Intergovernmental Oceanographic Commission

Workshop Report No. 103

IOC Workshop on Geographic Information Systems Applications in the Coastal Zone Management of Small Island Developing States

Organized in co-operation with and supported by the Government of Canada

Barbados, W.I.
20-22 April 1994

UNESCO

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17 Suppl.	Papers submitted to the Joint IOC/WMO Seminar on Oceanographic Products and the IGOSS Data Processing and Services System; Moscow, 2-6 April 1979.	E
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29	WESTPAC Workshop on Marine Biological Methodology; Tokyo, 9-14 February 1981.	E
30	International Workshop on Marine Pollution in the South-West Atlantic; Montevideo, 10-14 November 1980.	E (out of stock) S
31	Third International Workshop on Marine Geoscience; Heidelberg, 19-24 July 1982.	E, F, S
32	UNU/IOC/UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the context of the New Ocean Regime; Paris, 27 September-1 October 1982.	E, F, S
32 Suppl.	Papers submitted to the UNU/IOC/UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the Context of the New Ocean Regime; Paris, 27 September-1 October 1982.	E
33	Workshop on the IREP Component of the IOC Programme on Ocean Science in Relation to Living Resources (OSLR); Halifax, 26-30 September 1963.	E
34	IOC Workshop on Regional Co-operation in Marine Science in the Central Eastern Atlantic (Western Africa); Tenerife, 12-17 December 1963.	E, F, S
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40	IOC Workshop on the Technical Aspects of Tsunami Analysis, Prediction and Communications; Sidney, B.C., Canada, 29-31 July 1985.	E
40 Suppl.	First International Tsunami Workshop on Tsunami Analysis, Prediction and Communications, *Submitted Papers;* Sidney, B.C., Canada, 29 July - 1 August 1985.	E
41	First Workshop of Participants in the Joint FAO/IOC/WHO/IAEA/UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region (WACAF/2); Dakar, Senegal, 28 October-1 November 1985.	E
43	IOC Workshop on the Results of MEDALPEX and Future Oceanographic Programmes in the Western Mediterranean; Venice, Italy, 23-25 October 1985.	E
44	IOC-FAO Workshop on Recruitment in Tropical Coastal Demersal Communities; Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986.	E (out of stock) S
44 Suppl.	IOC-FAO Workshop on Recruitment in Tropical Coastal Demersal Communities, *Submitted Papers;* Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986.	E
45	IOCARIBE Workshop on Physical Oceanography and Climate; Cartagena, Colombia, 19-22 August 1986.	E
46	Reunión de Trabajo para Desarrollo del Programa "Ciencia Oceánica en Relación a los Recursos No Vivos en la Región del Atlántico Sud-occidental"; Porto Alegre, Brazil, 7-11 de abril de 1986.	S
47	IOC Symposium on Marine Science in the Western Pacific: The Indo-Pacific Convergence; Townsville, 1-6 December 1966.	E
48	IOCARIBE Mini-Symposium for the Regional Development of the IOC-UN (OETB) Programme on 'Ocean Science in Relation to Non-Living Resources (OSNLR)'; Havana, Cuba, 4-7 December 1986.	E, S
49	AGU-IOC-WMO-CPPS Chapman Conference: An International Symposium on 'El Niño'; Guayaquil, Ecuador, 27-31 October 1986.	E
50	CCALR-IOC Scientific Seminar on Antarctic Ocean Variability and its Influence on Marine Living Resources, particularly Krill (organized in collaboration with SCAR and SCOR); Paris, France, 2-6 June 1987.	E
51	CCOP/SOPAC-IOC Workshop on Coastal Processes in the South Pacific Island Nations; Lae, Papua-New Guinea, 1-8 October 1987.	E

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BACKGROUND

Some 35 scientists and coastal zone managers representing 18 Small Island States and Non-Governmental Organizations (NGOs) from around the world met for 3 days, from April 20-22, 1994 in Barbados, to explore potential applications of Geographic Information Systems (GIS) in the management of the coastal zone of Small Island Developing States (SIDS) to ensure their sustainable development. The Workshop was co-sponsored by the Intergovernmental Oceanographic Commission (IOC) and the Government of Canada.

GIS constitutes a powerful management tool as it is a computer-based system integrating as much information as possible on a given area, including scientific, social, cultural, and economic data, to assist decision-makers in managing their coastal zone in a proactive fashion. It allows a concise view of an often complex situation, and can be applied to most areas of relevance to sustainable development.

Sustainable development in SIDS, and in particular Integrated Coastal Zone Management (ICZM), can benefit greatly from the application of Geographic Information Systems (GIS), because GIS technology has the capability to integrate large amounts of data as well as the flexibility to accomodate the diverse ICZM needs of SIDS.

TECHNOLOGY OF GIS

The judicious use of GIS in ICZM will allow better quality output and decision-making at reduced costs, as the technology allows better allocation of limited financial and human resources, which is an essential prerequisite for sustainable development in SIDS. For example, remotely sensed data integrated through GIS offer the potential for satisfying multiple needs from a common data collection effort over wide areas.

GIS technology requires the sharing of data between SIDS and other countries as well, improved communications, training, and system compatibility. It is important that the origin of data be documented so that it can be verified and shared. Also, planning for new data collection should consider using standards to facilitate future data exchange.

Telecommunications are of critical importance for the transfer of data from remote data bases at local, regional and international sites. Improved communications will also enhance training, as well as facilitate the rapid interchange of knowledge, problem solving at the technical and operational decision-making levels, and the sharing of expertise at all levels.

CAPACITY BUILDING

A regional core of marine, coastal and social scientists, engineers and planners as well as multi-disciplinary technical support familiar with the use of GIS is needed for ICZM. ICZM requires comprehensive planning by SIDS to define their long-term objectives and needs. These include the identification of management objectives, the setting of standards, the design of data collection and monitoring systems, as well as the identification of GIS technologies appropriate to the situation of given SIDS.

Through education and training, the expertise in the use of GIS must be developed in SIDS. Moreover, this will lead to SIDS involvement at all levels in the development of GIS technology and applications best suited to the needs of small islands.

Furthermore, GIS technology can assist in promoting awareness at all levels of SIDS societies, from children to scientists to decision-makers, so that all can be educated on the protection, restoration, enhancement, and utilization of the coastal zone of their islands.

PLAN OF ACTION

Given the potential of GIS as an appropriate tool in ICZM for SIDS, Workshop participants suggested that a plan of action be developed for SIDS with regards to the use of GIS, comprising the following elements:

National initiatives

(i) undertake on an accelerated basis, in all SIDS that have not done so, a detailed assessment of needs for implementing an ICZM program utilizing GIS technology support;

(ii) develop and strengthen the national capacity for using GIS in ICZM on a continuing basis;

(iii) ensure that data and information from existing facilities are accessible to GIS systems for ICZM;

(iv) support the implementation of sustainable ICZM programs by organizing/facilitating continuing public awareness activities on GIS and their potential.

Regional initiatives

(i) improve interregional telecommunication networks;

(ii) assist SIDS in their efforts to conduct ICZM programs using GIS;

(iii) organize/facilitate regular regional training activities on GIS data acquisition and technology, making use of the strengths of existing regional centres of excellence;

(iv) establish modalities to ensure the compatibility of GIS systems for ICZM related activities.

International initiatives

(i) request IOC to organize GIS awareness workshops for decision-makers in SIDS, in collaboration with international development agencies, UN organizations and other NGOs;

(ii) improve communication systems into SIDS to enhance international coordination and cooperation in GIS development and standardization and exchange of data;

(iii) support locally driven projects aimed at demonstrating the usefulnessand economic viability of GIS and remote sensing in ICZM.

RECOMMENDATIONS

In light of this plan of action, Workshop participants formulated the following recommendations:

(i) IOC should organize regional workshops to ensure training of SIDS personnel in the use of the most appropriate GIS technology in ICZM.

(ii) IOC should promote state-of-the-art telecommunications amongst SIDS and other countries.

(iii) IOC and other international agencies and aid agencies should support SIDS in putting on projects demonstrating the usefulness and economic advantages of using GIS and remote sensing in ICZM.

1. INTRODUCTION

1.1 Background

The United Nations Conference on Environment and Development (UNCED), which took place in Rio de Janeiro in June 1992, recognized in Agenda 21, the programme of action it adopted, the challenges posed by the sustainable development of Small Islands developing states (SIDS). Indeed, the economy of SIDS very often depends mostly on their coastal areas, which display vulnerability towards tropical storms, sea-level rise, and invasions by foreign species among others. Thus, the UN General Assembly decided at its 47th session to convene a Global Conference on the Sustainable Development of Small Island Developing States, to be held in Barbados, starting April 25, 1994.

UNESCO and the IOC provided support and input to various activities preparatory to the Barbados conference. In direct response to recommendations contained in section G of chapter 17 of Agenda 21, concerning the use of Geographic Information Systems (GIS) in the coastal zone management of small islands, the IOC (see Annex I containing the welcoming comments from IOC) in association with the Government of Canada decided to sponsor a Workshop on GIS Applications in the Coastal Zone Management of Small Island Developing States, under the responsibility of IOC First Vice-chairman, Geoff Holland.

So as to be in a better position to channel recommendations to the global conference on SIDS, it was decided to hold the GIS Workshop in Barbados as well, in the week preceding the Conference. Canada, through Geoff Holland, took charge of the workshop organization: Jean Piuze was appointed as workshop chairman, Giulio Maffini as technical coordinator, and Darren Williams as administrative coordinator.

Financial support for the Workshop was provided by the IOC and the Government of Canada, including the Canadian International Development Agency (CIDA) and the departments of Foreign Affairs and Fisheries and Oceans, for salaries, travel, accomodation and workshop facilities at Sam Lord's Castle in Barbados.

Some 35 scientists and coastal zone managers representing 18 Small Island States and Non-Governmental Organizations from around the world thus met from April 20 to 22, 1994, in Barbados to explore potential applications of GIS in the management of the coastal zone of SIDS to ensure their sustainable development. The list of participants is given in Annex II.

1.2 Modus operandi for the Workshop

The primary objective of the Workshop was to obtain reactions and comments from SIDS representatives following technical presentations by experts on GIS technology and its applications. This point was reiterated by Ms. Janet Zukowsky, High Commissioner for Canada to Barbados and the Eastern Caribbean, in her opening remarks (see Annex III). The format chosen aimed at fostering as much discussion as possible. The first two days included panel discussions involving SIDS representatives at the start and at the close of each day. Four technical presentations were given in between on each of the two days, each followed by a period of questions and discussion. At the end of the first two days, time was reserved for hands-on sessions where participants could interact with experts. On the third day, three breakout sessions were formed to come up with the input and recommendations destined to form the Workshop report, following plenary discussion. Annex IV gives the agenda followed.

2. COASTAL ZONE MANAGEMENT FOR SIDS - ISSUES AND CHALLENGES

Coastal zone management (CZM) for SIDS can be extremely complex with environmental protection, sustainable development, resource and land use, population pressure, and global change all entering the equation. Vast numbers of data, including scientific, social, cultural, and economic data, are required to assist decision-makers in managing their coastal zone in a proactive fashion. Thus, powerful and versatile tools are required to handle these data and to bring them into a form suitable for practical use. This is where GIS can prove invaluable.

The initial panel discussion at the workshop highlighted the importance and the complexity of CZM for the sustainable development of SIDS. Guillermo Garcia (Cuba) reminded participants that SIDS are in fact mostly made up of coastal marine areas, including important natural resources such as beaches, coral reefs, and mangroves. These are usually quite vulnerable to natural and anthropogenic factors affecting the environment. Thus the establishment of a plan of action for research and monitoring in the coastal zone is essential. Regulatory measures and coordination mechanisms for CZM must also be put in place. And all of these should be conducted in a context of international cooperation and capacity building, taking into account the reality of the present economic situation. All these points are detailed in Annex V.

The example of the establishment of a CZM programme by a SIDS was presented by Leonard Nurse (Barbados). It was shown that the first step was to assess the needs by identifying critical issues facing the coastal zone (e.g. beach erosion, water pollution, reef degradation, habitat loss). This in turn provided the basis for determining requirements in terms of data and monitoring as well as the funding necessary for the equipment and personnel and training needed for the establishment of a Coastal Conservation Unit (CCU). At every stage of the process, the need for an adequate data management system was obvious and it was clear that a functional GIS was the best way to achieve this. Annex VI explains why and how the Barbados CCU was set up, and gives a summary of its nature and function.

Hence, it appears that sustainable development in SIDS, and in particular Integrated Coastal Zone Management (ICZM), can benefit greatly from the application of GIS technology because it has the capability to integrate large amounts of data as well as the flexibility to accomodate the diverse ICZM needs of SIDS.

3. APPLICATIONS OF GIS TECHNOLOGY

In order for SIDS representatives to appreciate the broad range of possibilities offered by GIS technology for CZM, eight presentations were given by GIS experts covering the IOC experience on coastal zone data management, principles and strategies for GIS applications in CZM, the use of remote sensing, case studies, GIS dynamic modelling, and the future of GIS and information technologies. Each presentation is summarized in the following paragraphs, while detailed presentations are to be found in annexes VII to XIV.

3.1 IOC experience and views on marine data and information management in support of CZM systems for SIDS (Paul Geerders)

GIS technologies provide a means to an end. In establishing and utilizing these technologies, however, one must focus on, and keep in mind, what the goal of their use is, and what is required to make them function appropriately. At the centre of the application of a GIS system for coastal zone management should be the "consumer" of the products to be generated. In developing an effective and useful GIS system primary concern must be placed on determining what the consumer wants from the system and how to best set up the system to meet their needs. The second focus must be on the data requirements of the system and whether these can be adequately met. To function effectively, a continuous and consistent stream of data is required from three sources including: in-situ data, remotely sensed data, and data from numerical models. GIS systems act as an excellent carrier to combine, evaluate, and present large amounts of different types of data. This relates closely to the IOC concept for a world-wide system for operational ocean observations GOOS (Global Ocean Observing System). To enhance accessibility to marine data, the IOC has developed a number of programs to facilitate the collection and exchange of standardized data on the marine environment. The IOC is likewise capable of providing training in marine data management, marine information management, and remote sensing for marine applications through individual and regional training courses to promote the effective use of information by end-users. Annex VII gives the detailed presentation.

3.2 GIS methods and coastal zone management (Michael Arno)

GIS is a new model for understanding complex real world systems. An extension of existing geographic models, GIS developed with the advent of electronic data systems to become a powerful vehicle for information management and decision support. GIS now offers an ideal way to represent and build an understanding of complex coastal systems. Functions of GIS include allowing decision makers to visualize, organize, combine and analyze data as well as to make predictions and to interrogate data to provide answers.

GIS functions through a five step input-output process, beginning with data input into a system of data management, data processing, analysis and modelling, and ending with data output. Data input includes the capture and integration of spatial and non-spatial data from a variety of sources including paper maps, aerial photographs, satellite images and other sources of data acquisition. Data is then digitized or scanned and often combined with existing digital data to build useable data bases of information. Representations of data in the GIS can be spatial, thematic, temporal or take the form of spatial data models. Visualization or appearance of the data can be affected by the scale of the image, the type of generalization used (simplification, classification, symbolization or induction), the cartographic process, and the accuracy.

Data management involves the integration of a data base management system, with input from spatial and/or tabular data bases, with geographic objects including geographic features and entities. Data management issues include security, integrity, filing, access, maintenance, and currency. Data processing includes the transformation of projection and coordinate systems data onto a two-dimensional plane surface and the conversion of spatial data into points, lines, areas, networks, and surfaces. Once the data is processed, GIS allows for both qualitative and quantitative analysis through a variety of tools including overlays, query, measure and proximity. Finally, modelling is an advanced form of overlay analysis. Modelling can be undertaken through the generation of maps from existing maps and data bases, through the comparison of information temporally, or through extrapolation of data. A copy of this presentation is included as Annex VIII.

3.3 GIS data aquisition strategies (Peter Grose)

Strategies for geographic data development can be achieved for efficient and effective coastal resource management, even given limited budgets, personnel and data availability. A realistic and usable GIS starter system could include two personal computers, a laser printer and page size colour printer, a scanner and software, GIS software and geographic data. Total resource costs equal $25-35 k and a resource staff of 4-5 persons, including a GIS specialist, a GIS operator and 2-3 technicians.

Data preparation includes the use of generic tools and editing operations for quality control and data maintenance as opposed to data delivery which focusses on presentation. Components of a data layer include data attributes and the location of data as represented by points, vectors and polygons. Each can be managed independently to reflect reality. When choosing a system, tradeoffs must be made in terms of system design and construction including the breadth of scope, available information (data), scale, and accuracy. Data collection for the building and maintaining of coastal zone data bases is an iterative process not a one-time operation. Once a problem has been defined and decision criteria developed, assessment of data requirements and availability, as well as the assembly and analysis of data must be undertaken to make effective management decisions. Efficient and cost-effective data development or acquisition techniques include: adapting existing digital data sets; table digitizing of hard copy maps; scanning, head-up digitizing and autovectorizing; updating from photographic or remote imagery; and real-time digitizing using GPS.

In choosing a data collection and preparation system one must consider that most effort and expenses will be devoted to data collection, editing and the synthesizing of data into usable information. One must be careful to design and focus on a particular set of decisions that will reduce costs. The assessment of needs is critical. Each information layer in a system needs a specific plan for data generation and maintenance. Finally, alternatives exist and should be considered in the design of a useful system. Beware, however, of techniques that become resource traps. The complete presentation can be found in Annex IX.

3.4 Remote sensing and coastal zone data acquisition and analysis (Bob Ryerson)

Remote sensing is the collection of natural resources information using imagery acquired from aircraft or spacecraft. To be useful the phenomena under observation must be understood, spatially manifested at the image scale, verifiable and visible. Remote sensing uses reflected or emitted electromagnetic radiation using either passive or active sensors. Interpretation variables include: colour, tone, brightness, shape, texture, pattern, context/juxtaposition, shadow, and size. Remote sensing is particularly useful to obtain information in hostile or hard to reach areas and to quickly provide similar information over large areas; is less costly than traditional field-based methods; can provide a permanent record and is useful to obtain a quantitative record. Increasing fiscal restraint combined with additional demands for environmental information suggests that remote sensing will be more widely used in the future. Remote sensing tools of the trade involve the use of a wide variety of collection platforms, sensors, and methods of data analysis including the use of GIS.

Satellite imagery, as opposed to aerial photography, is a cost-effective means of providing information on large areas with a 10 to 30 metre resolution. It provides a good overview of features such as land cover, vegetation conditions, water bodies, forest clear cuts, roads, topographic and other map updates. Remote sensing use includes a variety of natural resource applications including coastal zone management. Different sensors are capable of providing different information about the coastal environment. Photographic and digital MSS are capable of providing information on water quality and pollution monitoring by depicting changes in the visible environment. Infrared line scanning devices can detect thermal plume discharges and other heat sources. Synthetic aperture radars can display oil spills on water, the effects of erosion and other natural and man-made landscape changes and thus can be useful in shoreline and land use mapping. Finally, remote sensing can also be useful in local environmental monitoring by providing an updatable permanent record. The content of the slides used for this presentation is shown in Annex X.

3.5 GIS in coastal zone management: Barbados experience (Kenneth Atherley)

Integrated CZM in Barbados began with a 1983-84 Prefeasibility Study in Coastal Conservation including a diagnosis of problems, the suggestion of possible solutions, and an initiation of monitoring of beaches and reefs. From 1983 to the present the Coastal Conservation Unit was developed to continue monitoring, advise on coastal development and develop project preparation work. From 1991 to 1995 a Technical Feasibility Study is being carried out to study coastal processes and trends through expanded and concentrated monitoring, to develop a CZM plan for the Island, and to design and test specific physical engineering projects.

GIS was introduced in Barbados to manage and make useful the large amounts of data being produced as a result of the technical feasibility study. GIS was conceived as being a useful tool for combining temporal and spatial databases for discerning various permutations of associations and for assessing the potential for quantitative modelling. GIS met the data management needs of the CCU which included the storage and analyses of large volumes of data from numerous locations. Features of the Coastal Conservation Unit's GIS include AUTOCAD, ARCAD, ARCVIEW, and associated PC hardware capable of running the system.

GIS issues for those interested in developing their own system include: georeferencing standards and map scales; vector and raster models; a need to consider user applications including storing data, developing new perspectives and/or permutations, and development control and monitoring trends; lineage of data and quality control; and inter-institutional support including common ground, general standards, training, avoiding overlaps, cooperation between private and public sectors and who owns the data. Examples of GIS applications for CZM in Barbados include the use of GIS for flood hazard management, beach access planning, and as a research and engineering design tool for beach changes (erosion, accretion). Each of these examples demonstrates GIS's usefulness as an effective CZM management tool. The contents of this presentation can be found in Annex XI.

3.6 Desktop delivery systems for coastal zone information (Peter Grose)

Desktop delivery systems focus on the delivery of information directly to decision-makers. More appropriately described as desktop INFORMATION systems, desktop delivery systems concentrate on providing information tailored to meet the needs of a specific problem or theme. Custom design of delivery systems takes place primarily in the information development process, but also in the presentation of the information in the product form. Information development including the examination of the themes and issues to translate raw data into user-friendly information is the key to any project of this type. Generic or custom capabilities are used depending on the needs of the consumer. The design of the system, therefore, is a cooperative effort of many parties, not just the computer or data personnel. Two examples of desktop delivery systems including a Mid-Atlantic Mapping and Information System and a Coastal Ocean Management, Planning and Assessment (COMPAS) for Florida were presented to demonstrate the utility of these systems. The details are given in Annex XII.

3.7 GIS dynamic modelling in CZM (Guy Engelen and Roger White)

Cellular automata provide the key to a dynamic modelling and simulation framework that integrates socio-economic with environmental models, and that operates at both micro and macro geographical scales. An application to the problem of forecasting the effect of climate change on a small island state suggests that such modelling techniques could help planners and policy makers design more effective policies -- policies better tuned both to specific local needs and to overall socio-economic and environmental constraints. This presentation can be found in Annex XIII.

3.8 Information technology development directions (Giulio Maffini)

While GIS once ended at the office door new portable technologies have allowed for fully functional GIS to be deployed to the field. Key technology developments include those aimed at "reducing the cost of where" (acquiring data in the field), capturing data, and using data. Relatively low cost and highly accurate hand held technologies are now available to capture data and enter it into GIS systems. These include portable environmentally tolerant computers (PETCs) that are physically tolerant, pen enabled, utilize docking stations, dial up or are wireless capable, GPS attached, and operate on MS WINDOWS field GIS software. Ideal PETC operating environments include all types of vehicles and PETCs can withstand all common elements inherent to island environments. Wireless computing has significantly improved the accuracy and efficiency of providing data to build data bases but is still limited in ability and is costly to operate. Additional technological improvements in the near future, especially in the fields of digital still photography and voice recognition, will further contribute to the development of GIS and the use of information technologies by small island states. Annex XIV contains the detailed presentation on this topic.

In addition, an information document tabled at the Workshop, on the current status of remote sensing and GIS at the South Pacific Applied Geoscience Commission (SOPAC) is included as Annex XV as an example of developments taking place in this field in the Pacific.

4. TECHNICAL CHALLENGES OF USING GIS IN SIDS

Workshop participants agreed that, for using GIS in CZM, needs assessment and strategic planning are essential at the outset. Requirements in data, personnel and equipment must be clearly defined. This will usually mean different systems for different needs and financial means. Systems must be tailored to the needs, and the biggest, most expensive systems are not always the best choice.

The judicious use of GIS in ICZM will allow better quality output and decision-making at reduced costs, as the technology allows better allocation of limited financial and human resources, which is an essential prerequisite for sustainable development in SIDS. For example, remotely sensed data integrated through GIS offer the potential for satisfying multiple needs from a common data collection effort over wide areas.

GIS technology requires the sharing of data between SIDS and other countries as well, improved communications, training, and system compatibility. It is important that the origin of data be documented so that it can be verified and shared. Also, planning for new data collection should consider using standards to facilitate future data exchange. Data management and quality control really constitute key areas.

Pitfalls that SIDS must guard against include incompatible systems, problems in managerial support, software and capital acquisition, lack of technical help, and limited telecommunications networks. Indeed, telecommunications are of critical importance for the transfer of data from remote data bases at local, regional, and international sites. Improved communications will also enhance training, as well as facilitate the rapid interchange of knowledge, problem solving at the technical and operational decision-making levels, and the sharing of expertise at all levels.

