A RAINFALL-RUNOFF/FLOOD-INUNDATION MODEL FOR MYOHOJI RIVER BASIN KOBE JAPAN WITH RAINWATER SEWAGE CHANNELS

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ABSTRACT

The paper presents a development of a distributed rainfall-runoff/flood-inundation model for Myohouji River, Hyogo, Japan. The primary purpose was to study if the very rapid rise of the water level in flooding at very urbanized basin as Myohouji River could be reproduced with the rainfall-runoff model. The rain drainage network was also modelled to estimate the effect. The result exhibited that the model can reproduce the flooding situation on some level, though the simulated peak discharge was smaller than the estimated discharge by Space Time Image Velocimetry based on the images of a monitoring camera. Likewise, the effect of the rain drainage was estimated at around 10% of the total peak runoff, though this needs to be verified with the future observation.

Keywords: Myohuji River, rainfall-runoff, inundation, drainage, STIV

1. INTRODUCTION

Myohouji River, Kobe, Hyogo, Japan is an urban river with very steep slope flowing in the Rokko Mountain area. The river experienced flush floods several times due to the short travel time. Figure 1 shows a flush flood event on 4th September 2018 recorded by Kobe City monitoring camera. The water level rises around 4 m for 40 minutes at Kamiyoichi Bridge. The images show the very rapid rise of the water level as well as the occurrence of the hydraulic jump which may increase the water level.

The catchment area of Myohouji River is 11.81 km^2. The river has rainwater drainage channels connected to rivers, thus the effect of the rainwater drainage should be investigated especially in order to reproduce the flush floods. In this context, a distributed rainfall-runoff/flood-inundation model was adapted in this study to simulate rainfall-runoff processes with the drainage system and inundation processes in the watershed scale. The rainfall-runoff process was investigated in detail for the rainfall event by Typhoon 21, September 2018. Firstly the rainfall-runoff process was reproduced using X band radar-data around the time as input. The model simulates the water level and discharge at Kamiyoichi Bridge based on a 1D dynamic wave model. Then the simulated water level and discharge were compared with the observed water level, a discharge by a H-Q rating curve as well as a discharge estimated based on the images of river monitoring cameras using Space Time Image Velocimetry (STIV, Fujita, 2009).

2. MYOHOUJI RIVER AND MODEL DESCRIPTION

Figure 2 shows the river and rain drainage network as well as the location of Kamiyoichi Bridge in the left panel and its catchment boundary in the right panel. The length of the main river is 6975 m and the slope above Kamiyoichi Brdige is 1/80-1/100, thus it is very steep in the upstream. The blue color in the left panel is the river network, while the green color shows the rain drainage network. A water level observatory is located

