level: 3960
1986.8	Heavy rain / Typhoon No	Riverine cities of Ibaraki	Inundated house above floor level: 1240 Inundated house below floor level: 3230

3.4 Watersheds transition

For both natural factors and human factors of historical reasons, the Kinu River channel has changed many times; the present residential areas are completely new emerged. The most influential artificial one is the Tone River east transition project of the Edo period, this made many people are living in the active point bar of the old river by the present artificial levee, less of whom realized the false safety impression that levee brings to. Although rapid urban development has changed the original morphology to be livable, some places are often ignored where is vulnerable and needs to pay more attention. Figure 3-3 shows the downstream of the watershed transition from 29000 BC to 300 BC.

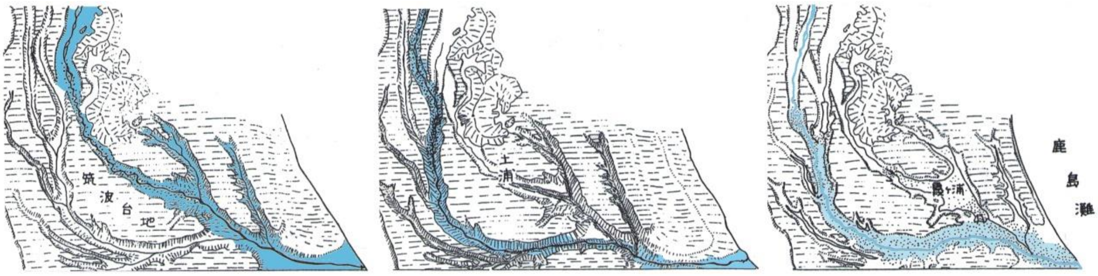


Figure 3-3 Downstream of the Kinu River of 29000 BC, 20000-6000 BC, and 6000BC-300BC (Ikeda, H et al. 1977).

(1) Thousand years ago, Tone River, Kinu River, and Kokai River

A thousand years ago the main channel of Kinu River and Kokai River were completely different from the current flow, as the Kokai River is the tributary of the Kinu River.

(2) The east transition of Tone River

It was during the Edo period that Tokugawa Ieyasu entered Edo Castle in 1590, the Tone River, which had flowed into Edo Bay (current Tokyo Bay), was replaced with the Taichi River and the Hitachi River, and artificially changed flows to Choshi in Chiba Prefecture until now. He created the new Tone River system.

(3) Separation of Kinu River and Kokai River

At the beginning of the Edo period, the Kinu River flowed almost in parallel with the Kokai River and then connected near Shimotsuma via the Itochi River. The broad-scale development of the Kinu River and Kokai River was started from early 1600; a new river channel was excavated shows in red in Figure 3-4. The original purpose of separation or Kinu River and Kokai River to aid ship transportation for the capital.

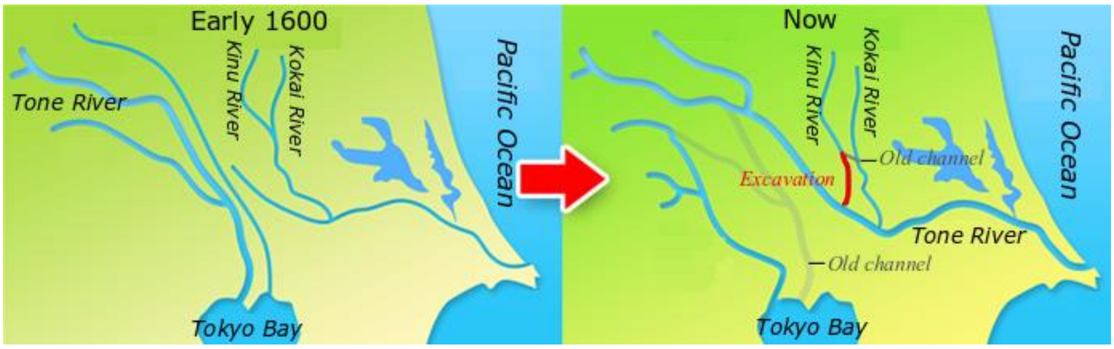


Figure 3-4 River channel Transition (Edited by the author from http://www.minumatanbo-saitama.jp/outline/minumadaiyousui.htm)

(4) Consequence

Separation of Kinu River and Kokai River had ensured more quick transport to move the goods from the north area to Edo. Also, vast wetlands of the Yawahara territory were protected from flood damage, and new paddy field development was promoted. As a result of this excavation, a large scale of new paddy field was developed with a lot of small-scale rivers excavation for water utilization and farming irrigation, at the same time, flood risk also shifted. In addition, dams were constructed in the upstream of the mountainous area.

This change of Kinu River had really changed the flood situation such as Joso city and Ryugasaki city.

3.5 Flood management

As the artificially changed the flood plain, the cities downstream suffered from the frequent flood by its instability. Most of them have strengthened the river levees. And this seems the only way to prevent a flood. Joso is one of them, which plays a pivotal role in the agricultural development of the social economy in Ibaraki Prefecture, the design standard of river levee was 1/30 return period to a flood event. Although problems such as water pollution, water shortage of the living environment have been greatly improved in recent years, sedimentation, discharge deterioration, and flood threat have yet to be well addressed downstream in recent years. The river transition actually restricts local development with the consequence that the old river ecosystem has completely disappeared.

Flood has become a key factor in the sustainable development of regional economies. It has been recognized that flooding is not possible to completely control by structure control facilities. As we all know, the basic is strengthening levees to avoid levee breach. However, the cost of investing in implementing measures including improvements to facilities is limited, and it does not seem to be many clear criteria and how to allocate them. In addition, as for land use in floodplains (Naef, F., et al. 2002.), although there are some actions that limit buildings or dwellings in hazardous areas, there are not many quantitative references to how much restrictions are needed. Non-structure measures such as developing appropriate warning systems seem to be good do help the residents to evacuate in the flood event to protect their lives but usually fail to be executed by residents.

4. Flood analysis of 2015 Kantou-Tohoku Heavy Rain (2015 KTHR)

4.1 Overview of Kinu River Flood

Typhoon No. 18 changed to a temperate cyclone at 21:00 on September 9, 2015, which brought a band pattern heavy rainfall in the Kantou region and Tohoku region, especially in the upstream of Kinu River watershed of Tochigi prefecture, Japan (Figure 4-1).

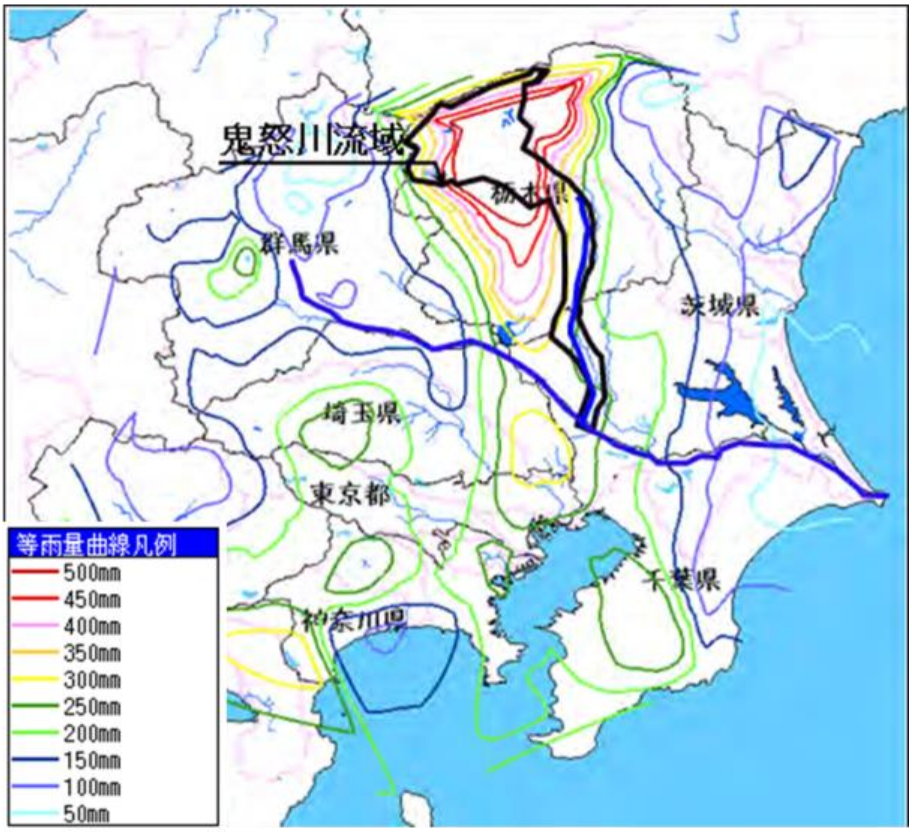


Figure 4-1 Rain contour line (Kantou Bureau of MLIT)

The average rainfall 3-day and water level were accompanied by the highest ever measured at many gauge stations and river water level observations, such as Ishii gauge station, it was 501mm (1/110 return period), which ranked the highest rainfall in the history (Figure 4-2).

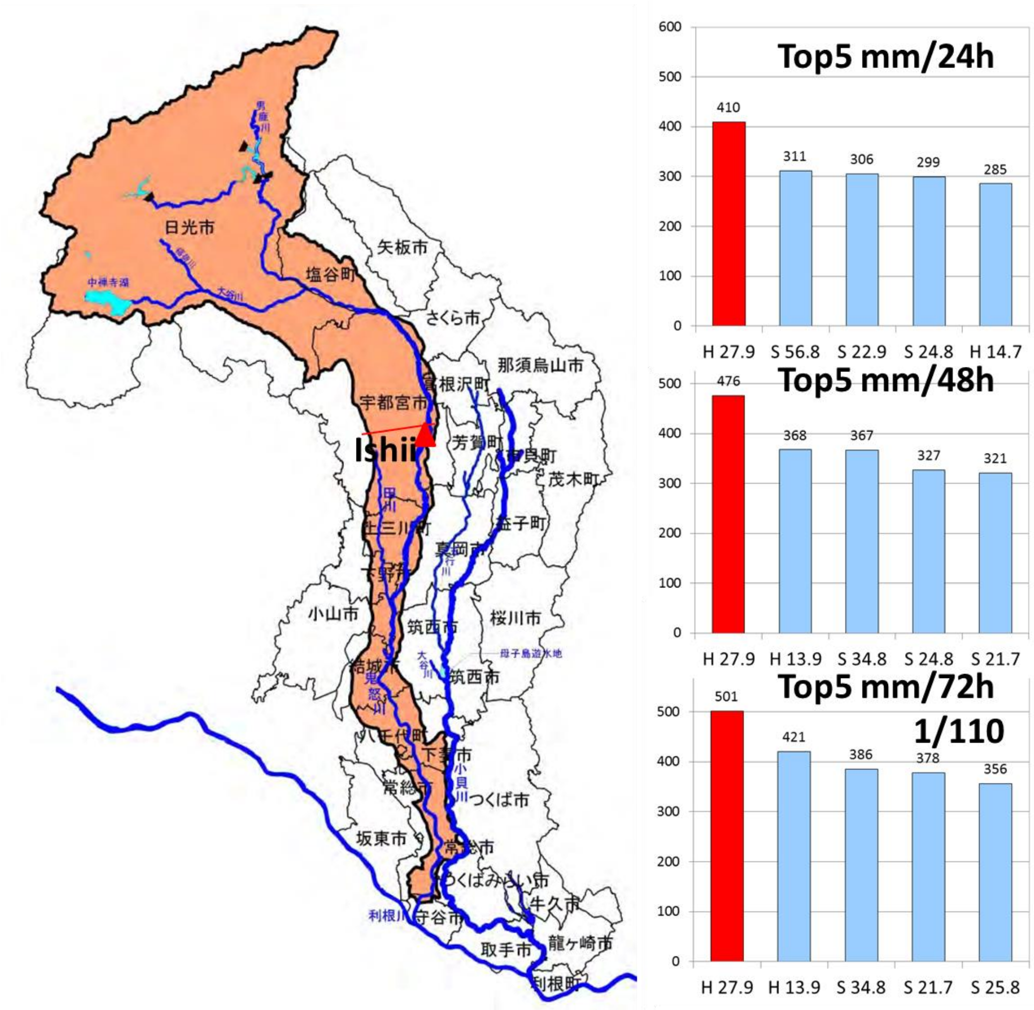


Figure 4-2 Location of Ishii gauge station in Mid-stream Kinu River watershed

(Investigation report about Kinu River flood in September 2015)

On Sep.10th, 2015, heavy rainfall hit the Kantou area of Japan, which resulted in a serious overflow in 25.35km, left bank (25.35k) and a levee breach in 21 km, left bank (21k) in the Kinu River watershed, downstream. The levee breach happened at 12:50 and the final width reached about 200m. The flood water spread out largely to the south and the west crossing the Joso City. For the south direction, the floodwaters went straight although temporarily blocked by the east-west road finally reached the densely inhabited district (DID) area, where is high elevation. For the west direction, the floodwater was stopped by the right bank of the Kokai River. There were 14 people dead and more than 159 billion JPY lost during the flood disaster.

4.2 Kinu River Flood Control Project

The flow capacity of the river is quite different from upstream to downstream. There are multiple locations whose discharge capacity less than 3000m^3/s in the 0-25k (downstream), while 4500m^3/s in the 25k-40k (midstream). Since the low discharge capacity downstream, MTIL implemented the river improvement project and gradually improved it as an HWL strategy. Joso is located range 10k-25k, an insufficient discharge capacity area.

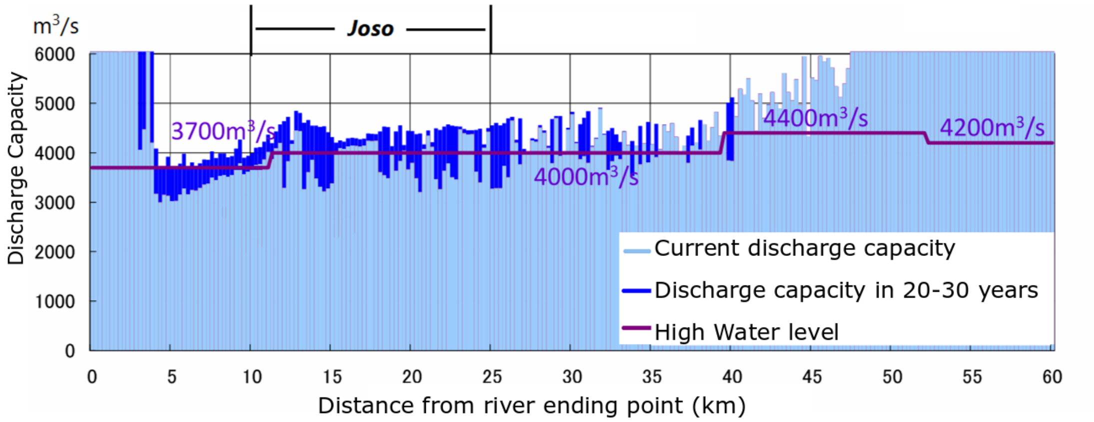


Figure 4-3 Flow capacity of the Kinu River (Source: Kinu River improvement project)

Table 4-1 Project plan transition

Year	Content	Details
1965	Kinu River Project was identified	8800 m^3/s in Ishii
1973	Improved to 3 dam (additional one)	3 dam: 2600 m^3/s; 6200 m^3/s in Ishii
1992	Improved in details, 4 dams (additional one)	
2006	Re-plan changed due to new Tone River law	5400 m^3/s in Ishii; 5000 m^3/s in Mitsukaido
2011	Project assessment (1/30)	12k-39k: 4000 m^3/s; 0-12k: 3700 m^3/s
2016	Re-plan based on 2015 flood	6600 m^3/s in Ishii; 4300 m^3/s in Mitsukaido

The current flow capacity of downstream 0-25k of the Kinu River is quite low, and Joso accords for half.

Since the cost of river project about 22.8 billion JPY in 16 years from 2000 to 2015, 1.4 billion JPY per year. Only 43% of the project is finished, and Tochigi accords for 67%, Ibaraki is 17%, there is a lot of work to do in the future.

4.3 Joso Flood Control Project

4.3.1 Levee breach position

The map of Figure 4-4 shows the location relationship of the present river channel and over the river channel, which is extracted based on DEM analysis. Coincidentally, the breach point of 2015 KTHR occurred at their intersection. Floodplains are often represented in the geological landscape by fluvial terraces, moreover, alluvial soil was found around 400m north to the breach point (Yoshimura et al., 2016, Figure 4-5), which is usually brought by floodwaters, it indicates there used to be flood water passing by in this area as indirect proof. According to the historic map, it was proved again this area was used to be the flood plain where floodwater used to release energy. In addition, there are many similar intersections existing in the flood plain. This can explain that a special position such as the intersection of the modified river is usually weak without special treatment (Bledsoe, B.P., Watson, C.C., 2001).

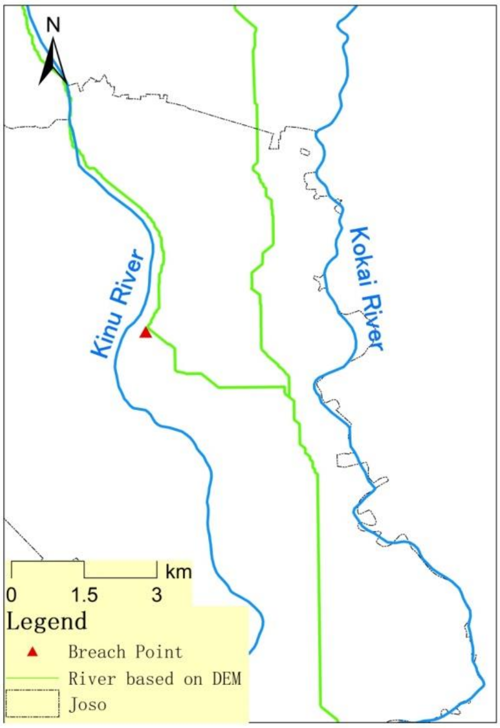


Figure 4-4 Hydrological analysis beads on DEM of downstream of Kinu River

Figure 4-5 Photo and location by Yoshimura ((Yoshimura et al., 2016)

4.3.2 Water level change

River water level change was explained in this section as Table 4-1 shown. On the day of, 9th September(the day before the break), the increase rate per hour was less than 5 cm from 6:00 to 14:00; the water level increased from 10 cm to 40 cm per hour from 15:00 to 1:00 of 10th, and then the water level increased extremely and continuously from 50cm to 1m per hour. It was 5:40 that overflow occurred in the Wakamiyato. The water level at 6:00 was 6.27m and continued to rise after that. Around 12:50 on the 10th, a levee breach occurred in the Misaka area, and the water level of the Kinu River in Mitsukaido at 13:00 was 8.07m. A large amount of river water flowed into the Misaka through the levee breach point, and after the peak of 13:00, the water level dropped to a safe situation gradually. Both of the overflow and breach were located upstream of the water level observation of the Kinu River in Mitsukaido.

The data of water level observation “Kamaniwa” in Shimotsuma on the upstream of overflow and breach is as Table 3-2. Similarly, the peak is at 12:00 on the 10th, just before the levee breach of 13:00, and the water level dropped rapidly thereafter.

