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Application of Water Quality Management System of Freshwater Lake

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Abstract

Lake water quality assessment information is useful to anyone involved in lake management, from lake owners to lake associations. It provides lake water quality criteria, which can improve the ways how to manage out lake resources and how to measure current conditions. It also provides a knowledge base so that the lakes can be protected and restored.

Here, the Freshwater Lake Water Quality Management System(FLAQUM) was developed. The results of FLAQUM application by scenario proved that pollutant load at rainfall by the nonpoint sources was much more than normal times at rainfall. From the result of Scenario Ⅰ (pollutant source increase case), the concentrations of Boryeong freshwater lake were BOD 9.43 mg/L, T-N 4.53 mg/L and T-P 0.21 mg/L, respectively, and those values exceed the standard of agricultural water. And in case of Scenario Ⅰ and Ⅱ (the present case) excluding Scenario Ⅲ (pollutant source decrease case), all of T-N and T-P are either mesotrophication or eutrophication, on the other hand when 60% of pollution source is removed, the concentrations of Scenario Ⅲ were BOD 3.21 mg/L, T-N 0.95 mg/L, T-P 0.11 mg/L, respectively, and which satisfies the standard of agricultural water quality.

Keywords : Freshwater lake water quality management system, Pollutant load, SWMM, WASP5, Control of pollutant source

Ⅰ. Introduction

Freshwater lake in the reclaimed land can be easily polluted since large portion of the pollutant load originated from upstream watershed flows into the lake. Recently, increasing pollutant loads accelerate the contamination and eutrophication phenomena of freshwater lakes. In case of the Asan and Yeongsan, and even Haenam fresh-water lake, eutrophication have been largely processed. For Boryeong freshwater lake, the subject of this study, the eutrophication is under processing because of the inflow of sewages. For the management of water quality of lakes in reclaimed area, the systematic countermeasures

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to improve water quality, for example, construction of management device of pollutant sources and reasonable treatment facilities are required, and the model to simulate water quality in the future is needed.

For the purpose, the Freshwater Lake Water Quality Management system (FLAQUM) was developed, and which was programmed to help regional managers assess the water quality of a rural basin. The integrated user interface system, FLAQUM, was written in Visual Basic and includes three subsystems such as a database management system, basin pollutant loads simulation model using the SWMM model and the freshwater lake water quality simulation model using the WASP5 model. And it is possible for FLAQUM to simulate through control of pollutant load for water quality management counterplan.

In this study, runoff and pollutant load from the watershed and water quality of freshwater lake were simulated. For water management counterplan of freshwater lake, FLAQUM was applied according to scenarios with increase and decrease of pollutant source.

Ⅱ. Materials and Methods

1. Project Site

Boryeong freshwater lake, the subject of this study, is located in Boryeong city, Chungnam province, and total watershed area is 14,180ha.[4),9)] Boryeong watershed is divided into nine small watersheds as shown as Fig. 1.

Input data was directly obtained from the measurement or other various data, such as precipitation, land use, slope and width of water

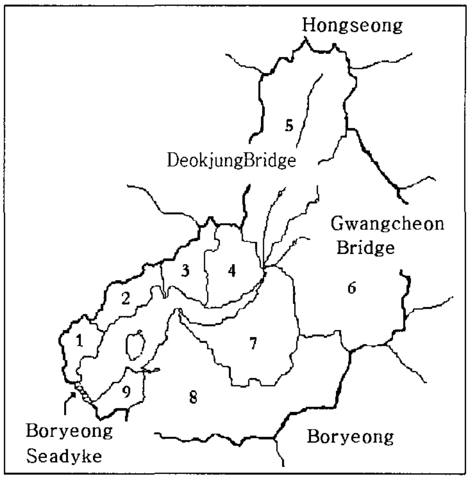


Fig. 1 Watershed of the Boryeong freshwater lake

Table 1 Characteristics of the freshwater lake

Items	Unit	Specification	Remarks
Watershed area	ha	14,180	
Irrigation area	ha	5,145	Full
Reservoir capacity	ha-m	2,410	water
Storage requirement	ha-m	1,963	level
Full water level area	ha	821	

shed, length and slope of streams etc. was surveyed. Table 1 shows the geographical input data of the study watershed.

