Consolidation of Predicted Disaster Information and Expectation of Coincident Disaster

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(Received October 7, 2013)

Synopsis

The 2011 off the Pacific Coast of Tohoku Earthquake brought serious damage in the wide area in Japan. We must learn most of knowledge and findings from this unexpected giant earthquake disaster. It is said that the return period of the giant earthquake as the 2011 off the Pacific Coast of Tohoku Earthquake is the order of a thousand years. The return period of the expected disaster so far, however, is a few hundred years. As a trial to get rid of an unexpected disaster, information about disaster predictions is collected and the effect of coincidence of some disaster is investigated in this study. The disaster information such as inundation by tsunami, storm surge and flooding, seismic intensity, liquefaction and subsidence is stored as a GIS data and easily used for investigation of coincident disaster.

KEYWORDS: Coincidence of disasters, Prediction of an unexpected disaster, Tsunami inundation, Storm surge and flooding, Seismic intensity, Liquefaction, Subsidence

1. Background and purpose of this study

Many human lives and property in the district along the Sanriku coast were lost by the 2011 off the Pacific Coast of Tohoku Earthquake. The giant earthquake brought not only strong ground motion over a wide area but also a huge tsunami and liquefaction and made the refuge of people difficulty. We did not have the scientific data that such a giant earthquake might have occurred in the Sanriku district. Hence, most of the researcher on earthquakes and tsunamis could not expect an occurrence of the giant earthquake and the provoked tsunami and liquefaction. However, it is not to say that the local governments and residents in the Sanriku district have not prepared measures against tsunami. If anything, there were some advanced cities for the tsunami disaster prevention in the district. A problem is not to have expected that the more severe situations than that brought by the past disasters may occur.

The disaster responses can be classified into hard ones and soft ones. The hard responses are the ones by rigid structures such as breakwaters against tsunami and storm surge barriers and help inhabitants to reach refuges. Because of excess reliability of concrete structures, unfortunately, most inhabitants have acquired a habit of not taking refuge action even if evacuation warning would be issued. On the other hand, the soft responses are the measures to help the rapid refuge action of inhabitants by markers, directional arrows and so on. These days, most local government makes the hazard map which expresses disaster potential on a map and has kept making efforts to let inhabitants know widely. As Tohno[1)] pointed out, however, there is hardly such a hazard map as some plural disaster potentials are presented in. From a viewpoint of reviewing prevention from disaster with estimating the severest disaster potential, it is necessary to consider not only a disaster with an extremely less-frequent occurrence but also a coincidence of plural disasters with occurrence frequency which local governments have ever expected.

One of the purposes of this study is to gather the disaster information that has been assumed so far in local governments. The other purpose is to estimate a coincident disaster which may occur in the future based on the knowledge when disasters anticipated in the past would occur concurrently or consecutively in a short duration. In this paper, the disaster information in the Kansai district will be shown by using a geographic information system (GIS).

2. Expected disaster

2.1. Inundation by river water

There are 10 class-A rivers which flow into the sea in the Kansai region (strictly speaking, under management by Kinki Regional Development Bureau of the Ministry of Land, Infrastructure, Transport and

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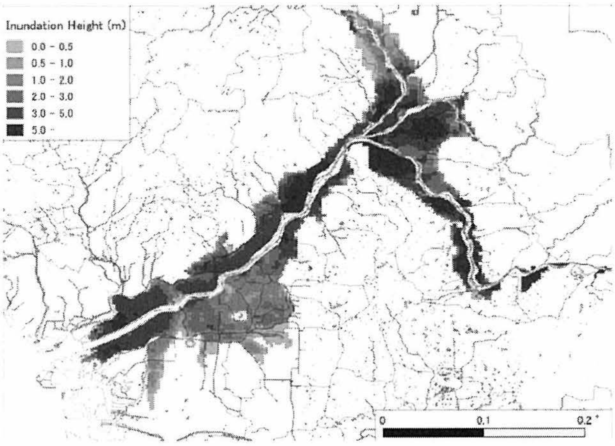
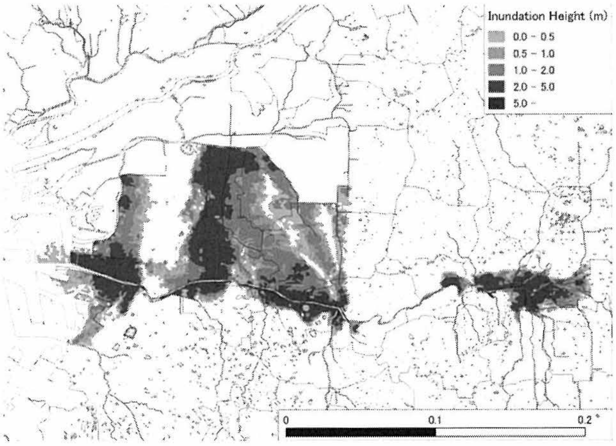
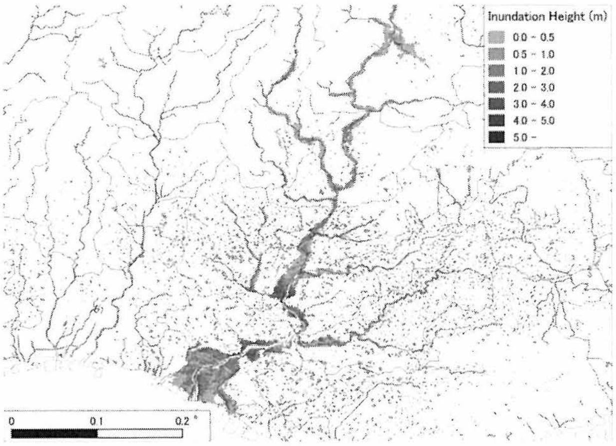


