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Predicting Stormwater Runoff and Pollutant Loads Using An Integrated GIS Tool

PREDICTING STORMWATER RUNOFF AND POLLUTANT LOADS USING AN INTEGRATED GIS TOOL

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Abstract: Predictions of stormwater runoff and the associated pollutant loads are continuing problems for decision makers and researchers when developing plans to control flooding, erosion and nonpoint source pollution problems in urban and agricultural areas. A user-friendly watershed analysis and management tool is needed to predict and evaluate surface runoff and water quality. A stormwater runoff and pollutant model (SRPM) was linked with a geographic information system (GIS) using ArcView software to meet this need. This integrated GIS tool can be used to estimate impacts of urban development, agricultural activities, and land use changes on downstream receiving water quantity and quality. This paper describes the development of the linkage between data coverages, watershed modeling, and data pre- and post-processing using AVENUE language.

INTRODUCTION

Stormwater runoff and associated water quality degradation are continuing problems in urban and agricultural areas. Water reuse and water resource controls such as flood and erosion protection are major concerns for decision makers in watershed planning and management. A user-friendly tool is desired to estimate water budgets in storm events, assess water quality impacts on existing watersheds, and evaluate stormwater management alternatives. In addition managers need data from such a tool that can be easily interpreted and communicated to non-technical audiences.

Geographic information systems (GIS) provide the power to analyze spatial watershed data such as land use types, slope, land use acreages, and soils. That can be used as inputs for a watershed model. A watershed model simulates stormwater runoff and its associated pollutant loads for present conditions and also as the result of changes in land use and other human activities. Linkage of GIS and the watershed model reduces the problem of data formatting for model users. The integrated GIS tool also provides capabilities for watershed decision makers and planners to estimate runoff and pollutant loads in various catchment areas within a county or over a large-scale region and to quickly evaluate and compare alternative actions using graphical results.

This paper presents a conceptual design of an integrated GIS and watershed model tool developed at the South Florida Water Management District (SFWMD). A Stormwater Runoff and Pollutant Model (SRPM) developed at the District (Xue, 1995) was linked with a GIS using ArcView software. The integrated tool estimates the results of urban development or agricultural activities on downstream receiving water quantity and quality. The development of the linkage between data coverages, preprocessors, watershed model, and postprocessors is described.

INTEGRATED SYSTEM DESIGN

Key components of the integrated GIS system are a watershed model, input and output data for the model, preprocessors and postprocessors for the model, and a GIS interface. Figure 1 presents the

conceptual design of the integrated GIS tool and illustrates the linkage among the key components. This conceptual design can be applied to other integrated Model-GIS systems by replacing the SRPM model with another model.

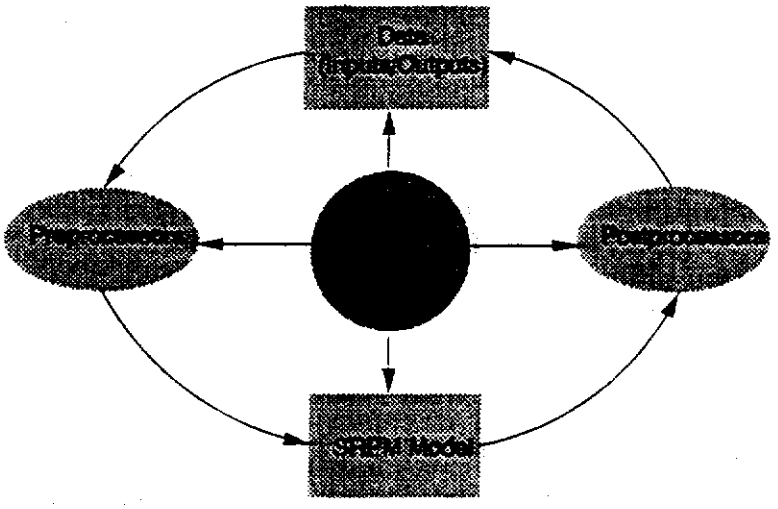

Figure 1. Conceptual Design of An Integrated GIS Tool

GIS as a major functional component in the integrated system is linked with all other key components. The Input Data component links with the Preprocessors component of the model via the GIS user interface. The outputs from the preprocessors are then fed into the SRPM model. The model is executed through a command from the GIS interface. The Postprocessors component displays model simulation results in tabular and graphic formats in various ways controlled by the GIS user interface. The files generated from the preprocessors and the SRPM model are stored in the system and can be reused or modified through the GIS user interface for further simulation analyses.