In this study, water column of Boryeong lake was divided into spatial interval that special quality of water seems to be similar, considering topography, depth of water and water quality distribution of lake.

Fig. 2 is the partition of water column, divided into 6 sections by 12 segments from lake inlet to tidal embankment.

Changes of water quality of the streams in watershed and freshwater lake have been monitored to construct basic database since November of 1998. Several points in main streams and

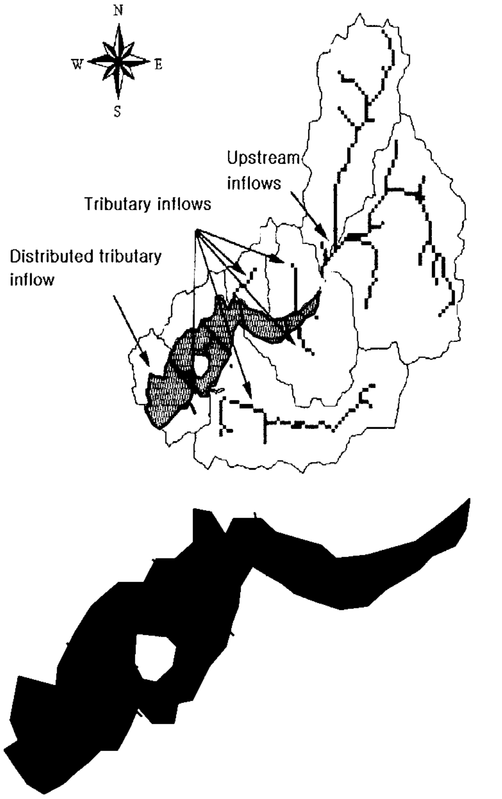


Fig. 2 Define the streams and boundary of Freshwater lake

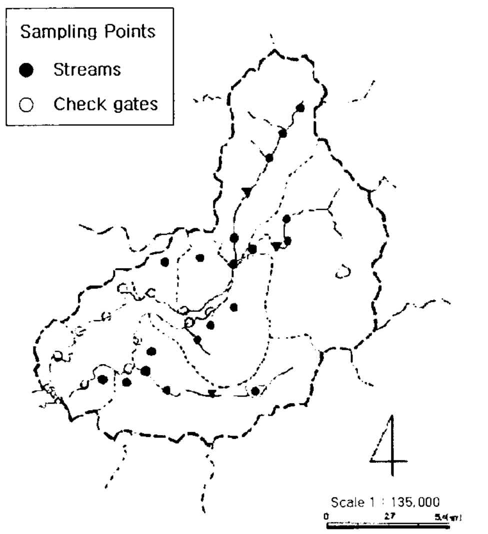


Fig. 3 Sampling points in main streams and check gates

check gates where the water flow into the freshwater lake from the streams were selected for sampling, and the sampling points are shown in Fig. 3.

2. GIS Data Construction and Database

Characteristics of Boryeong watershed were analyzed using GIS (Geographic Information System) and RS (Remote Sensing) technique. It is widely used gradually since Geographic Information techniques can analyze the characteristics of large scaled watersheds accurately and quickly.

