Evaluation of a Real-Time Control System for Combined Sewer Networks

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(Received October 2, 2006)

Abstract

In this study, we evaluated the amount of reduction of the combined sewer overflow (CSO) load using real-time control (RTC) for a combined sewer system region where a storage basin had been constructed. Reduction of the load is especially high when the amount of rainfall is 10mm. Moreover, the amount of BOD load was reduced by 18 – 26%, and the overflow frequency by 14 – 29% using on RTC system based on annual analysis. In addition, it was clarified that the effect of the reduction in cost of the RTC system was high as a result of cost-effectiveness analysis. It was confirmed that the introduction in RTC system was effective for reducing the CSO.

1. Introduction

When storms bring heavy rainfall that exceeds the threshold capacity of the combined sewage systems, untreated sewage flows into public bodies of water, not only causing an ugly scene, but also causing adverse effects to the environment, including water pollution and a threat to public health[1), 2)]. Measures to combat such combined sewer overflows (CSOs) include solutions such as building storm-water retention tanks and underground accumulation facilities, but these solutions entail high construction costs, the need to secure the required land in urban areas, and long-term maintenance of the facilities. In some countries, as measures against CSOs, real time control (RTC) systems are implemented to control existing facilities in such a way as to utilize the capacity to the full[3)-5)]. The use of RTC is also in the planning stage in some parts of Japan, with expectations for positive results. The main advantage of adopting RTC over the construction of new water-retention facilities is that it can be implemented at a lower cost by installing and operating weirs, gates and monitoring devices in conjunction with existing facilities. An additional benefit is that the equipment can be installed much more quickly than it takes for the construction of new facilities, such as retention tanks, offering a rapid option for reducing the effluent load.

In this study, we investigate the volume and properties of the water discharged during wet weather at actual pumping stations and sewage processing centres, and studied the operating method and effectiveness of RTC using analytic models.

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2. The Subject Drainage District and the RTC Method

2.1 Overview of the subject drainage district and the flow of sewage water

In our research, we studied the use of RTC in two drainage districts, "District 1" (389ha) and "District 2" (472ha), both of which are equipped with combined sewer systems. Fig. 1 shows an outline of the subject drainage district.

In dry weather, sewage water from the drainage district flows over the respective diversion weirs and into Processing Plant B. When there is precipitation, sewage water of up to 3Qs flows into the treatment plant (Qs is the peak hourly dry-weather flow). Of this volume, up to 1Qs is given advanced treatment, and anything beyond this is given only preliminary treatment before being discharged. Overflow sewage water from the diversion weirs (i.e. in excess of 3Qs) heads for Pumping Station A via the inflow culvert pipes. The rate of inflow at Pumping Station A is controlled by a gate located in front of the grit chamber. The gate, in turn, is controlled by a water gauge installed in the inlet well, and the gate opens when the water reaches a certain level. Sewage water that flows into the grit chamber is pumped into the storm-water retention tank situated inside Pumping Station A using two pumps. When the storm-water retention tank is full, there is a changeover in the pumping operation, and the sewage water is simply discharged into the rivers. Sewage water held in the storm-water retention tank is sent to Treatment Plant B for advanced treatment after the rain stops.