Table 4-2 Water level of Kinu River in Mitsukaido (Unit: meter)

Time	2015/9/9	2015/9/10	2015/9/11	2015/9/12	2015/9/13	2015/9/14
1:00	-3.2	0.77	5.56	2.16	0.82	0.08
2:00	-3.18	1.49	5.35	2.06	0.75	0.05
3:00	-3.15	2.47	5.16	1.96	0.7	0.01
4:00	-3.12	3.44	4.93	1.87	0.65	-0.01
5:00	-3.08	4.25	4.71	1.78	0.61	-0.03
6:00	-3.02	4.98	4.49	1.7	0.57	-0.05
7:00	-2.96	5.63	4.27	1.63	0.55	-0.08
8:00	-2.89	6.27	4.07	1.55	0.52	-0.1
9:00	-2.84	6.85	4.01	1.48	0.48	-0.12
10:00	-2.79	7.3	3.92	1.41	0.45	-0.14
11:00	-2.74	7.68	3.79	1.36	0.42	-0.16
12:00	-2.69	7.92	3.64	1.33	0.39	-0.19
13:00	-2.64	8.07	3.52	1.32	0.35	-0.21
14:00	-2.58	7.97	3.39	1.3	0.32	-0.24
15:00	-2.48	7.73	3.27	1.29	0.29	-0.27
16:00	-2.33	7.46	3.17	1.28	0.28	-0.27
17:00	-2.13	7.2	3.06	1.24	0.27	-0.28
18:00	-1.79	6.94	2.94	1.21	0.26	-0.29
19:00	-1.56	6.7	2.82	1.16	0.24	-0.32
20:00	-1.31	6.48	2.69	1.11	0.22	-0.36
21:00	-1.02	6.29	2.58	1.05	0.18	-0.39
22:00	-0.63	6.1	2.47	0.99	0.16	-0.4
23:00	-0.21	5.93	2.36	0.94	0.13	-0.36
0:00	0.22	5.75	2.26	0.88	0.1	-0.29

Table 4-3 Water level of Kinu River in Kamaniwa (Unit: meter)

Time	2015/9/9	2015/9/10	2015/9/11	2015/9/12	2015/9/13	2015/9/14
1:00	-0.57	1.93	2.89	0.85	0.69	0.57
2:00	-0.56	2.38	2.66	0.83	0.69	0.57
3:00	-0.55	2.93	2.37	0.81	0.69	0.56
4:00	-0.53	3.43	2.19	0.8	0.68	0.56
5:00	-0.51	3.95	2.03	0.8	0.68	0.56
6:00	-0.49	4.41	1.87	0.78	0.67	0.55
7:00	-0.48	4.79	1.76	0.75	0.67	0.55
8:00	-0.47	5.16	1.65	0.75	0.66	0.55
9:00	-0.43	5.36	1.54	0.76	0.66	0.54
10:00	-0.41	5.62	1.45	0.8	0.64	0.54
11:00	-0.39	5.75	1.39	0.83	0.64	0.53
12:00	-0.37	5.76	1.33	0.84	0.63	0.52
13:00	-0.30	5.69	1.29	0.85	0.62	0.52
14:00	-0.20	5.51	1.23	0.84	0.61	0.52
15:00	-0.12	5.27	1.19	0.83	0.61	0.51
16:00	-0.15	5.02	1.15	0.82	0.61	0.52
17:00	0	4.8	1.11	0.81	0.61	0.51
18:00	0.11	4.59	1.06	0.80	0.6	0.51
19:00	0.27	4.36	1.03	0.78	0.6	0.50
20:00	0.48	4.16	1.00	0.77	0.6	0.51
21:00	0.66	3.92	0.97	0.76	0.59	0.56
22:00	0.86	3.68	0.94	0.74	0.58	0.62
23:00	1.10	3.42	0.91	0.72	0.58	0.68
0:00	1.45	3.16	0.88	0.70	0.58	0.70

Both of the two observation was far exceeded the flood warning level.

It was clear that if there were no levee failures in Misaka, the volume of floodwater from upstream would result in a drastic and rapid rise of the water level of the Kinu River, and then naturally inundate on the other areas. People along the river are really high risk as the current levee level is only designed as 1/30 return period.

4.3.3 Roads and floodwaters

Comparing to the consequence of surface imperviousness of urbanization that hinders the infiltration of rainwater and increases the risk of urban waterlogging (Giudice, G. D., et al. 2012), complex facilities may significantly affect the behavior of floodwaters in case of inundation. In contrast to the discrete distribution pattern of houses, continuously distributed linear facilities, such as roads, railways, and canal levees may block floodwater from spreading. Consequently, these high raised continuous facilities may affect the flood water flow direction. As an example, Figure 4-6 shows the relationship of flood process and a road during the 2015 flooding event in Joso. Most reports and surveys indicated that the roads and houses were completely inundated; the city was almost isolated from the outside world. No roads were allowed to use, which led to a delay on both pumping trucks and support. As a volunteer, I participated twice in flood-post relief activities with the University of Tsukuba.

Most of the structures of roads and houses were not destroyed due to the slow floodwater speed, this was quite different from the area near the breach point, where violent flow discharge washed houses away, took people's lives away.

Figure 4-6 Photo shows road blocking floodwater by MTIL, 9 hours elapsed after the overflow, which is taken by the helicopter, an overview from the south-north angle.

The most important information in Figure 4-6 is that overflow floodwater flowed from levee down south to the floodplain slowly than the walking speed and blocked temporarily by prefectural road No.24. However, with more and more floodwater from the river coming in, as a consequence, floodwater flowed over the road from the low altitude section and spread south. As floodwater stays or flows over depend on the balance between the total amount itself and the shape of the road topography.

Since floodwater is blocked by road several times during inundation, the average speed is inevitably slowed down, Figure 4-7, 4-8. Slow average speed means less damage.

Figure 4-7 Photo shows road blocking floodwater by MTIL

Figure 4-8 Photo shows road blocking floodwater by MTIL

All submerged when meeting a flood no natural levee east-west along the old river channel

4.3.4 Encroachments in the flood plain of Joso

The floodplain is the natural area where the river dissipates its energy. But the current flood plain is now modified and encroached owing to its rich soil; the rainwater is only drained irreversibly by the canal, which should have flowed into the river before the river channel changed. Because of human factors, some river sections have become a raised bed river that would be extremely dangerous.

To know the recent trends in land use in the flood plain, we selected the aerial imagery data from GIS, since the 10m mesh resolution satellite data of land use from JAXA could not identify all the structural changes in flood plain area. We first made registration of aerial imagery in Ishige area (along prefectural road No.24) of the floodplain of 1948, 1968, 1999 and 2015 (Figure 4-9), then mapped the encroachments and analyzed the number differences of in Ishige area of each period, shown in Figure 4-10.

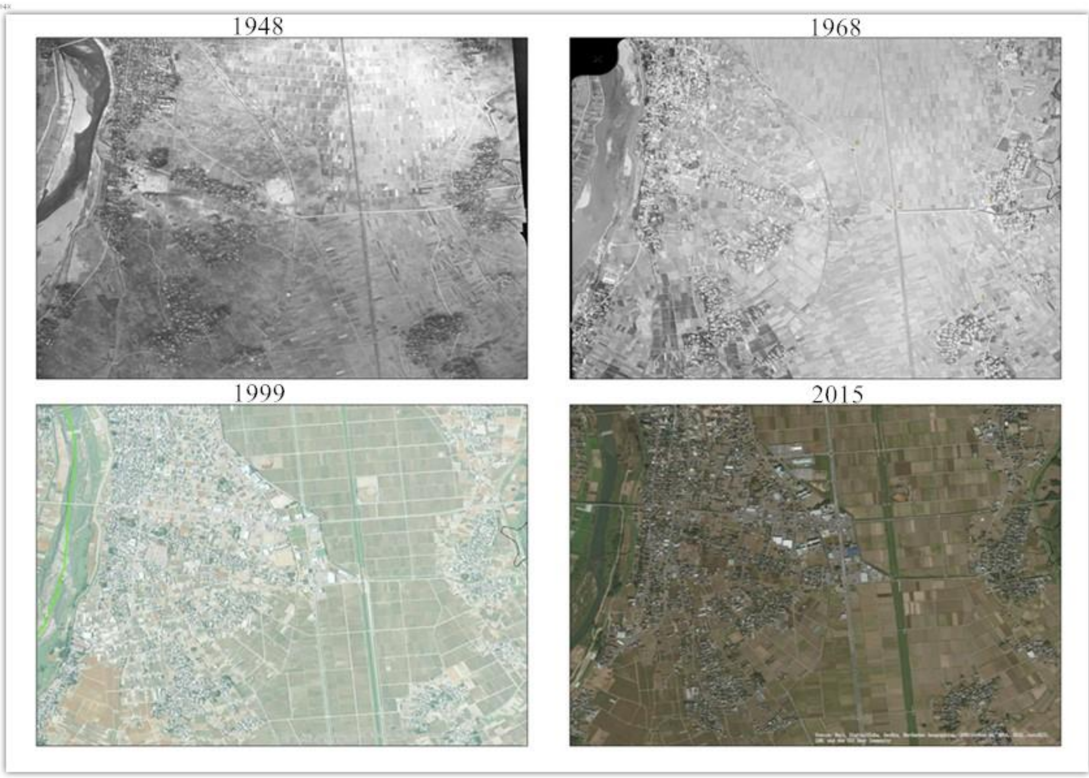


Figure 4-9 The graphic registration of encroachments in Ishige area of the floodplain in1948, 1968, 1999 and 2015. The range of years for each map reflects the dates

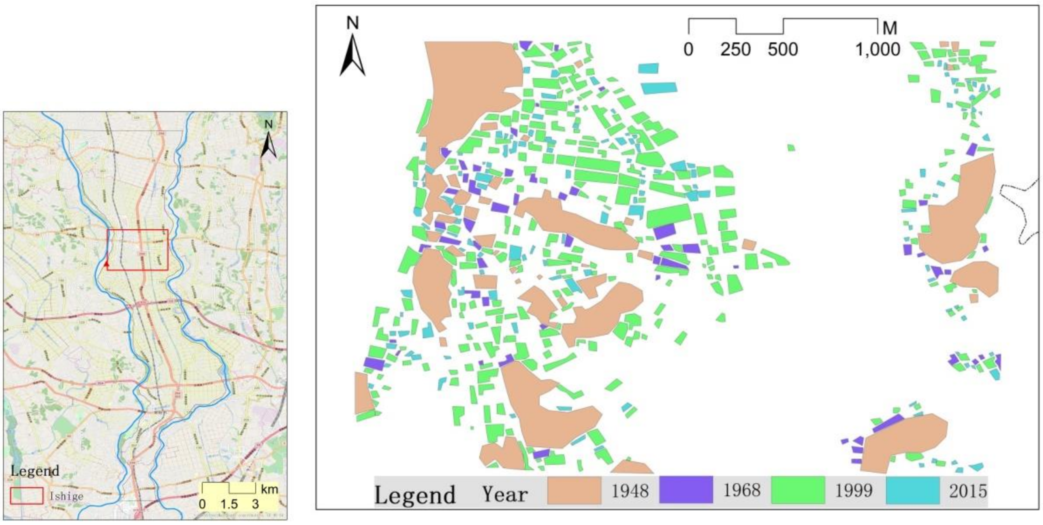


Figure 4-10 Orthoimage of an east-west oriented road within the flood plain flanked by residential settlement

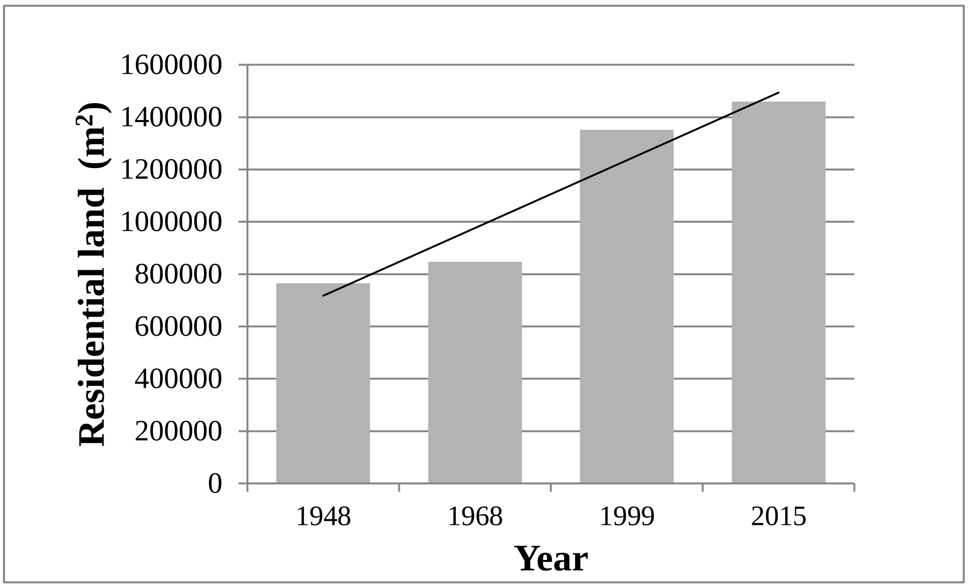


Figure 4-11 Residential land change in the past 70 years

Consequently, we found that the total encroachment of resident land had doubled in number over the past 70 years, see Figure 4-11. Some encroachment phenomenon of flood plain by resident lands occurred robustly which lies outside of the highland (natural levee) and has ‘spilled-over’ into the floodplain itself. According to these effective aerial imageries of land-use change, we can conclude that encroachments construction in flood-prone areas is not only limited in Ishige area of the selected rectangular area, which accords less of the whole flood plain but also encroachments phenomenon occurs over the whole flood plain. Although this is also an inevitable consequence of urban development, it is crucial to solving.

The encroachments within the flood plain have implications that go beyond the inundation of the poorly-sited structures themselves. The buildings concentrate along roads and almost form a connection from east to west roughly affecting the floodwater flow direction. The linear pattern may increase hydraulic roughness during floods, but no studies have been published assessing potential effects on the conveyance of the floodplain during levee breach floods. In some ways, this reflects the lack of enthusiasm to enforce land-use restrictions or too much trust on the river levee. These dispersed people lived in flood plains with the illusion of safety that the river levee brings to.

4.3.5 Population Change

In contrast to other regions' encroachments, DID is usually dominantly residential with some commercial, including some important facilities. People usually gathered in this area.

While, the DID population showed a decrease change during to past 40 years, see Figure 4-12, which is more difficult for the concept of intensive urban management (compact city). But even more desperate is that flood disaster has accelerated this decrease.

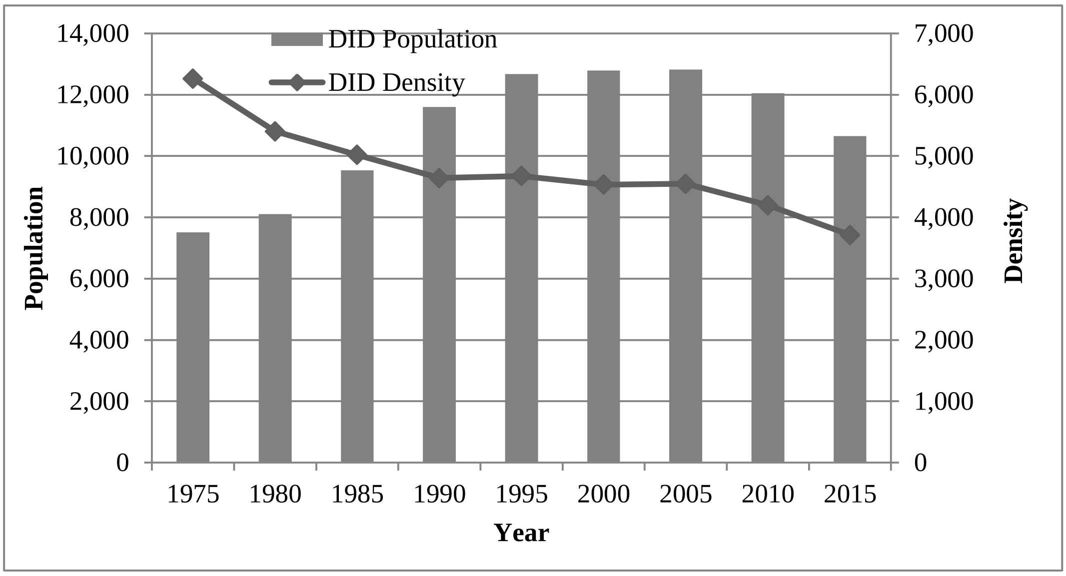


Figure 4-12 Population change in DID during 1975-2015

Based on the people move out data of 2014 and 2015 from city hall, it clearly shows that 2015 is 2 times over 2014, see Figure 4-13, especially along the Tsukuba Express Railway, which connects Tokyo to Tsukuba Science City, the number reached 3 times, the map shows in Figure 4-14.

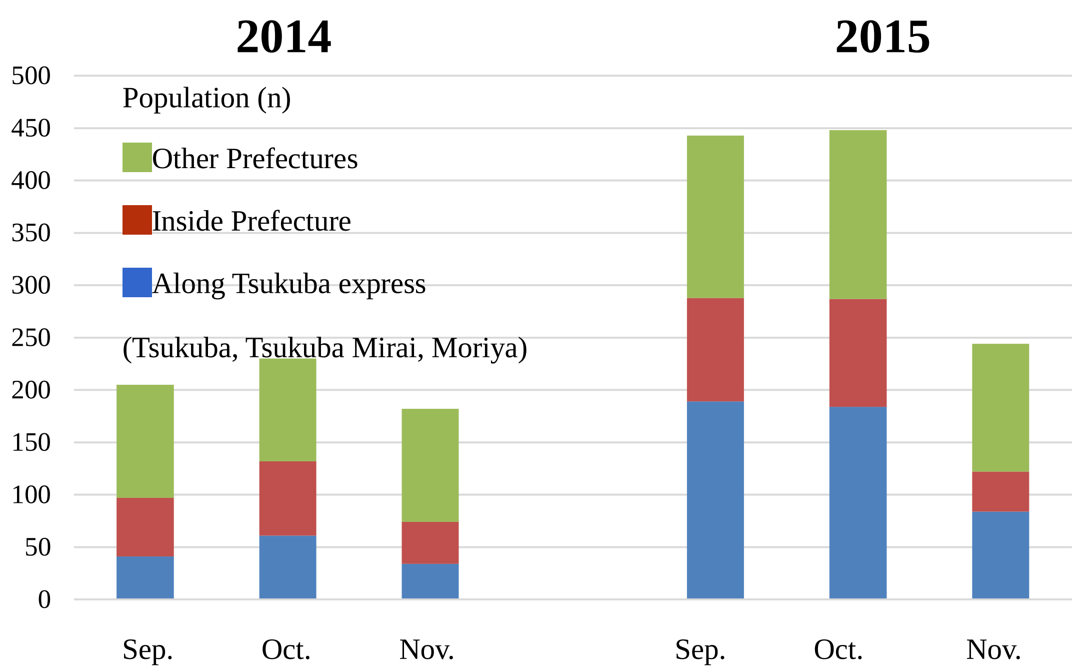


Figure 4-13 Number of people moved out during the flood month

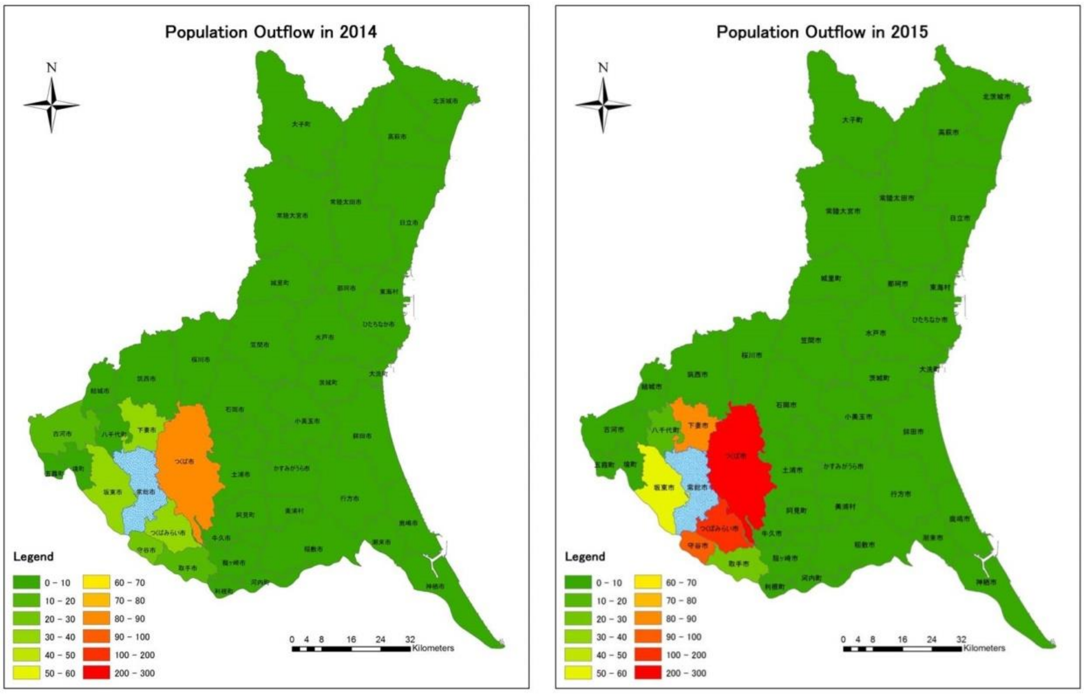


Figure 4-14 Immigration before and after flood, 2014 and 2015 in Joso and its surrounding cities

Populations changes before and after flood disaster also show the negative impact of the flood disaster, in September and October of 2015 show obvious vertices, see Figure 4-15.

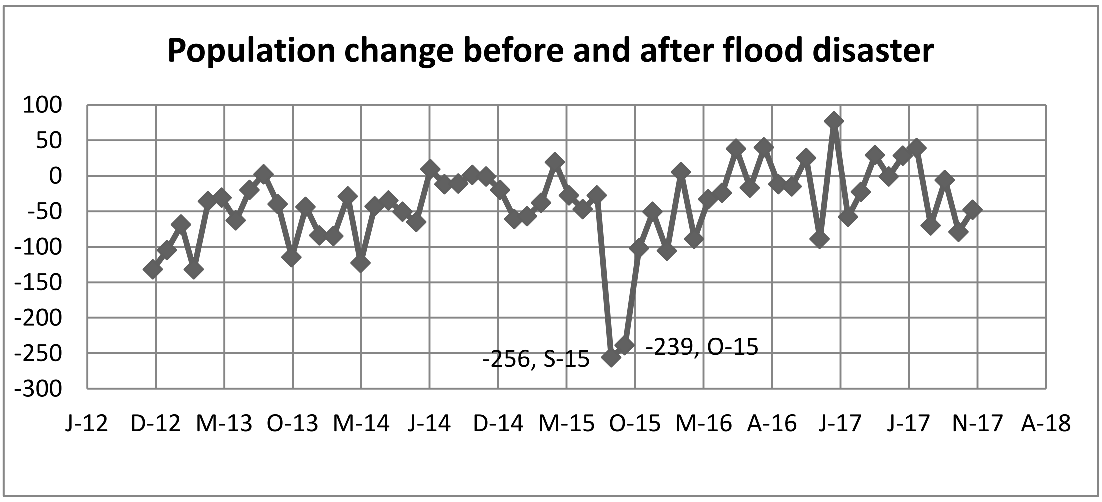


Figure 4-15 Population change before and after flood disaster

From Table 4-4 of age composition, we can find people in their 20s and 30s accounted for the largest proportion and their children ranked next.

