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Characteristics of pollutants discharged into rivers/streams & Plan to reduce CSOs in Urban Area when Raining

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Abstract

A comprehensive review on the policies for non-point source control to reduce contaminants discharged into the river by Seoul Metropolitan Government, was carried out to improve the quality of life standard of the citizens.

The optimum measures to achieve and maintain water quality goal were studied with prediction on river water quality and reduction of pollutant loading through basin-based management and improvement of treatment utilities to reduce CSOs when raining.

The average BOD load by an independent rainfall event of the non-point source management targets between 2005 and 2009 was 22,845.1 t/year while that of the effluent from the wastewater treatment plants in seoul. And, The amount of CSOs to be treated to maintain BOD load less than 40 mg/L, was estimated to be 3,950,600 m^3 per independent rainfall event.

Keywords: Pollutants load, Combined sewer system, Public water body, Non-point Pollution sources, Regulating system with Total Maximum Daily Load approach, BOD loads

Introduction

There are many rivers and streams in Seoul including the Han river and the 36 streams regulated and managed by law. Seoul Metropolitan Government has kept the water quality of those rivers and streams to meet water quality standards for swimmable condition for the citizens to enjoy the environments of the river and the streams.

As a result of implementation of policy on water management to provide all the citizens with the service of wastewater treatment and sewage system, the service rate became 100% and the river water quality has been improved magnificently by reduced pollutants load to the river. However, there are still some difficulties in maintain the effluent water quality to meet the standard when rainfall exceeds the capacity of the sewer system, i.e., the combined sewer system forms 86% of the total sewer system of Seoul, pollutants are discharged directly into the river and the streams without any treatment.

Although contaminants do not flow into the public water body or the river and the stream without raining, high concentration of contaminants flow into the water system as CSOs (Combined Sewer Overflows) and influence the ecosystem in the river and the stream.
The Ministry of Environment expanded the environmental policies for the 4 major rivers of Korea, to the tributaries, to maintain high water quality and healthy aquatic ecosystem with the goal to manage all the rivers and the streams in Korea with BOD level higher than 5mg/L. CSOs reduction project has been carried out to achieve the goal. In accordance with the policy of the central government, Seoul Metropolitan Government has made every effort to reduce CSOs which takes great portion in contaminant load by raining in urban area, and to manage and regulate non-point pollution sources to meet the effluent water quality standards in the public water body and the rivers.

As water quality deterioration by CSOs in the area with combined sewer system has been worse and the regulating system with Total Maximum Daily Load approach has taken effect in the Han river basin since June 2013, Seoul Metropolitan Government needed to manage CSOs more effectively.

A comprehensive review on the policies for non-point source control to reduce contaminants discharged into the river by Seoul Metropolitan Government, was carried out to improve the quality of life standard of the citizens.

Methods

The total system of Seoul was classified into 13 small basins by the characteristics of the basin including area, topography, geography, and sewer pipe system. The path of pollutants by stream basin when raining was investigated first. The pollutant loadings through 1,028 storm overflow outlets, and those discharged to stream basins by rain pattern, were estimated.

The optimum measures to achieve and maintain water quality goal were studied with prediction on river water quality and reduction of pollutant loading through basin-based management and improvement of treatment utilities to reduce CSOs when raining.

Results and Discussions

1) Distribution of pollution loads

The population of Seoul was 10,456,000. The large population was one of the major sources of pollution in Seoul. The sources can be categorized into household pollutants, industrial pollutants, livestock pollutants, and land-originated pollutants. The land area was

602,252,502㎡ and the plottage was 42.1% of land area, i.e., 254,928,689㎡ and the road took 12.5% of the land area, i.e., 75,497,253㎡.

The total BOD loads of Seoul was 371,103.2 t/year; 353,170.6 t/year (95.2%) from house, 10,465.9 t/year (2.8%) from land, and 7,454.6 t/year (2.0%) from industry, 1.4 t/year from livestock, and , 10.7 t/year from landfill.