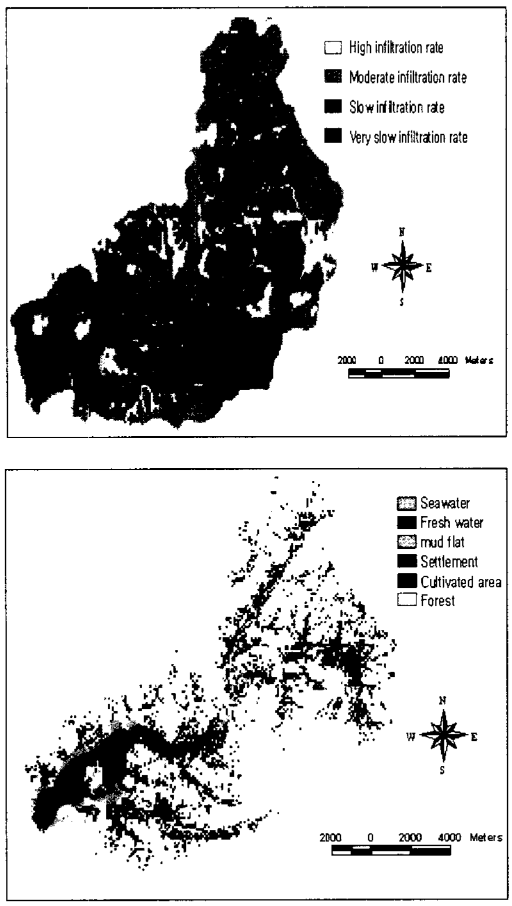


Fig. 4 Soil drainage distribution and land use in Boryeong ares

GIS data in this study was constructed using IDRISI and ARC/INFO program from the geographical map, soil map and DEM data (Fig. 4).

Ⅲ. Development of Freshwater Lake Quality Management System

1. Basic Theories

The model basically used the theory of SWMM model which was developed by the United States of America EPA (Environmental Protection Agency)[12] in 1971. Since version 3, serial simulation became possible, version 4(1988) is used at present.[13] This model can be applied in urban and ordinary non-urbanized regions to forecast the quantity and quality of discharged water. SWMM is widely used not only simulation of separated single events but also continuous simulation of discharge of urban storms.

WASP5 model theory is used for water quality of freshwater lake, it is possible to simulate the movement of water column in reservoir, river, estuary and ocean. And it is possible a simulation about movement and interaction of main water quality item with BOD and DO, eutrophication item and poison. And it is the box type model that is possible segment partition by element and element partition model that regard each element as one box. Because this model can consider change by time, analysis of water quality change of short interval as well as all the year round is possible. According to necessity, it is model that analysis of 1, 2, 3 dimension is possible.

For development of water quality estimation and management user interface system of freshwater lake, in this study, simulated using SWMM and WASP5 theory which was applied by Kim(2002).[1),2)]

2. Development of FLAQUM

1) Method of the System Development

Development of freshwater lake quality management system allows purpose to give the convenience in water quality estimation and management. In this study, the Object-Oriented Programming method by general PC program was used so that nonprofessional can operate system. Program language is made by Visual Basic, simplified input and output for simulation of system maximum.

Object-Oriented Programming method includes variability that can modify, supplement and add a interior function. And because it used standard interface, it can support existent application program.

2) Design of Freshwater Lake Quality Management System

The FLAQUM are consisted that inflow pollutant load estimation model using SWMM for simulation of runoff and inflow pollutant load from basin, water quality estimation model using WASP5 for simulation of freshwater lake quality and DBMS (DataBase Management System) managed topography of basin, meteorological data, input data and output data. Inflow pollutant load estimation model of FLAQUM constructed input data to DBMS through calculation of discharge amount and pollutant load from basin and consisted so that can change the land utilization rate for water quality management (Fig. 5). Water quality estimation model calculates pollutant

