FUNCTIONS OF NATURAL LEVEES ON THE CONTROL OF INUNDATION WATERS IN THE ARA RIVER BASIN

Shigeru SAITO[1] and Shoji FUKUOKA[2]

ABSTRACT

Abstract: Natural levees are a kind of micro-topography produced by past flood inundation. Although many studies on geological features of natural levees have been conducted, there are few suggestions for effective utilization of natural levees to reduce flood damages by inundation waters. So, we have studied functions of natural levees on flood control and presented the ability to reduce flood damage. The objective of this study is to clarify effects of sizes and arrangement of natural levees on behaviors of flood inundation water in entire Ara river inundation area. The effects of natural levees on flood inundation are discussed by superimposing simulation results of flood inundation by the Ara River designed flood on topographical classification maps. For this purpose, natural levees in Kumagaya city, Kazo city and Koshigaya city in Saitama prefecture are investigated. We identified that functions of natural levees on behaviors of inundation water had differences every inundation areas. They can block spreading of inundation water and inundation water is advancing between the natural levees. However, inundation water is concentrated by the natural levees, and the water depth becomes deeper in the vicinity of the junction point of natural levees.

1. INTRODUCTION

To discuss reasonable measures for potential flood inundation areas, it is important to understand topographical characteristics on inundation water behaviors. Natural levees are a kind of micro-topography produced by flood inundations in ancient time. Although many geomorphological studies of natural levees have been conducted, there are few studies focused on effective utilization of natural levees to reduce flood damages. The objective of this study is to clarify functions of sizes and arrangement of natural levees on behaviors of flood inundation waters in the Ara River inundation area.

In this study, characteristics of natural levees in the cities of Kumagaya, Kazo and Koshigaya in Saitama prefecture are investigated and compared. Kumagaya city is located on the Ara River alluvial fan. Kazo city is located downstream of the alluvial fan, and Koshigaya City is downstream of Kazo city. We identify natural levees by using topographical classification maps (Geographical Survey Institute, 1974) and ground level data surveyed by aerial laser profiler. The functions of natural levees on flood control are discussed by superimposing simulation results of 1-100 year flood inundation of the Ara River on the topographical classification maps.

[1] Department of Civil Engineering, Graduated Student of Science and Engineering, Chuo University, Japan. (shigeru-s@civil.chuo-u.ac.jp)
[2] Research and Development Initiative, Chuo University, Japan. (sfuku@tamacc.chuo-u.ac.jp)

2. NATURAL LEVEES IN THE ARA RIVER BASIN

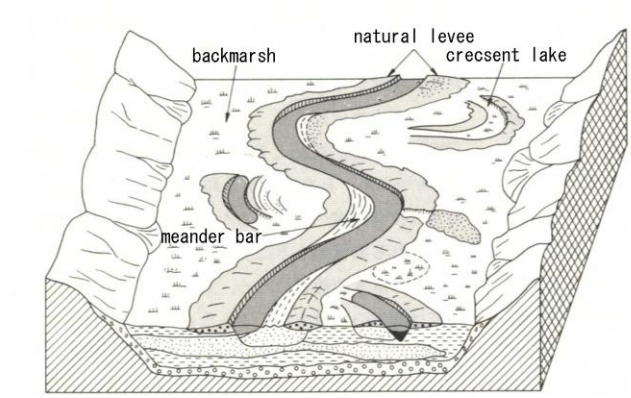

Figure 1 Natural levees along rivers (Kagose, Y. 1975)

