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Management, Modelling & Maintenance of water and wastewater Using GIS- A review

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Abstract
Communities are routinely faced with wastewater management decisions with limited data. Local goverments need tools that make the most of available information to manage the sewerage systems. Geographical Information Systems (GIS) are becoming the universal backbone in most information systems managing data for water and wastewater systems. Using GIS is a great aid in graphically presenting geo referenced information and providing the necessary tools to accurately locating needed information and linking water and wastewater management and modeling systems using the spatial position as the main indexing mechanism. In fact the capability of this technology offers great tool of how the water quality monitoring and managing can be operationalised in this country. In conclusion remote sensing and GIS technologies coupled with computer modeling are useful tools in providing a solution for future wastewater management planning to government especially in formulation policy related to sewerage.

Keywords:GIS, management systems, GIS sewer maintenance, Arc-GIS

Introduction
The collection of data about the spatial distribution of the significant features of the earth's surface has long been an important part of the activities of organized societies. From the earliest civilizations to modern times, spatial data have been collected by navigators, geographers and surveyors, and rendered into pictorial form by map makers or cartographers. Originally, maps were used to describe faroff places, as an aid for navigation and military strategies (Hodgkiss 1961). During the eighteenth century, many governments realized the advantages of systematic mapping of their lands, and commissioned national government institutions to prepare topographical maps. These institutions are still continuing the mapping work. Many of the developing countries are making all attempts to obtain the status of a developed country. These attempts are based on certain strategies relating to areas like natural resources management and development, information technology, tourism development, infrastructure development, rural development, environmental management, facility management, and e-governance. In order to make an effective study of these thrust and emerging fields, new and innovative technologies have been developed.

In the last two decades innovative technologies have been greatly applied to experimental and operational activities. These technologies have their historical antecedents. For instance, Remote Sensing and GIS have been developed from earlier technologies such as surveying, photogrammetry, cartography, mathematics, and statistics. Laurini and Thompson (1992) adopted the umbrella term "Geomatics" to cover all these disciplines. They stated that the different aspects of each of these areas are necessary for formulating and understanding spatial information systems. The traditional method of storing, analyzing and presenting spatial data is the map.

The map or spatial language, like any other language, functions as a filter for necessary information to pass through (Witthuhn et ai, 1974). It modifies the way we think, observe, and make decisions. Maps are thus the starting point in any analysis and are used in the presentation of results of any operational project. Whether it is remote sensing, photogrammetry, cartography, or GIS, the ultimate output will be the production of high quality, more accurate and clearer map, so that the user finds it easy to make appropriate decisions. Therefore, maps and their production using modern technologies is an essential starting point and

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they are the necessary tools to explore the characteristics of spatial phenomena.

Fundamentals of Geographic information system

GIS is defined as a system of capturing, storing, manipulating, analyzing, and displaying spatial information in an efficient manner. It can be characterized as a software package that efficiently related graphical information to attribute data stored in a database and vice-versa (kurt et al., 1993). GIS provides tools to improve efficiency and effectiveness when working with map and non-graphic attribute data. Although different GIS software may vary in capabilities, most contain the following components (Marble, 1984)

- A data input subsystem which collects and/or processes spatial data derived from existing maps, remote sensors, etc. the data input is usually accomplished using computers tapes, digitizers, scanners or manual encoding of geographically registered grid cells, points, lines, polygons or tables.
- A data storage and retrieval subsystem which organizes the spatial data in a form that permits it to be quickly retrieved by the user for subsequent analysis, as well as allows for rapid and accurate updates and corrections to be made to the spatial database. Typical directories include: land covers, soils imagery, topography, and water information.
- A data manipulation and analysis subsystem which converts data through user defined aggregation rules, or produces estimates of parameters and constraints for various space-time optimization or simulation models.
- A data reporting subsystem which displays all or part of the original database, as well as manipulated data, and the output from spatial models in tabular or map form.