As a final caveat, it was mentioned that GIS do not incorporate the time dimension very well, and that other tools, such as spatial/temporal modelling, may be needed to complement them.

5. HOW TO PROMOTE AND IMPLEMENT THE USE OF GIS IN DECISION-MAKING FOR CZM

5.1 Promotion of GIS

While there was general agreement on the potential of GIS technology, workshop participants discussed whether or not it could play an important role in decision-making in the CZM of SIDS. For GIS to become an attractive tool as a decision support system, it was concluded that its usefulness first must be sold to decision-makers. GIS must be presented to a certain extent as a "black box", but an efficient management black box which can reflect the complexity of CZM, and include social, cultural and economic aspects in addition to scientific data. Adequate marketing strategies are required to foster awareness of the full potential of GIS.

5.2 Capacity building

Even though GIS teams made up of several people would be ideal for SIDS, the reality of the situation is that human resources are usually quite limited, and budgets low. Therefore, innovative approaches at the national level are required: the best use must be made of existing structures and tools through good coordination.

At the regional and intergovernmental level as well, with help from the regional bodies, scarce resources must be shared. A regional core of marine, coastal and social scientists, engineers and planners as well as multidisciplinary technical support familiar with the use of GIS is needed for ICZM. ICZM requires comprehensive planning by SIDS to define their long-term objectives and needs. These include the identification of management objectives, the setting of standards, the design of data collection and monitoring systems, as well as the identification of GIS technologies appropriate to the situation of given SIDS.

Furthermore, communications and information sharing between SIDS should be enhanced and used to the fullest. Data should be exchanged for free, except for commercial applications, and the lineage of data should be recognized. Maximum use of structures (e.g. data centres), tools and standards developed by bodies like the IOC should be made. There also exist networks with information on small islands which can be queried.

Where developed countries and aid agencies are present, they should be involved in the support of GIS development in SIDS. However, it is critical that the needs of both donor and recipient countries be adjusted well so as to avoid difficulties which often stem from differing expectations by the partners.

5.3 Training and education

In order to implement the use of GIS for the sustainable management of coastal areas of SIDS, the approach must be multidisciplinary and aimed at all levels in society, including technicians, scientists, managers and politicians. Workshop participants felt that training was of the highest importance in developing the expertise in the use of GIS in SIDS. Technical regional training workshops should be organized as well as exchanges of trainees.

Regional pilot projects demonstrating the use of GIS technology for CZM of SIDS could also be implemented by regional organizations and regional universities to assist SIDS in offering training facilities and in providing the feedback necessary to adjust GIS to their particular needs.

In addition to training, education is an extremely important target for the longer term development of the use of GIS for ICZM in SIDS.

Hence, through education and training, the expertise in the use of GIS must be developed in SIDS. Moreover, this will lead to SIDS involvement at all levels in the development of GIS technology and applications best suited to the needs of small islands. In this respect, it should be noted that a number of workshop participants felt that the participation of SIDS in different areas of the information industry, in addition to their technology user role, should be encouraged and promoted.

Finally, GIS technology can assist in promoting awareness at all levels of SIDS societies, from children to scientists to decision-makers, so that all can be educated on the protection, restoration, enhancement and utilization of the coastal zone of their islands.

6. SUGGESTED PLAN OF ACTION

Given the potential of GIS as an appropriate tool in ICZM for SIDS, Workshop participants suggested that a plan of action be developed for SIDS with regards to the use of GIS, comprising the following elements:

NATIONAL INITIATIVES:

- undertake on an accelerated basis, in all SIDS that have not done so, a detailed assessment of needs for implementing an ICZM program utilizing GIS technology support;
- develop and strengthen the national capacity for using GIS in ICZM on a continuing basis;
- ensure that data and information from existing facilities are accessible to GIS systems for ICZM;
- support the implementation of sustainable ICZM programs by organizing/facilitating continuing public awareness activities on GIS and their potential.

REGIONAL INITIATIVES:

- improve interregional telecommunications networks;
- assist SIDS in their effort to conduct ICZM programs using GIS;
- organize/facilitate regular regional training activities on GIS data acquisition and technology, making use of the strengths of existing regional centres of excellence;
- establish modalities to ensure the compatibility of GIS systems for ICZM related activities.

INTERNATIONAL INITIATIVES

- request IOC to organize GIS awareness workshops for decision-makers in SIDS, in collaboration with international development agencies, UN organizations and other NGOs;
- improve communication systems into SIDS to enhance international coordination and cooperation in GIS development and standardization and exchange of data;
- support locally driven projects aimed at demonstrating the usefulness and economic viability of GIS and remote sensing in ICZM.

7. RECOMMENDATIONS

In light of this plan of action, Workshop participants formulated the following recommendations:

(1) IOC should organize regional workshops to ensure training of SIDS personnel in the use of the most appropriate GIS technology in ICZM.

(2) IOC should promote state-of-the-art telecommunications amongst SIDS and other countries.

(3) IOC and other international agencies and aid agencies should support SIDS in putting on projects demonstrating the usefulness and economic advantages of using GIS and remote sensing in ICZM.

These recommendations were submitted to the IOC just prior to the start of the Global Conference on the Sustainable Development of Small Island Development States.

8. CONCLUSION

Participants agreed that the technical information provided on GIS at the Barbados Workshop was extremely valuable. Discussion between representatives from SIDS and from various agencies showed that GIS technology can definitely help SIDS manage their coastal zone. However, this will be efficient only if needs are assessed at the outset and if plans are tailored to the needs of SIDS. In this respect, coordination of efforts and cooperation between states and agencies are of the utmost importance.

The potential of GIS applications in ICZM of SIDS is very well illustrated by the example of Barbados. This comes across clear in the concluding remarks (see Annex XVI) given to the Workshop by the Honourable Senator Harcourt Lewis, Barbados Minister of the Environment, Housing and Lands.

Now it is up to SIDS and to their supporting international partners to take action as required in each country and region.

WELCOME COMMENTS FROM THE INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION BY PAUL GEERDERS

Ladies and Gentlemen: On behalf of IOC and its Secretary Dr. Gunnar Kullenberg I would like to welcome you to Barbados and to declare that IOC is very pleased to be so closely involved in this meeting. This provides an excellent opportunity to contribute to the follow-up and implementation of some declarations of UNCED and Agenda 21 in relation to Coastal Zone Management.

Because of its intergovernmental character IOC has an excellent relation with the governments of its Member States, with a wide range of international and intergovernmental organizations such as WMO, UNEP and IMO and with relevant NGOs. To further improve the effectiveness of its activities IOC has established a number of regional subcommittees such as IOCARIBE for the Caribbean and adjacent regions, WESTPAC for the western Pacific and IOCINDIO for the Central Indian Ocean. This enables IOC to operate more closely to the specific character of a region and to be more effective in meeting regional needs and requirements. Through joint research programmes and capacity building activities networks have been established which in turn have led to an increased scientific and technical collaboration in the field of the marine sciences.

The possible effects of world-wide changes in climate and environment are relevant to all countries. However they are of particular and often vital importance for small island states. Furthermore, the increasing pressures from tourism as well as the population expansion and the related needs for more food, space and energy are leading to dramatically conflicting interests specifically in the coastal zone. In view of the present state of the art in computer science and informatics including Geographic Information Systems we may expect this technology to be able to provide effective tools to support integrated coastal zone management.

In this context, IOC has launched the concept of the Global Ocean Observing System, GOOS. This intends to be a worldwide ocean monitoring system providing data on the oceans alike the present systems such as World Weather Watch in meteorology. Similar systems are the Global Climate Observing System (GCOS) and the Global Terrestrial Observing System (GTOS). National and regional integrated coastal zone management systems could be considered as coastal modules of GOOS.

One essential and basic element for coastal zone management is the collection, synthesis and sharing of data and information. Recognizing the vital importance of this field, IOC already more that two decades ago established a world-wide network of national and responsible oceanographic data centres, collaborating closely with each other and with the World Data Centres-Oceanography operating under the International Council of Scientific Unions ICSU. Experts active in the IODE network actively collaborate in the IOC Committee on International Oceanographic Data and Information Exchange, IODE.

IODE has developed and implemented a number of procedures, guidelines and standards for marine data and information acquisition, quality control and assessment, processing and exchange. In addition IODE has initiated and guided the development of the standardized software package OCEAN-PC to assist scientists and data managers with marine data and information management. A first version of OCEAN-PC for evaluation by a limited group was published last year. It can be stated that IODE provides an effective, global, operational network giving access to a wealth of marine data and information. Various aspects of IODE will be treated in my later presentation in more detail.

Another essential element for coastal zone management is formed by numerical models. For their development historical data are of unique value. IOC devotes special attention to historical data through its Data Archaeology and Rescue

Project. Within this project assistance and support can be provided to activities aimed at making valuable historical data accessible.

Remote Sensing forms another crucial element of coastal zone management systems. IOC is actively engaged in forming an interface between the IOC community as consumers of derived products on the one hand and the producers of these products on the other. Special attention is given to aspects such as content, quality, accessibility, periodicity of these products. On a personal basis I would like to add that in view of recent trends in the space industry aimed at dedicated satellites, it seems very timely to consider the feasibility of a dedicated satellite system for coastal zone monitoring.

Through its TEMA programme (Training, Education and Mutual Assistance), IOC provides training opportunities both in the region and elsewhere on subjects such as marine data and information management, remote sensing for marine applications, and specific data acquisition training. TEMA also includes an activity on equipment where requests for specific instruments or computer systems are matched with offers of surplus equipment received by IOC.

Finally smooth communications form a basic element for collaboration and cooperation with regard to coastal zone management. Besides telephone and fax, facilities such as electronic mail and data communications (Internet) should be made available as a prerequisite for SIDS to commmunicate between each other and with the rest of the world. Proper communications are essential to the effective implementation of decisions related to integrated coastal zone management systems in small island states.

IOC is happy to offer its intergovernmental network and its specific and wide experience to the current efforts aimed at establishing integrated coastal zone management capabilities in small island developing states. Thus IOC provides a contribution to the responsible management of the coastal marine environment from which we originate and upon which we strongly depend for our survival. I look forward to a most useful and interesting meeting that will result in concrete and feasible recommendations. Thank you!

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OPENING REMARKS BY JANET ZUKOWSKY, HIGH COMMISSIONER FOR CANADA TO BARBADOS AND THE EASTERN CARIBBEAN

BARBADOS, APRIL 20-22, 1994

Mr. Chairman, representatives of Small Island States and regional organizations, representatives of the Intergovernmental Oceanographic Commission, UNEP regional bodies, NGOs, and other international organizations, presenters, ladies and gentlemen:

On behalf of the Government of Canada, I welcome this opportunity to make a few brief remarks at the opening of this important Workshop on Geographic Information System Applications in Coastal Zone Management of Small Island States.

It may at first seem strange that the Government of Canada should be taking an active interest in matters such as the topics you will be examining over the next three days. But when you remember that Canada is, by definition, a maritime nation, possessed of the longest coastline of any country in the world, not to mention some several thousand coastal and inland islands, it becomes more apparent that we share many common interests and problems related to coastal zone management. It is perhaps in partial response to these problems that Canada has become preoccupied with, and ultimately has developed considerable expertise in, the application of modern electronic data processing, remote sensing and cartographic techniques designed to help decision makers working in the coastal zone.

Many other countries and international and regional bodies have simultaneously come to the realization that the seemingly intractable problems of harmonizing the many legitimate and beneficial activities which take place in our coastal zones can be made somewhat more approachable by the effective use of technologies such as these. During this Workshop you will hear from decision makers and specialists from all over the world who will recount their experiences in programmes aimed at addressing the various aspects of this broad subject and you, in turn, I have no doubt, will contribute to these discussions by your own observations on the opportunities and the impediments which still must be addressed to effectively employ these technologies to their ultimate advantage.

This Workshop represents a valuable opportunity to introduce many of you to both existing and emerging applications of GIS technologies in the field of coastal zone management. For those of you who already have a working knowledge of GIS, the Workshop may present some very new applications of the technology as well as more focussed employment with respect to coastal zone management of small island states. For all, the Workshop, and the recommendations that will emanate from it, represent a valuable opportunity to forward your views on the utility of this technology to the Global Conference on the Sustainable Development of Small Island Developing States beginning here in Barbados next week. Canada, in cooperation with the Intergovernmental Oceanographic Commission of UNESCO, is pleased to play a role in this fundamental process of collaborative learning.

It would not be reasonable to assume that we will leave here after three days having developed a master plan that will lead to a universal remedy to coastal zone conflicts which stand in the way of sustainable development of the coastal resources of small island states. But we will have a much clearer picture of the issues and, I trust, some usable technological methods for addressing them. It will be up to each one of you to take from this what you can and apply it locally or regionally in your own context. For those of you who will be staying to attend the international conference, I hope that we can rely upon you to take these discussions and recommendations with you and carry the process one more step forward in seeing that decisions affecting the coastal zone are made in the full awareness of the lessons we gain from this workshop.

May I wish you every success in your discussions and thank you all once again for having joined us here to help make this Workshop the valuable contribution to sustainable resource planning that I am now confident it will become.

WORKSHOP PROGRAMME

WEDNESDAY, APRIL 20, 1994

08:30 - 08:40	Welcome and introduction (J. Piuze, Workshop Chairman)
08:40 - 08:45	Opening Remarks (J. Zukowsky, High Commissioner for Canada)
08:45 - 09:00	Welcome Comments from IOC (P. Geerders)
09:00 - 10:15	Opening Panel Discussion Coastal Zone Management for Small Island States (SIDS) - The Issues and Challenges. Panelists: G. Garcia, L. Nurse, and A. Robertson
10:30 - 11:30	IOC Experience and Views on Coastal Zone Data Management Presenter: P. Geerders
11:30 - 13:00	Principles for use of GIS in Coastal Zone Management Presenter: M. Arno
14:30 - 15:30	Strategies for Building and Maintaining Coastal Zone Databases Presenter: P. Grose
15:45 - 16:45	Remote Sensing and Coastal Zone Data Acquisition and Analysis Presenter: B. Ryerson
16:45 - 17:30	Closing Panel Discussion Focus on identifying new issues raised by the technical presentations. Discussion open to the floor. Panelists: N. Bleuse, A. Duncan, and C. Gray
17:30 - 18:30	Hands-on GIS Free Time Review and Interact with the tools presented and discussed earlier in the day. Delegates will have an opportunity to consult with the technical experts.

THURSDAY, APRIL 21, 1994

08:30 - 09:15	Opening Panel Discussion Panelists: L. Cassel, J.Eade, and T. Mellen
09:15 - 10:30	Coastal Zone Management in Barbados with GIS Presenter: K. Atherley
10:45 - 12:00	Desktop Delivery Systems for Coastal Zone Information Presenter: P. Grose

13:15 - 14:15	GIS Dynamic Modelling in Coastal Zone Management
	Presenters: G. Engelen and R. White
14:15 - 15:30	Information Technology Development Directions
	Presenter: G. Maffini
15:45 - 16:30	Closing Panel Discussion
	Panelists: J. Akiwumi, S. Aniyar, and W. King
16:30 - 17:30	Detailed Demonstrations of Case Studies
	An opportunity to review and discuss the case studies presented earlier in the day.

FRIDAY, APRIL 22, 1994

08:30 - 09:00	Modus operandi for three Workshop Breakout Sessions			
09:00 - 10:15	Breakout Sessions Part I (Three concurrent)			
	Leaders:	S. Aniyar,	C. Gray,	A. Duncan
	Rapporteurs:	W. King,	T. Mellen,	J. Eade
10:45 - 12:00	Breakout Sessions Part II (Three concurrent as above)			
13:00 - 14:30	Report from Session Leaders and Rapporteurs			
14:30 - 16:00	Plenary Discussion and Development of Recommendations and Conclusions			
16:00 - 16:30	Concluding Address (Senator Harcourt Lewis, Minister of the Environment, Housing and Lands, Government of Barbados)			
16:30 - 17:30	Workshop Conclusions			

REMARKS FOR THE OPENING PANEL DISCUSSION
BY
GUILLERMO GARCIA

For many small island states tourism represents an important economic activity and its development is based on the recognition of environmental beauty as a valuable natural resource. In other words, tourism activities are today recognized as very sensitive to the quality of the environment.

But, when talking about small islands in general, "the environment" could be understood as the marine and coastal zones from which they obtain one of their basic resources.

Small island states are, in fact, "coastal marine" countries.

Moreover, if the importance of the coastal zone for small island states has to be emphasized it is because it contains several of the most important natural resources:

(i) beaches
(ii) coral reef areas
(iii) mangrove areas

That is why one should say the coastal zone is a fundamental factor for the sustainable development of small island states. It means that when planning the short, medium and long term use and exploitation of this complex natural resource one should preserve it to satisfy the needs of future generations.

Small islands have several common characteristics that make them very sensitive to natural and man-made effects, generally influencing the natural equilibrium of the coastal zone. I would like to point out the following characteristics:

(i) Susceptibility to natural environmental events (hurricanes, cyclones, storm surge phenomena, etc).

(ii) Tenancy towards ecological instability.

(iii) Almost immediate repercussions on the coastal zone and marine environment of terrestrial events.

(iv) Coastal resource planning and management is essentially synonymous with natural resource planning and management.

(v) Remarkable vulnerability to global environmental phenomena, such as sea level rise, an increase in the frequency and severity of tropical storms, etc.

For an important part of the community (scientists, environmental managers and policy decision-makers) the problems associated with the coastal zone were initially related to some extent with climate changes, and in particular to continuous sea level rise. But, it is already accepted that these problems are the consequences of the immediate response of the coast to many human induced activities, including not only those resulting from an environmentally erroneous planning of the coastal space but also those ensuing from mitigation actions improperly implemented.

In consequence, any activity or program dealing with Coastal Zone Management shall include the following items:

(i) Identification of coastal resources, including those of public/social character.

(ii) Definition of priority uses.

(iii) Establishment of short and medium term research programs including:

(a) general characterization studies
(b) base line determination
(c) studies on processes/interactions

(iv) Establishment of long term or permanent monitoring program based on the results of research and base line determination.

(v) Definition of common methodologies for research and monitoring, and development of intercalibration and standardization exercises.

(vi) Establishment of coastal ecosystems data bases, including not only scientific research and monitoring data, but also those of social character (i.e. recreational, touristic, etc) and of economic character (i.e. land-based industries, agriculture, fisheries, etc).

(vii) Development of mathematical models of coastal ecosystems (including those of specific or general character and use) that could contribute to predict the effects of management decisions and/or climate change.

Other items have to be borne in mind if one has to manage damaged ecosystems. These items are as follows:

(i) To find the causes of the damages.

(ii) To define the ecologically sustainable measures to mitigate, or at least to solve the consequences and causes of damages.

(iii) To restore, as far as possible, natural conditions to the affected ecosystem.

On the other hand, an important aspect in support of coastal zone management is the existence of local and national regulatory and coordination mechanisms.

A coordination mechanism is essential to look for the best solution to a problem and to find the most adequate decision for the management of the resources. A regulatory, and an enforcement (or compulsory), mechanism is essential to force people to act in the right way.

Finally, if we want to succeed in coastal zone management several challenges have to be faced. The changes include:

(i) To increase public education, also for decision-makers, on environmental issues.

(ii) To create and/or increase the necessary human resources at different levels of scientific and technological knowledge.

(iii) To employ, or create when necessary, a mechanism for cooperation and coordination at local, national and international levels.

(iv) To develop the free exchange of scientific information and data between national institutions, and countries.

(v) To develop the widest possible exchange of experiences in success and errors in coastal zone management at national and international levels.

(vi) To define and establish the necessary methodologies and technologies for research and monitoring. This shall include intercalibration and standardization exercises.

In closing, I want to say again that coastal zone management is a very complex exercise, not only of scientific nature but also of social and economic character. This exercise has to be continuously improved if we intend to succeed, because in our specific case, as small island states, the present economic situation is perhaps the biggest obstacle to apply the principle of sustainable development.

COASTAL ZONE MANAGEMENT (CZM) IN BARBADOS - COASTAL CONSERVATION UNIT (CCU)

BY

LEONARD NURSE

INITIAL PROBLEMS IN ESTABLISHING CZM PROGRAM

* NEEDS ASSESSMENT
  - identification of critical issues facing coastal zone
  - beach erosion/ coastal water pollution/ reef degradation/ sand mining/ habitat loss (seagrasses, wetlands, beach vegetation)?

* Needs assessment provides basis for determining DATA REQUIREMENTS; MONITORING SCHEDULE & DESIGN; EQUIPMENT; INSTITUTIONAL & PERSONNEL.
  - in Barbados case, triggering concerns were perceived beach loss, deteriorating water quality and reef morbidity and mortality.
  - led to establishment of Coastal Conservation Unit, with a critical core staff in oceanography, marine biology, engineering, coastal planning, surveying.

* After birth of CCU, problem of adequate funding commitment - maintenance/continuity of activities. Many SIDS do not have strong commitment to maintenance of infrastructure and programs, especially environmental programs; only relatively recently regarded as priorities in region.

DATA MANAGEMENT ISSUES

* Assembly of FRAGMENTED DATA SOURCES
  - data on range of variables gathered by variety of agencies: maps, aerial and ground-level photos, coastal survey plots, information on currents, waves, etc related to specific projects; water quality data.
  - in cases no reference to sampling methods, protocols, thus difficult to determine reliability of existing information.
  - requirements for RETRIEVAL/ QUALITY CONTROL/ STORAGE/ MANAGEMENT for decision-making.

* ORGANIZATION/CLASSIFICATION of available data into discrete, manageable subfields to meet requirements identified in "Needs Assessment".
  - coastal engineering, marine biology, oceanographic, surveying and other data files. Files then used as basis for developing time series - requirement for sound CZM.
  - in case of CCU, process useful in identification of DATA GAPS and deficiencies - thus highlighted the need for modification of data gathering and monitoring.

THE REALITY

* At every stage of process the need for an adequate data management system was highlighted.
  - The system chosen must have the necessary flexibility to accommodate increasing volume, complexity and sophistication of information, as data base expands.

* In case of Coastal Conservation Unit, Barbados, program at a stage where higher levels of efficiency can only be achieved with a functional Geographic Information System

COASTAL CONSERVATION UNIT

THE FUNCTION OF THE COASTAL CONSERVATION UNIT

WORKING TO ENSURE THAT THE COAST RETAINS ITS VITAL AND PIVOTAL ROLE IN THE ECONOMIC, SOCIAL AND PHYSICAL DEVELOPMENT OF BARBADOS

BACKGROUND ON THE ROLE AND FUNCTION OF THE COASTAL CONSERVATION UNIT

BACKGROUND

The Coastal Conservation Unit (C.C.U.) was established in 1983. Conceived as a specialized governmental unit the C.C.U. is specifically concerned with issues relating to coastal erosion and the application of management strategies for dealing with this threat.

OBJECTIVE

The long term objective of the Unit is to design and implement an effective, comprehensive Coastal Zone Management Plan for the island of Barbados.

PROJECT EXECUTION

The 1983-1984 Diagnostic and Pre-feasibility Coastal Conservation Study was the first major project work executed by the Unit. The Study was designed to determine and assess the causes of coastal erosion in Barbados and to make recommendations on remedial strategies. This work was funded by the Inter-American development Bank.

The Feasibility and Design Coastal Conservation Study will be the next major step in pursuit of the Unit's overall objective. The major components of this project are to research and define strategies for:

- Beach creation and stabilization
- Water quality improvement
- Legal and institutional arrangements

PRESENT WORK

The Unit's work currently includes the following:

(a) OCEANOGRAPHIC ASSESSMENT

- Beach profiling at over 100 sites
- Wave climate analysis
- Tide level monitoring
- Water quality assessment
- Fringing and bank reef surveys
- Longshore sediment movement.

(b) COASTAL RESEARCH

Staff undertake applied research relating to various coastal matters, for example:

- Coastal legislation
- Lagoon monitoring and improvement
- Beach access
- Ocean data management
- Jetties in Carlisle Bay
- Revegetation and dune management
- Artificial seaweed as a means of erosion control
- Impact of effluent discharge (including thermal effluent on beach dynamics, marine and coastal ecosystems.

(c) CONSULTATION ON COASTAL ENGINEERING

The Unit advises public and private sector agencies on shoreline protection methods and engineering design standards:

- Management strategies
- Design criteria
- Implementation
- Monitoring and impact assessment

(d) DEVELOPMENT CONTROL

The Unit participates in the decision-making process vis-a-vis development control by evaluating all proposed developments in the littoral and marine zone. This work is done in association with the Town Planning Department.

