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APPLICATION OF URBAN HYDROLOGICAL MODEL FOR PREDICTION OF RUNOFF FROM AGRICULTURE DOMINATED AREA

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Abstract*- *Infoworks has remarkable ability in predicting runoff from urbanized area through stormwater drainage network. Here, by changing three land surface hydrological parameters such as surface runoff ratio, routing value and initial loss, runoff from agriculture dominated area (basically agricultural area but includes some paved area and drainage systems) was predicted. Effects of each parameter on the predicted runoff during2 rainfall events observed in Sendai were discussed. Runoff ratio which designates ratio of the surface runoff volume against total rainfall volume on given land use pattern was always most sensitive in predicting runoff. Routing value which designates speed of runoff water till entering the drainage system showed detectable effects on drainage profiles. Initial loss which designates the volume of water not contributing to runoff by retaining rainfall water at the surface was not significant on drainage profiles at the peak discharge. These results underline the high possibility of predicting runoff from agriculture dominated area using Infoworks.

Keywords – Infoworks; Surface Runoff Ratio, Routing Value, Initial Loss, Agriculture dominated area, Stormwater drainage systems

I. INTRODUCTION

Infoworks is mainly used to predict runoff of stormwater and some pollutants in urbanized areas. In some cases, this model is used to make inundation hazard map as governmental purposes. Figure 1 shows the storm water drainage network at Fukumuro area in Sendai city prepared by the Sewage Governmental Office.

Figure 1 Stormwater drainage network at Fukumuro area in Sendai city.

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In the Figure 1, solid circles indicate manholes and lines indicate drainage pipes. Information of three dimensional geological position of the manholes and the pipes, shapes of the manholes and the pipes and slope of the pipes etc. were set up by the office.

Using Infoworks, the authors had succeeded in evaluating the effects of small farming areas and open space in Sendai city by changing three surface hydrological parameters such as runoff rate, routing value and initial loss [1]. Based on the same approach, here, we analyse the sensitivity of three parameters mentioned above on the prediction of runoff from the network (Figure 1). This analysis verify the ability of Infoworks to predict the agriculture dominated area. This focus is important because, in Japan, it is common that the agricultural areas are consisted of small farming area and residential area with stormwater drainage systems.

II. MATERIALS AND THE METHODS

In Figure 1, catchments were defined for all the manholes .Three hydrological parameters i.e. runoff ratio, routing value and initial loss were given to each catchment reflecting its land use pattern.

Runoff ratio is defined as the ratio of the volume (or intensity) of the surface runoff against the volume (or intensity) of the temporal rainfall. There are common runoff rates for given land use pattern such as Table 1.

Routing value is defined as the speed of runoff water till entering the drainage system [2]. Normally the value is bigger at impervious area [2].

Initial loss is defined as the volume of water not contributing to runoff by retaining some part of water at the land surface.

The value is given by the following equation [3].

$$\text{Initial loss (mm)} = k / \sqrt{s} \qquad \text{Eq (1)}$$

where k is a parameter smaller at impervious area (such as residential ara) and vice versa at pervious area (such as farming are), and s is slope of the surface.

Table 1 Common Runoff Ratio at Given Land Use Patter

Land Use	Runoff Ratio
Paved Area	0.70 – 0.95
High Residential Area	0.70 – 0.90
Farming Area	0.05 – 0.25
Open Space	0.05 – 0.25

We compared the runoff at the Fukumuro area when parameters at urbanized area are given to that when parameters at agricultural areas are given as shown in Table 2

Table 2 Cased for predicting runoff from the network shown in the Figure 1

Case	1	2	3	4	5	6	7	8
Runoff Ratio **Urbanized : 0.75** **Agricultural : 0.1**	0.75	0.75	0.1	0.1	0.75	0.75	0.1	0.1
Routing Value **Urbanized : 1** **Agricultural : 20**	20	1	20	1	20	1	20	1
Initial Loss (k in the q.(1)) **Urbanized : 0.07** **Agricultural : 0.1**	0.07	0.07	0.07	0.07	0.1	0.1	0.1	0.1

About 250 heavy rainfalls were picked up out of all rainfalls recorded during 1962 – 2011 (50 years) using HP of the Metrological Agency Japan. Then, two rainfalls: rainfall A (68.5 mm in volume and 22.0 mm/h in the maximum intensity) and rainfall B (363.0 mm in volume and 43.5 mm/h in the maximum intensity) were selected for the analyses here. Frequency analyses for the 250 heavy rainfalls showed that the volume of the rainfall A was most frequent and the volume of the rainfall B was the heaviest, respectively, during 1962 – 2011 (50 years).