The BOD load from road area was 2,367.1 t/year and took 0.6% of the BOD loads from land. The BOD load discharged to the river was 56,894.8 t/year (15.3%). The BOD loads discharged to the river by CSOs was 34,080.2 t/year (59.9%) while by effluent from wastewater treatment plants was 18,305.5 t/year (32.2%). The BOD loads without treatment was 4,200.8 t/year (7.4%).

When raining, pollutants were discharged into the river and the streams through storm overflow outlets. There were 1,556 storm overflow outlets in Seoul and 1,028 outlets had storm overflow chambers.

2) Pollutants loads and their characteristics when raining

① Pollutants to be managed when raining

As the main sources of pollutant loads to the river and the streams when raining includs urban wastewater, contaminants from non-point source, and sediments from sewers, appropriate management of the non-point source pollutants can affect reduction of CSOs directly.

The following pollutant sources were controlled to improve river water quality when raining; (1) CSOs from storm overflow outlets, (2) intercepted 3Q of raw wastewater without treatment, and (3) direct discharge from non-point sources in the area without wastewater treatment system. As CSOs and untreated wastewater were the main sources of pollutants, those two sources were selected for management study.

② Pollutants load when raining

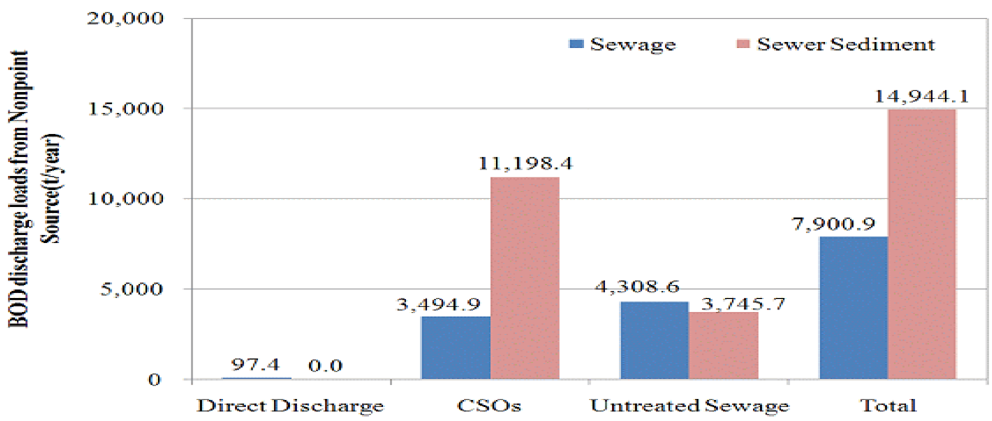
Wastewater from CSOs from non-point source, untreated wastewater, and private discharge were discharged to public water body and streams as wastewater and sediments. BOD loads of the wastewater and sediments were estimated by the data of independent rainfall events between 2005 and 2009.

Pollutants loads by pattern were listed in Table 1 and Figure 1. The average BOD load by an independent rainfall event of the non-point source management targets between 2005 and 2009 was 22,845.1 t/year while that of the effluent from the wastewater treatment plants, which were point source management targets, was 18,010.3 t/year. Pollutants loads discharged as wastewater was 7,900.9 t/year and took 34.6% of total BOD loads while those discharged as sediments was 14,944.1 t/year and 65.4%, e.g., most of pollutants loads was discharged as wastewater and sediment. Considering the pattern of pollutants loads, CSOs took 64.3%

(14,693.3 t/year) while untreated wastewater took 35.3% (8,054.4 t/year), and direct discharge 0.4% (97.4 t/year).

