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**DEVELOPING A USER-FRIENDLY TOOL FOR BMP ASSESSMENT
MODEL USING A GIS**

by

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Title: Developing a User-friendly Tool for BMP Assessment Model Using a GIS

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The best management practices assessment model (BMPAM), developed by the District, was linked with a geographic information system (GIS). BMPAM is a structure-based water quantity and water quality model for applications in urban and agricultural BMPs. ArcView software was selected as a GIS platform for the linkage. The user-friendly interface of the system allows stormwater managers to assess water quality impacts due to stormwater runoffs and associated pollutant loads.

The integrated GIS tool consists of three components: (1) pre-processors, (2) run model, and (3) post-processors. The pre-processors were designed to obtain all input data required by BMPAM. The run model component enables users to run BMPAM without worry about model input formats. The post-processors display results of simulation runs. Hourly, daily, monthly and annual simulation results of flow and pollutant loads are summarized in tabular and graphic formats. An example of application of the integrated GIS tool is presented to demonstrate the capabilities of the tool and the potential uses in urban and agricultural areas for stormwater assessment and management.

DEVELOPING A USER-FRIENDLY TOOL FOR BMP ASSESSMENT MODEL USING A GIS

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ABSTRACT: Best management practices (BMPs) have been widely applied in agricultural and urban areas to minimize stormwater runoff and the associated pollution problems. Currently, the effectiveness of BMPs is evaluated mainly based on limited field data of similar type of BMPs, which can only serve as a preliminary evaluation. A model based on runoff flow and pollutant removal mechanisms is needed to assess BMPs performance in more precise manner. We developed a mechanism-based Best Management Practices Assessment Model (BMPAM) to accomplish this goal. The model was linked with a geographic information system (GIS) platform using ArcView software. The integrated tool is intended to analyze stormwater management plans for decision makers and researchers. The user-friendly tool includes pre-processor and post-processor for the BMPAM model. This paper describes the development of the linkage using AVENUE language between data coverages, BMP modeling, and data pre- and post-processing. An example of BMP assessment simulations is presented to demonstrate the potential uses and capabilities of the integrated GIS tool.

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INTRODUCTION

Best management practices (BMPs) used as stormwater control systems have been widely applied in agricultural and urban areas to prevent flooding, to reduce soil loss, to provide a reservoir, and most importantly to reduce pollutant loadings to a receiving waterbody (Chen et al., 1995). Performance of BMPs varies from site to site and season to season. A user-friendly tool is needed to evaluate the performance of BMPs, to project future stormwater quantity and quality in drainage systems, and to identify key design parameters to improve pollutant removal efficiencies of BMPs.

A best management practices assessment model (BMPAM) developed for evaluating the performance of various BMPs (Xue, 1995a) was selected for this tool. A user-friendly interface of the BMPAM model was developed by using a geographic information system (GIS) platform. Integration of GIS and the BMPAM model reduces the tedious work of data formatting for model users and allows watershed managers, planners and decision makers to easily interpret data inputs and model simulation results. The integrated GIS tool has potential capabilities to analyze stormwater treatment systems and watershed management plans spatially within a county or over a large-scale region.

This paper describes a conceptual design of the integrated GIS and BMPAM model developed at the South Florida Water Management District (SFWMD). The integrated tool was implemented using ArcView software. The development of the linkage between data coverages,

pre-processors, the BMPAM model, and post-processors using AVENUE language is presented. An example of application of the integrated GIS tool was performed to demonstrate its potential uses and capabilities.

INTEGRATED TOOL DEVELOPMENT

The BMPAM model and its input and output data, model pre- and post-processors, and the GIS-Model interface are key components in the integrated GIS tool. In the integrated modeling system, GIS serves a major function in providing all information to other key components. The Input Data component links with the Pre-processor component of the model via the GIS user interface. The outputs from the pre-processors are then fed into the BMPAM model. The model is executed through a command from the GIS interface. The Post-processors component displays model simulation results in tabular and graphic formats in various ways controlled by the GIS user interface. The files generated from the pre-processors and the BMPAM model are stored in the system and can be reused or modified through the GIS user interface or other utilities under UNIX or DOS operating system environments. This conceptual design is similar to that was applied to an integrated watershed model-GIS system presented by Xue and Bechtel (1996).