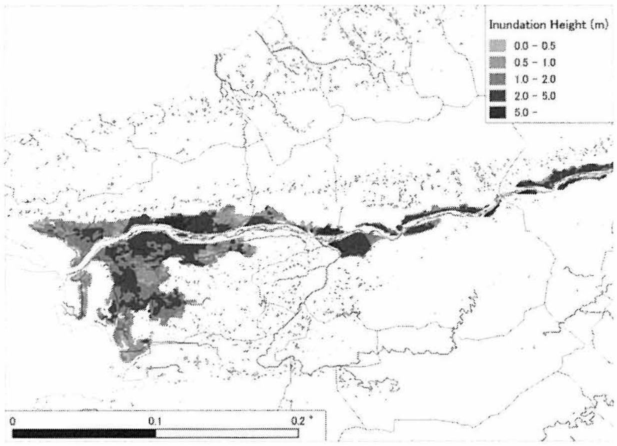
(a) Yodo-gawa river



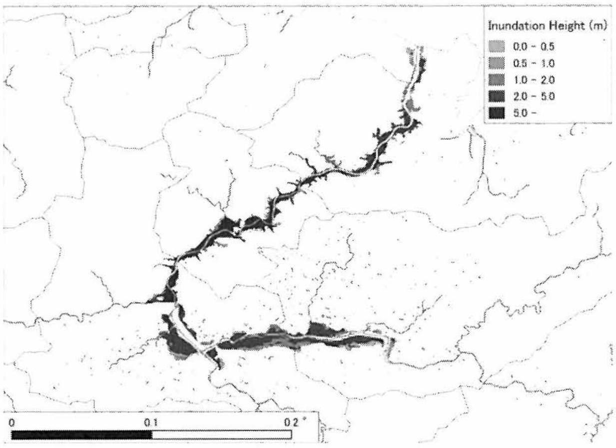
(b) Yamato-gawa river



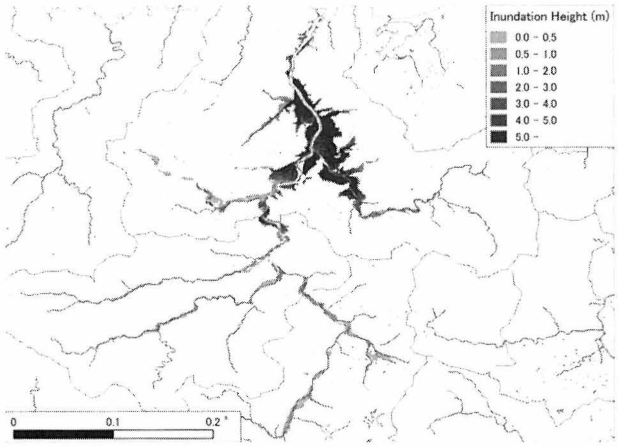
(d) Kako-gawa river



(c) Kino-kawa river



(d) Yura-gawa river



(e) Maruyama-gawa river

Fig. 1 Anticipated inundation area and depth.

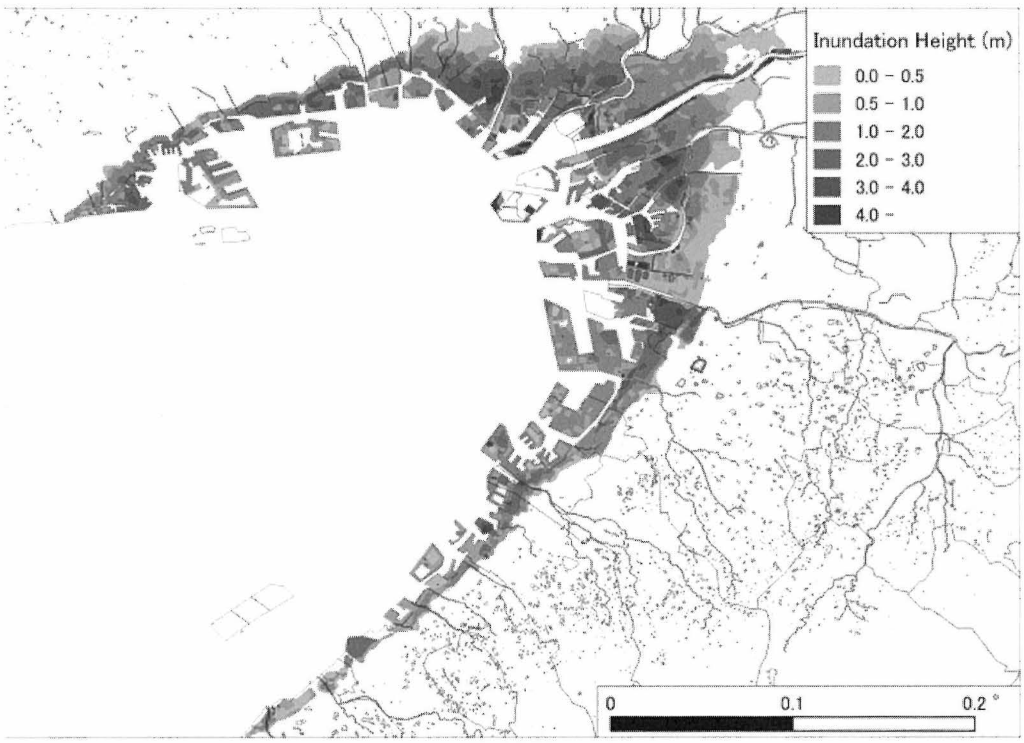


Fig. 2 Anticipated inundation area by storm surge.