<Table 1> BOD load by untreated wastewater and direct discharge when raining

division		2005	2006	2007	2008	2009	Average (t/y)
sewage	domestic	6,168.1	7,077.8	6,790.4	6,973.5	7,063.1	6,814.6
	industry	6.5	7.6	7.2	7.4	7.5	7.3
	livestock	0.1	0.1	0.1	0.1	0.1	0.1
	land	261.5	222.7	236.9	221.1	260.4	240.5
	land(except roads)	950.5	748.2	822.1	748.8	922.7	838.5
	small total	7,386.7	8,056.4	7,856.8	7,950.9	8,253.8	7,900.9
sewer sediment	domestic	13,745.0	17,403.6	11,114.1	13,972.5	18,135.5	14,874.1
	industry	12.0	14.9	9.6	12.0	15.6	12.8
	livestock	0.0	0.0	0.0	0.0	0.0	0.0
	land	28.0	34.4	22.7	27.8	35.6	29.7
	land(except roads)	27.8	30.3	22.5	25.7	31.3	27.5
	small total	13,812.7	17,483.2	11,168.9	14,038.0	18,217.9	14,944.1
total		21,199.4	25,539.6	19,025.7	21,988.9	26,471.7	22,845.1



<Figure 1> Average annual BOD load by pattern of discharge when raining

③ Occurrence of CSOs and events requiring management

Pollutants discharged when raining could be regulated by frequency and allowable discharge concentration. The allowable discharge concentration of pollutant which was target for non-point source management, was regulated by law, i.e., BOD of CSOs should be less than 40 mg/L. According to the Sewer system act amended in 2007, private sewage system could be excluded from combined sewer systems. The number of events and the quantity of CSOs to be treated were analyzed by investigating the number of events of CSOs and untreated wastewater, in order to understand discharging characteristics of pollutants loads when raining. The average number of events of CSOs in storm overflow outlets when raining was 31.8 a year and the number of events of CSOs to be treated to meet the standard of BOD less than 40 mg/L was 29.1 per year.

④ **Water quality of CSOs**

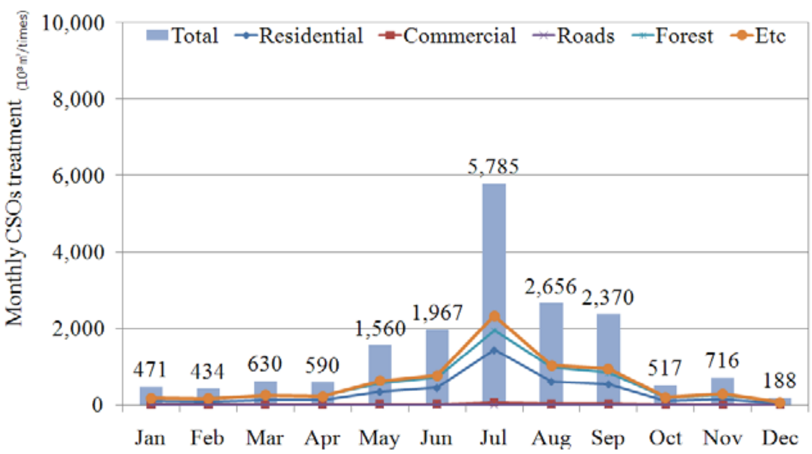
CSOs when raining exerted bad influence on river water quality and ecosystem, due to increased pollutants loads at the beginning of raining event, from re-suspended sediments in sewer pipes and 'first flush' of the surface of urban area. The concentration of pollutants in CSOs with short rain with flushing potential in spring time when pollutants were accumulated in high concentration during dry season of winter from December to February, i.e., with less precipitation and long dry time precedent to rain.

The average BOD of Jungrangcheon basin within 10 minutes after CSOs occurred was 176.7 mg/L in dry season (December - February) while that in flood season was 108.1 mg/L (June - September) and that in the rest seasons was 120.8 mg/L (March - May, October - November). In Tancheon basin, the average BODs within 10 minutes after CSOs were 201.2 mg/L, 79.2 mg/L, and 114.5 mg/L, in dry, flood, and the rest seasons, respectively. For Anyangcheon basin, they were 175.7 mg/L, 104.4 mg/L, and 136.4 mg/L.

