GIS in water resources: stormwater master plan

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Abstract

A Graphics Data Base Management System is developed for use with computerized Master Plans of Drainage and Storm Water Plans. The Storm Water Plans are prepared according to particular governing agency specifications involving multiple hydrologic and hydraulic modeling options, integrated into a single software package. Data bases are prepared for graphical representation of streets, land uses, hydrologic soil groups, rainfall, master plan system elements, topographic, and other data, as well as computational results developed from the Master Plan of Drainage computer model. Two applications are available; an integrated package enabling editing and upgrading of the Master Plan, and another package designed to publish and distribute the Graphics and the Master Plan of Drainage data bases to the public in an access-only data base retrieval environment. The opportunities provided by such public information programs are significant, in that the entire Master Plan becomes available to the public in an easy-to-read and easy-to-use environment. The public therefore becomes an integral and important member of the Master Plan team, exchanging input and easing the way for acceptance of the project.

INTRODUCTION

The advent of graphical display software and linkage to hydrology / hydraulics modeling is gaining in popularity (e.g., Bergman and Richtig (1990); Djokic and Maidment (1991)). The several problems typically encountered in storm water master plans now have computer packages available to provide solutions (e.g., Hromadka, 1983; Hromadka et al, 1985 and 1987). Interface of hydrological solutions to hydraulics models has also been integrated into computer software packages, providing a single software source to solve coupled hydrology/hydraulics problems (Hromadka, 1988).

In this paper, an integrated hydrology / hydraulics / planning / deficiency-analysis Master Plan of Drainage computer model, which simultaneously performs several master planning and engineering analysis tasks, is linked to a graphics data base management program developed for the purpose of easy display of data and graphics without distributing expensive proprietary software. The computer Master Plan of Drainage and Storm Water Plan modeling approach evaluates each link of the Master Plan of Drainage for deficiencies with respect to several defined street flow criteria, and determines mitigation measures of parallel and replacement systems. Because different hydraulic systems have different flow characteristics, hydrology estimates are recomputed as the master plan is developed. Although small areas (less than about one square mile) are modeled by a rational method technique, the computer model integrates the small area hydrology techniques with the unit hydrograph technique for tributary catchment areas greater than one square mile.

The resulting Master Plan of Drainage and Storm Water Plan is represented by a simple to use (and inexpensive to distribute) Graphics Data Base Management System (or GDBMS) which allows for rapid communication of master plan data and estimates in graphical form. Two applications are developed:

Application 1: Graphical representation, storage, and editing via an AutoCAD environment, wherein hydrologic, planning, topographic, and geographic data are accessible for processing in AutoCAD, and thence transferable to the Master Plan of Drainage computer model, with access to a data base retrieval system; and

Application 2: Graphical representation of data, and access to a data base retrieval system, which is noneditable, and which can be published and distributed to the public.

In the following, each major element of the above described GDBMS will be discussed. An application of GDBMS to an example Master Plan of Drainage and Storm Water Plan (hereafter, simply Master Plan of Drainage) will be used to demonstrate graphical display opportunities.

COMPUTERIZED MASTER PLAN OF DRAINAGE AND GRAPHICS DATA BASE MANAGEMENT SYSTEM

The total Master Plan of Drainage software package and data base system contains numerous elements and components that span several technical fields including data base management, geographic information systems (or GIS), hydrologic/hydraulic computer modeling, graphical data base management, flood control engineering and planning, among others. In the following, a brief survey of the key elements of the total software package is provided.

Coupled Hydrologic Modeling Technique

Most flood control agencies at the city, county or state level require specific procedures for the calculation of flood flow quantities. Often the procedure may involve the use of two or more estimates, depending on conditions such as watershed size. In Southern California, several county flood control districts require use of two flood flow estimation techniques depending on catchment area. The rational method for areas smaller than about one square mile. The design storm unit hydrograph method for areas larger than about one square mile. The transition between techniques has been coupled into an integrated computerized Master Plan of Drainage model, for the first time, enabling the development of an integrated hydrologic computer model with one pass of the analysis, rather than two separate studies. As a result of coupling hydrologic techniques in a single computer model, a single system is available for use in preparing Master Plans of Drainage and upgrading the master plan, thereby greatly reducing the complexity, review and cost involved.