GIS

ArcView Version 2.1 (ESRI Inc., 1994), a by-product of ARC/INFO developed by

Environmental Systems Research Institute, Inc. (ESRI), was selected for the integrated GIS tool because it has capabilities of displaying bar and line charts. Another reason of selecting ArcView was that an application developed under UNIX operating environment can be used on other operating systems such as Microsoft Windows and Apple Machintosh with minor modification.

ArcView 2.1 allows developers to customize applications using AVENUE, an object oriented scripting language (Hutchinson and Daniel, 1995). The integrated GIS tool was developed as a project (an application) under the UNIX operating environment at the SFWMD. Three menu bars will appear when users open the project in the ArcView window: (1) Pre-processors; (2) Run Model; and (3) Post-processors. Each menu bar contains the pulldown menus which were customized for this integrated GIS tool.

Pre-Processors

The pre-processors were designed to obtain all input data required by the BMPAM model. The pre-processors have the following menu items: (1) Select a BMP; (2) Input Hydraulic Parameters; (3) Input Infiltration Parameters; (4) Input Initial Concentrations; (5) Input Pollutant Decay Rates; (6) Input Particle Parameters; (7) Input Microphyte/Macrophyte Coefficients; (8) Input Monthly Plant Coefficients; and (9) Save Input File.

The first menu item enables users to select the type of BMPs to be simulated. There are three types of BMPs available in this integrated tool: (1) Detention Basin (e.g., wet detention

pond, dry detention pond, and wet extended detention pond); (2) Retention Device (e.g., infiltration trench, dry well, and porous pavement); (3) Vegetative Control (e.g., wetland, grassed swale, and filter strip) (Figure 1). Once a BMP type is selected, users input physical and hydraulic parameters of the selected BMP from the second menu item, including depth and surface area, initial water elevation, water elevation above weir, weir coefficient and width as well as size of the upstream drainage area (Figure 2).

The integrated GIS tool allows users to simulate three infiltration layers of BMPs. Infiltration parameters of each layer, such as maximum and minimum infiltration rate, decay parameter, infiltration regeneration ratio, area, depth, and porosity are input in the third menu item of each infiltration layer. Pollutant initial concentration and decay rates are input in the fourth and fifth menu items, respectively (Figure 3). For simulation of particles/solids, users can specify up to five particle classes and enter percentage, diameter, and specific gravity of each class in the Input Particle Parameters menu item.

In order to simulate wetlands or other vegetative control practices, users need to provide microphyte and macrophyte information in the tool. All required microphyte and macrophyte data are entered in the seventh menu item. Monthly coefficients for plant uptake are input in the Input Microphyte/Macrophyte Coefficients menu item (Figure 4). The last menu item saves all previous selections and entered data. Meteorological data such as precipitation and evaporation are pre-stored in the integrated GIS system.

Run Model

The second menu bar in the integrated GIS tool is Run Model. The BMPAM model will be executed when the menu item Run BMPAM is selected. BMPAM is a continuous simulation water quality model that routes runoff and associated pollutant loads generated from a watershed model to a stormwater control BMP. It simulates the removal process of runoff and pollutants within a stormwater treatment device in urban and agricultural areas. The model can be used to simulate a single storm event or a long term period, e.g. 20 years. BMPAM is a deterministic analytic model that simulates various hydrologic and water quality constituent transport mechanisms in a structural BMP. The mechanisms used in BMPAM for simulating water movement and pollutant reduction include evaporation, evapotranspiration, water storage, infiltration, overflow/outlet flow, settling of suspended solids, first order kinetics for biological decay processes, adsorption, partitioning of metals between soils and water, and plant uptake of nutrients (Xue, 1995a). Users can analyze different types of structural BMPs as indicated above using the model. BMPAM can simulate up to nine water quality constituents in the following categories: biological oxygen demand (BOD); total suspended solids (TSS); total nitrogen (TN); total phosphorus (TP); heavy metals such as zinc, lead, and copper; pesticides and other non-volatile organics; and non-reactive tracers.

Post-Processors

The post-processors read files generated from the BMPAM model and display hourly,

daily, monthly, and annual simulation results in the Charts window. There are six menu items under this menu: (1) Select One Parameter; (2) Select Two Parameters; (3) Enter Hourly Display Period; (4) Enter Daily Display Period; (5) Comparison for Two Parameters; and (6) Comparison for Pre/Post-BMPs.