INTEGRATED SYSTEM IMPLEMENTATION

ArcView Version 2.1 developed by Environmental Systems Research Institute, Inc. (ESRI), was selected for the integrated GIS system. ArcView provides the power to visualize, explore, query, and analyze data spatially (ESRI Inc., 1994). ArcView 2.1 allows developers to customize applications using its own macro language AVENUE, an object oriented scripting language (Hutchinson and Daniel, 1995). One advantage to choose ArcView for developing the integrated

system is that it has capabilities to plot bar charts and line charts for displaying simulation results. Another advantage is that Arcview's features in Microsoft Windows, Apple Machintosh, or UNIX operating environment are generally the same (ESRI Inc., 1994). This means that an application using ArcView developed under one operating system can be used on another operating environment with minor modification.

In ArcView, an application is stored in one file as a project. The integrated GIS system was developed as a project under UNIX operating environment at the SFWMD. To run the integrated GIS system, users need to open the project from the Project window appearing in the ArcView window. View, Table, Chart, Layout, and Script windows in Arcview still remain in the project for standard graphic user interface (GUI) application if users desire. Three menu bars were created for the Preprocessors, Run Model, and Postprocessors components in the integrated GIS system. Each menu bar along the top of the ArcView window contains the pulldown menus which were customized for this integrated system.

Preprocessors

The Preprocessors, the first menu bar in the system, were designed to obtain all input data required by SRPM. The preprocessors have the following menu items to choose: a) Select a County; b) Select a Site; c) Input Site Parameters; d) Input Pollutant Parameters; and e) Save Inputs.

The first menu item enables users to select a county of interest from the SFWMD's county-level coverages. The selected county is highlighted in the SFWMD's county boundary map and the coverage table (Figure 2). The county map is then displayed in a new view. The second menu item lets users select a site from the selected county's land use coverages in the new view. One or more sites can be selected for simulation as long as the primary land use type is same (Figure 3). Once the site(s) are selected, users input physical parameters of the site(s) from the third menu item, including width and slope of overland flow and infiltration parameters (Figure 4). Data for land use type and acreages of the selected site(s) are automatically obtained from the previous site selection process. Monthly hydrologic data as well as water quality parameters required by the SRPM model are inputed from the preprocessors (Figure 5). The Input Pollutant Parameters menu item asks users to enter pollutant buildup and washoff parameters for water quality simulation. The last menu item saves all previous selections and entered data. Meteorological data such as precipitation and evaporation are pre-stored in the system.

Run Model

The second menu bar in the integrated GIS system is Run Model. The SRPM model will be executed when the menu item of Run SRPM is selected. The SRPM model is a simplified version of the Storm Water Management Model (SWMM) (Huber et al. 1987). The model is a field-scale watershed model which can be applied in urban or agricultural areas to predict stormwater runoff and associated pollutant loads. Due to its simplification, SRPM requires few hydrologic and water quality parameters and therefore is easy to link to a GIS system. The SRPM model can run continuously at an hourly time step for a storm event or for a longer time periods such as five or ten years. It generates hourly, daily, monthly, and annual runoff and the associated pollutant concentrations during simulation. SRPM has been successfully applied in a Lake Okeechobee watershed in central Florida (Xue and Zhang, 1996).