Tourism). The data are offered by local governments and the Ministry of Land, Infrastructure, Transport and Tourism as figures. Authors made GIS information from the data as Fig. 1. Populations in each river area are 11,650,000, 2,150,000, 820,000, 689,000, 300,000, and 150,000 respectively. The areas of each river are 8,240, 1,070, 820, 1,750, 1,880, and 1.300 km^2 respectively. Authors made GIS information from the data which are offered by local governments and the Ministry of Land, Infrastructure, Transport and Tourism as figures. The inundation of Yodo-gawa River is anticipated under the condition of 500 mm two-day precipitation in the upstream region of Hirakata. The inundation of Yamato-gawa River is anticipated under the condition of 268 mm two-day precipitation in the upstream area from Oji or 280 mm two-day precipitation in the upstream area from Kashiwara. The inundation of Kako-gawa River is anticipated under the condition of 288 mm two-day precipitation at Itaba and 271 mm at Kunikane. The anticipation condition of Kino-kawa River is 484 mm two-day precipitation at Hashimoto and 440 mm one at Funato. The condition of Yura-gawa River is 359 mm two-day precipitation in the river basin, which is the same condition of flood on September 1953. The condition of Maruyama-gawa River is 327 mm two-day precipitation in the basin.

2.2. Inundation by storm surge

Fig. 2 shows the anticipated inundation area by the storm surge which is the severest case presented in the guideline of the action plan for crisis management against a storm surge of Osaka bay. The Osaka plain has ever suffered severe damage by storm surges such as Typhoon Muroto, 1934, Typhoon Jane, 1950, Typhoon Nancy, 1961. Osaka Plain was formed by accumulation of a large amount of sand carried by Yodo-gawa and Yamato-gawa River. Much land was formed by some reclamation and landfill. Combining with groundwater pumping due to economic development, zero-meter area, of which elevation is lower than the mean monthly-highest water level T.P. +0.9 m in the typhoon season, spreads widely along the coast line in Amagasaki and Osaka City. In the anticipation of the damage by a storm surge, tide level in consideration of influence of global climate change (T.P. + 1.1 m) and power (900 hPa), a scale, and the decrement of the typhoon are taken into account. Fig. 2 is the anticipated result where the typhoon will cause the water gates to malfunction and some dikes to be not working.

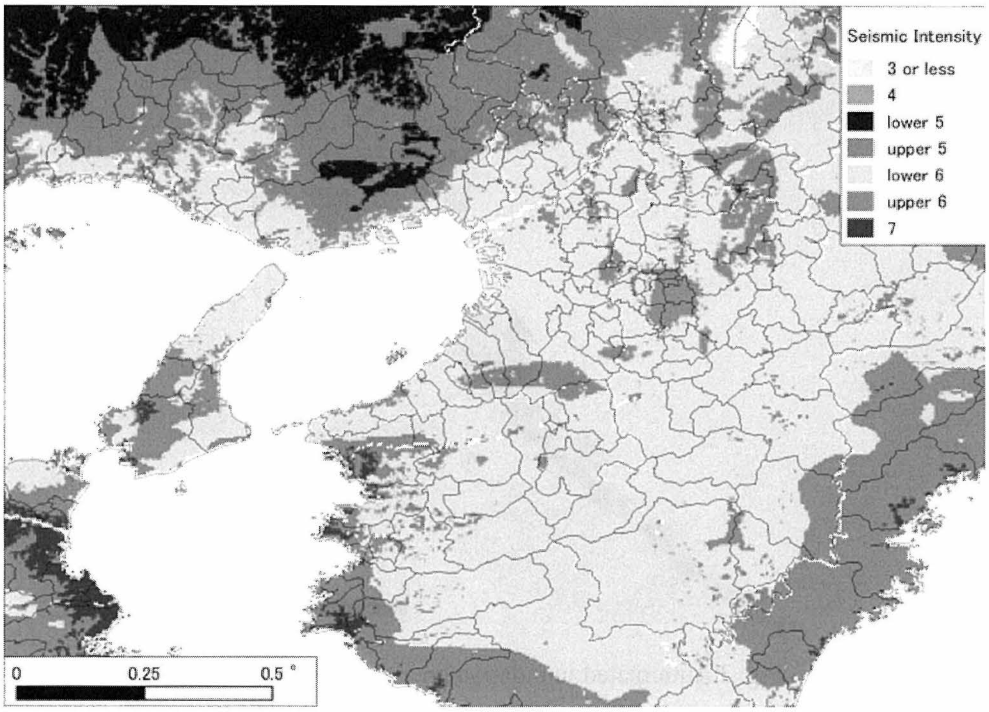


Fig. 3 Seismic intensity map by the Nankai Trough earthquake.

