

Model Estimation of Dynamic Surface Runoff in Urban Drainage Areas Consisting of Infiltration Facilities

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INTRODUCTION

In Japan construction of infiltration facilities began in 1980's for reduction of peak flows and pollutant loads in urban sewer systems. The infiltration facilities include permeable pavements, infiltration inlets, infiltration trenches, LU curbs, and soakaways. The configuration of infiltration facilities are shown in the Figure 1. However, these infiltration facilities provide other secondary benefits and several disadvantages. The main reason for slow implementation of infiltration facilities is the lack of an acceptable design calculation approach to quantify the effects and the reliability of storage and infiltration. The main objective of this research is to quantify the dynamic effect of the infiltration and storage facilities on the surface runoff reduction, using a distributed model software (InfoWorks CS).

HIGHLIGHTS

- Model the dynamic effect of infiltration facilities using distributed model software.
- Two methods were proposed to describe the functions of infiltration facilities in the distributed model
- Dynamic change of storage capacity as well as infiltration provided satisfactory estimation of the runoff.
- Proposed method is useful for quantifying the secondary effects of the infiltration facilities.

METHODOLOGY/ PROCESS

Study drainage are located in a highly urbanized residential area. They are "Ooizumi" and "Shakuji" having catchment areas of 7.15ha and 8.28ha, respectively (Figure 2). Their land use and surface type distributions are shown in Figure 3. Ultimate infiltration rates and storage volume of each infiltration facility is given in Table 1. Characteristics of the rainfall events selected for runoff simulations in Ooizumi and Shakuji areas are given in Table 2 and Table 3 respectively. Characteristics of the each surface type is given in Table 4. Any distributed model has no option to model the infiltration facilities. Therefore, two methods were proposed to describe the functions of infiltration facilities in the distributed model. In the first method, the stored water in the facilities is accounted by increasing the initial loss and the infiltrated water is expressed by giving an infiltration rate for impervious areas in an effective rainfall model. In other words, adjusted effective rainfall was given to impervious area.

In the second method, an additional submodel describing storage capacity and infiltration function was developed. Effective rainfall and surface runoff models were routinely calculated. The submodel estimated the overflow from infiltration facilities to sewer pipes in each subcatchment by considering the change of stored volume and infiltration in each calculation time step (5 minutes). Then, the estimated overflow was introduced to the node/manhole for hydraulic calculation using option of QIN file in the software. Advantages of the second method over the first one are properly assignment of infiltration facilities to each sub catchment and consideration of dynamic change of storage capacity by the facilities.

RESULTS

Comparison with and without infiltration facilities

Figure 4 shows the measured and simulated hydrographs at the outlet of Ooizumi area with and without infiltration facilities during a rainfall event with high intensity. It can be seen that the simulation without the facilities gave much higher peak flow than the measured one in June 15 rainfall, while the estimated hydrographs almost explained the observed level of flow for the both methods considering the functions of infiltrations facilities. In addition, the method 2 gave better and higher estimation of flow rate than the method 1, although it is still lower than the observed one

Application of the two methods for different rainfall events in Ooizumi area

Both methods were applied to the other rainfall events with weak intensities. As shown in Figure 5, they gave good estimate of flow level for rainfalls at different intensities, although the proposed methods could not precisely express the sharp and fluctuated flow pattern appeared in the measured hydrographs. The disagreement at low flow rate came from the inaccurate measurement of flow velocity, but not from poor simulation. However, there is still a limitation in estimating the initial peak flow in June 18 rainfall, which is highlighted by the dotted circle line. A possible reason for under estimation is ignorance of increased overflow due to clogging of infiltration facilities.

Application to runoff events in Shakujii area with different infiltration facilities

The method 2 was applied to runoff simulation in Shakujii area where main infiltration facility is the infiltration trench. Figure 6 shows the simulated hydrographs using method 2. The consideration of the storage capacity and infiltration function in the method 2 also worked well for Shakujii area.