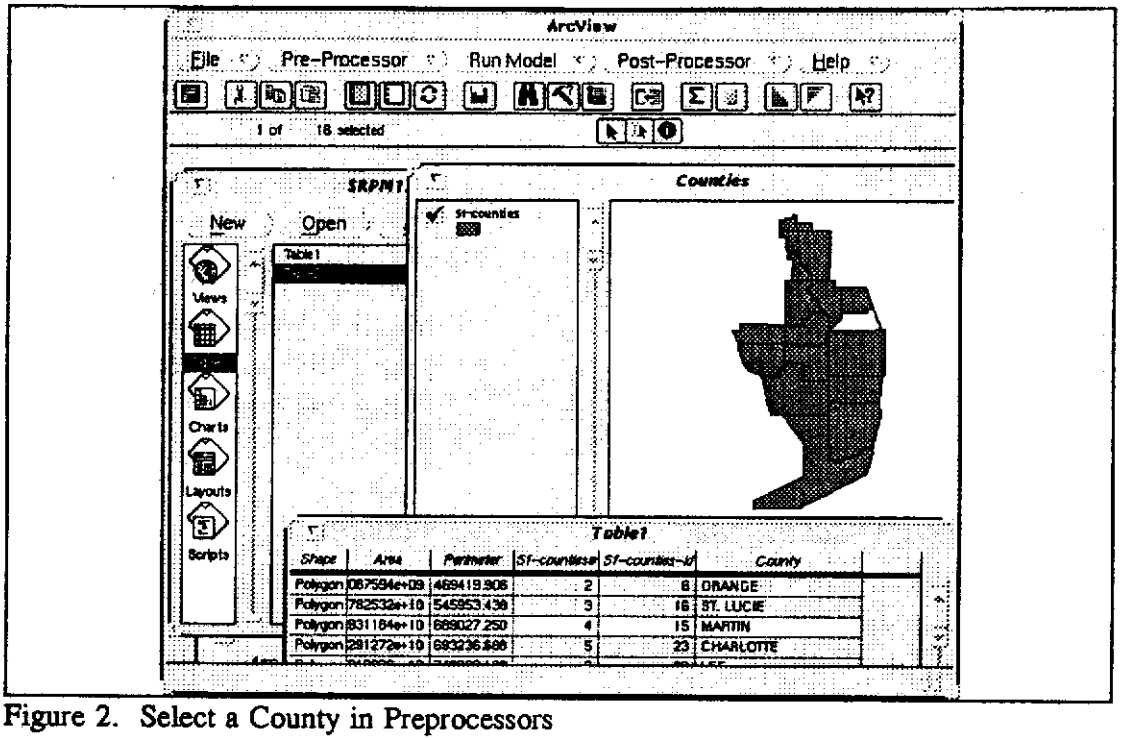

Figure 2. Select a County in Preprocessors

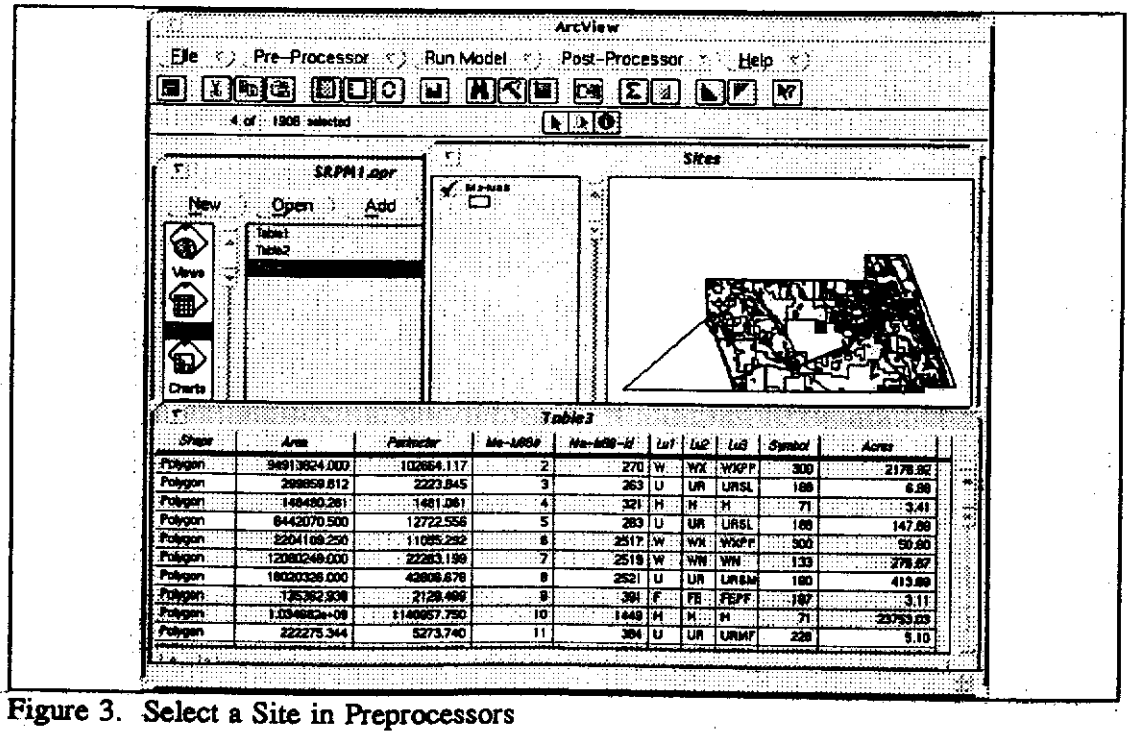

Figure 3. Select a Site in Preprocessors

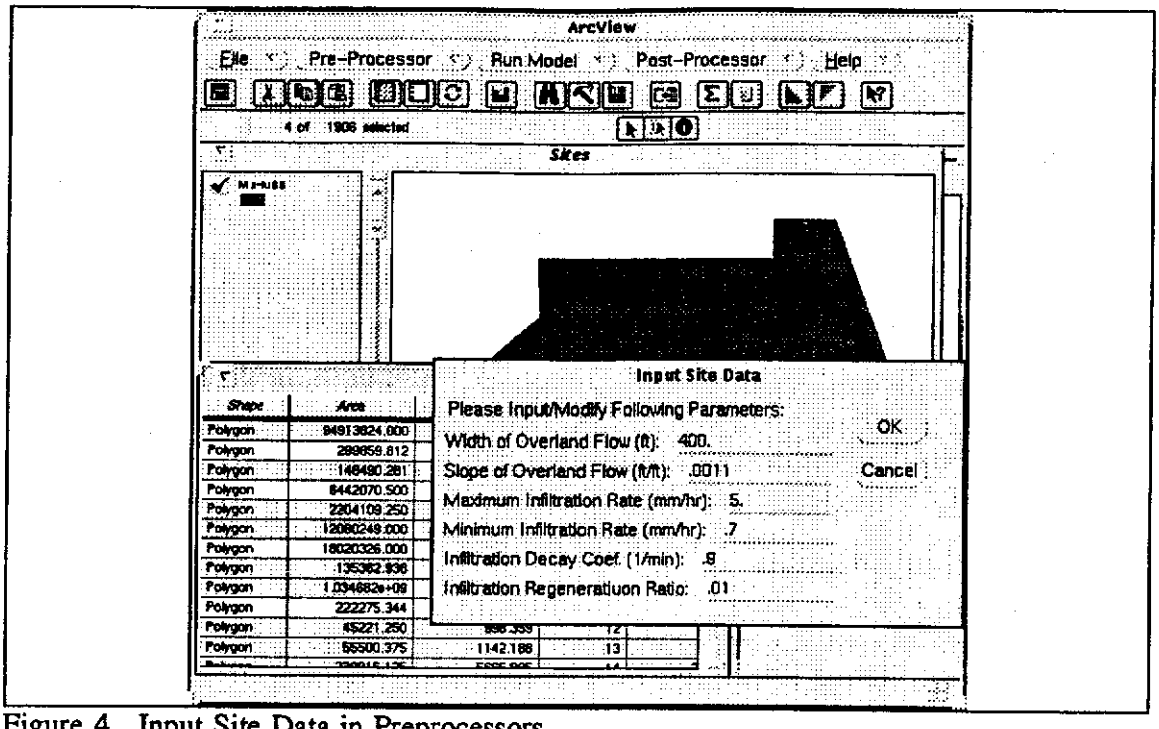

Figure 4. Input Site Data in Preprocessors

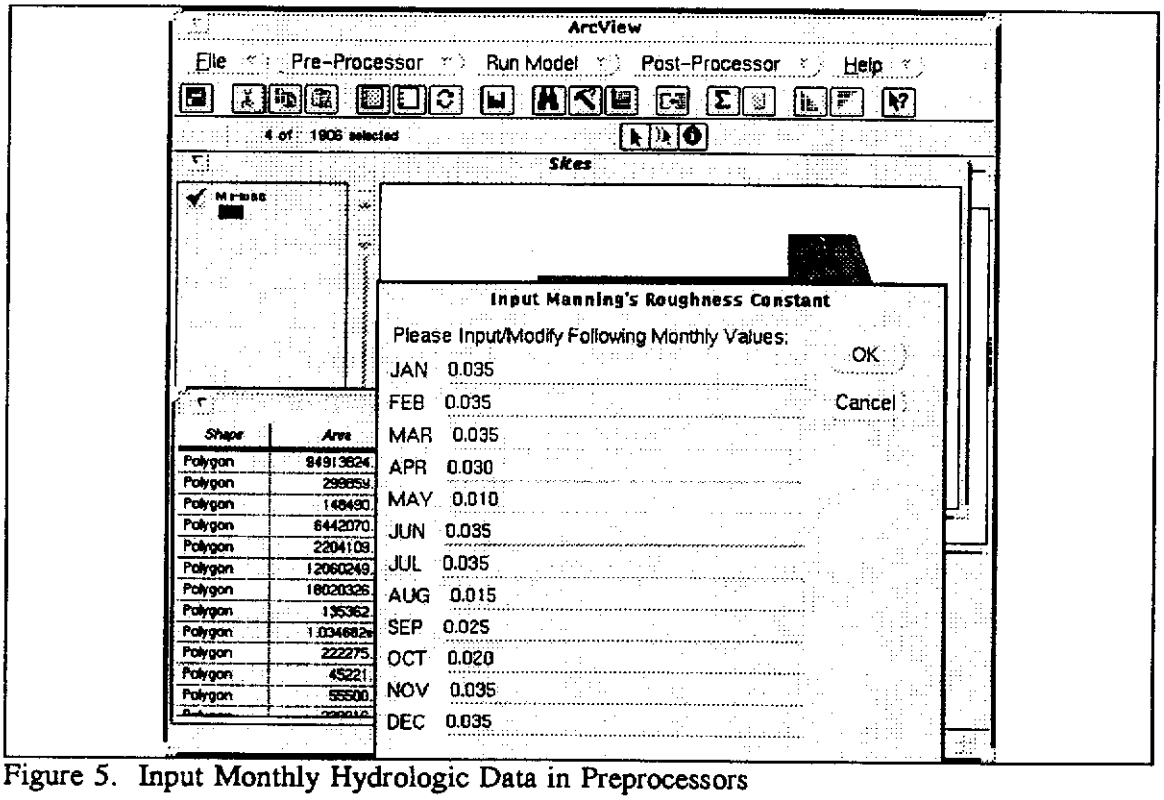

Figure 5. Input Monthly Hydrologic Data in Preprocessors

Postprocessors

The Postprocessors, the third menu bar in the integrated system, read files generated from the SRPM model and display hourly, daily, monthly, and annual simulation results in the Charts window. Seven menu items under this menu bar are as follows: a) Select Parameters; b) Enter Hourly Period; c) Enter Daily Period; d) Display Hourly Results; e) Display Daily Results; f) Display Monthly Results; and g) Display Annual Results.

The Select Parameters menu item asks users to choose two parameters for displaying simulation results of runoff and pollutant concentrations/loads. The second and third menu items enable users to define the hourly and daily period of simulation results, respectively (Figure 6). The next four menu items allow users to display the hourly, daily, monthly, and annual simulation results, respectively. The hourly and daily simulation results are plotted in line charts (Figure 7), whereas the monthly and annual results are plotted in bar charts (Figures 8 and 9). All charts are displayed side by side for the two parameters selected.

FUTURE DEVELOPMENT

This integrated GIS system is still underdevelopment. The results presented in this paper describe the first phase of development. Additional functions and improvements being considered in future development of the integrated GIS system are: a) spatial distribution and linkage of precipitation and evaporation data; b) channel routines; c) comparison of simulation results with observed data; and d) pollutant ranking in a county or in the SFWMD.

