BIOGRAPHICAL INFORMATION

1. Md. Shah Alamgir
Ph. D Candidate in Hydro-meteorological Remote Sensing
INRS-ETE, University of Québec, Canada

Specific Responsibilities

Water Resources Planning Organization, Bangladesh, 1997-2000, Working as Principal Scientific Officer to establishing the National Water Resources Database (NWRD) and developing advance Generic and Planning tools, Data quality control guidelines and GIS & Remote Sensing application for flood mapping.

Past Experience

In Surface Water Modelling Centre, Bangladesh, 1994 -1996, working as System Manager, GIS system design, configuration and installation, Topographic, Hydrometric and bathymetric survey. In River Research Institite, Bangladesh, 1991-1993, working as GIS and System Analyst, Computer System Administration in a mixed environment (DOS, UNIX and Windows). GIS database management for all sector studies in Bangladesh. Assisted in interfacing of GIS and MIKE11 hydraudynamic model.

Educational Information

M. Sc. Engg. in Remote Sensing and GIS ; Asian Institute of Technology (AIT), Thailand
B. Sc. Engg. In Civil Engineering, Bangladesh Institute of Technology (BIT), Bangladesh

Professional Membership

Member of the Institute of Engineers, Bangladesh
Member of the Bangladesh Computer Society
Member of the Remote Sensing Society, England
Member of Canadian Aeronautics and Space Institute, Canada

2. Monique Bernier
Professor, INRS-Eau, University of Québec, Canada
Ph. D in Water Science; INRS-ETE, University of Quebec, Canada

3. Sardar M. Shah-Newaz
Senior Specialist, Water Resources Division, Institute of Water Management, Bangladesh
M. Sc. Engg. in Water Resources Development, Asian Institute of Technology

DEVELOPMENT OF GIS DATABASE FOR WATER RESOURCES PLANNING IN BANGLADESH AND GEO-SPATIAL TOOLS FOR PLANNERS

Md. Shah Alamgir [1], Monique Bernier [1], Sardar M. Shah-Newaz [2]
1. INRS-ETE, University of Québec, C. P. 7500, Sainte-Foy (QC), G1V 4C7, Canada
Telephone : 1-418-654-3771 and Fax : 1-418-654-2600
2. Surface Water Modelling Centre (SWMC), Mohakhali, Dhaka, Bangladesh
Telephone : 8802- 8824590 and Fax : 88002- 8827901

ABSTRACT

Water resource planners need access to a wide rang of data and tools to assess resources, demands and constraints to evaluate various options toward formulating alternative strategies. Water resources planning activity needs a vast amount of geo-spatial data. An attempt was made to organise all the available spatial and time series data related to water resources of Bangladesh through the development of the National Water Resources Database (NWRD). The GIS database of NWRD provides access to the available spatial data through a number of tools developed for the national level planners. The metadata module of the NWRD helps planners to assess the data availability and quality along with their spatial and temporal extent. This paper discusses various issues of constructing the GIS database and narrated various planning tools and their usefulness in the context of Bangladesh.

1. INTRODUCTION

Bangladesh is richly endowed with water resources. The natural surface water resources are mainly obtained from the country's dense river systems, which include a combination of inflow from outside of the country and flow generated from rainfall within the country. There are about 57 rivers, which are originated outside Bangladesh, and they carry about 93% of the total water from outside the country. The water eco-system of Bangladesh also includes numerous perennial and seasonal wetlands.

Water resources planning and management in Bangladesh has to take into account the dual problem of flooding and water scarcity along with the competitive demands of various sectors like agriculture, domestic, fisheries, industry, navigation and ecology. The National Water Council (NWC) of the Government of Bangladesh formulated and approved a National Water Policy (NWPo) in late 1998. As per the recommendation of NWPo a project was initiated to prepare a comprehensive and pragmatic National Water Management Plan (NWMP) for a long-term time frame. As such Water Resources Planning Organization (WARPO), the apex body in Bangladesh for macro-level water resources planning, has been given the responsibility to carryout the project.