The Master Plan of Drainage software contains internal editing and computational elements that involve 152 hydraulic and hydrologic submodels and global modeling commands. The software enables analysis of an integrated open channel or closed conduit flood control system on a study-wide basis (Hromadka et al, 1987, 1993).

Graphical Data Base

Primary hydrologic parameters used in the Master Plan of Drainage computer model are land use, hydrologic soil group, rainfall, and hydrologic subarea topographic data such as area, length of water course, and elevation. In general, a study is discretized into subareas that are 10 to 20 acres in size. These subareas require definition with respect to each of the parameters listed above. Additionally, maps are needed in order to communicate these data. By obtaining in digital form or actually digitizing the land use maps, hydrologic soil group maps, rainfall maps, and subarea maps, not only is a digital/graphical representation available for display, but the data can then be processed by a "polygon processor" (described below) in order to partition the subareas into the intersection of all of the graphical layers (e.g., Hromadka et al, 1993). Further enhancement possibilities exist, such as automated elevation data extraction from topographic maps (Jenson and Domingue, 1988) that significantly simplify complex storm water model data base construction. Geographic location is provided by use of street layout layers, right-of-way maps and freeway maps. The graphics data base is used to prepare hard-copy maps for reports, as well as graphical layers for display on the computer monitor.

Polygon Processor

The use of geographic information systems (GIS) has become widespread in many facets of engineering and planning, among other fields. A key element of a GIS is the ability to intersect graphical layers so that several forms of information are resolved into "cells" wherein all parameters are constant.

In the Master Plan of Drainage, each subarea requires definition of land use, hydrologic soil group, rainfall subarea size, and the proportions of each within the subarea. The polygon processor performs this important task, and then develops a data base for use in the Master Plan of Drainage computer model. The subarea data are stored in tabular format, on a subarea basis, indexed according to subarea number (Hromadka et al, 1993; Smith, 1993). Thus, the retrieval of a specific subarea number will access these several data, automatically developed by the polygon processor (for specific issues, see Smith and Brilly, 1992).

Master Plan of Drainage Data Base

The Master Plan of Drainage may be represented, in a data base form, as a collection of nodes (specific points along the catchment flood control system), and subareas (10 to 20 acres in size). All information computed by the Master Plan of Drainage, such as deficiency system mitigation needs, flow quantities, hydraulic properties, streetflow characteristics, flood control system characteristics, hydrologic parameters, and costs, among others, are stored in agency-designed tabled form in a data base indexed according to node number, link number, and subarea number. Data entered directly into the data base such as flood control system history, age, and so forth are also stored. Once the data base is assembled, it may be linked to the graphical data base which displays the digital graphical layers constructed for the polygon processing (i.e., multiple use of a data base form), while allowing easy access to the Master Plan of Drainage data base.

Modeling analysis programs access the data base, in turn, supplying computational results.

HydroGraphics Management System

The graphical data base and retrieval software and the Master Plan of Drainage hydrologic/hydraulic computer software are coupled to form the Graphics Data Base Management System. Each of the above software packages are developed specifically for this application, and do not require use of other software packages.

Two applications are available. Application 1 is the actual Graphics Data Base Management System which includes all the features of Application 2, but also includes the ability to upgrade the Master Plan of Drainage due to changes in system requirements, land use, hydrologic parameters, among other factors. Because the agency can perform the upgrade, the master plan can be kept current, enabling up-to-date drainage fee assessment to be developed.