Table 4-4 Age group of people immigrated

Age group	Census 2015	Moved out	Moved out /Total
0-9	5416	98	1.81%
10-19	6338	39	0.62%
20-29	6576	226	3.44%
30-39	8488	201	2.37%
40-49	8905	108	1.21%
50-59	8199	87	1.06%
60-69	9946	36	0.36%
70-79	6680	33	0.49%
80-89	4147	17	0.41%
90-99	851	7	0.82%
100+	32	0	0.00%
Total	65578	852	1.30%

4.3.6 Impact on region development

The indirect impact of flood disasters on the regional population will bring long-term negative impacts (Figure 4-16). The reason is that floods are extremely destructive once it occurs, so the people will lose their homes, some of whom will select a reconstruction and some will move away. Young people prefer to move away with his family because of stronger survival adaptability. Rest aged people are lack of purchasing desire; this will cut the local economy and the attractiveness. Less and less attractiveness will accelerate young people moving out and the negative spiral will occur. This is very different from the promoting regional development goals of the authorities.

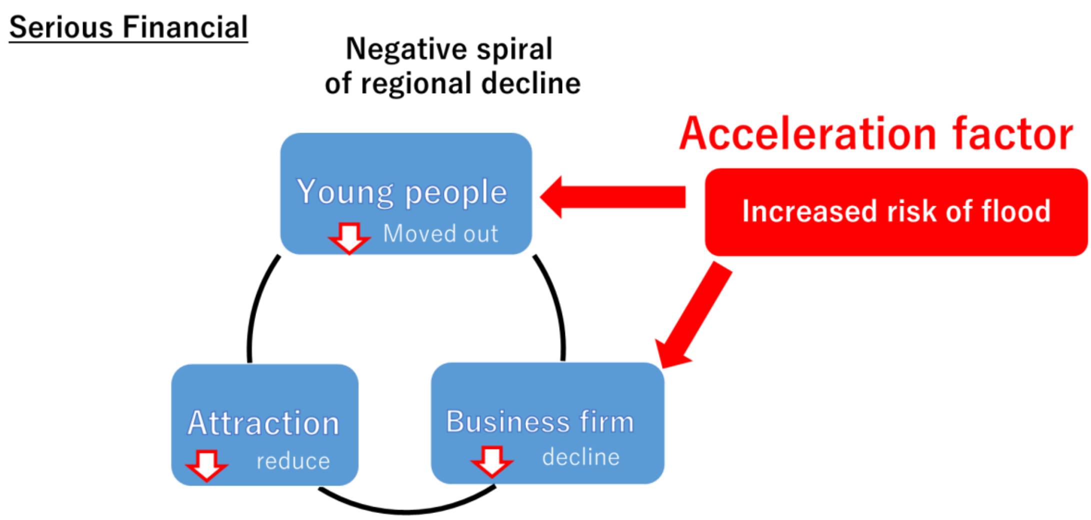


Figure 4-16 Image of a negative spiral of regional decline

4.4 Summary

Chapter 4 mainly analyzed the flood of 2015 Kantou-Tohoku Heavy Rain. A new finding of the levee breach position was obtained firstly. Although we have not proved that the levee break is directly related to its location. We will explore and study it in future research. The committee of inquiry of Kinu River made the decision according to several times discussion, which is a quick recovery of the river levee breach point. Many examples like the Hakojima detention basin project after the 1986 flood, Iowa floodway construction after flood in the USA. Learning from the disaster and upgrading from disaster to adapt to the future of climate change.

Then we did the analysis factor of river water, road distribution on flood, land used to change, population change and regional development of the study area, the result that flood damage was inevitability, road-farmland played some roles in floods, resident land encroachments in the floodplain, flood accelerated the speed of population moving out, spillover happened in the study area seriously, a negative sprawl of region was accelerating were carried out respectively.

Disaster would cause an indirect impact on regional sustainable development, especially on the population in flood behavior changed area (Shang, J.; Wilson, J.P. 2009); it will bring long-term negative impacts.

Furthermore, MLIT has reported that flood events occurring in Japan as a rural problem and mainly due to insufficient river levee and a lot of breach and overflow before the 1970s (Ikeuchi., K., et al., 2011), but became a more urban event since the late 1980s due to a lot of urbanization and waterlogging, and now back again to the regional area cause of financial difficulties, talent ‘spillover’ and aging of flood control structure is considered as the most serious social problem.

5. Flood process simulation and best location of the concept

5.1 Proposed concept in details

As mentioned above, KK watershed was originally a unified one but separated nowadays, the flow discharge capacity of downstream is proved quite low in the Joso area. In addition, the original floodplain was used to eliminate flood energy but developed as new paddy fields; this is undoubtedly a kind of disrespect for the natural development of a river and the watershed, which burdened the flood protection pressure. Although kinds of structures of wetlands, retention basins, ring-levee, and double-levee have been constructed for flood control to protect a certain area, there is still a lack of countermeasures of coping with future floods that exceed the design of the current flood control system in the downstream area. A common of these methods is to block floodwaters from inundating the target areas, which is necessary to consider measures against the present approach of high water level strategy.

Since the levee breach happened at 12:50 on the 10th of September and spread out largely to the south and the west crossing the Joso City. The logic is that more inundation area causes much economic loss. The linear pattern of roads could affect the floodwater flow direction (Mori N, et al., 2011), we propose that reconnecting the rivers together again with their co-owned floodplain by establishing a floodable area where can be temporary and energy elimination using natural topography and roads. And we shut the floodwater in this area, where would be also considered as the connection of the two watersheds. When disaster struck, help came from all sides.

Roads are usually vulnerable to a flood, and they do not have a flood-prevent function or tall enough, but they do have more or less affected floodwaters on about reaching the target area in the south of arriving time during the 2015 Kantou-Tohoku Heavy Rain in the flood plain. This is the premise for us to make the hypothesis of re-directing floodwaters to meet the future floods that exceed the design of the current flood control system such as an overflow or a levee breach of a river to protect the more assets-concentrated area as ‘flood management beyond watershed-scale’, at the same time, in this area, the flow of rivers from each other is not irreversible. Also, climate models of IPCC suggest extreme precipitation, higher watershed-boundary water flows, and sea-level rise will increase beyond the existing river capacity. The hypothesis in detail is that the existing roads are raised forming temporary floodable areas from inundating the more areas (Figure 5-1).

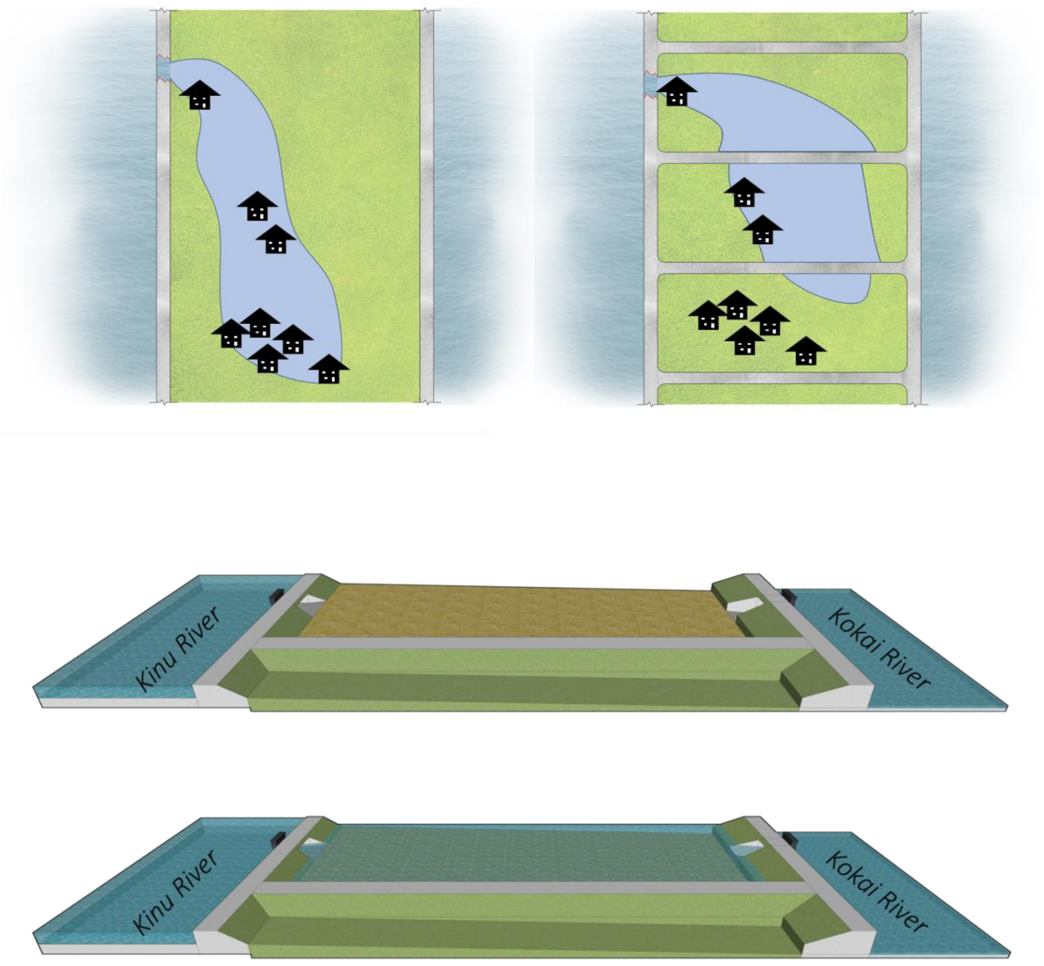


Figure 5-1 Image of 'flood management beyond watershed-scale'. The top image is 2D. The bottom is 3D (for illustration purpose only)

5.2 Modeling

Generally, four methods including geomorphology, field survey, hydrology, and hydraulics are often used. These are usually important evidence for development guidance in a floodplain.

The future flood that exceeds the design of the current flood control system such as overflow and levee breach of a river is the main influencing factor of the flood risk in the floodplain. These problems can be dimensionally generated as two-dimension depending on its spatial representation of the surface feature. Thus, the hydraulics model of flood inundation will be set for the framework of a new proposal idea in this chapter.

It is a mathematical method that reflects flood water movement computationally by equations formulated by applying the laws of physics. At the same time, the basic equations of floodwater movement and related parameters are adopted. The flooding process was simulated to obtain duration, velocity, depth, and impact on the floodplain in the study area.

Two-dimensional (2D) shallow water equations have been proved no analytical solutions to represent mass and momentum conservation (Teng, J., et al. 2017), but it can be obtained by depth-averaging the Navier-Stokes equations. Lots of numerical models are therefore developed for algebraic approximation. Usually, they can be classified as finite element, finite difference, and finite volume methods depending on numerical discretization strategies. According to discretization in time, the models can be divided into implicit and explicit. For spatial representation, the models can use rectangular mesh, triangular mesh, and flexible polygon mesh. The two-dimensional hydrodynamic model is the most widely used model on studies flood hazard mapping and risk zoning (Brath, A., et al., G. 2006). The essential architecture of the two-dimensional hydrodynamic model system is described in Figure 5-2, and the input value and parameters would be explained gradually.

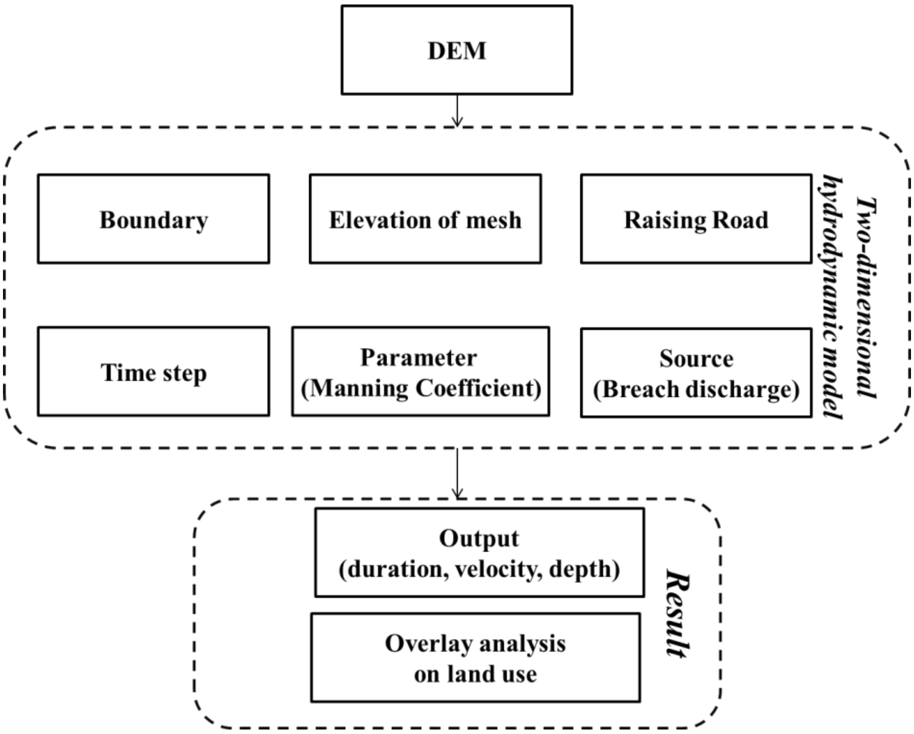


Figure 5-2 The essential architecture of the two-dimensional hydrodynamic model system

The basic expression is shown below when the Coriolis force, surface wind and turbulent diffusion are not considered:

$$\frac{\partial h}{\partial t}+\frac{\partial M}{\partial x}+\frac{\partial N}{\partial y}=0$$

$$\frac{\partial M}{\partial t}+\frac{\partial}{\partial x}\left(\frac{M^2}{h}\right)+\frac{\partial}{\partial y}\left(\frac{MN}{h}\right)=-gh\frac{\partial H}{\partial x}-\frac{gn^2}{h^{7/3}}M\sqrt{M^2+N^2}$$

$$\frac{\partial N}{\partial t}+\frac{\partial}{\partial y}\left(\frac{N^2}{h}\right)+\frac{\partial}{\partial x}\left(\frac{MN}{h}\right)=-gh\frac{\partial H}{\partial y}-\frac{gn^2}{h^{7/3}}N\sqrt{M^2+N^2}$$

where, *M, N* are the flux of *x, y*; *g* is the acceleration of gravity; *H(=h+Z)* is the water surface elevation, *h* is the water depth, *Z* is the elevation, *n* is the Manning coefficient, shown as Figure 5-3.

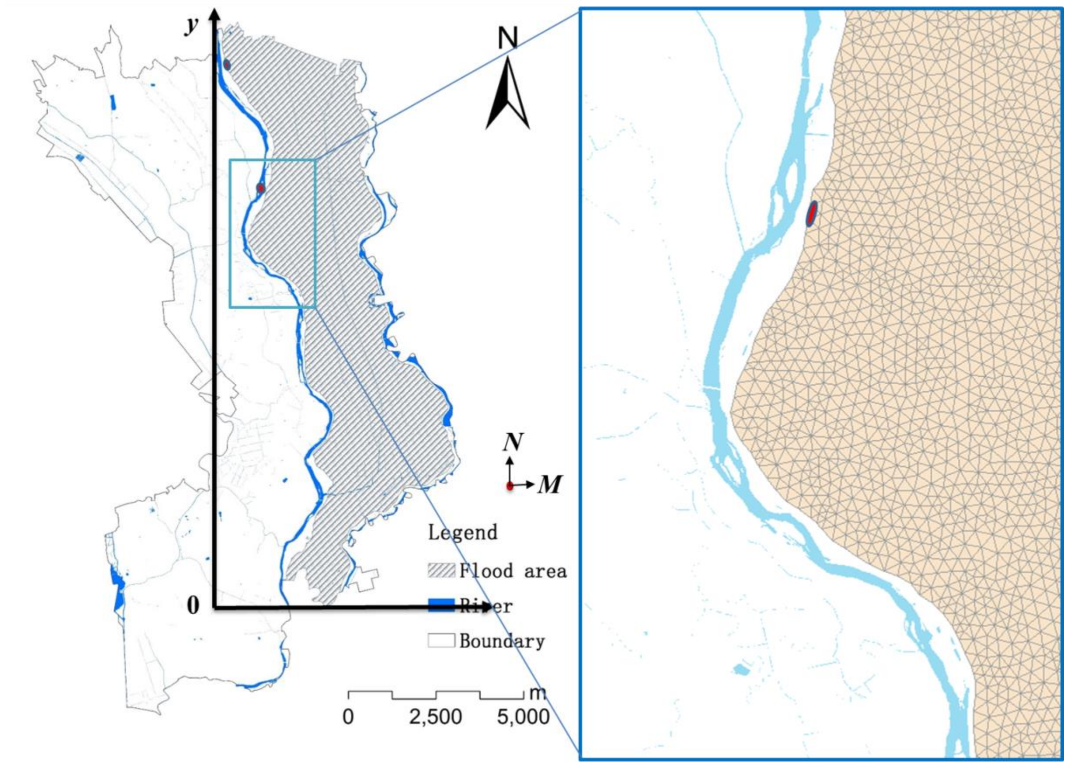


Figure 5-3 Modeling of Two-dimensional by a triangular mesh method

5.2.1 Basic processing

In this section, we selected the 2015 Kantou-Tohoku heavy rain as a study case. Firstly, we downloaded the 5×5m Digital Elevation Model (DEM), Land use/Land Cover (LULC) data of Joso city and shape file type files of boundary from Geospatial Information Authority of Japan (GSI) respectively as the basic data, secondly, we transferred these data into available format on GIS software (ArcGIS, ESRI Ltd.) and redefined geographic coordinate system; thirdly different height of road was set by raster calculation for the two parallel rivers.

5.2.2 Boundary conditions

We chose the floodplain between the levees of the two rivers. The triangular mesh was generated and interpolated according to the DEM data. Overflow and breach were set as the sources (Figure 5-3).

5.2.3 Time steps

Time steps are set from the beginning of overflow to the end of the levee breach, according to the report of the Kinu River Levee Investigation Committee; it will be set as 27 hours. Sometimes it takes much more time for the floodwater to get a stable state; we will do these calculations in different cases.

5.2.4 Discharge of levee breach (Hydrograph)

Discharge data was collected and reversed according to the estimated value of the 2015 Kantou-Tohoku Heavy Rain Report using the generalized triangle formula.

(1) Calculation of the breach hydrograph

This was based on the height, width, and duration of the damage survey shown as Fig. x. Instant levee breach width reached 200 meters (Figure 5-4). The levee height was 3-4 meters, water speed 1-2 meters/sec during the report of the Kinu River Levee Investigation Committee. The peak of discharge could be estimated as 600 m^3/s.– 1600 m^3/s.

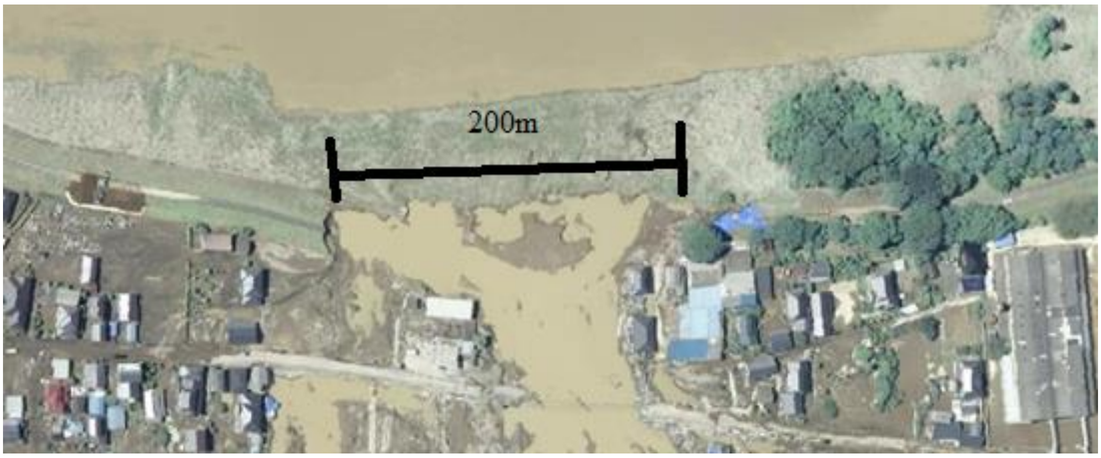


Figure 5-4 Levee breach (Image from GSI, edit by author)

(2) Calculate the total water volume through the flooding range

The total amount of floodwater was calculated by elevation of floodwater boundary and then extracted the terminal, interpolated as a continuous surface, using the formula as below, we can get the volume of floodwater.

$$\sum V = s \times h$$

$$h = D_W - D$$

Where s is the area of a DEM mesh, h is water depth, D_W is the elevation of water surface, D is the elevation of land, image is shown as Figure 5-5, Figure 5-6.