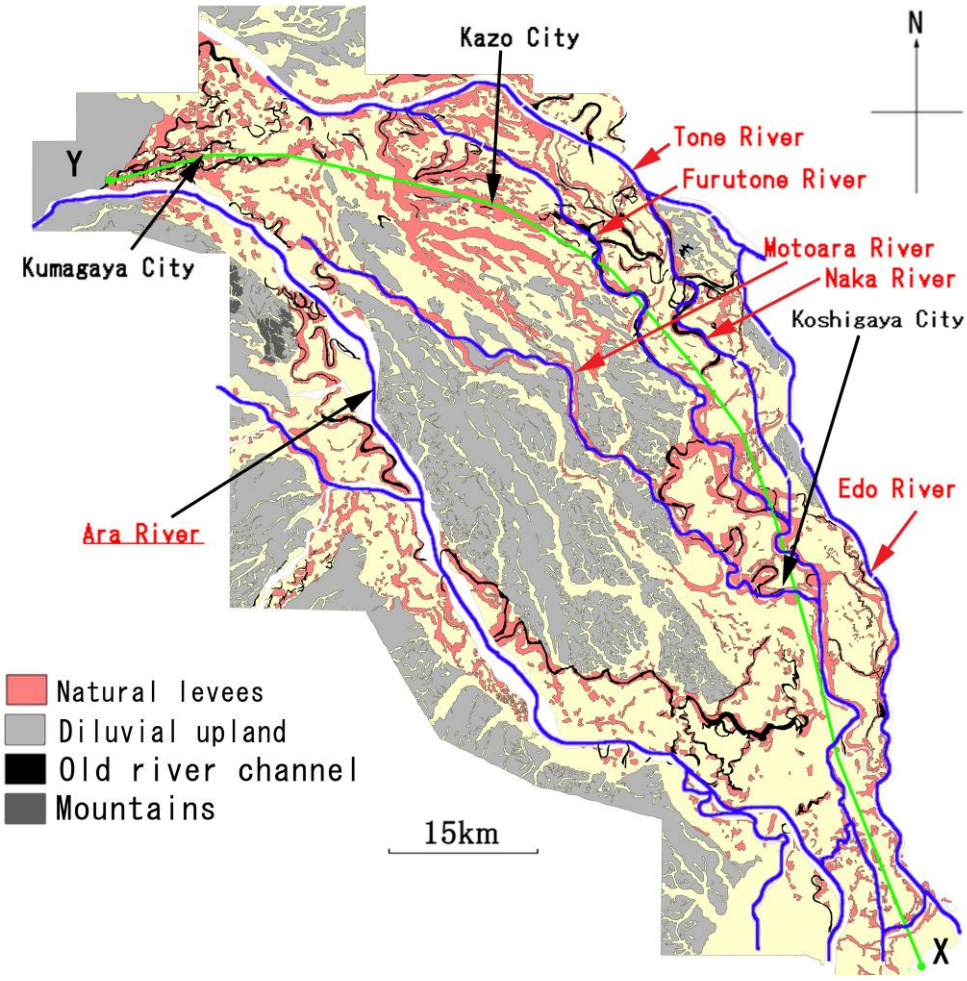

Figure 2 Natural levees in Ara river basin (Geographical Survey Institute of Japan, 1972)

Natural levees are a kind of micro-topography and are formed along the river (Fig. 1). Generally, they have developed in the alluvial fan and its downstream. Ara river basin includes some areas where many natural levees exist. Fig. 2 shows the locations of natural levees and major rivers in Ara river basin. Natural levees have developed mainly at Kumagaya city, Kazo city and Koshigaya city.

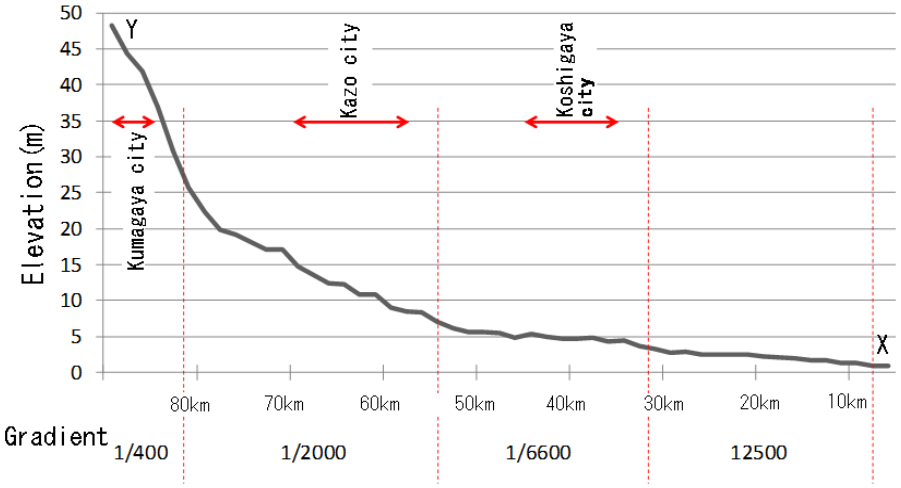

Figure 3 The elevation and ground gradient along the green line in Fig.2.

Fig. 3 shows the elevation and ground gradient in the Ara River basin. The gradient of Kumagaya city indicates larger than that of Kazo City and Koshigaya City. Magnitude of natural levees have close relations with the gradient of the land surface. The gradient of land surface in Kumagaya City has been steeper because this city locates on alluvial fan. That is, since river flowing through Kumagaya city is prone to channel change, this area has less natural levees developed large and long. On the contrary, natural levees which in Kazo city and Koshigaya city have developed larger as shown in Fig. 2.

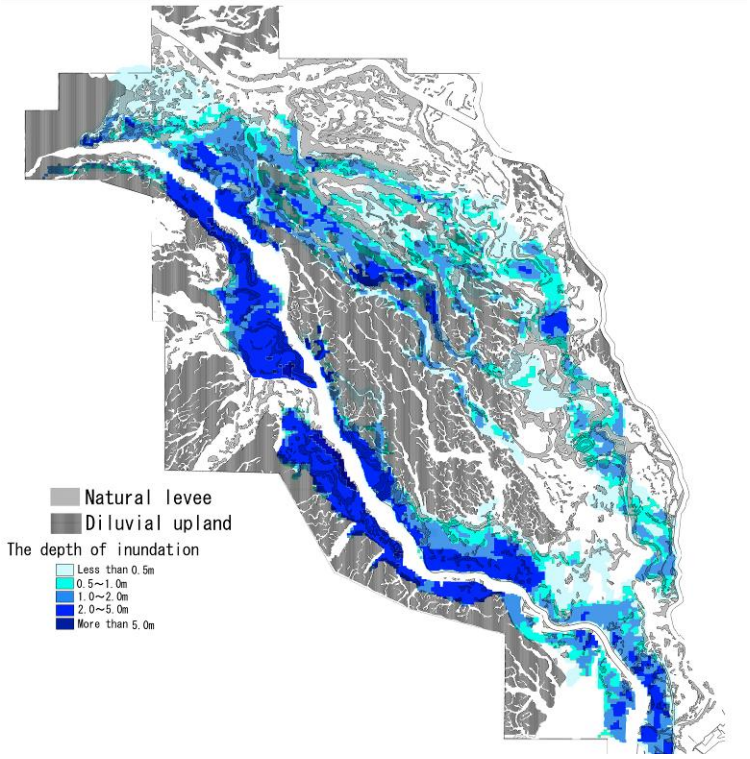

Figure 4 Depth of 1-100 flood inundation water.