III.RESULTS AND DISCUSSION

The effect of the difference in rainfall ratio was quite large in the occurrence of inundation. When the runoff ratio was 0.75, inundation occurred at wide area of the network (Figure 2). This means the occurrence of inundation was inevitable on the biggest rainfalls during 50 years at the area when the site was highly urbanized. While when the runoff ratio was 0.1, inundation occurred at narrower area of the networks (Figure 3). These results underline the importance of controlling land use pattern to keep low runoff ratio for the flood control in the city. And they also underline the ability of Infoworks as a tool for predicting the runoff from the area of low runoff ratio such as agricultural areas.

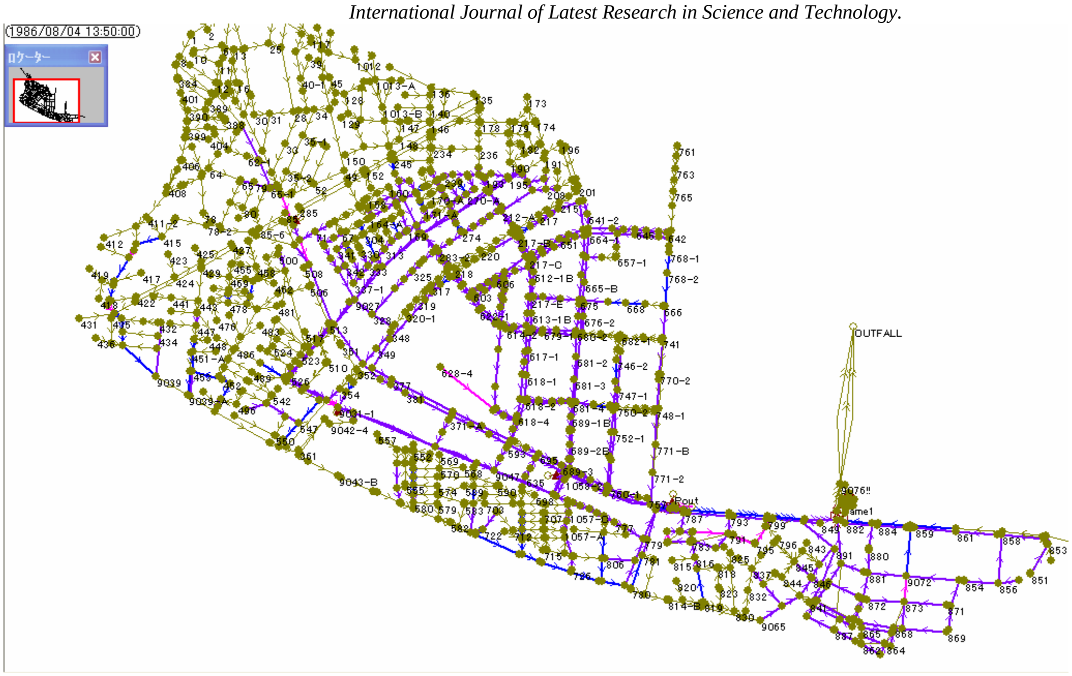

Figure 2 Occurrence of inundation for the case 1 of Rainfall B (blue lines showed the occurrence of inundation)

Figure 3 Occurrence of inundation for the case3 of Rainfall B(blue lines showed the occurrence of inundation)

Vertical profiles of the drainage water in the sub-network (long section) shown in Figure 3 as red line were analyzed for rainfall A. The parameters were set up as shown as the 8 cases in the Table 2. The analyses were done as follows: i) water depth in the sub-networks for the case 1 was monitored, ii) the time recording the highest depth was decided and iii) water depths in the same sub-network for the other 7 cases were obtained.

The results shown in Figures 4 to 11 show the following information.

Concerning routing value, the effect of larger routing values at the case 1 (Figure 3), case 5 (Figure 7) and case 7 (Figure 10) which reflect the slower movement of runoff water into the drainage system could be seen when each compared to the case 2 (Figure 4), case 6 (Figure 8) and case 8 (Figure 10). The water depths at the sub-network were smaller when the routing value was larger. The larger routing value on case 3 might be less effective to decrease the water depth i.e. the depths of case 3 (Figure 5) seemed to be almost same as those of case 4 (Figure 6).