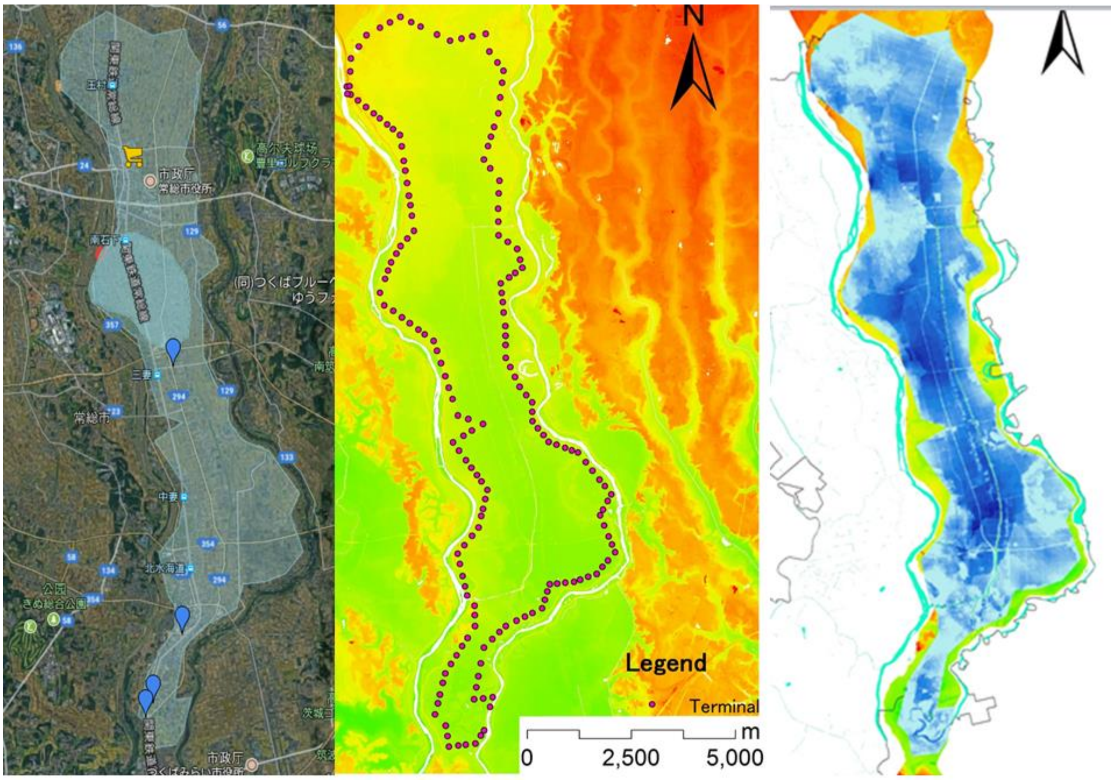


Figure 5-5 Result of total amount of floodwater (Left image from Google, middle and right edit by author)

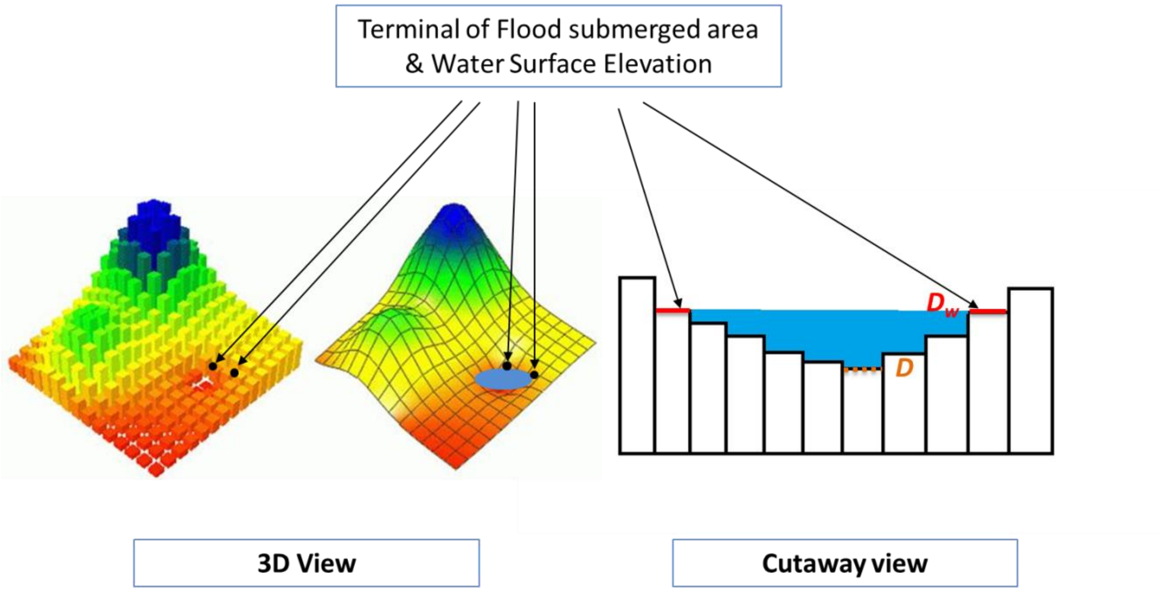


Figure 5-6 Calculation of the total amount of floodwater (for illustration purpose only)

(3) Calculation of overflow

According to break duration and the total amount of floodwater, we can calculate the amount of overflow, and then hydrograph could be possible to be designed.

Based on the analysis steps above (1)-(3), the hydrograph was designed with a generalized triangle method as Figure 5-7.

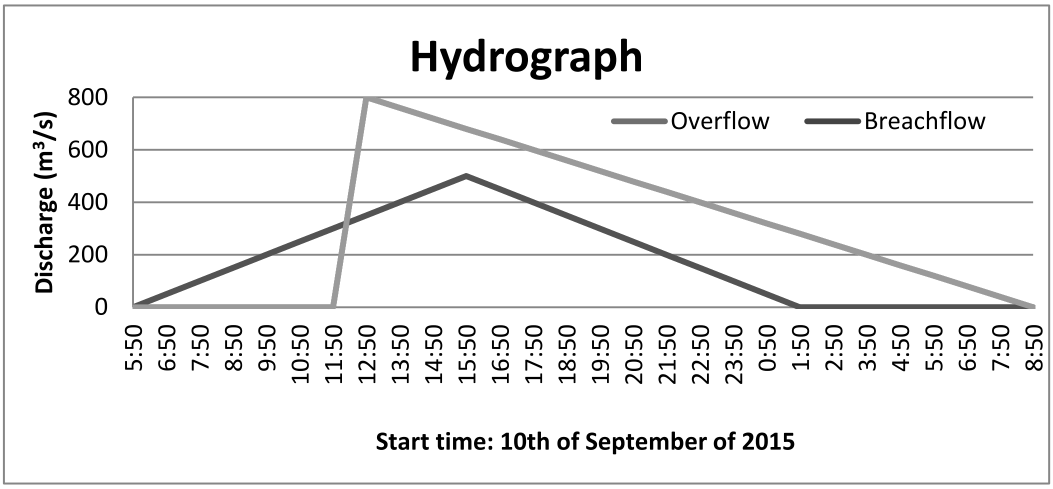


Figure 5-7 Generalized triangle method of hydrograph of overflow and breach flow

5.2.5 Manning coefficient estimation

The magnitude of the roughness is usually represented by the Manning coefficient, which is another crucial factor of the flooding process. According to the experience of the floodplain land surface, the Manning coefficient is estimated to be 0.5.

5.2.6 Verification

Based on the above analysis, the calculation result inundation area is 38.85 km^2 to 40 km^2 which GSI published as Figure 5-8 shown, and the relative error is less than 2.8%, mainly distributed in Area A and B. In general, the parameters are basically reasonable.

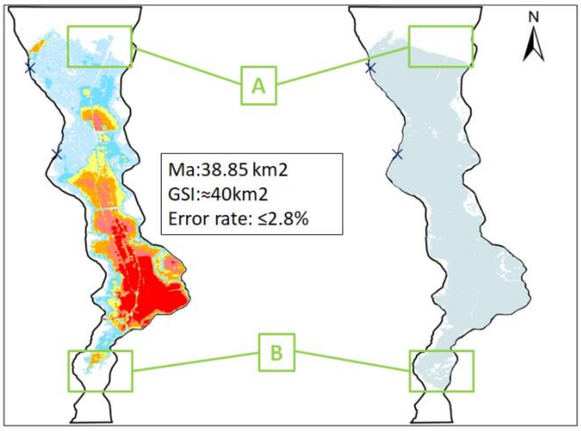


Figure 5-8 Inundation distribution comparison

5.3 Simulation of road-raised in Joso flood plain-Case study

In addition to the above basic parameters, this study considered the hypothesis of raised roads and all available drainage measures such as pump station, pump trucks, and flood gate (sluice) when it is necessary.

Raised roads are limited, of which the most important thing to consider is human life. The timing and routes of evacuation were not appropriate due to the recent floods, so the vertical evacuation is more often used to save lives than the horizontal evacuation. The normal size of a house in Japan is shown in Figure 5-9, where the second floor is often used to save lives in which height is average 3m above ground. So the road would not be taller than 3m considering with human life (Jonkman, S.N.; et al., 2009).

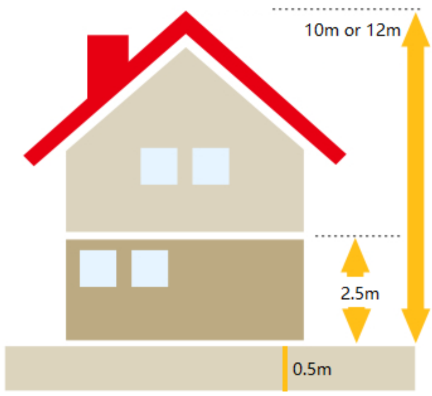


Figure 5-9 Normal size of a house in Japan (According to the normal size of a house in Japan, edit by author)

In order to illustrate the practicality, we set up multiple cases to raise the main road which is crossing the floodplain, shows in Figure 5-10, since these roads are mostly far from the residential area which is much easier to start a raise road project, and divided the study area into several parts to analyze the different flood disaster loss.

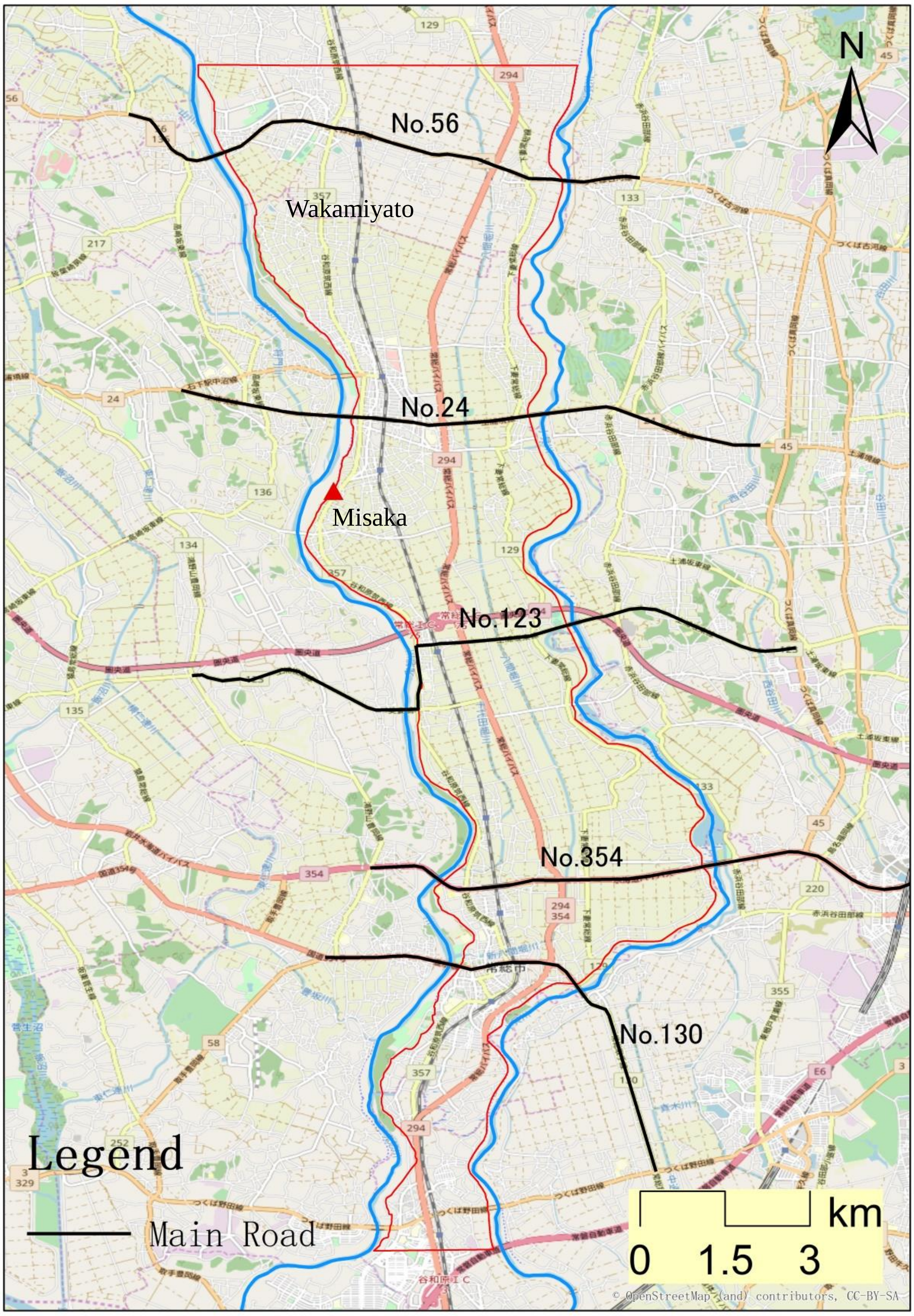


Figure 5-10 Main roads crossing the plain

5.3.1 Case 1: Raise Prefectural Road 24 and 123

According to the 2015 Kantou Tohoku Heavy Rain, the overflow occurred at 5:50 near Wakamiyato and levee breach occurred at 12:50 near Misaka, we raised the road as following criteria:

(1) Roads should be continuous, especially connect across with the two river levees (Kinu River and Kokai River), which could get fast support from other cities;

(2) Roads should be close to the position of overflow and levee breach to limit the inundation area as small as possible;

(3) Roads should be vertical to the direction of water flow as much as possible.

Thus, the raised road would be Prefecture Road No.24 and No.123 shows in Figure 5-11. And the study area would be divided into 3 parts in this case.

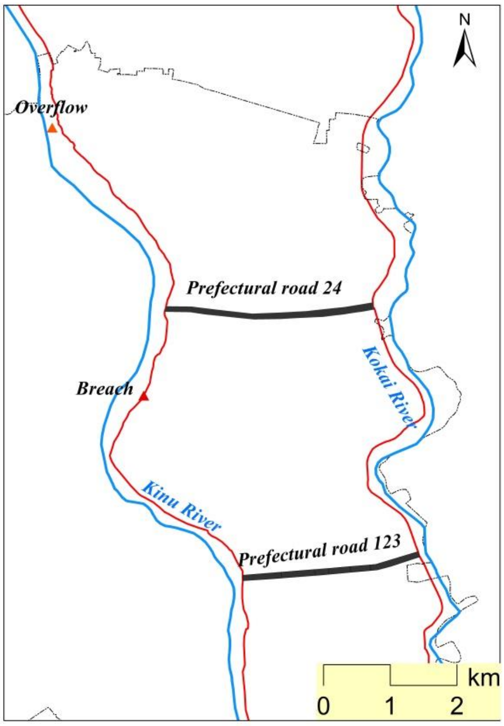


Figure 5-11 Two main roads crossing east-west near overflow point and breach point

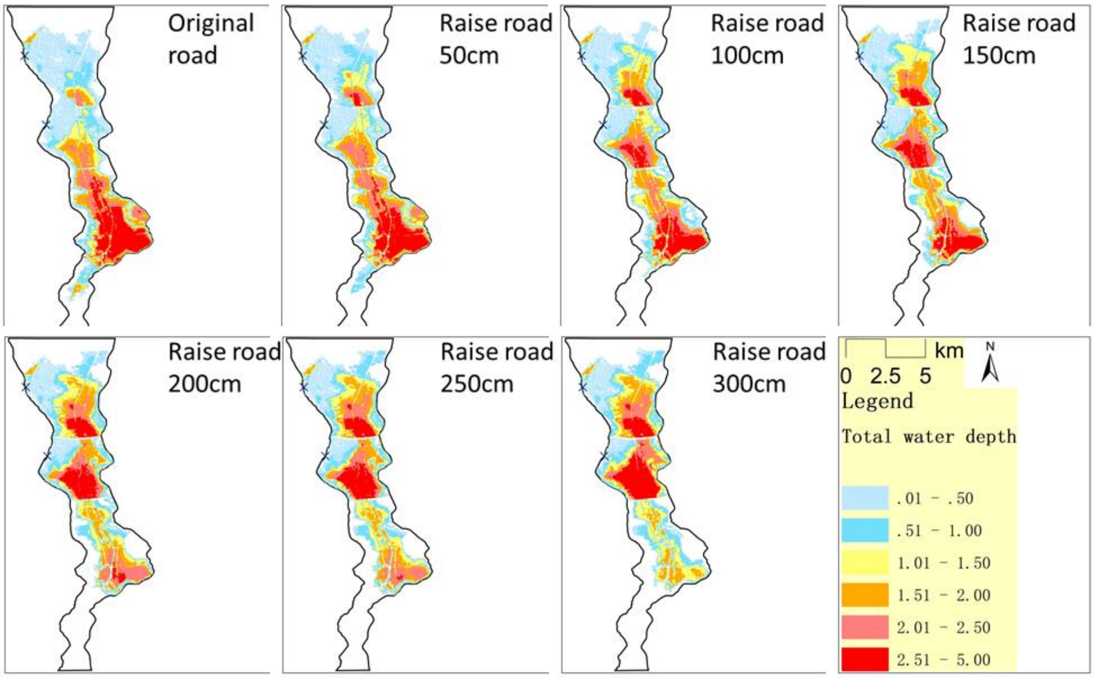


Figure 5-12 Inundation of overflow and breach with road rising as 0, 50cm, 100cm, 150cm, 200cm, and 300cm.

Figure 5-12 showed floodwater was would be temporarily stopped and then proceed southward with more and more floodwater coming out from the river levee. The inundation zone of “2m-” was transferred from the bottom to the top of the study area, as the roads rose from 0 to 3m.

The showed in Figure 5-13 indicates that the total inundation area is reduced by 3.15 km^2, 8.1%. The area of depth of “0.01m-0.5m” and “2m-” reduced by 47.5% and 16.9% respectively with the road rising 3m, and the “0.5m-1m” and “1m-1.5m” increased 37.7% and 32.6% respectively tend to inverse proportion by the same time.

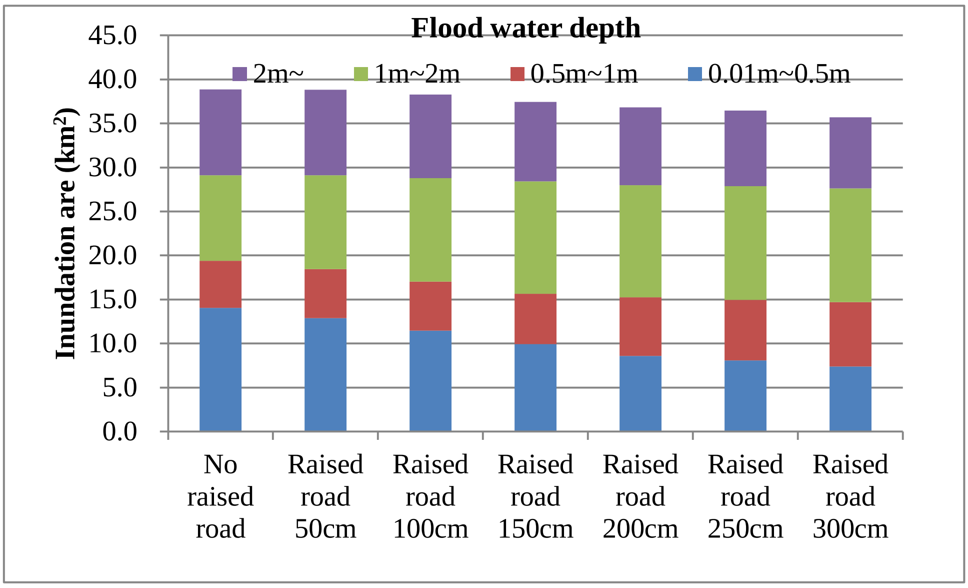


Figure 5-13 Inundation area change of different groups of depth with the road rising as 0, 50cm, 100cm, 150cm, 200cm, and 300cm

According to the damage degree and water depth in Japan, shown in Table 5-1. We statistically obtained that the complete damaged house reduced by 67.1%, half-damage reduced 10.9% showing in Table 5-2. A result could be expected if roads are raised taller.