(e) EDUCATION OUTREACH

The education programme which seeks to sensitize the public about coastal problems involves active participation in exhibits, media programmes and lectures. Library information is also made available to university secondary schools students, and *bona fide* researchers from the general public.

STAFFING

At present eleven (11) key technical and support staff members perform the routine work of the Unit. They also provide critical support during the major research and coastal engineering projects. There are plans to have the staffing complement upgraded to include positions which have been considered necessary and essential to the functioning of the Unit. The present complement of Senior Technical staff consists of :

Project Manager
Coastal Planner
Marine Biologist
Coastal Engineer
Civil Engineer
Water Quality Technician

The following presents an outline of the technical expertise which resides within the Unit:

<u>TECHNICAL POSITION</u>	<u>SPECIALITY</u>
Project Manager	Coastal Geomorphology
Coastal Planner	Coastal Planning
Marine Biologist	Marine Biology
Coastal Engineer	Coastal Engineering
Civil Engineer	Civil Engineering
Scientific Officer	Natural Science
Research Officer	Natural Science
Surveyor/ Assistant Surveyor	Hydrographic Surveying
Draftsman	Computer Aided Design
2 Surveyors Chainmen	
Technician	

<u>ADMINISTRATION</u>

Accountant
Clerical Officer
Secretary
Clerk/Typists

SUMMARY

Although the Coastal Conservation Unit is a relatively young agency (10 years), it has earned a reputation for high productivity/professionalism and quality research in its field. It has been able to effectively pool and utilize its own resources and those of other technical agencies in Barbados to address a variety of coastal zone management issues. To this end the Coastal Conservation Unit is working to ensure that the coast retains its vital and pivotal role in the economic, social and physical development of Barbados.

IOC EXPERIENCE AND VIEWS ON MARINE DATA AND INFORMATION MANAGEMENT IN SUPPORT OF CZM SYSTEMS FOR SIDS

by

Paul Geerders

THE CONSUMER
THE PRODUCER
POSSIBLE IOC ROLE
CONCLUSIONS
(DEMOs)

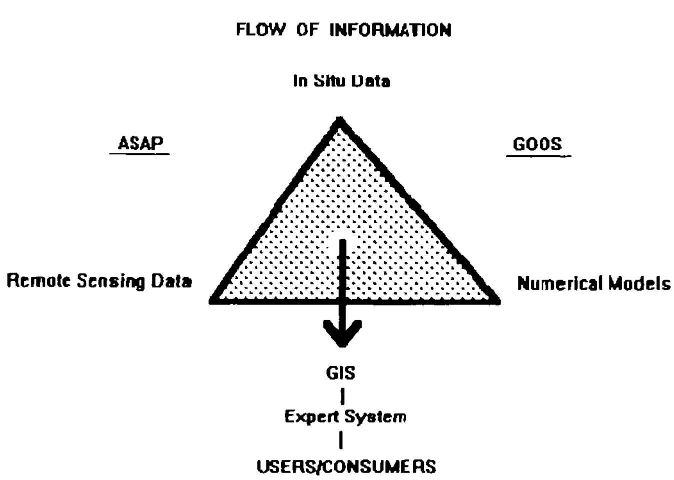
This presentation will first focus on the basic elements of the end-users, the consumers of coastal zone management data and their needs. Then it will look at the various aspects of the producers of the relevant data. Furthermore, the possible role and contributions of IOC will be presented followed by a number of conclusions. A demo was given of the OCEAN-PC package of IOC.

REQUIREMENTS CZM:
ACTUAL SITUATION
HISTORY
FUTURE

In coastal zone management the basic needs refer to: the actual situation (especially in calamity situations), the past (to detect trends) and the future (to evaluate the consequences of certain actions or events).

A PRIORI KNOWLEDGE
DATA
INFORMATION
KNOWLEDGE
MODELS
SECURITY
STANDARDS

The proper basis of the application of technology such as GIS systems is an a-priori knowledge of the processes to be captured in the system. This knowledge, to be obtained through scientific research, should be complemented with standardized, quality-controlled data and with reliable information. Scientific knowledge leads to numerical models describing with certain limitations and assumptions the processes included in the system. Security needs to be applied at several levels: internally to ensure consistency, and externally to prevent external influence on systems of which the proper performance can be vital for environment and national economy. Standards need



from technology push
to
user-driven systems

to be applied at all levels to ensure the required compatibility between data from different sources and of different types.

In order to provide the consumers with a continuous, consistent stream of data and information, three sources need to be combined: in-situ data, Remote Sensing data and data from numerical models. GIS systems form an excellent carrier to present and evaluate large amounts of different types of data and information. Expert systems (including decision-support systems) could not only facilitate the access for the user but also provide a dynamic element, especially vital in calamity situations. We need to develop from technology-pushed systems to systems driven by concrete user requirements. The IOC concept of GOOS, the Global Ocean Observing System, is based upon this model. The system ASAP (A System for Assessment of Pollution, developed by a Netherlands consortium for UNEP to be applied primarily in Kuwait to assess the environmental situation after the liberation) is a good example of a practical system including several of the aspects mentioned above.

NATIONAL	NODCs
REGIONAL	RNODCs
GLOBAL	WDCs

In order to enhance the accessibility of marine data and information on a national, regional and global scale, IOC has developed the concept of the IODE network (International Oceanographic Data and Information Exchange). This network includes: national oceanographic data centres (about 55 around the world), responsible oceanographic data centres (both for specific regions and for specific subjects) and the World Data Centres - Oceanography, the latter operating under ICSU.

DATA ACQUISITION
SAMPLING
PROCESSING
ARCHIVAL
EXCHANGE

The IODE system follows closely the stages of sea-going campaigns from data acquisition until archival and exchange of the data. This is the basic process required to provide the essential supporting data for coastal zone management systems.

planning	NOP	national oceanographic programme
completion	CSR	cruise summary report
datafile	MEDI	marine environmental data inventory
exchange	GF-3	general format -3
publication	ASFA	aquatic sciences and fisheries abstracts

IODE has developed a number of specific procedures and guidelines to monitor and facilitate the flow of marine data. NOP is used to announce planned cruises on an international level. This could be important e.g. to provide an opportunity for other scientists (e.g. ornithologists). A CSR report is used to describe what has actually happened during a cruise in terms of: where data or samples were acquired, what type of data or samples were acquired and which ship, institutions and scientists were involved in the cruise. IODE provides international exchange of NOP and CSR. IOC regularly publishes updated MEDI Catalogs. GF-3 is a technical format provided to exchange marine data, mainly in large quantities. Reduced and specific formats have been developed for specific types of data and for small amounts of data. IOC is a co-sponsor of the ASFA system, operated by FAO, an automated literature system containing references to a wide range of marine-related publications. It is advisable to assure that the results of marine scientific work finally are included in ASFA.

STANDARDS	
PROCEDURES	
GUIDELINES	
OCEAN-PC	quality control and processing
ETI	taxonomy
DATA ARCHAEOLOGY	historical data
ELECTRONIC MAIL	Sciencenet/OMNET

IOC and IODE has developed a range of standards, procedures and guidelines related to marine research, from data acquisition to final data archival. These have been documented and published in the series IOC Manuals and Guides.
OCEAN-PC is software package for marine data quality control, processing and presentation. It consists of a number of modules from different origin. It is intended to be expanded over the years. OCEAN-PC could be most effective to provide standardized marine data input to coastal zone management systems using GIS. In relation to OCEAN-PC, IOC publishes an inventory of useful marine research related software packages developed all around the world. Most of these are freely available.
ETI, the Expert System on Taxonomic Interpretation, is being developed with IOC support to lead to a world-wide system compiling and making accessible the slowly vanishing expertise in the world on taxonomic interpretation. This system could form an effective component of coastal zone management systems.
Historical data form an essential element for research for trends in the environment leading to numerical models which in turn are crucial for coastal zone management systems. IOC's Data Archaeology and Rescue project is aimed at providing assistance and advice to making valuable historical marine data sets accessible.
Communication through electronic mail and other digital communication systems is vital for research in general and for marine research in particular. The effective implementation and operation of coastal zone management systems will depend on the availability of reliable, cost-effective digital and non-digital communication technology.

TRAINING in:
MARINE DATA MANAGEMENT
MARINE INFORMATION MANAGEMENT
REMOTE SENSING FOR MARINE APPLICATIONS
ON-BOARD PROCEDURES

IOC can provide training opportunities in marine data management, marine information management and Remote Sensing for marine applications. These can be in the form of (mostly regional) training courses and individual training. Also IOC provides opportunities for training in on-board data acquisition procedures.

WHAT DOES GIS MEAN?

GHASTLY IMPRESSIVE SHOW
GREAT IMPRESSION SIMULATOR
GONZO'S IDEA SNATCHER

"gis" (Dutch) means "smart, cunning"

GENERATION

INTERCALIBRATION

STANDARDIZATION

We should be cautious concerning the value and capabilities of GIS systems as such. They often turn into fancy data presentation and manipulation systems providing its users with apparently credible views of "reality". However, we must keep in mind that only operational infrastructures for the generation of the required data, that only a perfect intercalibration between the many different sources of input data and that only strict standardization at all levels can make GIS systems provide results useful for their users.

CONCLUSIONS:
WHAT DOES THE CONSUMER WANT?
WHAT CAN WE DELIVER?
WHAT CAN IOC CONTRIBUTE?

A thorough analysis of user (consumer) requirements is essential to develop and implement GIS and related technology to support coastal zone management. There are immense possibilities from technology: let's make a wise use of them. Finally IOC can contribute in several ways to this process, both with its experience and with the specific tools it has developed for marine science and for marine data and information management.

GIS APPLICATIONS IN COASTAL MANAGEMENT OF SMALL ISLAND STATES
GIS Methods and Coastal Zone Management

Prepared by:

Michael Arno
President, Spatial Insights, Inc.
Arlington, Virginia, U.S.A.

Wednesday April 20, 1994

Spatial Insights, Inc.
A Geographic Information Services Company

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Introduction

- Presentation provides an introduction to GIS methods and application to coastal zone management
- Conceptual framework of GIS for coastal management applications
- Overview of the basic functions of a GIS
- Examine the working methods of GIS today
- Concepts will be illustrated with CZM examples

Presentation Format

- Stand-alone desktop PC GIS's
- System is 486-based with 16 MB RAM and operating with VGA graphics (running under Windows 3.1)
- Review hand-out materials
- Case studies include:
    - Aerial photographic retrieval system (Florida)
    - Coastal polution identifaction (Cyprus)
    - Coastal Resource Assessment (Sri Lanka)

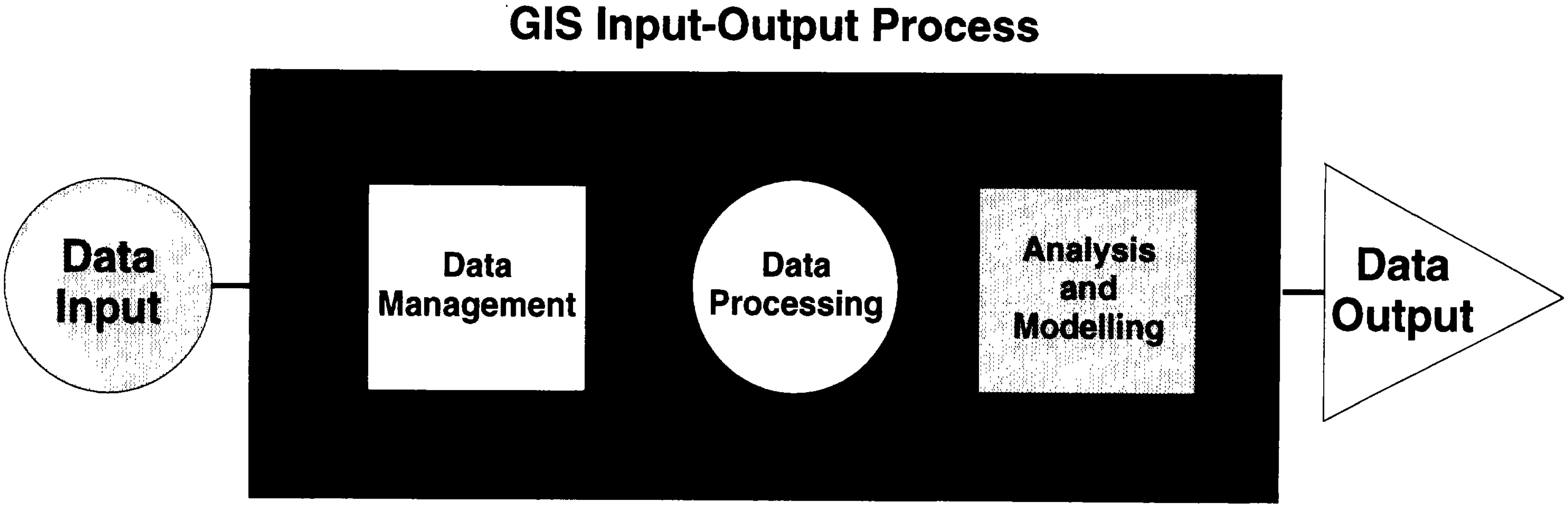
What's Different About GIS?

- GIS is an alternative model for understanding complex real world systems
- The globe and paper map is the traditional model used by cartographers
- With the advent of electronic data systems, GIS provided a logical extension to existing geographic models
- Through this linkage, GIS can become a powerful vehicle for information management, investigation and decision support
- GIS offers an ideal way to represent and build our understanding of complex coastal systems
- GIS technology has been developed since the mid-1960's

Functions of the GIS

Visualize	Assessing information by the use of sight
Organize	Ordering information by using logical linkages between data elements
Combine	Integrating data from disparate sources
Analyze	Extracting meaning from data
Predict	Assessing the future from patterns in the data
Question	Interrogating data to provide answers

How Does the GIS Work?



Data Input Overview

Data Sources	Geographic data sources are rapidly expanding as more data becomes available from public and private agencies.
Data Integration	GIS has exceptional range of functions for combining data from disparate sources.
Data Capture Methods	Multiple options depending on the application, accuracy and precision required.
Data Representation	GIS offers flexibility in accessing spatial and non-spatial data.

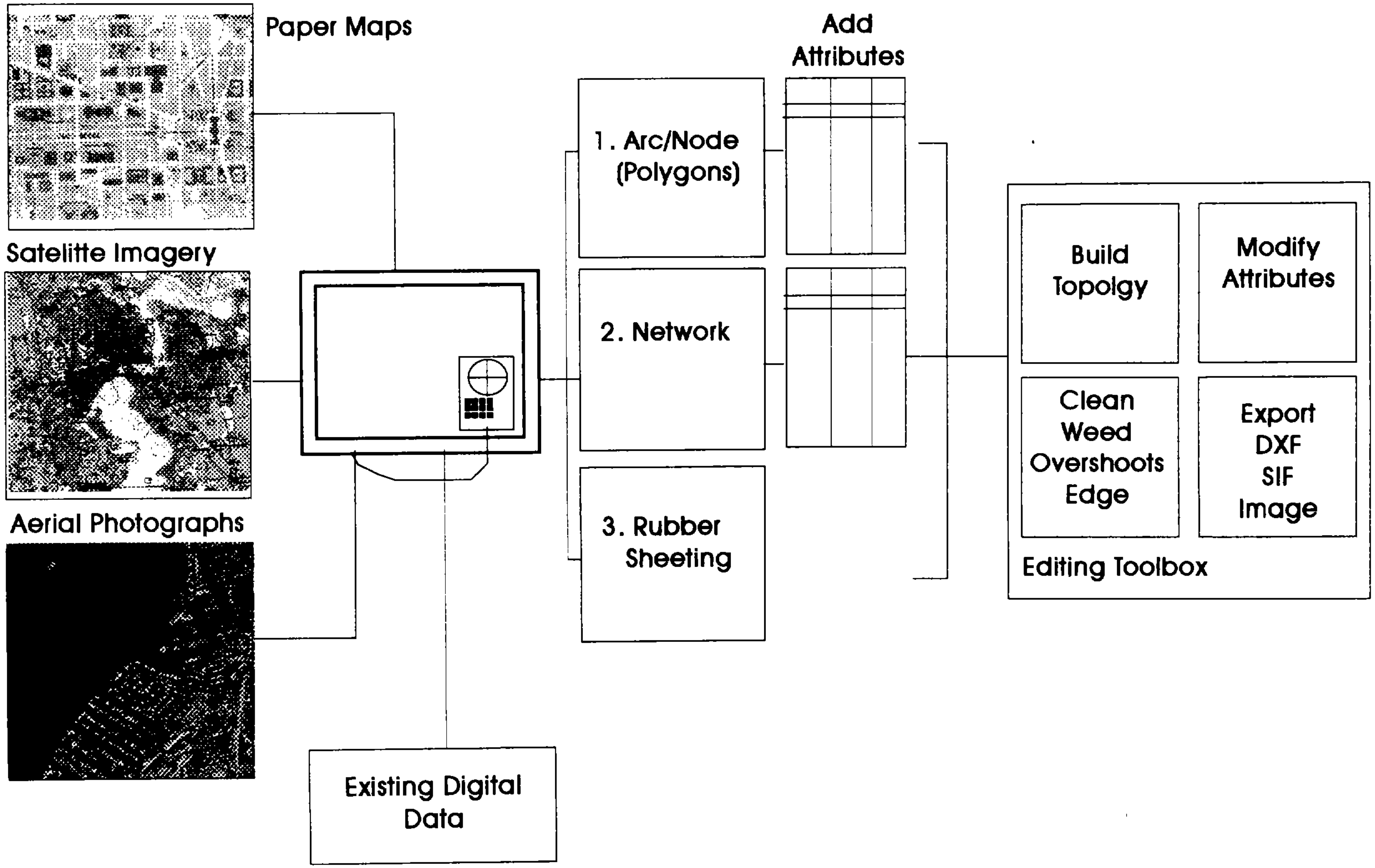
Data Sources

- Paper maps
- Aerial photographs
- Satelitte images
- Other GIS
- Global Positioning Systems
- Tabular sources, reports, exisitng computer systems

Global Data Products

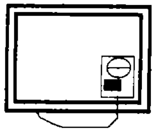
Name	Type	Resolution	Source	Status
Digital Chart of the World	Vector	1:1,000,000	US Defense Mapping Agency	Unclassified
Digital Terrain Elevation Data	Raster	100 M.	US Defense Mapping Agency	Unclassified/Classif ied
AVHRR	Raster	1 KM.	NOAA-USGS	Unclassified
Global Elevation Data	Raster	1 KM.	NOAA	Unclassified
Global Unbanization	Raster	1 KM.	NOAA	Unclassified
Conservation Areas	Vector	1:1,000,000	United Nations	Unclassified
Species Location	Point	1:1,000,000	United Nations	Unclassified
Major Vegetation				

Data Input - Digitizing



International Workshop: GIS in CZM of SIDS, Barbados '94

Data Capture Methods



- Digitizing - Typing in X,Y coordinates or tracing a line with a mouse or digitizer

- Scanning - Developed to improve the speed and efficiency associated with manual entry methods. Two methods - photographic image (grid) and laser tracing of lines on a map.

- Aerial Photography and satelitte imagery - Digital image files or scanned analog images corrected for distortion.

- Tabular data entry - Information in existing digital databases that can be georeferenced.

- Global Positioning System (GPS) - Collect on a continual basis via satelitte-earth communication.

- Image - Non-spatial images.

Application Case Study Digitizing Using Imagery as a Background

Demonstration of on-screen digitizing approach using NOAA aerial photography for South Florida. The GIS will be used to identify those areas affected by a recent hurricane.

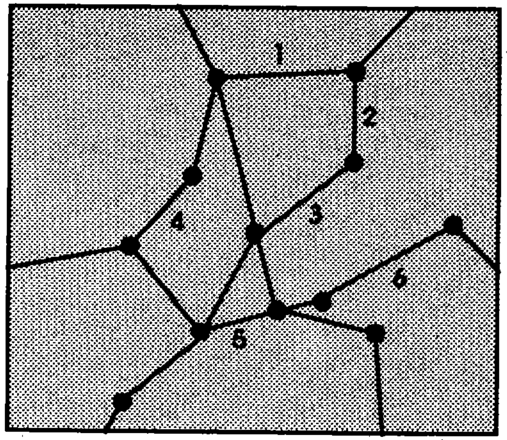
The demonstration will show the use of vector and raster data in a combined database and will show how the GIS can create both spatial and related tabular information.

Representations of Data in the GIS

Spatial	Applies to all data that can be observed in the real world and identified by geographic location.
Thematic	Identifies the attributes associated with a location.
Temporal	Measures an entity over time by comparing data collected at one point in time to another time period to quantitatively measure changes that have occured.
Spatial Data Models	Various representations of data within the GIS.

Representations of Data in the GIS

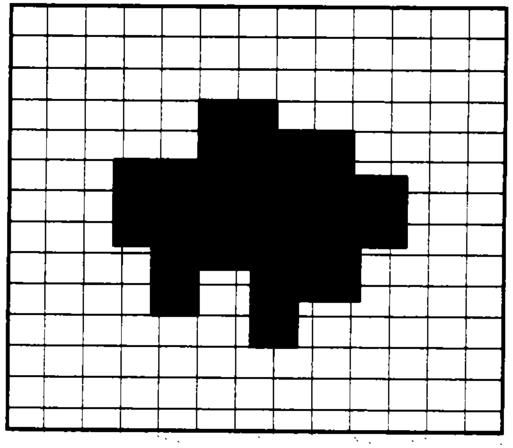
Line-Network



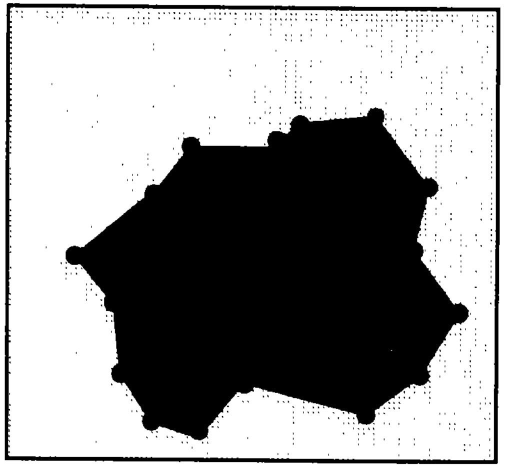
Primary Attribute Table

1	1001	GA
2	1002	BT
3	1010	MV
4	1050	
5	2000	
6	5500	
7		
8		
9		
10		

Grid



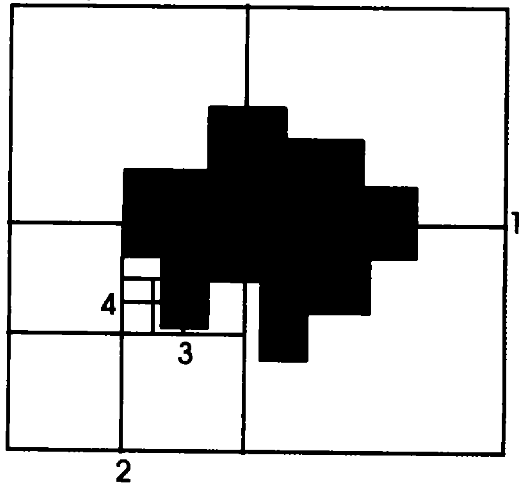
Area



Primary Attribute Table

A	LAND	53.2 10

Grid Hybrid

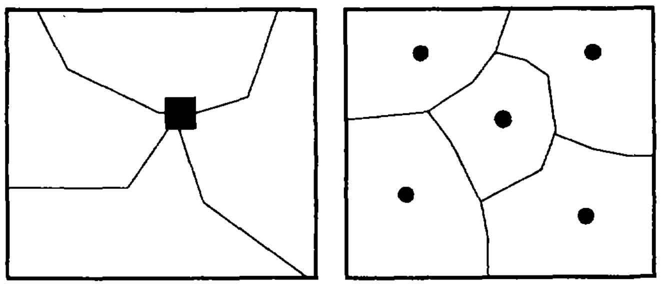


Visualization

Scale	Usually represented as a comparison of distance such as 1 cm on the image = 1 m. in reality; or as a ratio 1:1,000 where 1 cm = 1,000 cms.
Generalization	A geographic image is a representation of reality. Four main types of generalization: Simplification Classification Symolization Induction
Cartographic Process	The elements of the map, design and presentation
Accuracy	Need to continually assess the precision and real accuracy of the information used in the GIS.