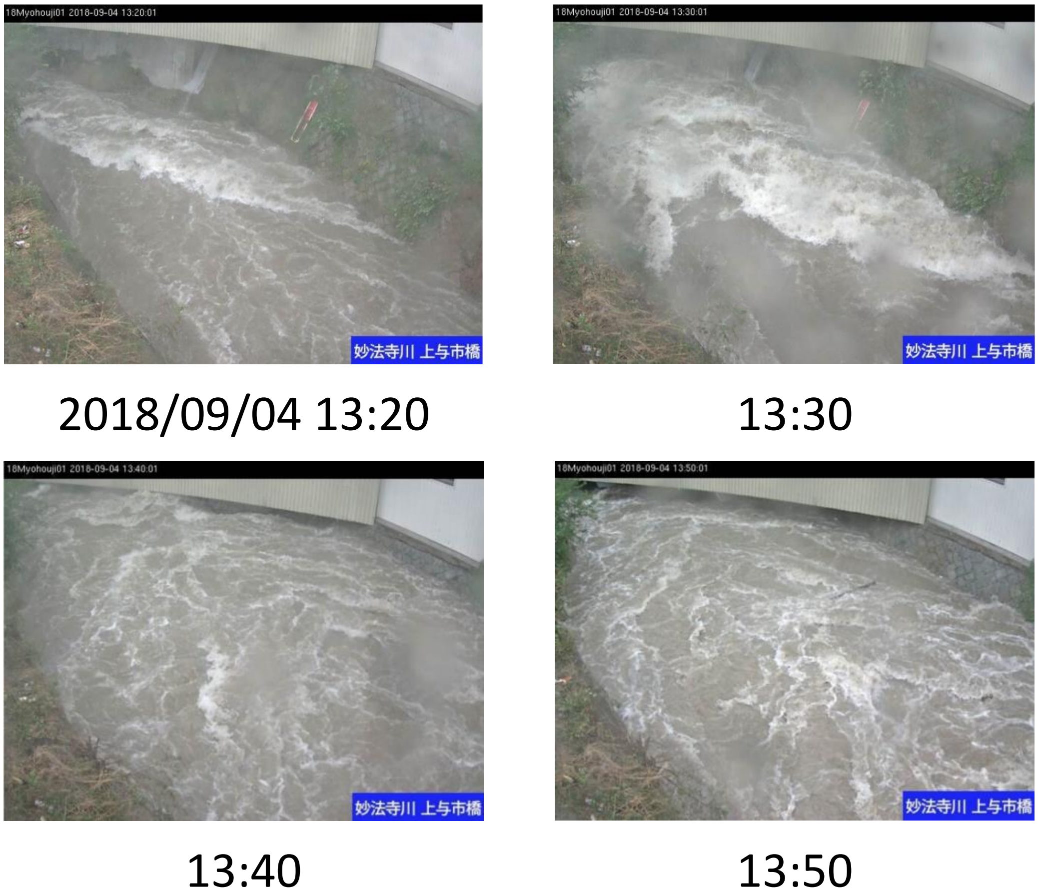


Figure 1: Sudden rise of the river water level at Kamiyoichi Bridge, Myohouji River (Kobe City Monitoring Camera)