SUMMARY

An integrated GIS tool for predicting stormwater runoff and pollutant loads was developed using the ArcView software with its own object oriented scripting language AVENUE. The integrated GIS system incorporates land use coverages, hydrologic and water quality input data, a watershed model, and simulation outputs via three key functions (i.e. Preprocessors, Run Model, and Postprocessors). The integrated tool enables users to run the SRPM model easily without knowing any input data format of the watershed model. The integrated system also lets users visualize the simulation results through line charts and bar charts. Hourly, daily, monthly, and annual simulation results in graphics and tabular formats provide the power to analyze data in different ways for watershed managers, planners, or researchers.

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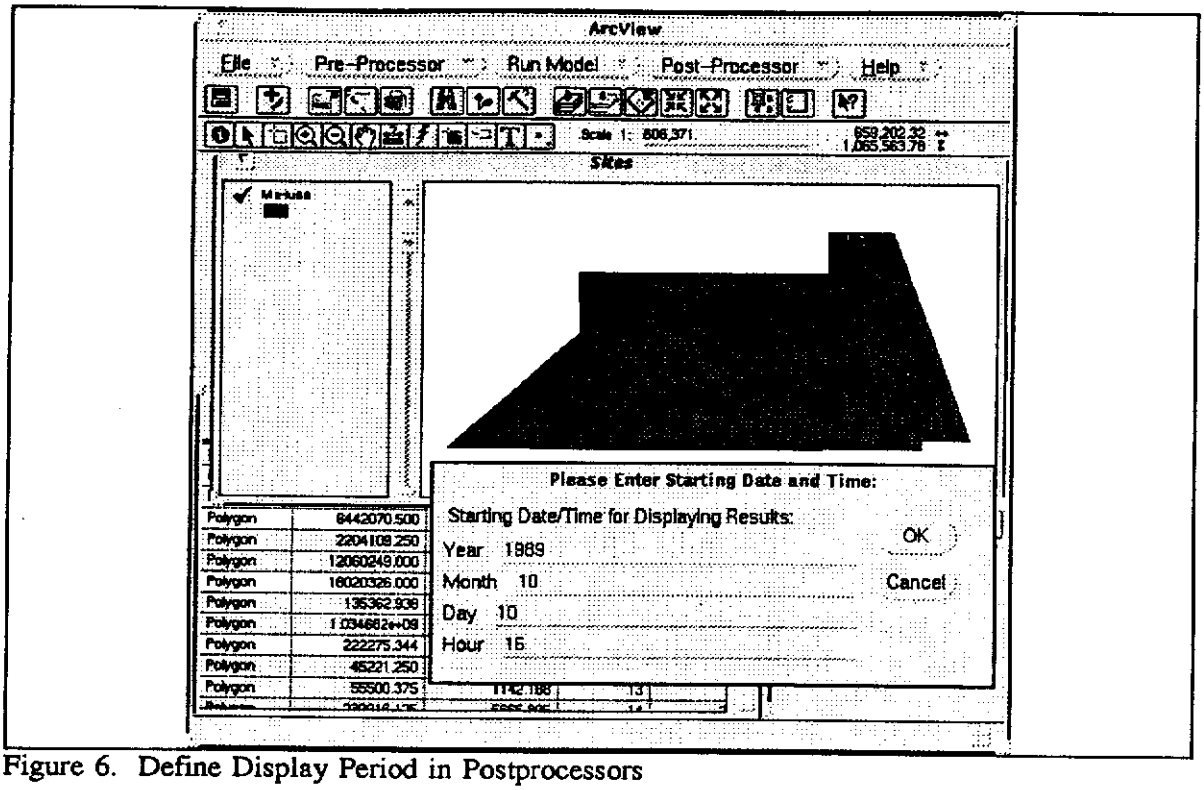