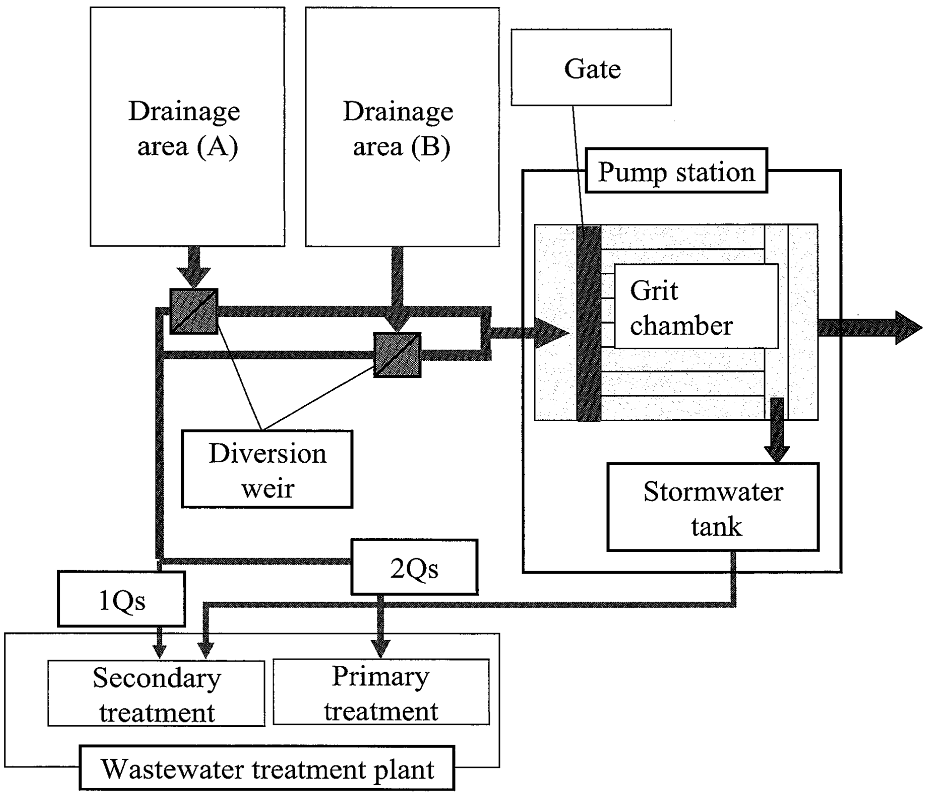

Fig. 1 Outline of subject drainage district

2.2 The RTC method

The components required for implementing RTC in the subject drainage districts are summarized below:

(A) Data monitored includes volume of precipitation, water level within the culvert pipes, water level within the storm-water retention tank, and the 3-hour rain forecast.

(B) Water flux at control points are predicted using a distributed analysis model.

(C) The facilities controlled by the RTC method are the gates in front of the diversion weirs and those at the pumping station. Using information (A) and (B) cited above, the gates are controlled in such a way as to take maximum advantage of the storage capacity of the storm-water retention tank and inflow culvert pipes connected to the pumping station.

The control algorithm based on the above premises is illustrated in Fig. 2 below.