Water resource planning needs a huge collection of reasonably accurate spatial and time series data, which is a sub-set of the total data needed by the Government for managing its affairs. Different government and semi-government agencies collect national and project level data for their own or for the national interest. NWPo has established WARPO's responsibilities to create and maintain a central database with data collected from other agencies to improve water resources management and planning at all levels. Consequently

the implementation of a database, the National Water Resources Database (NWRD), was initiated under NWMP.

The NWRD has a metadatabase that holds a catalogue of available data sets. The metadatabase holds sufficient descriptive data of the data stored in the database. It has a navigational database for searching data sets from different tools. And it contains the actual data tables in RDBMS that are defined with spatial links in the navigational database. Some data in NWRD are in operating system file formats, especially the spatial data, e.g., administrative boundaries, river courses, rails, roads, etc. These are also described in the metadatabase as well as in the navigational database.

The NWRD includes both spatial and non-spatial (hydrological and hydro-meteorological time series data) database. The main threshold was the development of GIS database that organised and standardised many of the spatial data sets of Bangladesh. This paper focuses only the GIS database and the term *NWRD* and *GIS Database* are used synonymously.

A number of Geo-spatial tools were also developed for querying the database, displaying and retrieving data and analysing data. Metadata browsing tool covers the metadatabase query, retrieval and export functions. It enables the user to search the database and obtain information about specific content, quality and history of the data. The development of the GIS database has helped the water resource engineers, planners and other users to get multi-sectoral and authentic geo-spatial data with a one-stop service. The strategy involved in this development is a pro-active and forward-looking approach, making full use of the many technical possibilities in the so-called "Information Age". It has the vision that in the future NWRD will be accessible from all relevant institutions in Bangladesh.

2. SPATIAL DATA IN NWRD

The NWRD holds all the available spatial data along with other data sets related to the water resources of Bangladesh from different sources in many formats. It also contains maps produced in different scales and projections. WARPO has collaboration with those 25 government and non-government agencies so that NWRD will be getting updated data constantly. Data in NWRD are very much different in characteristics and they are categorised in 10 groups as stated in Table 1.

Table 1. Data groups and data sets in NWRD

Group	*Data sets*
Base Data	Administrative boundaries at various levels, road, rail, embankment, catchment, hydrological planning unit, hydrological region, topography and coastline, images. Digital elevation model (DEM)
Surface Water	Rivers, water bodies, water use, hydro-metric data
Groundwater	Water level, water use, recharge, water quality
Soil and Agriculture	Soil association, soil map unit, soil sampling sites, crop statistics, draught, land type, agriculture inputs, crop suitability
Fisheries	Fish catch, shrimp culture, ponds, water bodies

Socio-economic	House hold data, economic data
Geology and Morphology	Geological map, coast line, major river Morphology, bore log
Hydro-meteorological	Rainfall, evaporation, sunshine, wind speed & direction, temperature
Environment	Water quality, air pollution, poverty, global warming, sea level rise
Satellite Images	Land cover, flood mapping, pond survey

The GIS database consists of differently stored data:

a) Online data
These data can be divided into

- Tabular data stored in the RDBMS (database server)
- Files stored on disk (file server). These files are directly readable for the query and analysis in known file formats.

b) Semi-online data
These data are stored in files in the file-server. They are in different file formats, which are readable by available statdard applications other than the customised tools developed for NWRD.

c) Offline data
Offline data does not form a part of the actual planning database, but exists as part of the registered available data of interest to the potential users. They supplement the online data, however, they may exist in computerised form or on paper (e.g. as part of reports) and are only referred with a reference to the institution where the data can be obtained.

