GEOGRAPHICAL INFORMATION SYSTEM FOR SHORELINE MANAGEMENT – A MALAYSIAN EXPERIENCE

Dr. Rongxing Xi
Department of Geomatics Engineering, The Universiti of Calgary 2500 University Drive, NW,Calgary Alberta, Canada T2N 1N4

Ir. Cho Weng Keong
Coastal Engineering Division , Department of Irrigation and Drainage Malaysia, Jalan Sultan Salahuddin , 50626 Kuala Lumpur, Malaysia

GEOGRAPHICAL INFORMATION SYSTEMS FOR SHORELINE MANAGEMENT - A MALAYSIAN EXPERIENCE

Dr. Rongxing Li
Department of Geomatics Engineering, The University of Calgary
2500 University Drive, NW, Calgary Alberta, Canada T2N 1N4

Ir. Cho Weng Keong
Coastal Engineering Division, Department of Irrigation and Drainage
Jalan Sultan Salahuddin, 50626 Kuala Lumpur, Malaysia

INTRODUCTION

Shoreline change is affected by both natural processes and human activities. The natural processes may be caused by phenomena such as waves, currents, storms etc. Human activities affecting the shoreline are, for example, land reclamation, recreation beaches, landuse of the coastal zones, and structures built along the shoreline. The shoreline change may produce an impact which can be evaluated positively or negatively. Shoreline accretion may create more usable land for recreation or other purposes. However, a resort which was close to the beach may find itself out of the view from the new beach and thus, unattractive to tourist visitors. On the other hand, shoreline erosion may cause problems if it develops towards, for instance, a resident area. No mater how the shoreline will change, the current shape of the shoreline will be changed and furthermore, the environment of the coastal zone will be changed.

The coastal zone represents diversified and important areas along the shoreline, ranging from swamps, farmland, aquiculture land, recreation beaches, mangroves, to resident areas, industrial land, and harbors. The shoreline status is crucial to the human being, wildlife, and properties of these areas. Maintaining of an appropriate shoreline status is of interest to all members of the coastal zone. This in turn requires a great joint effort to make the coastal zone sustainable. Interdisciplinary and sometimes international cooperation among government agencies, the private sector, and institutions is the key to the success of the shoreline management..

Geographical Information Systems (GIS) can be utilized to support various stages of the modernized shoreline management. Data involved in shoreline management are diverse, including spatial data, time series data, social and economic data, and multimedia information. The spatial data are shoreline positions, topographic data, bathymetric data, parcel data, buoy locations etc. The social economic and policy information is an equally important data category in coastal GIS, which is integrated with spatial data and used to support decision making. Time series data, for example wind and wave observations, can be integrated with spatial data through the locations of the sensors. The integration of the spatial data, time series data, coastal engineering modeling, environmental data, and social economic data the GIS environment makes it possible to examine the current shoreline and coastal zone situations in terms of environmental, social economic and other impact. Furthermore, it is an important system for decision making in shoreline and coastal zone management.

Introduction

THE MALAYSIAN SHORELINE

General Information

Malaysia has a total length of shoreline 4,800 km including the peninsula, Sabah, and Sarawak. According to the national erosion study in 1985 (Stanley 1985), more than 90% or 4,300 km of the shoreline is erodible alluvium. Sandy coasts are along the shoreline of east peninsula Malaysia, Sarawak and several stretches of west peninsula Malaysia such as Penang, Port Dickson and Melaka. Coasts of clay, mud and silt etc. are distributed along the shoreline of west peninsula Malaysia and Sabah. The current eroding shoreline reaches 1,300 km, 29% of the national shoreline. The erosion rate ranges 1-100m per year, with some areas eroding even more severely. In 1985, there were 140 km of eroding shoreline segments threatening facilities. That number increases upto 240 after 1985 (Willis 1995, Kjerfve 1994). To response to the situation, a National Coastal Erosion Control Council was established, under the coordination of the Prime Minister's Department to coordinate coastal erosion control programs and formulate policy for the management and development of the coastal zone.

A large part of shoreline erosion or accretion in Malaysia is a natural phenomenon. But some are man-related. In the later cases, the erosion or accretion is a shoreline response to economical or social development of the coastal area. Wave driven coastal processes are the major cause of shoreline erosion in Malaysia. Waves approaching the shore at an angle with respect to the shore release energy. The longshore component of the released energy transports the sediments along and away from the shore. Thus, erosion of the shoreline occurs. Areas where the transported sediments are accumulated have accretion.

Since much of the economic and social life of Malaysia is supported by activities in its coastal area, erosion consequences continues to affect the activities and facilities severely, which include agriculture, community life, recreation, transportation, and tourism (Stanley 1995). It is necessary to understand the erosion process and to manage and plan the existing and future activities and facilities based on a sound foundation, so that the erosion consequences can be controlled.

There are two general ways to control the erosion and to keep the erosion consequences within a limit. The first approach is to implement structure measures such as revetments, seawalls, breakwaters, groins, and protective beaches. This expensive way may have immediate control of erosion in the protected area. However, care must be taken to prevent the cases where new erosion be accelerated or initiated by the newly built structures. The second approach is to allow the erosion to continue without the unacceptable consequence. Non-structural measures such as landuse zoning, construction set backs, and relocations can be implemented.

Information about the current erosion status and the erosion rate, and analysis of the erosion impact are critical to coastal decision making processes. GIS technology is applied to support shoreline management projects in the Coastal Engineering Division (CED), Department of Irrigation and Drainage (DID), Malaysia, which is responsible for national coastal planning, coastal zone management and development, coastal project monitoring and implementation, and river mouth and dredging.

