# Tsunami Simulation along Kitakami River with Effects of Morphological Changes and Breaching of River Embankments

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The 2011 Great East Japan Earthquake Tsunami induced huge damages on Pacific Coast of Japan. The rapid and farther run-up of the tsunami along rivers extended the damaged area to the area farther from the coast. Although there have been many researches on numerical simulation of tsunami run-up into rivers, due to its huge scale the 2011 tsunami has some features which have not been considered well before this event. One of the biggest differences is big morphological changes especially around river mouths. Sand spits at the river mouths were flushed by the tsunami and also erosion of river mouth terraces was observed. Morphology of river mouths has been considered as one of the important factors to limit the volume of the tsunami flow running into the rivers. Another important feature is the tsunami wave height more than heights of river embankments. The tsunami overflow flushed the river embankments completely in many areas. These phenomena themselves are important problems which should be considered well, and their effects on the tsunami waves running up along the rivers also should be included in numerical models for the proper designs of hard and soft countermeasures. In this study, numerical simulations with different numerical conditions were done to discuss the effects of morphological changes and collapse of river embankments on their propagation along rivers.

In this study, propagation of the 2011 tsunami into Kitakami River, located in Miyagi Prefecture, Japan, was simulated with Shallow Water Equation (SWE) model, which is horizontal 2D model and commonly used for tsunami simulation. A sand spit at the river mouth was flushed and a part of river embankment along this river was broken by the 2011 tsunami. Many water level stations were damaged by the earthquake and the tsunami, while one station survived and recorded the time series of the water level during this event with 1 min of sampling rate. Input wave condition of water level and velocity was calculated in advance through a simulation from the wave source to the numerical domain. In order to include the interaction between the tsunami intrusion into the river and the morphological changes around the river mouth, a sediment transport model proposed by Takahashi et al. (1999) was coupled with SWE model. The river and coastal embankments were included in the bathymetry data. Only in the area where actually the embankments were flushed by the tsunami, they were considered as a part of the movable bed, and no morphological changes were calculated in the other part of the embankments to keep their height. The result of the movable bed simulation was compared with real observed water level data at Fukuchi Station and the simulated data with fixed bed to have no erosion of the embankments and the river mouth sand spit.

In the movable bed simulation, the embankments were rapidly eroded by the strong flow over them. The peak of the water level at the Fukuchi Station shows overestimate by about 1 m in the fixed bed simulation, while the peak with the movable bed shows good agreement with the observed data. However, the decrease of the water level after the first peak was smaller in the both simulation cases. In the movable bed case, the erosion around the river mouth was not as big as the real condition, no flushing of the spit was observed in the simulation. And there is also an uncertain point on the time when the collapse of the embankment happened in the real tsunami. More discussion should be done on sediment transport model and embankment collapse model under tsunami waves to improve the accuracy of simulation of tsunami run-up into rivers.

 

Keywords: Shallow Water Equation, Tsunami run-up into river, sediment transport model