# Water Quality Management System at Mok-hyun Stream Watershed Using RS and GIS

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**Abstract**

The purpose of this study is to develop Water Quality Management System(WQMS), which performs calculating pollutant discharge and forecasting water quality with water pollution model. Operational water quality management requires not only controlling pollutants but acquiring and managing exact information.

A GIS software, ArcView was used to enter or edit geographic data and attribute data, and MapObject was used to customize the user interface. PCI, a remote sensing software, was used for deriving land cover classification from 20 m resolution SPOT data by image processing.

WQMS has two subsystems, Database Subsystem and Modelling subsystem. Database subsystem consisted of watershed data from digital map, remote sensing data, government reports, census data and so on. Modelling subsystem consisted of NSPLM(NonStorm Pollutant Load Model)-SPLM(Storm Pollutant Load Model). It calculates the amount of pollutant and predicts water quality. This two subsystem was connected through graphic display module.

This system has been calibrated and verified by applying to Mokhyun stream watershed.

## 1. Introduction

Industrialization needs the additional land for development, so agricultural fields, hilly terrain, riverside area has been changed for that purpose. This exploitation causes water resource shortage. So it is required for municipalities to manage water resources based on land use management.

Water quality in the river is determined by the amount of water, inflow pollutants, and land use. Amount of pollutants is determined by productive pollutants of basin, physical · chemical · biological process during the inflow. For effective control of water quality requires the information about each pollutant source and influence of pollutants to water quality. Especially amount of non-point source pollutants are influenced by landuse, topography, soil and so on.

For effective water quality management, technical methods, legal · executive restriction and exact information of water contamination are needed. It also requires various information - physical environment, topography, water quality surveying, soil, meteorology, and so on -. These data are huge and managed by several agencies independently. So, information system is required. GIS(Geographical Information Systems) and remote sensing(RS) are effective methods to enter, edit, store, retrieve, and analyze and display information in establishing WQMS for Environmental Impact Assessment(EIA) according to the change of land use.

Therefore, the purpose of this study is to develop WQMS(Water Quality Management System) using GIS and RS. It has two subsystems, Database subsystem and Modelling subsystem. Database Subsystem consisted of watershed data from digital map, remote sensing data, government reports, census data and so on. Modelling Subsystem consisted of NSPLM(NonStorm Pollutant Load Model)-SPLM(Storm Pollutant Load Model). It calculates the amount of pollutant and predicts water quality. This two subsystem was connected through graphic display module.

## 2. Study methods

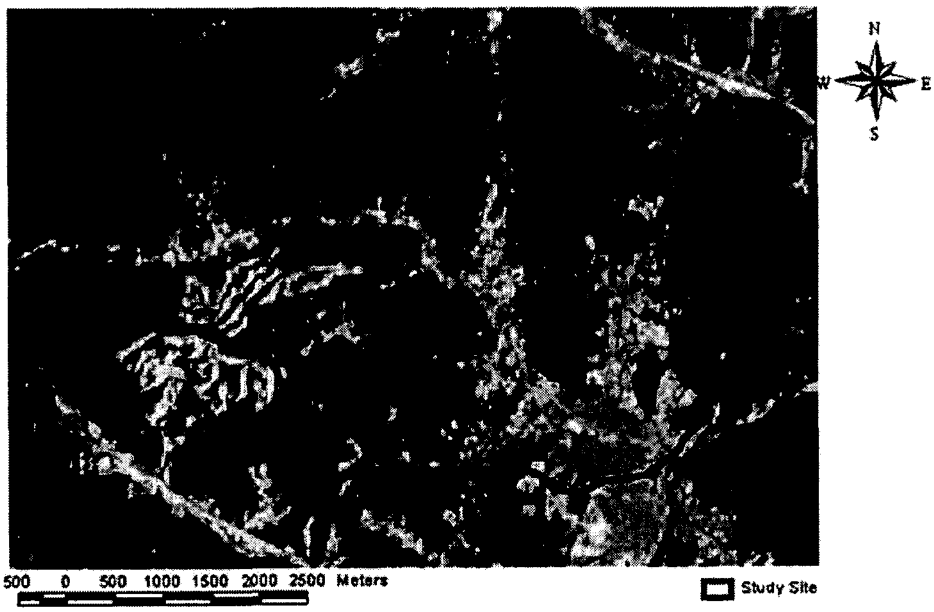
### 2.1 Study Site

The study site is Mokhyun watershed. Mokhyun stream is located at Kwangju-eup, Kyunggi-do which is the lower part of Kyung-an stream. The upper part of watershed is almost covered hilly terrain and a golf course. Otherwise lower part is urban area.