Databases

GIS consist of three components, namely hardware, software and databases. The last component is usually most important and costly. It often takes a large percentage of the project budget. Considering the nature of the application of this GIS, the following data should be included in the GIS databases:

Shoreline history: Aerial photographs of the entire national shoreline should be taken every 5 years in order to accumulate data for monitoring long term shoreline changes (Stanley 1985, Li 1995). The photographs should have about 60% longshore overlap so that the 3D shoreline can be extracted from the photographs by stereo photogrammetric processing. For shoreline segments eroded severely, larger scale aerial photographs should be taken more frequently, for example every 1 - 3 years. The larger scale photographs may also be used for other purposes such as coastal zone topographic mapping, beach profiling, and erosion interpretation. For very small sites, total stations and GPS receivers may be used to capture the shoreline periodically and compare the shoreline changes.

Bathymetric data: Hardcopy nautical charts of 1:15,000 and 1:200,000 provide important bathymetric information. Bathymetric data in digital format become available recently because of the advances in computer technology and application of acoustic sounding surveying systems (Li and Saxena 1993). In Malaysia, this kind of data are maintained by Royal Malaysian Navy and some oil and gas companies. Hydrographic survey of small areas are conducted or contracted out by CED. Bathymetric data are crucial to structure design, hydrological modeling, and shoreline changing monitoring. The data acquisition is usually expensive.

Topographic data: Topographic maps of 1:50,000 are maintained by Department of Surveying. Until 1994, 30% of the peninsula Malaysia and 5% of East Malaysia were digitized. CAM (DST format of a Swedish mapping system), ASCII, and DXF formats of the digitized maps are available. These data cover the features on the land side of the shoreline. DTM (Digital Terrain Models) describe the land terrain relief which determines the shoreline shape along with the bathymetric data, the water level and other factors.

Attribute data: GIS attribute data such as demography, land use, geology, soil types, environment quality etc. are included. These data are sometimes necessary in decision making, for example for setback planning, protecting resident areas, limiting or avoiding environmental impacts, and other purposes. A lot of coastal attribute data can be associated with shoreline segments, including erosion categories, structure costs etc. Once the shoreline geometry is built as routes in the network system of ArcInfo, dynamic segmentation can be used to model the change of the attributes of the shoreline. It should be noted that the change of the attributes does not require the resegmentation of the shoreline.

Multimedia data: Terrestrial and aerial photographs are available for shoreline sections of different periods. They are important for interpreting erosion status. Hardcopy photos are scanned into the system. The scanned images are then related to the desired features and can be displayed by clicking the corresponding features using a hot link. Design drawings can also be associated with features so that the features and corresponding drawings can be examined at the same time. Sound of waves approaching structures, video clips, and results of simulation and animation may also be included in the future.

Time series data: Wave data, wind data, current data, wave surface elevations (tides), river data (daily discharge), and other time series data describe the processes affecting the shoreline and other coastal phenomena. A link between the time series data and the spatial data opens a new way of unified database management scheme and an integrated coastal modeling environment. In most cases, time series data have the following characteristics: a) the position of a sensor can be treated as a constant, and b) the observation data are large in size and expand rapidly along with time. Currently, the time series data included in this system are

- LEO (Littoral Environment Observation) data containing wave, wind, beach slope, current, and water level information. Two tables in dBASE format are given, one for location and general information and the other for the observations (Willis 1995, Kjerfve 1995). 18 LEO sites are distributed in the country and provide data every month to DID since 1985.
- Wave data: Waverider™ data are results of statistic analysis of wave data based on 20 minutes records sampled at 2.56Hz every 3 hours (Willis 1995). Pressure Gauge data of two locations and waterlevel data from two other sites are also available.
- SSMO (Surface Ship Meteorological Observations) data from NOAA National Climatic Data Center from 1949 - 1993 cover the Malaysian waters. Marsden squares are used as indexing frames, with each square of 10° (latitude) x 10° (longitude). The SSMO data are in dBASE format including both general information such as a Marsden square number, date and time of the data acquisition, and data fields containing information about wave, swell, wind, meteorological conditions, and ship speed and direction (Kjerfve 1995).

Functions To Be Supported By GIS

Activities of the Coastal Engineering Division can be summarized in the following four aspects:

Coastal Engineering: Coastal engineering sites are mostly in erosion category I areas indicated by shoreline condition maps. More detailed information is supplied by cadastral maps for site selection, although the shoreline on the maps is often outdated. A land/bathymetric survey has to be performed to provide topographic/bathymetric maps (e.g., 1: 1,000) for structure design. Tidal, water level, and storm surge data should be made available for determining structure heights. In addition, geotechnical data such as shear strength of soil etc. are also needed. Design drawings are generated using AutoCAD. With all these data available in digital form in the GIS database, a computerized (or partially) design procedure can be expected, which will make the design much more efficient and comfortable. Another aspect is the overview of projects in the whole nation. This includes LEO data and coastal constructions. An inventory system will be a good solution to this need. A database with status of all projects completed and planned in the GIS will enhance the project management and efficiency of administration.

Rivermouth Dredging: CED is often requested by Fishery Department to conduct rivermouth dredging and to improve port access and navigation of fishing boats at both high and low tides. The requests from Fishery Department usually indicate an approximate area. Detailed design boundaries need to be determined by CED on a topographic map (1:1 mile) and upon consultation with local fishing authorities. Thereafter, a detailed bathymetric survey of the specific area is performed and a survey map of 1:2,000 is produced. The final design boundary of the dredging area is located based on the survey map. A post-dredging survey estimates the volume of the dredged material solely for estimating dredging charges. Periodical surveys may be used to monitor trends of sedimentary movement and predict dredging sites. This may be combined with numerical modeling techniques. If the topographic database is in digital form and the survey data can be supplied in digital form as well, the design procedure, volume estimation, and long term trend analysis can be accomplished in a GIS environment.