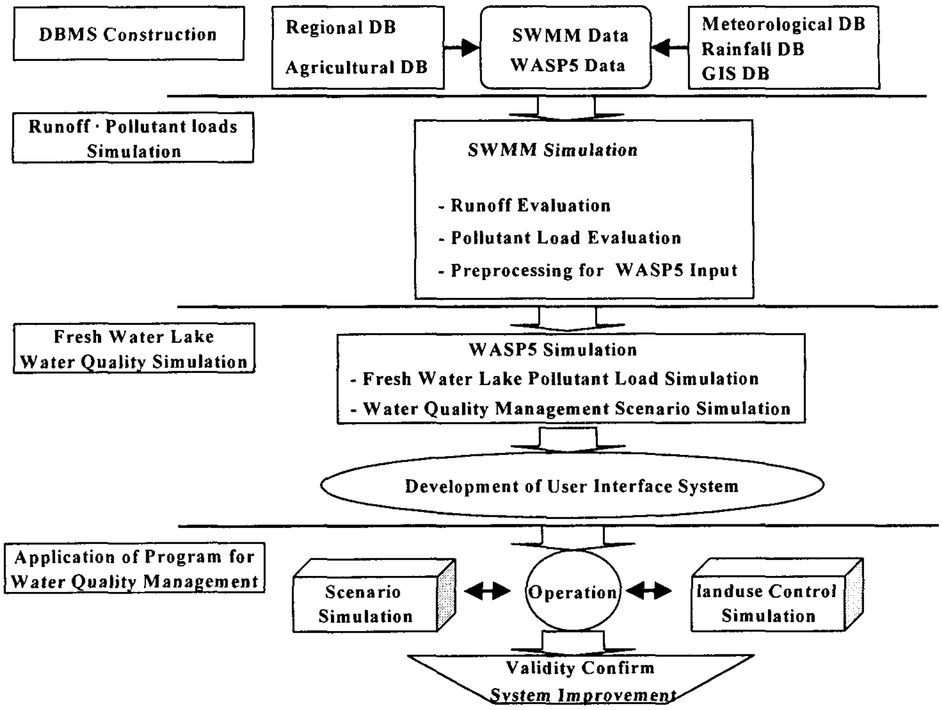


Fig. 5 Flow chart of freshwater lake water quality management system

density of BOD, DO, T−P and T−N on the basis of pollutant loads. DBMS was constructed data of study area, made so that can compare existing estimate data easily.

Because application of scenario by pollutant source control is possible, for management of freshwater lake quality, simulated so that can establish long term water quality management countermeasure of Boryeong freshwater lake.

Ⅳ. Results and Discussion

1. Revision and Verification of System

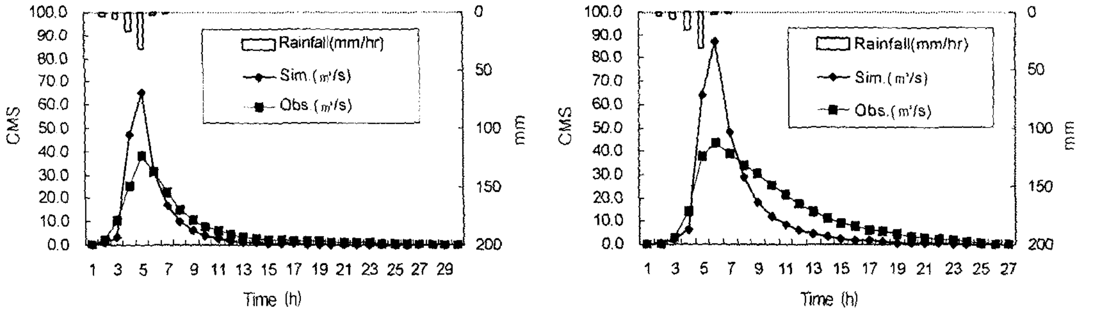
For the correction of discharge amount by rainfall, the discharge amount at Deokjong and Gwangcheon bridges were used (1990. 9. 11). The simulated results showed the relative error is each 1.5%(Deokjong bridge) and 2.1%(Gwangcheon bridge) when compared simulation runoff with observation runoff(Fig. 6).

For the correction of pollutant load, water quality data collected from the same rainfall was used (2000. 8. 24). The simulated and observed pollutant load for T−N and T−P are shown in Fig. 7. From the results of correction, relative errors of T−N and T−P were 0.17% and 0.37%, respectively.

2. Primary Simulation of Water Quality

1) DO

The total average concentration of DO was simulated as 7.26 mg/L, and that is much over



Deockjung Bridge   Gwangcheon Bridge

Fig. 6 Runoff calibration at Duckjung bridge, and verification at Gwangchun bridge