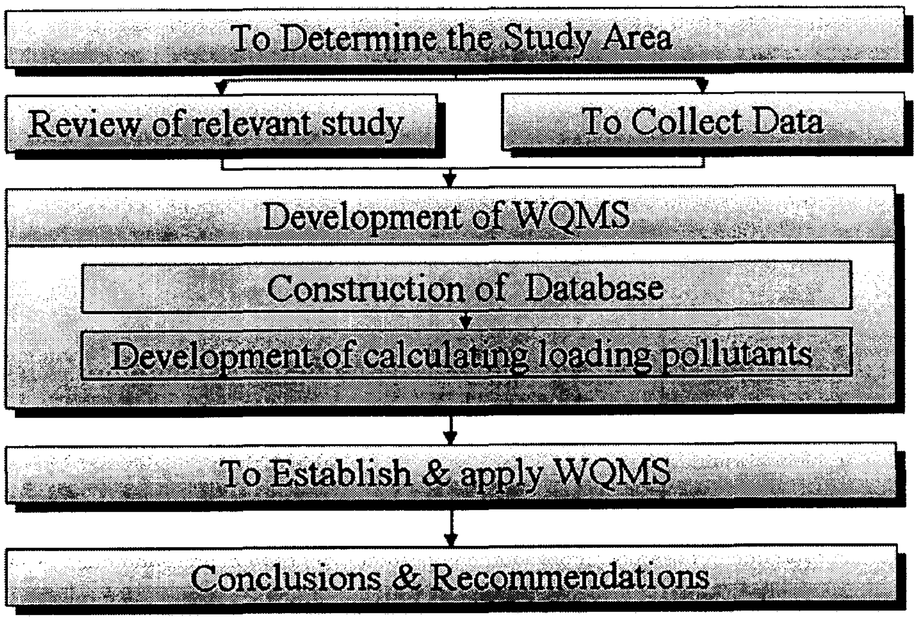
Total area of site is 20.9 km2. Fig. 2-1 shows the site

### 2.2 Study procedure

Fig. 2-2 shows the study procedure in this research.




<Fig. 2-1> Study site




<Fig. 2-2> Study Procedure

### 2.3 Development of WQMS

WQMS consists of data collection, database construction and modelling. There are two types of data. Remote sensing data and other attribute data. Landuse data from land cover classification through the image processing are entered into database. Attribute data consisting of pollutant sources, field-measured water quality data, hydrological data, etc are also entered into database.

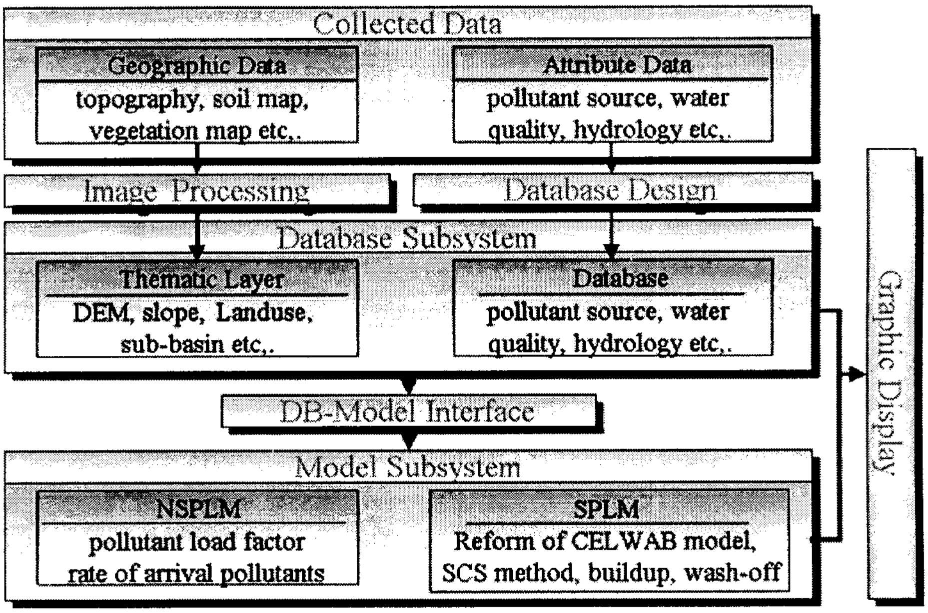
Field-measured data are used for modelling via DB-Model interface. Modelling subsystem calculates the amount of pollutant based on the weather condition and predicts water quality in the future.