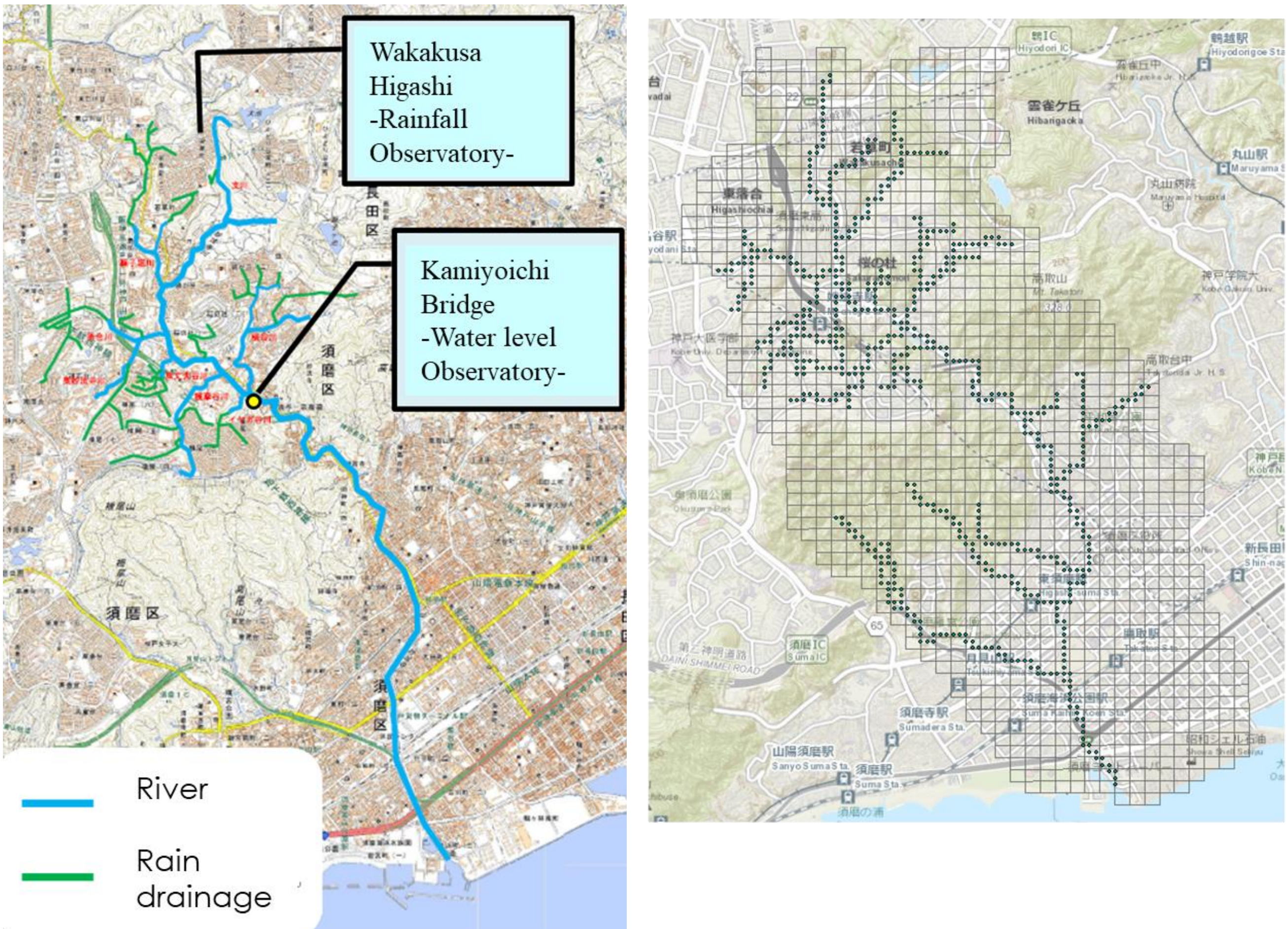
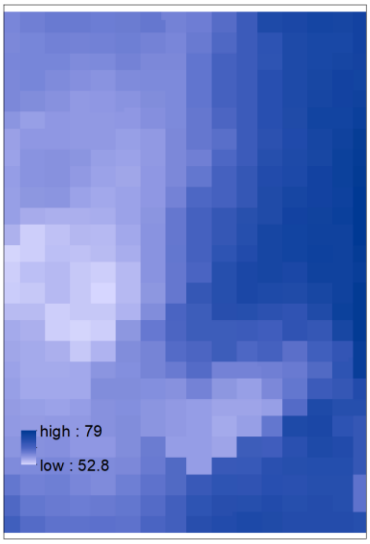
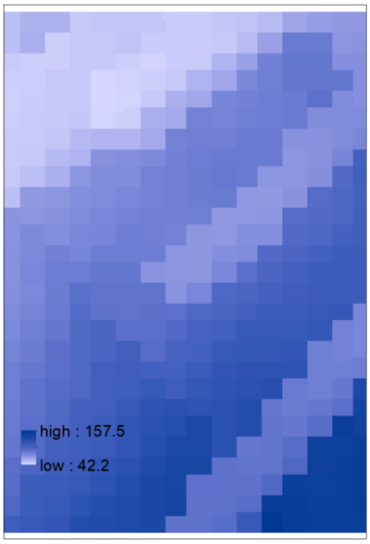


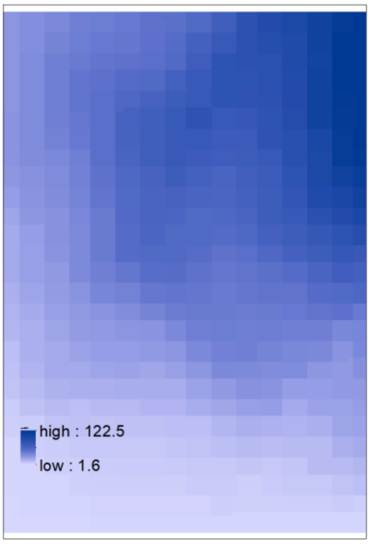
Figure 2: River and rain drainage network of Myohouji River and the location of Kamiyoichi Bridge (left); Catchment divide (right). Background maps are from ArcGIS base map.