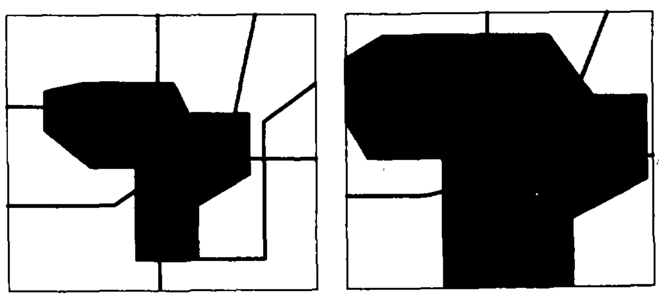
Visualization Concepts

Visualization



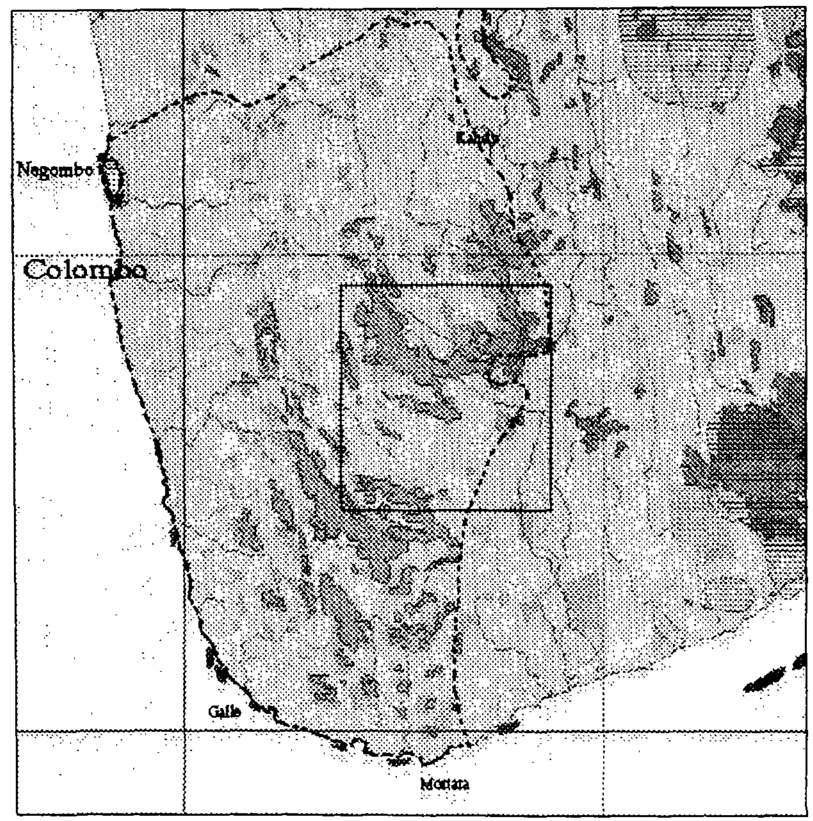
Point	Area
1 XXXXX, YYYYY	A XXXXX, YYYYY

Scale

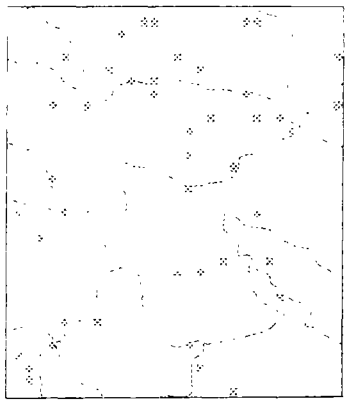


1:1,000,000 1:250,000

Generaliztion

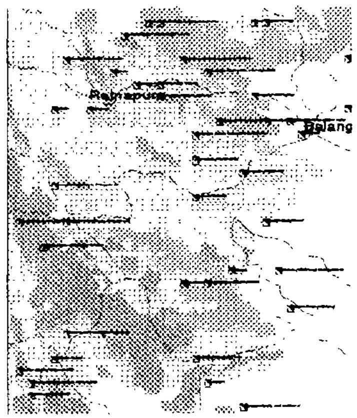


Visualization Concepts - Generalization



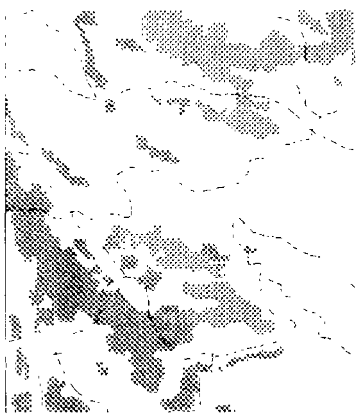
Simplification

The geographic feature is simplified to show the approximate location and character



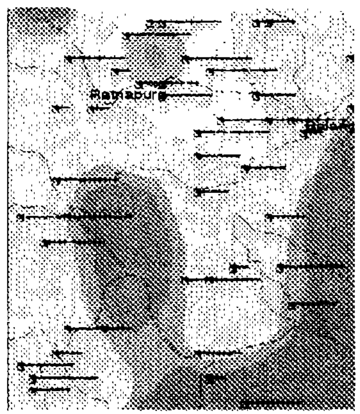
Symbolization

Presentation of simplified and classified data



Classification

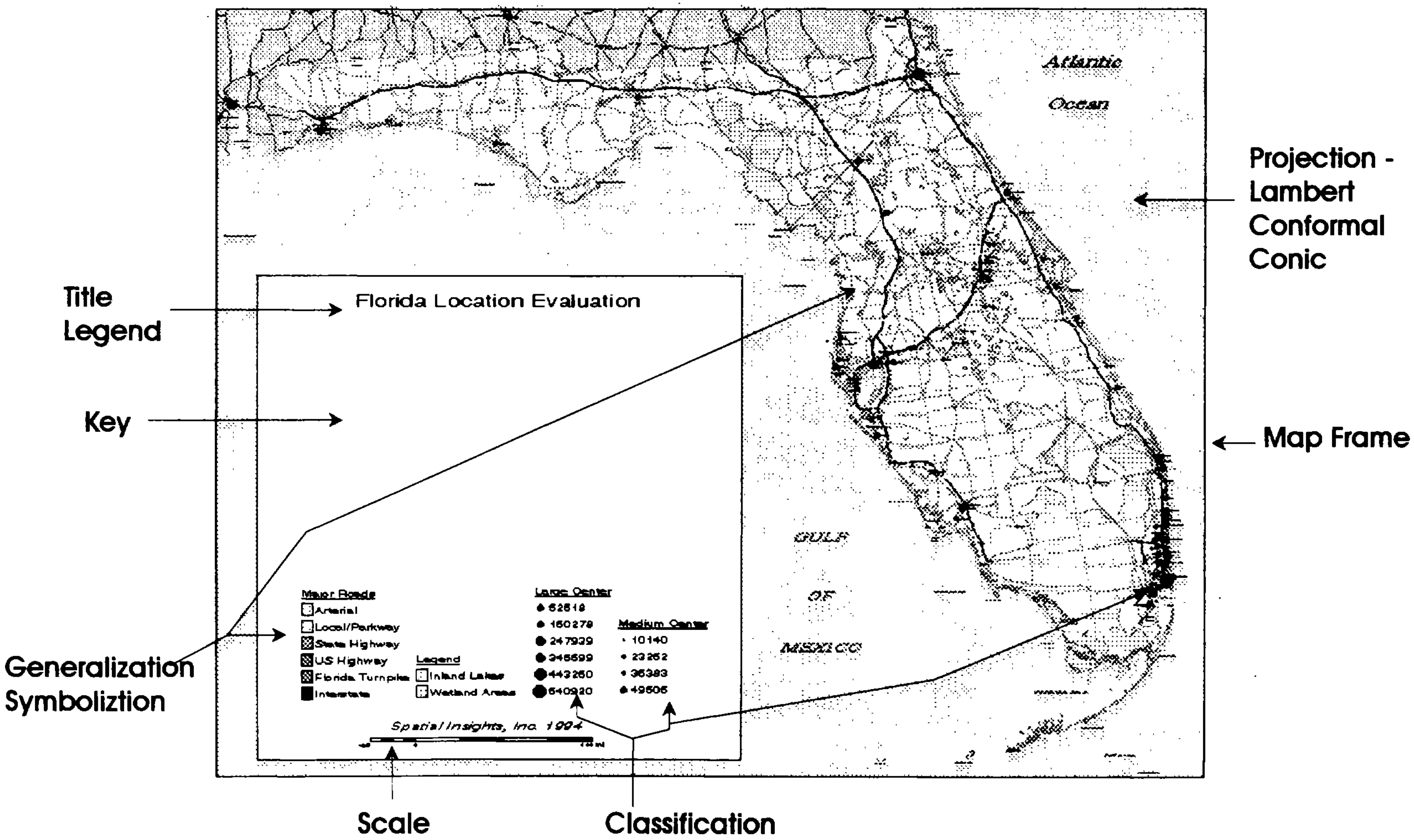
Summary and reduction of data to reveal more general patterns and trends



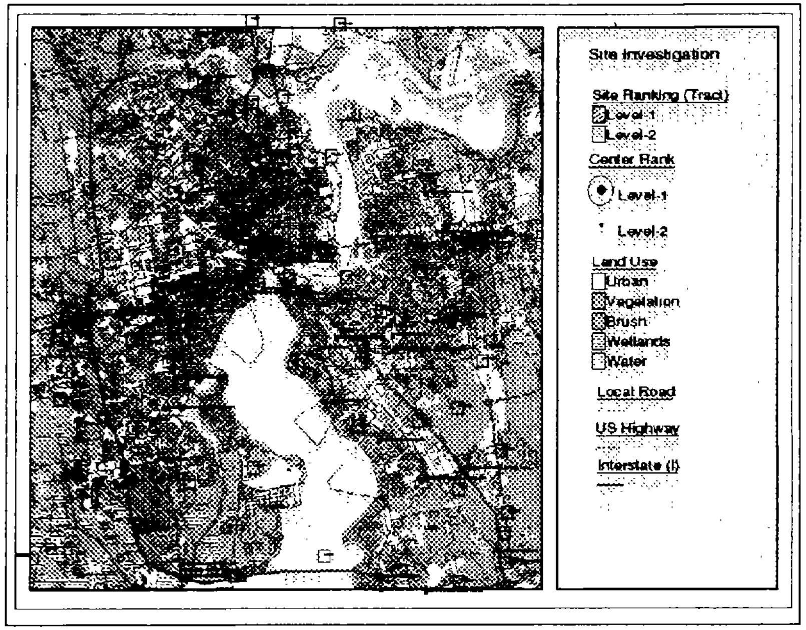
Induction

The extrapolation of information contained in a geographic image or within the data

Cartographic Processes and Map Design



Application Case Study Florida Map Composition



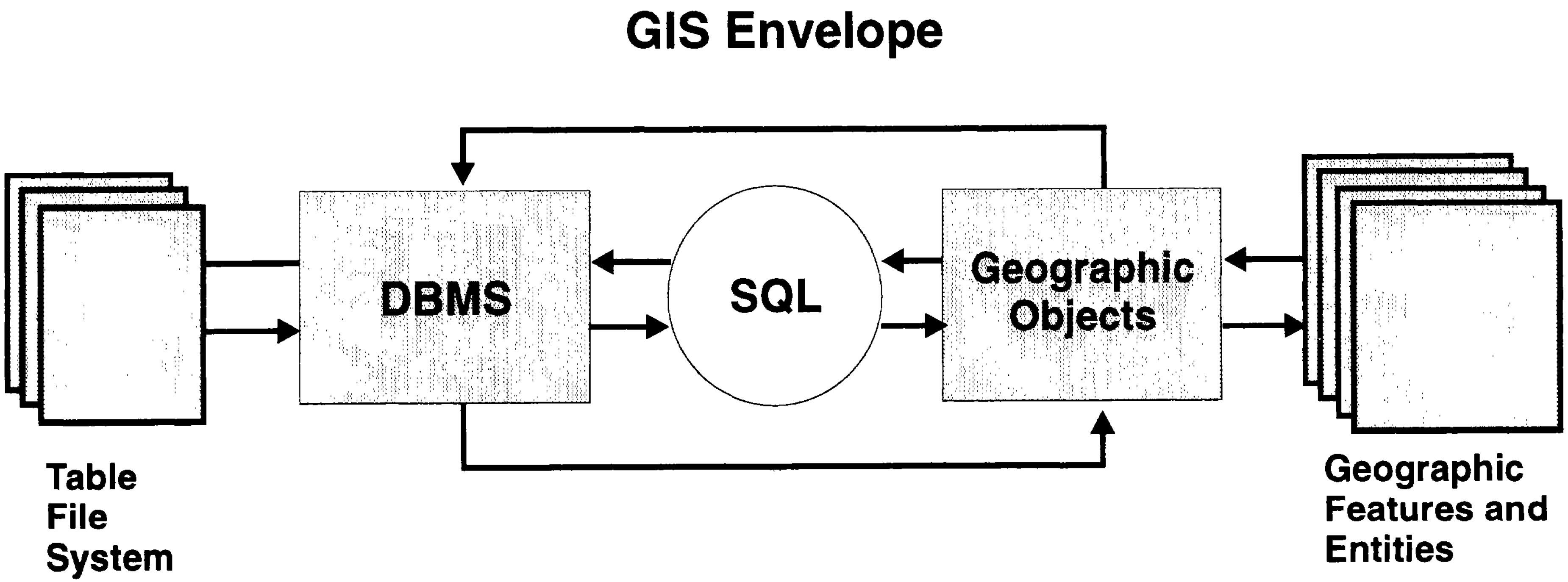
Using the FLorida database, this application will show how the GIS can be used to assemble map compositions and link those to related tabular and image databases.

The application will show how the GIS can be used for decision-support and as an integrated information system.

Data Management

- Link to database management systems
- The spatial data coverage
- Linking spatial and tabular databases
- Data management issues:
    - Security
    - Integrity
    - Filing
    - Access
    - Maintenance
    - Currency

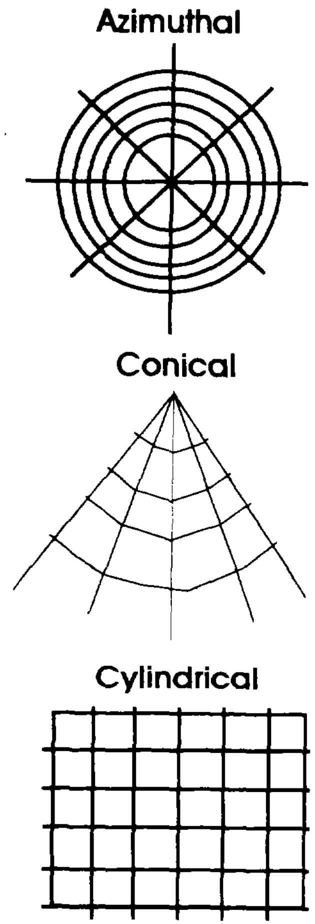
GIS and Database Management Systems



Data Processing

- Projection and coordinate systems
- Data conversion
- Data transformations
- Spatial data transformations

Projection and Coordinate Transformation



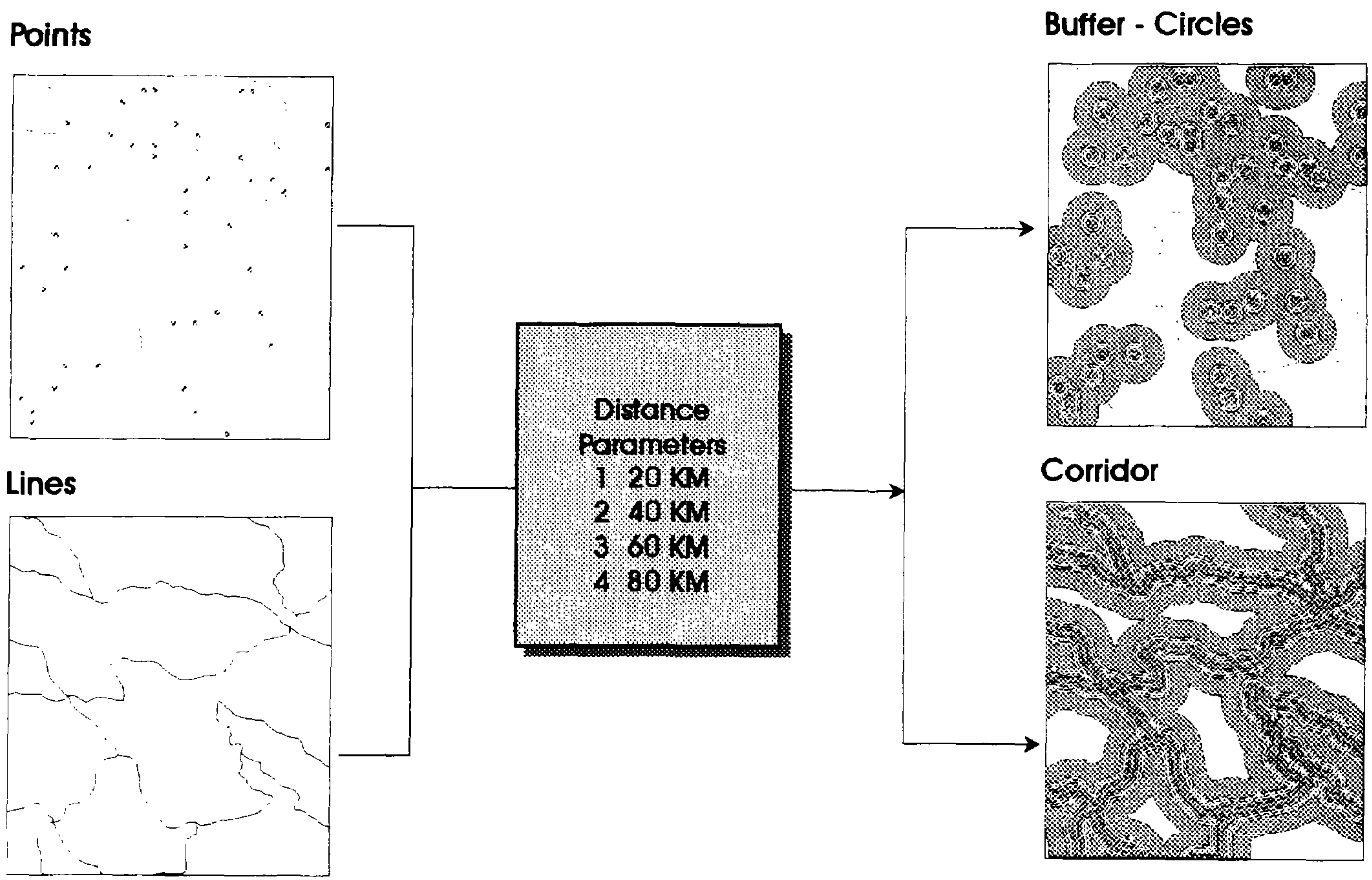
Example of Graticules for Three Major Classes of Map Projection

- Handle the transformation of the spherical earth surface onto a two-dimensional plane surface
- All GIS systems work in a two-dimensional plane
- Map projection converts real world features onto the two-dimensional plane
- Multiple options for the map projection depending on the application and scale
- The coordinate system (latitude/longitude, X/Y Grid) is the method for representing the true location in a map projection

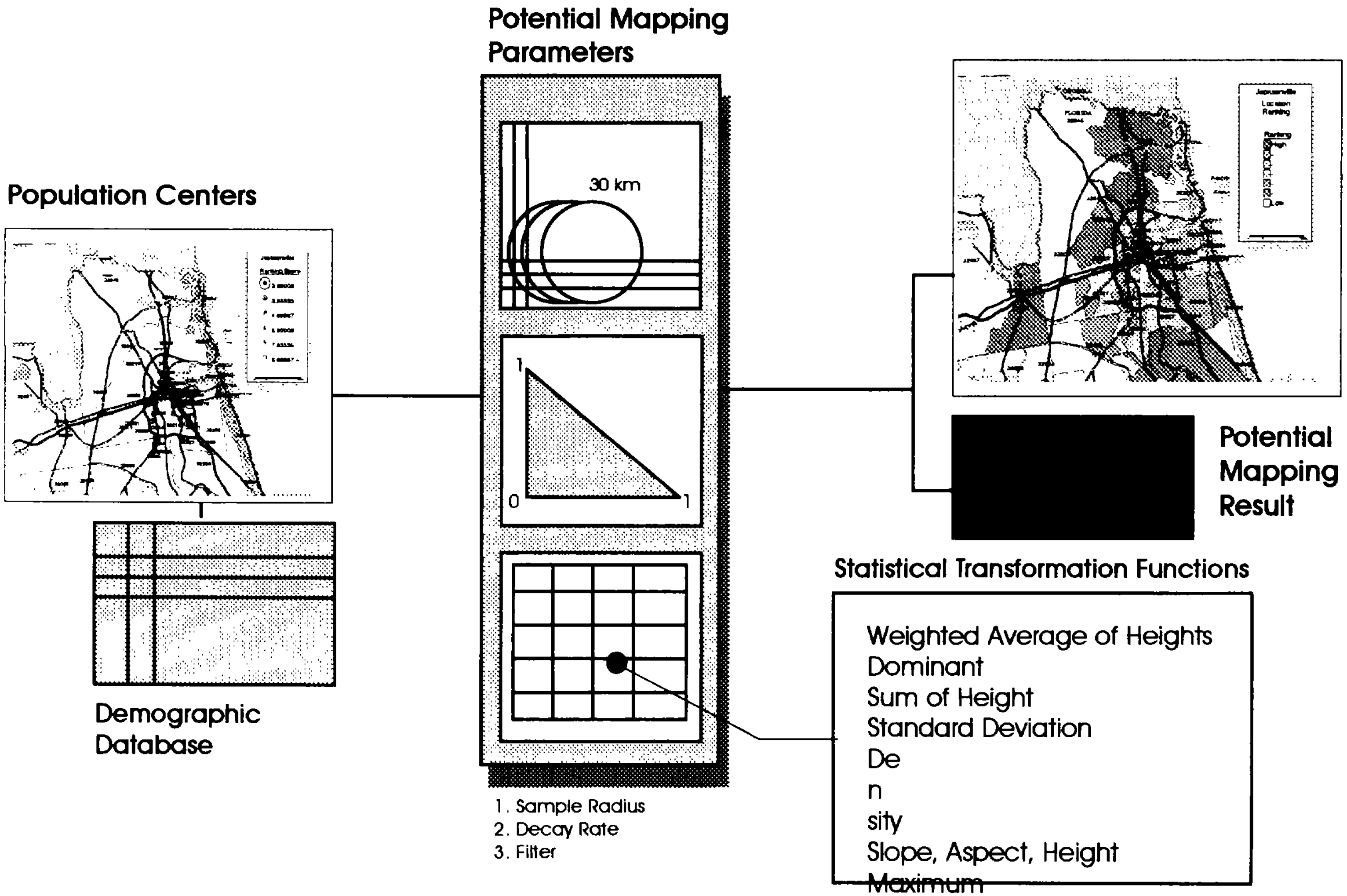
Spatial Data Transformations

	POINTS	LINES	AREAS	NETWORK	SURFACE
POINTS	Generalize	Arcs	Polygon	Intersection	Interpolate
LINES	Disolve	Generalize	Polygon	Connection	Interpolate
AREAS	Centroid	Perimeter	Generalize	Generalize	Interpolate
NETWORK	Nodes	Links	Generalize	Generalize	Interpolate
SURFACE	Grid	Borders	Polygon	Interpolate	Generalize

Spatial Data Transormation - Buffer-Corridor Generation

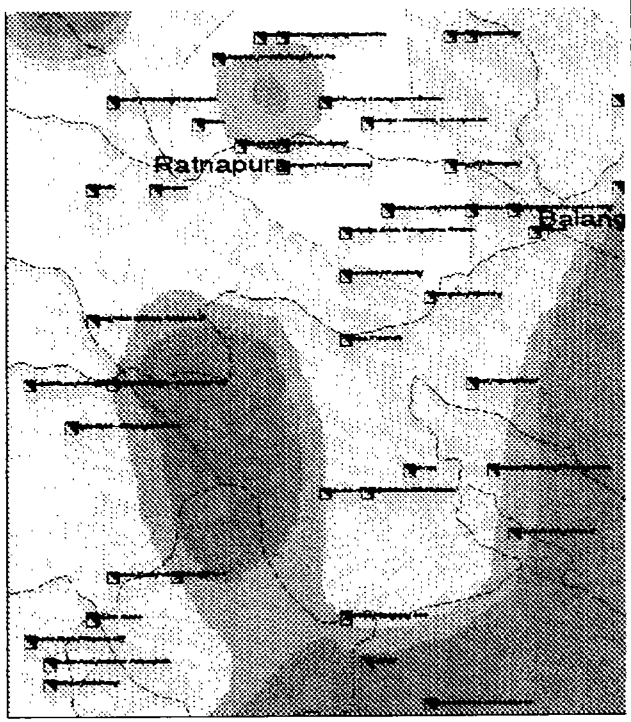


Spatial Data Transformation - Potential Mapping



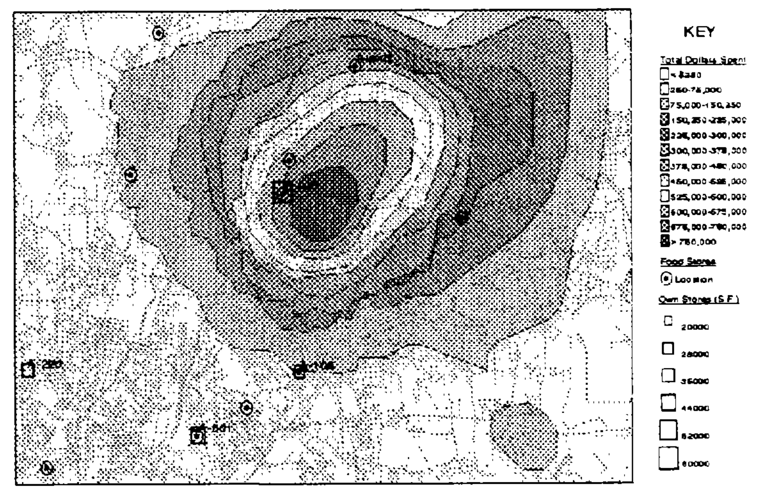
Spatial Data Transformation - Surface

Population Trend Applications



Species Distribution

Assessment of species distribution from point based sighting data



Food Store Geographic Market Assessment
Total Dollar Sales - Store A-100

Applications in demand forecasting and the assessment of population-based demographic and economic trends

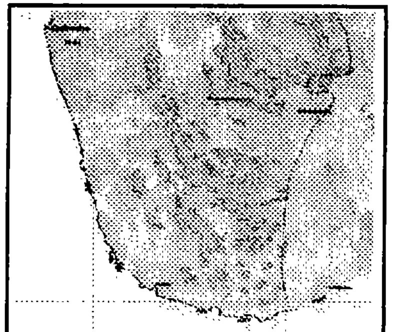
Analysis

GIS provides the capability to qualitatively and quantitatively evaluate information that has been integrated.