Each subsystem is connected through Graphic Display Module(GDM) in order to show the results.

Fig. 2-3 shows the structure of WQMS.

#### (1) Data Acquisition and Database Construction

In order to establish database, literature survey about relevant studies are done. It required field-survey, visiting many relevant agencies, and finally water quality analysis. Table 2-1 shows thematic maps and, Table 2-2 shows pollutant sources. Former measured water quality data are collected form Ministry of Environment and Kwangju-kun municipality office.




<Fig. 2-3> General Structure of Water Quality Management System

<Table 2-1> Thematic maps

| Thematic map | scale | Source data | Attribute value |
|---|---|---|---|
| Stream network | 1 : 5,000 | Digital topographic map | Stream name |
| administrative boundary | 1 : 85,000 | Kwangju-kun administrative map | Administrative division name |
| Watershed map | 1 : 5,000 | DEM from digital topo map | Watershed |
| DEM | 1 : 5,000 | Digital topographic map | Elevation |
| Laduse map | 20×20m | RS SPOT XS | Landuse |

Types of water quality data are $BOD^5$, T-N and T-P.

Landuse map was derived from land cover classification of 20m resolution SPOT XS image(July 1, 1996) using PCI software. The visual interpretation was used for land cover classification, because it is appropriate for the area with high density land use. Before classification, image color composition and square-root contrast stretches were done.

### (2) Development of Modelling Subsystem

Modelling subsystem consists of NSPLM(Non-Storm Pollutant Loading Model) and SPLM(Storm Pollutant Loading Model) by weather condition. Constant discharge of pollutants occurs from point source while weather-dependent discharge of pollutants occurs from non-point source. So, water sampling collection is done on rainy day or sunny/cloudy day during this study.

#### a) NSPLM

Rate of concentration and pollutant load factor are used in this study. Pollutant load factor represents pollutants discharged by a unit of pollutant source during one day or one year. Total amount of pollutants from actual measurements to total amount of pollutants from pollutant load factor is rate of concentration. It can be used in predicting and calculating water quality.

<Table 2-2> Pollutant Source Data

| Division | Details | Year | Source |
|---|---|---|---|
| Human | population of sewage treatment or sewage un-treatment | 1998 | Kwangju-kun municipality |
| Domestic Animals | Cow and Pig | 1998 | Kwangju-kun municipality |
| Industrial Discharge | Factory & Sewage disposal plant etc. | 1998 | Kwangju-kun municipality |
| Landuse | Forest, Urban, agricultural fields & golf course | 1996 | SPOT XS |

<Table 2-3> Pollutant Load Factor

| Division | BOD5 | T-N | T-P |
|---|---|---|---|
| **Human source** (g/person · day) | | | |
| Population | 60.00 | 17.36 | 1.63 |
| **Domestic animal source**(g/head · day) | | | |
| Cow | 175.00 | 22.75 | 3.61 |
| Pig | 60.00 | 7.80 | 1.24 |
| **Industrial source**(g/ $m^3$ · day) | | | |
| Paper making | 224.00 | 7.13 | 0.48 |
| Food processor | 2431.00 | 13.37 | 13.81 |
| Drink processor | 164.00 | 37.76 | 17.22 |
| Leather & fur making | 6348.00 | 450.74 | 26.07 |
| Fiber industry | 987.00 | 103.42 | 11.25 |
| others | 288.00 | 51.99 | 21.46 |
| **Natural source**(g/ $km^2$ · day) | | | |
| Urban area | 11670.51 | 1338.82 | 7.37 |
| Mainly agriculture | 721.63 | 1052.20 | 109.66 |
| Forest | 197.54 | 602.25 | 2.83 |
| Golf course | 2701.37 | 1200.00 | 210.96 |

Rate of Concentration

$$= \frac{\text{Aount of arrival pollutants in base point (kg/day)}}{\text{Amount of Discharged pollutants in watershed (kg/day)}}$$

$$= \frac{\text{Water quality (Kg/}m^3) \times \text{Water volume(}m^3\text{/day)}}{\text{Amount of Discharged pollutants in watershed (kg/day)}}$$

**b)SPLM**

SPLM consists of hydrological process, calculating pollutants and determining runoff direction in each cell.