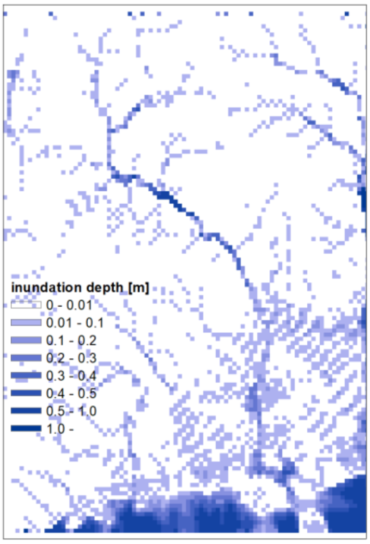
Rainfall intensity [mm/hr]
at 2018/9/4 13:20



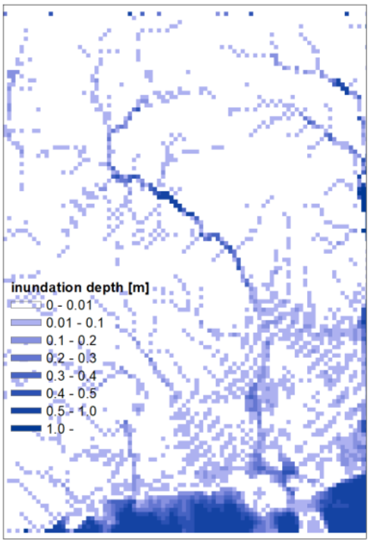
Rainfall intensity [mm/hr]
at 2018/9/4 13:30



Rainfall intensity [mm/hr]
at 2018/9/4 13:40



Simulated inundation depth [m]
at 2018/9/4 13:20



Simulated inundation depth [m]
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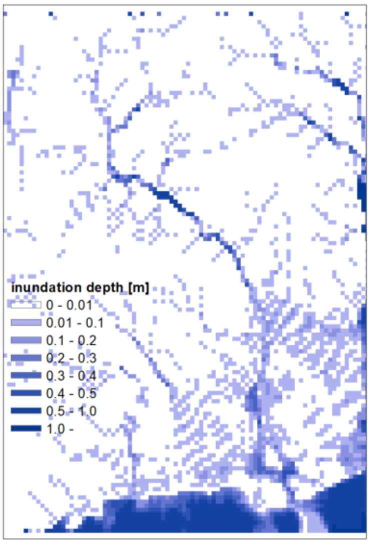
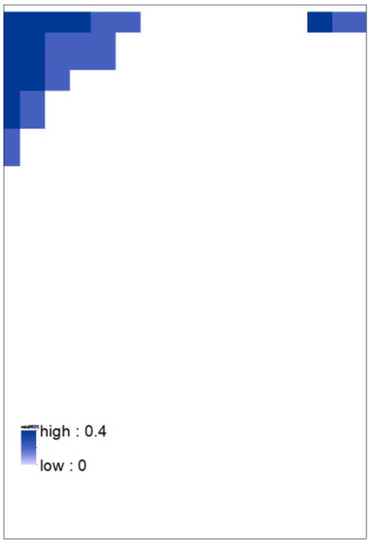
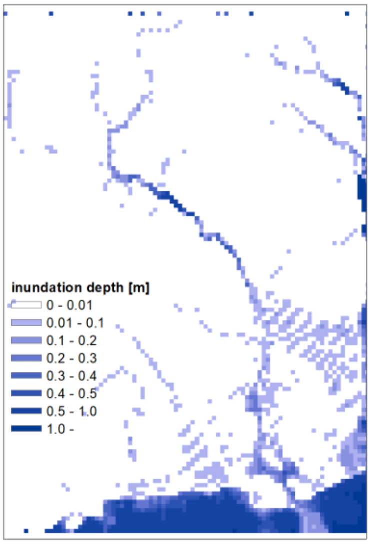


Simulated inundation depth [m]
at 2018/9/4 13:40



Rainfall intensity [mm/hr]
at 2018/9/4 13:50



Simulated inundation depth [m]
at 2018/9/4 13:50

Figure 3: Rainfall intensity and inundation depth at four time steps same as in Figure 1.

at Kamiyoichi Bridge, thus the focus of the discussion in this paper is put on Kamiyoichi Brdige and its upstream region.