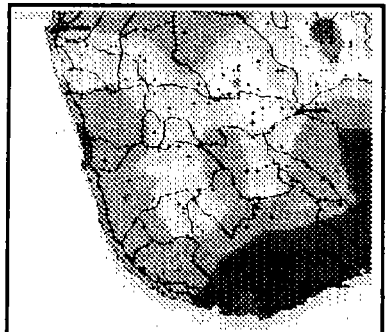
Many tools available for spatial analysis:

- Overlay
- Query
- Measure
- Proximity

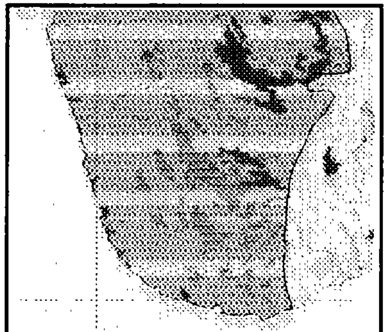
Analysis - Multi-Criteria Analysis



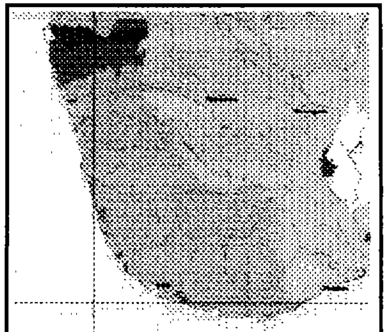
Environmentally Sensitive



Biodiversity Assessment



Forest Cover



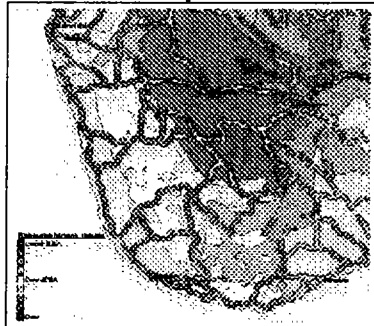
Population and Urbanism

Multi-Criteria Input

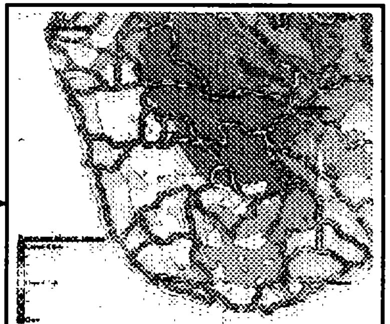
Overlay Input File

new mapid & title : combined
Combined Land Assessment (Cons.)

33.333 devurban : Urban Development Pattern
33.333 esa : Environmentally Sensitive Areas
33.333 landcap : Land Capability
:In 10 - 1: 10
:In 9 - 2: 10

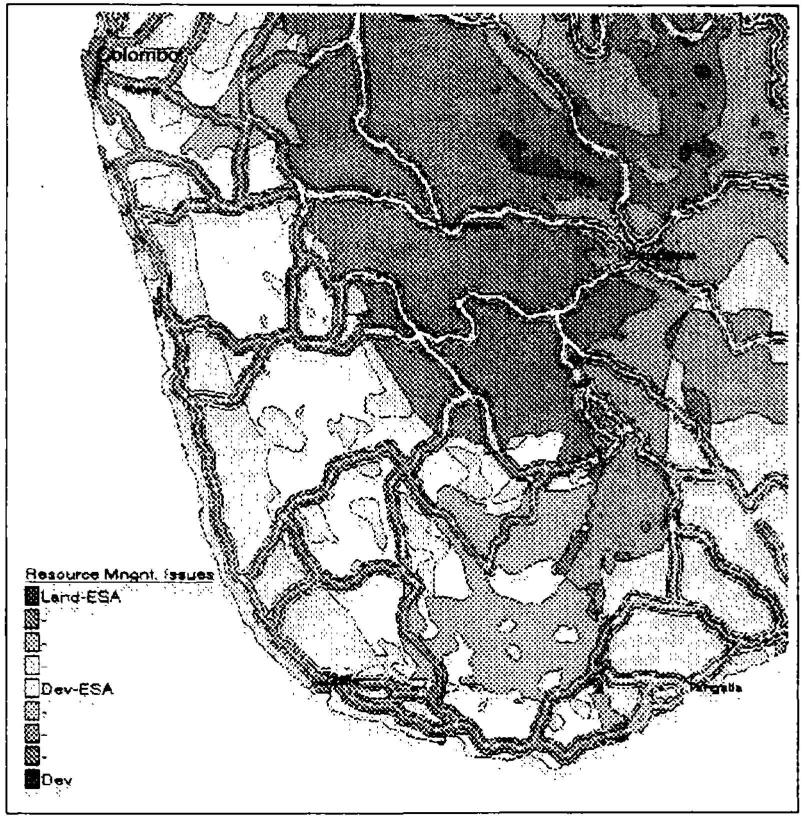


Resource Issues



Potential Conflicts

Application Case Study - Analysis

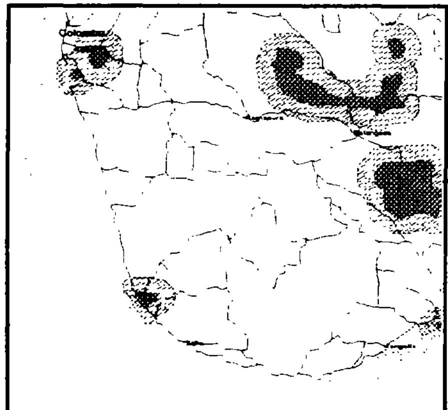


Using the Sri Lanka database, we will evaluate several resource management issues by using the overlay and area reorting functions within the GIS.

This information would eventually be incorporated into a detailed coastal zone management plan or would identify areas that require detailed scientific investigation. The case study will combine a variety of the analytical tools built into the GIS.

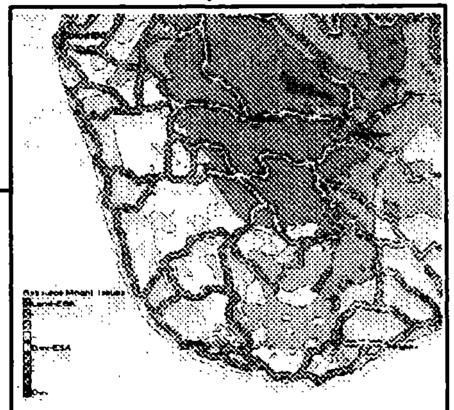
Analysis - Overlay (Two Maps)

Map 1



Wildlife Reserves - Buffer

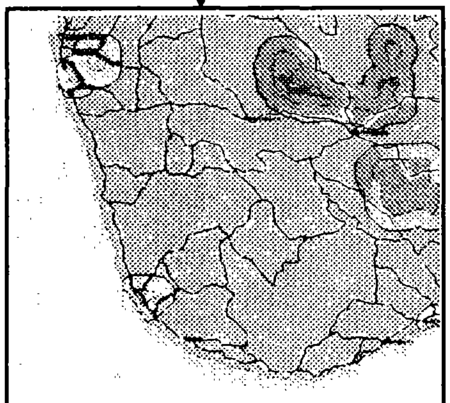
Map 2



Resource Mgmnt Issues

Overlay Criteria Table

Overlay Result



Resource Adjacent Reserves

Matrix Overlay Criteria

Row : combined - Combined Land Assessment (Cons.)
Col : widbuf - Distance to Wildlife Reserves

Window : wz Wet Zone
Cramers V 0.2427

Area (km sq)
Total %
Row %

Col %	0.5km	1 km	1.5km	5 km	Total
Dev-ESA	40.65	24.01	195.63	13.41	273.69
	1.76	1.04	8.45	0.58	11.82
HighDens	0.00	0.00	0.25	0.00	0.25
	0.00	0.00	0.01	0.00	0.01
Total	304.40	154.57	1170.12	685.87	2314.95
	13.15	6.68	50.55	29.63	

Modeling

- Advanced form of overlay analysis that allows maps to be generated from existing maps and attibute tables.

- Link to database and statistical analysis systems where GIS becomes the visualization engine

- Other modeling techniques invlove the consideration of the temporal dimension for assessing conditions that change over time

- Diffusion models can be used to track oil spill movement, model weather conditions, and consider the effects of erosion processes

GIS Data Acquisition Strategies

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Coastal Zone Management of Small Island States
Presentation: GIS Data Acquisition Strategies
Barbados, April 1994

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Who I Am

- Dr. Peter L. Grose
- Manager of NOAA's GeoCoast GIS Facility
- Phone: (in USA) 301-713-3000 (ext. 132)
- Internet: PGrose@seamail.nos.noaa.gov

What I Do

- Provide geographic data for strategic assessments of US coastal and marine resources
- Develop and distribute base geographies
- Provide specialty GIS services as needed for NOAA and state agencies
- Examples: Benthic habitats, shoreline, Coastal Assessment Framework

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Objective: Strategies for Building and Maintaining Data Layers

To give you (resource manages, decision makers, and delivery system implementors) the background and insight on strategies for geographic data development which are likely to be successful for effective and efficient Coastal Resource Management given limited budgets, personnel, and data availability.

I will use the Integrated Coastal Management paradigm rather than single resource management. (discussed in an earlier presentation: Case Studies: GIS Applications in Coastal Management).

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What I Will Talk About

- Background, basics, and tradeoffs
- Elements of a reasonable strategy
- Summary of available techniques

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Points to Ponder

Most raw data is unusable and not understandable by decisionmakers

Exact or enough information is never available- Answers are crafted from information teased from raw observed data.

Make the most of what is available

Generally almost all source data are second hand and were collected for other purposes-

Environment is evolving

Information delivery systems and their underlying data require maintenance to respond to new problems and to keep information from becoming dated or obsolete.

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A Realistic Starter System

- Two PC's (Pentium CPU, operating systems & base utilities) - $12k
- Laser printer and page size color printer - $4k
- Scanner and software (either)
  - Page size (autotracing) - $2.5k
  - Large format (autovectorizing) - $12.5k
- GIS software (Atlas*GIS or equivalent) - $3.5k
- Geographic data - $1k

Total resource cost: $25-35k, plus

4-5 person staff (GIS specialist, GIS operator, 2-3 technicians)

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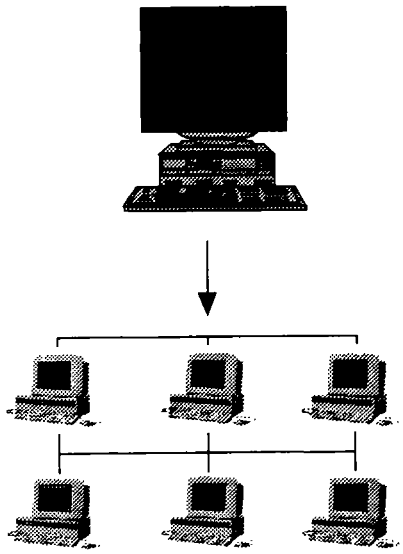
Data Preparation versus Data Delivery Systems



Data Preparation System (used by specialists)
subject of this presentation

- Generic tools
- Editing operations
- Quality control
- Data maintenance

Data Delivery System (used by managers)
subject of earlier presentation

- Presentation for easy understanding
- Ease of use
- Limited focus

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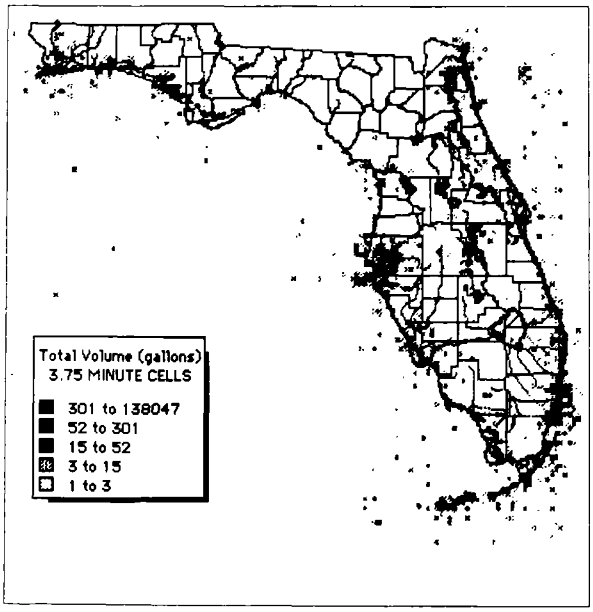
Components of a Data Layer



A map of Florida showing the distribution of oil spills from 1970 to 1990. Used to identify areas of vulnerability.

- Data attributes (what it is)
- Location (where it is)

  Points
  Vectors (arcs)
  Polygons

- Attributes and location can be managed independently

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Tradeoffs in System Design and Construction

- Wide focus/general purpose *versus* limited scope
- Use of data models *versus* what's easy and available
- Scale *versus* accuracy (more detail->more data)
- Accuracy *versus* timeliness (natural variability)

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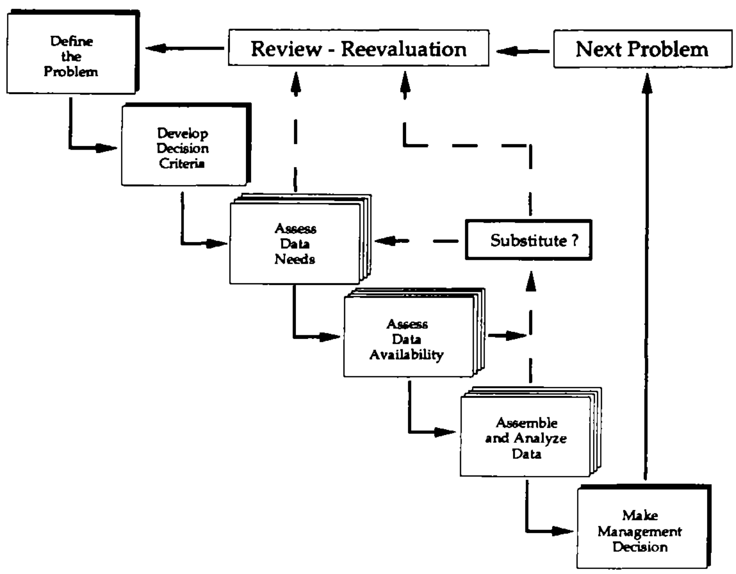
A Basic Strategy: A Process, Not a One-time Operation



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Data Development Techniques

- Adapting existing digital data sets
- Table digitizing of hard copy maps
- Scanning, heads-up digitizing and autovectorizing
- Updating from photographic or remote imagery
- Real-time digitizing using GPS

Adapting Existing Digital Data Sets (on CD-ROM)

Digital Chart of the World (DCW)
U.S. Defense Mapping Agency
Distributed by US Geological Survey

Data Source: 1-1 Million Operational Navigation Charts
Geographic features: shorelines, lakes and rivers
Thematic features: land cover, political boundaries, transportation, and others

Global Relief Data
National Oceanic and Atmospheric Administration
Distributed by National Geophysical Data Center

Data Sources: Varied
Contents: shorelines (from DCW) and global elevations for "five minute" cells

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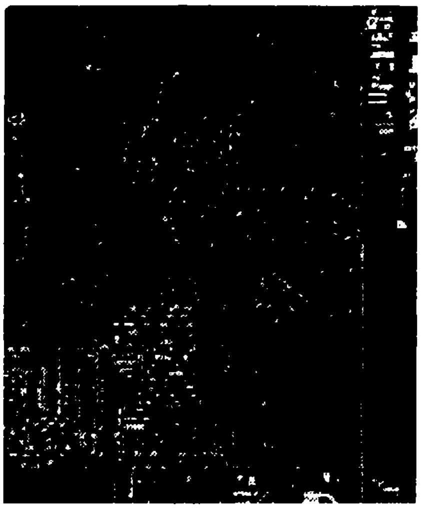
Satellite Imagery



SPOT Image: 5-10 meters resolution,
$2,600 for a 60x60 kilometer area
$950 for 7.5 minute orthophotoquad

Thematic Mapper Image: 40-80 meters resolution,
$4,050 for a 50x100 kilometer area fully corrected

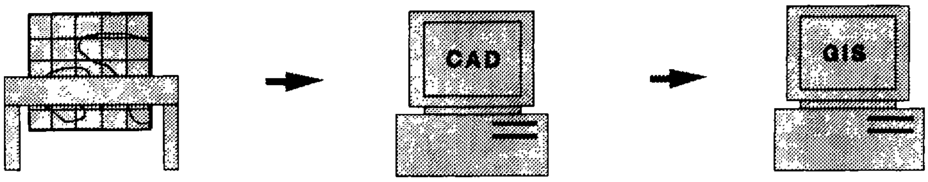
Table Digitizing of Hardcopy Maps

Image of NOAA Navigational Chart of the mouth of Chesapeake Bay.

- Pro: Inexpensive system costs
- Pro: Can be relatively fast
- Pro: Effective for point data
- Con: No real-time feedback
- Con: Expensive to verify
- Con: Difficult to correct errors

Scanning, Heads-Up Digitizing, and Autovectorizing

Scan | Capture | Georeference



Scan
- Prescan Map
- Set Threshold
- Scan Map

Capture
- Capture Graticule
- Analyze Graticule
- Evaluate Graticule
- Capture points, lines, and areas
- Attribute Data
- Quality Control

Georeference
- Translate Files
- Construct Coverages
- Georeference, Project, Rubbersheet, and Convert to NAD'83
- Build Mosaic
- Export and Archive

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Scanning, Heads-Up Digitizing, and Autovectorizing

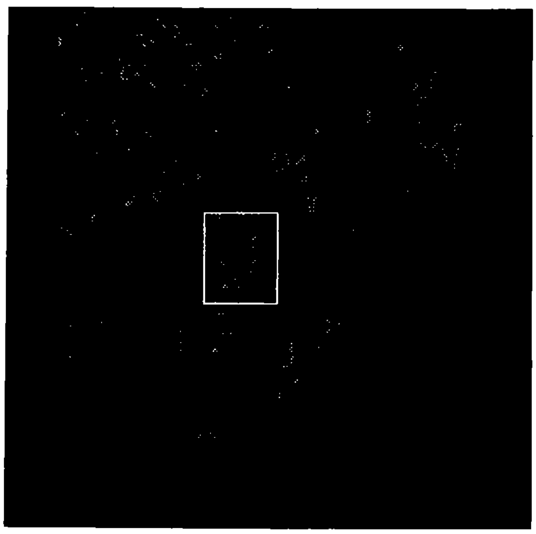
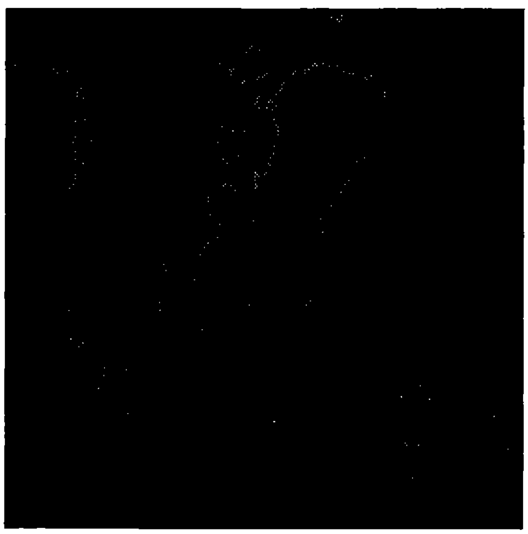


Image of 1-20,000 scanned map of coastal Maine after capture of target information



Zoom showing detail for verification

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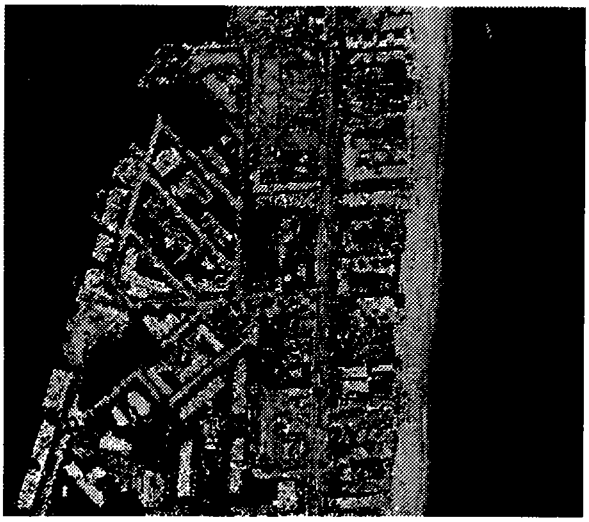
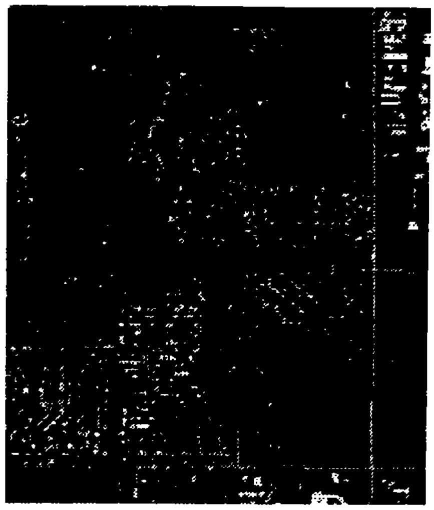
Updating from Photographic or Remote Imagery



Precision aerial photograph of south Florida beach front.
Detail to less than a meter



SPOT image of urban area.
Detail to 5-10 meters.

