Building a GIS-based Environment Information System for a Land Reclamation Project

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Abstract

In an effort to conserve water quality through the identification of the major impacts from the land-reclaimed project, EIS has been established using a GIS. All different types of layers were generated including topography, hydrography, soils, geology, etc. Also pollutant DB including point and nonpoint source pollutants from landuse, live stocks, manufacturing facilities was constructed. The pollutant DB was used to manage all different types of pollutants in a efficient way, and also linked with the water quality models to forecast the level of the water pollution over the streamflow. Qual2E was used for the streamflows and WASP5 for the freshwater lake, respectively. Also, a decision support system was developed to propose the best alternative to treat wastewater fit to local situation considering topography, population, cost, etc.

In addition to that, a integrated system has been developed for efficient linkage between model, water quality DB, decision support system based on a GUI (Graphic User Interface). The integrated system could be used as a major tool for using a EIS in evaluating all the major factors for estimating water pollution over the land-reclaimed region and lead to the best management practise (BMP) through the utilization of all the available environment-related information.

Keywords: GIS, pollutant DB, water quality model, decision support system, BMP

1. Introduction

To identify more effective BMPs to reduce the water pollution, more discrete modeling approaches using relatively higher accuracy of the pollutant database covering point and nonpoint source pollutants would be required. Also, a number of modeling scenarios could be analyzed to establish more realistic mitigation strategies of the water pollution. On that ground, an integrated water quality management system, which includes the essential parts for water quality management such as a pollutant

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database, a pollutant calculation module, a water quality model, and a decision support system to propose a BMP, definitely needs to be developed. The integrated system can also easily analyze a number of scenarios, which accompanies sequential analysis of data accessing, calculating pollutants, water quality modeling, and decision making to identify a BMP.

To develop such an integrated water quality management system, it is crucial to adopt GIS (Geographic Information System) technology due to its advantages such as the easier storing, accessing, editing, and analyzing of all the pollutant data related to the graphic data in the forms of the computer-based digital layers. This GIS functionality could be applied to efficient retrieval and management of the water pollution related information such as landuse activities, and point and nonpoint pollutant source information. Also, the expansion of the water pollution of an individual watershed could be easily identified through the automatic links between a pollutant database and a water pollution model. This would lead to a decision support procedure to propose a locally-fit and more effective pollutant treatment method considering numerous local factors such as population, topography, hydrography, etc. Also, GIS has another advantage such that all the data could be visually displayed and analyzed based on the spatial coordinates, which leads to the easier understanding and problem solving approaches for the users with less expertise (Kim, 1998).

2. Objectives and study area

This study mainly concentrates on the development of an integrated system for agricultural water quality management using a GIS technology. The system supports the easier management of the pollutant database, automatic links between a model and a pollutant database, thereby providing various scenarios of the water pollution over the watershed, and proposing an effective pollutant treatment method considering numerous local factors using a decision support system.

The study area is the Sapkyo Lake area—one of the biggest land reclamation project sites in South Korea—which is located in the mid-western part of the Korean peninsula and includes two cities and five counties. The size of the watershed is approximately 16,400 hectares and has three major watersheds: Sapkyo, Muhan, and Gokyo.

3. Methods

A pollutant database was built in two parts: graphic data using the local coordinates, and attribute data collected annually by government agencies. The pollutant database was used to calculate the pollutant discharges for individual sub-watersheds. The calculated pollutants were used as the input data for running a water quality model.
Also, all the modeling procedures were graphically displayed for the users' easier understanding.

Two water quality models were used in the modeling process: QUAL2E for streamflow modeling and WASP5 for the Sapkyo lake area modeling. The modeling results were used to identify the most critical area with the higher pollutant loadings. Following that, the most effective treatment method to treat wastewater and to reduce pollutants was selected using a decision support system.

To recommend the most effective treatment method, a pollutant allocation procedure was carried out through the calculation of the pollutant amounts to be reduced from individual small-sized catchments within a sub-watershed, to achieve the target water quality set by a government agency. A decision support system based on the analytical hierarchical process (AHP) was used to select the best-fit treatment method.

3.1 System Structure

The integrated system for agricultural water quality management was developed using a window-based GIS tool, Arcview of ESRI, considering the cost and users' convenience. The major modules of the system includes a pollutant database, a water quality model, a decision support system for selecting a pollutant treatment method, and a GUI for interfacing the modules with graphical display. The pollutant database was made to facilitate users' requirements by linking graphic and attribute data using the spatially unique keys, thereby enabling any type of data manipulation.