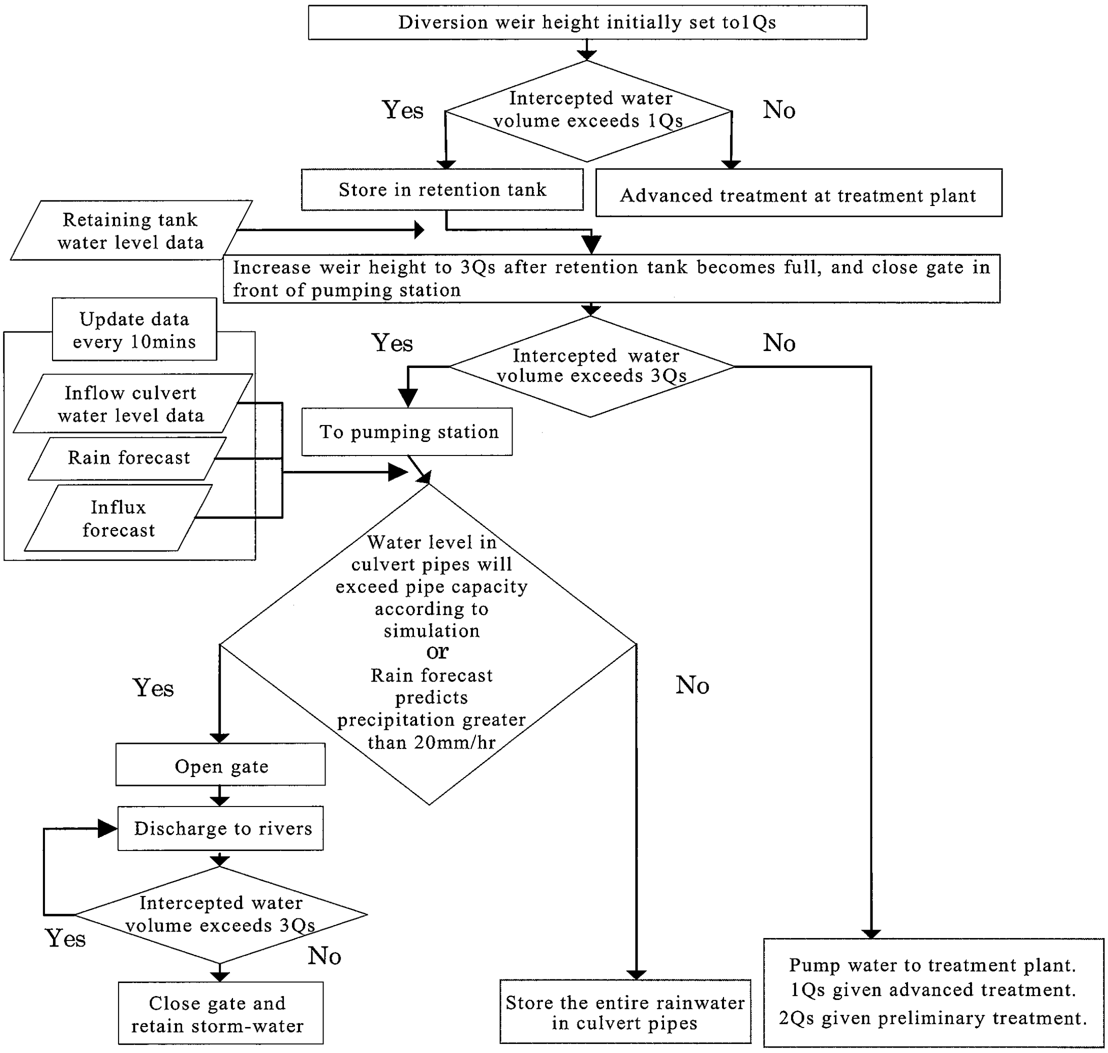

Fig. 2 RTC method

3. Quantifying the reduction in effluent load as a result of implementing RTC

In this study, we computed the reduction effects in effluent load by conducting various simulations on a distribution model created using InfoWorks CS software.

3.1 Reference precipitation

We analyzed the data for a one-year period, in order to evaluate the effectiveness of RTC as a measure for preventing overflows in combined sewer systems. As the computed annual effluent load varies according to the precipitation pattern, we created three models. Since a typical precipitation pattern was recorded in the subject drainage district in the year 2000, we used the data from 2000 as average precipitation year (total rainfall; 1,310.5mm), and used data from 1990 as heavy precipitation year (total rainfall; 1,725.0mm), and used data from 1994 as light precipitation year (total rainfall; 772.0mm) Then we quantified the effectiveness of RTC on the effluent load and compared the results for various precipitation volumes. Table 1 shows the condition of the rainfall.

Table 1. Outline of subject rainfalls

Year	Total rainfall (mm)	Frequency of rainfalls (no. of times)
Heavy precipitation year (1990)	1,725.0	95
Light precipitation year (1994)	772.0	85
Average precipitation year (2000)	1,310.5	76

3.2 The effect of RTC on the combined sewer overflows

As a result of the simulations, we found that with a total volume of precipitation of around 10mm, the entire sewage volume can be retained in the inflow culvert pipes, making it possible to reduce both the number of overflows and the effluent load. However, when the total volume of precipitation reaches around 20mm, the water level inside the culvert pipes increases, making discharge necessary in order to prevent flooding, and therefore the pollution-reducing effect is lessened. The following are observations from the perspective of overflow frequency and effluent load.

3.2.1 Frequency of overflows

Fig. 3 shows frequency of overflows. By using RTC, the frequency of overflows can be reduced by 14% for an average precipitation year, 19% for a heavy precipitation year, and

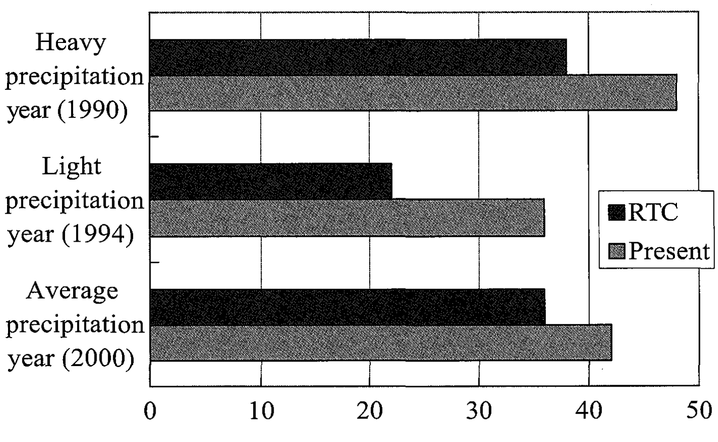

Fig. 3 Frequency of overflows

by 29% for a light precipitation year. This can be attributed to the fact that a precipitation of about 10mm, is the most frequent of rainfall patterns throughout the year. In such a case, the entire volume of storm-water can be retained inside the culvert pipes.