Table 5-1 Damage degree and water depth in Japan

Category	Depth（H）
Complete damaged	H≥2.0m
Half damaged	1.0m≤H < 2.0m
Above floor level	0.5m≤H < 1.0m
Below floor level	H≤0.5m

Table 5-2 Relationship of inundation depth and house damage

Items	Simulation /0cm	Simulation /300cm	Loss reduction rate
Half damaged	3756	3345	-10.9%
Complete damaged	1195	393	-67.1%

5.3.2 Case 2: Suppose only an overflow with rising Prefectural Road 24

The previous results prove that the 3-meter raised-road will not take the people's life away. In this case, we suppose that there is no levee breach, which is only an overflow that means the amount of 17 million m^3 flood water would flow into the study area.

According to the hydraulic model, the result showed 17 million m^3 floodwater would be well blocked by Prefectural Road 24 in Figure 5-14. Since roads are proved to be able to change the floodwater process in a flat floodplain. Moreover, a more significant result could be expected if there is less floodwater discharge of an overflow.

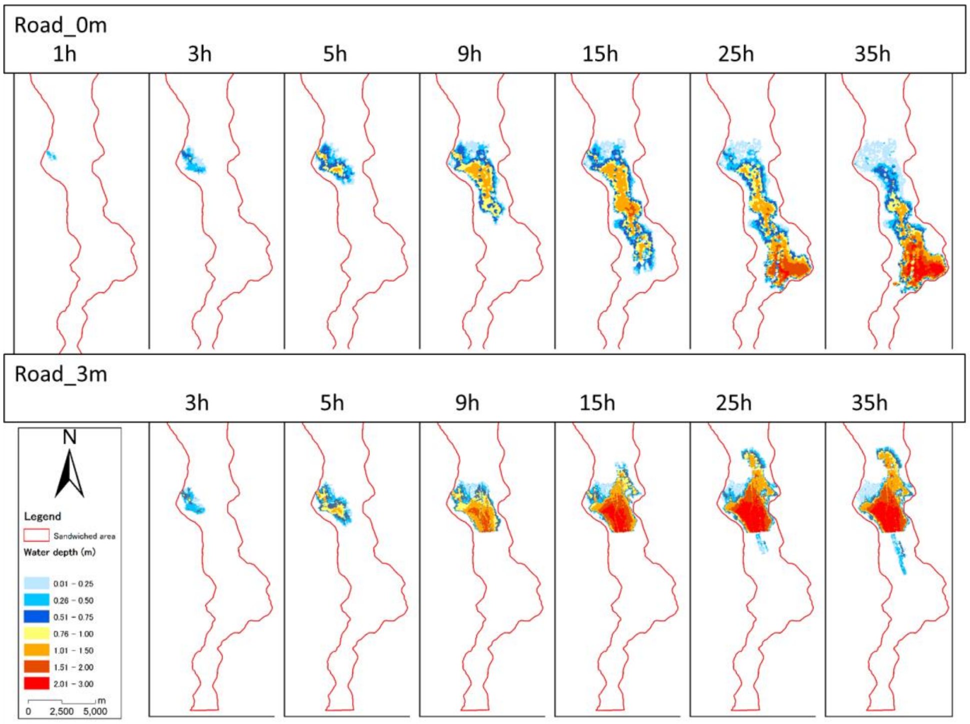


Figure 5-14 Comparison of 0 and 300cm. raised road of inundation of the only overflow

5.3.3 Case 3: No overflow nor levee breach – isobaric rainfall in Joso

If the rainfall is considered as isobaric in the study area, the inundation will vary according to the terrain. According to the 36 times of the simulation, results show in Figure 5-15. Inundation would start to spread from the lowest position of the floodplain. Thus we infer this is a flood-prone area. This also proves our previous analysis that this area was the intersection of the original rivers before river channel transition.

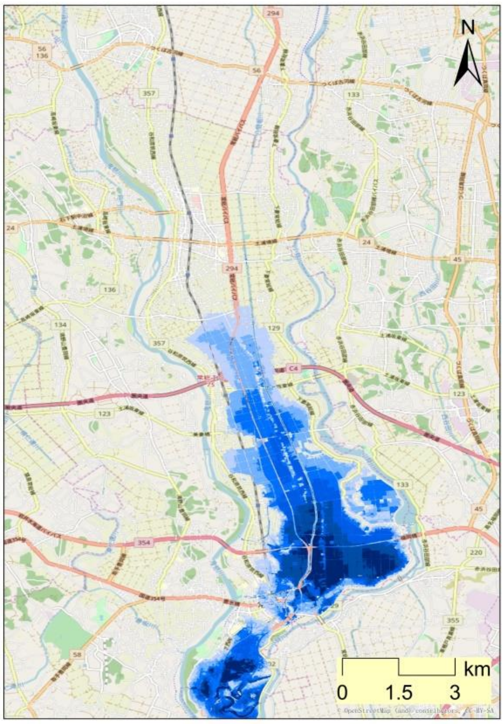


Figure 5-15 Inundation of isobaric rainfall

And the inundation area will increase while there is a long return period torrential rain, shows as Figure 5-16.

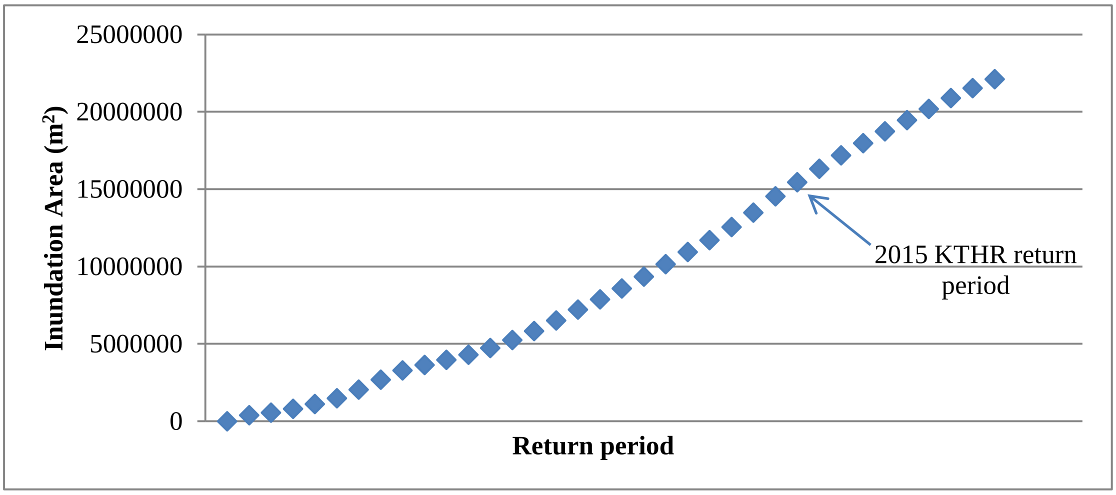


Figure 5-16 Relationship of inundation area and different return period rainfall

In any situation, some areas are always inundated, because of its natural lowland. From the perspective of historical geography, this area located at the intersection of two rivers, which was formed by countless floods.

5.3.4 Findings

These countermeasures are very effective in reducing the overall flood inundation area, but an upstream and downstream problem is caused as the result of the increased floodwater damage upstream caused in order to reduce the damage downstream. Therefore, these countermeasures should be considered in combination with the land-use features to achieve the necessary to match the scale of the upstream flood. In addition, according to Article 3 of the Basic Law of ‘Food, Agriculture and Rural Areas’, the floodwater storage function of paddy fields should be promoted to reduce the regional flood risk.

5.4 Location selection

Allocation problem has always been a hot topic whether in natural science or social science. In this section, we would discuss the location selection based on a flood perspective.

5.4.1 Land use pattern analysis in the study area

Since the main roads are easy to reconstruct as fewer people living nearby, it also provides efficient connectivity with cities locating on other sides of rivers after the flood. The main roads would divide the study area into 5 districts, considering with the residents' distribution, we counted the number of each district to determine the drainage destination in a general direction. As a result, shown in Figure 5-, there are fewer people living in zone B and zone C, which would be the best option for a drainage destination. But 3000 and 5000 houses also would be a problem of relocating. The plan needs to be more detailed.

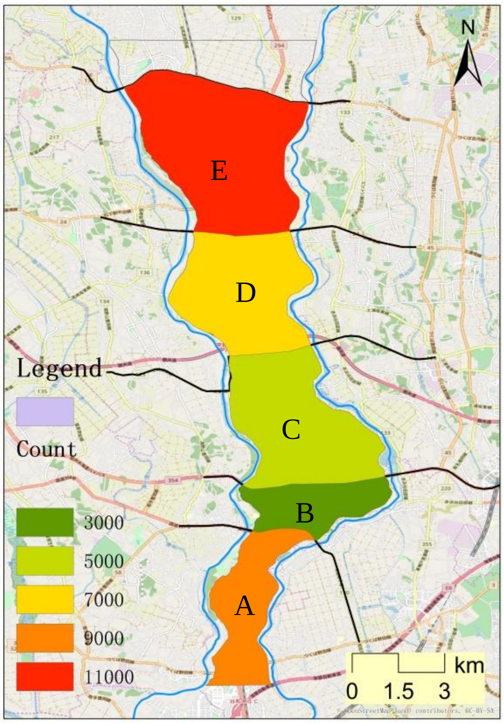


Figure 5-17 Count of house distribution of each zone

We use the road data from Open Street Map to divide the study area into 2289 districts, and calculated the density of house (number/area), then divided it into 5 levels by the natural breakpoint method. The result showed in Figure 5-17 that house and property concentrated mainly in 3 parts including Wakamiyato, Ishige, and Mitsukaido (DID), which is consistent with the result of Figure 5-18. There are paddy fields joined together in zone B and zone C, although few people located in the middle part of the two rivers, these 2 areas are much easier to plan a 'retarding basin' than Zone A, D, and E.

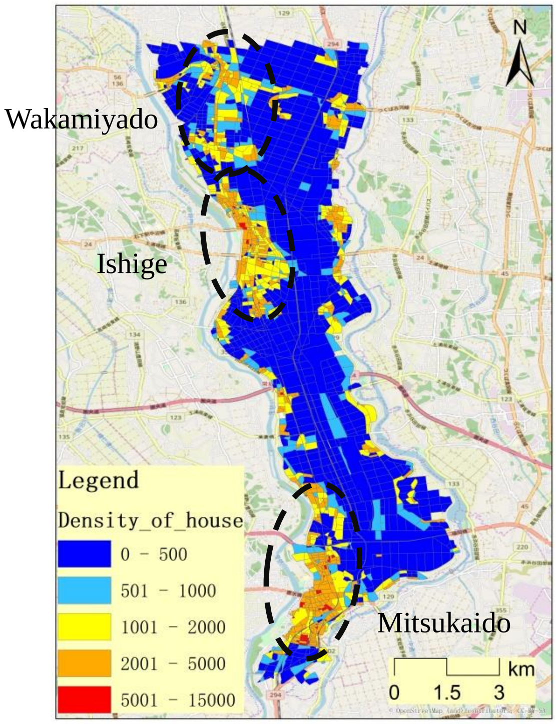


Figure 5-18 Density of house and suggested the roads

This kind of land use pattern does not seem to have any problem as residents are being protected by the river levee, however, it is quite different levee-protect-residents relationship from the Metropolitan area such as Tokyo, where is constructed by the super dam and no risk of a levee breach. In addition, it is a kind of irregular, resource-wasting distribution pattern, which conflicts the concept of a compact city in an urban plan viewpoint. Concentering dispersed populations together is considered to be an important strategy for sustainable urban development.

5.4.2 Escape time analysis

Since all of the study areas would be inundated under an extreme flood, residents need to arrive at the other side of the river to be safe, as the shelter is not reliable (cited). There are a total of 8 exits in the study area, located the junction of the river levee and main roads (Figure). Different residents in different regions would cost different time to get out of the study area. Here we used the open street map data to calculate the cost time.

First, we assign the speed limit of each type of roads (Table).

Table 5-3 Speed limit of each type of roads

Road grade	Speed limit (km/h)
National road/ Prefecture Road	60
Service road	40
No road area	10

Second, we transfer the polyline data of the road network into 5m*5m raster data, and the cumulative travel cost from the cell *a* through cell *b* to cell *c* is as follows:

$$Acc\_cost\_dis =$$
$$a_1 + ((cost\_sur(b) * hor\_f(b)) + (cost\_sur(c)$$
$$* hor\_f(c))/2 * sur\_dis(bc) * vertical\_fr(bc)$$

Where a_1 is the cost distance from *a* to *b*, *b* is the road raster, *c* is the exit point.

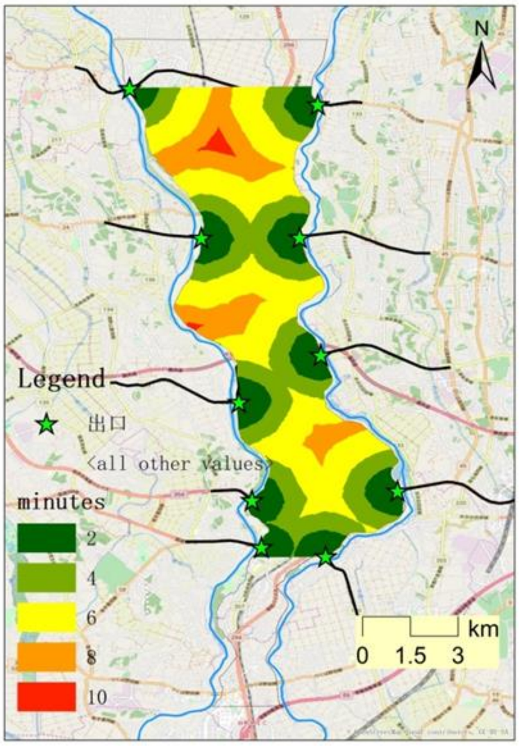


Figure 5-19 Time to leave the sandwiched area

According to formula, we could calculate the time cost of each cell in the study area shows in Figure 5-19. The longest time cost area is considered as the most uninhabitable area.

5.4.3 Location selection

According to the simulation of Case 3 with no countermeasures, the “2m-”, deepest area during 2015 KTHY, which could be considered extracted.

Then we overlap the 3 layers ‘Land-use’, ‘Time cost’ and ‘Deepest area’ together to get a new layer, which can be explained as the best location of ‘retarding basin’. The distribution would change as more factors to be considered. But its center would be Zone B and Zone C roughly.

As our goal is to let floodwater flow into areas with low-density property and be blocked using linear roads and then drainage to other rivers through appropriate terrain and countermeasures. This area should be holistic with appropriate diversion weir connected with two rivers and appropriate sluices to prove our proposed methodology. In order to reduce the damage of 2015 KTHR, this study supposes that a tentative area of flood-prone paddy field with fewer people to be a bidirectional ‘retarding basin’ roughly, shows in Figure 5-20. The shape and boundary would differ according to the topography features.

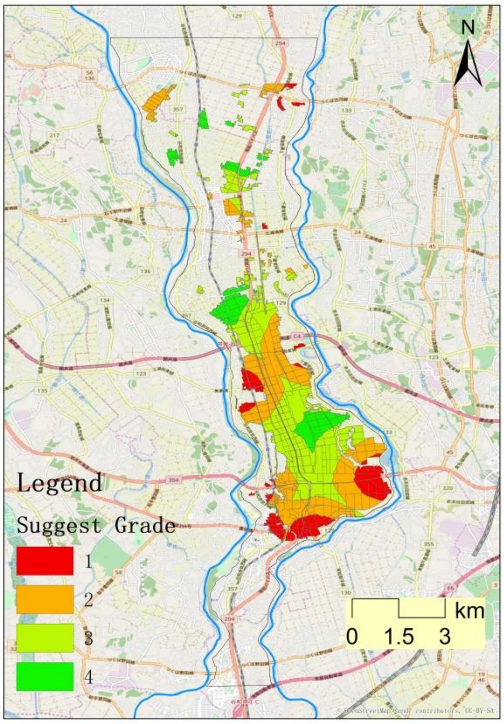


Figure 5-20 Bidirectional retarding basin and raised road

5.5 Benefit and cost

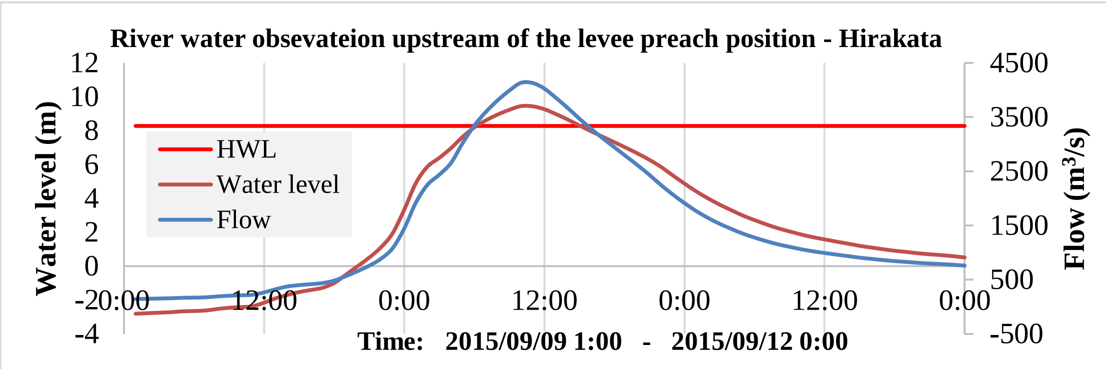
To test the benefit of the proposed methodology, we select the 1986 Kokai Flood and 2015 KTHR to analyze the flood.

2015 KTHR: To figure out how the flow of the river water affected the river levee and led the levee breach, we have got the river water observation data both upstream and downstream of the river breach position, shown in Figure 5-21.

First, we analyzed the observation upstream. The maximum water level was 9.45m, higher than the high water level (HWL), which is 8.28m, and this over-load situation consists of 10 hours from 6:00 to 16:00, 9th Sep 2015. The levee breach happened at around 13:00 between the two observations we selected.

Second, we analyzed the observation downstream, the maximum water level was 8.07m, higher than the high water level (HWL), which is 7.33m, and this over-load situation consists of 7 hours from 10:00 to 17:00, 9th Sep 2015.

Last, we did an analysis of river flow according to the synchronous water level data, 300 m^3/s was inferred to be over-loaded in Mitsukaido.



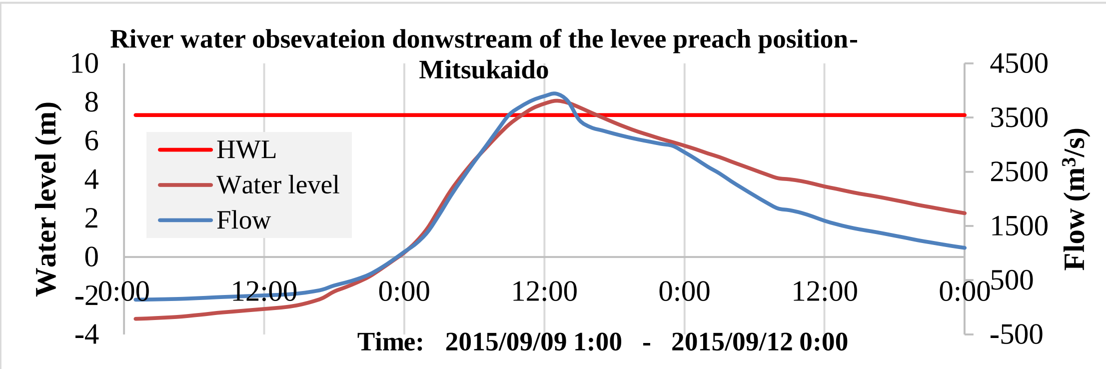


Figure 5-21 Relationship of water level, flow, and HWL of the river water observation both upstream and downstream of the levee breach

1986 Kokai Flood: Since there was no accurate levee breach flow data in 1986. We have reviewed various materials and found that the maximum flow in 1986 was 711.9 m^3/s, last less than 12 hours. Thus, the volume of 5,240,000m^3 would well accommodate the floodwater to make sure there was no overflow and levee breach. In addition, there is a pumping station capacity is -30 m^3/s of Kinu River direction.