Figure 6. Define Display Period in Postprocessors

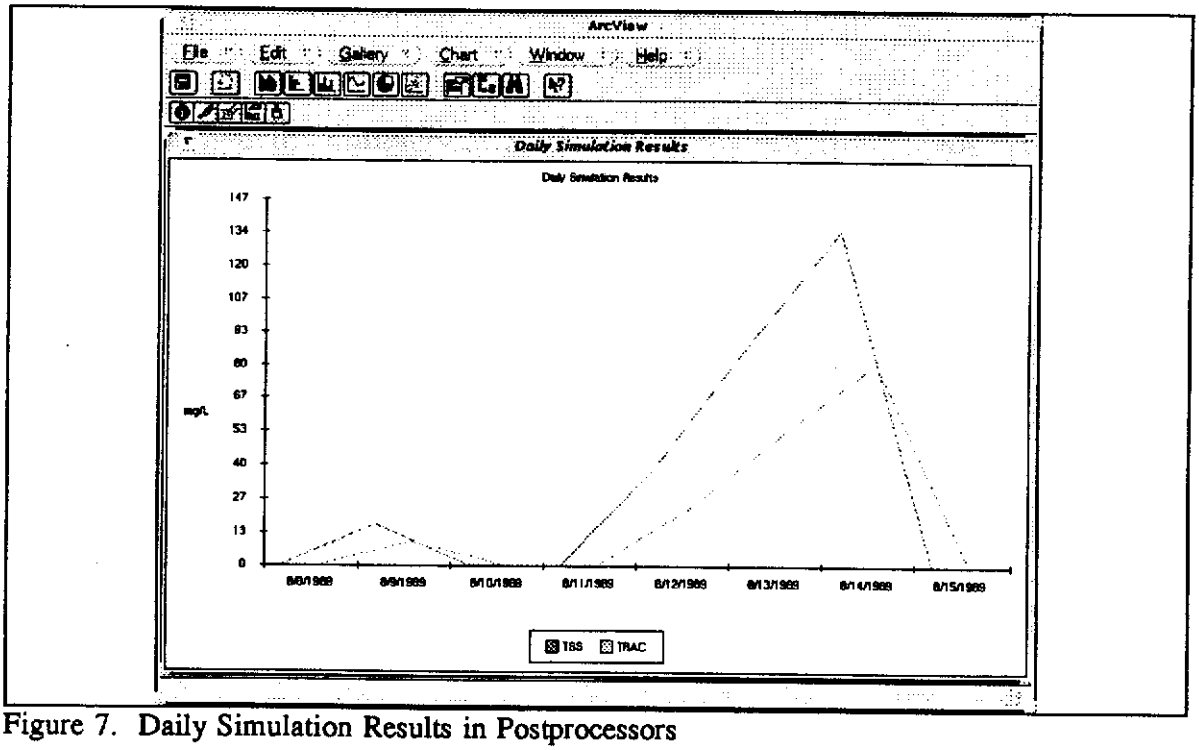

Figure 7. Daily Simulation Results in Postprocessors

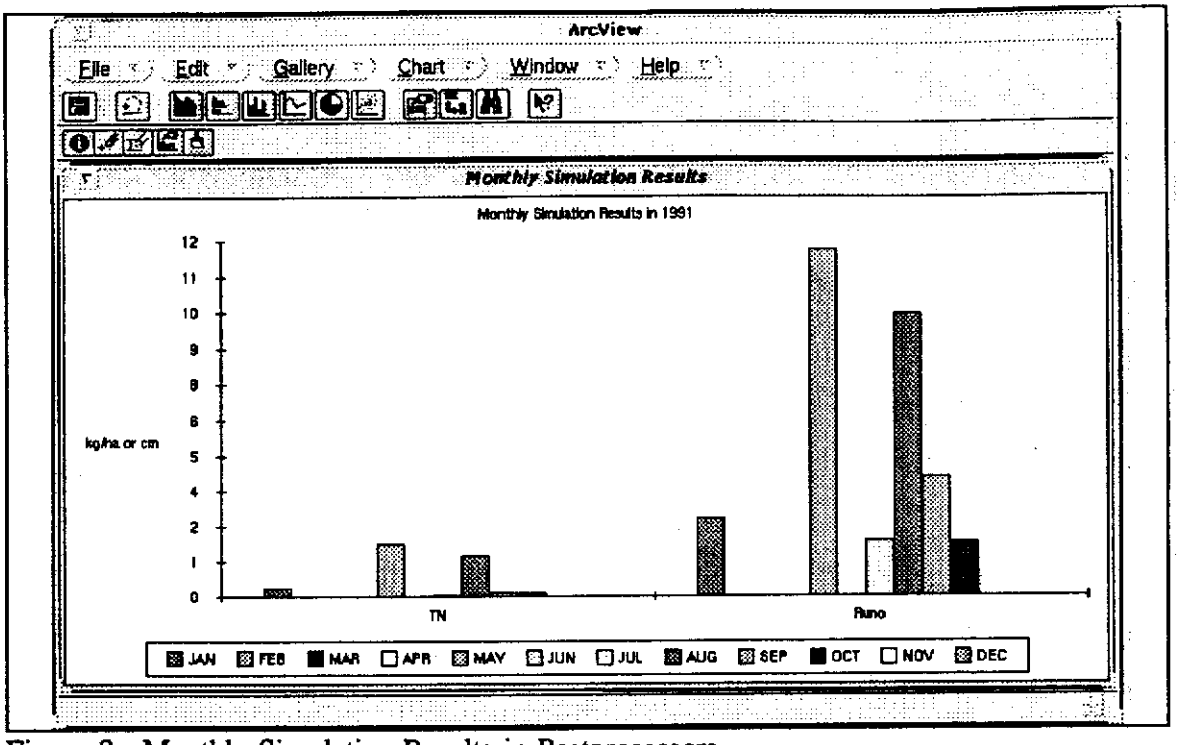

