Wave Setup at River Mouths in Japan

Hitoshi Tanaka[1] and Nguyen Xuan Tinh[2]

Abstract: Empirical study on wave setup at river mouths is becoming very important in terms of river mouth morphology change, navigation transportation, saline intrusion into river and water environment especially for a river which has a lagoon or lake at the entrance. Each year, there have been many extremely events that caused the wave setup occurring around of Japan. One of them is the continuously big wind from Japan Sea impacted to the coastline during the winter; this will created a very high wave and then caused a significant wave setup height at river mouths. In this study, there two river mouths, namely Yoneshiro River and Iwate River which faced to Japan Sea, will be concentrated on. The main objectives of this study are to investigate the influence of wave setup height to sand spit evolution at Yoneshiro river mouth, and the effect of regularly extreme wind to wave setup height at river mouth. The final results will be contributed a technical diagram of relationship between wave setup height with offshore wave height and average water depth at river mouth. This empirical study is helpful for river authority, coastal management and coastal engineers to find out the best solution in controlling the river mouth morphology change and environment.

Keywords: wave set-up, water level rise, river mouth

1. Introduction

A Wave setup height is mainly caused by wave breaking at the entrance; however, the differences of river mouth morphology can be affected to wave setup variation. In order to investigate the wave setup the requirement data sets are wave height in deep water, tidal level and water level at some distance upstream of river, as well as the average water depth at river entrance.

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Because of each river entrance has their own morphology (Figure 1), for instance with and without jetties construction, or with and without sand spit at river entrance so the wave setup height needs to be analyzed individually and compare them.

There are several researchers studied on wave setup at river entrance such as Hanslow et al. [1], [2] Tanaka et al. [3], [4], Dunn [5], Oshiyama et al. [6], and Nguyen et al. [7]. The wave setup is the height of Mean Water Level (MWL) above Still Water Level (SWL). In most of cases, the estimation of wave setup at a river mouth have been based on water levels measured some distance upstream from river mouth and then compared with a tidal level that measured in deep water where wave effects can be neglected (Tanaka et al. [3]). Figure 2 are shown the definition sketch of wave setup at a river or tidal inlet entrance. The wave setup caused by wave height, however, the water depth at the entrance and river discharge can be affected to its height.

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[1] Professor, Department of Civil Eng., Tohoku University, Japan;
E-mail: tanaka@tsunami2.civil.tohoku.ac.jp
[2] Ph.D. Student, Department of Civil Eng., Tohoku University, Japan

