HIROSHIMA AS RIVER AND STORM SURGE FLOODING-PRONE AREA

Yoshiaki KAWATA
Research Center for Disaster Reduction Systems, DPRI, Kyoto University
Gokasho, Uji, Kyoto, 611, JAPAN

INTRODUCTION

Historically, urban areas in Hiroshima are flood-prone area. Annual rainfall at the areas facing the Seto Inland Sea is not so large (annual rainfall in Hiroshima City: 1,603mm). But, sometimes typhoon crosses this area or passes near and carries much rain. Unfortunately, weathering granite is widely distributed in Hiroshima Prefecture. This area is the largest in our country. Therefore, due to heavy rainfall, debris disasters have occurred periodically. Storm surges are also amplified due to geographical situation. In the bay whose mouth orients south-west, much sea water compiles in the back of the bay. They are not so high frequent events, but they occur certainly at the time when residents forget them In this paper, we describe the 1945 flood disasters accompanied with Makurazaki typhoon and the 1991 storm surge disasters generated by typhoon 9119.

METEOROLOGICAL CONDITIONS IN HIROSHIMA

THE 1945 MAKURAZAKI TYPHOON

After the world war II, we had severe storm disasters in almost every year before 1960. Although they were due to strong typhoons and concentrated heavy rainfall, the effects of the war can not be neglected. During the war, natural environments as well as social ones were much changed. Typhoon 4516 landed on 17 September 1945 and passed near Hiroshima as shown in **Fig.1**. The pressure on landing at Makurazaki, south end of Kyusyu island was 916.4hPa which is the second lowest recorded pressure in Japan. At that time, our meteorological networks were much destroyed and confused by the war so that the typhoon track could not be traced well. As well known, Hiroshima where an atomic bomb was dropped on 6 August 1945 was still in ruins, therefore, the typhoon damage were enlarged. The number of the loss of lives due to the typhoon in Hiroshima was more than 2,000.

The damage occurred at (1) flooding in the basin of the Oota river which flows through Hiroshima City, (2) debris flow in Kure city and (3)debris flow around country sides in Hiroshima Prefecture. We discussed on the effects of the war on the damage through the data analysis with newly developed tools.

Fig.2 shows the changes of meteorological conditions in Hiroshima. The maximum wind speed (10min averaged) was 30.2m/s and its direction was north. We had unseasonable weather (much wetted due to a long continued rain) late August in 1945. The total rainfall in the disaster was 218.7mm and the rainfall intensity was 57.1mm/hr in Hiroshima City. The daily maximum and the four-hours maximum rainfalls in Kure City are 185.1mm and 113.3mm respectively.

The maximum total rainfall due to this typhoon 886mm was recorded at the Shikoku mountains. Therefore, the rainfall observed in Hiroshima area was not remarkable in comparison with that at other places influenced by the typhoon.

THE TYPHOON 9119

Typhoon 9119 landed at Sasebo, the Kyusyu Island on 27 September 1991 and passed along the Hc island as shown in **Fig.3**. The central pressure on landing was 940hPa. The typhoon 9119 accompanied with high wind velocity after landing. In Aomori Prefecture, northern end of the Honsyu island, apples of the total weight of 32,000ton were dropped from the trees. This was big damage. We have had many lessons learned by this typhoon disasters, but 63 people were killed. Most of them were more than 60-years-old. They mostly forgot the lessons due to decrease of typhoon disasters. A typical example is the apple problems. We have good agricultural product insurance systems. Most apple farmers spared the insurance charge.

The damage in Hiroshima was due to storm winds and storm surges. The maximum instantaneous wind speed was 58.9m/s. This was the largest recorded at Hiroshima Meteorological Observatory established in 1935. Especially, much salty air was carried from nearshore breaker zone to not only coastal urban area but also inland rural area at a distance of more than 40km, so that insulation equipments of electric power supply on electric poles lost function. Maximum number of households with power failure was 1,126,000. Power failure in Hiroshima City stopped the urban activities as well as urban life.