A distributed rainfall-runoff/flood-inundation model (DRR/FI; Kobayashi and Takara, 2012; Fujita et al., 2016) was applied in the following discussion. DRR/FI consists of a 2D surface flow simulation model based on a shallow water equation for the inland area and a 2D subsurface flow model of the forest area based on a depth-integrated unsaturated flow equation (Nakayama et al., 2001). The river and drainage network were modelled by a 1D dynamic wave equation using Flux Difference Splitting scheme. The model resolution is 50m. DRR/FI simulates the discharge and water level in the river and drainage, inundation depth in the inland area as well as the volumetric water content in the mountain area.

As mentioned, the rainfall event by Typhoon 21, September 2018 was considered in this study. XRAIN data (X Band radar-rainfall data: 250 m spatial resolution, 1 minute temporal resolution) was used as the input to DRR/FI. The spatial rainfall intensity over the catchment is shown in Figure 3 for four time steps same as Figure 1. For instance, at 13:30, 1 minute rainfall equivalent to 157.5 mm/hr intensity is observed in XRAIN.

3. DISCHARGE AND WATER LEVEL

Figure 4 shows the simulated and observed water levels. Note that the water level gauging is placed before the curve as shown in Figure 1, thus the water level was influenced by the backwater and hydraulic jump at the curve. Without them, the water level is considered smaller. Since the resolution of the 1D river flow model is 50 m, this local effect cannot be captured by the model. In this sense, fine resolution 2D/3D flow modelling as well as a research by the physical model experiment is preferable. However, bearing these aspects in mind, the manning’s roughness coefficient of the cross section is adjusted so that the simulated water level fits with the observed water level as shown in Figure 4. Sudden water level rise was reproduced on some level by the model, though some details were different between the simulation and observation.

Figure 5 shows the simulated and observed discharges. H-Q discharge indicates the discharge converted from H-Q rating curve by Hyogo Prefecture. STIV discharge was obtained from monitoring camera image using STIV technique (Fujita, 2009). Comparing these two “observed” discharges, it is recognized that the one by STIV is smaller than H-Q. On the other hand, the simulated discharge by DRR/FI becomes further smaller than STIV. Actually, the simulated discharge could not be larger by any parameter adjustment. In other word, the amount of simulated discharge is an upper limit for the DRR/FI model setting this time. Note that the discharge is simulated by a dynamic wave model. Provided that the STIV discharge is the true value, then it is considered that DRR/FI model requires denser drainage network such as the rapid water collection from house area (i.e. denser drainage network which is not necessarily shown in the drainage plan of Kobe city).

