ESTIMATION OF FLOOD STORAGE VOLUMES IN THREE RETARDING BASINS ALONG THE TONE RIVER

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ABSTRACT

The Tanaka, Sugo, Inadoi retarding basins were constructed along the Tone River for reducing the flood discharge for the downstream river. In this paper, we apply the unsteady two-dimensional flood flow analysis based on the time series data of the observed water surface profiles to the Tone river including the three retarding basins and confluence of the Kinu river and estimate inflow discharge hydrographs and flood storage volumes at the retarding basins. From the calculation results, we discussed and evaluated storage effects of the three retarding basins against 2001 and 2007 floods.

INTRODUCTION

The Tone river having the largest drainage area (16,840km^2) in Japan flows through the Kanto plain. The Tanaka, Sugo and Inadoi retarding basins are located around the confluence of the Tone and Kinu river (see Figure 1) to control the flood discharge in the lower Tone river. Due to the increase of the design flood discharge in the Tone river, expansion of the flood-control capacities of the three retarding basins has been implemented. Therefore, the storage functions of the three retarding basins for the past flood events should be investigated.

Nakai et al. [1] showed that inflow discharge hydrograph and storage volume of flood flow entering in a retarding basin can be calculated from high accurate estimation of the time series of the water surface profiles in the river reach including a retarding basin by the unsteady two-dimensional flood flow analysis. The objective of this paper is to estimate inflow discharge hydrographs and flood storage volumes in the Tanaka, Sugo and Inadoi retarding basins for the large floods in September 2001 and 2007 by using the above numerical analysis method.

STUDY AREA AND FLOOD

The Tanaka and Sugo retarding basins were almost completed in 1960 and flood waters in the Tone river are stored in the retarding basins through the overflow levees constructed on a part of the river bank (see Figure 1). The height and shape of the overflow levee at the Tanaka retarding basin changed from a broken line to a solid line in Figure 2 as a result of the repair works between the 2001 and 2007 floods. The overflow levee in the Inadoi retarding basin was not completed and flood water entered into the Inadoi retarding basin by overflowing the lower part of the surrounding levee indicated by the gray (2001 flood) and white (2007 flood) squares in Figure 1, respectively.

In the 2001 and 2007 floods, water level hydrographs and discharge hydrographs in the river channels and three retarding basins were obtained at the observation points of Figure 1. Figure 3 shows the observed discharge hydrographs at the Mefukibashi (104.1 km), Toride (85.3km), Kinugawamitsukaido (11.0km) and Takishitabashi (3.0km) in 2001 and 2007 floods. The flood duration of the 2001 flood is long and the peak discharge is over 7,500m^3/s at the Toride as shown in Figure 3(a). Peak discharge was observed at almost the same time at the Toride and Kinugawamitsukaido. On the other hand, the peak discharge of the 2007 flood was about 7,000m^3/s at the Toride and the shapes of the discharge hydrographs are sharp compared with that of the 2001 flood (see Figure 3(b)). Additionally, peak discharge was observed at almost the same time at the Kinugawamitsukaido and Mefukibashi.

CALCULATION METHOD AND CONDITIONS

Unsteady two-dimensional flood flow analysis was made for estimating accurate flood discharge hydrographs and flood storage volume in the river channels and three retarding basins. The upstream and downstream boundary conditions are given by observed water level hydrographs at the Mefukibashi, Toride and Kinugawamitsukaido observation stations shown in Figure 1.

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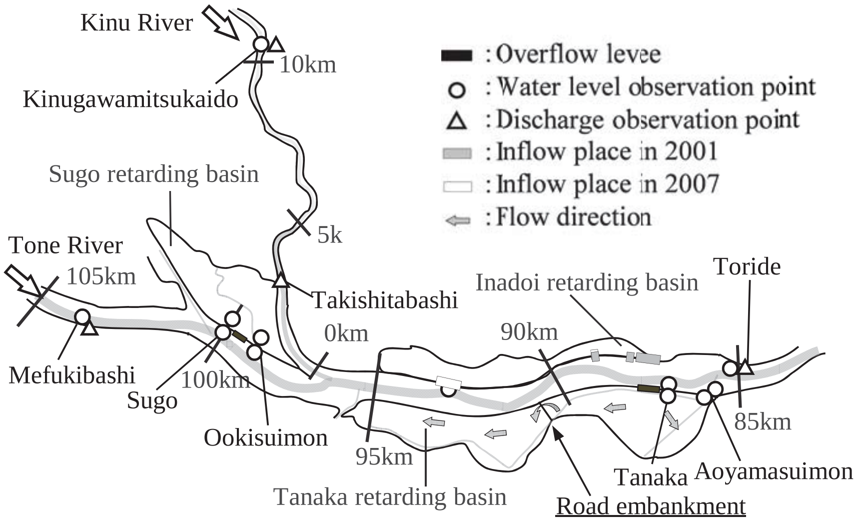