To ensure proper use of the ‘retarding basin’, the road must be raised to the same height as the river levee, assuming the residents are evacuated out of the area. In addition, diversion weirs or flood gates should be set up on the river levee. And the time step will be set up as 10h to ensure safety until water level below HWL, pumping station capacity is 7 m^3/s of Kokai River direction. Thus, at least the volume of 5,240,000m^3 needs to be stored and drainage.

We have designed 4 plans (Figure 5-23, 5-24, 5- 25, 5-26) of the road-farmland system to analyze the cost.

5.5.1 Land purchase system

As construction of our suggestion is like to be a detention basin, it must be mainly used as low economic land such as farmland, and the elevation should be lower. The project cost is the sum of the construction cost of the basic structure, the land cost, relocation fee and restoration cost. While basic structures are consist of three parts: surrounding dike (road), overflow dike (diversion weir), and flood gate. As all the 4 plans are using a canal (Hakkenbori River) with its flood gate (Luke, A., et al., 2015), and flood gate costs will not be calculated. While the plans will do the farm in normal years, so the basic formula of land purchase system would be expressed as:

$$M_p = L_{road} \times a + A_{farmland} \times b + N_{household} \times c + r_c$$

Where, L_{road} is the length of road to be raised, a is unit price, 50 million JPY/km, (source: interview of local government employee from Fukushima); $A_{farmland}$ is the area of farmland, b is unit price, 2000 million JPY/km2, (source: Real Estate Guidance. 2016); $N_{household}$ is the number of house which need to be relocated, c is unit price of house purchasing and demolishing (assume an average value of 5 million JPY/household, including 100% the land price and 0% of house because of post-flood). r_c is the restoration cost once flood happen.

For the cost of the road, different sections need to be raised at a different height. Besides, the floodwater would not be too fast and water pressure would not last too long to break the roads; the geometrical characteristics of roads would not be like a super dam. However, the amounts of dirt need to calculate.

According to the raised road project in Sendai (Tsunami Defense Project), it is 6m high, 7m-9m width of the road and 30m-40m width of the roadbed, which will cost 19.2 billion JPY of 10.2 km. Thus, we can easily draw the cross-section of the road tend to a trapezoid, Figure5-22.

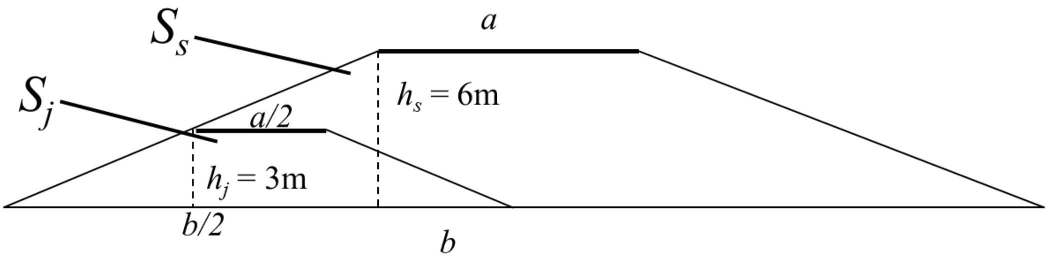


Figure 5-22 Cross-section of the road tend to a trapezoid

$$S_s = \frac{(a+b)\times h_s}{2}$$

$$S_j = \frac{\left(\frac{a}{2}+\frac{b}{2}\right)\times\frac{h_j}{2}}{2}$$

3m raised road would cost a quarter of 6m road, that C_s would be 47 million JPY / km, and the expression of C_j could be as:

$$C_j = \sqrt{\left(\frac{6}{h}\right)^2 \times C_s}$$

$$h = h_s - h_j$$

So, the dirt how much the Plan need is possible to be calculated and strong enough to temporarily storage floodwater.

The benefit is the amount of damage reduction due to flood control. Our assumption is to avoid the 2015 KTHR. So the benefit will be the total loss of 2015 KTHR in Kinu River, 1,470 hundred million JPY, according to the Kinu River Report.

And the result shows as Table 5-4, 5-5, 5-6, 5-7.

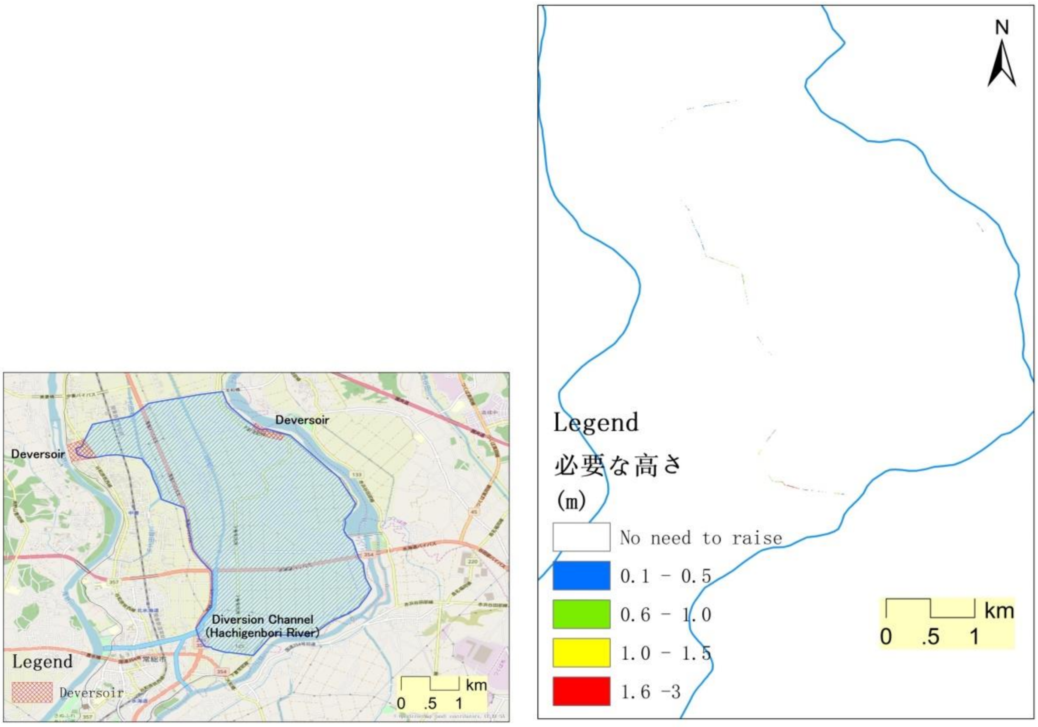


Figure 5-23 Plan A: all the high-risk flood area

Table 5-4 Benefit and cost of plan A

Plan A				
Content	Area (km2)	Quantity of houses (N)	Road (km)/ Average raise height (m)	Volume (m3)
	9.5	2666	7.7/1.0	5400000
Expected result of benefits	Reduction of average inundated house			184
	Reduction of average inundated area			30.5 ha
Investment efficiency	B: Benefit (100 million JPY)	C: Cost (100 million JPY)		B/C
	1470	376		3.9

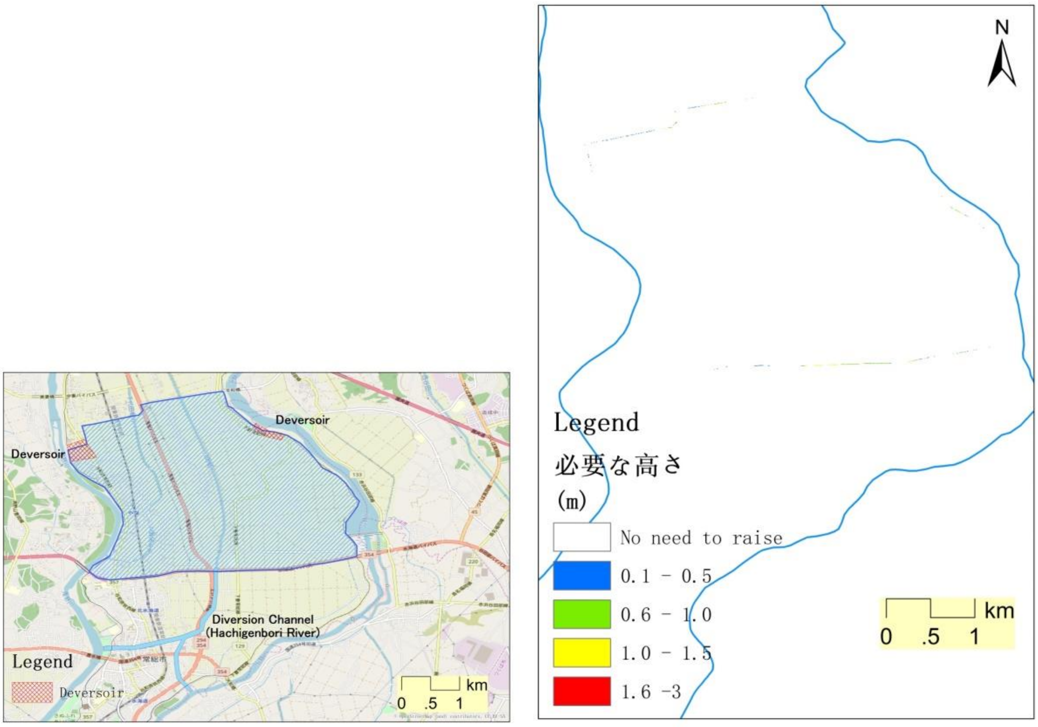


Figure 5-24 Plan B: raise the road No.354

Table 5-5 Benefit and cost of plan B

Plan B				
Content	Area (km2)	Quantity of houses (N)	Road (km)/ Average raise height (m)	Volume (m3)
	10	4049	4/1.2	5400000
Expected result of benefits	Reduction of average inundated house			161
	Reduction of average inundated area			30 ha
Investment efficiency	B: Benefit (100 million JPY)		C: Cost (100 million JPY)	B/C
	1470		432	3.4

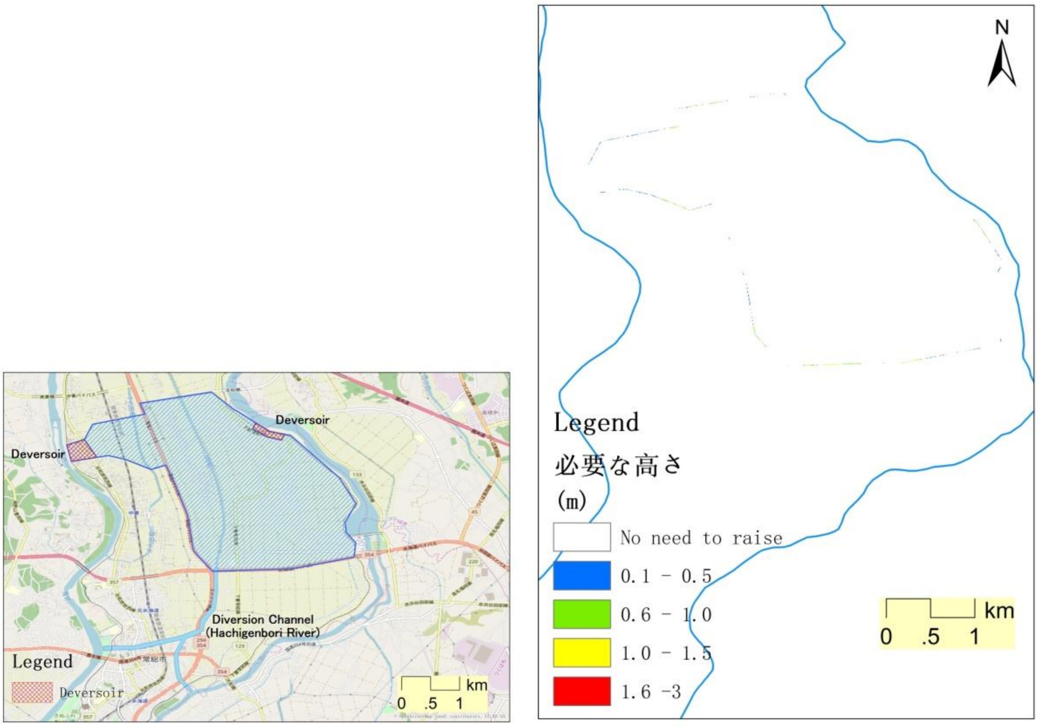


Figure 5-25 Plan C: raise the road No.354 and No.294

Table 5-6 Benefit and cost of plan C

Plan C				
Content	Area (km2)	Quantity of houses (N)	Road (km)/ Average raise height (m)	Volume (m3)
	6.7	1871	6.7/1.1	5400000
Expected result of benefits	Reduction of average inundated house			192
	Reduction of average inundated area			33.35 ha
Investment efficiency	B: Benefit (100 million JPY)	C: Cost (100 million JPY)		B/C
	1470	276		5.3

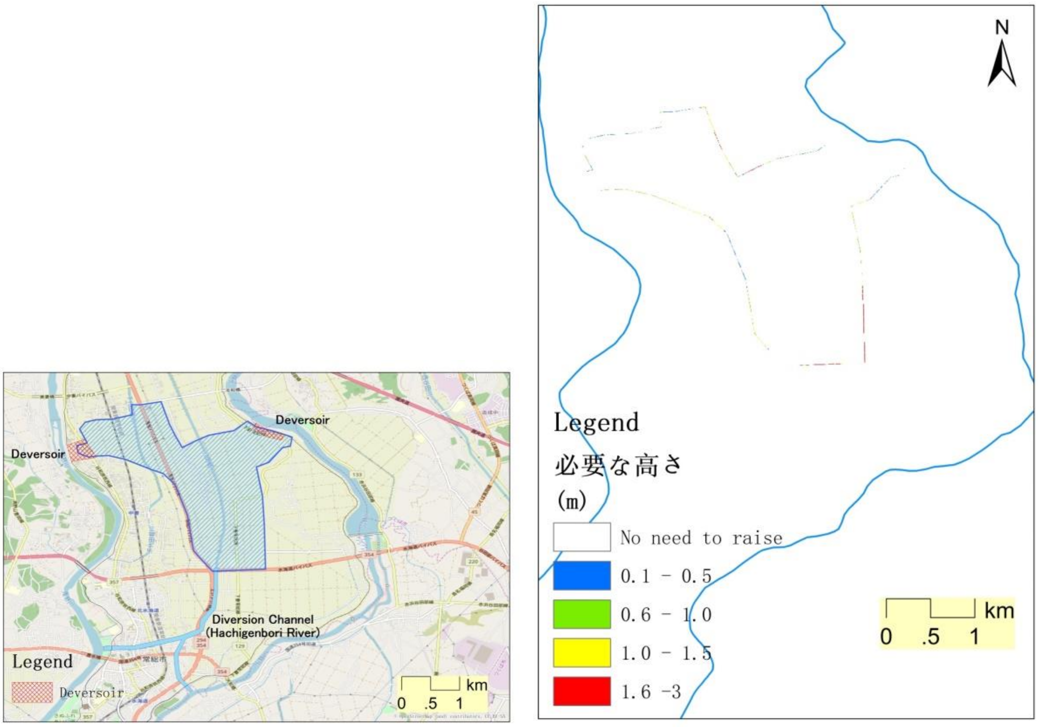


Figure 5-26 Plan D: raise the road No.354, No.294 and a farmland road

Table 5-7 Benefit and cost of plan D

Plan D					
Content	Area (km2)	Quantity of houses (N)		Road (km)/ Average raise height (m)	Volume (m3)
	3.84	518		10.9/2.5	5400000
Expected result of benefits	Reduction of average inundated house				205
	Reduction of average inundated area				36.2 ha
Investment efficiency	B: Benefit (100 million JPY)		C: Cost (100 million JPY)		B/C
	1470		220		6.7

Four plans show that B/C ranges from 3.4 to 6.7, and the cost range from 220 to 432 hundred million JPY, comparing with other retarding basins project, in Table 5-8.

Table 5-8 A brief comparisons of several Japanese retarding basin projects (Source: Board of Audit of Japan)

Name or location	Volume (m^3)	Area (km^2)	100 million JPY
Ishikari River and Chitose River	45,400,000	11.50	1,150
Kitamura Retarding Basin	42,000,000	9.50	700
Kinu River and Tone River	30,800,000	4.48	438
Yodo River and Kizu River	9,000,000	2.48	717

Any of our tentative plans would not cost more than 432 hundred million JPY; the reason may be that the relocation fee is set too low. As serious encroachments happened inside the floodplain, any of our tentative plans will conflict with land use and economic environments. It will be a big problem, but its benefits are huge in the long-term, not only for Joso but also for riverine cities both upstream and downstream.

5.5.2 Insurance system

For the cost of raise road construction, it will be the same; the only difference is the way of land acquisition. This section will discuss an alternative method instead of purchasing farmland, insuring it. Farmland for the temporary storage of floodwater would usually be used in case of a serious flood. Local people’s willingness of whether to provide their farmland depends on the compensation they would get. In this section, it aims to identify an optimal insurance method for compensation in flood event. For a serious flood, diversion weir or flood gate might be enabled to work to avoid whole downstream damages. The benefit here is the reduction of flood damage between only farmland and the whole downstream. Farmland damage mainly depends on both farming type and farming period (others such as farm tools). As in Joso, rice is the main crop (See Figure 5-27), which paddy field accords close to 80% of total non-resident land, uplands accords for 20%. Moreover, crops in Plan A, B, C, D are almost rice.

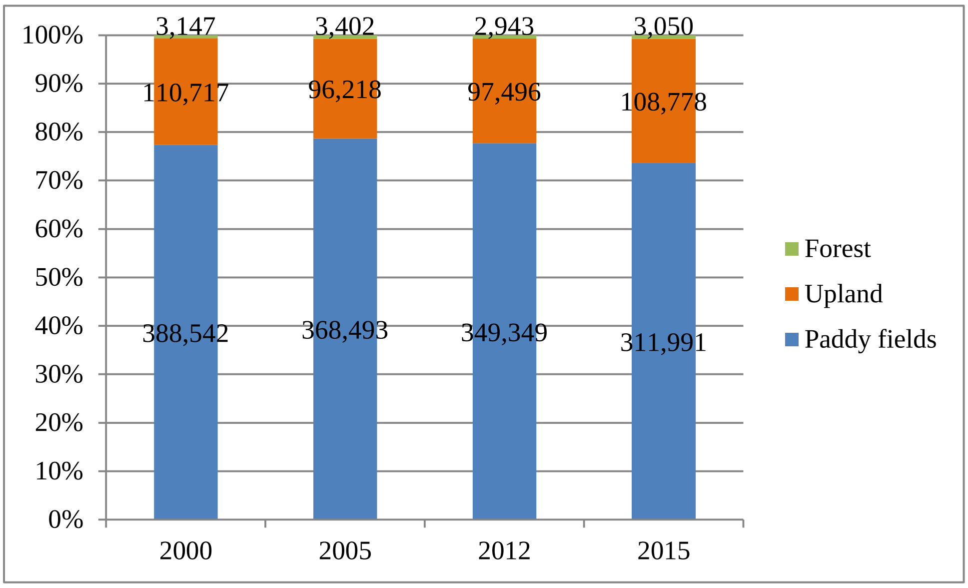


Figure 5-27 Non-resident land use proportion (Source: Statistics of Joso)

For the convenience of calculation, we assume a compensation method that area *s* (Plan A, B, C, D), average unit price rice p_r, and reparation compensation are r_c once flood happens, the monetary compensation M_c can be expressed as:

$$M_c = L_{road} \times a + A_{farmland} \times p_r + N_{household} \times c + r_c$$

Where p_r is 30% of farmland value (source: Ueno retarding basin project), this is the only factor different from M_p.

Thus, the 4 plans will decrease 133, 140, 94, and 53 hundred million JPY respectively.

In addition, considering more comprehensively, for example, the expectation of flood probability is 1/100, the maintenance fee is 1% of the construction cost, while the social discount rate is 4% of benefit (Nakago M, 2010). The total cost will turnover in a period.

As for the benefit and cost, we just did it roughly, and we will make a reasonable budget in the future.

5.6 Impact on Landscape

In terms of landscape, we did the fieldwork to compare the raised road on the landscape using the traditional "before-after method".

For the national road No. 354, we measured the average height of 1m in the ordinary section, and in the section with no mater natural river or intake channel under the road, it will have a large slope. But it does not affect normal driving. In addition, most people working in this area are local farmers, the one-meter-high road itself does not cause much landscape discomfort, the cars on the road and the scene across the road does not affect the local farmers (Figure 5-28). In addition, these national roads are usually equipped with guardrails to ensure safe driving. Thus, a 1m to 2m rise of the road would do be like a river levee some impact on the landscape (Figure 5- 29). But people's daily life, agriculture would not change too much because of the continuous paddy field with fewer people living.