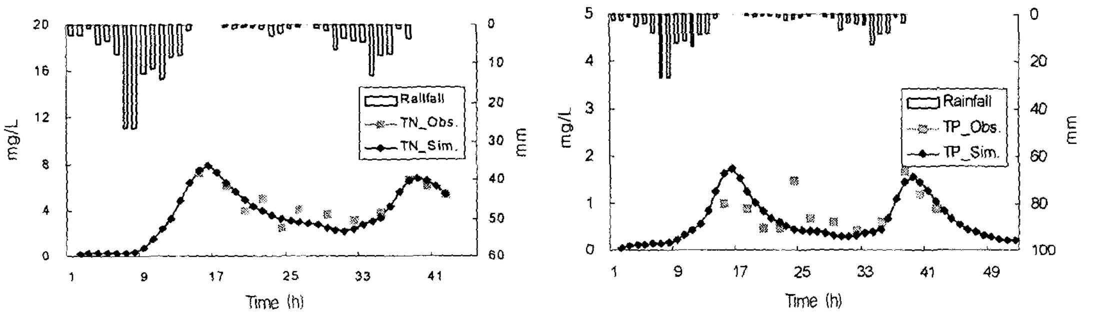


Fig. 7 Simulated and observed results of T-N and T-P

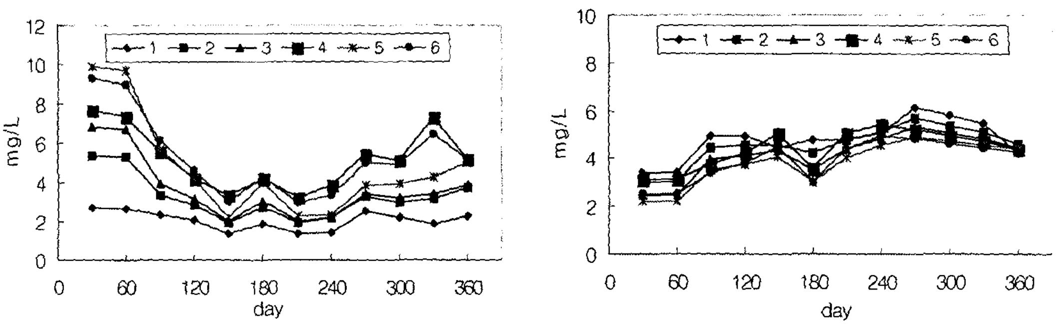


Fig. 8 Changes of DO and BOD of each segment

the standard of agricultural water, 2 mg/L, of river and freshwater lake. DO was high in winter and decreased from spring, and DO of down-stream was slightly higher than upstream.

2) BOD

The total average concentration of BOD was simulated as 5.74 mg/L, and that is satisfying the standard of agricultural water, 8 mg/L, of river, however many points were above the standard. Simulated BOD level is considered to influence the quality of freshwater lake, so it will be recommended to remove organic matter before flow into lake (Fig. 8).

3) T-P (Total Phosphorus)

The total average concentration of T−P was simulated as 0.128 mg/L, and that is slightly above the standard of freshwater lake, 0.1 mg/L, however total average concentration from April to August was 0.219 mg/L exceeds more than double compare to the standard, and this is because of the eutrophication by the increase of algae in summer.

4) T-N (Total Nitrogen)

T−N is not included in the water quality standard of river, but it is very important factor influencing the eutrophication of freshwater lake. The total average concentration of T−N was simulated as 4.54 mg/L, and that is much more above the standard of agricultural water, 1mg/L (Fig. 9).

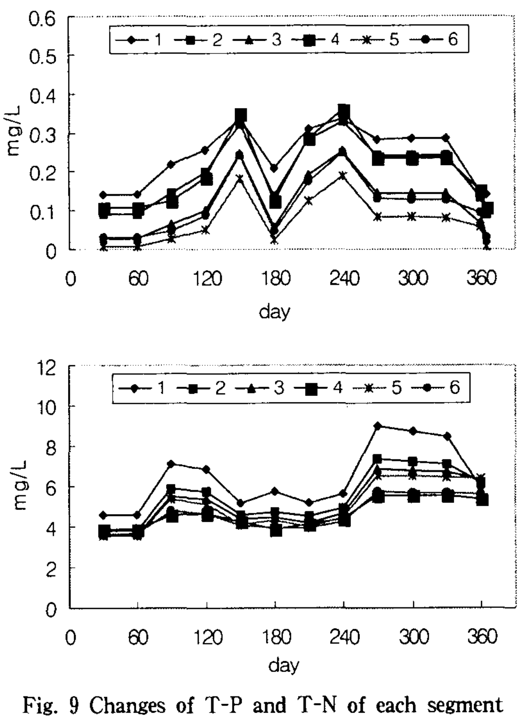


Fig. 9 Changes of T-P and T-N of each segment

3. Application of Scenario for Freshwater Lake Quality Management

For effective water quality of agricultural basin, detailed analysis are needed about present condition and distribution of pollution source. Based on this, must be able to forecast present and future water quality of basin and select optimal method among various management method.[3)]