Figure 1 - Plan form and observation points of the Tone and Kinu rivers

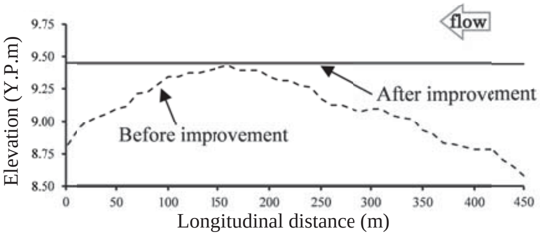
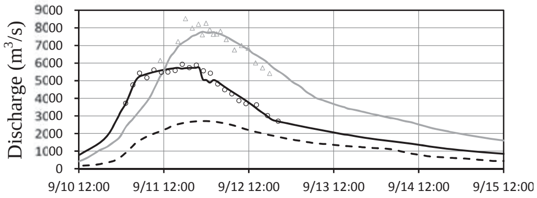


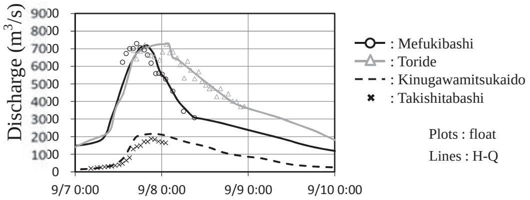
Figure 2 - Overflow levee elevation at the Tanaka retarding basin

Table 1 - Manning's roughness and vegetation permeability coefficients

	2001		2007	
	Tone	Kinu	Tone	Kinu
Manning's roughness coefficients in main channels ($s \cdot m^{-1/3}$)	0.018	0.019	0.018	0.02
Manning's roughness coefficients in flood plains ($s \cdot m^{-1/3}$)	0.030〜0.032		0.030〜0.040	
Vegetation permeability coefficients (m/s)	50〜65	40〜70	50〜65	25〜65



(a) 2001 flood



(b) 2007 flood

Figure 3 – Observed discharge hydrographs

Bed elevations of the computational grids for the river channels and three retarding basins are given based on the topographical data obtained from the cross-sectional bed shape measurements and laser profiler. Spreading of the flooding water in the retarding basins is largely affected by the road embankments and irrigation networks. To evaluate such propagation mechanism of the flooding water, we considered properly topographic features in the retarding basins such as the road embankments and irrigation networks.

The Manning's roughness coefficients and vegetation permeability coefficients in the channels and retarding basins were determined as Table 1 so that the calculated water level hydrographs agree with the observed water level hydrographs.

CALCULATION RESULTS AND CONSIDERATIONS

Comparison between the observed and calculated results

The calculation results are almost similar in the 2001 and 2007 floods. We investigate calculation results by focusing on the 2001 flood.

Figure 4 shows comparisons between the calculated and observed water surface profiles in the 2001 flood. The calculated water surface profiles show a good agreement with the observed data. Figure 5 shows the comparison between the calculated and observed water level hydrographs around the overflow levees at the Tanaka and

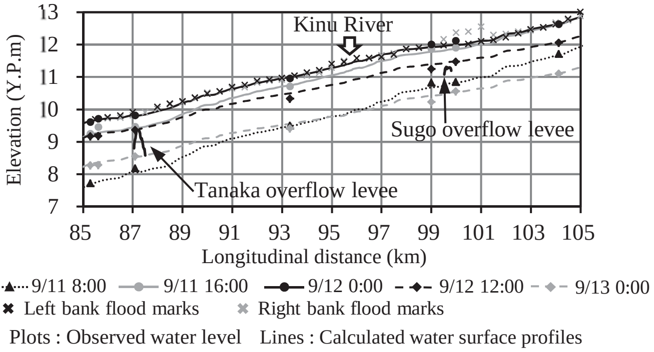
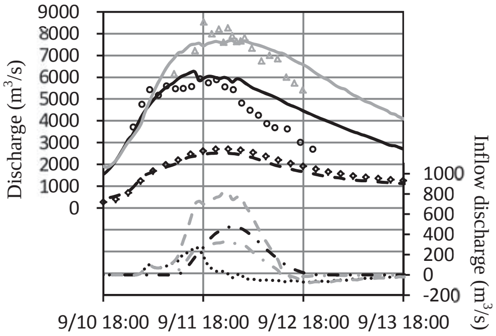
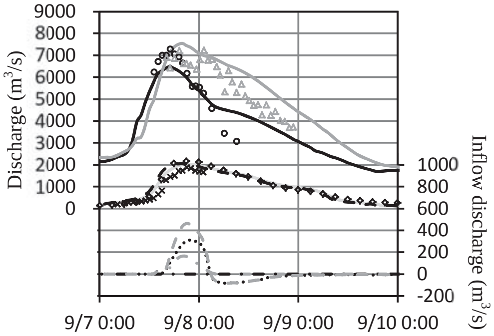