Fig. 4 shows the depth of inundation water due to 100 year flood of the Ara River. This simulation was done by two-dimensional unsteady flow analysis. The inundation water spreads eastward of the Ara river and flows through Kumagaya city, Kazo city and Koshigaya city.

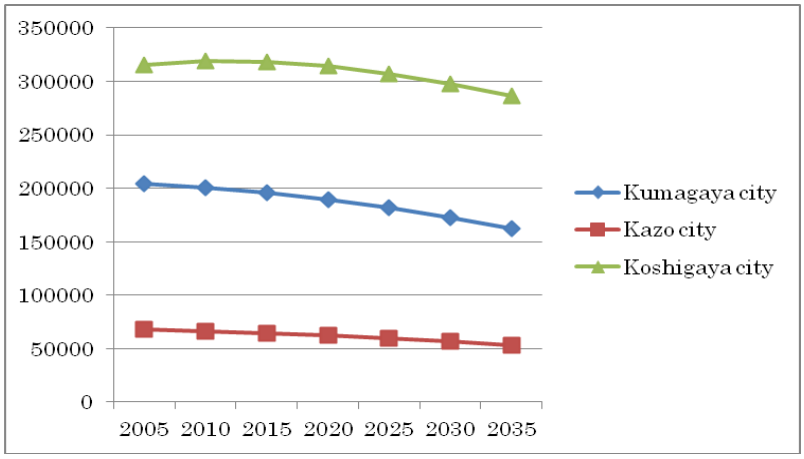

Figure 5 Future population change Kumagaya city, Kazo city and Koshigaya city. (National Institute of Population and Social Security Research of Japan, 2010)

Fig. 5 shows the future population change of the three cities. The population of three cities is predicted to decrease gradually. So, it is considered that residential district becomes narrower and key municipal functions concentrate in the central area of the city. In that case, we must discuss flood management as a concept of city planning how to treat inundation are.

3 THE FUNCTIONS OF NATURAL LEVEES ON THE FLOOD CONTROL IN KUMAGAYA CITY

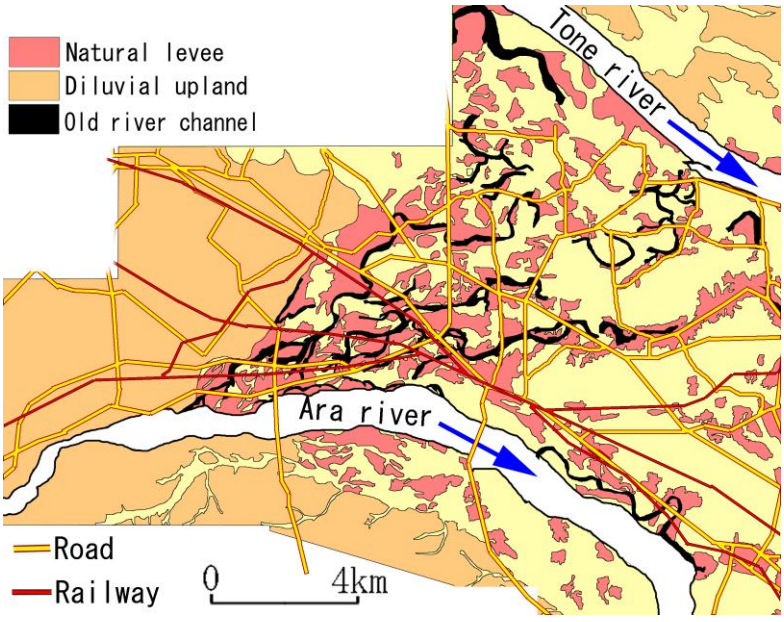

Figure 6 Natural levee distributions and traffic network in Kumagaya city.

Fig. 6 shows natural levee distributions and traffic network in Kumagaya city (Geographical Survey Institute of Japan, 2012). In this area, the elevation on the natural levees is about 0.5m higher than surrounding area. We can see that roads and railways have been constructed so as to connect the natural levees.

Fig. 7 shows the depth of inundation water at an hour after the dike was breached. Roads and railways block the spreading of inundation flow. Most roads and railways play a role of embankments. As long as embankments are higher than the depth of inundation water, inundation water is restricted by them.

Fig. 8 shows the depth of inundation water at nine hours after the dike was breached. Natural levees work with the bank of the roads and the railways and restrict flood inundation area.