In this study, FLAQUM was developed to forecast water quality and to management of freshwater lake. It used land utilization rate, was made so that can forecast water quality of inflow stream and freshwater lake. Water quality of inflow stream of Boryeong shows worse distribution than ordinary year, the fact appears that influence of livestock wastewater and life sewage Boryeong basin is lacking a waste water treatment system for freshwater lake quality management, for example sewage treatment plant, livestock wastewater plant.[10)] Therefore, made out scenario like Table 2 for water quality management, executed forecast of water quality.

We executed the forecast of water quality by following scenario. Like present, a waste water treatment system was not established, population and livestock land increases (Scenario Ⅱ), Pollution source keeps present state (Scenario Ⅰ), a septic equipment of water quality was established, population and livestock land decreases (Scenario Ⅲ). According to forecast result, executed forecast of water quality to residental and livestock land, because they give a potent influence to water quality. Scenario Ⅱ and Ⅲ executed forecast of water quality increasing residental and livestock land (20%, 40%, 60%)

Table 2 Design of scenario for water quality management

(Unit : ha)

Land use	Scenario Ⅱ			Scenario Ⅰ	Scenario Ⅲ		
	+60%	+40%	+20%	0%	-20%	-40%	-60%
residental land	336.51	294.45	252.38	210.32	168.26	126.19	84.10
livestock land	392.88	343.77	294.66	245.55	196.44	147.33	98.22

in present state.

Change of land utilization area, according to result of sensitivity analysis, considered using the others area (forest).

To confirm change tendency by rainfall, used rainfall of June and July among 1999, total rainfall was 276 mm.

According to water quality data of observation of "Development of water quality management system for freshwater lake in reclaimed land (1999)",[7] it is BOD 5.77 mg/L, T-P 0.19 mg/L and T-N 3.72 mg/L. When compared this result with result of scenario Ⅰ of Table 5, relative error was each 0.08%, 0.11% and 0.21%.

Like Fig. 10, 11 and 12, most water quality item of freshwater lake of Boryeong changes looking similar tendency by rainfall. Therefore, pollutant load by the nonpoint sources is very more than