Most data in the database have a geo-reference, either through reference to the base map data or by actual co-ordinates or spatial information in one of the supported co-ordinate systems. Spatial data in NWRD are mainly three types: *feature*, *image* and *grid*. Three types of feature are there, for instance, a gauge station for water level will be shown on maps as a *point*, whereas rivers should display as lines or *polygons*. Catchments are displayed as closed *polygons*. A good collection of satellite imageries is stored in NWRD. Images are used for object identification with geo-reference and for calibration and verification of mathematical modelling of different physical events. Grid type data are very limited. Mainly the altitudes of ground surface at all over the country are stored as regular grid points. Spatial data are stored as operating system files in a file server.

3. ORGANISATION OF GIS DATABASE

Being an engineering application oriented database, the NWRD has different groups of users. Some people will access the database only for viewing or for getting data, some people may edit or check the quality of data and some top-level planners need advanced analysis with data. Considering different type of uses, different characteristics of data sets and various types of storage schemes the whole system has been modularised as four components. These are:

a) Metadata Information system

b) Navigational database
c) Data tables
d) Spatial data files

a) Metadata is 'data about data'. In NWRD the *metadata information system* is working as the background information repository, which describes the content, quality, condition and other appropriate characteristics of a data set. This database will hold all descriptive data. It is serving many important purposes, including data browsing, data transfer and data documentation. It ensures that potential data users can make an informed decision about whether the data are appropriate for the intended use. The metadata information system is an independent system. It has its own database server and an Internet based browsing tool. The metadatabase is defined and maintained by the tool GeoKey developed by Geodan IT of the Netherlands. The GeoKey Editing tool, an Windows application, is used for metadata creation and the GeoKey Query tool, an Internet browser tool, allow users a flexible search to the domain of NWRD data.
The implementation of the metadata information system for NWRD evolves into a national standard for metadata. Metadatabase in NWRD acts as the catalogue of the available data sets. It has been created in such a way that it allows a hierarchical search about NWRD data sets. It has an independent setup and architecture apart from the NWRD, but the design of the system has been done keeping in mind that the information should be consistent with that of NWRD. For this a temporary metadatabase is there within RDBMS.

In developing the metadata system an extensive investigation over the existing metadata models was conducted to find the appropriate model to Bangladesh context. A report was published in this regard in 1999 (Matin, et. al., 1999). It was found that the International Standard Organization ISO has given a model identifying four major uses of metadata as *Locate, Evaluate, Extract* and *Employ*. The report strongly recommended for ISO metadata model for NWRD metadata system as it suits the NWRD data sets most. Initially the system was created for spatial or geo-reference data sets. Later, it has been extended for time series and other data sets. There are about 70 metadata elements in NWRD for defining different data sets. Table 2 gives a list of some of the key metadata elements for NWRD metadata system.

Table 2. List of key metadata elements of NWRD metadata

Element	*Type*	*Element*	*Type*
Language of Data set	Text	Data source name	Text
Title	Text	Data source location	Text
Abstract	Text	Data type	Text
Purpose	Text	Temporal extent date	Date/Time
Progress code	Number	NWRD Category	Text
Access constraints	Text	Theme code	Number
Use constraints	Text	Key words	Text
Qualitative narrative report	Text	Group code	Number
Distribution identifier	Text	Geographic extent name	Text
Distribution format	Text	Spatial representation type	Number
Distribution media	Text	Spatial reference type	Number
Size of data set	Number	Coordinate system type	Number
Level of conformance	Number	Map projection identifier	Number

		code	
Language of Metadata	Text	Feature attribute name	Text
Metadata date	Date/Time	Feature attribute data type	Number
Responsible party information	Text	Feature attribute value unit	Text
Responsible party organization name	Text	Feature attribute domain type	Number
Postal address	Text	Feature attribute domain	Text
City	Text	Feature attribute value	Number
Postal code	Text	Feature attribute value definition	Text
Country	Text	Feature type name	Text
Electronic mail	Text	Feature type definition	Number

b) The metadata structure, however, cannot define the complexity in possible combinations of display of data, as well as relations between different data sets, which require each other to present a consistent whole to the user. For these reason, a separate set of tables is defined as *Navigational database* within RDBMS. This database clearly points the links between related data sets.
The Navigational database serves as the application-oriented links between the metadata registrations of data and the data itself. As the some applications retrieve and present data with the GIS software, these link tables hold information on spatial relationships, possibility for spatial display and link to time series tables. The navigational database contains a number of tables for storing data source information, data storage information, time series data references and spatial data references. It has appropriate link with the metadatabase. Most of the tools access the spatial or time series data through this database.