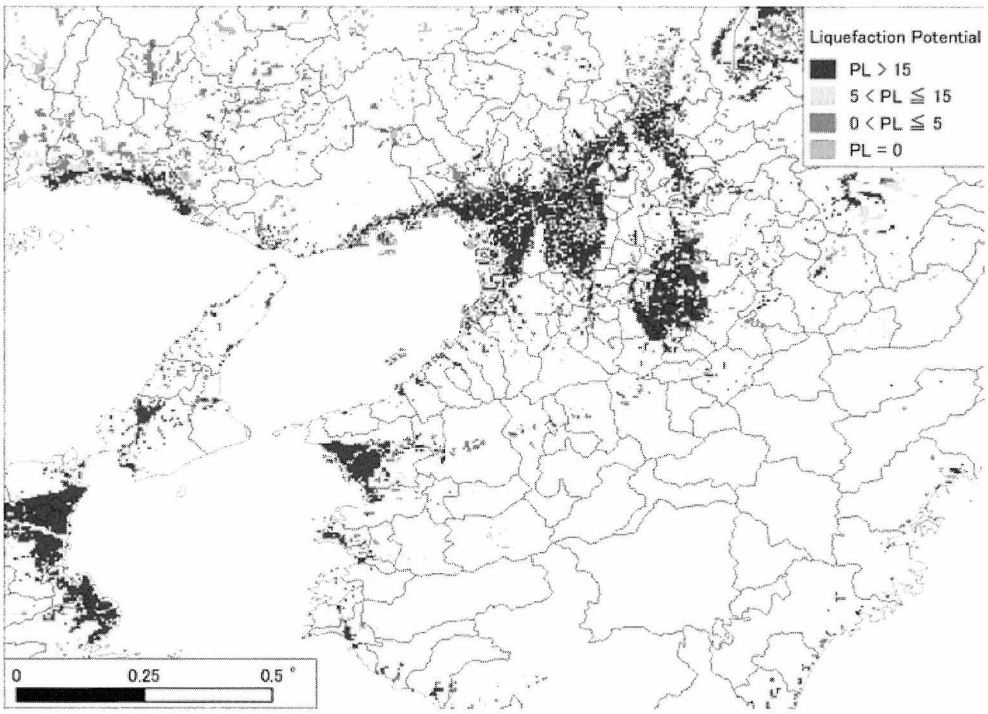


Fig. 4 Liquefaction hazard map by the Nankai Trough earthquake.

2.3. Nankai trough earthquake

After the 2011 off the Pacific coast of Tohoku Earthquake, Cabinet Office, government Japan examined the other giant earthquake which would occur in the Nankai trough with considering every possibility. Fig. 3 shows the expected seismic intensity map in the case where a strong ground motion area will spread into

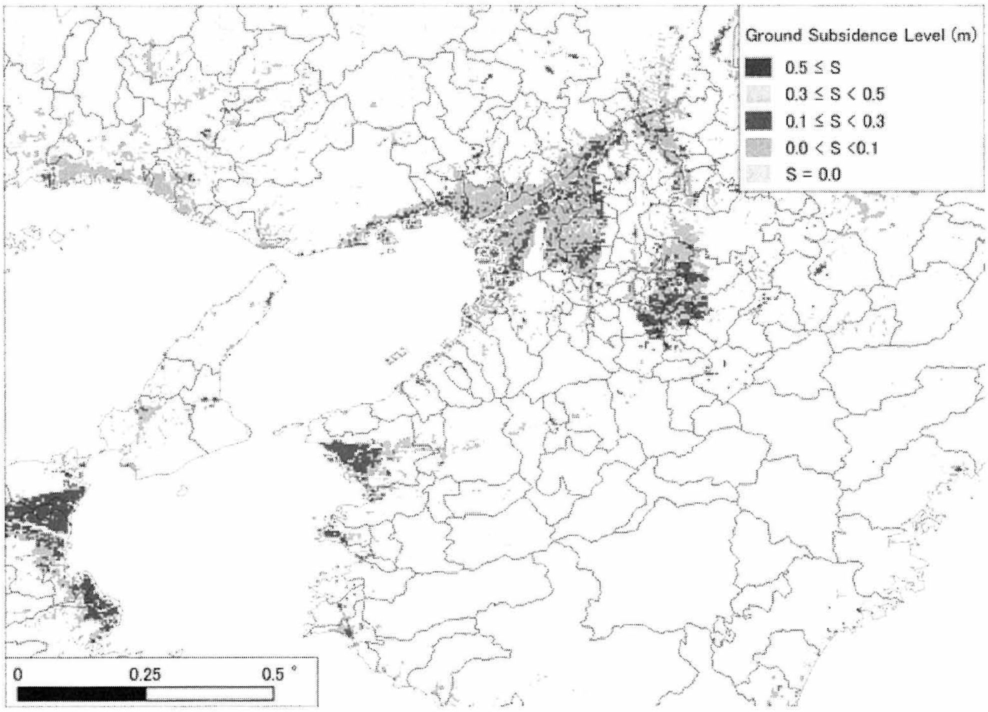


Fig. 5 Subsidence displacement by Nankai Trough earthquake.