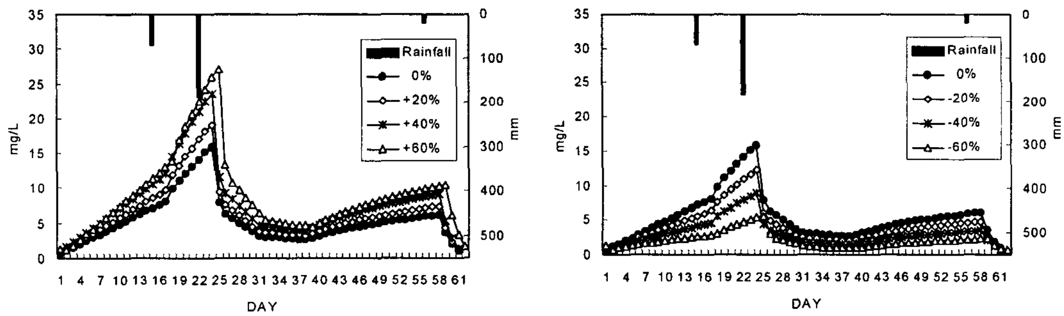


Fig. 10 Change of BOD concentration simulated by the scenario Ⅰ, Ⅱ, Ⅲ

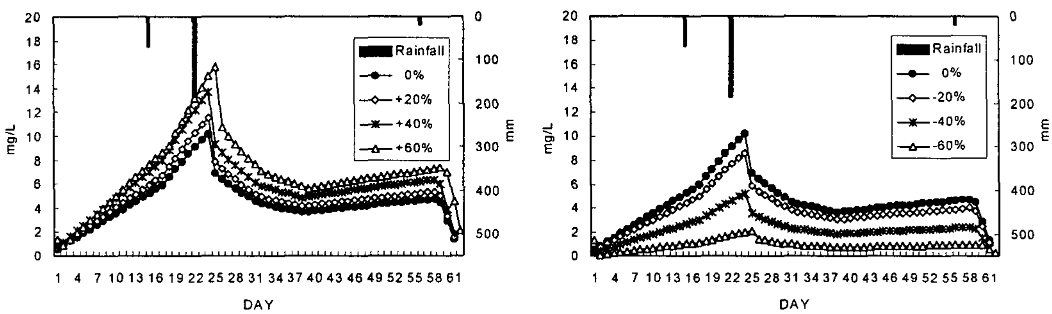


Fig. 11 Change of T-N concentration simulated by the scenario Ⅰ, Ⅱ, Ⅲ

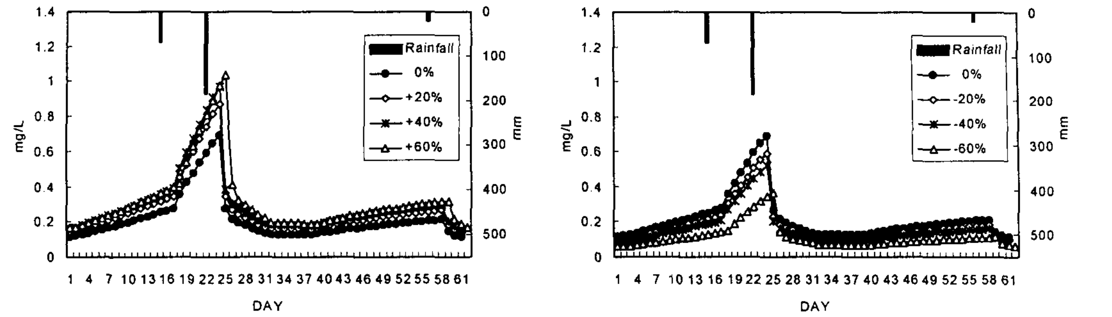


Fig. 12 Change of T-P concentration simulated by the scenario I, II, III

Table 3 BOD, T-N and T-P concentration simulated by the scenario I, II, III

Contral rate (%)		BOD (mg/L)				T-N (mg/L)				T-P (mg/L)			
		Branch ave.	Lake			Branch ave.	Lake			Branch ave.	Lake		
			Max	Min	Ave.		Max	Min	Ave.		Max	Min	Ave.
II	+60	11.36	27.12	1.21	9.03	7.04	15.80	0.84	7.01	2.75	1.04	0.17	0.32
	+40	9.97	23.47	1.05	7.82	6.01	13.66	0.72	6.06	2.42	0.97	0.16	0.30
	+20	8.03	19.03	0.85	6.34	5.06	11.52	0.62	5.11	2.17	0.87	0.14	0.27
I	0	9.43	15.86	0.71	5.28	5.02	10.19	0.54	4.53	1.67	0.69	0.11	0.21
III	-20	4.94	12.24	0.72	4.14	3.08	8.58	0.46	3.81	1.25	0.59	0.10	0.18
	-40	3.50	8.84	0.73	3.07	2.17	5.20	0.28	2.31	0.88	0.52	0.08	0.16
	-60	2.36	5.64	0.67	2.07	1.39	2.13	0.11	0.95	0.51	0.37	0.06	0.11

normal times at rainfall, it must consist many examinations about decrease countermeasure of the nonpoint pollutant sources at rainfall.

In the case of Scenario I, BOD was 9.43 mg/L in stream, this exceeds 8 mg/L of "A Guide for the Water Quality Management of Agriculture Water (1977)"[8] but 40% increase of pollutant source by Scenario II satisfy standard of water quality in freshwater lake, the problem of water quality by BOD proved that is not greatly. And BOD decreased as 7.07 mg/L in stream and 3.21 mg/L in freshwater lake for Scenario III with pollutant source control of 60%.

In the case of Scenario I, the concentration of T−N was 4.53 mg/L, this exceed greatly standard of agricultural water quality 1 mg/L, and T−N proved as 1.39 mg/L in stream and 0.95 mg/L in freshwater lake about pollutant source control of 60% by Scenario III. This satisfy standard of water quality, therefore it is judged that need management of pollutant source.