The first menu item allows users to choose one parameter either runoff or a pollutant constituent, for comparing results of Pre-BMP and Post-BMP simulations. The Select Two Parameters menu item asks users to choose two parameters for displaying Post-BMP's simulation results of runoff and/or pollutant concentrations/loads. The third and fourth menu items enable users to define the hourly and daily period of simulation results, respectively. The next two menu items allow users to display the hourly, daily, monthly, and annual simulation results for Post-BMP only and for comparison of Pre-BMP and Post-BMP, respectively. The hourly and daily simulation results are plotted in line charts, whereas the monthly and annual results are plotted in bar charts. Tabular results of hourly, daily, monthly, and annual runoff and pollutant loads for one or two parameters are also available through the Post-Processor.

APPLICATION EXAMPLE

The integrated GIS tool was applied to a hypothetical wet detention pond to demonstrate how to evaluate the effectiveness of a BMP. The surface area and the storage depth of the hypothetical detention pond is 6070 m² (1.5 acres) and 0.9 m (3 feet), respectively. The pond has one natural infiltration layer at the bottom of the pond. No plant uptake for nutrient was

considered for this example. The wet detention pond was applied to a farm in Okeechobee County, Florida with drainage area of 631,632 m² (156 acres).

Runoff and associated total phosphorus loads from the drainage area were obtained from simulation results of a calibrated stormwater runoff and pollutant model (SRPM) (Xue, 1995b). The simulation results consist of a 2-year calibration (1990-1991) and a 3-year verification (1992-1994). Precipitation and evaporation data were obtained from the data set prepared for application of the SRPM model to the farm (Xue and Zhang, 1996). The other required data for BMPAM were input through the Pre-Processors of the integrated GIS tool. The BMPAM model was run continuously for the five-year period at hourly time steps.

Simulation results can be reviewed via the Post-Processors of the tool. Hourly hydrographs of Pre-BMP and Post-BMP are shown in Figure 5 and daily hydrographs before and after application of the BMP are plotted in Figure 6. The comparison results show a significant reduction and delay of peak runoff. Hourly and daily pollutographs can also be viewed via the Post-Processors. Figure 7 presents monthly simulation results of runoff and total phosphorus in 1993 after application of the detention pond. By comparing two different parameters, users can directly identify the relationship between the two selected parameters. Figure 8 shows the annual comparison results of total phosphorus before and after application of the BMP. The results indicated that 56 percent of total phosphorus was reduced during the five year period.

SUMMARY

An integrated GIS tool for evaluating stormwater BMP was developed using the ArcView software with its own object oriented scripting language AVENUE. The integrated GIS tool incorporates hydrologic and water quality input data, a BMP model, and simulation outputs via three key functions: Pre-processors, Simulation Model, and Post-processors. The integrated tool allows users to run the BMPAM model easily without knowing input data formats and to display the simulation results in tabular and graphic forms. It provides watershed managers and planners a user-friendly and powerful tool to analyze the effectiveness of different types of BMPs.

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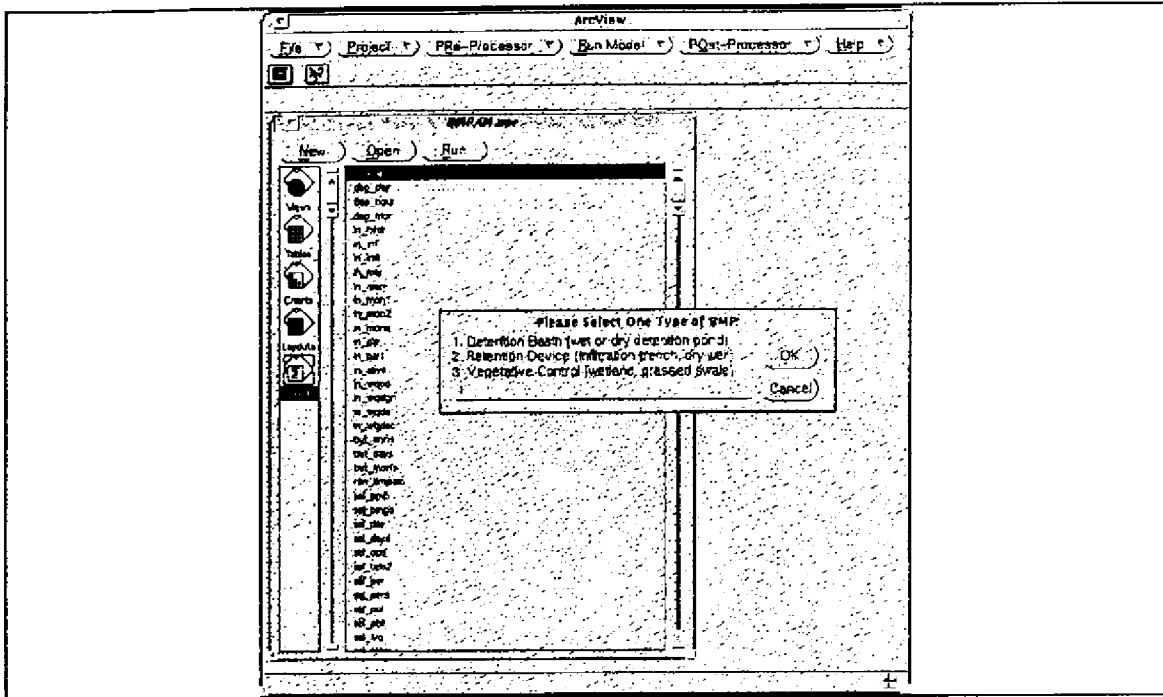