Simulation considering clogging of infiltration facilities in Ooizumi area

We focused on the clogging effect on runoff simulation in order to improve the estimation of runoff behavior in the event on June 18. Clogging of infiltration facilities lead to early runoff and increased peak flow. Figure 8 shows the simulated hydrograph of the clogging scenario using the method 2 for rainfall events on June 15 and 18. In the simulation, 10% of the LU curbs were assumed clogged. This assumption led to a better agreement between measured and simulated hydrographs. Increased overflow from the facilities raised the flow peak and explained the fluctuated flow satisfactorily. However, there was still a disagreement in the initial peak flow.

CONCLUSION

Two methods were proposed to estimate the dynamic runoff in urban drainage areas with the several infiltration facilities. The adjustment of effective rainfall (method 1) gave poor simulation of runoff behavior in events with week rainfall intensity. The consideration of dynamic change of storage capacity as well as infiltration (method 2) gave satisfactory estimation of the runoff in both study areas. Although the estimated runoff flow was lower than the measured one using an original method, assumption of facility clogging improved the agreement between measured and simulated hydrographs in small and medium-sized rainfall. Therefore, the proposed method might be useful for quantifying the secondary effects of the infiltration facilities on groundwater recharge and urban non-point pollutant trapping as well as runoff reduction.