Figure 4 - Comparison between calculated and observed water surface profiles



(a) 2001 flood



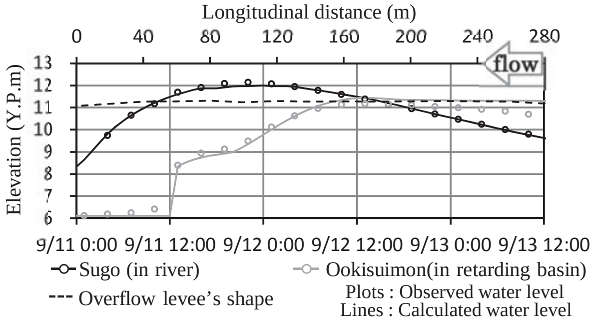
(b) 2007 flood

○ : Mefukibashi
△ : Toride
◇ : Kinugawamitsukaido
✖ : Takishitabashi
: Inadoi retarding basin
: Sugo retarding basin
: Tanaka retarding basin
: Total inflow discharge

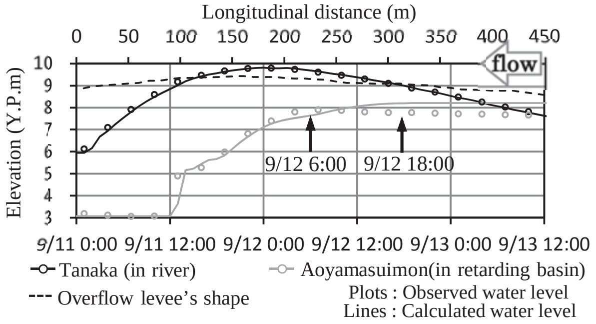
Plots : Observed data

Lines : Calculated discharge and inflow discharge

Figure 6 – River discharge and inflow discharge hydrographs to retarding basins



(a) Sugo retarding basin



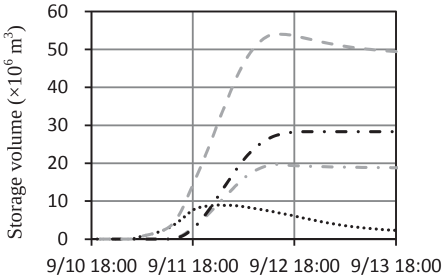
(b) Tanaka retarding basin

Figure 5 - Comparison between calculated and observed water level hydrographs in the Tone river and retarding basins

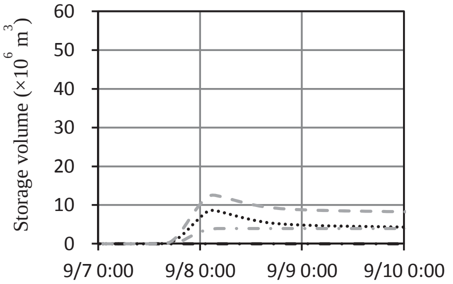
Sugo retarding basins. The calculated water level hydrograph in the Sugo retarding basin (see Figure 5(a)) becomes higher than the observed water level hydrograph in flood falling period. The main reason is discussed below. In reality, flooding water stored in the retarding basin returns to the Tone river channel through a drainage gate in the falling period, however, it was not considered in this analysis.

The water level of Aoyamasuimon in the Tanaka retarding basin is almost unchanged after 6:00 September 12th as shown in Figure 5(b), however, the water level at the Tanaka observation point is higher than the height of the overflow levee until 18:00 September 12th. First, flooding waters in the Tanaka retarding basin are stored in the downstream area of the road embankment (see Figure 1). When the water level in the retarding basin is above about 8m, flooding waters spread to the upstream area across the road embankment.