The second application, or Application 2, enables publication of the Master Plan data base for distribution to the public. Using "slides" (i.e., screen images stored in the graphics data base), the entire study can be resolved into graphics slides of about one-half square mile in size, showing hydrologic master plan nodes, subareas, links, streets, land use, hydrologic soil group, among other designed data. Each slide is indexed to successively larger maps so that by selecting an appropriate grid from the monitor, one is able to navigate through the city to a select point. Additionally, each slide is cross-referenced to a Master Plan of Drainage data base map that stores all the data associated to the slide appearing on the monitor. Figure 1 shows a slide of the entire data base "Index" map which appears on the monitor. Data base operating commands are displayed at the top of the monitor screen, enabling the user to access the next level of the graphics slides. In this application, the map depicts the entire 45-square mile watershed catchment area relevant to the urbanizing City of Yucaipa, in the State of California. A grid system for selecting the next screen level (shown in more detail) is also shown in Figure 3. To access a particular grid slide, say D2, one first clicks onto the top "Grid Number" option.

This simple application provides significant communication opportunities for the agency to communicate with both the public and the technical sectors. The engineering and planning communities can access the data base for other technical needs, and also inspect the Master Plan of Drainage without reviewing the usual report documents (which typically run several volumes). The public inspect the Master Plan, and access information that would otherwise be unavailable. The cost of Application 2 is simply the cost of a 3.5-inch disc, or a micro-floppy. Figures 2 and 3 show successive steps through an application made for the City of Yucaipa, California by Boyle Engineering Corporation.

Computer System Requirements
The necessary computer hardware needs (e.g., IBM 486 system or equivalent) for a study of 100 square miles involves the data base of some 5,000 subareas, 6,000 nodes, 5,000 links, and about 250,000 pieces of information. The total graphics and Master Plan data base requirements is in the 40 to 50 megabyte range.

Hard Copy Products and Mapping
Hard copy maps and reports are readily prepared using the several constructed data bases. Consequently, once the graphical data bases are assembled, drafting time is significantly reduced by using hard copy printouts. Similarly, report technical appendices can be prepared using the Master Plan of Drainage data base.

Application to Sewer, Water, Environmental Systems
Extension of the Graphics Data Base Management System to use in sewer, water, and environmental systems is straightforward and has been accomplished in several applications in San Bernardino County, California. Both Applications 1 and 2 follow the procedural steps described for Master Plans of Drainage. A key element to use with other systems is the availability of an integrated processing model -- such as readily available integrated sewer and water system models. In the application described herein, the development of an integrated Master Plan of Drainage computer model was a crucial step in the evolution of the Graphics Data Base Management System approach for Master Plans of Drainage.

CONCLUSIONS

A graphics data base management system for computerized Master Plans of Drainage has been developed. Two applications are available which enables the agency to upgrade the Master Plan in the future, and to publish the Master Plan in computer graphics form for distribution to the public. Because of the ease of communication opportunities afforded by this approach, the utility in Agency public information programs may be significant.