Figure 5-28 One-meter-high road with cars on the road and scene across the road

Figure 5-29 Image of the raised road by 1 to 2 meters

5.7 Summary

According to historical disaster data, during the 80 years from 1935 to 2015, there were 16 flood events of the two rivers in the landside area. It can be regarded as a flood disaster of every 5 years for the reason of uncertain levee breach. This value is horrible with more and more extreme heavy rain under the background of global climate change. Thus, the landside area should take some countermeasures to reduce flood risk, moreover, flood management always takes into account the entire watershed; but usually, there is an unbalance between upstream and downstream areas. The downstream area is often riskier and ignored as the different topographical distribution to the upstream regions, so the downstream areas should have to take appropriate countermeasures to protect them as more and more exceed rainfall is coming under the global climate change. Since using river levee cannot fundamentally mitigate flood damage. Land-use regulation is proved to be an efficient measure to reduce the vulnerability of flood risk. Thus, it is crucial to change the land use pattern as soon as possible to accommodate more floodwater to meet global climate change.

In this chapter, we used the 2D hydrodynamic model to simulate the flooding process, and several of the case studies showed land use characteristics combined with the flooding calculation results in the study area, calculated the loss of inundated houses and farmland. We could infer that merely raised roads could benefit people in a certain area; it should combine the land use and actual situation. According to the inundation navigation issued by MLIT, an expectation of that the wherever a river levee breach happens, floodwaters would reach the DID of Joso, where is the most important area of a city, especially specific public infrastructures such as commerce, education, medical and manufacturing, but are also the basic guarantee for human life sandwiched by the two big rivers. Four tentative options using raised road-farmland according to geographic, land use and escape time analysis were listed and calculated for their benefit and cost as far as possible within the scope of the study roughly, although it conflicts with the land use and economic environment, it is beneficial in long term. Comparing to the Kinu River Project or the Kokai River Project, this proposal suggestion would be lower cost and do little impact on the landscape. However, this needs designated drainage and a social agreement, letting the floodwater flow into this area, so the determining factors are relocating the residents and land use regulation.

Flood management beyond watershed scale differs from the existing concepts of flood management, but they do have something in common, aiming at reducing flood loss resulting from a certain flood by blocking and transporting floodwaters in low vitality, low assets and low population area. It reconnected the watersheds to share the flood risk to benefit most of the residents living in the floodplain, which appropriate land use practice is a key to reduce the flood risk. Land-use pattern changes due to agriculture and industrial development over the last century were accompanied by both straightening of the rivers and loss of river space which led to an increase of urban flood risk. It is difficult to change in nowadays society. Similarly, raising roads and affirming high flood risk areas will decrease the risk of an uncertain levee breach. When the linear pattern of roads is raised, inundation will be confined. The relationship between house damage and inundation depth can also be conducted, while the intangible loss such as quality of life is usually impossible to estimate.

If the plan would pass, both the Kinu River and Kokai River would be reconnected to share the flood risk and stopped fighting alone to benefit more of the residents living in the floodplain sandwiched by two the rivers. The proposal suggestion could also provide advice for decision-makers and river managers. This suggested plan would also restrict the deregulated development, prompt people moving out of high flood disaster risk areas independently, and land use may align with the concept of a compact city in a sustainable urban plan viewpoint.

6. Available areas in Japan

This proposal concept is proven to be effective, but not limited to KK watershed. It should be considered on a macro scale. Water is regarded as the most important environmental resource for human survival and development (Khagram, S., et al, 2003). Cities (including rivers, lakes and reservoirs) are usually set by the river (Pentland, R., et al 1980) which is constantly affected by potential hydrodynamic force. In recent years, a large number of flooding occurred that are not only involved about structural engineering of flood infrastructure or meteorological change (Aktan A. E., et al., 1996) but also related to many factors like long term runoff management in upstream area (Kean, J. W., et al., 2013). Disasters bring a great loss of social capital and follow-up region restoration (White, M. D., Greer, K. A. 2006). So, it is necessary to evaluate available areas to achieve beyond watershed scale flood management.

6.1 Watershed analysis in Japan

Usually, a flood occurs in over medium-sized and small-sized watershed scale. Watershed delineation is a science (Jensen, S. K., Domingue, J. O. 1988; O'callaghan, J. F., Mark, D. M., 1984.; Verdina, K. L., Verdin, J. P., 1999) which can reveal all the geographical elements of their relationship inside a watershed.

Large-scale watershed delineation usually uses low-resolution data to adapt to computer requirements (Priya, S., Shibasaki, R., 2001.). While sometimes it is not accurate enough for medium-sized or small-sized watershed research (Turcotte, R., et al, 2001). Digital elevation model (DEM) is a three-dimensional representation of the region (Maune, D. F., 2007), which is a vector finite sequence $\{V_i = [X_i,\ Y_i,\ Z_i];\ i = 1,\ 2, \ldots, n\}$, where $(X_i,\ Y_i)$ is a plane coordinating, Z_i is elevation of $(X_i,\ Y_i)$. When the plane points of the vectors in the sequence are arranged in a regular grid, the plane coordinates $(X_i,\ Y_i)$ can be omitted, and then DEM can be simplified, which is a one-dimensional vector sequence $\{Z_i, i = 1,\ 2, \ldots, n\}$.

With the rapid development during the high economic growth period of Japan, land use/cover types had a great change (Saizen, I., 2006). Common consequences of urban development are increased natural- relevant problems (Priess, J. A., et al, 2011). Typically, the annual maximum discharge in a river or a watershed will increase as urban development occurs (Tu, M., et al, 2005; White, M. D., Greer, K. A. 2006). However, using multiple-watershed-connected to share runoff on small scale watershed is seldom discussed. Reinforcing all the flood infrastructures across the country at the same time is impossible especially municipal financial shortage is serious in Japan (Uda, N., 2015). It is an urgent task to quickly establish countermeasures to assess the potential influence of flood according to periodic land-use change, especially in different regions.

We used the DEM data to delineate watershed to find available potential multiple -watershed-connected areas to share and mitigate the flood risk to support sustainable regional development.

6.2 Materials and Methods

6.2.1 Data collection and pre-processing

In this section, we downloaded the 10 m × 10 m Digital Elevation Model (DEM) from the Geospatial Information Authority of Japan (GSI), a total of 4853 pieces including 47 prefectures, XML type files were used to get location information and find the contributing area watershed upstream. Lowland open data and river data of shape file format from GIS to find the potential watersheds and rivers to acquire our proposal suggestion. Main processing steps are as follows:

Firstly, we transferred all these data into available format on the GIS software (ArcGIS 10.6.1, ESRI Ltd.,);

Secondly, we redefined the geographic coordinate system of the 4853 pieces DEM data as GCS_JGD_2000 and projected coordinate system as JGD_2000_UTM_Zone_54N. Since function 'batch projection' was removed from ArcGIS v10.x, we repaired the toolbox to achieve batch processing as follows: find the Samples.tbx from folder of ArcGIS\Desktop10.6.1\ArcToolbox\Toolboxes, change the file name of 'Samples.tbx' to 'Samples .tbx '(a space is added), reload the ArcGIS Desktop, add the toolbox;

Thirdly, we removed duplicate values and mosaicked these 4853 pieces DEM data as one, which generated a huge-size file about 450 GB. To improve computing efficiency, we divided the 450 GB file into 7 blocks (Hokkaido, Honsyu_1, Honsyu_2, Honsyu_3, Honsyu_4, Kyusyu, and Shikoku) that correspond to 7 different regions in Japan, as shown in Figure 1. Computer with processor XEON E3-1220 v5 @3.00GHz was used for these above-described steps of pre-processing.

6.2.2 DEM data analysis based on D8 algorithm

The D8 algorithm is a hydrological process that does not consider the amount of rainfall, soil permeability, vegetation absorption or water blockage, and widely used on research of rivers extraction and watershed delineation. It assumes that rainwater falls on a grid in the terrain, and the water flows to the lowest grid of surrounded eight grids. The advantage is a fast calculation which can well reflect the effect of topography on the formation of surface runoff. On the other hand, a shortcoming is also obvious, because it is a single-line transmission that is the surface runoff water will concentrate on depression and lead to the phenomenon of cut-off. Thus, it is necessary to fill the depression in the terrain to ensure that the water can also flow out of the depression. Mainly 6 procedures were done as follows:

(1) River data burning

To acquire the correct watershed delineation under the rectified on a large number of land surfaces, first, we need the current river data into a raster format to be an analyzable state. We burn the river data from shape file to raster, 10m*10m resolution, same as DEM, 5 grid width and -10m depth.

(2) Flow direction analysis

Flow direction is computed for every cell so that the water would flow through it. The value of the cell is a number representing a cardinal direction.

(3) Sink

This step uses the flow direction grid to identify sinks in DEM. These are areas surrounded by higher areas so that there is no external drainage. Sometimes sinks are real, but often DEMs have erroneous sinks. Regardless of whether they are real or not, for the watershed delineation process to work, here we need a ‘depression less DEM’ with no sinks. Before the next step, we need to check that there are no conflicts in the fixage, minage or maxage nodes of the input tree to avoid terminating the program and displaying an error message. The official help of ArcGIS did not specify what kind of processing would be done after finding the sink after using the 'sink' tool. The depressions usually appear on almost flat plains which distributes with a large area. Most users ignored the importance of sink and fill if there is a real depression; however, this would lead to serious analysis error.

(4) Fill

This step will fill the sinks of DEM. We did both a basic Fill command and some Z value tests. The result of this step will generate a less depression DEM which will, in turn, be the basis of the rest of the process.

(5) Flow accumulation

This step calculates for each cell in the filled DEM array, the number of cells from which the water flows in. Areas of higher flow accumulation values are where water collects and drains. Thus, the areas of very high values are likely perennial streams or rivers, and areas with lower values may be intermittent streams. The flow accumulation grid will allow the software to determine the area draining to any specified point on the DEM.

(6) Watershed

This command performs the calculation of the contributing area in upstream and watershed delineation.

Because these steps (1) to (6) are common hydrological analyses based on ArcGIS, here we omit some of the accompanying figures.

6.3 Result and discussion

DEM analysis can be used to calculate the contribution area upstream of a specific snap point. In contrast, according to the DEM aspect analysis, we could also get a lowland area with less undulation. Lowland areas are usually considered as flood-prone areas, and the polygon of lowland will sometimes occupy several natural watersheds. According to the overlay analysis, we could calculate the numbers of watersheds. And then joint the river shape file which is longer than 50km including all the 1^{st}-grade rivers to find if there is a polygon of lowlands counting two or more rivers (watersheds). In this study, 1km or 2km extend of the lowland is considered that construction is possible. Results showed in Figure 6-1 and Figure

6-2, respectively.

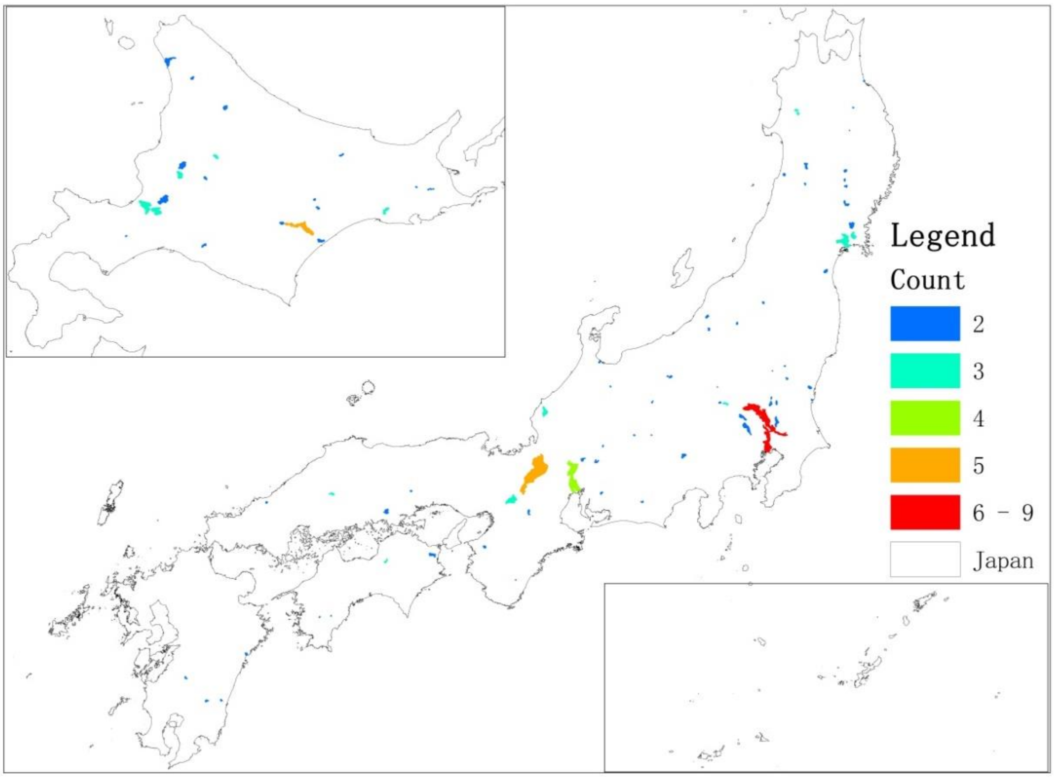


Figure 6-1 Available areas for retarding basin with buffer 1km

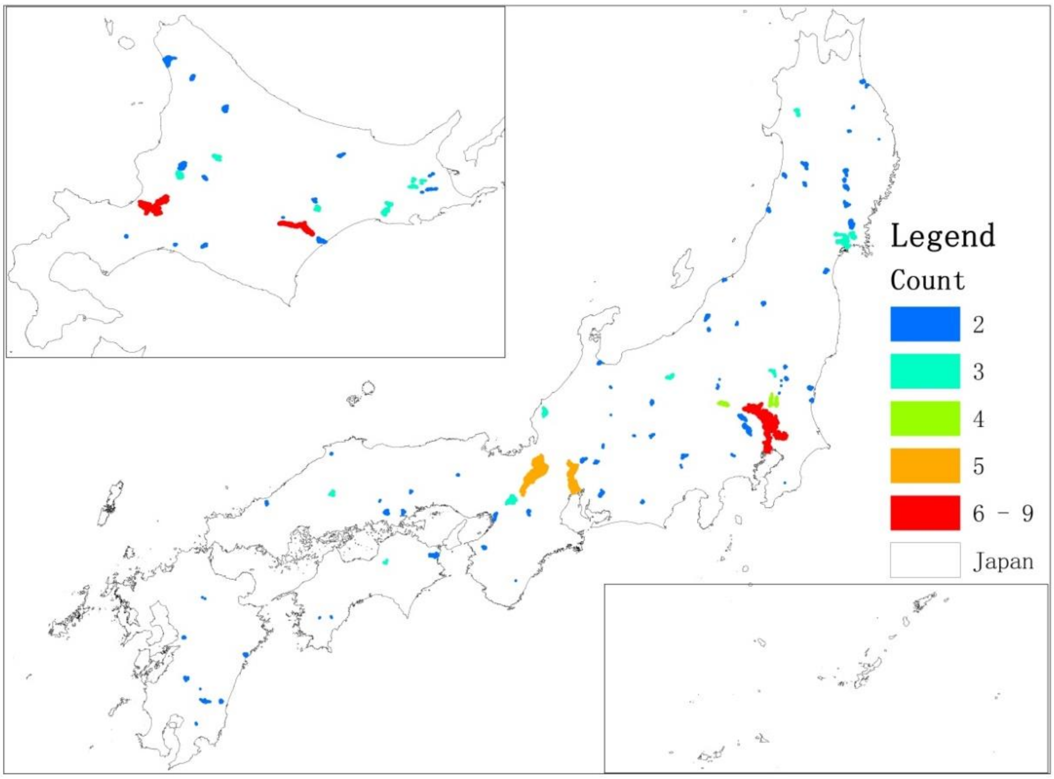


Figure 6-2 Available areas for retarding basin with buffer 2km

Table 6-1 Relationship of available areas and watershed

Group (watersheds number)	Count (1km buffer)	Count (2km buffer)
2	70	83
3	13	16
4	1	2
5	2	2
6-9	1	3
Total	87	106

Results show that available area numbers (counting more than 2) of 1km-buffer and 2km-buffer area 87, 106 respectively in Japan. Large-scale construction over 2km extend will change the available area numbers, which depends on the local flood situation and their willingness. But distribution will not change because of natural conditions. Counting more than 4 rivers (watersheds) was calculated as 4 of 1km-buffer which means that the areas could generally share the flood risk of more than 4 watersheds (rivers longer than 50km), it can be inferred as the best location of retarding basin. When the buffer extends to 2km, the original number 3 becomes the current number 4 or more. While the location is consistent with the Biwa Lake, Kisosansen, Kantou region and Hokkaido. Where there are natural detention basins existing or river improvements have been done, thus, developing additional ones is unnecessary, maintenance and upgrade based on it as much as possible is the best way. Counting 3 and 2 watersheds lowland areas are distributing across the country evenly. Counting 1 and 0 also are not showed in the map, but that does not mean they are not available for detention basin construction, while only not suitable for beyond-watershed-scale flood management, a good example is the flood event in Mabi Town, Okayama Prefecture, where tributaries system is vertical rather than parallel. An interesting finding was that most of these available areas were located in the river confluence reaches.

6.4 Summary

This chapter using the DEM data and lowland polygon data with D8 method to do the hydrologic analysis, in association with the river data river we calculated and discussed where the available areas are suitable for flood management beyond watershed scale in Japan, results showed that:

In addition to KK watershed, there are many areas available for our approach - flood management beyond watershed scale; although different buffer thresholds might get different results. And so-called flood management beyond watershed scale depends on the size and characteristics of river watersheds. Japan’s detention basins built so far are mostly at a river confluence. However, we have to mention that our study revealed parallel river water systems will be more efficient.

With the continuous updating and improvement of Remote Sensing data, DEM data and hydrological information extraction technology in future (McCabe, M. F., et al., 2017), the accuracy of watershed delineation will also be improved, especially for the flat areas which should have a certain impact on watershed analysis and calculation (Garbrecht, J., Martz, L. W. 1997.). Such signs of progress are of great significance in further watershed-related research such as flood prevention and digital watershed construction for regional sustainable development. Besides, according to the distributions urban area, decision-makers and river administrative departments could quickly respond and find where is vulnerable to be protected with the relationship between upstream, downstream and successive watershed conditions (Dittmann, R., et al., 2009).

7. Discussion of the operating mechanism of the flood plain

The land is a complex formation by the interaction of various natural and human factors (Fu BJ., et al., 2018). Natural factors such as landform, climate, soil, vegetation, and hydrology have profoundly restricted the land use patterns, structures, levels, and regional differences. But the land change caused by human factors is relatively quick compared to natural factors in a short period (Cao, S., 2010). The complex social activities such as paddy development and urbanization which have changed the original landform and river channel have led to variations in the flow direction, sediment production, and even the watershed patterns and intensified regional flood risks (Carling, P.A., 2013). The flood plain was aimed to store and discharge flood but now is used as residential land. It makes greater exposure to life and property to flooding damage (Galloway, GE., 1997). Land-use change and management in the flood plain for controlling flooding is not an easy task (Burby., RJ., French., SP., 1981), because it involves many stakeholders who will struggle for their different interests in that process.

7.1 Different Stakeholders and their conflicts of interest in the use of the flood plain

7.1.1 Stakeholders and their status in the use of the flood plain

Stakeholders in the flood plain refer to organizations or groups that have a direct or indirect interest relationship with the preparation, implementation, and application of the floodplain in society, economy, and cultures. Usually, they have different interest demands, mainly including the national government, national and local river administrative departments, local government and individuals (Browning., A, et al., 2007.).

(1) National government

The Government of Japan is dominant in reducing the flooding losses of the flood plain to the minimum (Ishiwatari, M. 2015). The government hopes that it will develop with less expenditure and can be well protected. The Japanese government also plays a leading role in making the relevant laws and river protection regulations, while the implementation is always entrusted to river administrative departments.

(2) River administrative department

The national river administrative department is closely connected with the local river administrative department, other relevant local departments, and the affected people. The interest of the national river administrative department is to adopt technical measures to prevent flood damage and reduce flood risk to the same minimum level as national interests. Therefore, the national river administrative department is in a dominant position in flood management. The local river administrative department is responsible for supervising the implementation of the projects and follows the ideas and policies of the national. Other local relevant departments, such as agricultural and civil affairs departments, should assist the national river administrative department when the areas under their jurisdiction belong to the flood plain, but also have their own interests.

(3) Local government

The local government that mainly considers local economic and social development implements that request from the national government while developing the local economy and balancing interests. However, the governments are very passive in planning and managing the flood plain due to the ownership of the lands which are owned by the residents or organizations, thus their attitudes are often contradictory. The dominant position of the country has determined that the overall interest demands for the use of the flood plain are minimized to prevent flood damages. The status of local government determines the duality of their interests. On the one hand, local governments should implement national policies; on the other hand, they should balance local interests and national interests.

(4) Individuals

Individual residents who live in the flood plain are the main implemented target of the flood control management from the governments. They are passive and their interest demands are often not satisfied. They know that there is a higher flood risk in living in the flood plain, but they still hope that the government can have better flood control measures to protect them from flood disasters. There are differences in economic and social development inside the flood plain due to natural geographical factors and historical reasons. Residents in different regions have a common interest in a better quality of life. However, in terms of policy compensation, there will be a strong sense of inequality once they find that some policies are more favorable to another.