Wastewater collection system overview

Wastewater collection systems convey domestic, commercial, and industrial wastewater (and in many cases storm water and groundwater) from its sources to a location where it may be treated and ultimately reclaimed for reuse or recycling, discharged to a receiving water body, or applied to the land. Wastewater is defined as "the spent or used water of a community or industry which contains dissolved and suspended matter." (American Society of Civil Engineers. 1982). The words *wastewater* and *sewage* are used interchangeably throughout this book. The pipes conveying the wastewater are referred to as *sewers.*

Sources of wastewater

Wastewater collection systems are designed to collect and transport wastewater from domestic, commercial, and industrial sources. However, inadvertent or illegal connections frequently result in entry of additional flows into the system. *Infiltration* is water that enters the system from the ground through defective pipes, pipe joints, connections, or manhole walls. *Inflow* is water discharged into the sewer from sources such as building and foundation drains, drains from wet or swampy areas, manhole covers, cross connections, catch basins, or surface runoff. Collectively, these flows are referred to as *infiltration/inflow* or *I/I*. These non wastewater flows may be separated into dry- and wet-weather components. *Rainfall-derived inflow and infiltration* or *RDII* is the component of the sewer flow that is above the normal dry-weather flow pattern. It represents the sewer flow response to rainfall or snowmelt in the system.

Types of conveyance

Although most sewer systems are designed and operated for partially full gravity flow, there are actually five types of flow conditions that can exist in a collection system, as illustrated in Figure 1.1.

- *Partially full gravity flow* – there is a free water surface in the pipe.
- *Surcharged gravity flow* – the depth of flow in the gravity pipe is above the pipe crown because of a downstream control.
- *Pressure flow in force mains* – sewage is pumped along stretches where gravity flow is not feasible, such as from one gravity drainage basin to another.
- *Pressure sewers* – each customer has a pump that discharges to a pressure sewer.
- V*acuum sewers* – flow is pulled through the system by vacuum pumps.

Even though most collection system pipes fall into the first category, systems can have a combination of all five types of flow.

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Pipe materials used in sewage systems include reinforced concrete, prestressed concrete ,cast iron, ductile iron, vitrified clay, polyvinyl chloride, and polyethylene. Due to the corrosive nature of sewage, metal pipes and, in some cases, concrete pipes may be lined to reduce the effects of corrosion.

Modelling

The words *model* and *modeling* are used in so many ways that it is helpful to distinguish among the many types of models. The *American College Dictionary* (Random House, 1970) defines a model as “a physical or mathematical representation to show the construction or operation of something.” With regards to wastewater collection systems, there are actually several kinds of models.

- A *mathematical model* is a set of equations that describes some physical process The Manning equation is an example of a mathematical model describing the relation between velocity, size, roughness, and hydraulic grade line slope in a pipe or channel. Mathematical models can be solved either analytically or numerically.
- A *computer model* is a computer program representing a physical system that approximates or reflects specific behaviors of that system. The numerical representation allows for computational numerical analysis. A computer model usually contains one or more mathematical models. A program such as Sewer- CAD can model flow in a sewage collection system.
- A *system model* consists of the computer model plus all of the data necessary for a particular system model. For example, SewerCAD, plus the data files describing the collection system in City A, comprise the sewer system model for City A.

In addition to these three types of models, the words *model* and *modeling* are also often used in software design to describe how data are structured. An *object model* is a graphical representation of the structure of objects (components) that make up a software package including their attributes, functions, and associations between other objects. A *data model* or *data schema* refers to the way that data are organized in database files and database tables. With a defined formal data schema, users and programs know exactly where to place or find the data. Once data are located, the schema further describes its type, size, and constraints.

Integration of gis functionability and hydraulic models

The open architecture of ArcGIS makes it an ideal connectivity tool for the many applications that are used in the management of data related to urban water infrastructure. As uses the ArcGIS Geodatabase as the central data repository, the different types of applications can easily exchange data and combine information that originates from seprate applications. The data model is open and documented and data can be accessed and even managed through other GIS applications. At the same time, use whatever other relevant data that the user may be storing in GIS system, eg land use data, aerial photographs, digital elevation data, etc background information for the modeling

Simulation model need information about the physical properties of the pipe network- pipe sizes, materials, hydraulic structures, pumps, valves, etc. such information is typically managed in an asset management system.

The integration with GIS functionability and enhanced update functionality is a major step ahead in data management for hydraulic models. For many years the main efforts among the vendors has been on development of tools for building of the hydraulic models. However many modelers are realizing that they are more or less forced to re-build the models 4-6 years in order to keep them up to date with the reality. The reason is simply because updating the existing models with all changes in the past period demands handling of large amounts of data, which are both tedious and often results in errors that can be very difficult to detect.

With the life time of the model can be dramatically by allowing the user to maintain the data in the existing GIS system and then update the model whenever needed. The key is to “recognize” the elements, which has been changed in GIS and then update the corresponding elements in the hydraulic models. This way the model can often be used for a significant longer period before re-calibration is needed, and at same time the management of the geometry for the networks data in the organization are significantly improved.