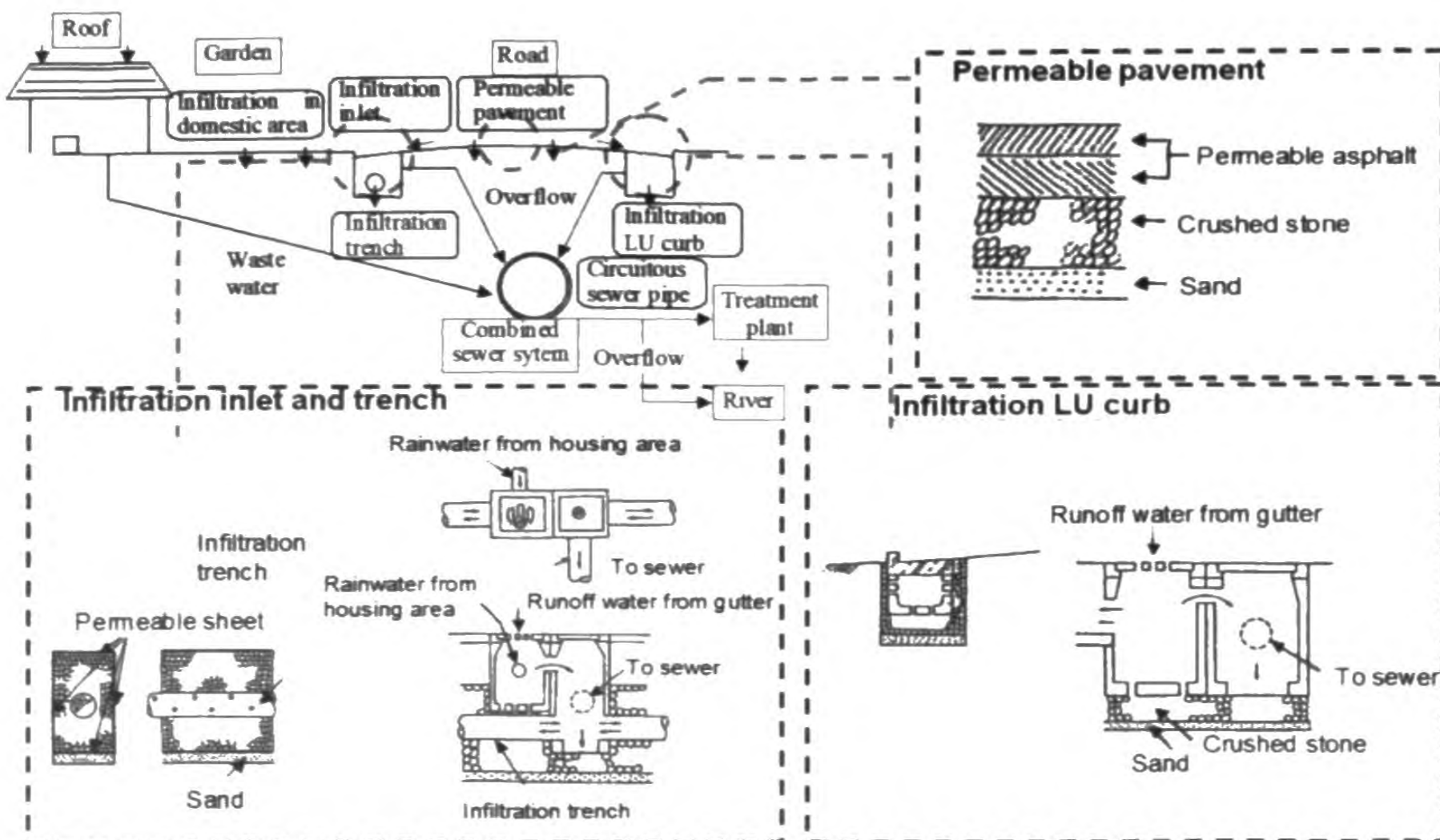


Figure 1: Configuration of infiltration facilities in the Experimental Sewer System