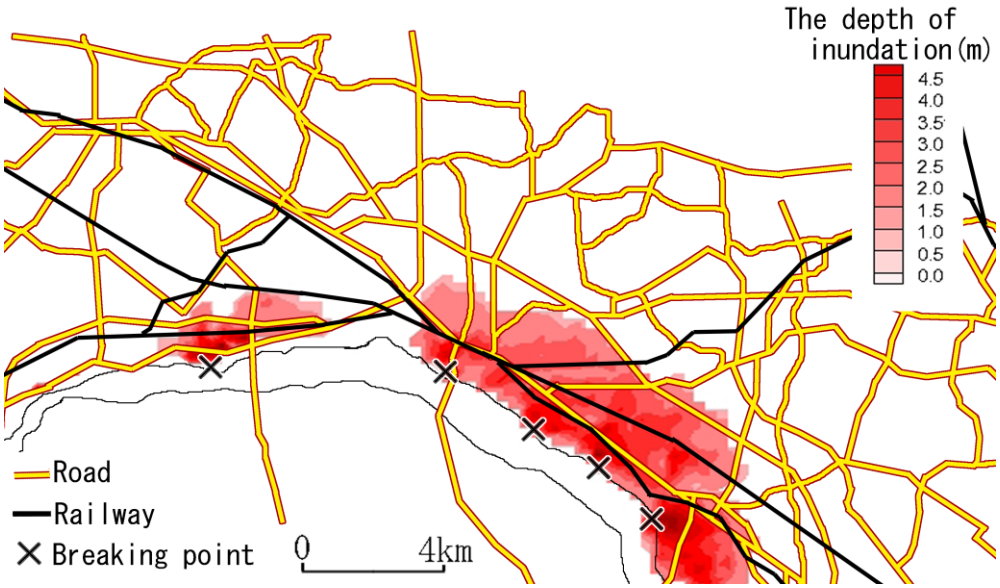

Figure 7 Depth of inundation water at an hour after the dike breach.

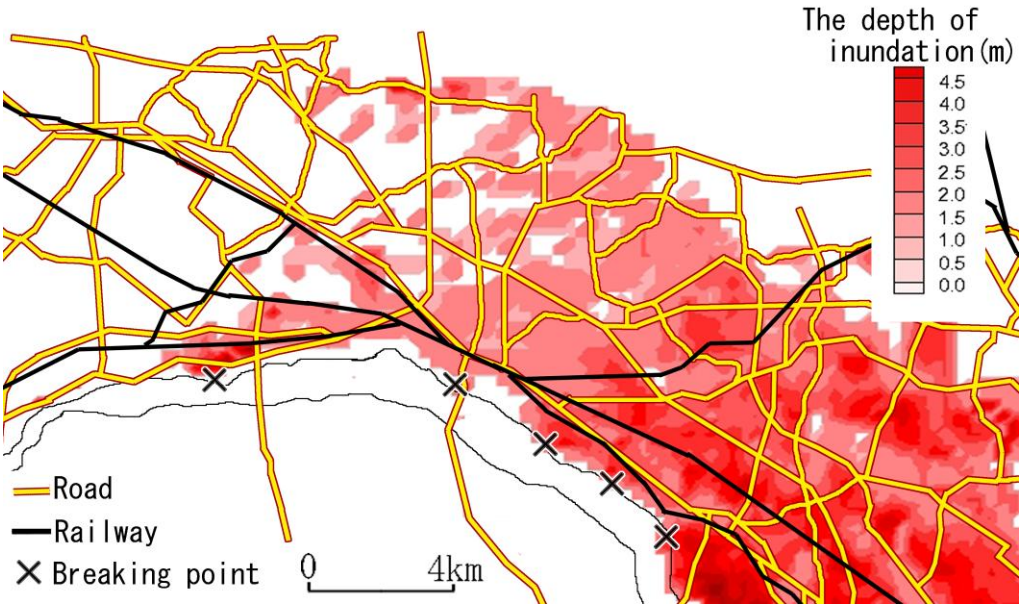

Figure 8 Depth of inundation water at nine hours after the dike breach.

4. THE FUNCTIONS OF NATURAL LEVEES IN KAZO CITY

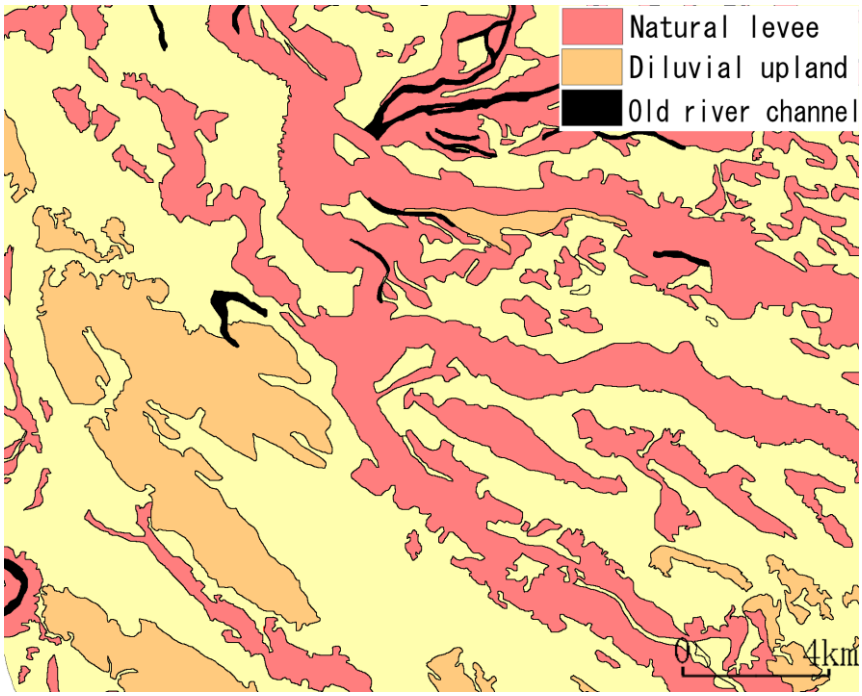

Figure 9 Distributions of natural levees in Kazo city.