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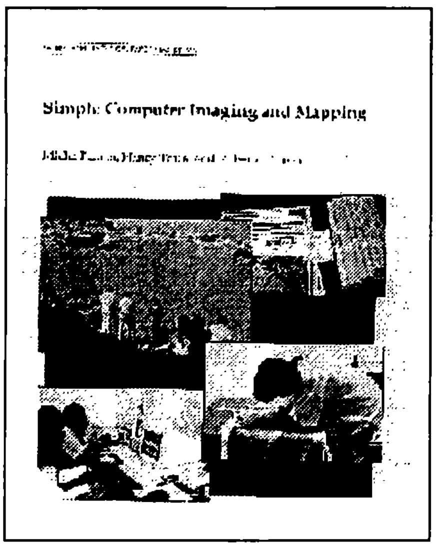
Simple Computer Imaging and Mapping



- Entry level operations
- Step-by-step primer
- World Bank Technical Paper 206
- ISBN 0-8213-2467-5, May 1993

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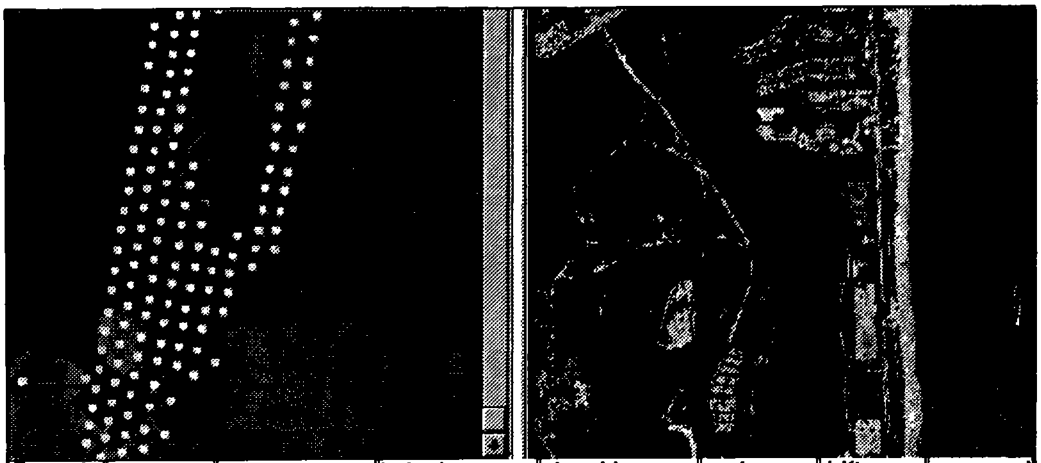
Organizing Imagery



Record	morton	longitud	latitude	photoid	scale	drift	cmpsread
114	0d713049	-80.342430	25.437250	8218	15000	-13	205
115	0d715b2d	-80.314987	25.435080	8300	15000	-13	205
116	0d719e88	-80.337967	25.458830	8216	15000	-13	205
117	0d721dc3	-80.383911	25.478830	8074	15000	-14	203

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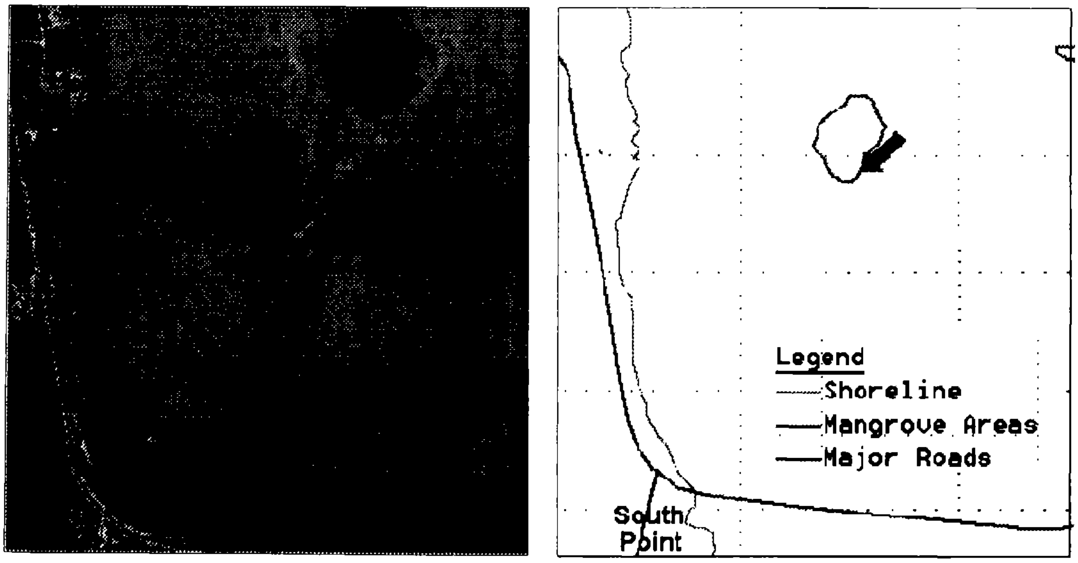
Heads-Up Tracing



Tracing of mangrove area (arrow) on photo updates map using flat earth approximation.

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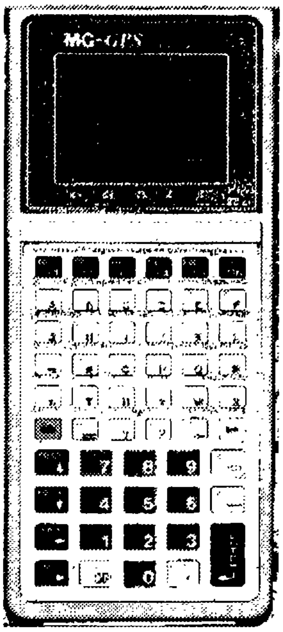
Real-Time Digitizing Using GPS



- Rugged field tool
- Has internal storage
- Data downloads to GIS
- 100 meter accuracy (single reading)
- 1 to 5 meter accuracy differential mode
- $700-4,000

Image of hand held GPS system.
(Corvallis MicroTechnology, Inc.)

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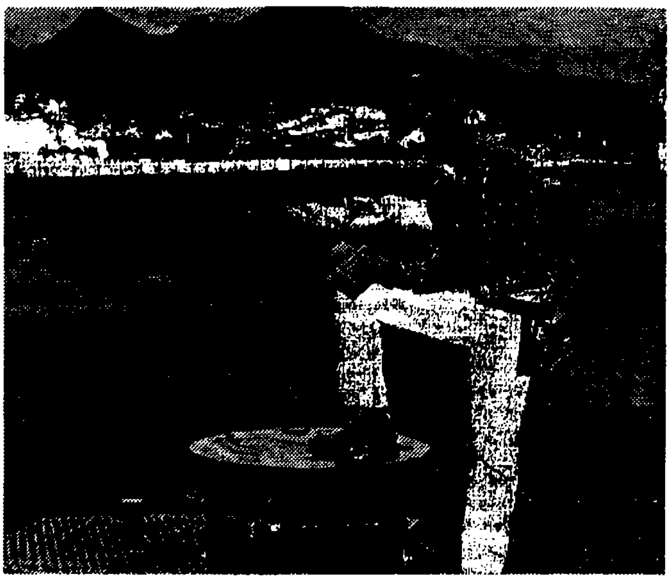
Uses of GPS Digitizing



- Locate and attribute point sites
- Trace roads
- Boundary must be evident at the site
- Requires being on site
- Difficult confirmation

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A Few Words of Caution

Resource commitment

Most effort and dollars are devoted to data collection, editing (quality control), and synthesizing data into usable information

Look before you leap

Careful design and focus towards a particular set of decisions will reduce costs

Plan the layers

Each information layer in the system needs a specific plan for its generation and maintenance.

Consider the options

Alternatives exist and should be considered as part of the design. Beware of techniques that become resource traps.

REMOTE SENSING AND COASTAL ZONE DATA ACQUISITION AND ANALYSIS

BY

BOB RYERSON AND CATHRYN BJERKELUND

Slide 1:

Remote Sensing and Coastal Zone Data Acquisition and Analysis

Bob Ryerson and Cathryn Bjerkelund
Canada Centre for Remote Sensing
Natural Resources Canada
Ottawa, Canada

Slide 2:

Remote Sensing is the collection of natural resource information using imagery acquired from aircraft or spacecraft

Slide 3:

We are looking from above - the implications for use

Phenomena must be:

* understood
* spatially manifested at the image scale
* verifiable
* "visible"

Slide 4:

RS uses reflected or emitted EM radiation using either passive or active sensors

Slide 5:

Interpretation Criteria

* spectral reflectance (colour/tone/brightness)
* shape
* texture
* pattern
* context/juxtaposition
* shadow
* size

..... all brought together by the interpreter's understanding of spatial relationships in the discipline and region being studied

Slide 6:

Why do we use remote sensing....

* to obtain information for hostile or hard to reach areas
* quickly get similar information over a large area
* less costly than traditional field-based methods
* to have a permanent (image) record
* to obtain a quantitative record

Slide 7:

"Two factors tell us that remote sensing will be more widely used in the future. The public purse strings are tightening. At the same time the publics demand for environmental information appears to be insatiable. Remote Sensing is the only way out."

Comment at a public forum on the importance of remote sensing made at the ASPRS, Washington, D.C. March, 1984.

Slide 8:

Remote sensing - tools of the trade:

Platforms

* drones/pilotless aircraft
* balloons
* aircraft-light
  -survey
* satellites
* manned spacecraft

Slide 9:

Remote sensing - tools of the trade:

Sensors

* cameras (Photo and video)
* scanners
* lasers
* radars

Slide 10:

Remote sensing - tools of the trade:

Analysis

* magnifiers
* projection tools
* image processing software
* geographic information systems
* skilled people with a natural resource/environmental background

Slide 11:

A variety of sensors and products are available

Satellite imagery
- SPOT Pan & MSS,
- Landsat MSS & TM
- NOAA
- SEAWIFS
- Worldview, etc. (1995 and beyond)
- ERS-1
- MOS-1
- JERS-1

Slide 12:

Satellite Imagery

- large area coverage
- low cost for large areas
- 10 to 30 metre resolution
- not generally suitable for local detail
- good for overview
- land cover, vegetation condition, water bodies, forest clear cuts, roads, topographic and other map updates

Slide 13:

Airborne Sensors

- B&W air photos
- colour air photos
- colour IR
- video cameras
- digital cameras
- IR scanner
- MSS
- radar
- laser profilers
- lidar bathymeters
- low light level TV

Slide 14:

Remote Sensing Applications

* environment
* geology
* engineering
* forestry
* agriculture
* oceanography
* hydrology
* cartography
* wildlife habitat
* urban/regional planning
* soil conservation
* disaster assessment/mitigation
* international development

Slide 15:

Coastal Applications

* Base geography - shoreline
* Base geography - topography/bathymetry
* Assessments of watersheds
* Resource locations (beaches, shell beds, etc)
* Demographics (population/supporting sampling)
* Land cover -> land use
* Discharges
* Transportation systems
* Ocean circulation and productivity
* Disaster assessment/mitigation
* Sediment levels
* Shipping activities

Slide 16:

Photographic, Video Cameras and Digital MSS

* Water quality and pollution monitoring
* Vegetation damage due to chemical or other toxic waste effects
* Land use mapping and surface activity mapping such as strip mining and industrial damage
* Urban/shoreline cadastral mapping
* Aquaculture studies
* Seaweed mapping

Slide 17:

Infrared Line Scanning Devices

* Thermal plume discharges to surrounding water bodies
* Forest fire mapping and detection
* Underground fires/heat sources
* Damaged subsurface pipelines and sewer systems
* Aquifer and dam leakage
* Oil spill detection and mapping
* Frost pocket mapping/heat loss from buildings (in north)
* Sea weed mapping

Slide 18:

Synthetic Aperture Radars

* Oil spills on water
* Flood Mapping
* Effects of landslides, earthquakes and erosion
* Forest depletion (?)
* Sea ice mapping * Human activity
  (eg. strip mining and land use mapping - bananas, etc)
* Aquaculture
* Shoreline mapping/coastal erosion
* shipping detection

Slide 19:

A role for Remote sensing in local environmental monitoring:

- historical examination possible
- revisit
- permanent record

Slide 20:

The benefits of airborne MSS

- digital
- GIS compatible
- calibration
- revisit

Slide 21:

A Look to the Future

- more companies offering products and services
- higher resolution satellite imagery available
- radar imagery more available
- more attention to coastal zones
- GIS/RS integration will be routine
- lower costs of analysis systems
- return to more simple solutions
- airborne digital costs will drop

**GIS in Coastal Zone Management:
Barbados' Experience**

by

Kenneth Atherley

Integrated CZM started with the 1983-84 Prefeasibility Study in Coastal Conservation:

(i) Diagnosis of problems
(ii) Possible solutions suggested
(iii) Initiate monitoring of BEACHES/REEFS

1983-Present:

Coastal Conservation Unit retained to perform basic functions, e.g.
(a) Continue monitoring
(b) Advice on coastal development
(c) Project preparation work

1991-1995:

Technical Feasibility Study (see table 1)

(a) Study processes and trends by expanded and concentrated monitoring.

(b) Develop CZM plan for island

(c) Design and test certain physical engineering projects

**BASIC COMPOSITION
OF CZM PLAN**

A: Map-based information on coastal and marine resources, processes and activities

B: Engineering design standards

C: EIA protocol

D: Water quality standards

E: Shoreline monitoring guidelines

F: Watershed monitoring guidelines

G: Shoreline management guidelines

H: Cost-recovery options

I: Public information and participation

J: Legislative arrangements

K: Institutional mechanisms

(Many of the above information can be presented on a stretch by stretch, region specific or point-to-point basis on the GIS).

Table 1: Main Tasks in Technical Feasibility Study

COASTAL ENGINEERING	TERRESTRIAL WATER	MARINE WATER AND EIA	SOCIO-ECONOMICS	PILOT PROJECTS
1. Data acquisition * wind, wave, current, tide, sediments, bathymetry 2. Shoreline mapping 3. Wave climate determination * Deep and nearshore * West & South coasts 4. Tides & Water levels 5. Coastal water circulation 6. Shoreline characterization * Sediment pathways, transport rates * Shoreline predictions * Sand nourishment resources 7. Beach/coast improvement techniques * Structural * Non-structural * Drainage stabilization * Pilot project design 8. Pilot project monitoring 9. Maintenance practices 10. Pre-investment designs 11. CZM plan	1. Data acquisition * Sewage, Fertilizers, Pesticides, Hydrogeology, Lab capabilities, Ranking pollution Impacts 2. Measurement programme * Surface flow * Rainfall * Subsurface flow * Water quality sampling 3. Analysis & modelling 4. Control options (evaluation) * Agriculture management * Sewage collection * Storm water management * Education * Legislation 5. CZM plan	1. Data acquisition * Sewage, Fertilizers, Pesticides, lab capabilities * Reef & Seagrass monitoring * Vegetation identification 2. Marine ecosystem threshold 3. Environmental impact analysis pilot project 4. General environmental scoping 5. CZM plan	1. Develop Cost-benefit analysis model 2. Tourism & recreation * Demand/Supply * Beach requirement 3. Land use issues * Regulations * Zoning * Open access * Coastal structures & implications 4. Analysis of / land use control 5. Public participation programmes 6. CZM plan	1. Evaluation of engineering options relative to coastal problems 2. Select main options for further experimentation 3. Design pilot projects * Beach face dewatering * Beach rock removal * Submerged breakwaters * Berm-type revetment * Beach nourishment * Reef rubble clearing 4. Modification of existing structures 5. CZM plan

(Atherley, Smith and Nurse)

HOW TO HANDLE THE MASS OF DATA

We are simply dealing with large amounts of data from numerous locations.

The data has to be:

- analyzed for trends, patterns and relationships;
- Stored for later retrieval and analyses; and
- Prepared and processed on spreadsheets, databases, and specific oceanographic and engineering programmes.

GIS was conceived as being useful for:

(i) combining the temporal and spatial database;
(ii) seeing various permutations of associations; and
(iii) assessing the potential for quantitative modelling.

FEATURES OF GIS SYSTEM

AUTOCAD: International drawing tool used by engineers, architects and planners.

ARCAD: GIS builder running through Autocad. Builds spatial coverages: points, lines, polygons etc (see page 4).

ARCVIEW: Windows-based GIS presentation and management package, to query database, view and plot maps (see pages 5 and 6).

HARDWARE: 486 50 Mhz, 16mb RAM
300MB Hard drive
Plotter and digitizing table

GIS ISSUES FOR STARTERS

(i) Georeferencing standards and map scales

(ii) Vector and raster models

(iii) Consider your applications

(a) Store data
(b) New perspectives/permutations
(c) Development control and monitoring trends

(iv) Lineage of data and Quality control

(v) Inter-institutional support, especially in Small Island States

(a) Common ground
(b) General standards
(c) Training
(d) Avoiding overlaps
(e) Cooperation between private and public sectors
(f) Who owns the data

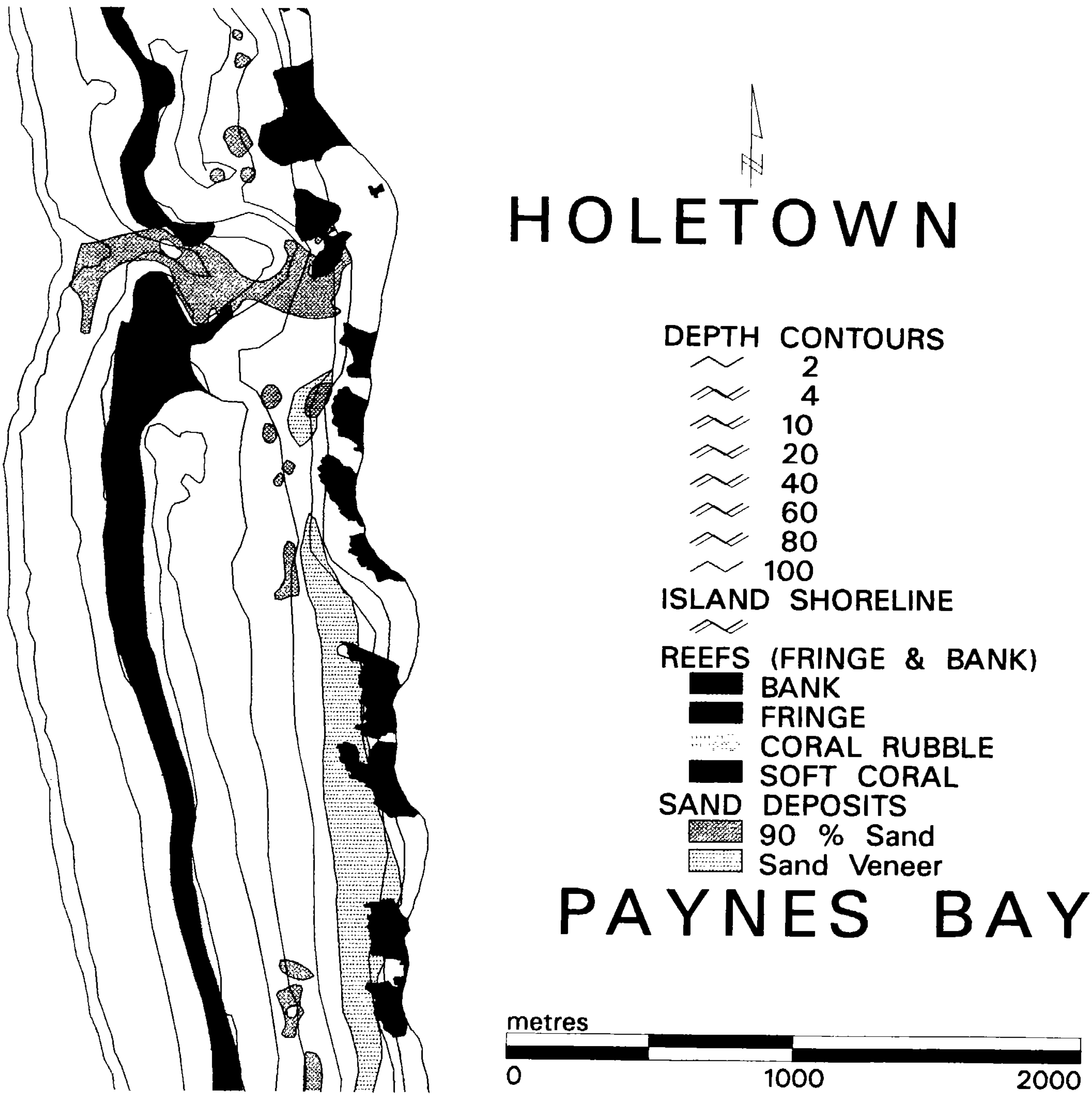
Examples of CZM Application in Barbados

Some examples of CZM Applications in Barbados can now be illustrated:

(i) Flood Hazard Management
(ii) Beach access Planning
(iii) Coastal Processes: beach changes

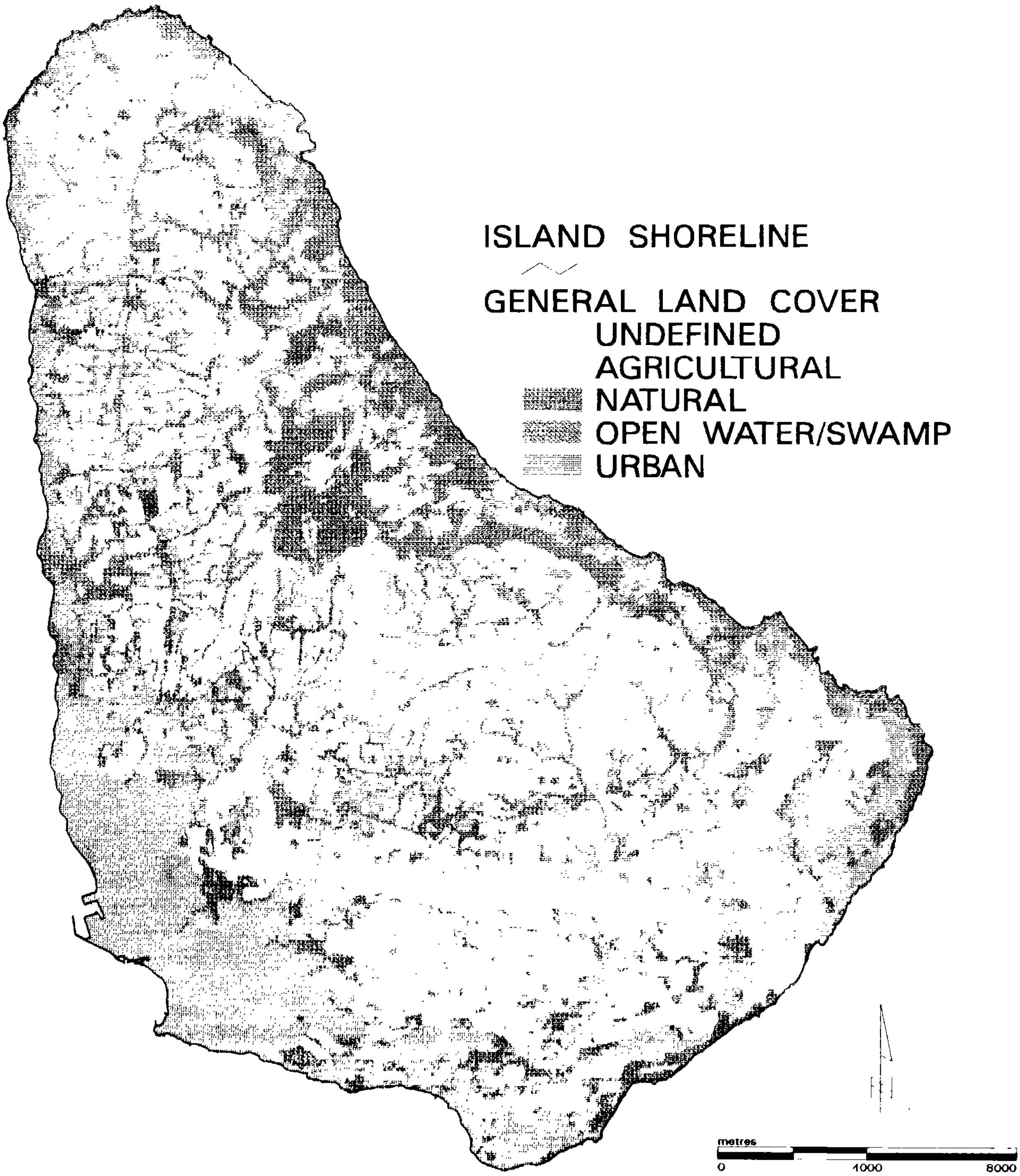
No	Coverage name	Geographic Feature	Respresentation	Attribute
	BATHYM	Depth contours	Line	Y
	BCHPRF2	Beach profile locations	Point	Y
	CURR_REC	BNG grid lines	Line	Y
	FOURSITE	Ocean bottom mapping	Polygon	Y
	MNTR_SC	Sub-catchments	Polygon	Y
	NRSHRNOD	Nearshore nodes(waves)	Point	Y
	PBEACH	Beach areas	Polygon	N
	REACH	Shoreline classification	Line	Y
	SANDBEDS	Sand bodies	Polygon	Y
	WAVEGRID	Wave refraction grids	Polygon	N
	WAVEREC	Wave recorder locations	Point	Y
	CST_STRU	Coastal structures	Point	N
	FLOOD	Flood maps for 100yr event	Polygon	Y
	OBGEO	Ocean bed geology	Polygon	Y
	CZONES	Water control zones	Polygon	Y
	GWUCATCH	Ground water catchments	Polygon	Y
	MGWA	Major groundwater abstractions	Point	Y
	RAINCONT	Annual rainfall contours	Line	Y
	RAINSTN	Rain gauge stations	Point	Y
	RIVER	River network	Line	N
	SOILS	Soil associations	Polygon	Y
	TERRA_WQ	Terrestrial water quality sites	Point	Y
	ISLND_RD	Island Road Network	Line	N
	LANDCOV	Land cover (4 classes)	Polygon	Y
	LANDUSE	Land use	Polygon	Y
	LANDVAL	Land Parcels on coast	Polygon	Y
	REEFS	Fringing and bank reefs	Polygon	Y

Sediment Distribution and Reefs on the Barbados West Coast



Coastal Conservation Unit (1994)

Generalised Landuse Map of Barbados



Coastal Conservation Unit (1994)

Bear in mind that the analyses will mostly be related to the preparation of the CZM plan and obviously will focus on finding solutions, tracing patterns and associations and for simply producing maps which look good.