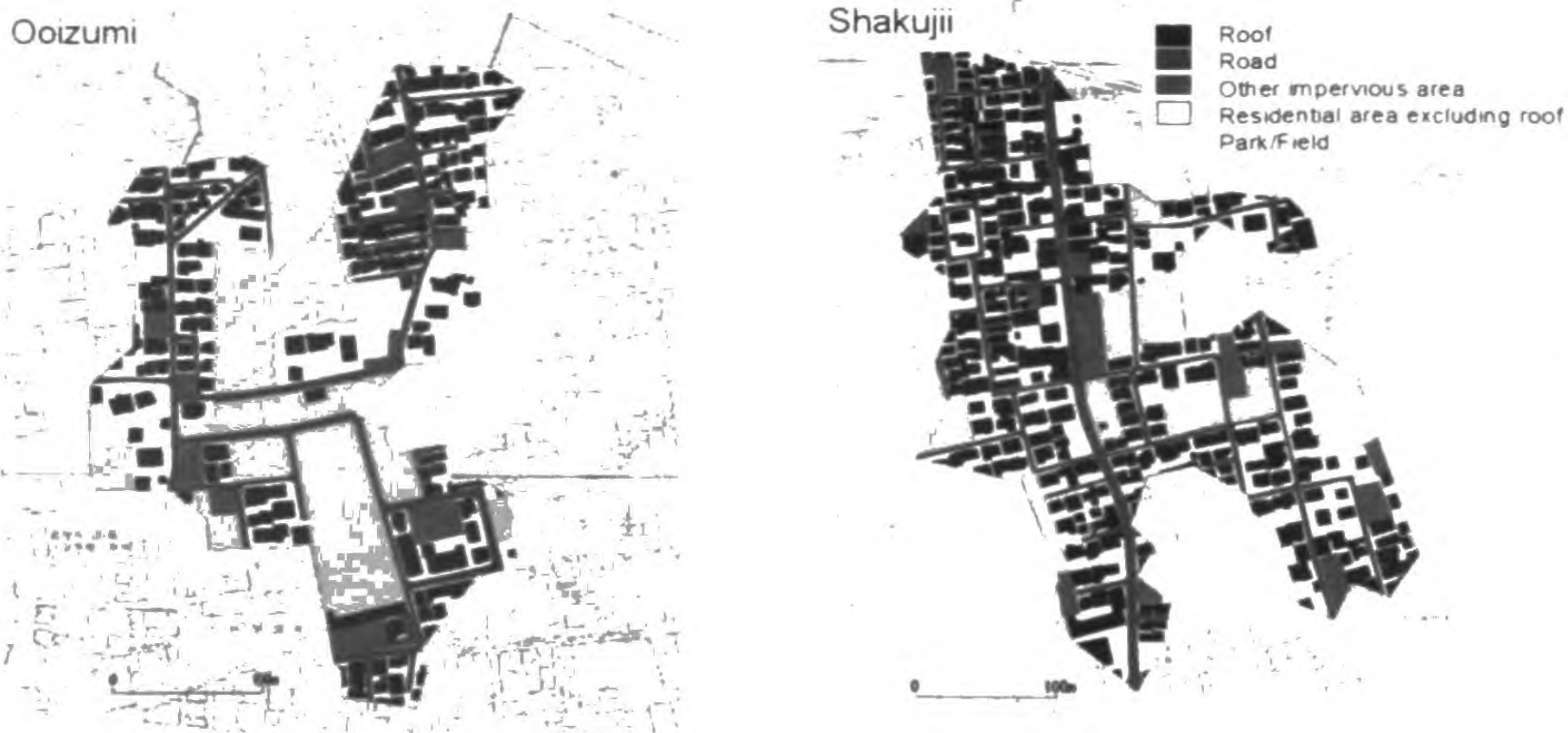


Figure 2: Map of the studied drainage areas

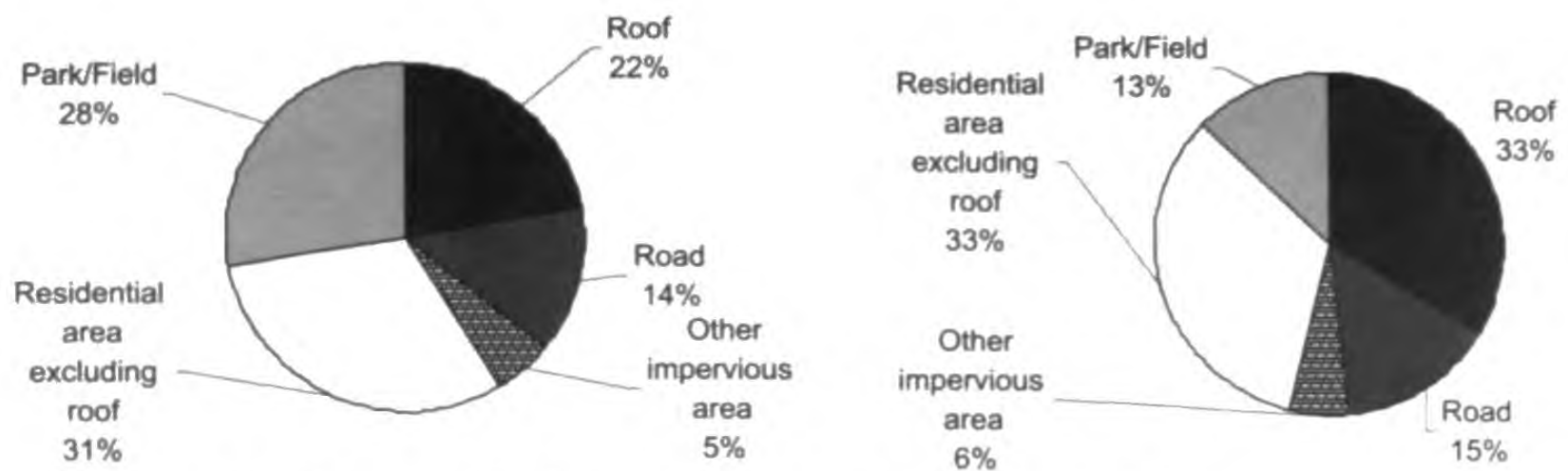


Figure 3: Map and surface type distribution in Ooizumi (left) Shakuji (right) areas

Type of facility	Infiltration rate	Storage volume
Permeable pavement	10 mm/hr	2 mm
LU curb	2.5 L/min/m	0.09 m ³ /m
Inlets	3 L/min/unit	0.108 m ³ /unit
Trench	8 L/min/m	0.0314 m ³ /m

Table 1: Ultimate infiltration rates and storage volume of each infiltration facility

Event	Total rainfall (mm)	Duration (hrs)	Maximum intensity* (mm/hr)	DWP (hrs)
Jun 15	29.0	9.9	48.0	33
Jun 18	43.3	13.1	15.6	67
Nov 25	22.1	26.0	8.4	18

Table 2: Rainfall events for runoff analysis in the Ooizumi area

* Maximum intensity is given in 5 minutes interval.