The interests of residents in the flood plain are the bottom of the pyramid of all interests who is the most easily ignored one. Whatever the pyramid spectacular is, it will be unstable if the interests are ignored and the problems continue to pile up.

7.1.2 Conflicts among these stakeholders

In the process of planning and implementation, conflicts among different stakeholders are generated in the flood plain, including among national and local governments, different local governments, river administrative departments, and other relevant departments, etc. But from a different perspective, the conflicts can be divided into the following.

(1) A country hopes to invest a certain amount of funds in building constructions in the flood storage and detention areas to reduce the loss caused by flood to the minimum and to protect the lives and property of most people. At the same time, the government also hopes that this cost is the lowest because of its serious financial problems. However, the local government believes that the more funds the nation invests, the better it is for local development not only in flood prevention but also in social and economic development. In fact, it needs a lot of money (except constructing) to be used to buy the lands owned by the residents or organizations.

(2) From a regional perspective, the conflict comes from the interest demands of the detention basins and benefited areas that benefit from the detention basins. Although the flood control constructions in the detention basins reduce the flood disaster risk and promote the economic development for the benefited areas, the frequent flood disaster makes the social and economic development of the detention basins slower than the benefited areas and the residents may be temporarily moved when there is a severe flood. Therefore the economic and social progress in detention basins is more difficult.

(3) From the perspective of residents living in the detention basins, the conflict is mainly on two aspects. On the one hand, they hope that their quality of life can be improved and the areas can be more stably developed. However, the areas which are under the flooding risk are often restricted development. After diverting and storing the flood water, the production and life of the areas will suffer losses. It is difficult to return to the original level. On the other

hand, the critical cause of the conflict of interest is residents in the flood plain are not the main beneficiaries while paying the same tax. People usually take activities to cooperate with the government only when the benefit is equal to or even more than the pays. A balanced mechanism needs to be designed to completely resolve this conflict.

7.2 Design of balance mechanism in flood plain

According to sociology, a stable social operation mechanism mainly includes two aspects: one is the dynamic mechanism; the other is the balance mechanism. The dynamic mechanism provides energy for social development; the balance mechanism maintains the coordination, stability, and balance among different stakeholders. All stakeholders will contribute to the development of society when they are satisfied with the benefits they receive. On the contrary, society will lose vitality and be an imbalance.

The coordination of interest relationship must be carried out according to certain concepts, procedures, and frameworks, rather than subjective and arbitrary to contribute to the real realization of social equity.

Because stakeholders have different advantages and different views on various flood control policies and projects, their participation awareness and status are also different. Regulatory policies for flood control are the result of cost constraints, stakeholder game, and rule cooperation. In other words, it is crucial to find a balance in these three, and this balance should follow these principles.

When designing the interest balance mechanism used in flood plain, it is necessary to consider the residents' requirements on maintaining the living standards, and stakeholders should share the benefits and losses of the flood plain.

(1) Establish a mechanism of sharing benefits and losses

It is more difficult to determine where a detention basin should be located in flood plain than to define flood-prone areas, while this is the basis to start the mechanism of sharing benefits and losses. Although determining the detention basin would take huge costs both in financial and human resources from the national perspective, national interest is generally increased in the long term. From the perspective of the benefited areas, the industrial and commercial enterprises can operate as usual, and the people can live and work in without any change, all of these are sacrificed for the benefits of the detention basin. Therefore, both the nation and the benefited areas should take some responsibility for flood losses to the detention basin.

(2) Ensure the implementation of sharing benefits and losses

It is necessary to ensure that the people who live in the detention basin can obtain economic benefits. The biggest conflict of interest between the detention basin the benefited area is the different economic benefits. First, it is suggested to develop flood control benefit fees for companies, institutions, and residents in the benefited areas. They should pay flood control benefit fees according to a certain proportion, which can emulate compulsory liability insurance for a vehicle traffic accident. Although it cannot prevent flooding, it can turn concentrated flood damage into a multi-year payment for the detention basin to transfer flood disaster losses in time and space. Second, the benefited areas should provide kinds of support such as labor and technology and give priority to resettlement and employment for the people from the detention basin. Third, the nation as one of the beneficiaries should pay for appropriate losses caused by detaining floods in the detention basin. In addition to the main financial support, it is also necessary to formulate various preferential policies for the detention basins after flood detention.

7.3 A comparison with other countries

Japan is a population concentration country with land well developed and has already promulgated and implemented a post-disaster compensation scheme to compensate residents who suffered house damage from natural disasters. However, compensation targets and standards are usually not satisfied. This is a complex policy work that is far-reaching and wide-ranging. It is necessary to strengthen theoretical research due to past experience and lessons, which related to social stability and reconstruction of post-flood. In this section, we reviewed experience across the world.

In France and many European countries (Samuels, P.G. 2000), it has been banned to buildings built in the designated flood area, where once there was a flood disaster, to prevent inappropriate construction in the area from affecting the effect of flood storage and detention; in addition, the personal safety in the area must be ensured. Therefore, these kinds of legislations directly affect the implementation of economic compensation policies. Furthermore, the combination with an effective forecasting-warning system should be used to reduce flood damage and avoid life loss for the people who haven't moved out yet.

In Southeast Asia, such as Vietnam and Thailand, subtropical climate countries, annual rainfall is much more than Japan'. The experience made people choose bamboo houses to spend the rainy season (China National Consultants Group C, 2002). Even though it's not a popular type in Japan, it is a kind of water-resistant material and it can help people to adapt to the flood for a long time.

In America and Canada, with broad land countries, their common point is to find the flood plain to meet an unstopped flood; they usually negotiate and purchase the houses inside the floodway to ensure proper use, while as a public playground in usual time. The famous examples are Iowa flood plain construction and Red River floodway construction (Dorothy O, Nunnally P, 2015).

Essentially the same conflicts have been merged but well solved using money. Yangtze River floodplain of China, detention basin has been used several times in the past decades (Gu, H., 2006). Administrators are still subject to criticism from the outside world, but it is efficient to protect large cities where more than 10 million people live in the multi-stakeholders scheme area. Also, compensation research needs to be further improved.

For this research, a raised road–farmland system, suggest road administrative departments and agricultural administrative departments set up flood-related studies for the cooperation development.

8. Conclusion

In this chapter, we conclude the result of the dissertation which has mainly provided future flood risk management based on past flood control systems and current land use considering not only in KK watershed of 2015KTHR but also the whole of Japan and draw the further research. Summary findings are described as follows:

1. Selection of the study area

The reason for selection on KK watershed is that flood hazard appears to be increasing in this region. Although structural measures of river improvement such as raising levee and enlargement of river channel width to have been done to increase floodwater capacity

2. About levee breach point.

Although we have not proved that the levee break is directly related to its location. We will further explore and study it in future research.

3. About reconstruction of the levee breach point

The committee of inquiry of Kinu River made the decision according to several times discussion, which is a quick recovery of the river levee breach point. Many examples like the Hakojima retarding basin project after the 1986 flood, Iowa floodway construction after flood in the USA. Learning from the disaster and upgrading from disaster to adapt to the future of climate change.

4. The proposed approach - flood management beyond watershed scale

The concept was applied to the KK watershed using the road-farmland rearrangement to determine the flood storage areas and resident area. The obtained results were validated against data from historical floods. The road-farmland could also reduce the uncertain levee break risk and unstoppable flood. When it comes, reserve farmland will make the flood damage controllable, fixed and minimized. Also, the landscape would do less impact on the local people's lives, production of agriculture and industry.

5. Available areas in Japan

A DEM hydrological analysis has been done to find the available areas. Each region has its own characteristics and how to select the prevention measures for flood damage may show more or fewer differences. In addition to KK watershed, there are many areas available for our approach - flood management beyond watershed scale; although different buffer threshold might get different results and so-called flood management beyond watershed scale would depend on size and characteristics of river watersheds. However, we have to mention that our study revealed parallel river water systems will be more efficient.

6. Discussion of the operating mechanism of the flood plain

All stakeholders' interests should be considered especially in a huge project like changing the river channel, which means vulnerable areas need special treatment. As mentioned in chapter 7, the flood plain is a conflict area to develop no matter what country its. The national government has an important role to coordinate geographically adjacent watersheds, they should be responsible to "share the challenge" and local governments of the related areas should make an appropriate land-use plan to reduce long-term risks. If not, loss of life and flood damages will continue to worsen in future floods.

Our proposed approach is not a modern technology methodology, but it does rethink the theory of current flood management (Plate, E. 2002.), with the emergence of more and more advanced materials, the human should have nothing to fear to meet the future of rapid climate change.

9. References

Aktan, A. E., Farhey, D. N., Brown, D. L., Dalal, V., Helmicki, A. J., Hunt, V. J., & Shelley, S. J. 1996. Condition assessment for bridge management. Journal of Infrastructure Systems, 1996. 2:108-117.

Bledsoe, B.P., Watson, C.C., 2001. Effects of urbanization on channel instability. Journal of the American Water Resources Association. 37:255–270.

Board of Audit of Japan: http://report.jbaudit.go.jp/org/h23/YOUSEI2/2011-h23-6565-0.htm

Brath, A., Montanari, A., Moretti, G. 2006. Assessing the effect on flood frequency of land use change via hydrological simulation (with uncertainty). Journal of Hydrology, 324:141–153.

Brouwer, R., Van Ek, R., 2004. Integrated ecological, economic and social impact assessment of alternative flood control policies in the Netherlands. Ecological Economics. 50:1–21.

Browning, A., Morehouse, B., et al., 2007. Climate, water management, and policy in the San Pedro Basin: results of a survey of Mexican stakeholders near the US–Mexico border. Climatic Change. 85, 323–341.

Burby., RJ., French., SP., 1981. Coping With Floods: The Land Use Management Paradox. Journal of the American Planning Association. 47: 289–300.

Calder, I.R., 2007. Forests and water – ensuring forest benefits outweigh water costs. Forest Ecology and Management 251:110–120.

Cao, S., Liu, X., Er, H., 2010. Dujiangyan irrigation system – a world cultural heritage corresponding to concepts of modern hydraulic science. Journal of Hydro-environment Research. 4:3–13.

Carling, P.A., 2013. Freshwater megaflood sedimentation: what can we learn about generic processes? Earth-Science Reviews. 125:87–113.

Chen, Y.R., Yeh, C.H., Yu, B.F., 2011. Integrated application of the analytic hierarchy process and the geographic information system for flood risk assessment and flood plain management in Taiwan. Natural Hazards. 59:1261–1276.

China National Consultants Group C, 2002. Mitigation, Management and Control of Floods in South Asia.

Dittmann, R., Froehlich, F., Pohl, R., et al., 2009. Optimum multi-objective reservoir operation with emphasis on flood control and ecology. Natural Hazards and Earth System Sciences. 9:1973–1980.

Dorothy O, Nunnally P, 2015. The New Madrid Levee: A New Take on an Enduring Conflict. Open Rivers: Rethinking The Mississippi.

Duan, W., He, B., Takara, K., Luo, P., 2014. Anomalous atmospheric events leading to Kyushu's flash floods, July 11-14, 2012. Natural Hazards. 73:1255–1267.

Fu BJ, Wang S, Zhu YG. 2018. Earth surface processes and environmental sustainability in China: Preface. Earth and Environmental Science Transactions of the Royal Society of Edinburgh. 109(3-4):1-2

Galloway, GE., 1997. River Basin Management in the 21st Century: Blending Development with Economic, Ecologic, and Cultural Sustainability. Water International. 22: 82–89.

Garbrecht, J., Martz, L. W. 1997. The assignment of drainage direction over flat surfaces in raster digital elevation models. Journal of Hydrology, 193:204-213.

Giudice, G. D., Padulano, R., & Rasulo, G. 2012. Factors affecting the runoff coefficient. Hydrology and Earth System Sciences, 9:4919-4941.

Gu, H., 2006. History for Flood Control in China: Irrigation and Water. Power Press. .

Hamaguchi, T.; Kamada, T. 1986.Report of Survey on Double-Dikes along Ara River; Technical Note of the Public Works Research Institute, No. 2328; Public Works Research Institute: Tsukuba, Japan.

Hayashi, S., Shogo, M., Xu, K.Q., et al., 2008. Effect of the three Gorges Dam Project on flood control in the Dongting Lake area, China, in a 1998-type flood. Journal of Hydro-environment Research. 2, 148–163.

Heidari, A., 2009. Structural master plan of flood mitigation measures. Natural Hazards and Earth System Sciences. 9:61–75.

Hirao, T. 2000. Living with floods (in Japanese). Japan Society for Natural Disaster

Science. 19:159–163.

Huang, G.W.; Isobe, M. 2005. A proposal for flood damage reduction in urban area by “Water Pathway” (in Japanese). Annual Journal of Hydraulics Engineering. 50:571–576.

Ikeda, H et al. 1977. Topographic development of lowlands around Tsukuba Plateau. 104-113.

Ikeuchi, K.; Ochi, S.; Yasuda, G.; Okamura, J.; Aono, M. 2011. Inundation patterns and fatality analysis on large-scale flood. Journal of Japan Society of Civil Engineers. 67:133–144.

Inoue, K., 2007. Flood disaster in Japan. Journal of Disaster Research. 2:3–10.

Investigation report about Kinu River flood in September, 2015.

IPCC, 2013. Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Ishiwatari, M. 2015. Disaster risk management at the national level.

Jensen, S. K., Domingue, J. O. 1988. Extracting topographic structure from digital elevation data for geographic information system analysis. Photogrammetric Engineering and Remote Sensing, 54:1593-1600.

Jonkman, S.N.; Maaskant, B.; Boyd, E.; Levitan, M. 2009. Loss of life caused by the flooding of New Orleans after Hurricane Katrina: Analysis of the relationship between flood characteristics and mortality. Risk Analysis, 29:676–698.

Kamada, S., 1989. Applications of a tank model affected by water stages in drainage canal to flood analyses. Japanese Society of Irrigation, Drainage and Rural Engineering. 142:49–56.

Kean, J. W., McCoy, S. W., Tucker, G. E., Staley, D. M., Coe, J. A. 2013. Runoff-generated debris flows: Observations and modeling of surgeinitiation, magnitude and frequency. Journal of Geophysical Research, 118:2190–2207.

Khagram, S., Clark, W., Raad, D. F. 2003. From the Environment and Human Security to Sustainable Security and Development. Journal of Human Development and Capabilities, 4:289-313.

Kinu River improvement project, 2012.

http://www.ktr.mlit.go.jp/ktr_content/content/000051861.pdf

Knight, D., Shamseldin, A., 2005. River Basin Modelling for Flood Risk Mitigation.

Kundzewicz, Z.W., Lugeri, N., Dankers, R., Hirabayashi, Y., Döll, P., Pińskwar, I., Dysarz, T., Hochrainer, S., Matczak, P., 2010. Assessing river flood risk and adaptation in Europe-review of projections for the future. Mitigation and Adaptation Strategies for Global Change. 15: 641–656.

Kundzewicz, Z.W., Takeuchi, K., 1999. Flood protection and management: quo vadimus? Hydrological Sciences Journal. 44:417–432.

Luke, A., Kaplan. B., Neal. J., et al. 2015. Hydraulic modeling of the 2011 New Madrid Floodway activation: a case study on floodway activation controls. Nat Hazards 77:1863–1887.

Maune, D. F. 2007. Digital Elevation Model Technologies and Applications: The DEM User's Manual. USA, American Society for Photogrammetry and Remote Sensing.

McCabe, M. F., Rodel, M., Alsdorf, D.E, Miralles, D. G., Uijlenhoet, R., Wagner, W., Lucieer, A., Houborg, R., Verhoest, NEC., Franz, T. E., Shi, J., Gao, H., Wood, E. F., 2017) The future of Earth observation in hydrology. Hydrology and Earth System Sciences, 21:3879–3914.

Mori N, Takahashi T, Yasuda T, & Yanagisawa H. 2011. Survey of 2011 Tohoku earthquake tsunami inundation and run-up. Geophysical Research Letters.

Naef, F., Scherrer, S., Weiler, M. 2002. A process-based assessment of the potential to reduce flood runoff by land use change. Journal of Hydrology, 267:74–79.

Nakago M, 2010. Economic evaluation based on cost-benefit ratio of retarding basin. The 37th Japan Civil Engineers Kantou Branch Technical Research Presentation.

Nakajima, H., Ohgushi, K., 2013. Numerical simulation of flood and inundation for understanding the river basin management in Jobaru River. Reports of Science and Engineering of Saga University. 42-1:1–6.

O'callaghan, J. F., Mark, D. M., 1984. The extraction of drainage network from digital elevation data. Computer Vision Graphics and Image Processing, 28:323-344.

Pedroli, B., De Blust, G., Van Looy, K., Van Rooij, S., 2002. Setting targets in strategies for river restoration. Landscape Ecology. 17:5–18.

Pentland, R. L., Bathurst, J., Sydor, M., 1980. Water Planning and Management in Canada. Water International, 5:22-34.

Plate, E. 2002. “Flood Risk and Flood Management”, Journal of Hydrology, 267:2–11.

Priess, J. A., Schweitzer, C., Wimmer, F., Batkhishig, O., Mimler, M., 2011. The consequences of land-use change and water demands in Central Mongolia. Land Use Policy, 28:4-10.

Priya, S., Shibasaki, R., 2001. National spatial crop yield simulation using GIS-based crop production model. Ecological Modelling, 136(2-3):113-129.

Rohde, S., Hostmann, M., Peter, A., Ewald, K.C., 2006. Room for rivers: an integrative search strategy for floodplain restoration. Landscape and Urban Planning. 78,:50–70.

Saizen, I., Mizuno, K., Kobayashi, S., 2006. Effects of land-use master plans in the metropolitan fringe of Japan. Landscape and Urban Planning, 78:411-421.

Samuels, P.G. 2000. A New Tool for Sustainable Flood Defense Planning — An overview of the EUROTAS Research Project. European Conference on Advances in Flood Research, At Potsdam.

Saskia, F., David, K., Martin, G., Axel, B., 2005.Flood risk reduction by the use of retention areas at the Elbe River, International Journal of River Basin Management, 3(1): 21-29.

Schneidergruber, M., Cierna, M., Jones, T., 2004. Living with Floods: Achieving Ecologically Sustainable Flood Management in Europe.

SDGs: https://sustainabledevelopment.un.org/sdgs

Sendai City Construction Bureau, 2018. Explanation of the Eastern Reconstruction Road Development Project in Sendai City.

Shang, J.; Wilson, J.P. 2009. Watershed urbanization and changing flood behavior across the Los Angeles metropolitan region. Natural Hazards 48:41–57.

Statistics of Joso in 2017.

Takano, K. 1983. Proposal for flood control and urban planning in the Mama River Watershed (In Japanese).

Tanabe, T., Okuma, T., 2001. A study on the roles and effects of "NOKOSHI" on the

Jobaru-River Basin - Example of flood control that allows overflowing and its future possibility. Historical Studies in Civil Engineering, Japan Society of Civil Engineers 21:147–158.

Teng, J., Jakeman,AJ., Vaze,J., et al. 2017. Flood inundation modelling: A review of methods, recent advances and uncertainty analysis. Environmental Modelling & Software. 90:201-216.

The Daily Iowan: https://dailyiowan.com/2017/11/01/iowa-city-purchases-100th-flood-property/

Tu, M., Hall, M. J., de Laat, P. J. M., & de Wit, M. J. M., 2005. Extreme floods in the Meuse river over the past century: aggravated by land-use changes? Physics and Chemistry of the Earth, 30:267–276.

Turcotte, R., Fortin, J.-P., Rousseau, A. N., Massicotte, S., & Villeneuve, J.-P., 2001. Determination of the drainage structure of a watershed using a digital elevation model and a digital river and lake network. Journal of Hydrology, 240:25–242.

Uda N. 2015. Japan: Fiscal Discipline of Local Governments. Japan, Ministry of Finance.

Ueda, T. 2003.Flood control works in Japan.

Van Stokkom, H.T.; Smits, A.J. 2002. Flood Defence in The Netherlands: A New Era, a New Approach; Science Press, New York Ltd.: New York, NY, USA.

Verdina, K. L., Verdin, J. P., 1999. A topological system for delineation and codification of the Earth's river basins. Journal of Hydrology, 218:1-12.

White, M. D., Greer, K. A. 2006. The effects of watershed urbanization on the stream hydrology and riparian vegetation of Los Peñasquitos Creek, California. Landscape and Urban Planning, 74:125–138.

Wilby, R.L., Keenan, R., 2012. Adapting to flood risk under climate change. Prog. Phys. Geogr. 36, 348–378.

Yoshimura K, Nakamura S, Hatono M, Mukaida K, Ishitsuka Y, Utsumi N, Kiguchi M, Kim H, Noda K, Makino T, Kanae S, Oki T. 2016. Incerstigation on Kinu-River occurred by Kanto and Tohoku Heavy Rain in September 2015. JSCE Proceedings B1 (Water Engineering) 72-4: 1273-1278.