PRACTICAL APPLICATIONS

Impacts of flooding on properties and the highway.

One of the challenges to CZM planning has to do with planning for emergency events. Hurricane events which drive storm surges have been known to flood important real estate and impose serious damage to coastal properties. GIS on Maps can show the impacts from a 1 in 100 year storm event on the coast of Barbados, based on separate computer analyses on reached based bathymetry and surface typology. Maps can show how the coastal roads and buildings would be affected, including hotels and critical facilities such as electrical generating plants, and oil storage and refining facilities.

The analysis is being extended to include an assessment of the value of properties that are at risk and recommendations will be made with respect to emergency response mechanisms:

(i) Relocation of the fire and police stations out of a zone.
(ii) Warning to hoteliers that they should take their guests to a safer zone during an event of similar magnitude.
(iii) Pre-planning of likely access routes during these events.
(iv) Building codes for properties in the area.

This example demonstrates the GIS' relevance to **emergency preparedness and hazards planning.**

Beach Access Planning

The provision of safe and comfortable beach accesses for the public is one of the expectations that people have of their government. The drive to develop the tourist industry in the island has reduced access space. A GIS map could show variation among the 68 beach accesses on the west and south coasts of the island, some with vehicular, lifeguard and changing facilities. On the south coast, while there are a lot of accesses (4/1km coastline on average), not many have the range of basic services to make bathing safe, comfortable.

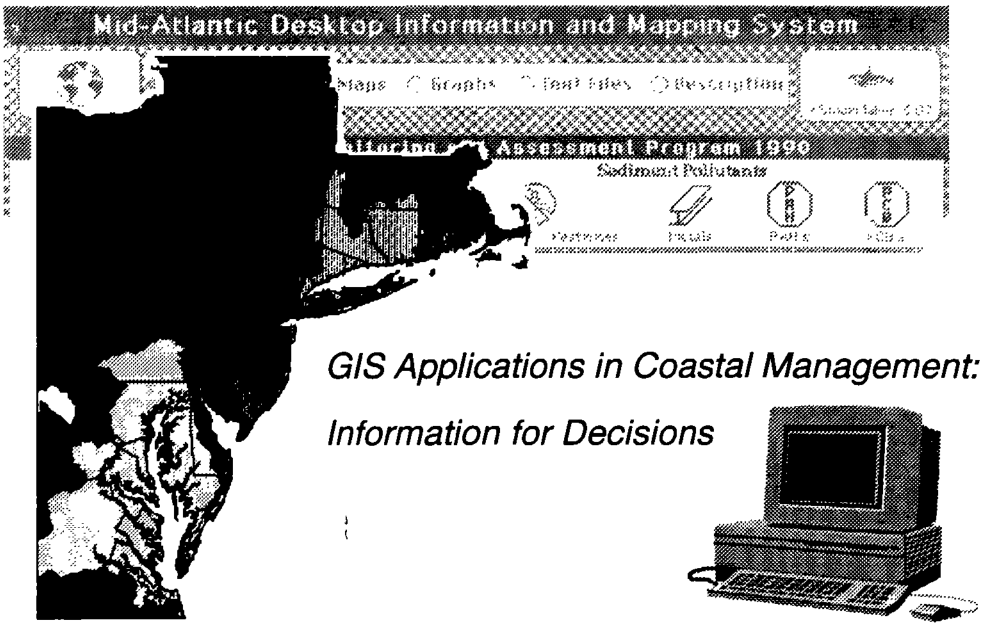
The analysis is being used to make recommendations on the need for certain facilities along the coastline. This coverage will also be related to water quality and reef quality to ensure that people are encouraged to use healthy environments. Here the GIS can show its worth in **physical planning.**

Beach Changes

The CCU has been able to input point attribute data for over 100 beach profile monitoring sites in the island. Attribute data attached to profile locations include information on when the profile started, the frequency of monitoring, raw data for each profile period (particularly beach width, volume and distance to the step), and regression coefficients (calculated in separate spreadsheet) of the beach change trend over the period for which data are available.

GIS maps can show trends for parts of the coast of Barbados coded as accreting and eroding sites. Such maps can show that a problem exists on the central part of the west coast, whereas most of the south coast is accreting and obviously in better condition. The reason, we believe, has to do with the fact that there is much more sand offshore of the south coast than off the west coast. Focussing on one of the west coast trouble spots, we can see the specific sites that are eroding, and also notice the offshore canyon which appears to be acting as a shute for removing sand from the already depleted nearshore.

Obviously, therefore, erosion prevention solutions and the application of engineering technologies to build beaches in this area will have to look at the possibility of pumping sand to the beach and the nearshore and blocking the pathway to the canyon through which sand is lost. The GIS in this case is a useful **research and engineering design tool.**



GIS Applications in Coastal Management:

Information for Decisions

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Coastal Zone Management of Small Island States
Presentation: Information for Decisions
Barbados, April 1994

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Who I Am

- Dr. Peter L. Grose
- Manager of NOAA's GeoCoast GIS Facility
- Phone: (in USA) 301-713-3000 (ext. 168)
- Internet: PGrose@seamail.nos.noaa.gov

What I Do

- Provide geographic data for strategic assessments of US coastal and marine resources
- Develop and distribute base geographies
- Provide specialty GIS services as needed for NOAA and state agencies
- Examples: Benthic habitats, shoreline, Coastal Assessment Framework

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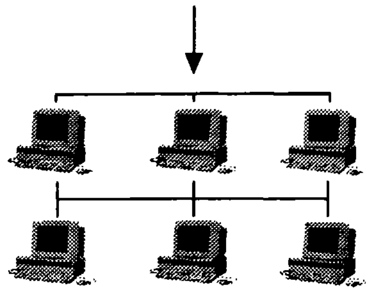
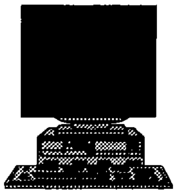
Focus of Presentation

Desktop Delivery Systems: delivery of information directly to decisionmakers



rather than

High End GIS Systems: data assembly, preparation, and quality control (discussed in later presentation)



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Outline of Presentation

- Characteristics of delivery systems
- Tailoring of systems to focus on specific decisions or content
- Case Study: Mid-Atlantic Information and Mapping System
- Case Study: COMPAS Florida

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Characteristics of Delivery Systems

- More appropriate term: desktop INFORMATION systems
- INFORMATION more important than capabilities
- Tailored to INFORMATION needs of specific problem(s) or theme(s)
- Capabilities designed for ease of use of the INFORMATION

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Custom Design

- Primarily in information development process
- Also, in presentation of information in product
- Generic or custom capabilities used depending on need
- Design is a cooperative effort among many parties, not solely "computer or data" personnel

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Information Development Process

- Key to any project of this type
- Examines themes and issues
- Translates "raw" data into "user-friendly" information
- Limited for the Mid-Atlantic system
- Could be expanded in the future

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Case Study 1: Mid-Atlantic Mapping and Information System

- Content Focus: Nationwide sampling program
- Geographic Focus: Estuaries and coastal ocean
- Scale: State and/or regional
- Uses: Understanding of problem areas
- Design User: Single analyst
- Design Principle: Rich data, simple structure, simple capabilities

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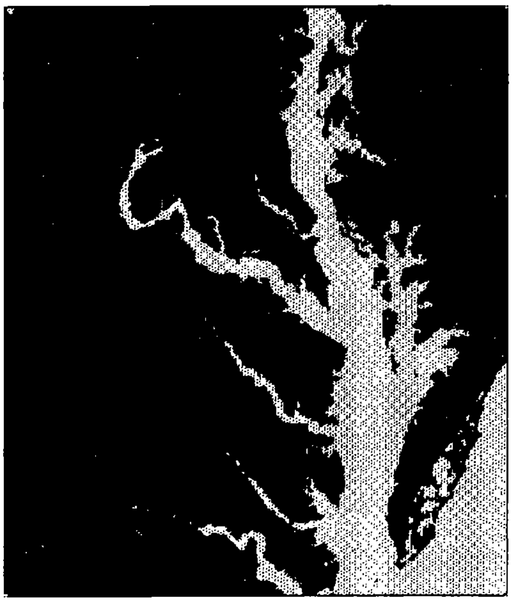
System Overview

Information Development Process

Information		Capabilities	
		Application Environment	
Data Files	Geographic Files	Database	Mapping
Theme Data	High Resolution 1 - 250,000	Viewing	Base Maps
Supplemental Data		Query	Data on Maps
		Export →	Direct Mapping
	Med. Res. 1 - 2,000,000		
	Very High Res. 1 - 80,000	User Data	

Geographic Files

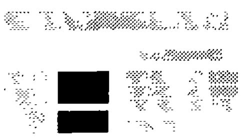


• 1 to 250,000 resolution

Counties
Estuaries and Estuarine Drainage Areas
Rivers
Water Bodies
Major Cities
Sediments

• Also available:

Most coverages at 1 to 2,000,000
Shorelines available at 1 to 80,000



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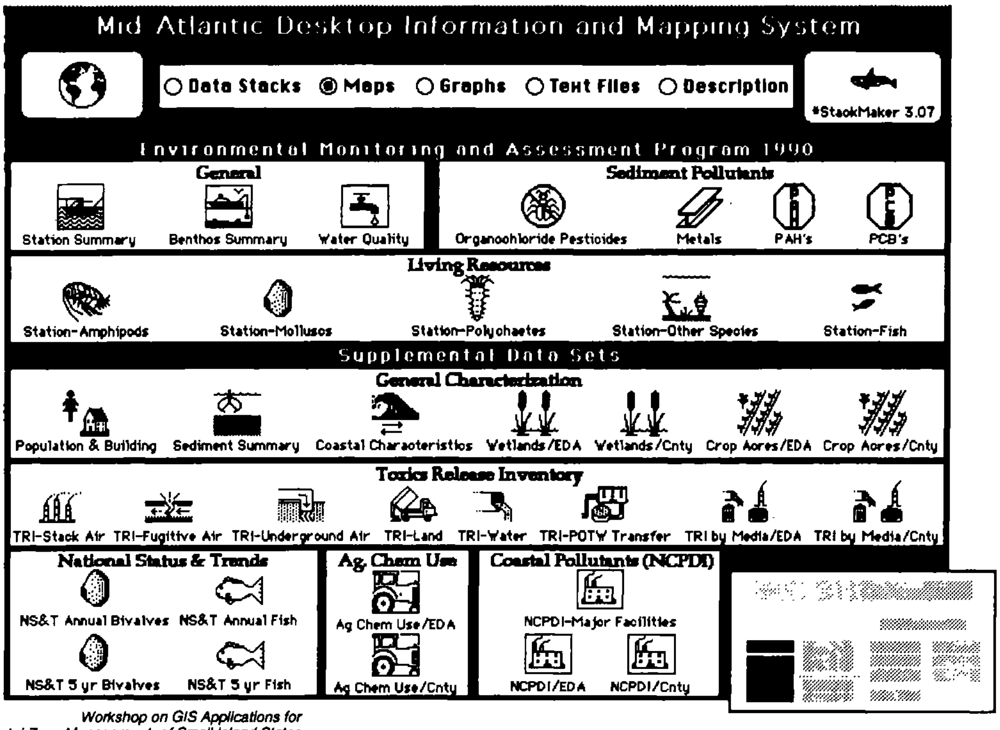
Information Content



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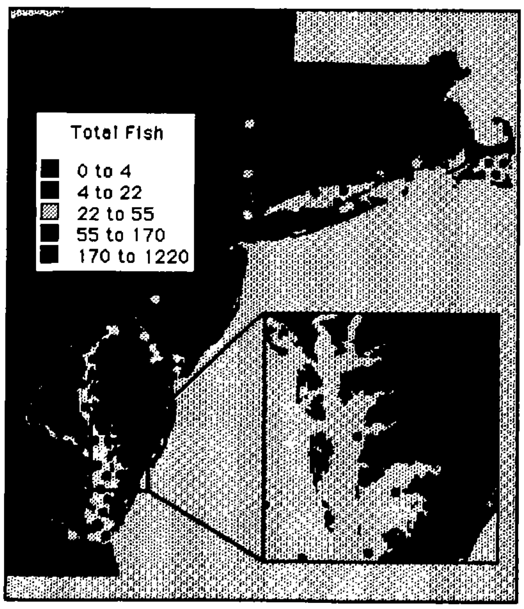
Example Data Layer: EMAP Virginian Province Data



- 1990 sampling at 144 sites
- Water quality
- Sediment chemistry
- Living marine resources
- Biotic community analysis

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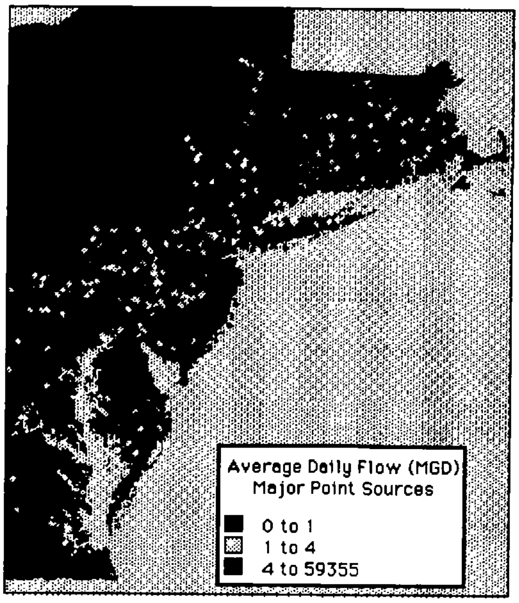
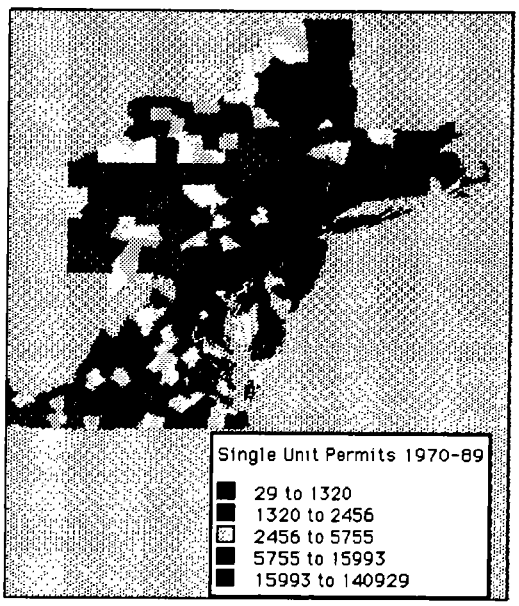
Example Data Layer: Point Sources of Pollution



- 2,000 individual sources
- Municipal and industrial facilities
- Annual loads for 18 pollutants

Example Data Layer: Population and Housing



- County Level
- 1970, 1980, and 1990
- Population and changes
- Housing permits
- Single and multiunit buildings
- Commercial and government buildings

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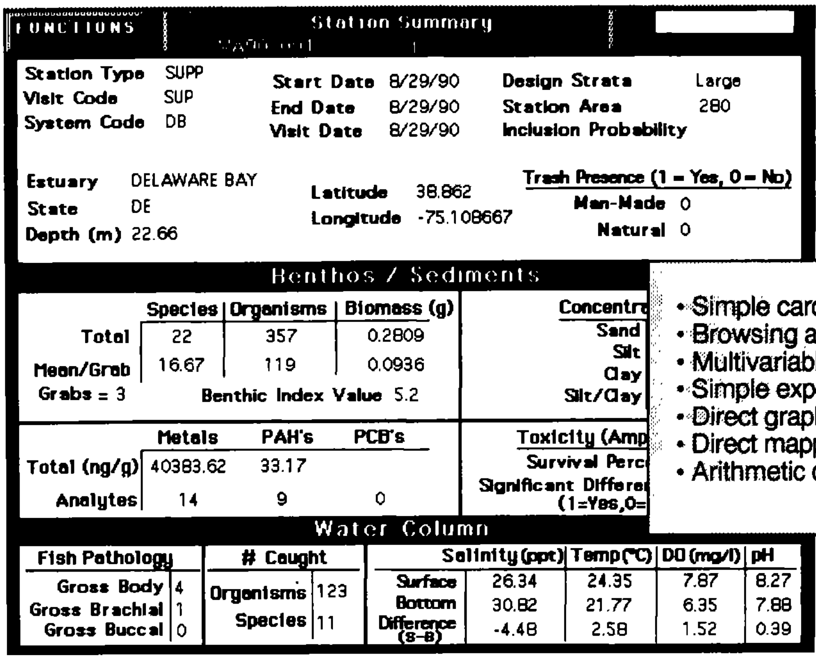
Simple Database and Query Capabilities



- Simple card views
- Browsing and sorting
- Multivariable queries
- Simple exports
- Direct graphing
- Direct mapping
- Arithmetic derivatives

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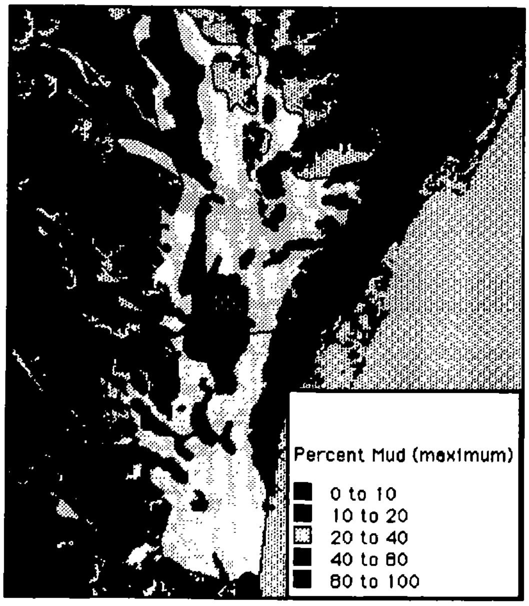
Simple Thematic Mapping



- Use of commercial application
- Set of standard base maps
- Data loaded maps
- Direct mapping of queries

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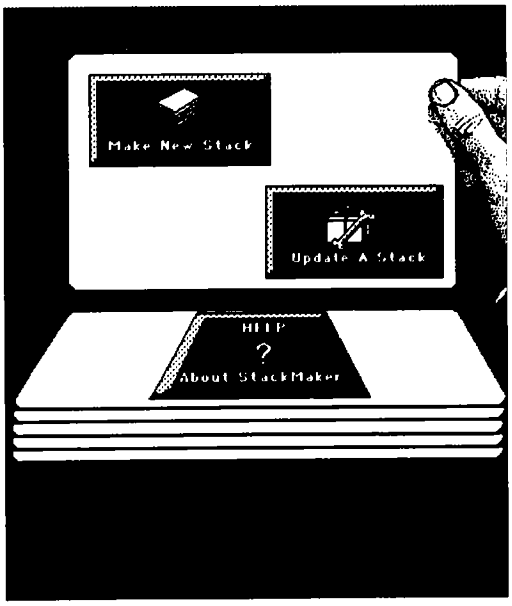
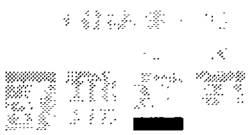
Additional Features



- Users can import own data sets and create customize views
- Automatic updating for software revisions
- Geographic utilities



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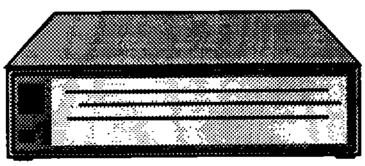
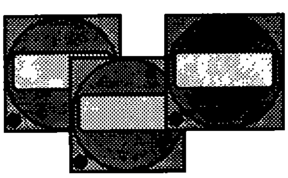
The Final Product

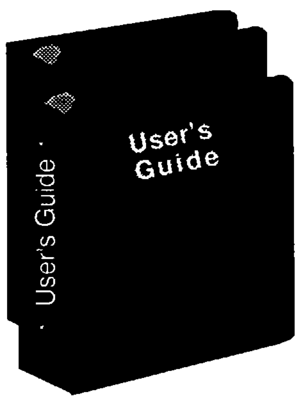
Apple Macintosh



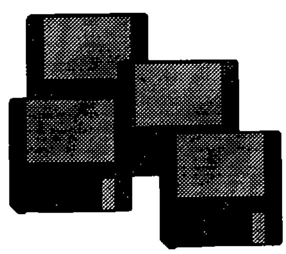
User External Hard Drive



Syquest Cartridges



DOS, Windows and OS/2



Data and Geography Files in Standard Formats

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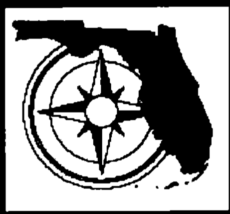
Case Study 2: COMPAS Florida

COMPAS

NOAA's Coastal Ocean Management, Planning and Assessment System



Quit COMPAS

- Content Focus: Uses of coast and coastal ocean of southern Florida
- Geographic Focus: State of Florida and southern Florida
- Scale: State and county
- Uses: Day-to day management of Florida Keys National Marine Sanctuary
- Design User: Major Institution
- Design Principle: Rich data, formal/relational structure, robust capabilities

Data Sets and Spatial Units of Aggregation

Data Sets	Spatial Units				
	County	Estuary	1 Minute Cell	Key Tract	Key Segment
Habitats	●	●			
Housing and Population	●				
Physical and Hydrologic		●			
Pesticides	●	●			
Recreation	●				
Shellfish		●			
Artificial Reefs			●		
Benthic Resources			●		
Common Reefs			●		
Enforcement			●		
Fishing					●
Florida Natural Areas Inventory			●		
Marine Facilities			●		
Protected Areas			●		
Shipwrecks			●		
U.S. Census				●	

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Geographic Files

State (1-2 M)

- State boundary
- Counties
- Major rivers and lakes
- Hydrologic units
- Estuarine drainage areas
- Coastal drainage areas
- Major highways
- Major cities

Florida Keys (1-40 K, 1-2 M)

- Shoreline
- Sanctuary boundary
- State waters
- Protected areas (13)
- Key tracts (17)
- Key segments (5)
- One minute grid

Relational Database Structure

MARINE_FACILITIES

FL_GRID_CELL	MAR_FACILITY	MAR_FACILITY	LONGITUDE	LATITUDE	MF_SITE_TYPI
(2,9,0,1)	(2,5,0,1)	(1,31,0,2)	(2,10,5,2)	(2,9,5,2)	(1,6,0,2)
80162518	1	MARINA INN	-80.28004	25.31227	?
80162518	2	OCEAN REEF CL	-80.2821	25.31141	M
80172518	3	KEY LARGO ANC	-80.29369	25.30745	MSJ