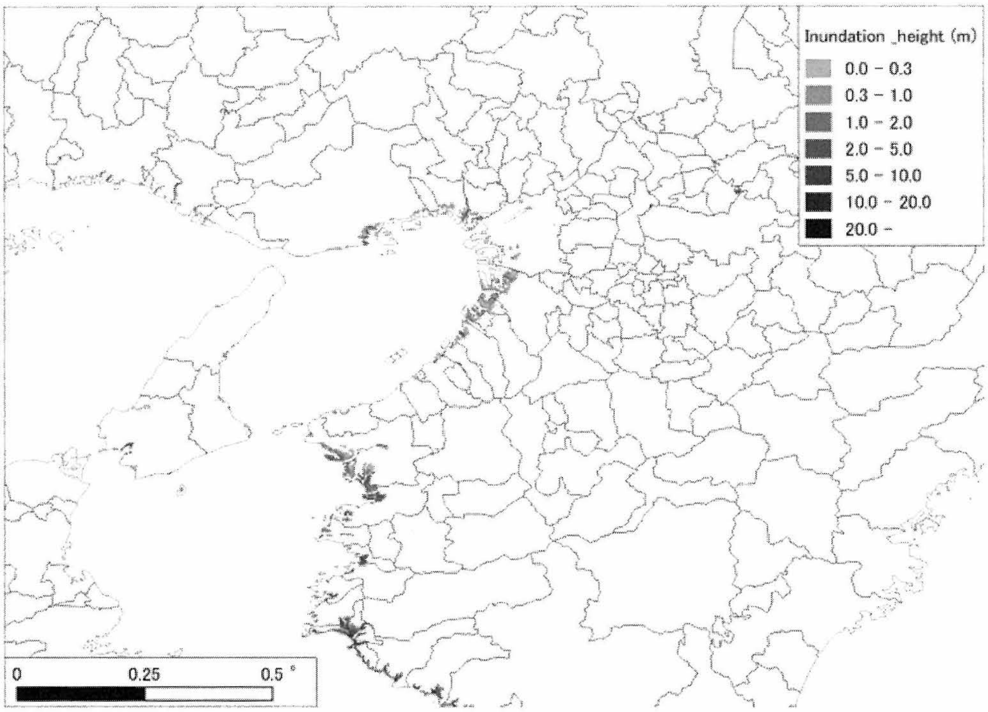


Fig. 6 Tsunami inundation area by Nankai Trough earthquake.

inland of Shikoku region and the Kii Peninsula.

Fig. 4 and Fig. 5 show the liquefaction prediction and subsidence settlement by the earthquake mentioned above. Fig. 6 shows the expected tsunami inundation area caused by Nankai trough earthquake. It should be noticed that the inundation map is made by gathering the maximum inundation depths of estimated results with different sizes and displacements of fault under the condition that sea embankments will be broken instantaneously at tsunami overflowing.

3. Anticipation of coincident damages by some origins

3.1. Anticipation of coincident disasters due to a single origin

It is well known that the giant earthquake sometimes induces liquefaction and tsunami. It was reported that liquefaction due to the 2011 off the Pacific Coast of Tohoku Earthquake made the refuge of inhabitants difficult. Liquefaction depends on not only seismic intensity but also geological condition. Inhabitants are required to get enough knowledge of the tsunami height which might attack and possibility of liquefaction of the inhabited area.

Fig. 7 shows the hazard map which is composed of the liquefaction hazard map shown in Fig. 4 and Tsunami inundation hazard map shown in Fig. 6. It is found from Fig. 7 that the wide area of the alluvial plain with the highly concentrated industry and population has a potential of both risks of liquefaction and tsunami inundation.

Thinking about refuge action after giant earthquake occurring, more detail information will be required. Fig. 8 shows the hazard information about liquefaction and tsunami inundation in Wakayama City located in the Kino-kawa River downstream basin. The color of circles in Fig. 8 represents the liquefaction potential PL, which the larger PL means the higher potential of the liquefaction occurrence. It is found from Fig.8 that the most part of plain in Wakayama City has a very high potential of liquefaction. In addition, tsunami inundation area spread along not only coastal line but also Kino-kawa River. If river bank, sea embankment, coastal levee and so on lost their function to protect the inland from water disaster due to liquefaction, the following tsunami will bring serious damage. Leakage and/or outflow of a hazardous substance including with heavy oil would cause further disaster such as fire disaster and health problem.

3.2. Anticipation of Coincident disaster due to some origins

River banks, sea embankments, coastal levees and so on have been constructed and managed in the past several decades. Consequently, severe damage by a storm surge and flooding has decreased. However, unexpectedly strong rain for a short period has frequently come occur recently. Further, sea level rise and change in the precipitation feature due to typhoon by global climate change are apprehended. It may be said that the flood potential will increase more and more in this sense.

Fig. 9 shows the hazard map which is composed of the inundation areas by Yodo-gawa, Yamato-gawa, and Kino-kawa River and the one by a storm surge. In the figure, the deepest inundation depth among the expected inundation depths is presented. It is found that most area along the coast line and rivers will be damaged if the events occur at the same instant. Severer damage may occur in the wider area if the sea level rises by the progress of the global warming.