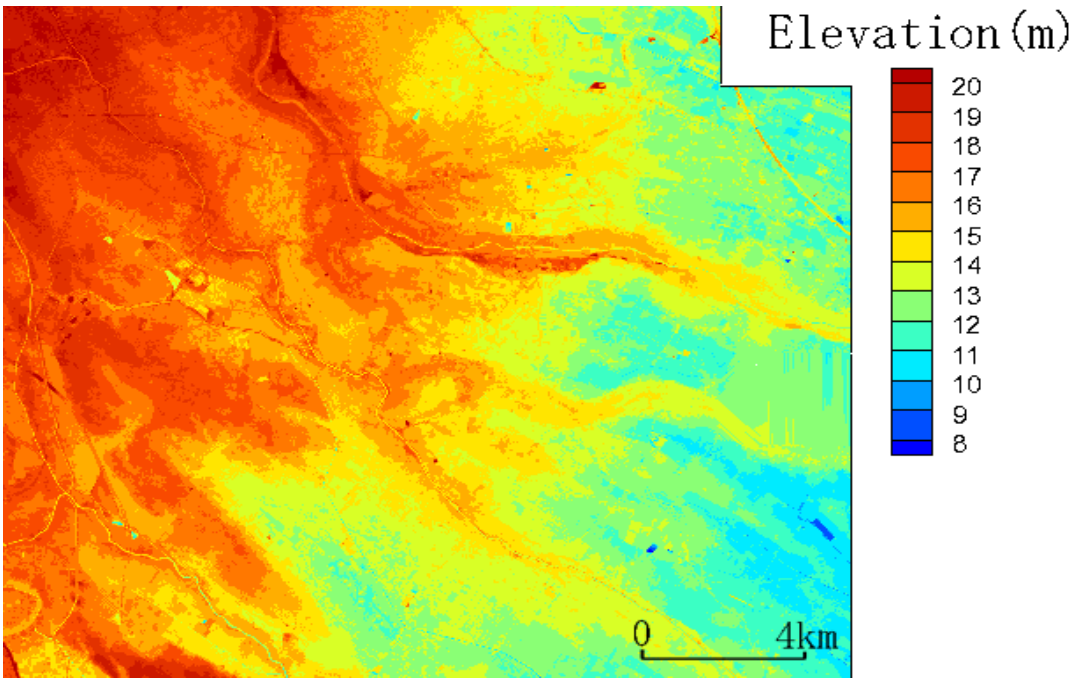

Figure 10 Contour diagram of elevation in Kazo city.

Fig. 9 shows distributions of natural levees in Kazo city. Natural levees are longer and wider than those in Kumagaya City. Fig. 10 shows contour diagram of elevation in this area. The natural levees are about 2m higher than surrounding areas.

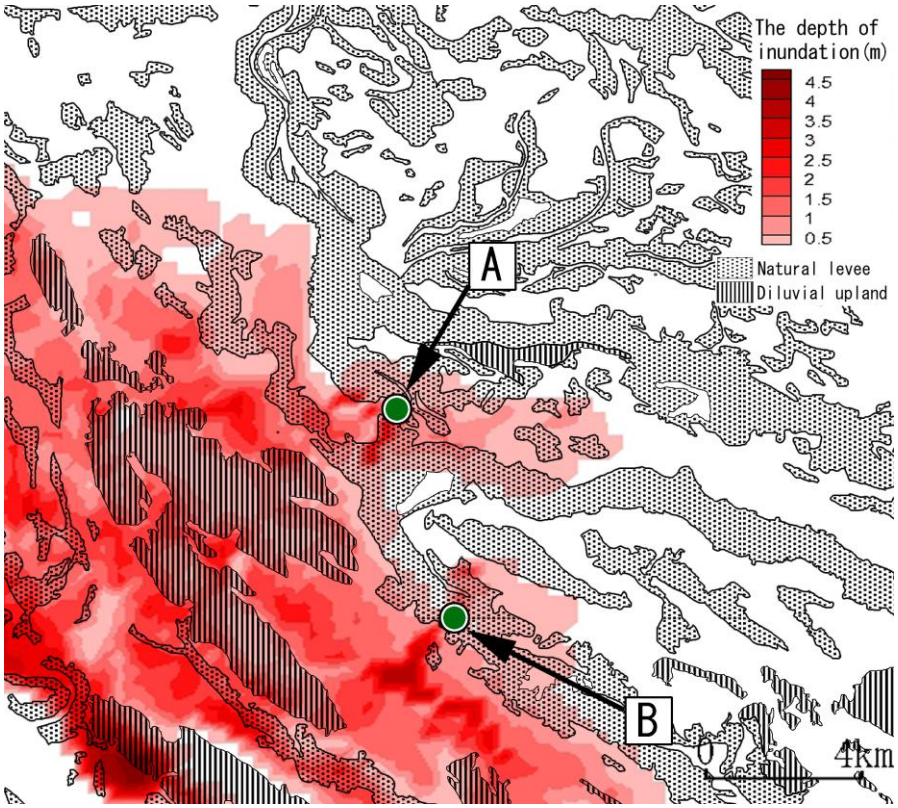

Figure 11 Depth of inundation water at six hours after the dike breach.