c) Data tables : Some data are stored on-line in the RDBMS (SQL Server). The structure and internal relationship of these tables will in some cases facilitate easy generic display and in others only allow for tabular display of the data itself. Time series and attribute data are stored within the RDBMS as table objects. The structure and internal relationship of these tables are used to facilitate tabular display or graphical display or different type of analysis with the data.

d) The tables : are derived from the input sources in a way that both facilitates the generic query and display tool and preserves the consistency of the data with respect to its original form. Data tables in RDBMS can be any of the following four types:

- *Simple table* has no time dependent information and no spatial components. Examples of simple tables are the attribute tables.

- *Simple time series table* contains time tag but no spatial component. But these are defined in the navigational database to link the station tables, which contains geo-references.

- *Table with spatial link* contains geo-references and used for spatial display and analysis.

- *Time series main table with spatial link* contains geo-references and has link with time series tables. For example, time series station information tables contain spatial link fields

and these are linked with their related time series tables. The link field in the definition table must have the same data type as the link field in the station table.

d) Spatial data files : What cannot and should not be stored in the RDBMS, but still has to be stored for on-line retrieval will be put into files in a file-directory hierarchical structure. These are mostly geo-referenced or spatial data and are kept as their native GIS software file.

File database mainly holds operating system files of the spatial features like administrative boundaries of different levels, countrywide river network, geological features, different data collecting station locations, etc. It also contains some previously organised data and textual information in different formats like dbase, excel, MS Word documents, text files, etc. All these data are defined in metadatabase and navigational database so that they are accessible through the applications.

A particular data source can be identified by a 3-layer keyword system. First layer contains data groups and second layer contains all data types under specified data group. The structure of the file hierarchy will follow the groups defined in the metadatabase. The total 10 groups are identified for the NWRD development as stated in Table 1.

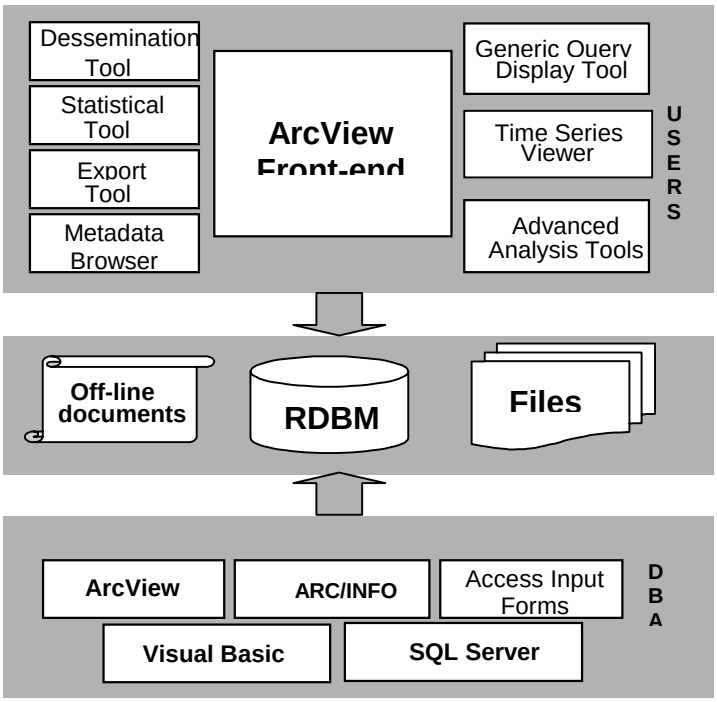

Figure 1 The GIS database and Geo-spatial Tools

Data stored in files are located on a computer configured as a central file server. The file server is reachable over a LAN. The structure of the file hierarchy follows the groups defined for grouping data referred in the metadatabase. For each of these groups a number of sub-directories are defined. These sub-directories reflect the data types referred in the group/type definition of the data set in the metadatabase. For each of this 2nd layer directory a number of sub-directories are defined grouping the data by file-type and/or data-set entity.