In the case of T−P, like Table 3, Scenario I was as 1.67 mg/L in stream, 0.21 mg/L in freshwater lake. And it proved as 0.51 mg/L in stream, 0.95 mg/L in freshwater lake about pollutant source control of 60% by Scenario III. Each standard of agricultural water quality is 0.11 mg/L and 0.01 mg/L. This exceed greatly standard of agricultural water quality.

The results of water quality estimation, T−N and T−P of Scenario I and II without Scenario III did not satisfy the standard of water quality−grade no. 4. According to trophic level valuation index of lake,[5] T−N and T−P of Scenario I is each mesoeutrophication and eutrophication, Scenario II is eutrophication and only Scenario III is oligotrophication step. Therefore, Boryeong freshwater lake require waste water treatment system in addition to techniques of natural water quality purifier. Alike Haedong, Madong and Samsan freshwater lake,[6),11)] because freshwater lake of Boryeong is also under eutrophication steps, eutrophication of freshwater lake is judged to be important subject of management.

For improvement of water quality and pre−vention of eutrophication, researches should be gone through continuously. In this study, we have to find method about management of phosphorus and nitrogen, because freshwater lake of Boryeong expect that it will be eutrophic lake by phosphorus and nitrogen.

The water quality of Boryeong is influenced by basin no. 5 and no. 6 that correspond to stream no. 1 in Sinjin and Gwangcheon. This area is a densely populated district. So it is judged that the sewage treatment plant is made quickly in down stream point of basin no. 5 and 6. The principal factor of pollution of basin no. 8 that correspond to steam no. 4 is stock raising wastewater, when considered many situation, it is difficult that it removes 60% like Scenario III. Also thinking about land utilization rate, the limitative proce−ssing of point pollutant source could not improve freshwater lake quality.

Consequently it is judged to be desirable that is not only to establish livestock waste water treatment facility immediately but to remove contaminant that is flowed into freshwater lake fundamentally, improve water quality, produce useful organic fertilizer as by−product and in−duce establishment of water purifier tank and facility in livestock farms.

V. Conclusions

In the first place, characteristics of runoff and input pollutant load in Boryeong basin was analyzed, and based on the result, pollutant load in Boryeong freshwater lake was simulated by FLAQUM.

In the case of the runoff in Boryeong basin, result of correction and verification, relative error is each 1.5% and 2.1% when compared simulation runoff with observation runoff. In the case of the pollutant load freshwater lake, result of correction, relative error of T−N and T−P is each 0.17% and 0.37%. In the results of correc−tion and verification, the system could be proved applicable in subject area.

The result of primary simulation of water quality simulated that the total average con−centration of DO, BOD, T−P and T−N were at the level of 7.26 mg/L, 5.74 mg/L, 0.128 mg/L and 4.54 mg/L and excluding T−P, these results far exceeded the quality standards of agricultural river water and freshwater lake.

For the establishment of water quality mana−gement counterplan, FLAQUM was simulated according to scenario with increase and decrease of pollutant source. The results of the forecast by scenario, it is proved that pollutant load by the nonpoint sources is much more than normal times at rainfall. The results of Scenario Ⅰ, Boryeong freshwater lake is BOD 9.43 mg/L, T-N 4.53 mg/L, T-P 0.21 mg/L, this data exceeds the standard of agricultural water quality. And in the case of Scenario Ⅰ · Ⅱ excluding Scenario Ⅲ, all of T-N and T-P are either mid-eutrophication or eutrophication, By removing 60% of pollution source, Scenario Ⅲ is BOD 3.21 mg/L, T-N 0.95 mg/L, T-P 0.11 mg/L, respectively, and which satisfies the standard of agricultural water quality.

When considering many situations, it is difficult that removing 60% of pollutant sources but through continuous management of livestock farms, must consider management method about eutrophication by T-N and T-P in priority. And it is proved desirable to remove the inflow of contaminant in freshwater lake fundamentally, improve water quality, produce useful organic fertilizer as by-product and induce establishment of water purifier tank and facility in livestock farms.

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