Fig. 4 (Konishi, 1993) shows the spatial distribution of maximum anomaly of storm surges. Much sea water was compiled in the west area of the Seto Inland Sea. In Hiroshima, this was 154cm and the maximum of 309cm was recorded in Onoda. **Fig. 5** shows the changes of tides in Hiroshima. Fortunately, there was time lag of about 2hours between occurrence of meteorological tide peak and astronomical one. The wind field of typhoon after landing in Japan is usually influenced by mountains so that it is very difficult to estimate wind field. Therefore, precise hindcasting of storm surges is only available. In **Fig. 5**, the result in Hiroshima was depicted with broken line by Yamashita et. al.(1993). In numerical simulation of storm surges, the open boundary condition of straits are very effective of the results.

DAMAGES DUE TO FLOODING

In Hiroshima, the weathering granite widely distributed and its area was the largest in our country. When trees in the granite area are cut down, afforestation and recover of forest are very difficult. Moreover, the coefficient of permeability of the weathering granite is large, so that the weathering has easily penetrate into a deep layer. The large sediment discharge accompanied with heavy rainfall depends on this characteristics. The occurrence of debris flow is also accelerated by man-made environment as revealed in this section.

DEBRIS FLOW IN OONO VILLAGE

Oono was located 20km west from Hiroshima city as shown in **Fig. 6**. In this village, we had the Oono Military Hospital in which the number of inpatients was about 800 including atomic bomb injured. Due to the debris flow, about 180 lives were lost. In the central part of the hospital area the Maruishi river whose catchment area was 0.617km^2. Usually the river discharge was very small and at the mountain site it changed to wadi. The debris flow has repeatedly occurred in 1804 and-1886.

The longitudinal slope of the river is divided into three portions as shown in **Fig.7**. We have many