4. GEO-SPATIAL TOOLS

A number of geo-spatial tools have been developed for different needs for planners or database users. These are Metadata Browsing Tool, Generic Query and Display Tool and Advanced Analysis Tool. These tools facilitate the users to display and retrieve spatial data from NWRD, analyse the data and export the data for other external uses. They reach the actual data with the pointers defined in the metadatabase and navigational database. Application tools do not directly access the data in RDBMS. They go through the views

defined within the RDBMS. A number of views are defined and they are very much application specific. Brief description of tools ate stated below.

4.1 Metadata Browser

To search metadata about NWRD data sources, GeoKey metadata software is used. To the NWRD, GeoKey acts as the catalogue of data. The configuration of GeoKey includes specifications for some items and look-up tables that make it possible for the NWRD applications to use the metadata in GeoKey system for all the data types in NWRD. Keywords in GeoKey are configured in such a way that a 3-layer hierarchy of data can be obtained allowing for a hierarchical search with dialog window. GeoKey will work with registration of geographical data sets, i.e. files on disk as well as tables in NWRD. The GeoKey metadatabase extension links the application with GeoKey server and provides the application with metadata information for the selected data source. If this extension is not loaded then only a subset of metadata will be available from temporary metadata tables in NWRD.

Searching a particular data source from the list of available data sources will show metadata about the selected data source in six categories (Overview, General, Access, Contents, Specific and Item) as shown in the Figure 2. Clicking any category will bring features of that category at top of the display. The File Server serve the applications with file based data - especially the base map data. The structure of the file hierarchy will follow the groups defined in the metadatabase.

4.2 Generic Query and Display Tool

This GIS application is the front-end Interface for the user for querying data in the database. By using this tool one can display data as theme for shape file, grid and image and other information in the tabular format. Tabular data can be linked to shape files by using ‘Spatial Link`. This tool can query the data layers on the basis of three hierarchical orders.