In addition, we found that RTC is most effective in light precipitation years, next most effective in heavy precipitation years, and least effective for average precipitation years. This is because the frequency of 10mm rainfall throughout the year is greatest during light precipitation years, followed by heavy precipitation years, and least in average precipitation years. Overflow frequency increases as the total precipitation increases, but RTC is most effective in reducing the frequency of overflow in years when precipitation averages around 10mm each time it rains.

3.2.2 Effluent load

Fig. 4 shows effluent load. And Table 2 shows the effluent load of each rain classification. By introducing RTC, the effluent load can be reduced by 18% for average precipitation years, 22% for heavy precipitation years, and 26% for light precipitation years as compared to the

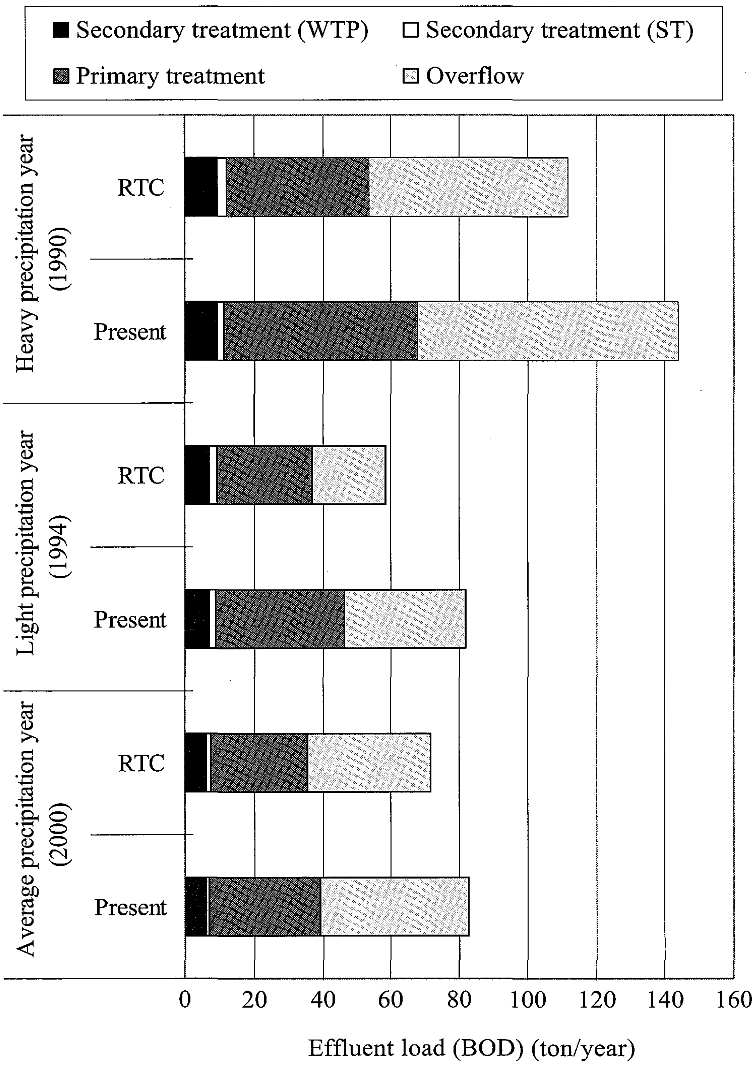

Fig. 4 Results of effluent load (BOD)

Table 2(a). Effluent load of each rain classification :heavy precipitation year (1990)

1990								
Rain classification	Frequency of rainfalls (times/year)	Present or RTC	Frequency of overflows (times/year)	BOD load (kg)				
				Secondary treatment (WTP)	Secondary treatment (ST)	Primary treatment	Overflow	Total
0.5～10mm	53	Present	6	3,490	621	17,562	997	22,670
		RTC	0	3,479	1,072	9,665	0	14,216
10～20mm	13	Present	13	1,680	437	10,738	10,761	23,616
		RTC	9	1,659	528	8,519	4,804	15,510
20～30mm	9	Present	9	1,220	292	8,363	14,325	24,200
		RTC	9	1,204	346	7,248	9,753	18,551
30～40mm	6	Present	6	774	196	4,947	9,233	15,150
		RTC	6	757	259	4,326	9,835	15,177
40～50mm	5	Present	5	818	168	5,848	11,373	18,207
		RTC	5	766	176	4,709	8,665	14,316
> 50mm	9	Present	9	1,343	247	8,863	29,209	39,662
		RTC	9	1,316	393	7,424	25,092	34,225