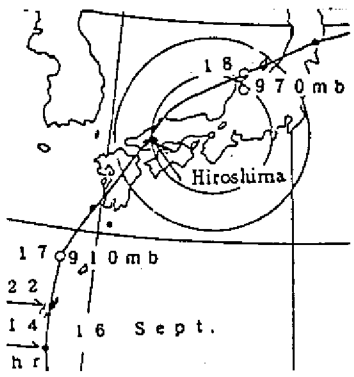

Fig.1 Track of Typhoon 4516

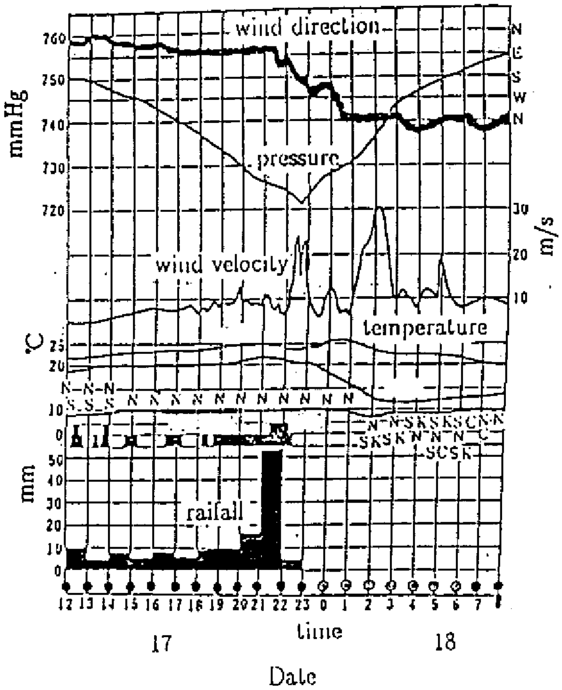

Fig.2 Meteorological conditions

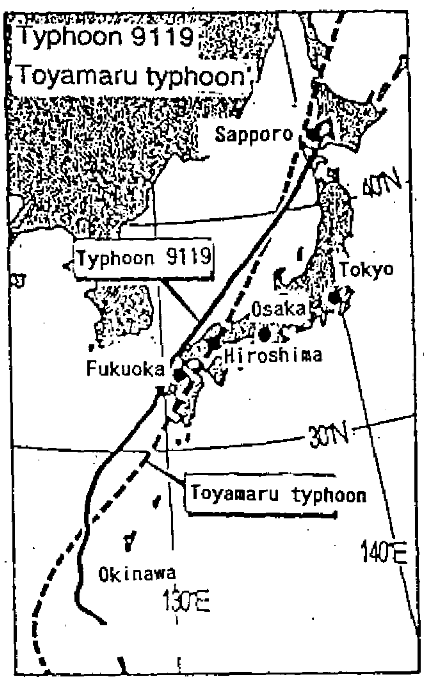

Fig.3 Track of Typhoon 9119

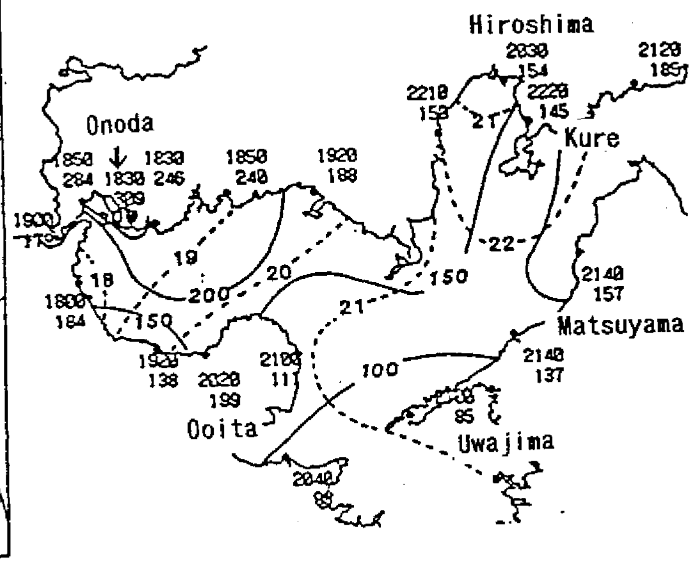

Fig.4 Spatial distribution of maximum anomaly of storm surges

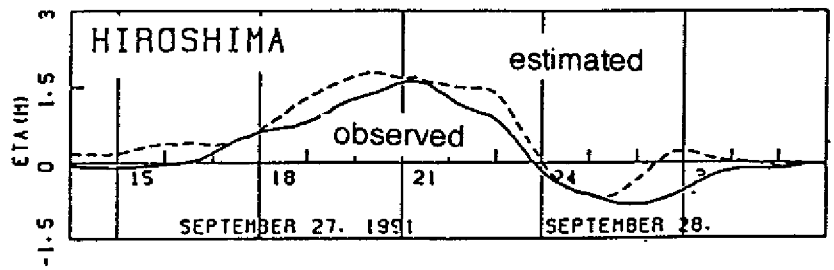

Fig.5 Tidal records observed and hindcasted

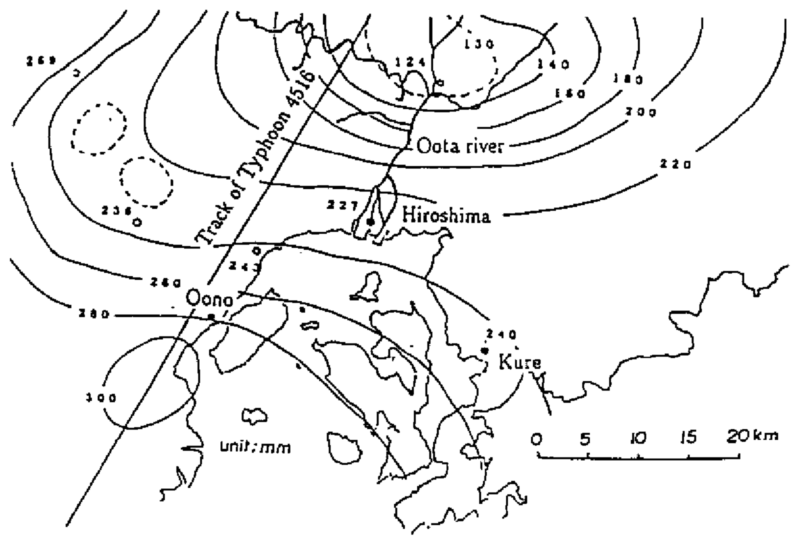

Fig.6 Location and total rainfall around Hiroshima

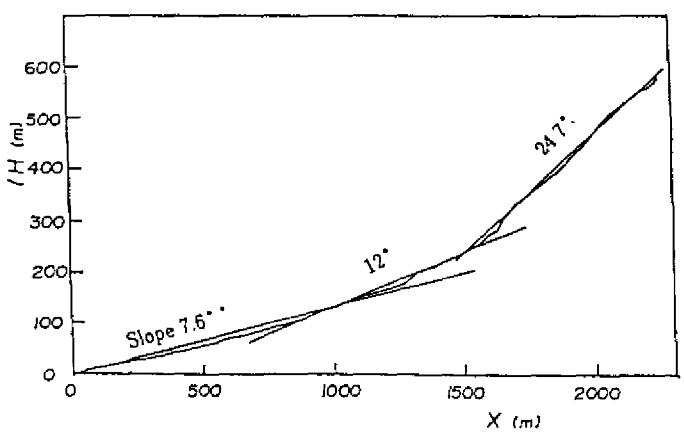