Coastal Project Monitoring and Implementation: Services such as cost estimation, project budget justification, tender calls, and budget monitoring etc. are included in the project monitoring function. These services can be enhanced by applying GIS technology. After a design is accomplished and the contract is awarded, CED has to monitor the progress of the project. This is currently be done by reviewing reports from state DID and contractors. If site conditions and other factors change, technical support may be provided to solve problems. Measures may be undertaken to make the project running smoothly and on time. In the monitoring work, important information needed is what has been done and what still has to be carried out. Since the current monthly reports are text based and photos may be supplied in addition, no intuitive view of the project progress is available. If the general layout plan with a scale of 1:1500 (which is a map overlaying the structure design drawing on the survey map) can be input as a digital map, the project progress report can be supplied in a digital form with both text and progress status on the map. For example, comparison of progress and costs can be performed by comparing progress maps in individual time periods. Overview of project status will become much more efficient. Financial statements and progress payment may also be supported by real status maps showing work completed.

Numerical Modeling: Numerical modeling is a technique to investigate behavior of the shoreline and the physical coastal environment using computer technology. It can be used for studying erosion process, shoreline changing, structure design, and shoreline erosion prediction. Data needed for numerical modeling including shoreline, bathymetric data, size of grain, wave data, tidal data, and wave approach direction. More sophisticated numerical model considers affect of wind as well. In an integrated system, if digital data are available, data for numerical modeling should be organized in GIS and provided to modeling system such as MIKE 21. The result of the numerical modeling can then be displayed in the GIS environment. For example, changes of shorelines caused by different input data sets can be overlaid and compared. The simulated shoreline can also be displayed with other features such as land parcels, and land use classes, so that effects of erosion can be assessed. After modeling, the newly calculated bathymetry can also be displayed in 3-D with other data layers together.

GIS SYSTEM DESIGN

Hardware and Software Configuration

A review of current hardware and software systems at CED/DID was conducted. Some government agencies, institutions, and the private sector with GIS facilities were visited. Considering specific aspects critical to CEDs GIS development (Li 1995), the hardware and software configurations shown in Figure 1 and 2 were suggested.

Overall, the hardware and software configurations were designed to meet requirements of the data collection program, shoreline management, GIS, and physical modeling, with the consideration of existing computing resources at CED. Following the fact finding meetings with other government agencies, experiences and lessons from these local GIS sites and related projects as well as compatibility and data transfer between agencies and the private sector were taken into account during the design. The following are some justifications to the major items in the hardware and software configuration design. 1) GIS systems handle large databases with both spatial and non-spatial data. The functions based on spatial information are usually very computationally intensive and require fast system responses during querying and analysis. In shoreline management, data sets of coastal zones are very diverse and of high volume that demand sound database management and high computing power. Therefore, a work station is recommended as the major platform for GIS modeling and analysis; while PCs are used for small tasks such as digitizing. In cases where more than one person will be working on the GIS modeling and analysis, two Pentium PCs can be accessed to invoke GIS on the work station. 2) Two Pentium PCs are dedicated to data collection program which requires high speed and large hard disks. Software packages listed in Figure 2 are used to process and manage the shoreline data collected. Two existing software packages for physical modeling MIKE 21 and LITPACK will be installed on one of the Pentiums. ArcInfo can also be invoked on these machines. Since these software packages and processing of large data sets are very computationally intensive, high speed processors are needed. Two 486 PCs are used for accessing ArcInfo for simple GIS applications such as digitizing. On the other hand, CED technicians are experienced in using AutoCAD software for engineering drawing and digitizing. Two laptop PCs are needed for field work such as data collection, display of design data, modification of design at engineering sites etc. 3) One CD-ROM reader for the work station and one for a PC will enable the system to accept data and system/application software on CD-ROM disks. A 4 mm cartridge drive will make the backup of the workstation easier. It is also an appropriate way for data transfer between agencies without networking (which was true in 1994). An Inkjet plotter is needed to produce maps of max. A0 size and up to 256 colors. An A0 size digitizer is recommended for digitizing large size maps, and a small A3 size digitizer is needed for small maps and in case more than two maps are to be digitized at the same time. 4) A network is necessary for communication between computers and peripherals in the configuration. It will provide data communication across platforms. For example, PCs can access GIS and databases on the workstation without licenses on the PCs. This network will also be expandable for adding a server and able to communicate with other government agencies and international partners through networking systems such as Internet.

Function Design

Based on the review of the internal and external working environment and GIS needs, as well as suggested hardware and software configurations, a general design of functions is presented, which serves as a base for the detailed data model design. Figure 3 depicts the function model of the GIS system. Data sets input to the system could be meta data of time series, digitized/scanned hard copy maps, existing digital maps, coastal engineering drawings, and scanned aerial photographs. These data are all in certain digital formats. If the digital format does not match the native format of GIS, in this case ArcInfo, a data format conversion (filtering) becomes necessary. If the data source is of an analog form, an Analog to Digital (A/D) conversion such as digitizing or scanning has to be performed before the information can be used in GIS. Three major application areas will be concerned in the development of the GIS, namely coastal erosion monitoring, coastal engineering, and coastal data inventory. They will be built based on ArcInfo system.

Under coastal erosion monitoring, shoreline erosion conditions at the national level are stored in the database. Shorelines are classified into four categories and represented on a map. This is implemented by using the existing results of the National Coastal Erosion Study (Stanley 1985). In this digital map, a base map with state and district boundaries is included. Shoreline with different erosion categories are represented by different colors and patterns. Specific information can be queried by clicking a mouse at an interesting shoreline segment. This kind of information is saved in databases and associated with spatial entities of the map, including location, length of coast affected, area or number of lots affected, protection works, description of erosion categories, and even a picture of a typical scene of the erosion in this area. In this sense, a map in GIS is not only a map. It integrates spatial and non-spatial data in a unique system and allows flexible queries. Similar digital maps are also generated, for example digital shoreline material distribution, critical erosion sites, and locations of existing erosion control structures. The digital map displayed could represent various erosion related factors. If a specific location is of interest, this area can be zoomed at an appropriate scale factor. Further queries may be performed