Event	Total rainfall (mm)	Duration (hrs)	Maximum intensity* (mm/hr)	DWP (hrs)
Nov 25	24.4	23.5	7.2	28
Dec 17	8.2	4.5	15.6	131

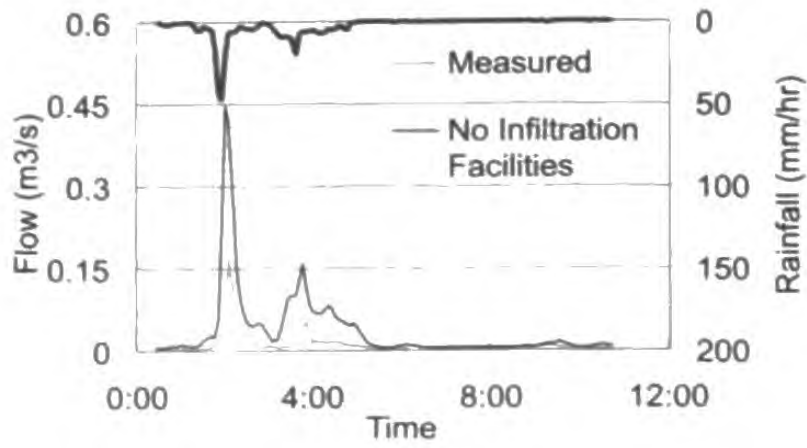
Table 3: Rainfall events for runoff analysis in the Shakuji area

* Maximum intensity is given in 5 minutes interval.

Surface type	Initial loss (mm)	Infiltration (mm/hr)
Roof	0.3	-
Road, Other impervious area	2.0	-
Pervious area	6.0	10.0
Permeable pavement	2.0	10.0

Table 4: Characteristics of the each surface type

(a) June 15 rainfall without facilities



(b) November 25 rainfall

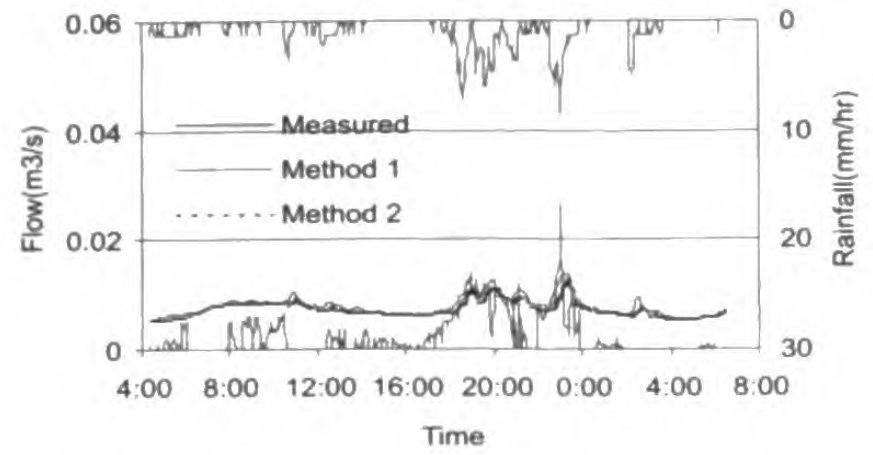
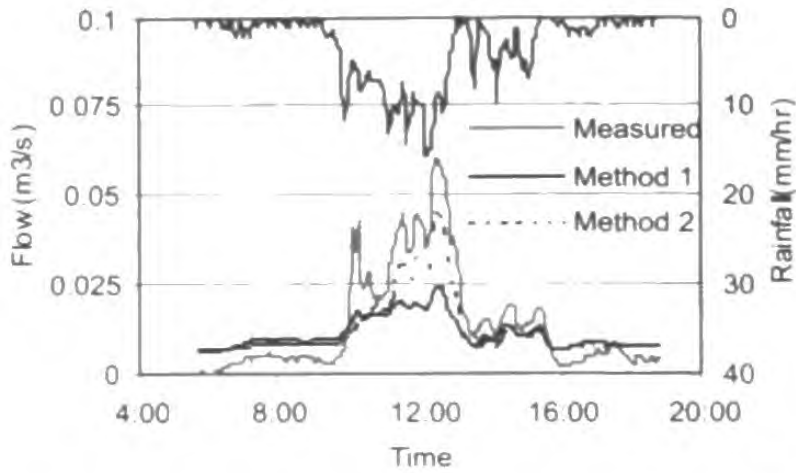