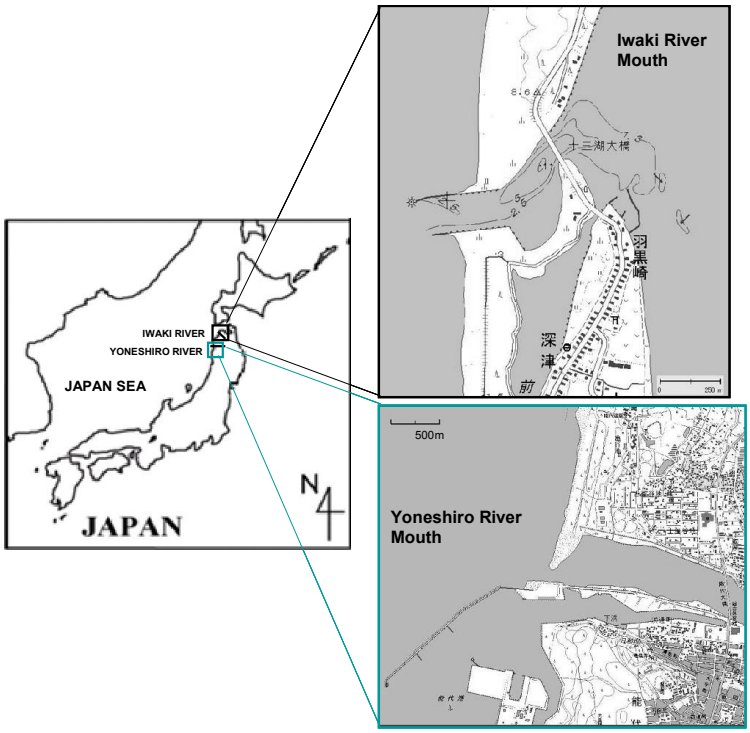

Figure 1: Study area and morphology of each river mouths

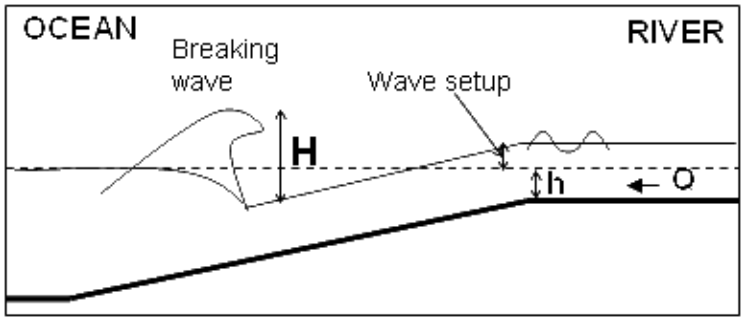

Figure 2: Definition sketch of wave set-up at a river mouth

2. Data collection

Iwaki and Yoneshiro Rivers are located in the western part of Aomori Prefecture and facing to Japan Sea as can be seen in Figure 1. Wave information and tidal level data were obtained in Fukaura station which is located in about 49.6m of water depth thus the effect of bathymetry to wave height can be neglected. The measured tidal level has already included the storm surge that is pushed toward the shore by the force of the winds swirling around the storm.Water level variations were measured at some distance upstream of Iwaki and Yoneshiro Rivers. The differences in elevation between water level in river and tidal level are considered as the water level rise at river mouth as shown in Figures 4, 5.

There are two long jetties construction at the entrance of Iwaki River (Figure 1). The river mouth is quite deep with the average of water depth up to 4.5m. It has a large lake called Jusan Lake on behind the jetty entrance. This lake is used for aquiculture; therefore, it is a big concern for river authorities and managements in term of water environment and saline intrusion into lake by wave setup.

On the north side of Yoneshiro River, there is a sand spit of 500m in length as can be seen in Figure 1. The morphological of this sand spit was changed year by year. It made the entrance is narrower and shallower so the high wave might break close to the river mouth causing the wave setup. The average of water depth is arranged from 2m to 3m depending on period. For this study, the authors have chosen 2.3m as the average of water depth at Yoneshiro River.

3. Results and discussions

In this study area, there are two separately phenomenal of wind systems. One is very high wind speed often occurring during the winter and another is almost no wind consequence rather small wave height in the summer. Figure 3 is shown the comparison of water level and tidal level for both Iwaki and Yoneshiro Rivers in the summer duration of 2005 indicating that there was no extremely event and water level variation is similar with the tidal level.

In the contrast, the frequently and continuously big wave caused by wind from Japan Sea was attacked to the coastline in the winter period. Figure 4, 5 are illustrated the hydrodynamic conditions of Iwaki and Yoneshiro Rivers from 18th January to 25th February 2008, respectively. There were several events that caused the wave height higher than 5.5 meters and a very significant water level rise was attained in both rivers (Figure 4, 5).

Monthly water level in the river, tidal level, and water level rise which is equal to water level minus to tidal level, as well as the offshore wave height for both Iwate and Yoneshiro Rivers are shown in Figures 4, 5, respectively.

Because of the morphology of Yoneshiro River mouth is narrow so the water level in the river is usually higher than tidal level. This indicated that the water was stuck in the river after the first event (Figure 5). When the second event impacted to the river mouth it can be seen that the duration of water level rise is much longer time but lower in magnitude. This long period of inundation probably explains the breaching and moving of sand spit to southern side of river mouth occurred in this year.