The coastal engineering subsystem will cover functions related to current activities of CED. A successful implementation of this part will greatly improve the productivity of the CED. In this GIS environment, basic data for design such as topographic data, bathymetric data, locations of time series data etc. are managed and geo-referenced in a unique system, without influence of scale, projection, and information generalization. For example, a digital topographic/hydrographic map can be overlaid with a cadastral map and an erosion condition map to find lots/parcels to be affected by coastal erosion. Design of a coastal structure may be accomplished on the screen in an interactive mode. Rivermouth dredging may be planned more efficiently using GIS as powerful tools because this system provides a unique environment for interactively defining the dredging boundaries, monitoring dredging progress, and representing post-dredging survey results. In this part of the system, a lot of CED tasks such as structure design, coastal zone management, coastal project monitoring, rivermouth and dredging, numerical modeling, and shoreline detection, are involved. These activities need specific coastal engineering and modeling software packages that are usually not provided by a commercial GIS software system. This will require the integration of these functions of special application software to the GIS environment. Therefore, development based on AML, Avenue; and C programs will be demanded.

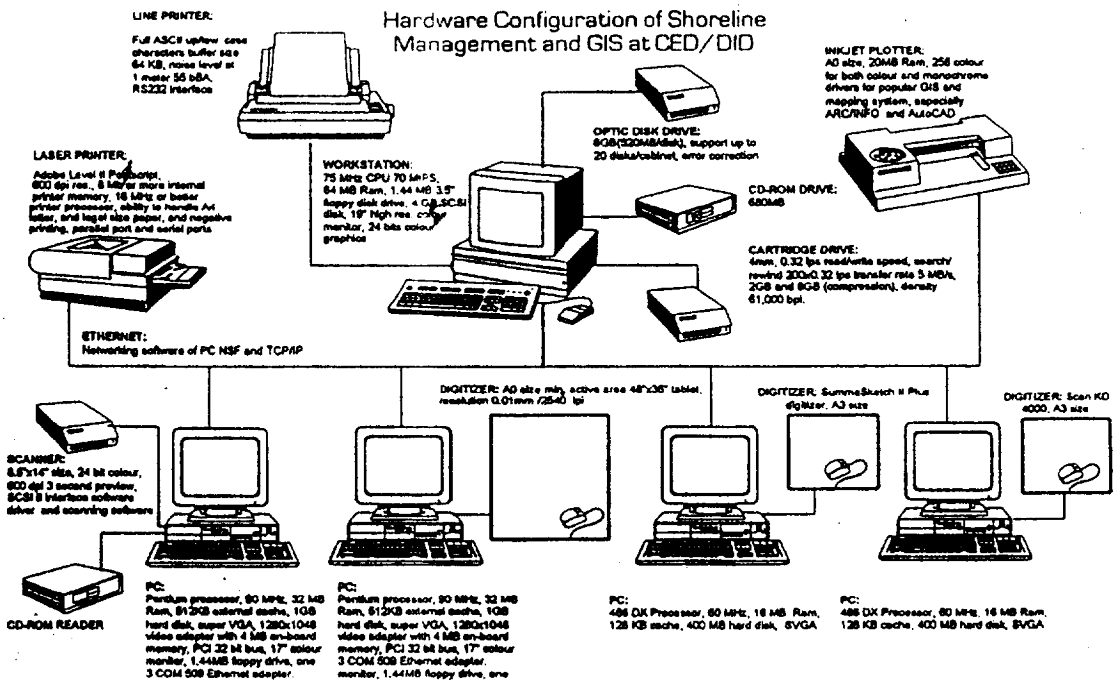

Figure 1 Hardware Configuration

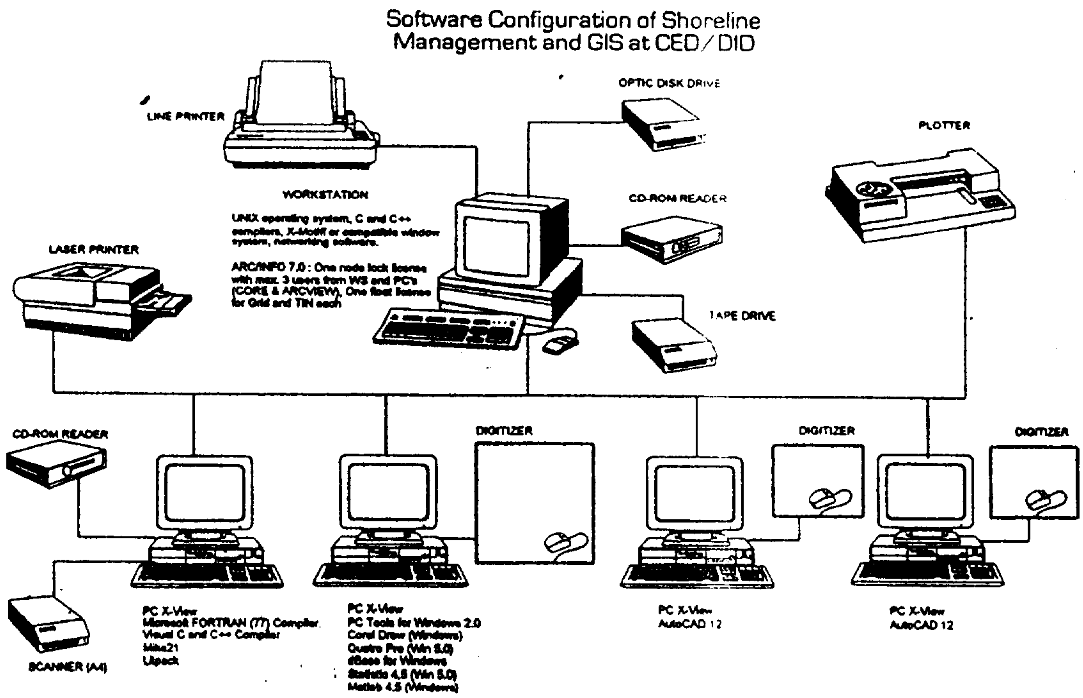

Figure 2 Software Configuration

The third part of the GIS system is coastal data inventory. The GIS is also a central coastal data inventory unit at the same time. If digital data are available at CED, they will be directly stored in the database. For digital data that are very large and not of spatial nature such as time series data, a meta data file may be stored instead of the actual data set itself. The meta data supply the information such as data collector, reference system, datum, date of collection, format for retrieving, storing site, availability, contact person etc. With this meta information, users would be able to have an overview of data collected and to know how to request. This is also beneficial to data collection planning. Other data which can be registered as meta data are hardcopy maps and photos, as well as digital data at other government agencies and the private sector. The query of the database should be graphic and interactive. A base map is displayed. The user can query either by location or by data types.