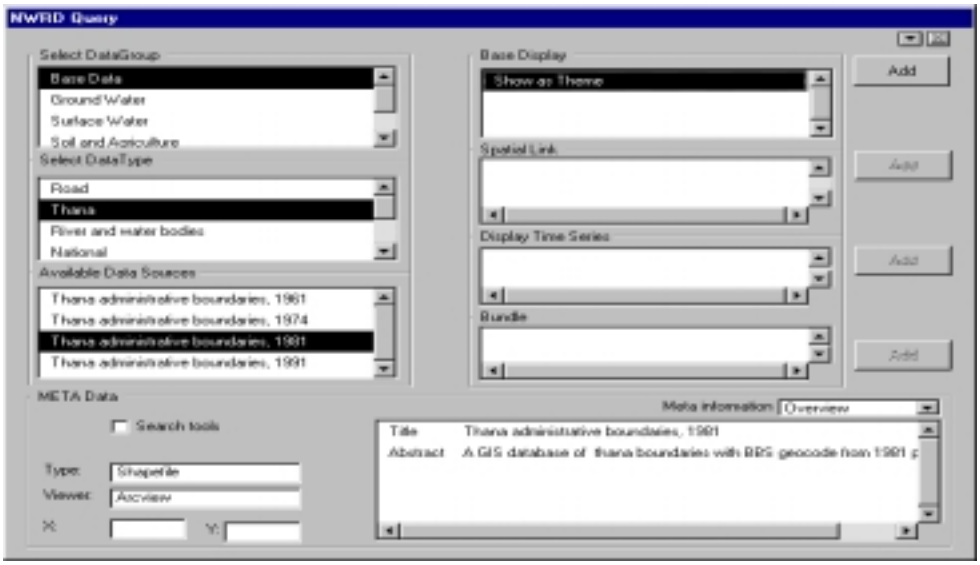

Figure 2 Interface of Generic Query and Display Tool

This query and display tool accesses the data through navigational database. This tools support overlying of multiple themes or spatial data layers in a single view window of the GIS application. There are a number of predefined layouts created for producing maps with different combination of data sets. These maps can directly be used for hard copy printing or using in other reports. This facility relieves the planners of the tedious task of composing maps for a long time.

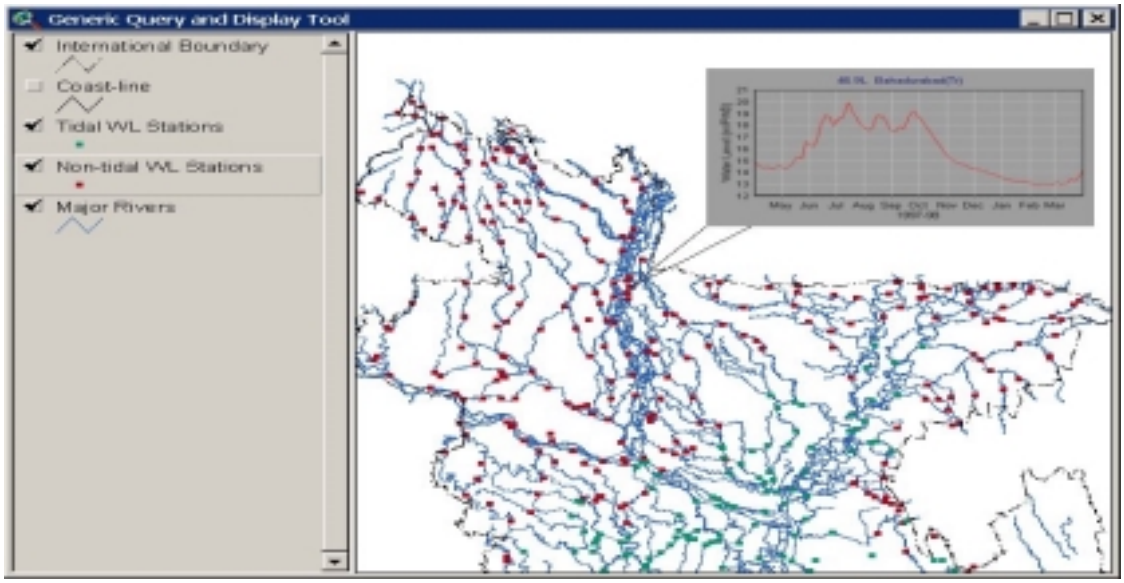

Figure 3 View window of Generic Query and Display Tool

The generic query and display tool provides direct access to time series data from spatial data layers. For example, water level of a particular station may be viewed as time series hydro-graph or in tabular form by clicking on that station from the view window.

Being generic query and display tool this application can only just display data in tabular format or as theme but no analysis is possible.

4.3 Advanced Analysis Tool

Advanced Analysis Tool is also developed with GIS software and its spatial extension. This tool is mainly of interest to the advanced users and the system management group, as this requires some GIS expertise to handle. The tool includes point to polygon attribute conversion, polygon to polygon conversion, spatial theme merging, area calculation, spatial distribution of point data, etc. The data, which is on-line, are found either in file database or in the SQL Server tables. For tables in the SQL Server the application uses SQL statement with ODBS connection for queering and retrieving data.

For both tables in RDBMS and files in the file database, a set of general functions are there for checking of file and directory existence, table existence and field existence, thus making the application robust to faulty specifications in the metadata. Depending on the type of data in the database different display options is available for the user to choose between. They can be grouped as *base display modes* and *advanced display modes*. The base display modes

define how the main data types are displayed. The advanced modes define how different data sets, which are related, can be displayed using each other. For certain tabular data reference to other data is relevant, which defines some other display modes. Tabular data can always be shown as table.