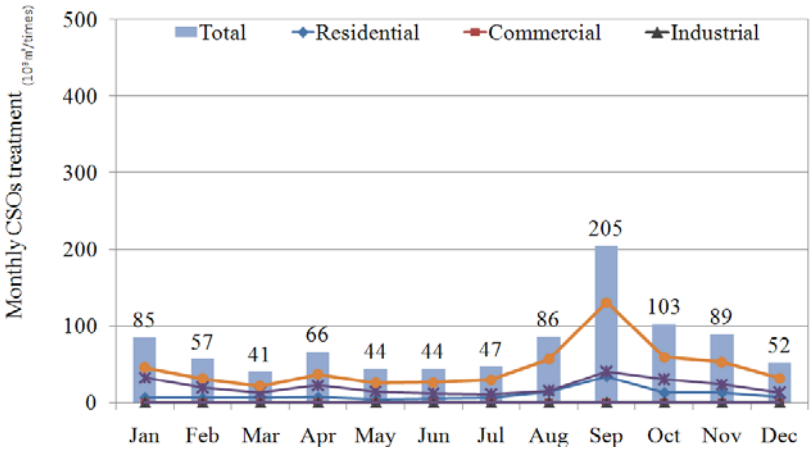
3) Reduction of CSOs in Seoul

① **Amount of CSOs treated**

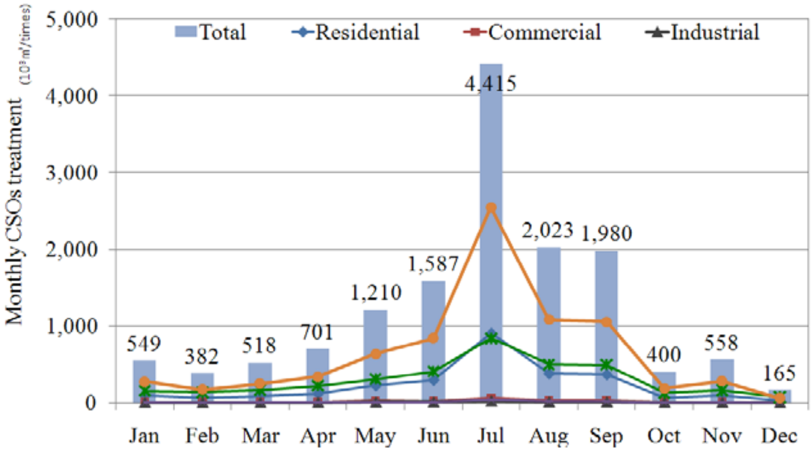
Monthly averaged amount of untreated wastewater and CSOs with the concentration exceeding 40 mg/L at one independent rainfall event, were analyzed to estimate the amount requiring treatment. The representative amount of untreated wastewater and CSOs to be treated, was determined from the largest monthly averaged amount to be treated between October and May, i.e., excluding the period between June and September with relatively large quantity of precipitation. Among the 13 stream basins in Seoul, the CSOs to be treated in an independent rainfall event in the main streams were illustrated in Figure 2, Figure 3, Figure 4, and Figure 5.