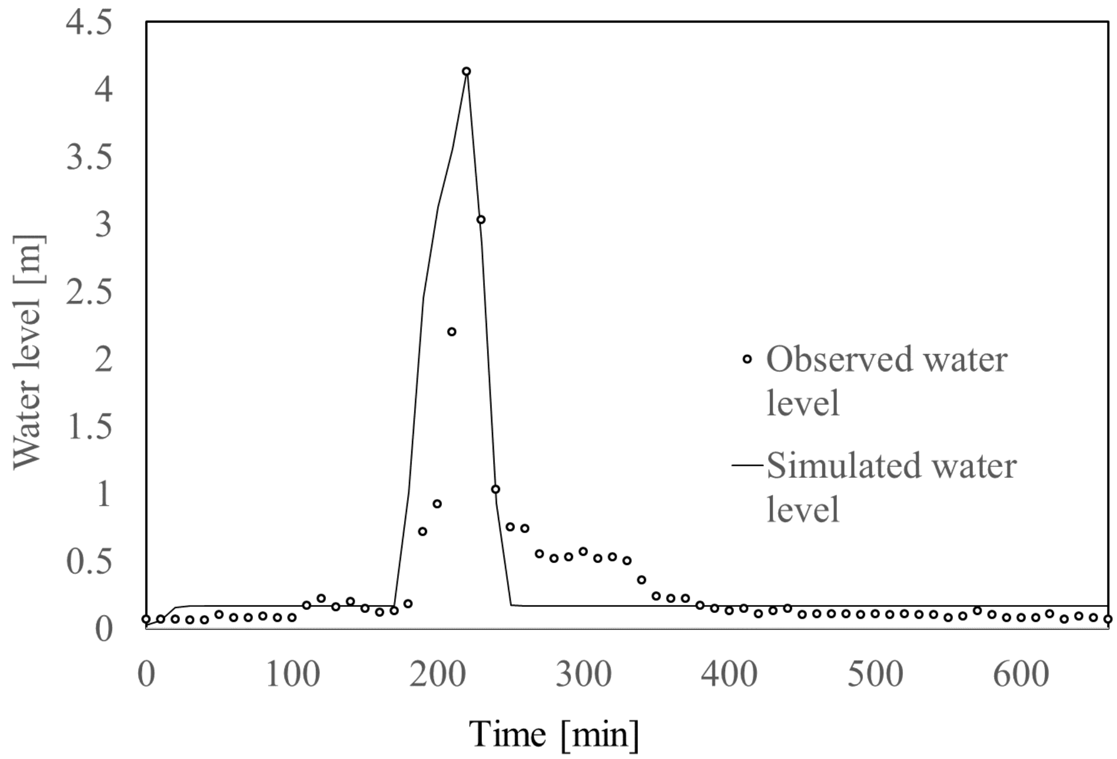


Figure 4: Simulated and observed water level

Back to Figure 3, the figure shows the simulated inundation depths around the peak time. By the nature of DRR/FI model which simulate inundation over the inland area, more drainage is necessarily to collect more water in the river given STIV is collect.

On the other hand, Figures 6 and 7 shows the simulated water levels and discharges with and without drainage respectively. The difference of the water levels with and without drainage at the peak was 0.3m, i.e. 7 % of the peak water depth with drainage. Likewise, the difference of the discharges with and without the drainage at the peak was 11 m^3/s, i.e. 13 % of the peak discharge with drainage. This differences were smaller than we expected. Similar research for Togagawa River shows that the drainage network contributed to 25 % of total runoff (Kobayashi et al., 2019). Probably, the drainage network for Myohuji River case is more like