Fig 7 Longitudinal slope of the Maruishi river

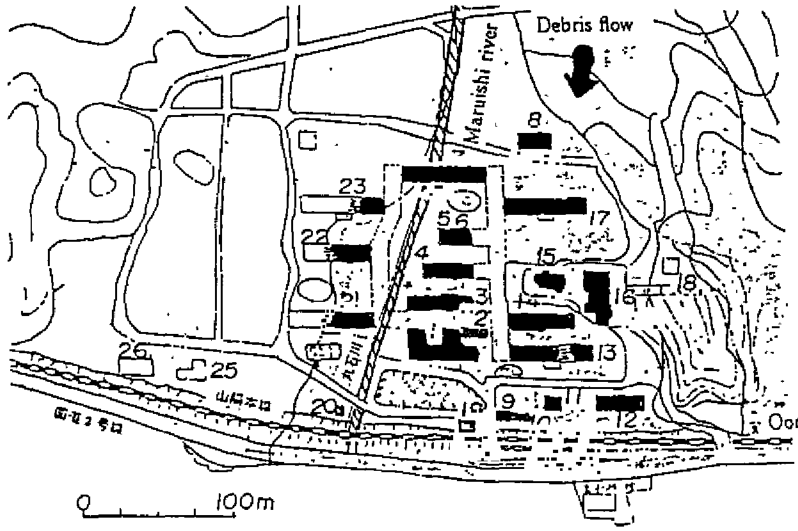

Fig 8 Debris flow and damaged buildings(black ones)

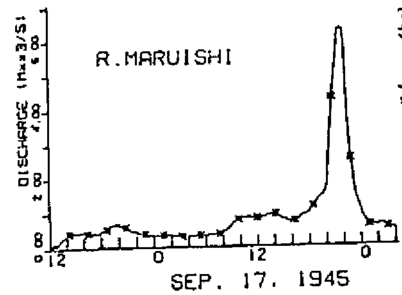

Fig 9 Discharge of the Maruishi river

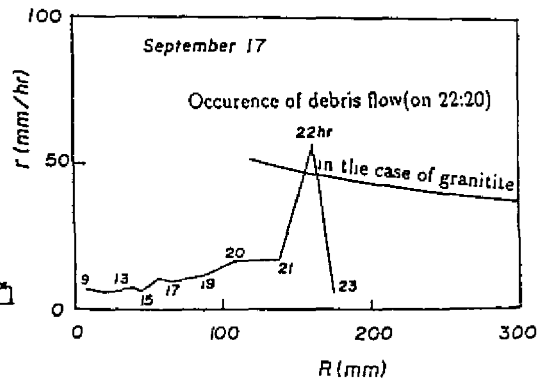

Fig 10 Prediction of occurrence of debris flow

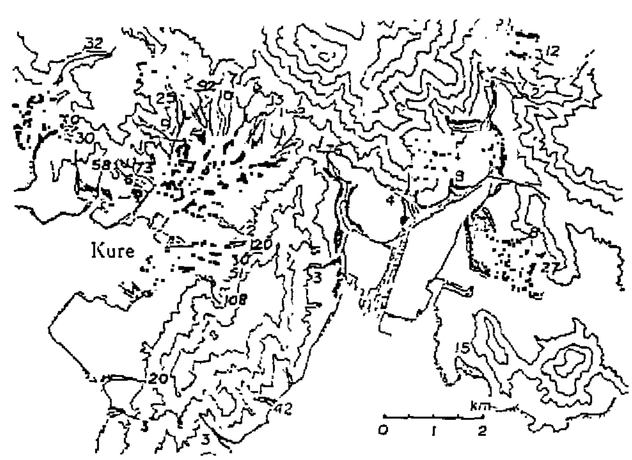

Fig 11 Flooding area of debris flow and the number of loss of lives

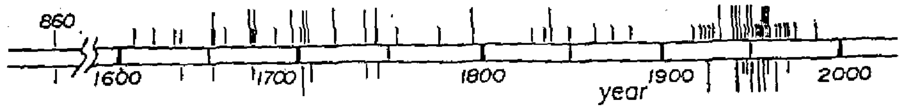

Fig.12 History of occurrence of flood disasters in the Oota river
(long bar shows occurrence of victims)