Figure 1. BMP Type Selection Screen in the Pre-Processor

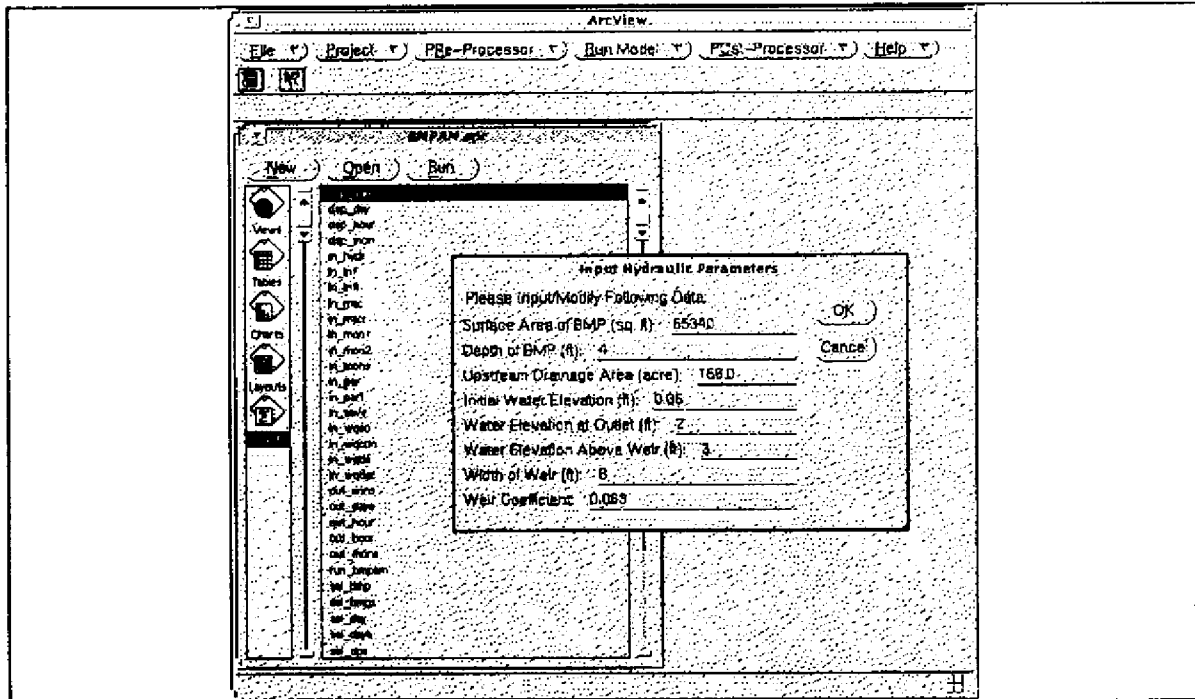


Figure 2. Hydraulic Parameters Input Screen in the Pre-Processor