The effect of bigger initial loss was not detectable by comparing the results shown in Figures 3 – 10. Analyses focusing the initial runoff behavior are needed.

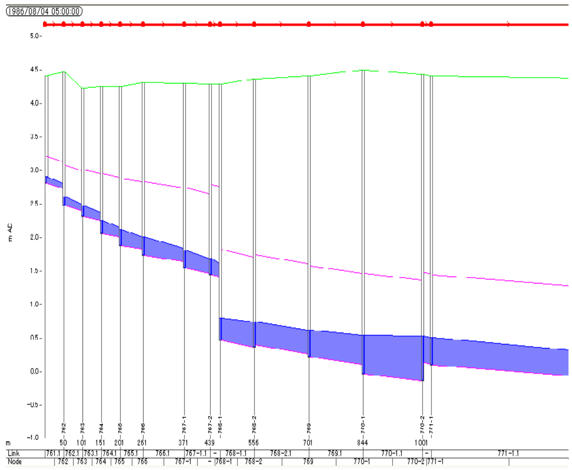

Figure 3 Water depths in the sub-network shown in Table 2 (Case 1)

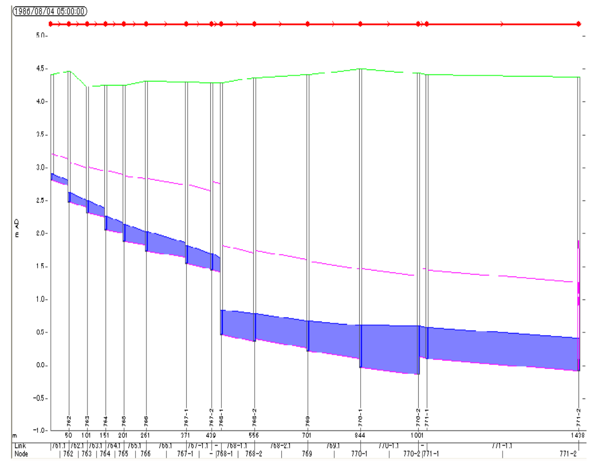

Figure 4 Water depths in the sub-network shown in Table 2 (Case 2)

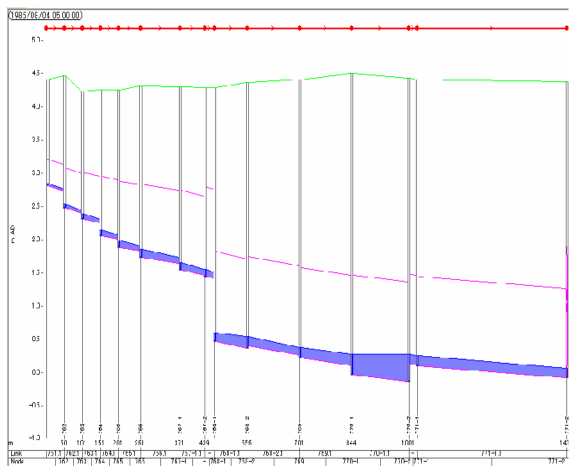

Figure 5 Water depths in the sub-network shown in Table 2 (Case 3)

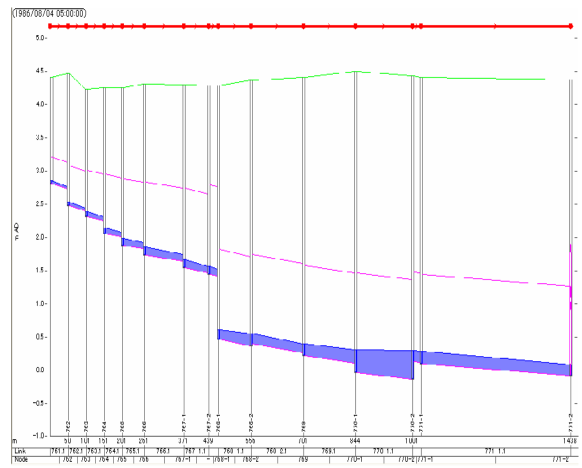

Figure 6 Water depths in the sub-network shown in Table 2 (Case 4)