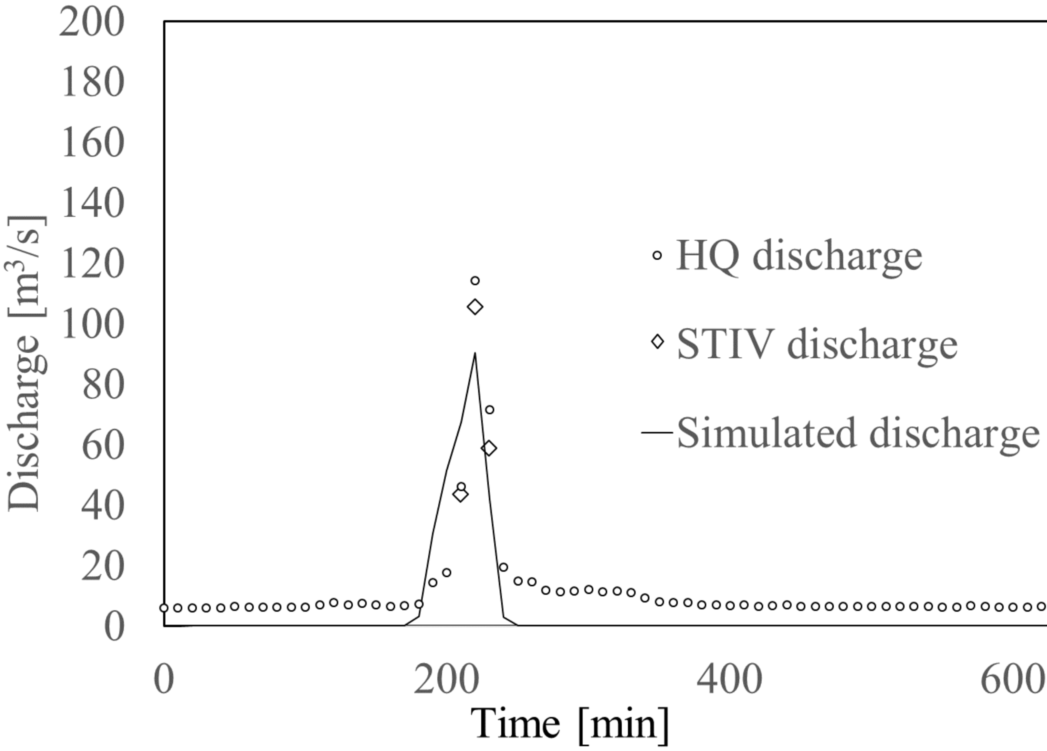


Figure 5: Simulated and observed discharges (H-Q and STIV)