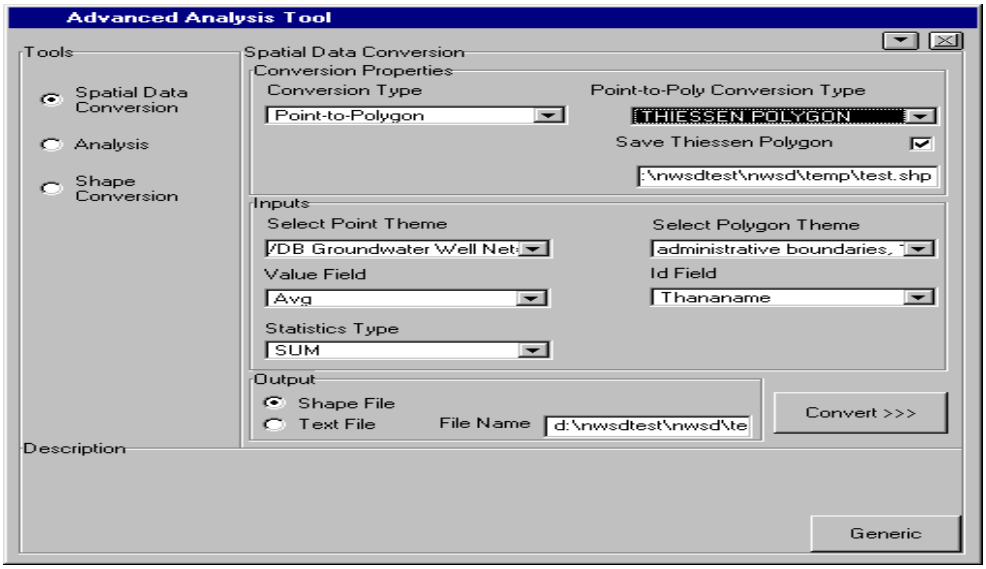

Figure 4 Advanced Analysis Tool

Furthermore some data sets may need information from other data sets for the user to be able to read and understand the entire content. An example of this is a look-up table with soil type definitions and codes for soil types registered in a borelog. A generic way of displaying these data is to refer to them as a bundle, with mandatory and optional components, and display all according to their base display mode.

Some of functionalities of this tool are: calculation of area elevation curve, generation of surface profile and conversion of shapes. Advanced tools are basically divided into three modules as stated below:

1. Spatial Data Conversion
   - Point to Polygon
   - Polygon to Point
   - Polygon to Polygon
   - Grid to Polygon

2. Analysis
   - Area elevation curve
   - Long profile

3. Shape Conversion
   - Point to grid
   - Polygon to grid

5. CONCLUSION

The implementation of NWRD has become a successful story of a complicated engineering data management system. With the establishment of the GIS database all relevant institutes, planners and researchers of water sector have been benefited to a very great extent. It has been recognized as a milestone for developing sophisticated and useful spatial data management system for other sectors of Bangladesh Government to run its affairs. With a further advancement, i.e., promoting the metadata browsing facility over the World Wide Web, information about geo-spatial data of Bangladesh can be found from every corner of the world.

The technicalities of designing the GIS database can be an example for establishing similar engineering application oriented databases. The issues like exploitation of RDBMS technology with consideration of planners' requirements and integration of more than 100 data sets of different characteristics may be the topic of interest of database researchers and practitioners.

The implementation of the GIS database has open the opportunity to establish Bangladesh Geographic Information Infrastructure (BGII) which will act as the national institute for storing and standardising geographical information of the country. With this objective initiative has already been taken and it has a vision to establish a Regional Geographic Information Infrastructure (RGII) to cooperate among the regional countries in sharing and exchanging geo-spatial data.

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