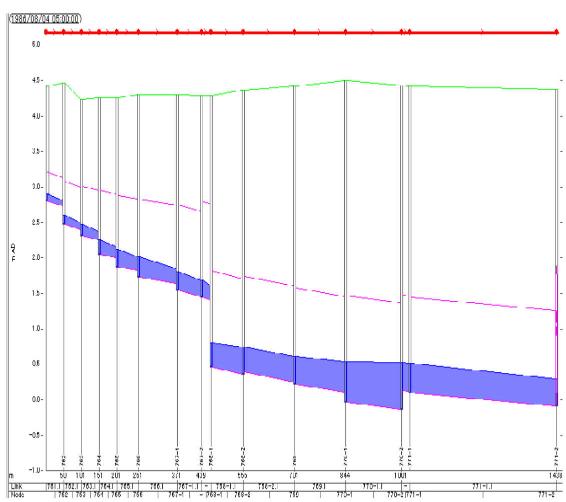

Figure 7 Water depths in the sub-network shown in Table 2 (Case 5)

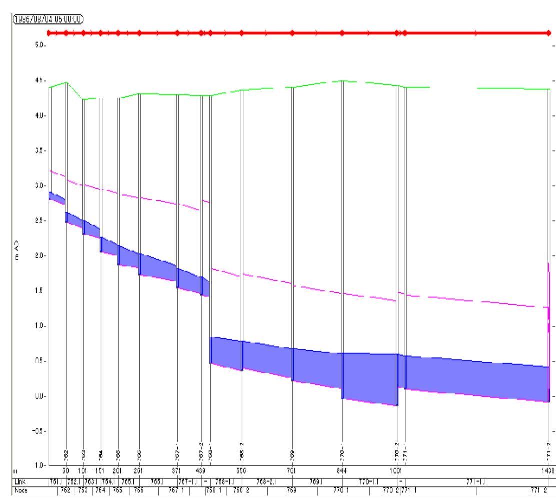

Figure 8 Water depths in the sub-network shown in Table 2 (Case 6)

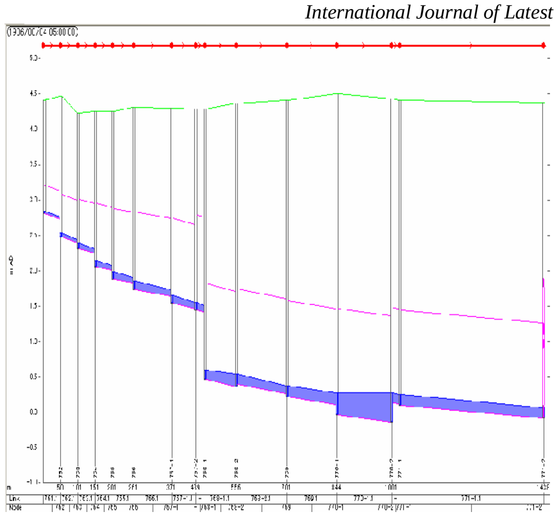

Figure 9 Water depths in the sub-network shown in Table 2 (Case 7)

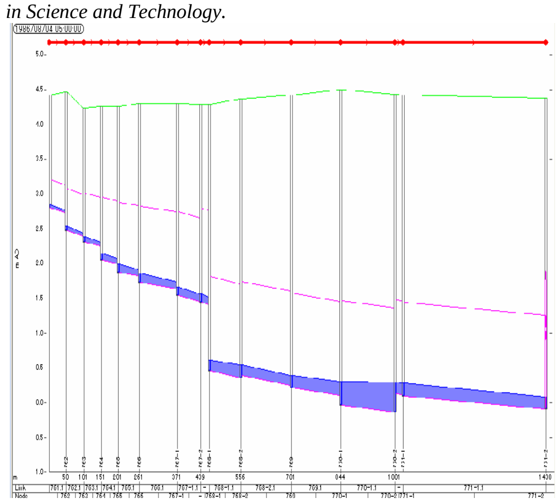

Figure 10 Water depths in the sub-network shown in Table 2 (Case 8)

IV. CONCLUSIONS

Of three surface hydrological parameters, the sensitivity of runoff ratio and routing value were higher than that of initial loss because we analysed peak discharge. The results are reasonable in predicting runoff from agricultural area and then Info works is capable to be used in the analyses at agriculture dominated area.

ACKNOWLEDGMENT

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