In addition to this some of the assets data is normally only accessible from GIS can be handled directly in the models. There are simply two or more synchronized tables in the data base for each data type. One tables handles the model data while the

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other handles asset data. This overlap between the structures in GIS and models are a great help in the daily work where a lot of time is often spent managing data from several sources.(et al J. Martin 2014.)

Examples

A few examples of where the GIS and the hydraulic modeling and integration with asset management systems from an efficient work bench for building, maintaining and graphically presenting sewer models are :

- Automated network geometry import and topography errors.
- Automatic discovery of network topology errors.

What do we want to achieve with GIS in local planning??

GIS is a possible tool to improve local planning by simplifying continuously increasing information. If the pool of arguments for decision making increases, alternatives will better fit to the needs of the concerned people.(et al Yamba Harouma Ouiba 2011.)

GIS is a possible means to visualize the likely local impact of exogenous large scale transformations, regional information.

How can we apply??

Three different possibilities of practical use of GIS are proposed. All of them are closely related to communication and selection of information. Fig. 2 explains that GIS works in three phases, as a means for presentation of expert results, as a tool for co-ordination for planners and as a means for integration of the public into the local planning process. In every phase the information becomes more simplified and more homogenous, relative to individual opinions and closer to the situation of the real world.

GIS as a presentation tool.

In this case the GIS produces maps of inventories of natural properties (climate, water, soil,vegetation, etc.) or human induced activities (agriculture, industry, traffic, settlement areas, nature conservation areas etc.). All collected data about a specific region, area or place can be transferred to a GIS. Specialists elaborate results of their disciplines in a detailed way. They transfer detailed information into various maps. Their view of the world is relatively restricted and is based on their own discipline (first dashed line of fig. 2). Their information has to be made known to others to get to know planning bases and needs. Instead of to present a huge amounts of tables and lists, specialists present information in pictures. Intuitively a person should understand the issue. .(et al Meinhard Breiling, 1996.)

GIS as a co-ordination tool.

The previous generated maps of inventories1have to be combined in a co-ordinated process. New perspectives will emerge that could not be detected from an isolated vantage point. Generalists having an overview of the situation shall connect different disciplines in a more comprehensive framework. Uncertainty and surprise during planning and implementation are already reduced because different opinions have to be taken into consideration (figure 2, second dashed line). New linked information becomes available for planning purposes. At the same time constraints and conflicts of interests become transparent.

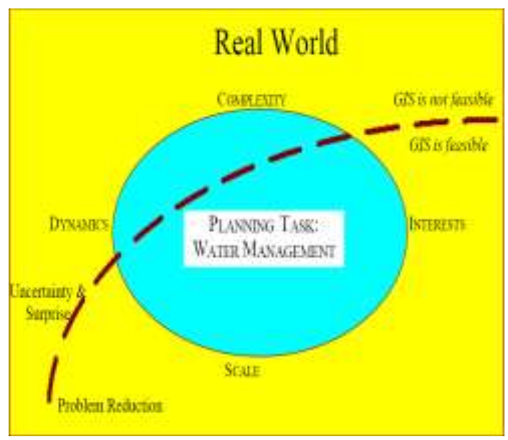

Fig. 1 (et al Scott Mcdonald)

GIS as a public participation tool.

The information load might be too dense for a general public that therefore keeps it passive. For this purpose a GIS has to be further simplified and contain only the main planning information. Instead of presenting hundreds of inventories and their combinations on maps one has to restrict oneself to a few essential results. A planner with sufficient overview should select this information . Uncertainty and surprise effects on planning are mostly reduced (third dashed line of fig. 2) since the public opinion is included and new aspects might appear.(et al Meinhard Breiling, 1996.)

Data for sewer system design

In designing sewer systems, the primary objective for the sewer network is to have gravity flow. In case gravity flow is not possible, the watershed needs to

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be broken into subwatersheds, and pumps are used to transport the flow.