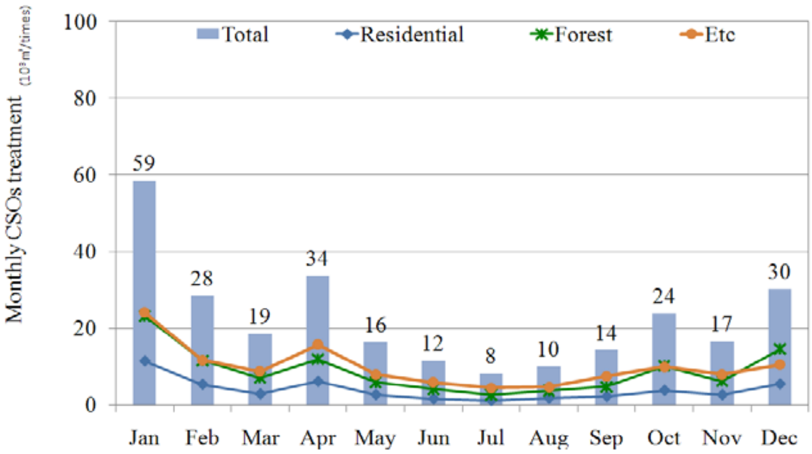
<Figure 2> Monthly averaged amount of CSOs to be treated in an independent rainfall event in the Jungrangcheon stream basin



<Figure 3> Monthly averaged amount of CSOs to be treated in an independent rainfall event in the Tancheon stream basin



<Figure 4> Monthly averaged amount of CSOs to be treated in an independent rainfall event in the Anyangcheon stream basin



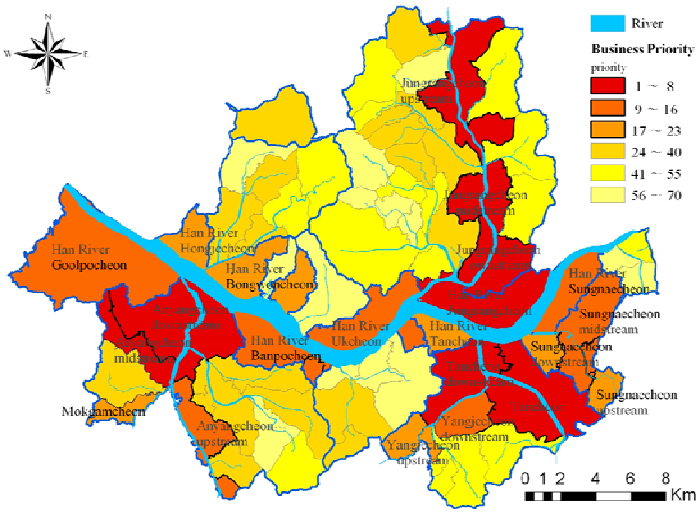
<Figure 5> Monthly averaged amount of CSOs to be treated in an independent rainfall event in the Hongjecheon stream basin

② Zones for CSOs management

70 zones were selected in Seoul for efficient management of CSOs considering the conditions of 1,028 storm overflow outlets with chamber, 13 river and stream basins, drainage sewer

network, and topography. The 13 river and stream basins were divided considering 9 river and stream basins flowing into the Han river. The 70 zones for CSOs management were determined by considering 36 statutory streams, the main stream of the Ukcheon, and storm overflow chambers. The major streams were divided into 3 sections, i.e., upstream, middle stream and downstream, and the zones for CSOs management were divided to understand the detailed impact of CSOs on each stream. The 70 zones for CSOs management were the basic unit for non-point source management by the City of Seoul as well as the unit for project.

4 main parameters were applied to determine priority of step-wise project considering importance of CSOs management on the 70 zones in Seoul, i.e., 1) frequency of use by the citizens, 2) reduction rate of pollutant loads, 3) achievement rate for stream water quality goal, and 4) importance of the role of the stream. After the order of priority of project for the streams was determined according to each parameter excluding dry streams, the comprehensive order of priority was estimated considering all the 4 parameters by zone. The resulting 23 management zones were listed in Table 2 and illustrated in Figure 6.