For hydrological process, the cell-based hydrology concept was used. Study area is divided into the equal cell, and inflow and outflow volume in each cell were calculated. Equation 2-1 shows this.

$$\frac{dS_{i,j,t}}{dt} = \sum I_{i,j,t} - \sum Q_{i,j,t} \quad \cdots \text{ eq. (2-1)}$$

where, $S_{i,j,t}$ :Volume of holding water in cell( $m^3$ )

dt : Interval time(hr)

$\sum I_{i,j,t}$ : Volume of inflow ( $m^3$ /hr)

$\sum Q_{i,j,t}$ : Volume of runoff ( $m^3$ /hr)

Inflow and runoff volume are calculated according to equations 2-2 and, 2-3.

$$\sum I_{i,j,t} = \sum I_d + R_t \times A \quad \cdots \text{ eq.(2-2)}$$

where, $\sum I_d$ :Sum of inflow in adjacent cell(i,j) ($m^3$/hr)

$R_t$ : Surface rainfall during dt (m/hr)

A : Cell area( $m^2$ )

$$\sum Q_{i,j,t} = DISCH_{i,j,t} + FMAX_{i,j,t} + EVAP_{i,j,t} \quad \cdots\cdots \text{ eq.(2-3)}$$

where, $DISCH_{i,j,t}$ : Runoff volume( $m^3$ /hr)

$FMAX_{i,j,t}$ : Infiltration volume( $m^3$ /hr)

$EVAP_{i,j,t}$ : Evapotranspiration volume ( $m^3$ /hr)

Surface rainfall refers to ARM(Agricultural Runoff Model), surface runoff to SCS method, and infiltration to Horton's capacity of infiltration. Sub-surface runoff and evapotranspiration are ignored.

Runoff direction are determined with inflow calculator and outflow calculator. Under the assumption that runoff flows only one direction, Greenlee's window is modified in this study(See <Fig. 2-4>).

For calculating amount of pollutants, the concepts of buildup & washoff were used in SWMM, STORM, HSPF and so on. Alley & Smith' equation were used for that.

$$\frac{dMa}{dt} = ACCU - DISP \times Ma \quad \cdots \text{ eq.(2-4)}$$

where Ma : Amount of buildup at time t(kg)

ACCU : Buildup rate(kg/day)

DISP : Destruction rate(1/day)

$$\frac{dMa}{dt} = -Ke \cdot i(t) \cdot Ma \quad \cdots \text{ eq.(2-5)}$$

where i(t) : Rainfall intensity(mm/h)

Ke : Washoff factor(1/mm)

| | | |
|---|---|---|
| 32 | 64 | 128 |
| 16 | | 1 |
| 8 | 4 | 2 |

Runoff calculator(O)

| | | |
|---|---|---|
| i-1,j-1 C6 | i-1,j C7 | i-1,j+1 C8 |
| i,j-1 C5 | i,j C0 | i, j+1 C1 |
| i+1, j-1 C4 | i+1,j C3 | i-1,j+1 C2 |

Cell coordinate(C)

| | | |
|---|---|---|
| 2 | 4 | 8 |
| 1 | | 16 |
| 128 | 64 | 32 |

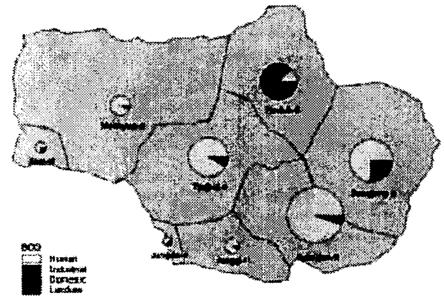
Inflow calculator(I)