The system will output results in various forms. Graphic display on the computer screen is the best way to check the results and perform operations for further improvements. This is especially important when data sets involved are multi-layer oriented, and complicated spatial operations are applied. Digital maps will be generated in ArcInfo format. They will be output to a plotter if necessary. In many cases, users/clients would prefer databases instead of maps. However, this requires that the user should be able to read the data.

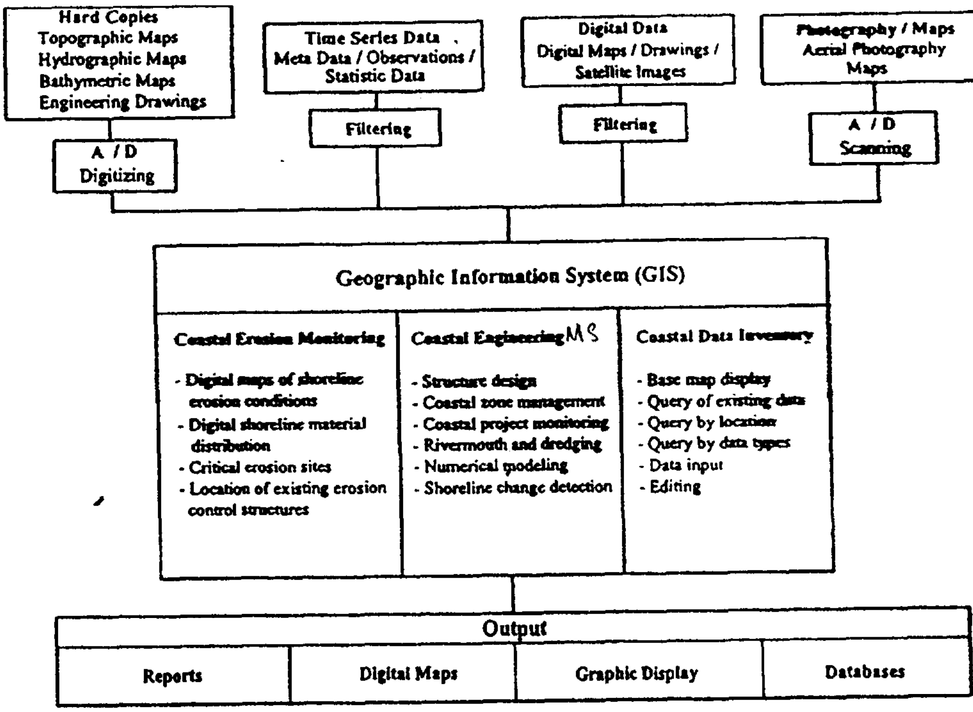

Figure 3. Functional Model

Databases Design

ANSI SPARC database design standard is adopted to design the database. This includes four design phases, namely external design, conceptual design, logical design and internal design (Laurini and Tompson 1992).

External Design: External design is the initial stage of any database design work. In this design stage, the real world is simplified according to the requirements of applications, because information from the real world is too rich to be all included in a database with current technology. The result of the external design is usually a data dictionary describing spatial and attribute data. An investigation of the existing data and potential functions was conducted in (Li 1994) and further continued in 1995. A list of data categories which should be included in this database is given (Li 1995). If some data are not available at this time they can be added to the system later. In case that some data are not list herein and will be found important to the application, these data can also be added.

Conceptual Design: At the conceptual design level, a structure for organizing the data mentioned above is constructed. Spatial data are defined as entities and transferred to GIS database features later. Attributes are associated with the entities. Associations/relations are used to describe relationships between entities. To implement the relationships, cardinality numbers are assigned to each relation, which check the consistency of the entities and relations defined in this stage. The data model deigned at this point is still independent of specific database management system and independent of computers which will be used. For instance, the model can be implemented using a relational database or an object-oriented (O-O) database management system. The result of the conceptual design is an Entity-Relation (ER) model. Data defined in the data dictionary in the external design should all be reflected in this model. Figure 4 is an ER model of the coastal erosion monitoring database.