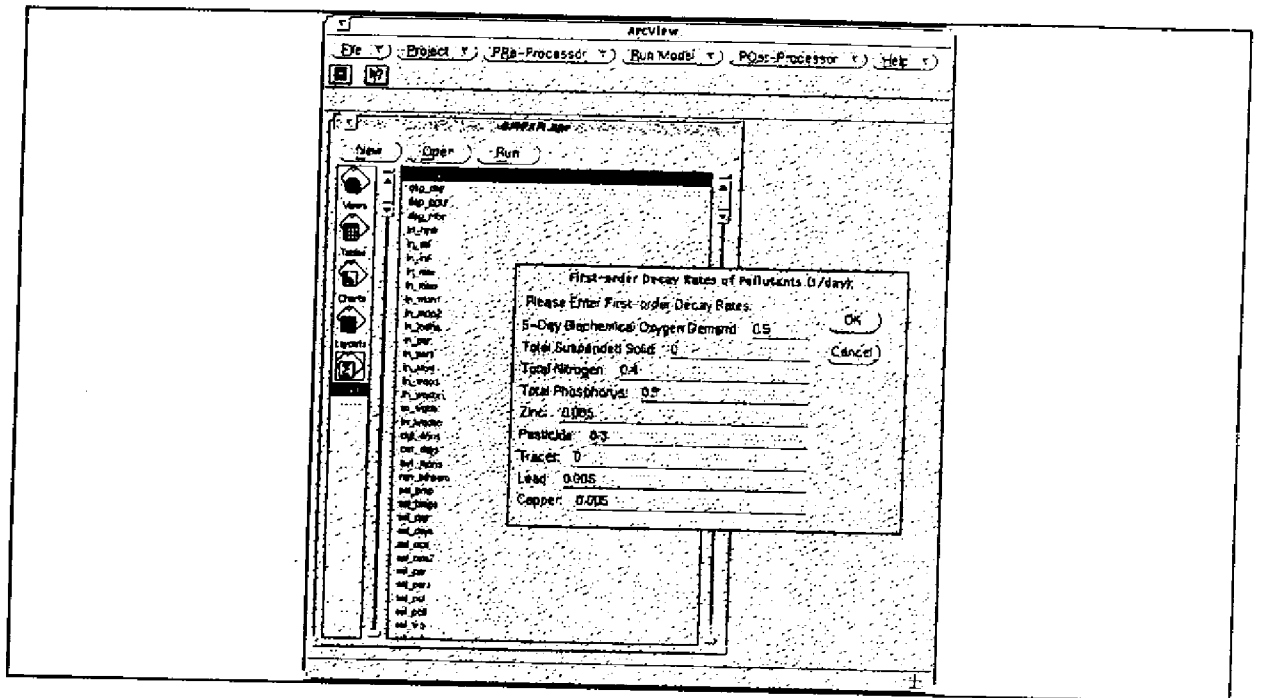


Figure 3. Pollutant Decay Data Input Screen in the Pre-Processor

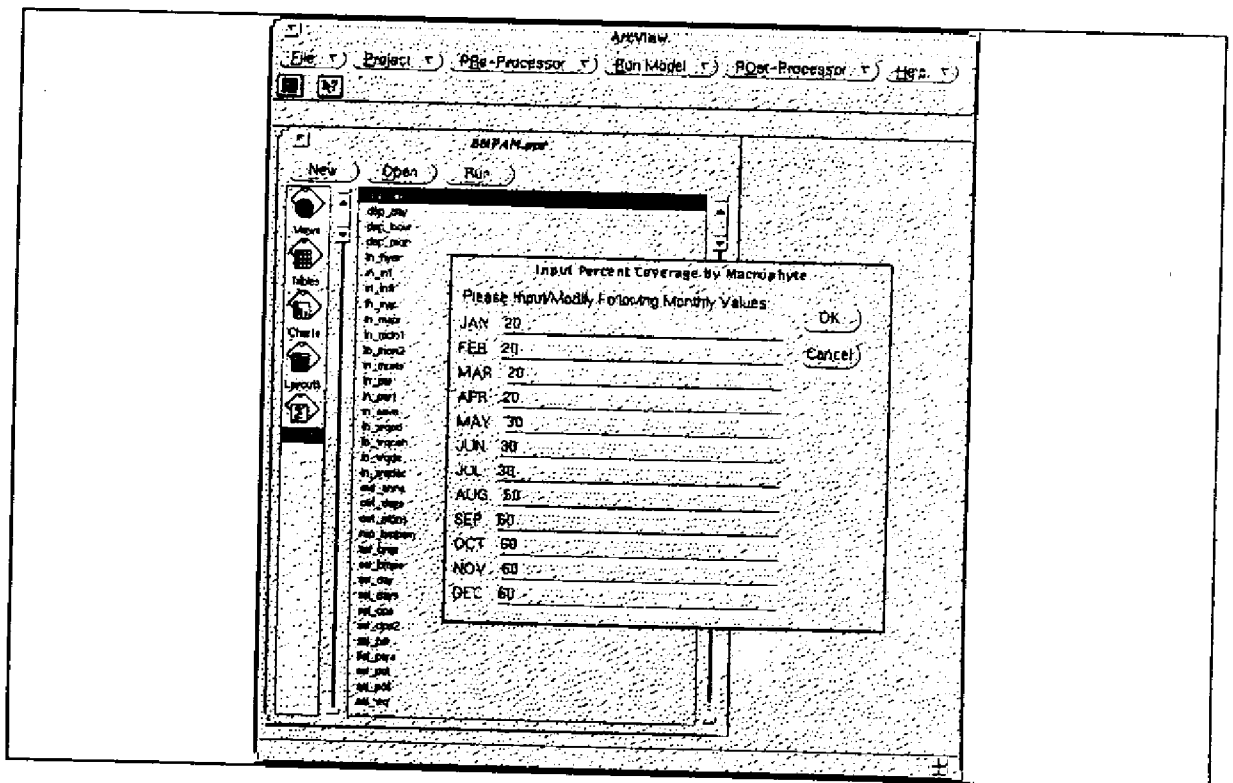