The water level rise at a river entrance can be attributed not only to wave set up, but also to backwater effect due to constriction of the flow caused by shallow and narrow of rivers or tidal inlets during ebb tide thus saline water that gets into river during high tide might not flow back to the sea. Therefore, to study the wave setup due to wave we have to neglect the effects of backwater by only considering the water level rise values during the high tide period.

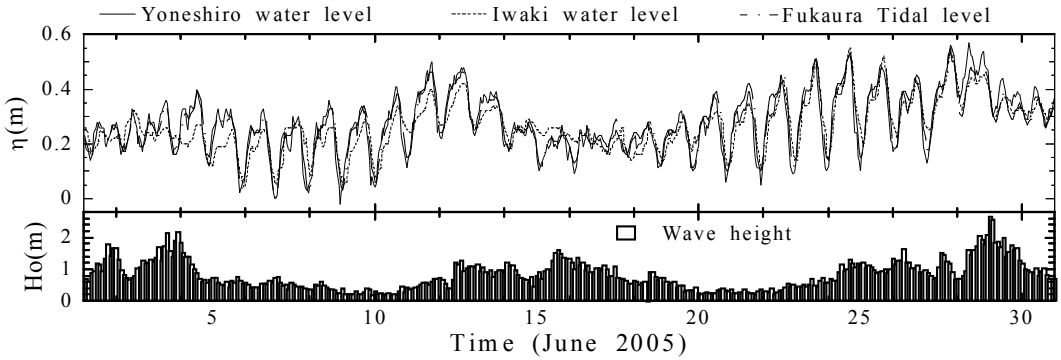

Figure 3: Comparison between Fukaura tidal level and water level at Yoreshiro and Iwaki Rivers in June 2005

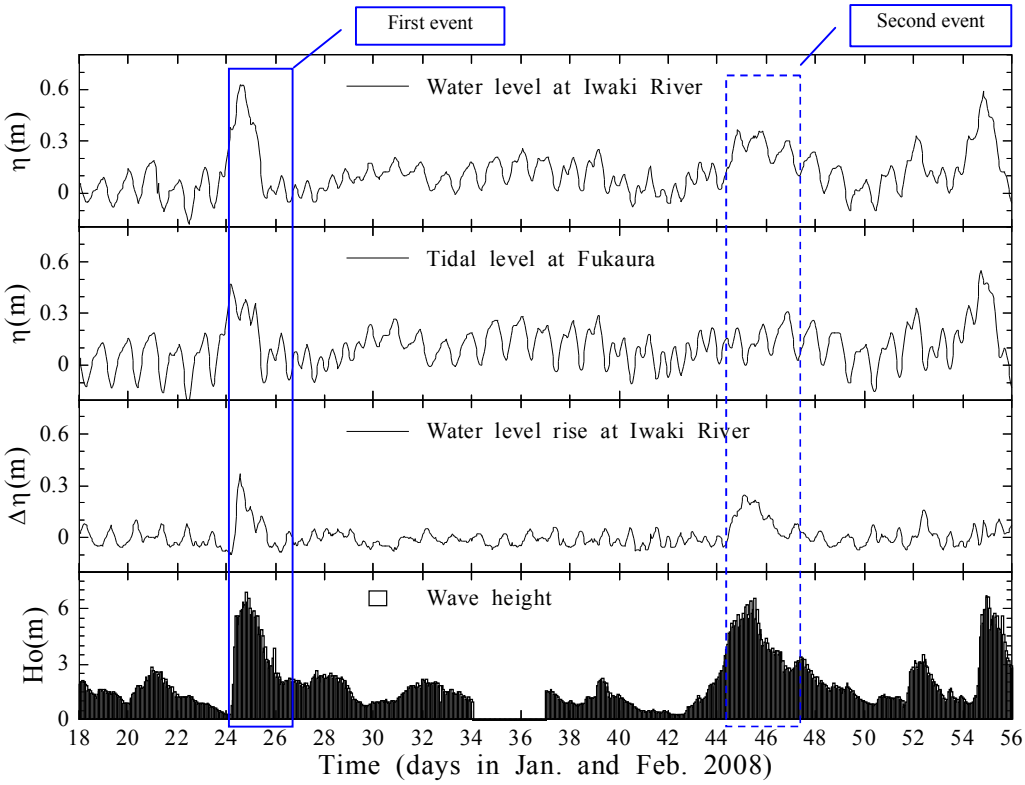

Figure 4: Hydrodynamic conditions and water level rise at Iwaki River during 18th January to 25th February 2008