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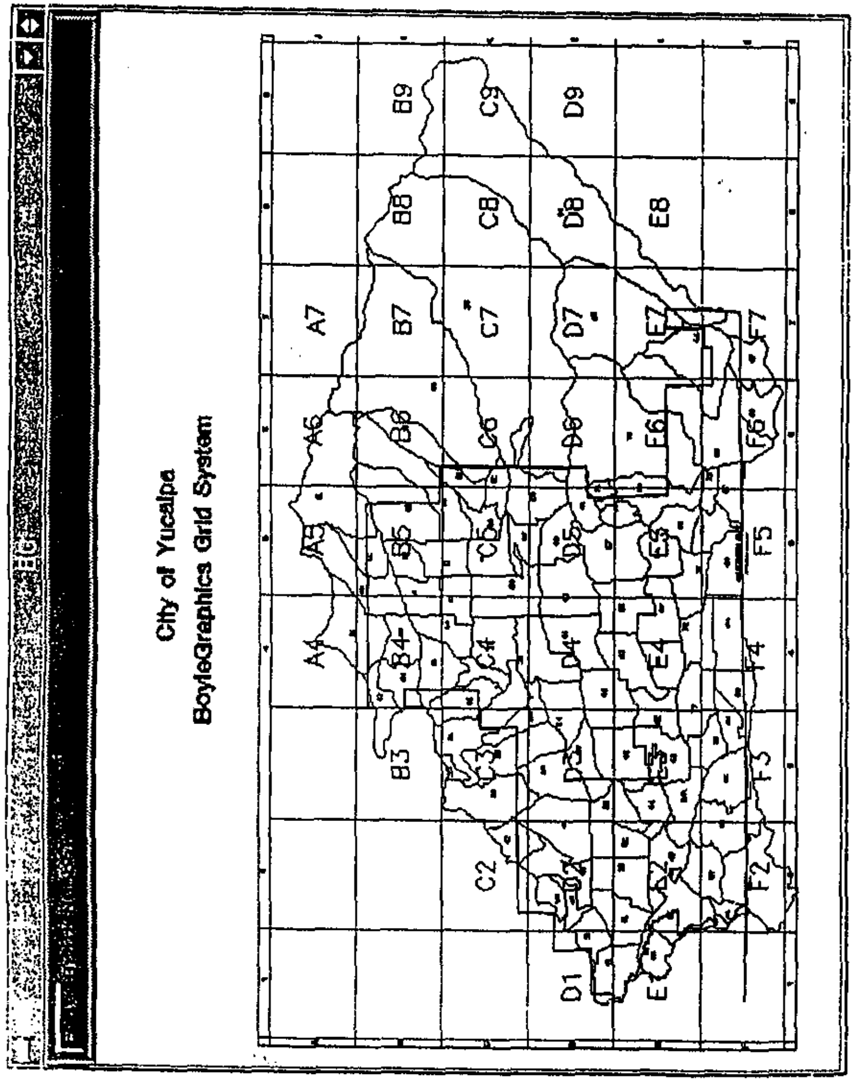
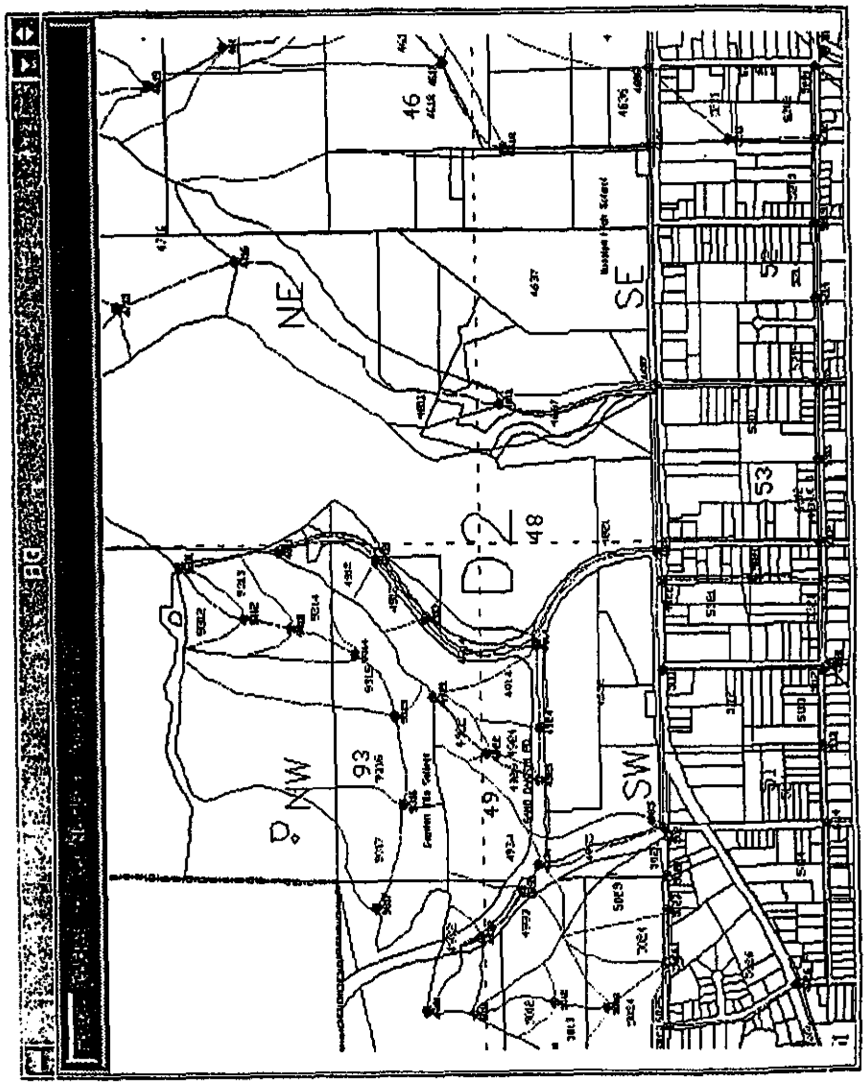