Figure 4. Monthly Macrophyte Data Input Screen in the Pre-Processor

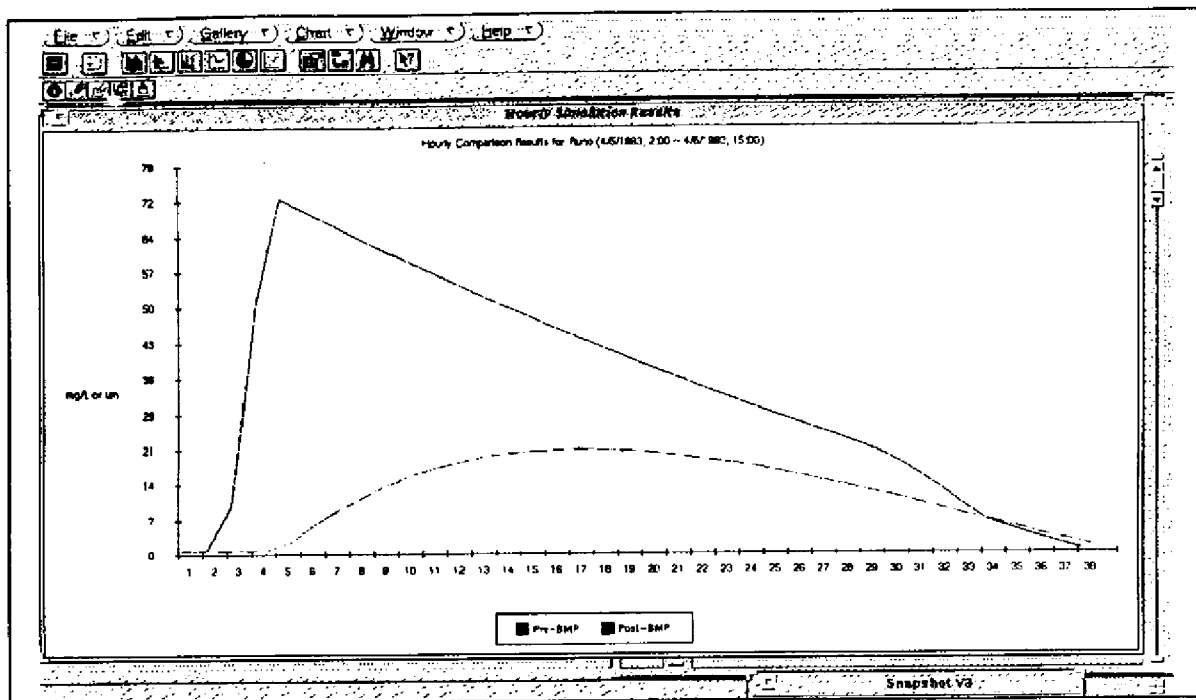


Figure 5. Simulated Hourly Runoff Before and After BMP