Fig. 10 presents the inundation area and depth when storm surge and flood by Yodo-gawa River would occur at the same instant. The storm surge is a phenomenon of the time scale for a few hours. On the other hand, flood is a phenomenon for a few hours of days. The coincidence of these disasters, storm surge and flood, has been hardly predicted because of the extremely low possibility. Although it is said that the return period of the giant earthquake as the 2011 off the Pacific Coast of Tohoku Earthquake may almost a thousand years, the research on the probability of coincidence of plural disaster should be necessary. It is found from Fig. 10 that deeper inundation area spreads not only along coast but also to the inland area in which there is much property and human activity. Some countermeasures are required to protect property and human lives. It is additional notice that the value of the inundation depth in the figure is not accurate because inundation depths by the storm surge and by flood from Yodo-gawa River are only added without considering the physical mechanism.

There are many rivers with bed above the ground in Japan. If river flooding occurred after land subsidence occurring due to earthquake, inundation area would spread wider than that only flood occurs. Fig. 11 shows

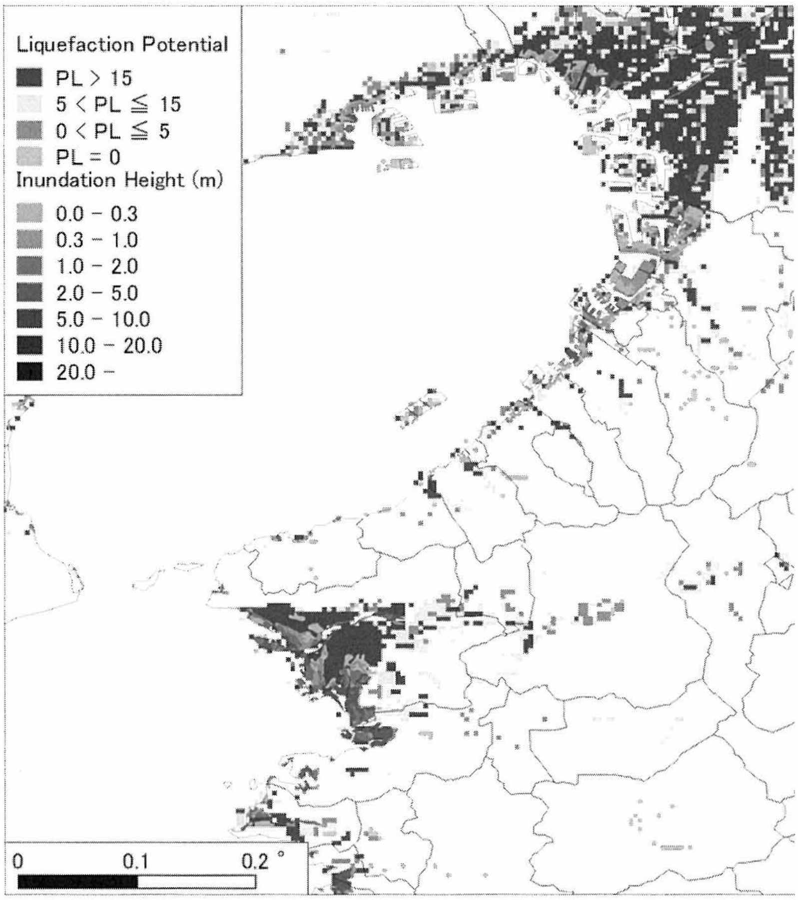


Fig. 7 Tsunami and liquefaction by the Nankai Trough earthquake.

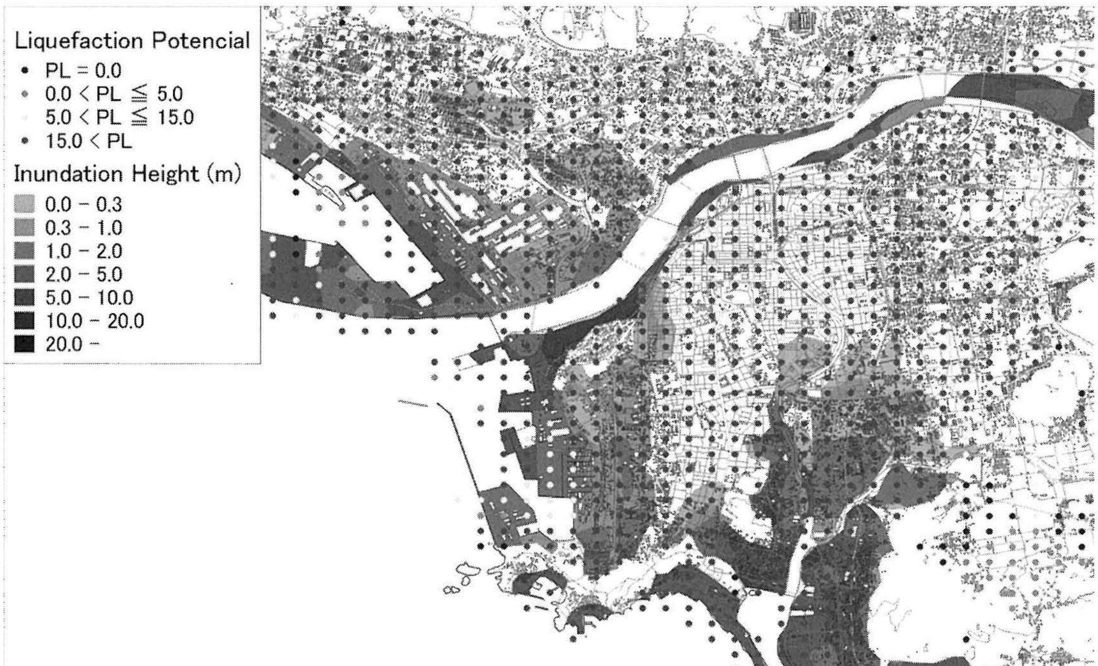


Fig. 8 Coincident disaster of tsunami and liquefaction in Wakayama City.