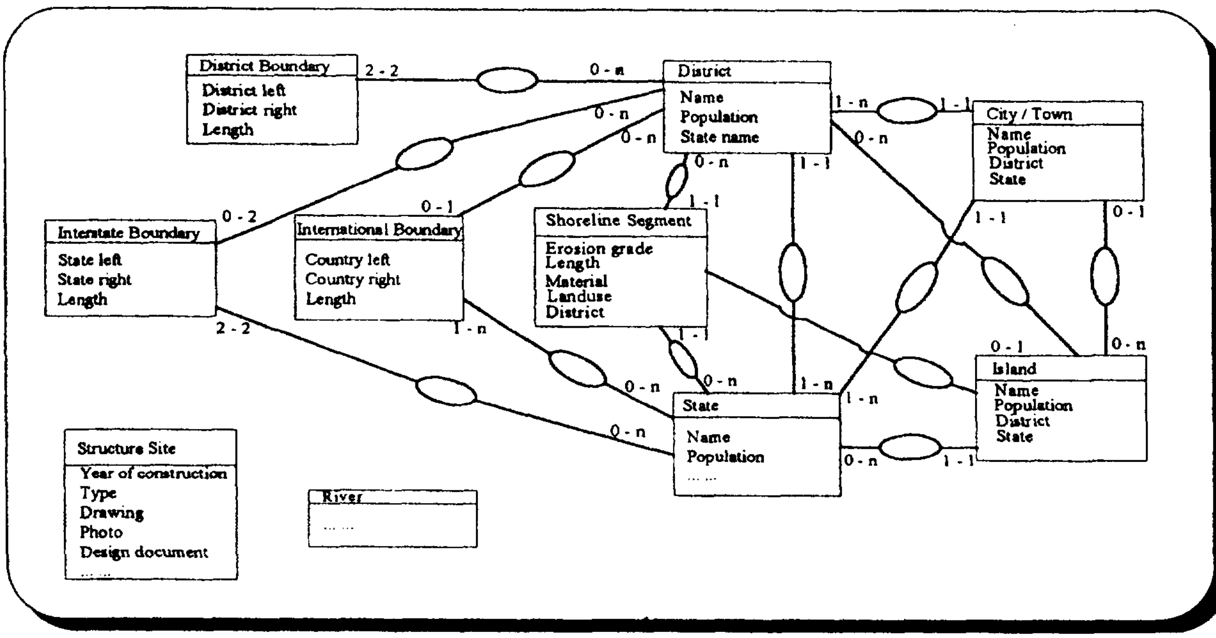

Figure 4. Entity Relationship Model of the coastal erosion status database

Logical Design: The ER model is converted to tables in the logical design stage if it is decided that the relational database is to be applied. Usually, each entity block or association/relation is converted to a table. However, some tables may be combined into one or split to a few tables in order to conform with consistency requirements of standard spatial relational databases (Laurini and Thompson 1992). The tables generated in this modeling stage will be used in the internal design which is dependent of the computer system used. By using table statements, logical design can be carried out in a very concise way. According to the ER model in Figure 4. Some relations are given below.

Point Tables:	City(City_ID, Name, Population, Distr_name, St_name)
	Const_site(Const_site_ID, Name, Type, Year, Drg_file, Img_file, Dsg_file)
Arc Tables:	Intern_line(Intern_line_ID, Count_l, Count_r, Length)
	Inter_s(Inter_s_ID, State_l, State_r, Length)
	Distr_line(Distr_line_ID, Distr_l, Distr_r, Length)
	Shore_l(Shore_l_ID, Node_f, Node_t, Length, Er_grd, Material, Landuse, Distr_name)
Polygon Tables:	State(State_ID, Name, Population)
	District(District_ID, Name, Population, St_name)
	Island(Island_ID, Name, Population, Distr_nsme, St_name)

Interior Design: The above three database design stages are all system independent (software and hardware). However, in the interior design, functions and capabilities of the hardware and software have to be considered. In this project, software packages supporting GIS and spatial data modeling include dBASE, ArcCAD, and ArcView. The tables designed are to be implemented based on the hardware and software systems whose specific limitations and strength are considered. In ArcCAD, the graphic data are all stored in an AutoCAD format as a drawing. Specific geometric entities/groups could be organized as blocks and layers. GIS data are organized according to themes which are close to layers in ArcInfo. Graphic data of theme could be from a drawing file, interactive generation and editing on the screen, or from ArcInfor coverages. Each theme is associated with a GIS data set where additional geometric data, attributes, and topological data are stored.

Since erosion status of segments of the shoreline within one state could have different attributes, therefore, a shoreline is separated at different levels such as state, district, and segments with individual erosion attributes, using "nodes" because of the limitation of ArcCAD. Polygon layers of districts and states can be built by combining arc elements from shoreline segments, international boundaries, interstate boundaries, and interdistrict boundaries. Because status of erosion along shoreline segments, which are usually shorter than the shoreline within a district or state, change from time to time, they need to be updated often or periodically. This cannot be done without problems if the shoreline segments are only defined in the polygon layers. Hence, a layer of shoreline is defined separately. In fact, out of the state polygon data in ArcCAD two themes can be defined, for instance one for line and the other for polygon. Any update on the line theme will be reflected in the polygon layer and the geometry and topology change automatically.

IMPLEMENTATION (Impres ?)

Pilot Project

In GIS, a pilot project provides an opportunity to implement and test the data model at both national and local levels with real spatial and time series data. The small scale data at the national level are to be acquired from related federal government agencies. Considering the extremely detailed and vast volume of local data and the time available for this project, it was decided to conducted a pilot project with large scale data for one state. Since the state of Penang has developed a state wide general GIS, PEGIS, some coastal related data may be useful to this project. Therefore, Penang has been chosen as the pilot project site. In addition, CED has LEO stations and coastal engineering structures built or planned on Penang.

Small Scale Data: The division of Information Management of the Department of Agriculture (DOA) had digitized basemaps and related layer for agriculture purposes which can be used as basemap information for shoreline monitoring and erosion status modeling at the beginning of the project. DOA has recently accomplished a coastal resource study project (1994). Some of the data such as coastal resource map with a 5km zone along the shoreline can be used for this project. DOA is also moving towards the application of raster data and satellite imagery technologies.

An inventory of existing hard copy maps at CED in terms of type (e.g., topographic, hydrographic, bathymetric, or engineering maps), location, index, scale, and others should be conducted. An investigation of existing aerial photographs should also be made. An inventory of existing time series data at CED will be needed, for instance, the LEO data and other time series data acquired for previous projects. Digital maps from the Department of Survey and Mapping cover the most part of the southern peninsula of Malaysia.