Figure 8. Monthly Simulation Results in Postprocessors

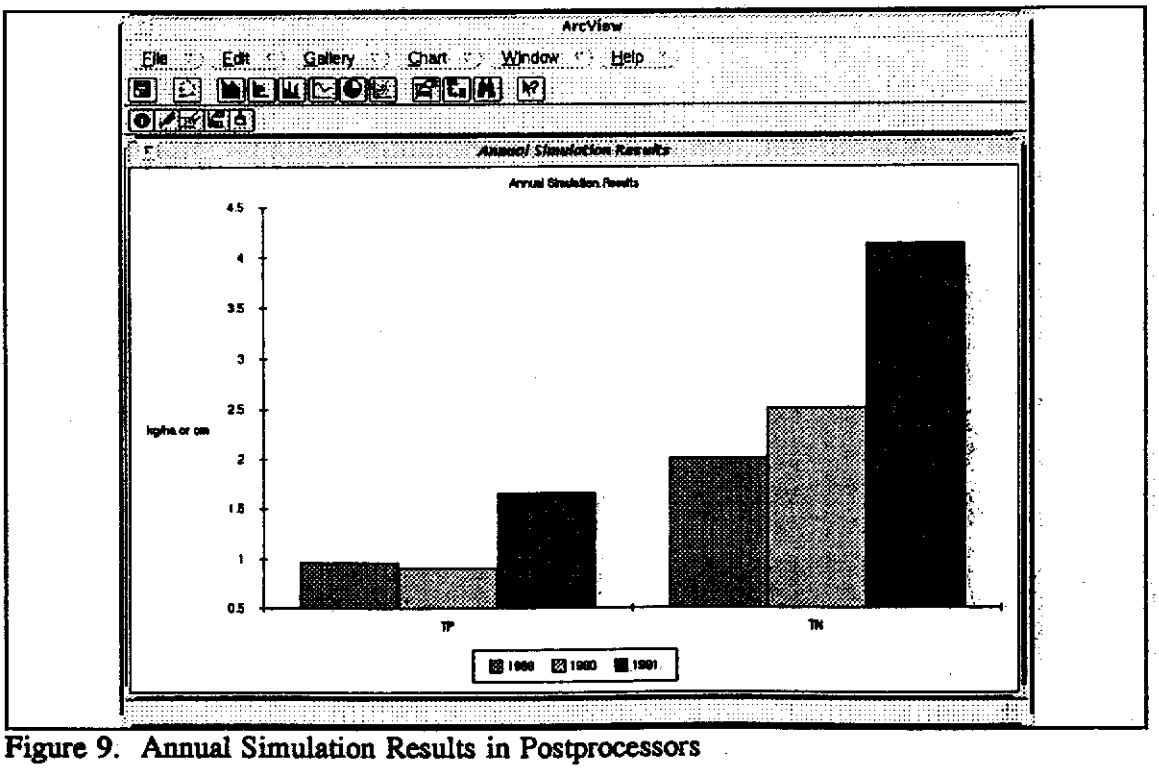

Figure 9. Annual Simulation Results in Postprocessors

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