3.2 Pollutant Database

The graphic database had six major thematic maps including topography, hydrography, watershed boundaries, soil, geology, and administrative boundaries. The watershed boundaries and administrative boundaries were made by digitizing the paper maps, while the other layers were scanned and transformed into the topological structure through the vectorizing process. The attribute database includes the status of the pollutants and other detailed information such as water use, weather, streamflow data, etc.

3.3 Calculating Pollutant Amounts

The whole study area was divided into three major watersheds and each watershed was further divided to produce a total of 12 sub-watersheds. To produce pollutant loadings for each sub-watershed, the unit loading coefficients were applied to a coverage made by overlaying the administrative boundary and the sub-watershed
boundary to produce pollutant discharges. The detailed procedure to produce the pollutant loadings was adopted from a GIS-based pollutant calculation process suggested by a previous study (Kim et al., 1997). For updating pollutant data for each administrative boundary, an automatic process was developed to facilitate recalculation of pollutant discharges through the updating of the attribute data of each administrative zone. Also, calculated pollutant loadings were enabled to be accessible for pertinent queries using the graphic menu system.

3.4 Model Linkage

The linkage of a GIS with a water quality model was made in three stages: pre-processing, modeling, and post processing. The pre-processing includes the calculation of the pollutant loadings for each sub-watershed, and segmentation of the streamflow considering hydraulic characteristics, which could be the basis of the water quality modeling. Also, the input data for the model was made in the GIS-format data using the Arcview script language. In the modeling stage, the water quality model was calibrated using the field-collected water quality sampling data, and the modeling results were also analyzed. For the QUAL2E model, the built-in model interface was used without any modification, while a separate interface was designed and implemented to enable data editing to run the WASP5 model. Also, the post-processing transformed the model results into the GIS format and text tabular form. Lastly, the modeling results were linked with graphic layers to be displayed in a graphic form for the users.

3.5 Decision Support System

A decision support system was developed to provide useful information to make a decision in terms of selecting an optimal pollutant treatment methodology by environmental policy makers considering a number of factors. The major treatment methods applied in the decision-making system were the extended aeration process, oxidation ditch process, sequential batch reactor activated sludge process, RBCs process, contact oxidation process, trickling filters process, which were mainly mentioned in the law for the Treatment of the Sewage, Nightsoil, and Livestock Wastewater of the MOE. The current decision making system did not include chemical or physical methods reducing nitrogen or phosphorus. This would be considered in the near future through the continuous research work to add more advanced treatment methods along with a naturally oriented mitigation method such as the construction of the water-pollutant buffering zone.
4. Results and discussion

The system developed in this study was used for the three watersheds of the study area. The results showed the livestock was the major pollutant contributor for the two sub-watersheds—Sapkyo and Muhan—while population and manufacturing facilities for the Gokkyo sub-watershed. For the Sapkyo sub-watershed, a decision making system was used to select the optimal treatment method reducing the water pollution. For the purpose of implementing a more discrete approach, the sub-watershed was further divided into 11 catchments. The pollutant loadings calculated from individual pollutant sources was used to estimate the pollutant concentration to be flowed into the mainstream, using the runoff amount forecasted from a rainfall-runoff model. The estimated pollutant concentration was used to estimate water quality fluctuation for major points of the Sapkyo stream.

The modeling results showed no rapid changes of water pollution from upstream to downstream, and the BOD index showed lower than 6.0mg/l which satisfied the MOE regulation. The concentration was decreased from upstream to downstream, due to less inflow of BOD and natural rehabilitation capacity of the streamflow. Also, the DO index over the lake area, in overall, showed lower than the MOE regulation.

5. Conclusion

The integrated system for agricultural water quality management enabled the more systematic establishment of the pollutant database which could provide the easier periodic modification and updating of the pollutant database, and the identification of the pollutant status with the estimation of the pollutant loadings for each sub-catchment. Also, the more effective analysis of the modeling results was possible through the linkage between a database and a model, and even lead to the better understanding of the modeling results through the visual display capabilities. Furthermore, proposing a locally-fit mitigation method using a decision support system provided an efficient tool to reduce pollutant loadings for a specific sub-catchment. All the data queries and modeling approaches including the decision making process was made based on a GUI therefore general users with less expertise could easily use the system, thereby contributing the improvement of the water quality.

The selection methodology developed in this study was a prototype system, especially requiring more consideration to treat nitrogen or phosphorus and adding more options to the evaluation factors for selecting treatment methods.
Bibliography


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