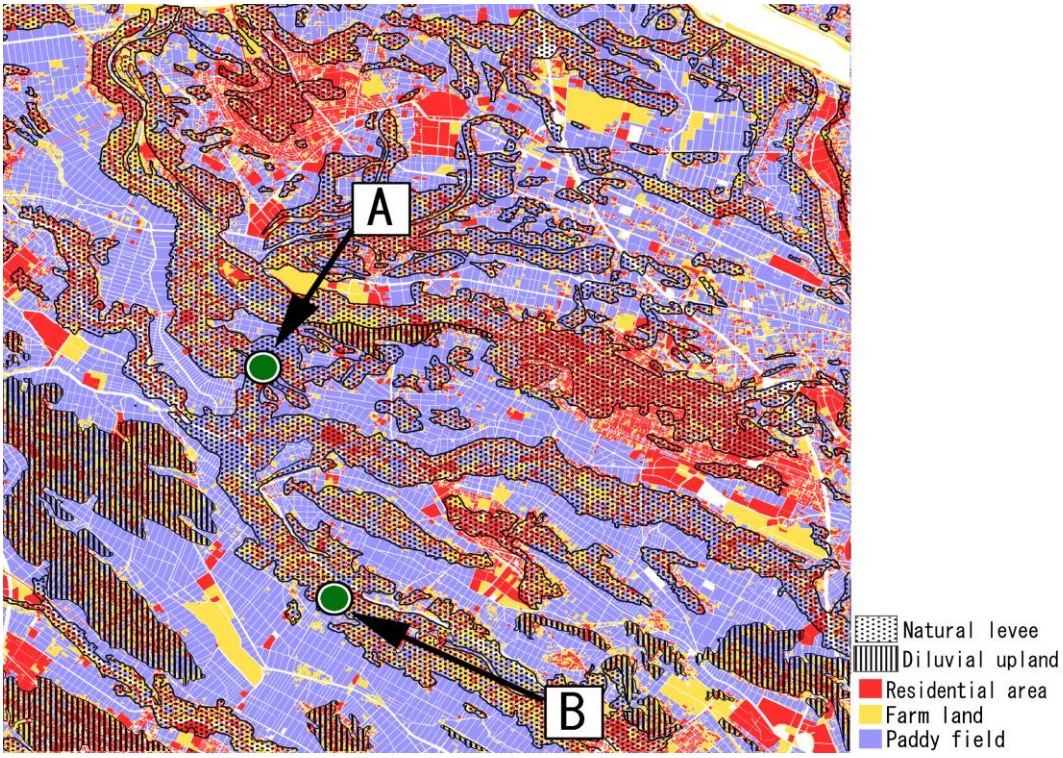

Figure 12 Land use in Kazo city. (Geographical Survey Institute of Japan, 2011)

The maximum depth of inundation occurs at six hours after the dike breach. Fig. 11 shows the depth of inundation water at that time. Spreading of inundation water stops in front of natural levees,

and inundation water flows with rather large depth between natural levees or diluvial uplands. Meanwhile, inundation water flows over natural levees at A and B. The elevation of natural levees at these locations is about 1m, and smaller than the depth of inundation water.

Fig. 12 shows the situation of land use in this area. Most of inundation area has been used for paddy fields. The damage of flooding is less because paddy fields have endurance to the inundation water. This is one of ideal examples of land use in inundation area. The key municipal functions and residences must make be located less damaged area of inundation. Inundation area should be remained as paddy fields. It is considered that natural levees can be used as the second levees to protect residences from flooding.