Figure 4: Measured and simulated outflow with and without infiltration facilities in Ooizumi area

(a) June 18 rainfall



(b) June 15 rainfall with facilities

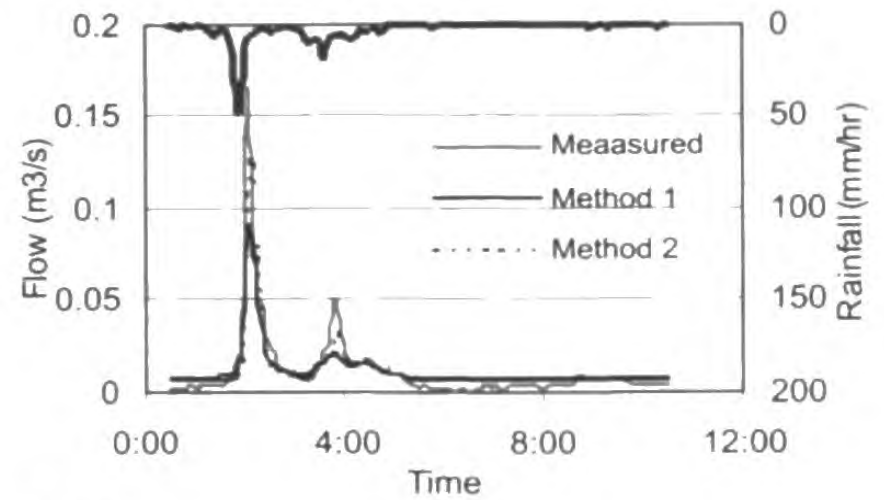
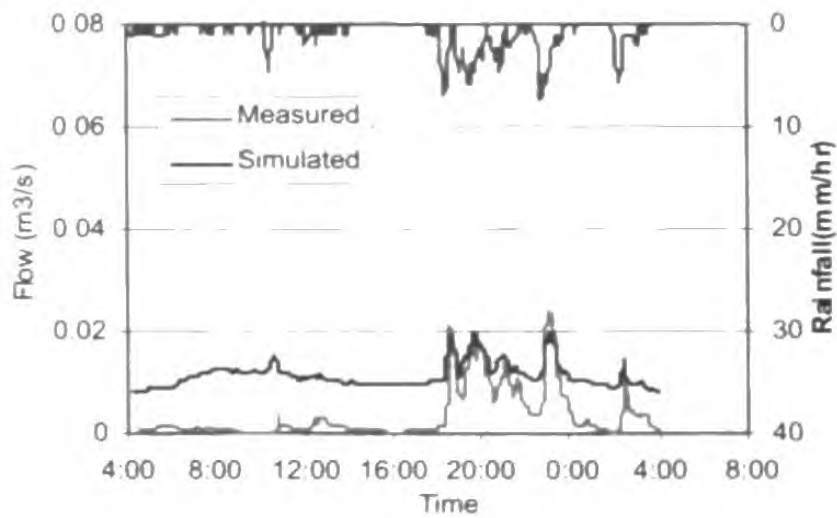
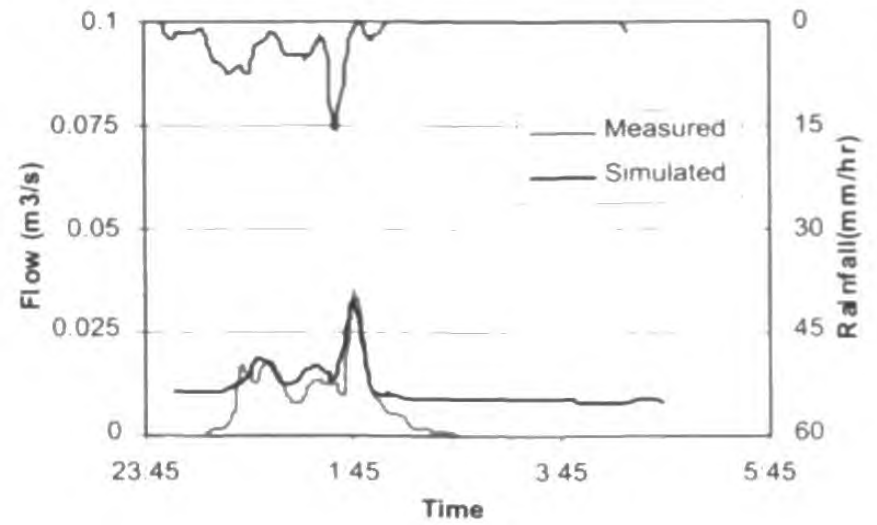