Large Scale Data on Penang: One LEO station is located on the Penang island, PP1 Lorong Abas, Tangung Bunga, and another on the mainland, SP1 Bagan Tambang. A structure is planned to be built along the segment of the eroded shoreline in Kampong Parmatang Bakar Kapor, close to the airport of Penang. Penang GIS (PEGIS) is the first GIS at state level developed in Malaysia. It was started in July 1992 initiated with a funding of 3.7 million Rm partially from Association of Surveyors. PEGIS has 105 layers (coverages) of data ranging from Penang basemaps and multipurpose cadastral data to coastal stability maps and traffic study data. Local large scale GIS data are supplied by PEGIS for this pilot project in ArcInfo format: a) Penang basemap (state and district boundaries) of Penang island and the mainland part, b) Hydrographic data with hydrostations, c) River and channel data, d) Roads, e) Geological maps, f) Contour / grids, g) Coastal stability, h) Mud and soil classes, i) Landuse, j) Census, l) Land reclamation areas (existing and planned), and m) Urban landuse.

Implementation of SEMS

The subsystem SEMS (Shoreline Erosion Monitoring System) has been implemented using the pilot project data. Two layers of thematic data are provided by DOA, Landuse (Lumsia, Lusabah, and Lusrwk) and Soil (Somsia, Sosabah, and Sosrwk) data which are of PC ArcInfo format. The digital data were digitized from 1:50,000 hardcopy maps. Both layers include shorelines. Since these maps are coastal resource series maps, international, state, and district boundaries are not contained. Therefore, a third map from ESRI is used, which gives information of international, state, and district boundaries.

Often coverages from other agencies are acquired through inter-agency cooperation. The ArcInfo coverages are then imported to ArcCAD system at CED by defining a theme and linking the ArcInfo coverage as the data set of the theme. A new theme can be built by extracting features from an existing coverage. Specifically, the following steps were performed to give an overview of the implementation.

Integrate erosion information with shoreline data: Suppose that *shore_li* contains shoreline data which is a line theme with arcs and nodes. On the other hand, the erosion information should be integrated with the shoreline data to indicate the erosion status of the shoreline segments. Erosion of the shoreline is categorized into four grades. Therefore, the shoreline is separated to individual shoreline segments with different erosion categories. Hence, the segments of erosions may not match the arcs from the basemap in *shore_li* (see Figure 5). For instance, considering the arcs 1-2 and 2-3 in the *shore_li* theme, they have to be split at the positions of 2 and 3 in the new theme and form new arcs with new erosion information associated.

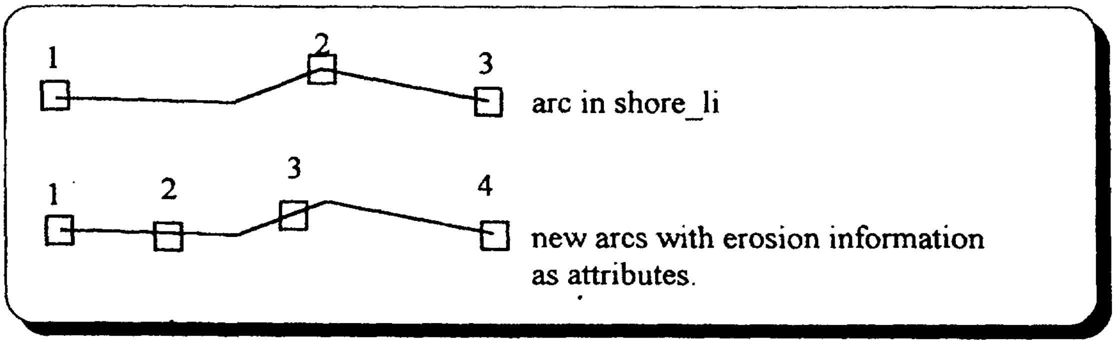

Figure 5. Association of erosion information with arcs

Add erosion attribute data into the shoreline map: In this stage, the geometry of the theme represents the shoreline segments with individual erosion categories. The next step is to associate the attribute information to all shoreline segments which are included in the standard table of AAT.

Build topology: Topology of the themes are built using interactive editing and ArcInfo functions CLEAN and/or BUILD which eliminate any errors made during the digitizing and AutoCAD editing.

Query and display of erosion information: Now, the geometric and attribute information is all in the new theme. Erosion status, material type etc. can be queried in the system. For example, it is to be found out which shoreline segments are of erosion category I and the material type of sand. It will find the lengths and place names. Other queries can either be done with the existing ArcView functions or developed using Avenue.

Display shoreline segment in color according to erosion categories: Layers built in ArcCAD are imported to ArcView where sophisticated tools for visualization and queries are available. SEMS is built as a view with eight themes. Erosion categories are displayed using various symbols and colors. Layers of shoreline materials, landuse etc are overlaid with the erosion category map to examine the causes of the erosion. Aerial photographs are also linked to the shoreline segments with severe erosion.

Coastal Engineering Management System (CEMS) and Coastal Data Inventory System (CDIS) are still in implementation.

4 SST-8

SHORELINE MAPPING FOR EROSION MONITORING BY GPS AND SOFTCOPY PHOTOGRAMMETRY

Monitoring of shoreline erosion needs a long term commitment. Objective decisions should be made based on erosion monitoring data acquired cumulatively during a long period of time. Therefore, efficient and economic ways for acquiring these data are an important issue in implementing the GIS application in erosion monitoring.

Shoreline mapping is a procedure to locate the geometric position of the shoreline. Depending on the scale of maps to be generated, various methods can be selected. For example, if a segment of shoreline is found to be severely eroded, a large scale shoreline mapping may be performed to record the hard evidence of the erosion status. These data can also be used to design coastal engineering protection structures. Small scale mapping covers large areas. However, details of objects are not mapped. Usually, small scale mapping is used to provide global information covering large areas. Currently, there are two key technologies in mapping which make survey and mapping efficient, affordable, and easier, namely GPS (Global Positioning System) and Softcopy Photogrammetry. With these new technologies, periodical shoreline mapping will become easier. A lot of field work can be reduced and most of the shoreline measurement can even be performed in offices. The following gives a very brief introduction to the two technologies.