The data required for the design of sewer systems for a particular area include the topography of the area, the desired location for the manholes, an estimate of the expected flows, and the locations of existing and proposed surface and subsurface features. An estimate of the expected flows can be obtained from the number of connections based on the expected or proposed surface and subsurface features and topography can be obtained from a topographical survey and from the local engineering and planning officers.(Richard greene et al 1999)

Interaction between gis and design process

The interaction of the GIS with the sewer system design process is shownin Fig. 1. The design process begins by the user interactively creating a layer in the GIS with the desired locations for the manholes. For each manhole, two attributes are added to the database: The number of connections to the manhole, and if the manhole is an outfall location. An attribute value of zero (0) or one (1) is used to indicate if the location is unsuitable (0) or suitable (1) for an outfall. In selecting the locations for the manholes, the user must meet the standards set by the ASCE and the Water Pollution Control Federation (*Manual* 1970). Additional requirements are also set by local health boards and town or city planning departments that must be satisfied. Some of these requirements include the spacing and maximum depths of manholes, minimum depth of cover for sewer lines, and the maximum allowable infiltration. The user must have knowledge of these regulations and how they are satisfied.

The other layers in the GIS include a topographic layer, a surface and subsurface features layer, a layer representing the street network, a land-use layer, and a zone layer. The surface and subsurface features layer contains features that will restrict or prohibit the passage of sewer lines. In this paper, the surface and subsurface features layer is referred to as the ‘‘prohibited areas’’ layer. In addition to the subdivision layout, the street network layer contains rights-of-way and easements for the location of the sewer and other utility lines. The zoning layer contains the various zoning designation within the area for the proposed sewer network. The topographic information and the other data are used to determine the surface elevation of the manholes, and the pipe lengths and ground slopes by using the GIS. The results from the GIS are subsequently passed to external computer programs that perform layout selection, pump station location, wet well design, and force main path determination. The results from the external programs are passed back into GIS for graphical display (Fig. 1).

Database utilization

GIS supports a series of spatial analysis functions that are ideally suited for design of sewer systems. These spatial analysis functions are used to preprocess the data for use by the sewer design program. For this study, the ARC/INFO GIS (*ARC/INFO* 1992) was used to accomplish the following tasks:

- Identification of the desired locations for manholes.
- Creation of buffers around prohibited areas.
- Creation of a triangular irregular network (TIN) for topographic information.
- Determination of surface elevations for manholes vertices of buffers.
- Creation of a preliminary sewer network as a TIN using manhole location and their elevations.
- Identification of potential lines for the sewer network through overlay operations that removes preliminary sewer lines that cross prohibited areas.
- To provide a graphical display of results.

Graphical user interface

To simplify the program operation, a graphical user interface was created using the Arc Macro Language of ARC/INFO. Menus are available to guide data entering and visualization of results. The initial menu allows the user to specify the various layers to be used by the design program. These layers include the desired manhole locations’ layer (created by the user), the topographic layer, the streets’ layout layer, and the prohibited areas layer. Another menu allows the user to specify the parameters for the GSDPM3 program. The users specify in this menu which of two regulatory standards, ten states standards or the West Virginia standards, to be used. Also specified in this menu are the means cost index, year of design, city cost index, type of material to be used for each of the sewer pipes, the maximum infiltration limit, the pump cycle time, and the width for sizing the wet well. A third menu is used to specify how the results are displayed on the screen using different colors and symbols.

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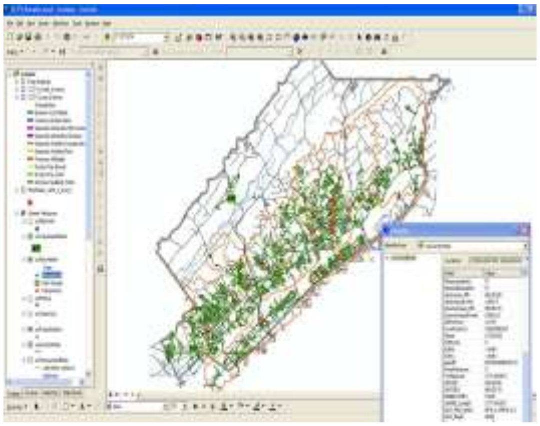

Fig. 2 Arc gis map

Conclusion

The price of modeling consists of hardware prices, software prices and the price of building the model, maintaining the model and running the model. The latter part often is the most expensive part, hence tools that support this process in the most efficient way will save costs. As GIS is becoming the universal backbone in most information systems managing data for water and wastewater systems, the integration and ability to retrieve an use information between GIS/Asset Management systems and the hydraulic models makes building and maintenance of the hydraulic models of water or sewer network systems much more efficient. Since constructing a sanitary system is tedious work and costly too. It require time and money both so we want to design a decision and support tool too make this thing easy and save man power and money also. The sanitation is main problem in india and through GIS we can make this system easy as we all know GIS is the simplest tool to make this things easy.

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