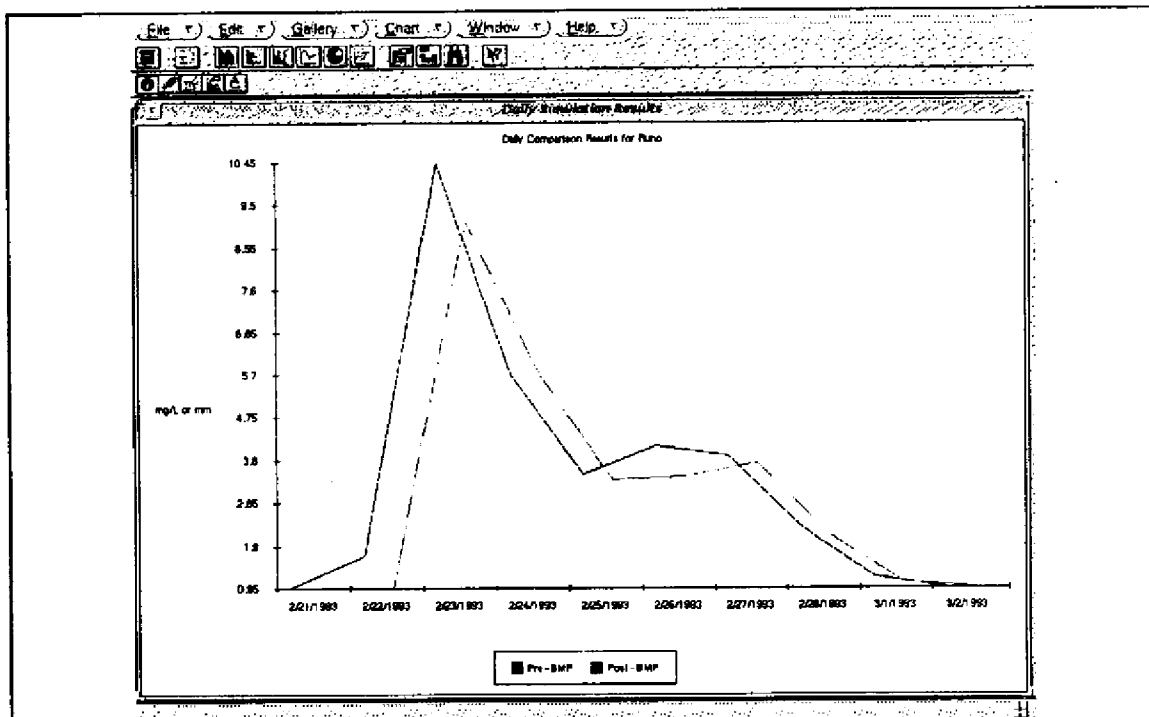


Figure 6. Simulated Daily Runoff Before and After BMP

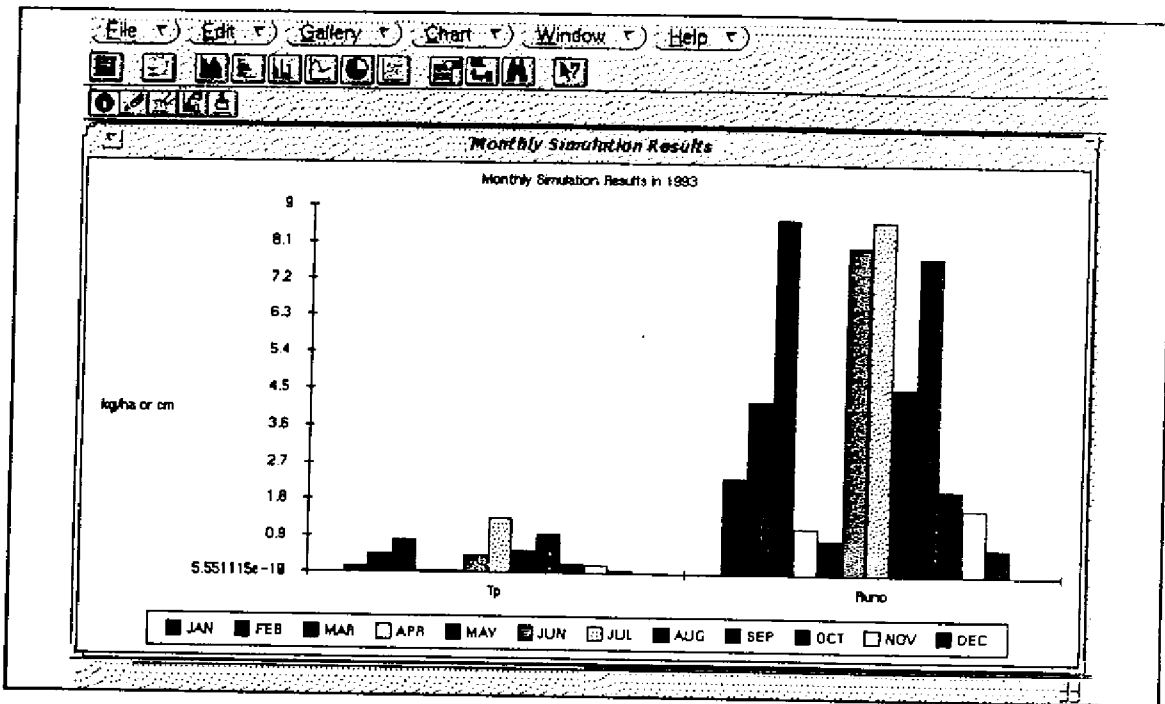