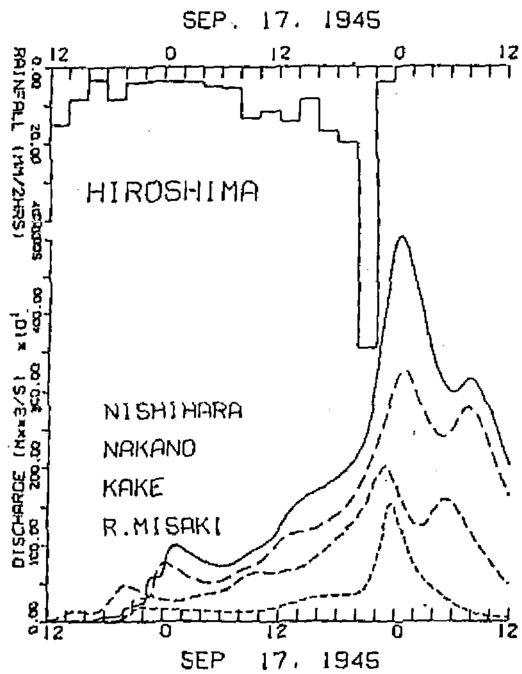

Fig.13 Some examples of flood discharge in the Oota river

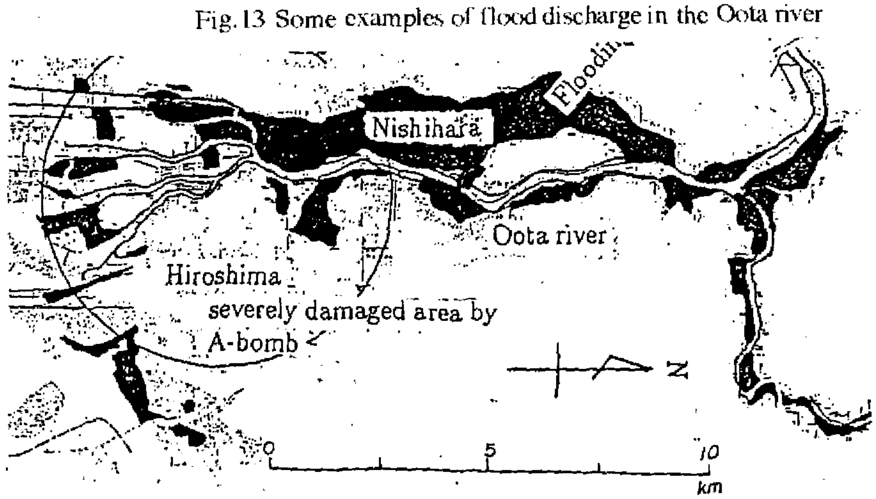

Fig.14 Inundated area due to flooding in Hiroshima

small rivers whose slope is larger than that of the Maruishi river, but the volume of sediment yielded by the debris flow reached to $2.6x10^5m^3$. The discharge volume per unit area $4.3x10^5m^3/km^2$ is nearly maximum (Mizuyama, 1989). The damage of buildings and the width of debris flow can be reconstructed with aerial photograph analysis in **Fig. 8.** The kinematic wave method can hindcast the river discharge as shown in **Fig. 9.** The dynamics of the debris flow can be analyzed with recent contribution on this problems by Ashida and Egashira(1989). **Fig. 10** shows an example that the theoretical prediction of occurrence of debris flow is good agreement with the field data.

DEBRIS FLOW IN KURE CITY

Kure was the second largest city in Hiroshima prefecture. During the war, naval base and dockyard were located in this city. The resident area had been developed on the slope of the mountains along the coast and so was very narrow. Rapid development due to naval demand of man-power and increase of military force make the population large. Although we have not accurate census of this city around 1945 due to military secret, the number of resident seems to reach more than 300,000. Therefore, there were no additional space to build living facilities in the city area so that some rivers were covered to build houses over them or the mountain slopes were newly developed. Moreover, at the end of the war, naval headquarters constructed some roads on a steep slope of the mountains. These roads were used to construct anti-aircraft emplacements. Due to the debris flow and flooding, the number of the dead were 1,154.