5 THE FUNCTIONS FONATURAL LEVEES ON THE FLOOD CONTROL IN KOSHIGAYA CITY

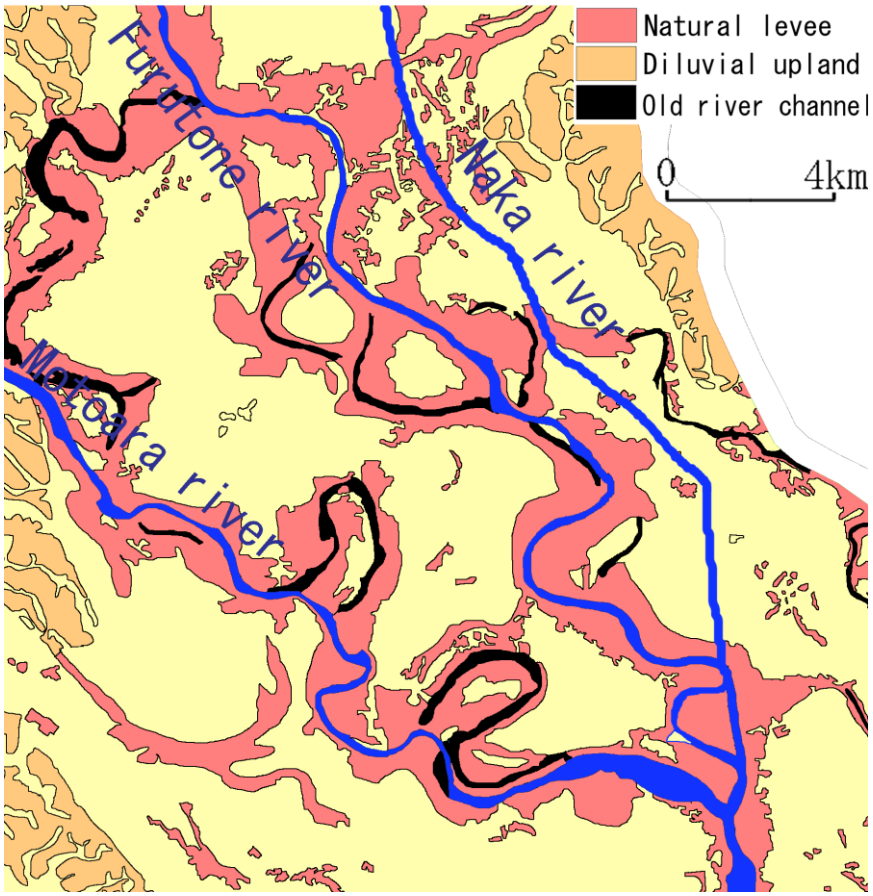

Figure 13 Distributions of natural levees in Koshigaya city.

Fig. 13 shows the distributions of natural levees in Koshigaya city. The Naka river, Furutone river and Motoara river concentrate in this area, and therefore, natural levees also converge near the confluent point of rivers. Fig. 14 shows contour diagram in this area. Natural levees are about 2m higher than surrounding as elevation the case of Kazo city.

Fig. 15 shows the depth of inundation water at 4 days after the dike breach. The inundation waters are avalanching from upper area concentrates at the confluent point of the rivers. Therefore, the depth becomes large at this point. Natural levees have functions to bring the inundation water to the confluent points.

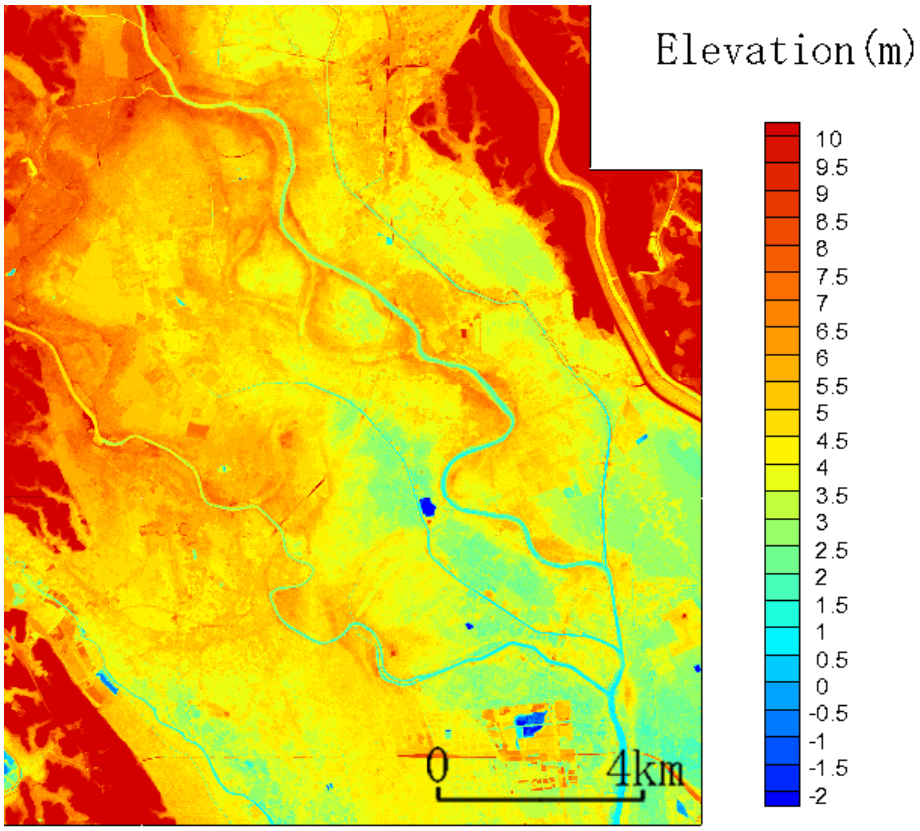

Figure 14 Contour diagram of elevation in Koshigaya city.

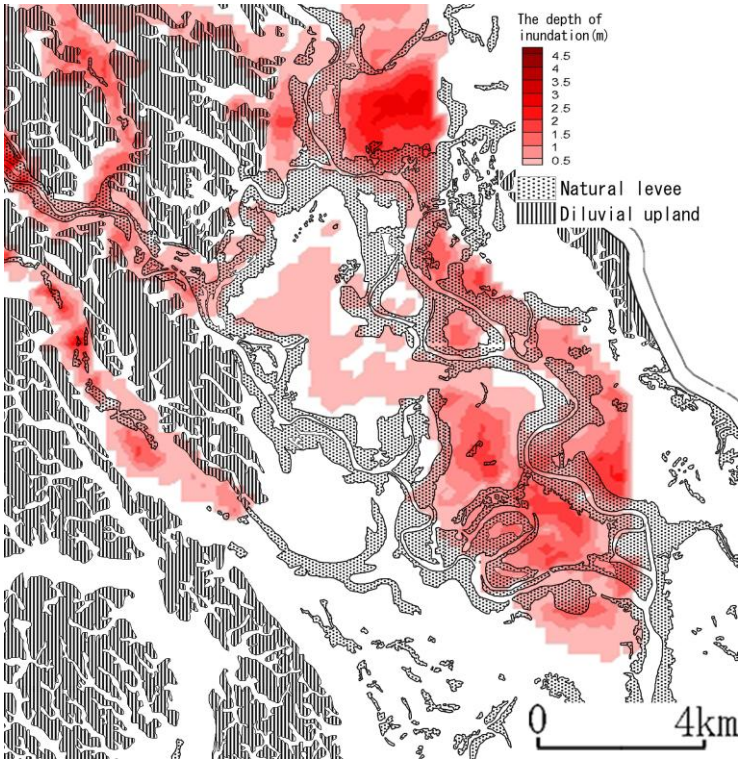

Figure 15 Depth of inundation water at four days after the dike breach.