<Figure 6> 23 important CSOs management zones

<Table 2> 23 important CSOs management zones

1～8	9～16	17～23
Jungrangcheon downstream	Sungnaecheon midstream	Sungnaecheon downstream
Jungrangcheon midstream	Yangjecheon downstream	Han River Hongjecheon
Tancheon	Anyangcheon upstream	Sungnaecheon upstream
Anyangcheon downstream	Han River Ukcheon	Han River Tancheon
Jungrangcheon upstream	Han River Anyangcheon	Mokgamcheon
Han River Jungrangcheon	Han River Sungnaecheon	Han River Bongwoncheon
Anyangcheon midstream	Han River Goolpocheon	Yangjecheon upstream
Tancheon downstream	Han River Banpocheon	

③ Comprehensive treatment plan for CSOs

The amount of CSOs to be treated to maintain BOD load less than 40 mg/L, was estimated to be 3,950,600 m^3 per independent rainfall event.

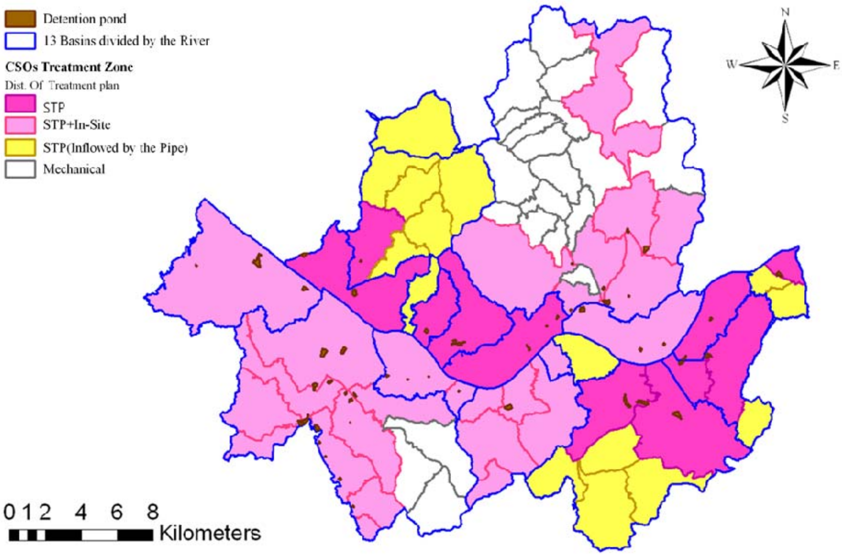
Treatment plan for 3,950,600 m^3 of CSOs from the 13 stream basins was established. It was found to be efficient that 910,121 m^3 (23.0%) should be treated by mechanical type while 3,040,459 m^3 (77.0%) by reservoir type. Among the 3,040,459 m^3 treated by reservoir type, 39.3% (1,193,383 m^3) should be treated after transferred to wastewater treatment plant when it would be clean after rain stopped while 60.7% (1,847,076 m^3) should be treated on sites.

<Table 3> Wastewater treatment plants for the 13 CSOs management zones

13 river Stream basins	STP	CSOs management plan				Total (㎥/times)
		Wastewater treatment plants	Wastewater treatment plants+on sites	Sent to Wastewater treatment plants	Mechanical type	
Han River -Jungrangcheon	Jungrang		147,289			147,289
Jungrangcheon	Jungrang		871,104		711,297	1,582,401
Han River - Tancheon	Tancheon	31,013		20,388		51,401
Tancheon	Tancheon	123,898		25,512		149,410
Godeok River	Tancheon	1,265		6,439		7,704
Sungnaecheon	Tancheon	78,769		18,879		97,648
Han River - Anyangcheon	Seonam		306,024			306,024
Anyangcheon	Seonam		975,416		198,824	1,174,240
Banpocheon	Seonam		289,223			289,223
Han River –Hongjecheon	Nanji	55,210		2,948		58,158
Hongjecheon	Nanji	15,412		43,735		59,147
Bongwoncheon	Nanji			5,832		5,832
Ughcheon	Nanji	22,103				22,103
Seoul total		327,670	2,589,056	123,733	910,121	3,950,580