Table 2(b). Effluent load of each rain classification :light precipitation year (1994)

1994								
Rain classification	Frequency of rainfalls (times/year)	Present or RTC	Frequency of overflows (times/year)	BOD load (kg)				
				Secondary treatment (WTP)	Secondary treatment (ST)	Primary treatment	Overflow	Total
0.5～10mm	56	Present	7	2,926	496	14,270	1,649	19,341
		RTC	0	2,927	1,023	7,938	0	11,888
10～20mm	19	Present	19	2,636	950	15,639	17,696	36,921
		RTC	12	2,710	907	13,841	6,872	24,330
20～30mm	5	Present	5	869	214	4,389	7,043	12,515
		RTC	5	672	223	3,689	5,644	10,228
30～40mm	3	Present	3	362	109	2,129	5,219	7,819
		RTC	3	343	153	1,456	4,701	6,653
40～50mm	2	Present	2	197	117	1,217	3,613	5,144
		RTC	2	199	113	969	3,954	5,235
> 50mm	0	Present	—	—	—	—	—	—
		RTC	—	—	—	—	—	—

Table 2(c). Effluent load of each rain classification :average precipitation year (2000)

2000				BOD load (kg)				
Rain classification	Frequency of rainfalls (times/year)	Present or RTC	Frequency of overflows (times/year)	Secondary treatment (WTP)	Secondary treatment (ST)	Primary treatment	Overflow	Total
0.5～10mm	38	Present	4	1,192	188	5,656	377	7,413
		RTC	0	1,206	263	3,472	0	4,941
10～20mm	16	Present	16	1,870	527	10,437	13,344	26,178
		RTC	14	1,956	637	10,008	8,346	20,947
20～30mm	13	Present	13	1,820	337	10,610	15,852	28,619
		RTC	13	1,866	449	9,797	13,379	25,491
30～40mm	4	Present	4	473	107	2,506	4,334	7,420
		RTC	4	480	142	2,063	4,580	7,265
40～50mm	2	Present	2	182	25	862	1,953	3,022
		RTC	2	180	37	767	1,870	2,854
> 50mm	3	Present	3	343	54	2,111	7,723	10,231
		RTC	3	343	86	1,899	7,782	10,110

current state. Examining this in greater detail, we find that the overflow effluent load is reduced by between 18% and 34%, and the preliminary treatment effluent load is reduced by between 27% and 33%. As is the case with the frequency of overflows, it seems that effluent load has been reduced by such a degree because precipitation where the volume averages about 10mm is prevalent through the year.

Paralleling the overflow frequency, the effluent load increases as the volume of precipitation increases, but through the implementation of RTC, the reduction rate increases when the frequency of precipitations of around 10mm becomes more frequent.

4. Conclusions

In this study, using simulation models, we evaluated the effectiveness of RTC as a measure for reducing CSO. Our comments on the results we obtained are as follows:

(1) In a case when the total precipitation at any one time is around 10mm, the entire volume of sewage water that currently overflows can be accumulated in the culvert pipes using the RTC methods proposed in this research. More over, since the initial weir height was set to 1Qs, the highly polluted sewage that results when the rain first begins, which is currently being given only preliminary treatment, can be diverted into the retaining water tank and subsequently given advanced treatment, thereby reducing the effluent load.

(2) Having analyzed different annual precipitation pattern models, we found that the effluent load can be reduced by between 18% and 26%, and the overflow frequency can be reduced by between 14% and 29%. In addition, through analysis of different precipitation categories, we showed that a wet weather effluent load of BOD can be reduced by

between 10% and 40% in a case where total precipitation is under 30mm.

As our study has shown, the implementation of RTC as a measure for reducing CSOs- an urgent issue for the current sewage system administration- has been found to be a highly valuable approach toward reducing the BOD effluent load as well as the overflow frequency, especially when there are frequent overflows due to precipitation of less than 30mm at any given time.

References

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