Figure 6 shows the comparison between the calculated and observed river discharge hydrographs and the calculated inflow discharge hydrographs entering into three retarding basins in the 2001 and 2007 floods. The calculation results in the rising period can almost reproduce the observed discharge hydrographs at the Toride, Mefukibashi and Kinugawamitsukaido (see Figure 6(a)). But, the calculated discharges tend to be larger than the observed discharges at the Toride and Mefukibashi in the falling period. In this calculation, the Manning's roughness coefficient was determined so that the calculated water surface profiles agree with the observed water surface profiles around peak-water levels. So it is highly possible that the Manning's roughness coefficient of flood falling period is higher than that of rising and peak period. It seems to be related with the formation of dunes in the falling period.



(a) 2001 flood



(b) 2007 flood

········ : Inadoi retarding basin — · — : Tanaka retarding basin
— · — : Sugo retarding basin — — — : Total storage volume

Figure 7 – Calculated storage volume hydrographs

Table 2 – Maximum inflow discharge

retarding basin name	maximum inflow discharge(m^3/s)	
	2001	2007
Inadoi	273	311
Sugo	333	164
Tanaka	474	0
total	829	462

Table 3 – Maximum storage volume and usage percentage of flood-control capacity

(a) 2001 flood

retarding basin name	flood-control capacity ($\times 10^6$ m^3)	maximum storage volume ($\times 10^6$ m^3)	usage percentage of flood-control capacity (%)
Inadoi	19.08	8.99	47.1
Sugo	26.90	19.71	73.3
Tanaka	60.68	28.33	46.7
total	106.66	54.02	50.6

(b) 2007 flood

retarding basin name	flood-control capacity ($\times 10^6$ m^3)	maximum storage volume ($\times 10^6$ m^3)	usage percentage of flood-control capacity (%)
Inadoi	19.08	8.62	45.2
Sugo	26.90	3.95	14.7
Tanaka	60.68	0.00	0.0
total	106.66	12.55	11.8

Calculated inflow discharge and flood storage volume in the 2001 and 2007 floods

In the 2001 flood, the calculated inflow discharge of the Tanaka and Sugo retarding basins take a maximum when the flood discharge at the Toride was almost in peak (see Figure 6(a)). On the other hand, the inflow discharge of the Inadoi retarding basin reaches its maximum before the flood discharges is in peak at the Mefukibashi, Toride and Kinugawamitsukaido. Table 2 shows the calculated maximum inflow discharges at the three retarding basins in each flood. The maximum total inflow discharge of the three retarding basins becomes 829m^3/s in the 2001 flood. Figure 7 shows the calculated storage volume hydrographs of the three retarding basins. The storage volume in the Sugo and Inadoi retarding basin decreases in the flood falling period in the 2001 flood (see Figure 7(a)) since the flooding waters returned from the retarding basins to the Tone river through the overflow levee at the Sugo retarding basin or lower part of the surrounding levee at the Inadoi retarding basin. Table 3 shows the maximum storage volume and usage percentage of the flood-control capacity in the three retarding basins in each flood. The maximum total storage volumes comprise 50.6% of the total flood-control capacity in the 2001 flood.

As shown in Figure 6(b), flood water doesn't enter the Tanaka retarding basin in the 2007 flood because the height of the overflow levee becomes higher than that in the 2001 flood (see Figure 2). The maximum inflow discharge of the Inadoi retarding basin becomes larger than that of the Sugo retarding basin, contrary to the 2001 flood. The maximum storage volumes at the Inadoi retarding basin is almost same in the 2001 and 2007 floods, but the total storage volume of the three retarding basins in the 2007 flood is about one-fifth of that in the 2001 flood (see Table 3).

CONCLUSIONS

By the unsteady two-dimensional flood flow analysis using the time series data of the observed water surface profiles, we estimated flood discharge hydrographs in the river channels and flood storage volume of three retarding basins for the 2001 and 2007 floods and compared the analysis results with measured results. The maximum inflow discharges of the three retarding basins were 829m^3/s in the 2001 flood and 462m^3/s in the 2007 flood, respectively. Additionally, the calculated maximum total storage volumes comprise 50.6% of the total flood-control capacity even in the long duration flood of 2001.

REFERENCES

[1] Nakai T., Sutoh J. and Fukuoka S., "Study on flood control of Watarase retarding basin in 2007 flood", *Proceedings of 66th Annual Conference of JSCE*, (2011), pp 243-244.