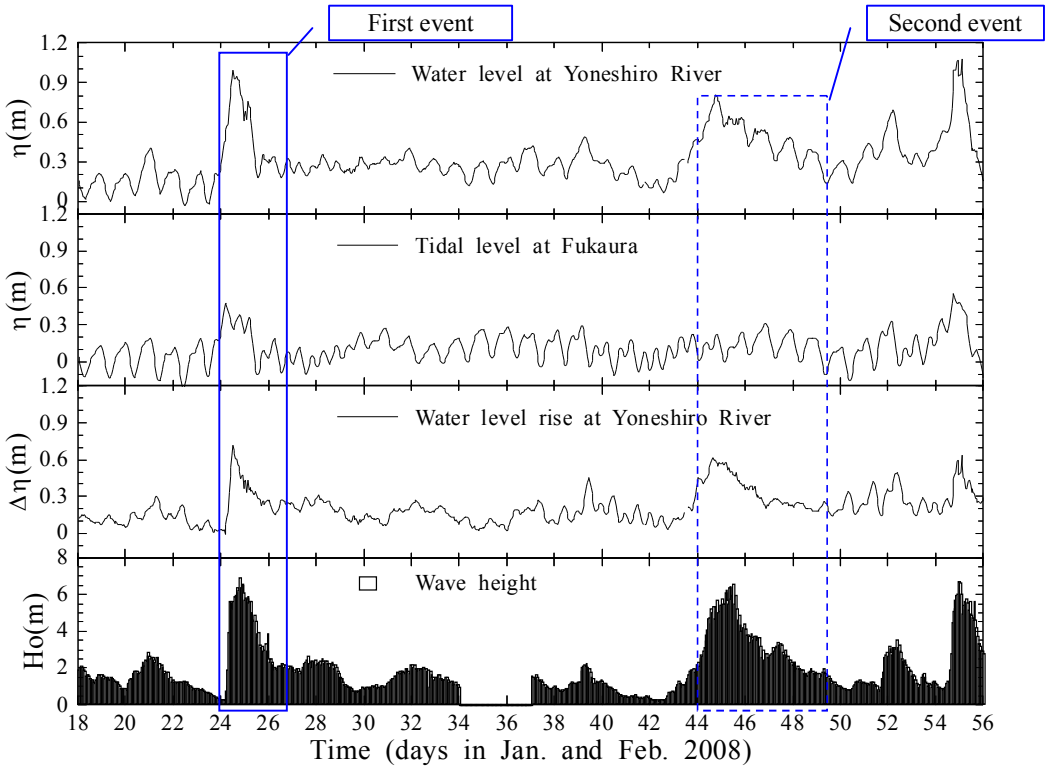

Figure 5: Hydrodynamic conditions and water level rise at Yoneshiro River during 18th January to 25th February 2008