In the mountains, a large number of landslide and mass movement were occurred around the mountains (from the visual survey of aerial photographs they were found at 591 points.). They almost played triggers of the debris flow. **Fig. 11** shows the flooding area and distribution of the number of the dead in the old city area. The disaster report (1951) described the process of the enlargement of the damage. The large amount of sediment discharge buried river courses and debris control dams, and overflow water with large velocity carried away or destroyed the wooden houses in the midnight.

RIVER FLOODING IN HIROSHIMA CITY

The riverhead of the Oota river is located at Mt. Kanmuriyama (1,339m in height) and the area of watershed is $1690km^2$ and its length of major river course is 104km. In the Edo period (1603-1867), Hiroshima had developed as a castle town in the lowered course of the river. The local government had promoted to get newly reclaimed rice field, so that the occurrence of flooding had increased. As shown in Fig. 12, the flood disasters occurred about 80 since 863AD.

In the kinematic wave method, the governing equations are well known. The numerical calculation gives the hydrograph of the flooding as shown in **Fig. 10.** In the Oota river, we had severe flood disasters in 1988. In the run-off analysis, the various coefficients and constants included in the governing equations were already authorized by Oka (1989). The maximum flood discharge $6,700m^3/s$ at Nishihara was recorded in 1943. In the 1945 flood, however, the estimated peak discharge was $5,024m^3/s$ as shown in **Fig. 13.** The area inundated by flood water was very large in comparison with the scale of flood discharge as shown in **Fig. 14.** After the 1943 flood, the river improvement works had not also done due to the war as shown in **Fig. 15.** The cut-off budget and the lack of river engineers were very severe problems to continue the works. About 45,000 people escaped from north part of Hiroshima city lived temporarily on the riverbed and the neighboring of the Oota river at that time.

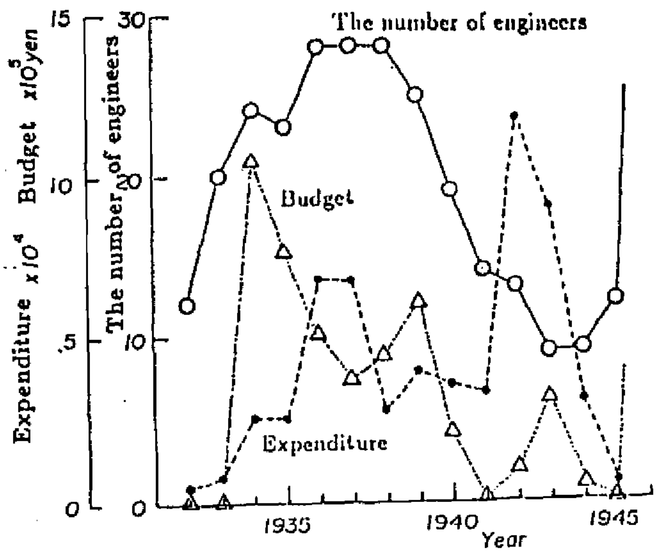

Fig. 15 Changes of the number of civil engineers and budget at Oota Construction Office, Ministry of Home Affairs