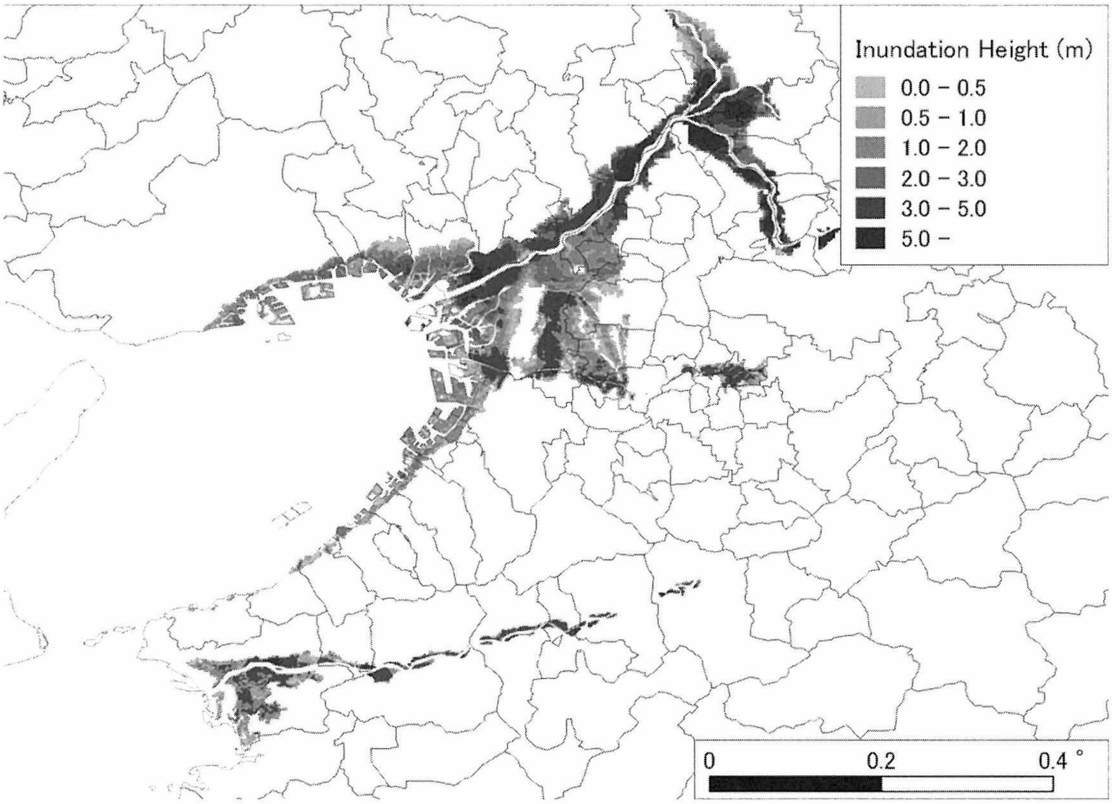


Fig. 9 Coincident disaster of storm surge and river flooding.