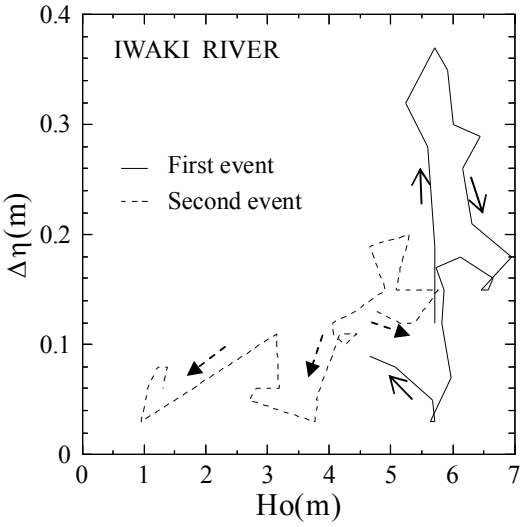

Figure 6: Wave setup variation during the first and second event at Iwaki River

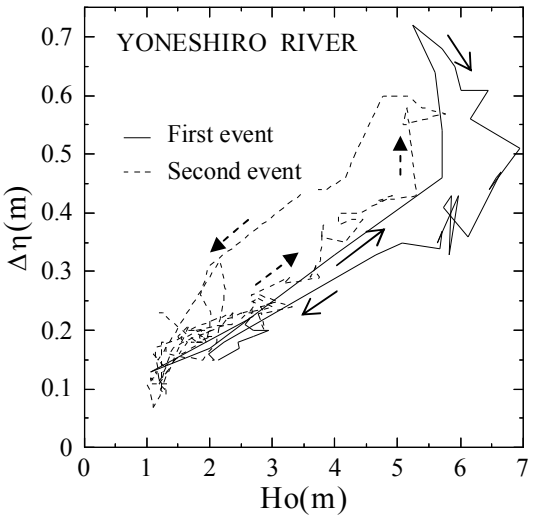

Figure 7: Wave setup variation during the first and second event at Yoneshiro River

The relationship between wave setup height and offshore wave height was plotted for both rivers in different events as shown in Figures 6, 7. The results in Iwaki River shown that the wave setup during the first event only caused by the wave height varying from 4.5m to 7m and its amplitude is larger than in the second event (Figure 6). This is because of continuously wave flushing up to the river mouth.

The wave setup in the second event at Yoneshiro River is always higher comparing with the first event. This is probably due to after the first extremely event on 25th of January the sediment was intruded into the river, it made the water depth at the entrance is shallower so that the wave might be easy to break that causing wave setup height.

In order to investigate the wave setup height due to wave we have to neglect the effects of backwater and river flood as mentioned above by only considering the water level rise values during the high tide level. By using the regression method as shown in the Figure 8, the relationship of wave setup height and offshore wave height can be estimated by using this following equation

$$\Delta\eta = aH_0 \tag{1}$$

where: $\Delta\eta$ is wave setup height at the entrance (m), H_0 the offshore wave height (m), a regression slope.

The regression slope, a, which also means the percentage of wave setup height compare to offshore wave height, for Iwate River and Yoneshiro River are equal to 2.67 and 8.98, respectively (Figure 8).

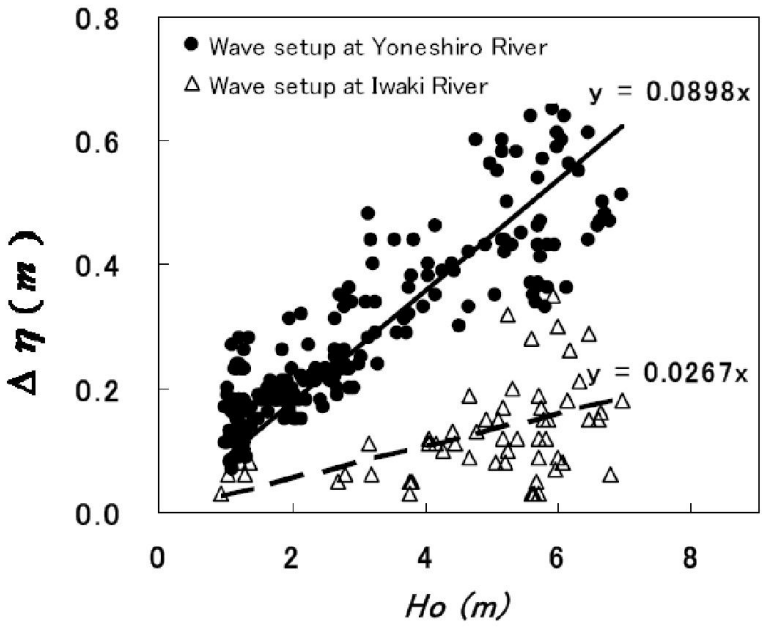

Figure 8: Relationship between offshore wave height and wave setup height.