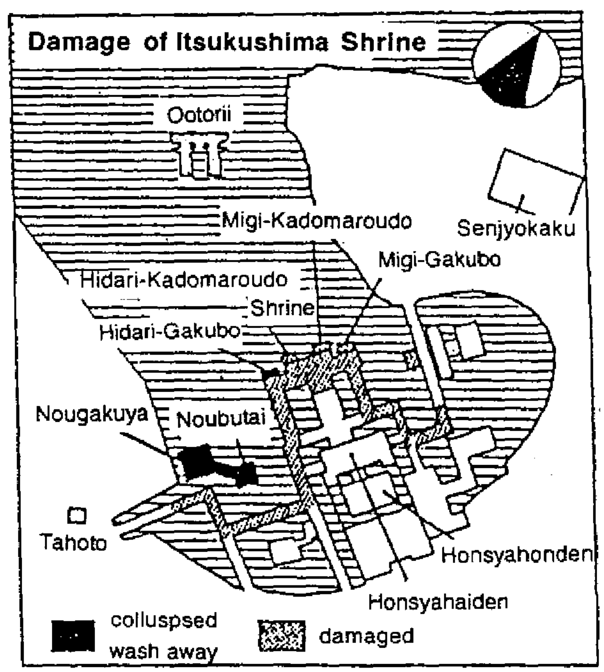

Fig. 16 Damage of Itsukushima Shrine due to the 1991 typhoon

Unfortunately, it is impossible to classify the victims due to atomic bomb or river flooding. For example, the number of the victims due to atomic bomb surveyed on 10 August 1946 (one year after) were 122,338. In the flood plane, the estimated mean inundation height was 3.3m which is sufficient to carry out poor housing materials set temporarily. Therefore, this number surely include the victims due to the flooding. Our meteorological observation systems were almost out of use in nationwide due to damage of the war. Especially, Hiroshima Meteorological Observatory was severely destroyed by an A-bomb. Practically, no one knows that big typhoon came nearer. Sudden violent wind and heavy rainfall at night in Hiroshima must made people hopeless.

STORM SURGES IN HIROSHIMA BAY AREA

Storm surge flooding occurred at coastal lowland in Hiroshima City. But, inundated water depth was about 80cm above ground level. There was no loss of lives due to storm surges in Hiroshima. Property damage was very large in a cultural asset and in fishery facilities.

Itsukushima Shrine in Miyazima island had much damage due to winds and storm surges This shrine was constructed in 593 AD. The spokesman in the Shrine said that the 9119 typhoon damage was the worst in the history. High winds blew off the roofs of wooden structures and storm surges carried off outdoor wooden passages. The trace showed that height of storm surges reached about 80cm above the passages. Some national treasures and important cultural assets were damaged or lost. The recovery took more than three years. **Fig. 16** shows a plane view of the damage.

Hiroshima is very famous for its oyster culture. Storm winds and following currents carried the rafts of oyster preserves downwards. Some of them landed on downdrift beaches. Twelve fishermen's cooperative associations in Hiroshima bay had 3,000 rafts, and 40% was damaged. The total number of damaged rafts was 3,100 of 12,000 in Hiroshima Prefecture. Usually, sea climate is very moderate in Hiroshima and adjacent bay area so that structure of the rafts is simple. The methods of raft anchoring and oyster hanging should be improved against storm surges accompanied with high winds. In order to reduce storm surge disasters, the maximum hjghest tidal level should be estimated by numerical simulation. Knowing hazard is the key of risk management in disaster management. Adequate countermesures can be established through some experiences and disaster studies.

CONCLUSIONS

Through data analysis of the disasters caused by Typhoons 4516 and 9119, the flooding damage in Hiroshima were discussed. The 1945 Makurazaki typhoon enlarged human and property damage due to the effects of the war. The major factors are pointed out as follows· 1) a lack of proper meteorological observation systems, 2) delay of public works in the field of debris and flood control due to budget cut and draft of civil engineers , and 3) atomic bomb-devastated areas and occurrence of many refugees. The 9119 typhoon amplified storm surges in the west area of the Seto Inland Sea. Cultural assets of Itsukushima shrine and oyster culture were severely damaged From the view point of disaster management. the maximum highest level of storm surges in Hiroshima bay is urgently recommended to be estimated. This is the first step of Mitigation in disaster management.

REFERENCES

Ashida, K. and Egashira, S. (1989): " Occurrence of Debris Flow and Its Affected Area", Technical Report on Heavy Rainfall Disasters in Shimane and Hiroshima, pp. 8-21(in Japanese).

Oka, T. (1989): "Characteristics of Flood Discharge", ditto, pp. 86-102.

Mizuyama, T. (1989): Debris Control, Handbook of Civil Engineering, JSCE, p.2068 (in Japanese).

Yamashita, et. al. (1993): "Hindcast of Storm Surges Generated by Typhoon 9119 in The Seto Inland Sea", Proceedings of the 40th Coastal Engineering, JSCE, pp. 206-210 (in Japanese).

Konishi, T. (1993): "Storm Surges Generated by Typhoon 9119 in The West of The Seto Inland Sea", Annual Meeting Report in Autumn of JSO, pp. 311-312 (in Japanese).