Figure 5: Measured and simulated hydrographs in Ooizumi area

(a) November 25 rainfall



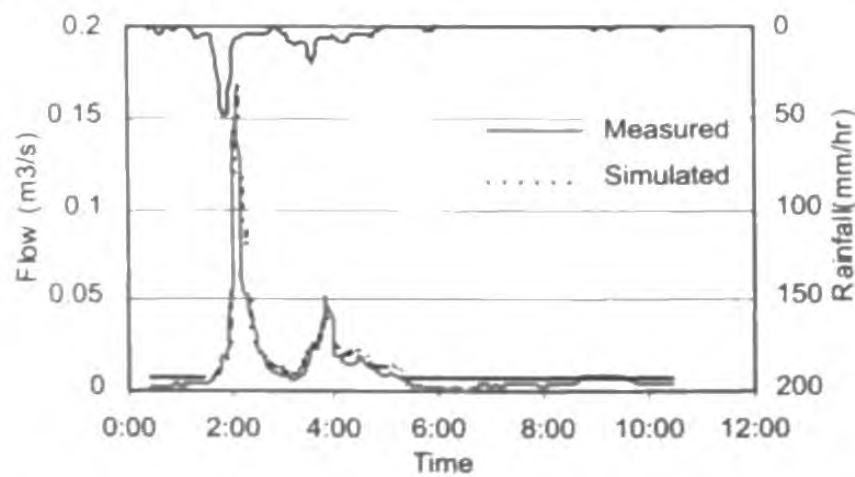
(b) December 17 rainfall



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Figure 6: Measured and simulated hydrographs in Shakuji area

(a) June 15 rainfall



(b) June 18 rainfall

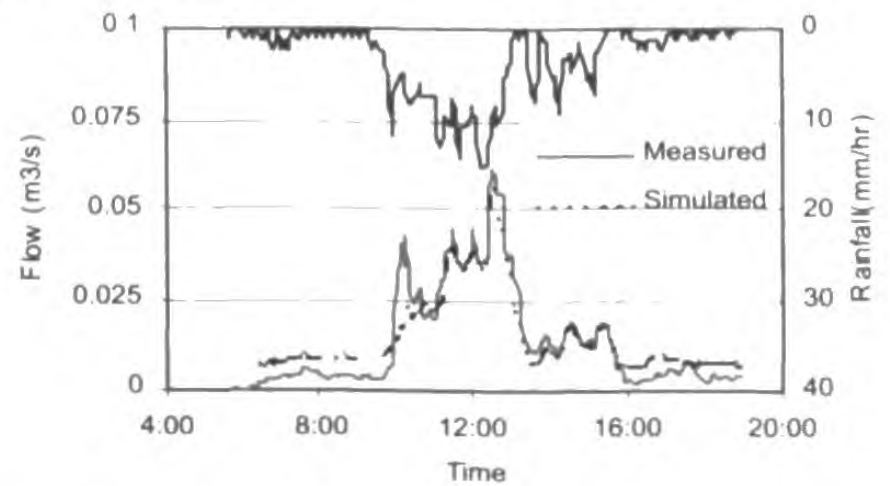


Figure 7: Simulated results considering clogging of infiltration facilities