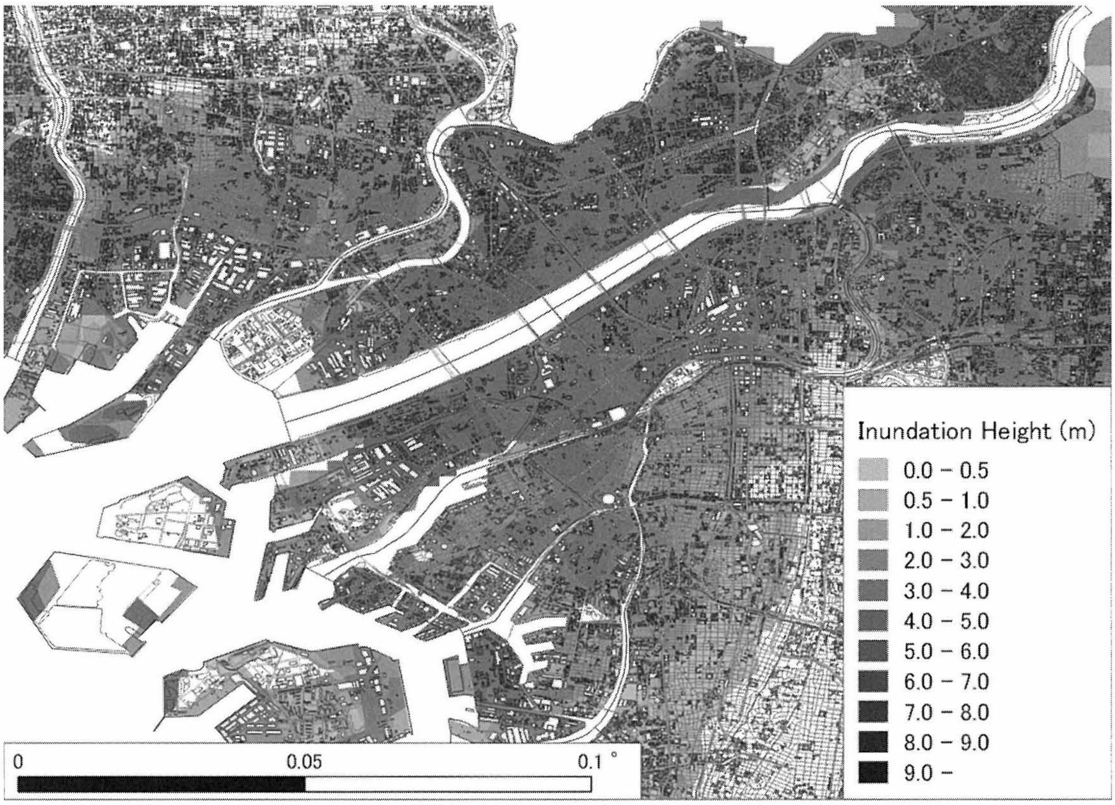


Fig. 10 Coincident disaster of storm surge and a river flooding in the Yodogawa downstream basin.

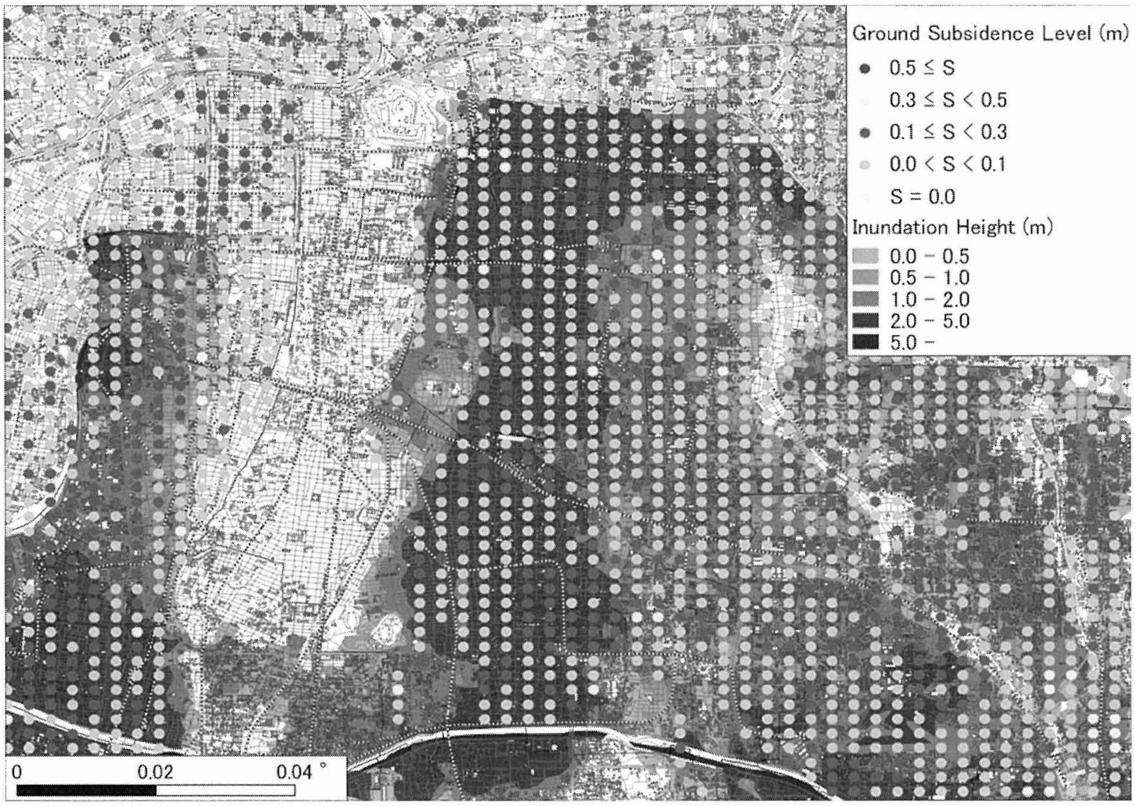


Fig. 11 Coincident disaster of river flooding and subsidence.

the inundation area in the northern part from the Yamato-gawa River, which presents ground subsidence level and inundation depth. Subsidence with 0.3 m is predicted in the area shown in Fig. 11. It is easily inferred that the subsidence makes danger of outbreak of flooding increase and enhances the probability of the rise of propagation velocity and of enlargement of the inundation area.

4. Afterword

In this paper, some disaster information in a part of the Kansai district is presented by using the geographic information system. Some examples of coincident disaster are presented by integrating information about the anticipated disaster. Coincident disaster shown in this paper must be different by the combination of the origins and the time lag between origins. In addition water disaster is anticipated by integrating the values anticipated under the condition which a single origin individually occurs but not considering the physical mechanism. More accurate anticipation with considering change of phenomena over time is necessary to provide rapid and appropriate actions.

5. References

1) I. Tohno, "A Study on the Natural Disasters Caused by Multiple Origins - Their Influences and the Comprehensive Hazard Map - ", *The Quaternary Research*, **32(5)**, 339-352. (1992).