Nguyen et al. [7] has done the wave setup analysis for seven river mouths which faced to Pacific Ocean due to an extremely typhoon no.18 at the beginning of October 2006. Their study has been concluded that the wave setup height at the entrance is arranged from 2 percent to 14 percent of offshore wave height in connecting with the average water depth at the entrance from 1.2 m to 6.5 m. In addition, the wave setup height is inversely proportional to water depth at the entrance and river discharges also can be affected to wave setup. The current study is again in agreement with previous study by Nguyen et al. [7]. The regression slope, *a*, is consistent with his study.

For technical point of view, the diagram of relationship between water depth at the river mouth and offshore wave height to wave setup height is very useful for engineers to estimate the wave setup height. By combining all the data sets and introduce two dimensionless indices, $\frac{\Delta\eta}{H_0}$ (relative wave setup height) and $\frac{h}{H_0}$ (relative water depth at the entrance), we obtained the Figure 9. The logarithm relationships are expressed as follows.

$$\frac{\Delta\eta}{H_0} = -0.067\ln(\frac{h}{H_0}) + 0.0019 \quad (2)$$

where: $\Delta\eta$ is wave setup height, H_0 is offshore wave height and h is average water depth at the entrance. The more water depth is, the less wave set up height will attain.

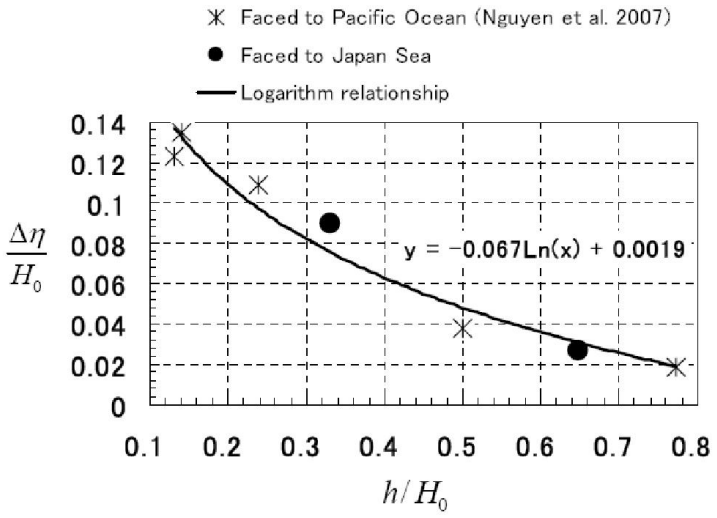

Figure 9: Empirical diagram for predicting wave setup height at the river mouth.

4. Conclusions

A comprehensive study on wave setup due to an extreme event at different river entrance morphologies was carried out. Water level rise at river entrance is not only depending on the offshore wave height but also depend on river discharge and morphology of river mouth. Wave setup height was attained from 2 to 14 percent of offshore wave height for the cases of average water depth at the entrance from 1.2 m to 6.5 m. Wave setup height is inversely proportional to the average water depth at river mouth.

Study on prototype scale of wave setup is not easy to be carried out since the difficulty of field measurement. This empirical study is helpful for river authority, coastal management and coastal engineers to find out the best solution in controlling the river mouth morphology change and environment.

Acknowledgements

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Biography

Hitoshi Tanaka: He received the degree of Dr.Eng from Tohoku University, Japan in 1984. His research interests include coastal sedimentation and nearshore hydrodynamics. He is also interested in estuarine circulation processes and their impact on exchange of freshwater and saltwater, water quality, and sediment transport.

Nguyen Xuan Tinh: He has got a Master of Science in Water Resources Engineering from Lund University, Sweden in January 2006. He is currently being a Ph.D fellow at Tohoku University in Japan. His research is mostly focused on beach morphology change due to wave overwash and the interaction between ocean and river especially in river entrance zone.