GPS for Shoreline Mapping

GPS is a system for global positioning and navigation developed by US Navy. With 24 GPS satellites on orbits, it is possible that the positioning and navigation can be carried out at any time and anywhere in the world, without being dependent of weather. Because of national security reasons, a Selective Availability (SA) - artificial noise - is added into the satellite signals sent to civilian users. This makes positioning capability of a single GPS receiver without post processing down to around 100 meters. With a known point and a second GPS receiver, Differential GPS (DGPS) is possible to reduce various affects and reach an accuracy of a few centimeters in static mode and a few tens of centimeters in a kinematic mode (Leick 1995). Restrictions of applying this technology are where the satellite signals are blocked, for instance by high rises in downtown areas, structures of tunnels, trees, and water body in the underwater environment.

DGPS can be employed for a number coastal surveys, for example, determination of LEO station locations, beach profiling, and shoreline survey. By GPS survey, each point surveyed is given 3D coordinates of (X, Y, Z) or (Lat, Lon, Elevation). To associate GPS survey data with GIS layers, usually a point or vertex in GIS would need a GPS point. Although GPS may save time in comparison to total stations, it usually is not recommended to be used for acquiring large GIS databases.

Therefore, GPS technology is recommend to a) perform surveys of LEO station sites which could be combined with the LEO data survey; b) survey the shoreline in a small local area where the GPS receiver could be mounted on a vehicle running along the shoreline; c) survey beach profiles; and d) survey control points of aerial photographs for large scale shoreline mapping.

Softcopy Photogrammetry

Softcopy photogrammetry is another technology for efficient spatial data collection. The processing procedure in a softcopy photogrammetric system is based on fully digital operations. Thus, the aerial photos must be in a digital form, for instance by scanning films or hardcopies. This kind of scanners are of higher quality and provide a higher resolution, for example with a pixel size of 5-40μm. Another way to get digital photographs is to have digital CCD (Charge Coupled Device) cameras, instead of film cameras, on the aircrafts.

The softcopy photogrammetric system accepts the digital images and perform image preprocessing if necessary, for instance to enhance the brightness and contrast, or to run a digital filter for enhancing line features including shorelines. After that, the relative and absolute orientation of the images will be performed so that the orientations and locations of images are known. Finally, objets appearing in the images can be measured in the images displayed on the screen. Their corresponding coordinates in the object space are registered in the database and can be further used in a GIS.

One of the importances of aerial photographs is that these photographs recorded all visible information at the time of photographing, including the shoreline shape. The images can be stored in the digital form. Only objects need to be extracted at the time are interpreted and measured. All other information is not lost by storing on the hard discs or tapes. It may be found out later that some other objects are needed. In this case no resurvey of the same area is necessary because the data are available in the digital image format in the system.

Recommendations

1) Aerial photographs should be acquired along the shoreline in Peninsula Malaysia, Sabah and Sarawak, with a period of five years. The photoscale should vary, 1:5,000 for shoreline segments with erosion grade one and two, and 1:10,000 for shoreline segments with erosion category three and four. The along track overlap shall be 60%. Shorelines should be measured from the photographs for periodical shoreline change detection.
2) A very efficient and flexible way to obtain detailed shoreline segments in a small area is to apply softcopy photogrammetry. The photos will be scanned. The computers will handle the digital images, on which image coordinates are measured. Subsequently, the softcopy photogrammetric system will calculate 3D coordinates (X, Y, Z) in the ground coordinate system. Using this technology, historical photos can be used to reconstruct the historical shoreline, in addition to the current shoreline. Beach profiles can be also measured in office using this system.
3) If detailed shoreline segments in a small area, for example a category I site, is required or shoreline changes within five years are to be monitored, DGPS should be applied.

ACKNOWLEDGMENT

The authors would like to thank Mr. Ooi Choon Ann for his support. Technical support and assistance from Mr. Dzulkifli Bin Abu Bakar, Mr. Nor Hisham Bin Mohd Ghazali, and Mr. Najib Bin Abdulah are very appreciated. Discussions with Dr. Eugene Ramcharan, Mr. David H. Willis, and Dr. Bjorn Kjerfve is also appreciated.

REFERENCES

A. Leick 1995. GIS Satellite Surveying. John Willy & Sons, Inc., New York.

ESRI 1994. Introducing ArcCAD release 11.3. ESRI, Redland, CA.

Kjerfve, B. 1994. Institutional Strengthening for Shoreline Management, First and second report by the Database Management Specialist, AGRA Earth & Environmental Limited, Calgary, Alberta.

Kjerfve, B. 1995. Institutional Strengthening for Shoreline Management, Third report by the Database Management Specialist, AGRA Earth & Environmental Limited, Calgary, Alberta.

Laurini, R. and D. Thompson 1992: Fundamentals of Spatial Information Systems. Academic Press Ltd, London.

Li, R. 1994. Institutional Strengthening for Shoreline Management, First report by the GIS Specialist, AGRA Earth & Environmental Limited, Calgary, Alberta.

Li, R. 1995. Institutional Strengthening for Shoreline Management, Second report by the GIS Specialist, AGRA Earth & Environmental Limited, Calgary, Alberta.

Li, R., L. Qian and J.A.R. Blais 1995. A Hypergraph-Based Conceptual Model for Bathymetric and Related Data Management. Journal of Marine Geodesy, Vol.18, pp.172-182.

Li. R. and N.K. Saxena 1993. Development of an Integrated Marine Geographic Information System. Journal of Marine Geodesy, Vol.16, pp.293-307.

Shaw, B. and J.R. Allen 1995. Analysis of a Dynamic Shoreline at Sandy Hook, New Jersey Using a Geographic Information System. ASPRS annual conference, pp.382-391.

Stanley 1985. Final Report of National Coastal Erosion Study. Stanley Consultants, Inc. Vol. I and II, 1995.

Willis, D.H. 1995. Final Report of the Coastal Engineering Specialist. AGRA Earth & Environmental Limited, Calgary, Alberta.