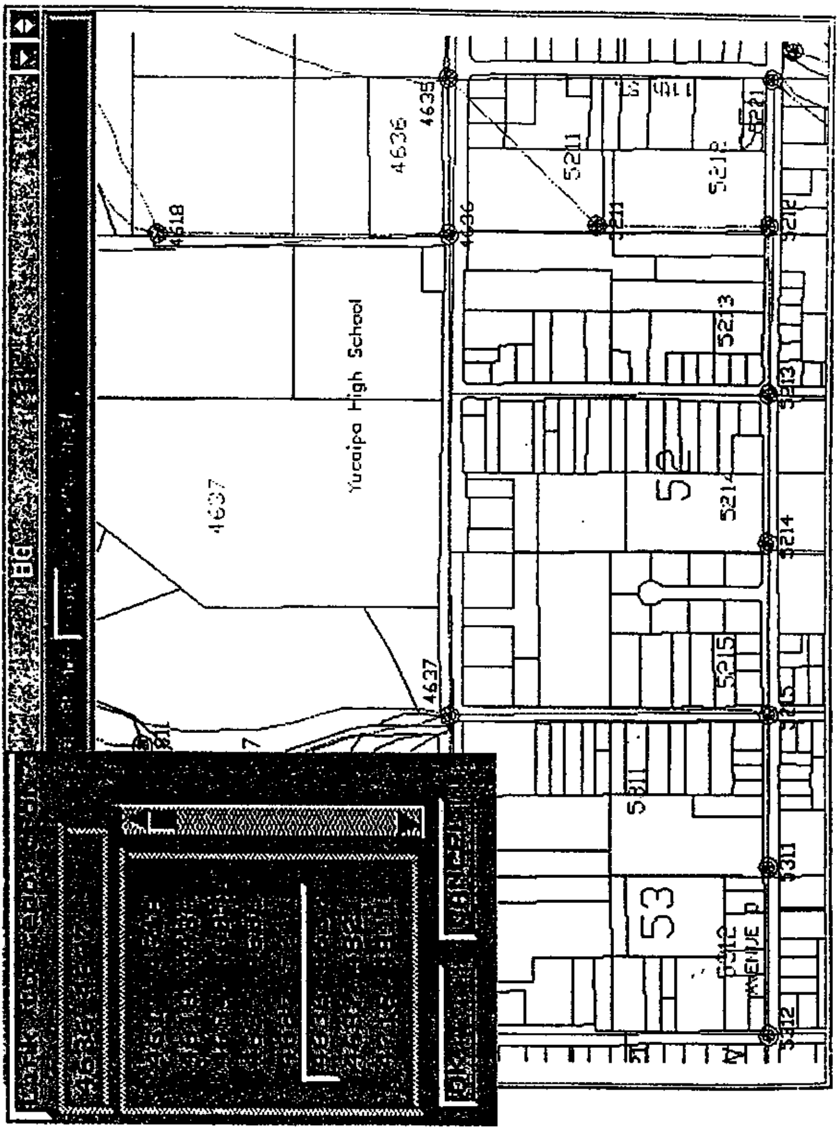


Figure 1. Cover Page of GDBMS

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