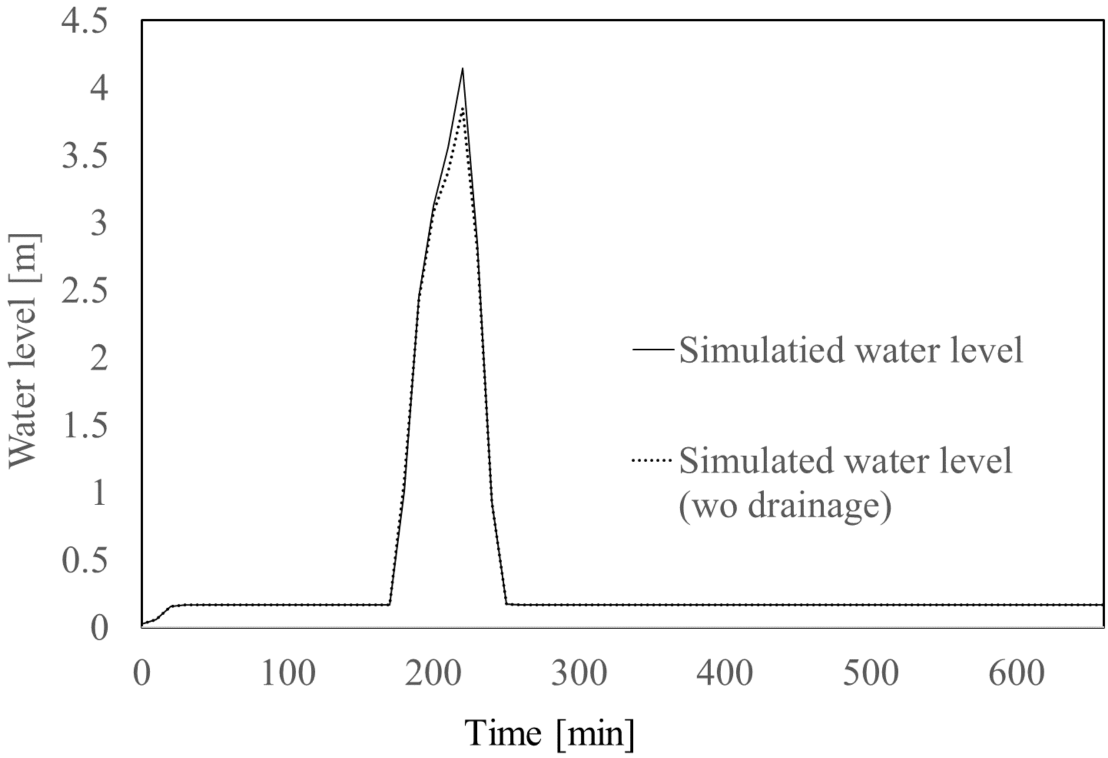


Figure 6: Simulated water levels with and without drainage

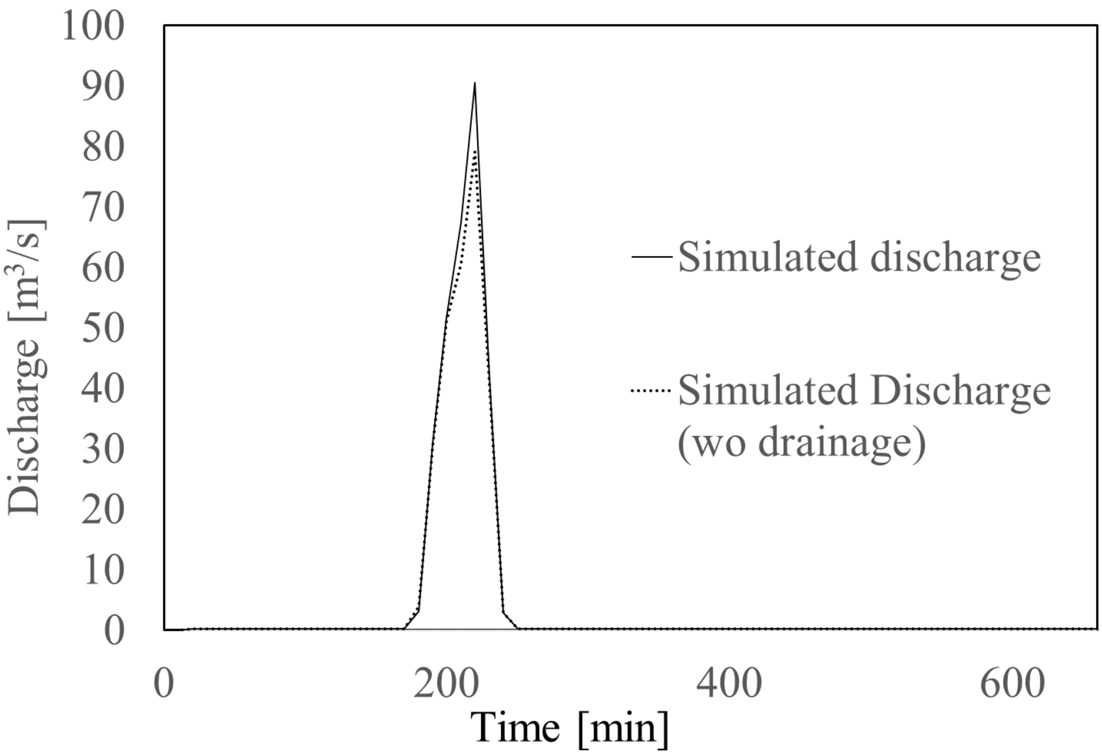


Figure 7: Simulated discharges with and without drainage

extension of the tributaries of Myohouji River as shown in Figure 2 which is different from Togagawa River whose drainage is often connected directly to the main river.

4. CONCLUSIONS

This paper dealt with the development of a distributed rainfall-runoff/flood-inundation model with rainwater drainage network for Myohoji River Basin, Hyogo, Japan. The primary purpose was to see if the very rapid rise of the water level at Kamiyoichi Bridge in flooding can be reproduced by the model. The water level rise was around 4.0 m for 40 minutes. XRAIN data (250m resolution, 1 min. interval) was used as the input for the model. As the result, the model could reproduce the situation on some level, though it shows some difficulties such as the smaller amount of total discharge at the peak compared to STIV discharge. The effect of the rain drainage network for the runoff is also examined as a first trial without verification by observation data. The result shows that the effect of drainage network for Myohouji River is around 11 % at the peak runoff which is smaller than those of Togagawa River (25 %), though this needs further investigation in future. Likewise, the possibility of flood forecasting in the catchment feeding forecast rainfall is to be investigated as a future work.

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