Figure 7. Simulated Monthly Total Phosphorus Before and After BMP

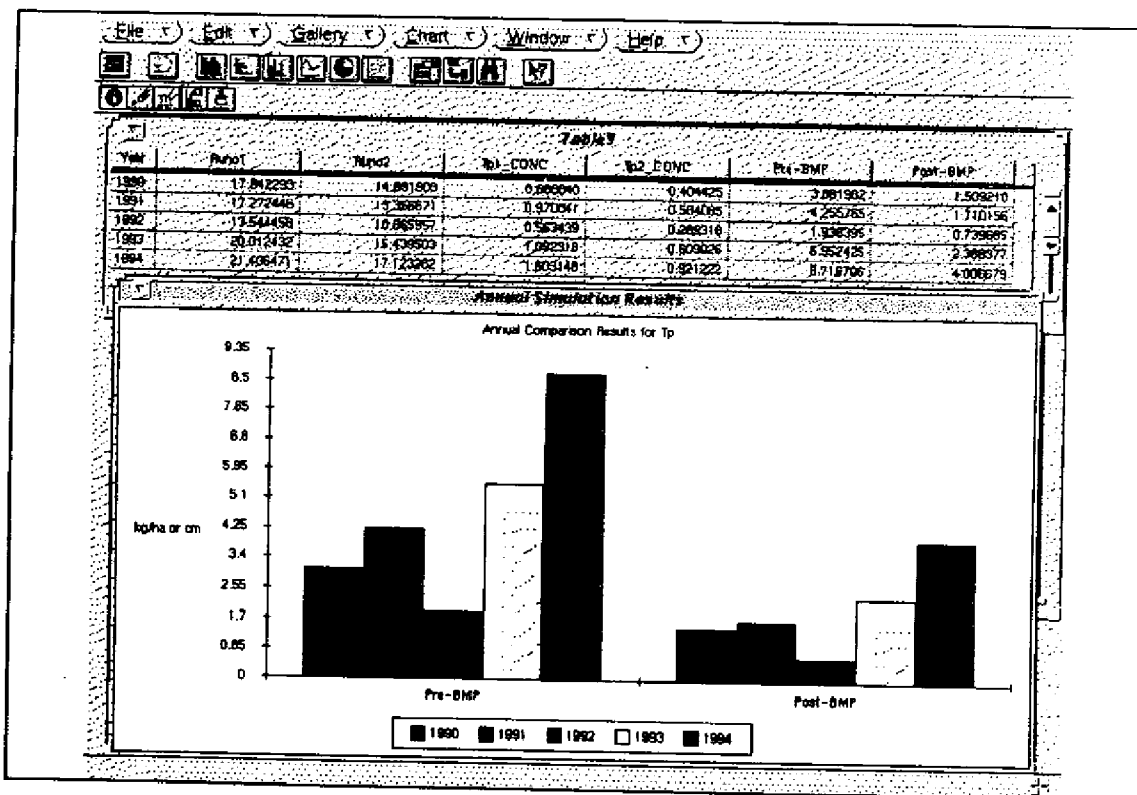


Figure 8. Simulated Annual Total Phosphorus Before and After BMP