<Table 4> Plan for CSOs treatment for the 70 CSOs management zones

Wastewater treatment plants	Number of CSOs management zones			Area of CSOs management zones		
	Reservoir type	Mechanical type	Total	Reservoir type	Mechanical type	Total
Jungrang	7	18	25	100.2	90.0	190.2
Tancheon	14	0	14	114.9	0.0	114.9
Seonam	16	3	19	167.2	22.8	190.5
Nanji	12	0	12	109.8	0.0	109.5
Total	49	21	70	492.6	112.8	605.4



<Figure 7> Plan for CSOs treatment

4) CSOs treatment plan by 2020

The management zones were selected for treatment project of CSOs by 2020 according to the priority of the site. The selected 8 zones were located at Jungrangcheon stream, Tancheon stream, and Anyangcheon stream Basins. There were 4 management zones in the Jungrangcheon stream basin, including downstream, midstream, upstream and the Han River-Jungrangcheon stream. There were 2 management zones in the Tancheon stream basin including Tancheon stream and downstream, and 2 zones in the Anyangcheon stream including downstream and middlestream. The plan was listed in Table 5.

<Table 5> Plan for CSOs treatment plants in Seoul by 2020

Division			Capacity of CSOs Management zones			STP	
Step projects	70 of CSOs Management zones	Sewage treatment plants	Mechanical type	Reservoir type	Total	Clean weather	Transportation Rate
1st Step	Jungrangcheon downstream	Jungrang		133,661	133,661	34,304	25.7
	Jungrangcheon midstream	Jungrang		300,164	300,164	77,036	25.7
	Jungrangcheon upstream	Jungrang					
2nd Step	Tancheon	Tancheon		72,997	72,997	72,997	100.0
	Anyangcheon downstream	Seonam		352,637	352,637	107,904	30.6
3rd Step	Han River Jungrangcheon	Jungrang		147,289	147,289	37,801	25.7
	Anyangcheon midstream	Seonam		99.676	99.676	30,500	30.6
	Tancheon downstream	Tancheon		50,901	50,901	50,901	100.0
Before 2020			0.0	1,157,325	1,157,325	411,444	35.6
After 2021			910,121	1,814,475	2,724,596	764,318	42.1
TOTAL			910,121	2,971,800	3,881,921	1,175,762	39.6

4. Conclusion

The City of Seoul needs to reduce CSOs, which takes the largest part in pollutant loading with rainfall in urban area as the regulations on pollutants discharge will be tightened by implementation of the act on total load of pollutants to river to the Han river basin in June 2013.
In addition, it is expected that pollution by non-point sources increase due to increased activities related with production, higher utilization of land, and increased impermeable pavement.
Seoul has controlled the pollution base on clean weather conditions.
As the management of wastewater considering conditions with rain has become more important, the city investigated rainfall characteristics, amount of CSOs, pollution load by CSOs, and water quality change at 1,028 storm overflow outlets in the 13 stream basins. The number of CSOs events and the number of CSOs to be treated were estimated based on the results.
The long- and short-term plans and strategy to control non-point sources were laid to achieve stream water quality goal under clean weather condition by reducing pollutants discharge during raining events.
It is expected that pollutants, which deteriorated river water quality, can be reduced and the citizens can enjoy clean water and environments through the plans and the strategies.

Acknowledgement
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Reference

SungHwan Hwang. (2011). A Study on Discharge Load Change of Nonpoint Pollution Source by Watershed Management Using Long Term Runoff Model of Urban Area. Universe of Seoul.

Sartor J.D, Boyd G.B. (1972). Water Pollution Aspects of Street Surface Contamination. EPA R2-72-081, U.S. Envir, Protection Agency, Washington, D.C.

Pisano W.C., Queiroz C.S. (1984). Precedures for Estimating Dry Weather Sewage Inline Pollutant Deposition-Phase II. Report No. EPA-600/2-84/020(NTIS PB 84141-480), U.S. Environmental Pretection Agency, Municipal Environmental Research Laboratory, Cincinnati. OH.