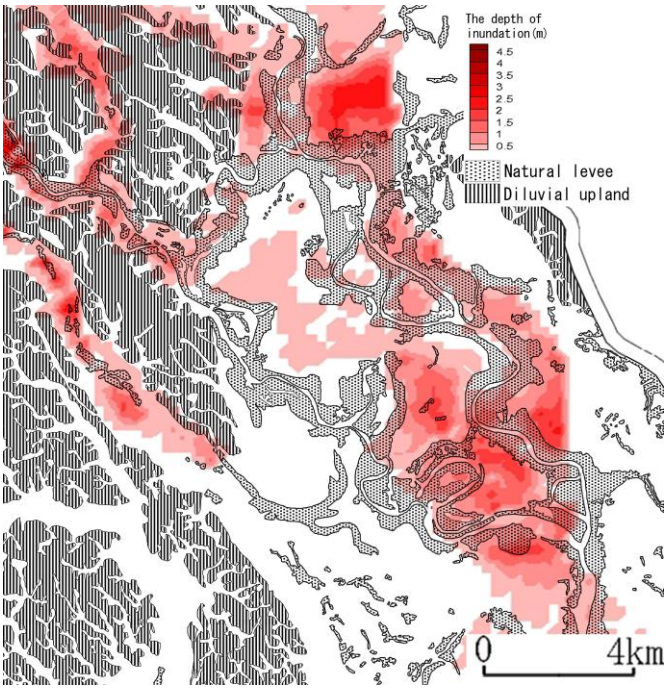

Figure 16 Depth of inundation water at seven days after the dike breach.

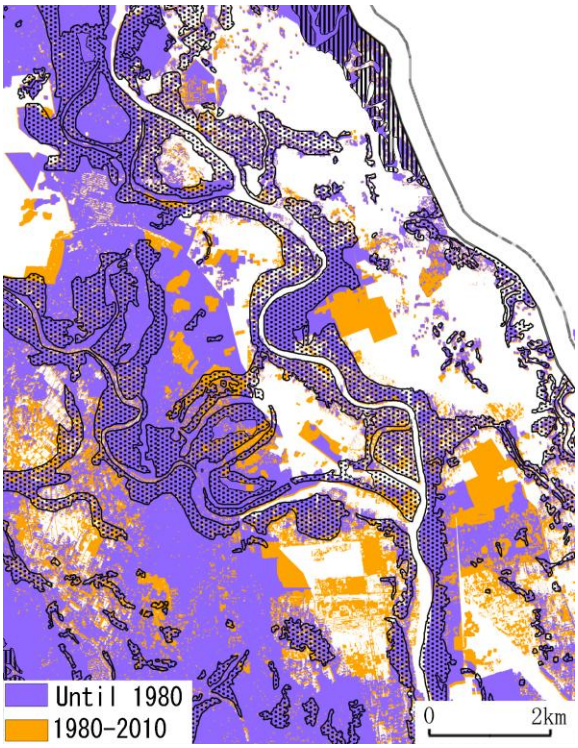

Figure 17 Situation of residential development in Koshigaya city.

Fig. 16 shows the depth of inundation water at seven days after the dike breach. There is little change in the depth of inundation water from four days after. Since large depth of the inundation is maintained for long time, the land use such as paddy field is desired in this area. However, the population of Koshigaya city has increased as indicated in Fig.5 and residential districts are currently spreading.

Fig. 17 shows the situation of housing area development in this area. At the present, residences tend to be constructed on the places of predicted large inundation depth because less damage area by inundation water have already used for residences. It is important to discuss the measure to construct endurable houses against inundation waters and to consider the land use reducing damages of flooding.

6. CONCLUSIONS

Functions of natural levees on flood control vary with of morphological characteristics of the inundation area. Primary conclusions are shown below.

1. In Kumagaya city, the elevation of the natural levees is about 0.5m higher than surrounding area, and roads and railways were constructed so as to connect the natural levees. Flood inundation area is restricted by the banks of the roads and railways, so it is considered that natural levees work together with the bank of the roads and the railways to block the inundation flow in this area.
2. In Kazo city, natural levees are larger than those of Kumagaya city. The natural levees are about 2m higher than surrounding area and they can block inundation flow. Since the inundation waters advance between the natural levees and diluvial uplands, it is considered that natural levees can be used as the second levees by reinforcing their depressions with banks of roads and railways.
3. In Koshigaya city, natural levees have height and size similar to those in the Kazo city. Some natural levees concentrate inundation waters at the confluent point. Therefore, it is needed to discuss the land use to reduce the damages due to flood inundation waters.

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