<Fig. 2-4> Inflow-Outflow Calculator

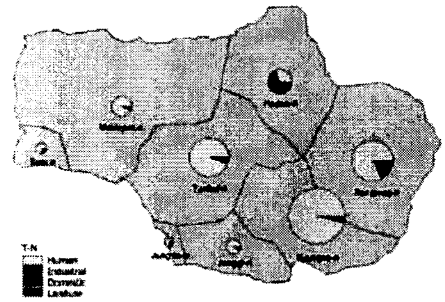
## 3. Results

### 3.1 Calculating pollutant amount

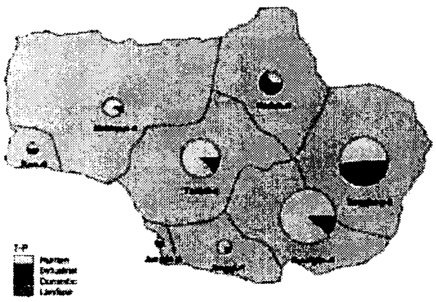
The total amount and rate of concentration are shown in Table 3-1. And Figures 3-1 to 3-3 show the pollutant amount for each administrative region.



<Fig. 3-1>BOD loading



<Fig. 3-2>T-N loading

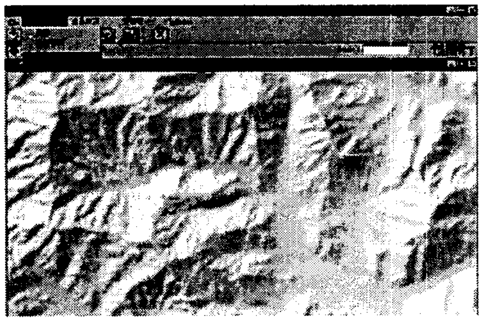


<Fig. 3-3>T-P loading

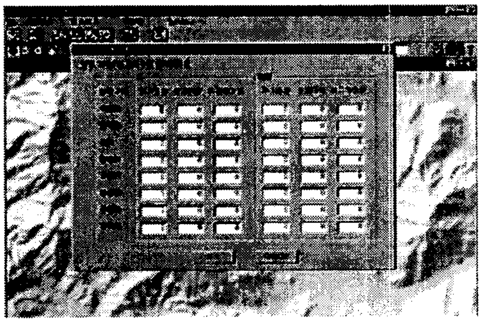
### 3.2 Application of WQMS

For User interface, the system was customized to show the result, present condition of the watershed and to enter the modeling factor. Additionally, it performs the modeling.

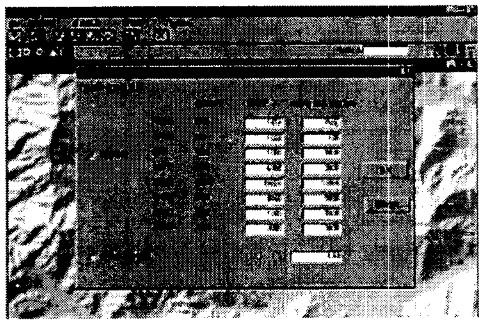
Figure 3-4 to 3-6 show scenes of system performing.



<Fig. 3-4>Delineating watershed



<Fig. 3-5>To enter and modify data



<Fig. 3-6>Modeling(after modifying condition)

<Table 3-1> Total amount of pollutant and Rate of arrival pollutant

| Section | BOD$^5$ | T-N | T-P |
|---|---|---|---|
| Total amount of pollutant with PLF (kg/day) | 2266.70 | 567.00 | 63.88 |
| Total amount of pollutant with actual measurement(kg/day) | 13.12 | 25.72 | 1.61 |
| Rate of Concentration(%) | 0.58 | 4.54 | 2.52 |

## 4. Discussion

This study is done to develop WQMS which are managing and predicting the water quality by using RS and GIS. In fact, the water quality is predicted based on pollutants and landuse. Pollutant information is entered using GIS and landuse information is derived using RS. This system can be used in EIA(Environmental Impact Assessment) by integrating other data such as physical · social-economic environmental data.

Considering the results, the following issues were discussed.

1) Lack of calibration in SPLM

Not enough rainfall during the research. So, the parts of SPLM are missed. It is necessary for non-point source pollutant processing. It will be complemented soon.

2) Inaccuracy of PLF(Pollutant Load Factor)

PLF is various and different depending on each agency. So, average of recent data in nearest site was used . It should be investigated further.

3) Coarse resolution of Remote Sensing Data

For Landuse mapping, SPOT XS image was used. The 20 m resolution is not enough to classify land cover type for delineating land use information in this study. So, field surveying for ground truth data was done.

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