ENFORCEMENT_ACTIONS

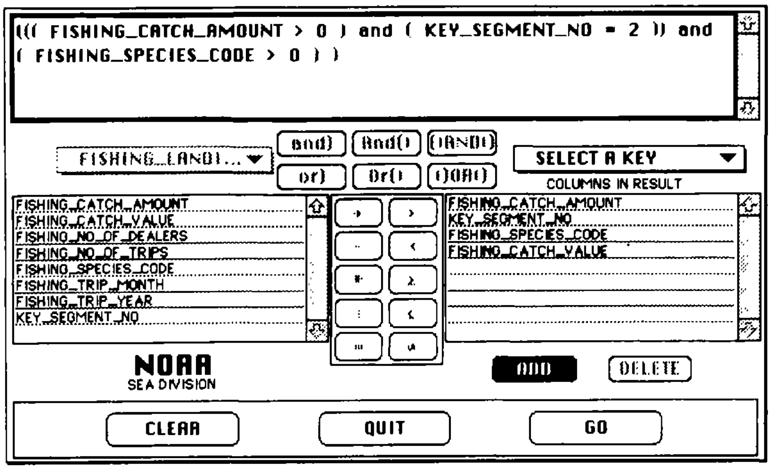
FL_GRID_CELL	PATROL_NO	VIOLATION_COI	ENFORCEMENT	NUM_ACTIONS
(2,9,0,1)	(2,5,0,1)	(1,5,0,2)	(2,5,0,2)	(2,5,0,2)
80102511	387	TR	1	5
80102511	385	SF	2	1
80102512	388	US	1	1

PATROL_TABLE

PATROL_NO	BOAT_NUMBEF	BOAT_OPERAT(	FUEL_GAL	PATROL_DATE
(2,6,0,1)	(1,5,0,1)	(1,21,0,1)	(2,6,1,2)	(3,12,0,2)
1	PH1	DAVIS	158.3	1-Oct-91
2	PH1	DAVIS	90.2	2-Oct-91
3	CR1	DAVIS	0	2-Oct-91

- Data tables
- Varying data structures
- Key columns
- Design process
- Not automated

Feature: Relational Data Query



Purpose:

To allow users to relate different data sets to one another (literally or arithmetically)

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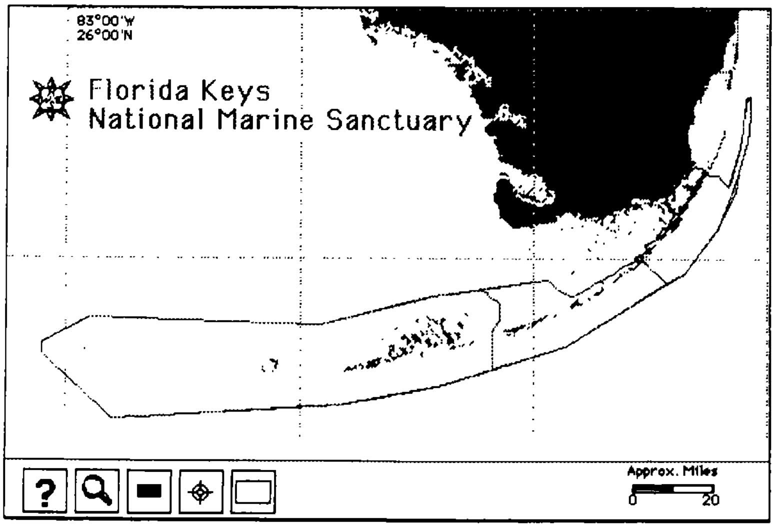
Feature: Map Query



Purpose:

To retrieve information from COMPAS on a specific geographic area

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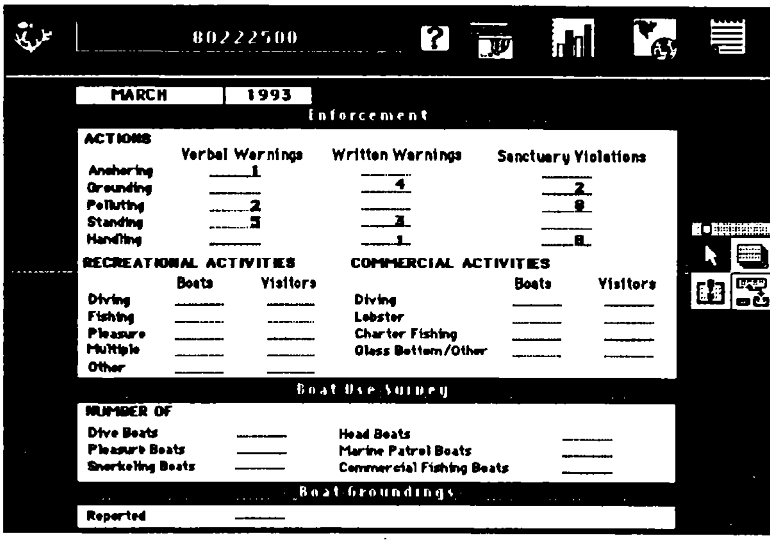
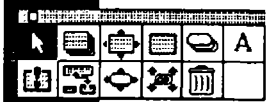
Feature: User Generated Views



Purpose:

To provide custom screens for problem-focused information needs



Summary Comments

- *Desktop Information Systems can be an effective way to deliver important information to resource managers and analysts.*
- *The focus of these systems should be clearly on the INFORMATION content rather than high-end capabilities.*
- *Providing easily used information requires a deliberate and thoughtful process.*

Using Cellular Automata for Integrated Modelling of Socio-environmental Systems

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Abstract

Cellular automata provide the key to a dynamic modelling and simulation framework that integrates socio-economic with environmental models, and that operates at both micro and macro geographical scales. An application to the problem of forecasting the effect of climate change on a small island state suggests that such modelling techniques could help planners and policy makers design more effective policies -- policies better tuned both to specific local needs and to overall socio-economic and environmental constraints.

Introduction

Town and country planners face the difficult task of dealing with a world that is complex, interconnected, and ever-changing. Coastal zone management, urban land-use planning, and the design of policies for sustainable economic development all pose the problem of dealing with systems in which natural and human factors are thoroughly intertwined. There is growing scientific evidence that a purely macroscopic approach to these problems does not suffice, because spatial and organizational details are important in understanding the dynamics of such systems (Allen and Lesser, 1991; Kauffman, 1993; Langton, 1992; Nicolis et al. 1989).

At the descriptive level, the need for spatial detail is attained in Geographical Information Systems. But, in order to put forward effective measures for changing --or maintaining-- the organization of socio-economic and environmental systems, it is necessary not only to know what is where but also why it is there. These systems must be understood and managed as coherent dynamic entities, so that system integrity is maintained. We present here a dynamic modelling framework and encompassing decision support shell that is capable of integrating socio-economic and environmental factors at a variety of scales, while representing spatial dynamics with a high level of geographical detail. This modelling framework is quite general in terms of the situations to which it can be usefully applied. But we will present it here in the form of an example --an application concerning the impact of climate change on a small island state.

An example: Exploring the Impact of Climate Change on a Small Island.

Shifting climate conditions, expressed at the *macro-scale* in terms of changes in temperature, precipitation, and storm frequency, are likely to affect productivity levels, demand patterns, and exports and imports, and will probably cause migration of people and their activities as well (see e.g. Alm et al., 1993). But all of these effects are actually expressed, on the ground, as *micro-scale* phenomena. For example, an increase in the total export demand for a particular agricultural product will normally mean that more land will be required. But the consequences will be very different depending on whether the land is found by converting existing agricultural land or by clearing forested land, especially if the latter is easily eroded or is itself ecologically significant. Furthermore, changes in productivity that may occur as other activities are displaced onto more marginal land, or as erosion causes loss of fertility, will in turn have repercussions on the macro-level economics. In other words, the spatial details of land use are important in understanding the impact of macro-level changes.

No one model is capable of capturing the whole range of these phenomena, from those operating on a world scale down to those that threaten strips of beach or affect individual fields. For example, spatial interaction based models, consisting of sets of linked dynamic equations, are useful for representing spatial and temporal dynamics at regional scales (White, 1977; Engelen and Allen, 1986; Pumain et al., 1989), but become computationally impractical when much spatial detail is required (White and Engelen, 1993). On the other hand, models capable of dealing with extreme geographical detail, such as those available in Geographical Information Systems, lack the dynamics required to represent the processes operating in the system (Brimicombe, 1993). One solution to the problem is to make use of a modelling framework consisting of the linked components --one for macro-level processes and another

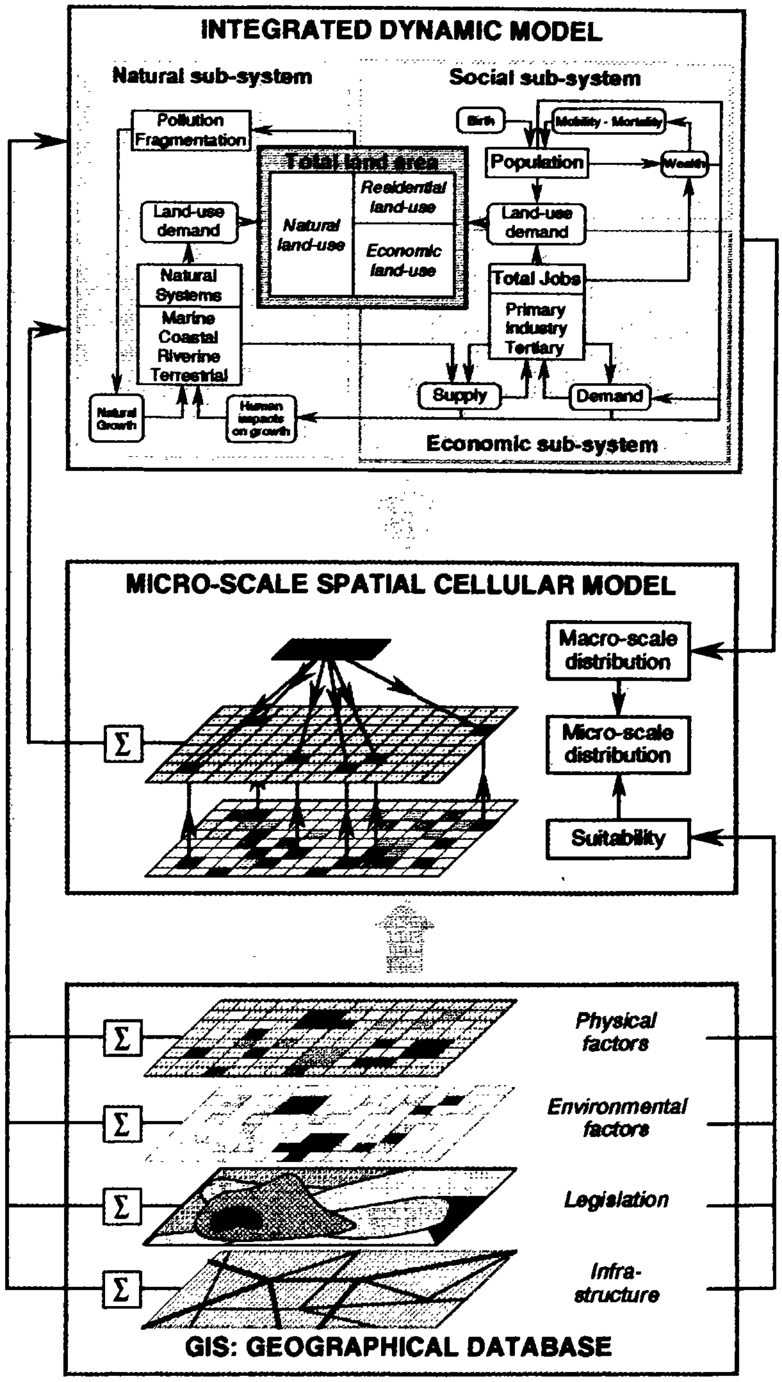

Fig. 1: A two-level model. On the macro-level, long range interactions are modelled by means of an integrated model. The macro growth coefficients are fed into a micro-level cellular model to perform the detailed allocation based on short range mechanisms. Both levels of the model will retrieve data from the same GIS.

for those operating at the micro-level. Both components exchange results continuously during the simulation and get the data relevant for their level of detail from the same geographical database, ideally a GIS (Figure 1).

At the *macro-level*, the modelling framework integrates several component sub-models, representing the natural, social, and economic sub-systems. These are all linked to each other in a network of mutual, reciprocal, influence (Figure 1, top). The macro level allows for the use of regionalised representations and for different types of mathematical formulations, thus permitting a more or less detailed modelling of various aspects of the sub-systems as required for specific applications. For the case of the small prototypical Caribbean Island, the macro-level is modelled as a single point in interaction with the world outside.

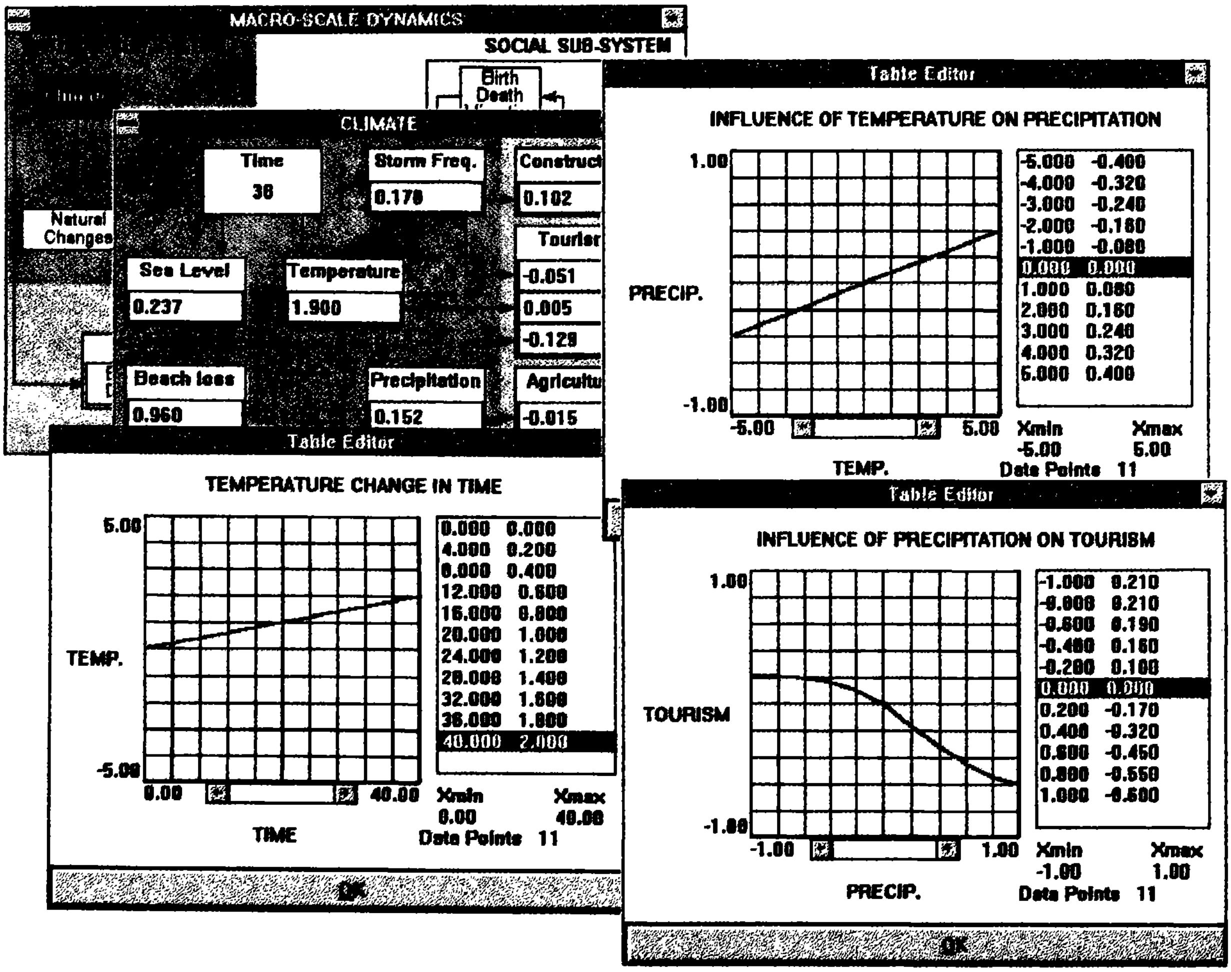

Fig. 2: Diagram showing part of the Natural System of the model of the Caribbean Island. Most of its relations are entered as semi-qualitative rules.

The *natural sub-system* consists of a set of linked relations representing the expected changes through time of sea level and temperature, and the effects of those changes on precipitation, storm frequency, suitable land area, and external demands for services and products. Due to the limited knowledge currently available as to the exact nature of these relations, they are incorporated in the model as semi-qualitative expressions of expert knowledge or as hypotheses supplied by the user, rather than as empirical laws (see Figure 2).

In the *social sub-system* the demography is modelled as a single population group growing as the result of birth, death, and migration. The birth rate is specified to follow a long term structural trend, while mortality and migration rates depend on both structural trends and on the well-being of the island population as indicated by the employment rate.

The *economic sub-system* is modelled by means of a highly aggregated (five sector) input-output model solved at each iteration. The economic sub-system is coupled with the natural sub-system through climate-induced changes in export demands; with the social sub-system through household demands; and with the micro-level component of the model via a land productivity expression which translates activity levels into land use demands.

The *land demand module* takes the growth coefficients calculated by the macro-level model -- expressed as changes in population and in number of jobs in the various economic sectors-- and returns the amount of additional space required to carry out the corresponding activities. To this end, it takes into consideration both the relative scarcity of land as measured by price, and the productivity of the land for particular activities. The total area of land required by each activity drives the micro-level part of the model.

The *micro-level* model (Figure 1, middle) is developed on a cellular array with each cell representing a parcel of land 500 meters on a side, and it is by means of *Cellular Automata* transition rules that we calculate the changing land-use. Cellular Automata are mathematical objects that have been studied rather extensively in mathematics, physics, computer science and artificial intelligence (Gutowitz, 1991), although until recently they were best known as games (Gardner, 1970). Tobler (1979) defined them as *geographical* models, but they have only rarely been applied in human geography in the years since he proposed them (e.g.

Couclelis, 1985, 1988; Engelen et al. 1993a; White and Engelen, 1993, 1994). A cellular automaton consists of an array of cells in which each cell can assume one of *k* discrete states at any one time. Time progresses in discrete steps, and all cells change state simultaneously as a function of their own state, together with the state of the cells in their *neighbourhood*, in accordance with a specified set of *transition rules*. Transition rules can be either qualitative, quantitative or both.

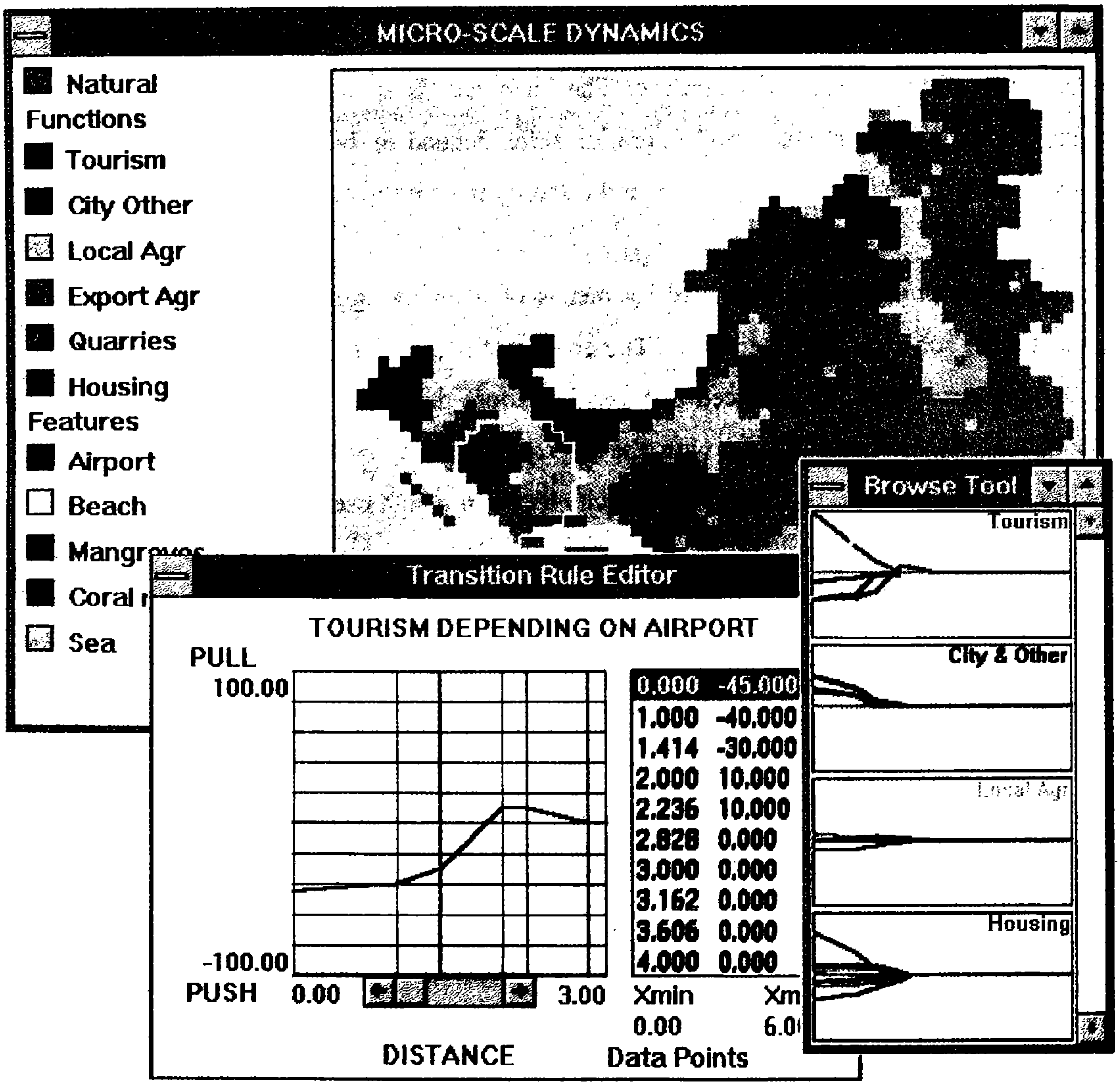

Fig. 3: Micro-level of the Caribbean Island model, showing the size and shape of the neighbourhood and part of the transition rules.

For our application the neighbourhood is a circular template of 113 cells (Figure 3). (In most other, more theoretical, studies, the neighbourhood is limited to the 4 or 8 immediate neighbours of a cell.) Each cell in the grid is in one of thirteen states, each representing a land-use. Transition rules reflect the interaction of activities with each other within the local geographical space of the neighbourhood. Thus, push and pull effects are expressed by means of attraction-versus-distance functions for each pair of activities or land-uses modelled. The aggregate, distance weighted push and pull effects of all the cells in the neighbourhood together determine the *locational suitability* of the cell for each possible land use.

This locational suitability, expressing how well the cell is positioned locally in relation to supporting or competing activities, is not, however, in itself sufficient to determine the cell's potential for transition from one type of activity to another. The cell's *intrinsic suitability* in terms of its own physical, environmental and institutional characteristics must also be taken into account. This suitability is an aggregate measure calculated from a number of geographical attributes such as soil quality, elevation, or land use regulations (see e.g. Burrough, 1989) stored in a geographical database (Figure 1, bottom). A cell's suitability, or any of its constituent attributes, can change during a simulation, due either to user interventions (e.g. representing a policy measure) or to changes in environmental or physical conditions (e.g. flooded by a rising sea). Such changes are taken into consideration in the remainder of the simulation.

Although transition rules operate at a very local scale, cellular automata have the capacity to organize space at a macroscopic scale. We have demonstrated that geographical clusters can be generated that are realistic in terms of their size, spatial distribution and socio-economic composition (White and Engelen, 1993; Frankhauser, 1991).

Some results.

The modelled Island is designed to resemble a typical Caribbean island[1]. The Island has an area of some 940 km^2, and is rather flat in the west with highlands in the eastern part (Figure 4). It has a total population of 24500 initially, growing at nearly 2% a year, and a total of 11000 jobs

[1]The decision support system and modelling framework presented in this article has been developed for UNEP (United Nations Environment Programme). A more ample discussion can be found in Engelen et al., 1993a and Engelen et al., 1993b.

in tourism, subsistence agriculture, export agriculture, commerce and industry, and construction (in order of importance). It has a very open economy, exporting agricultural products and tourist services, and importing a wide range of goods and services.

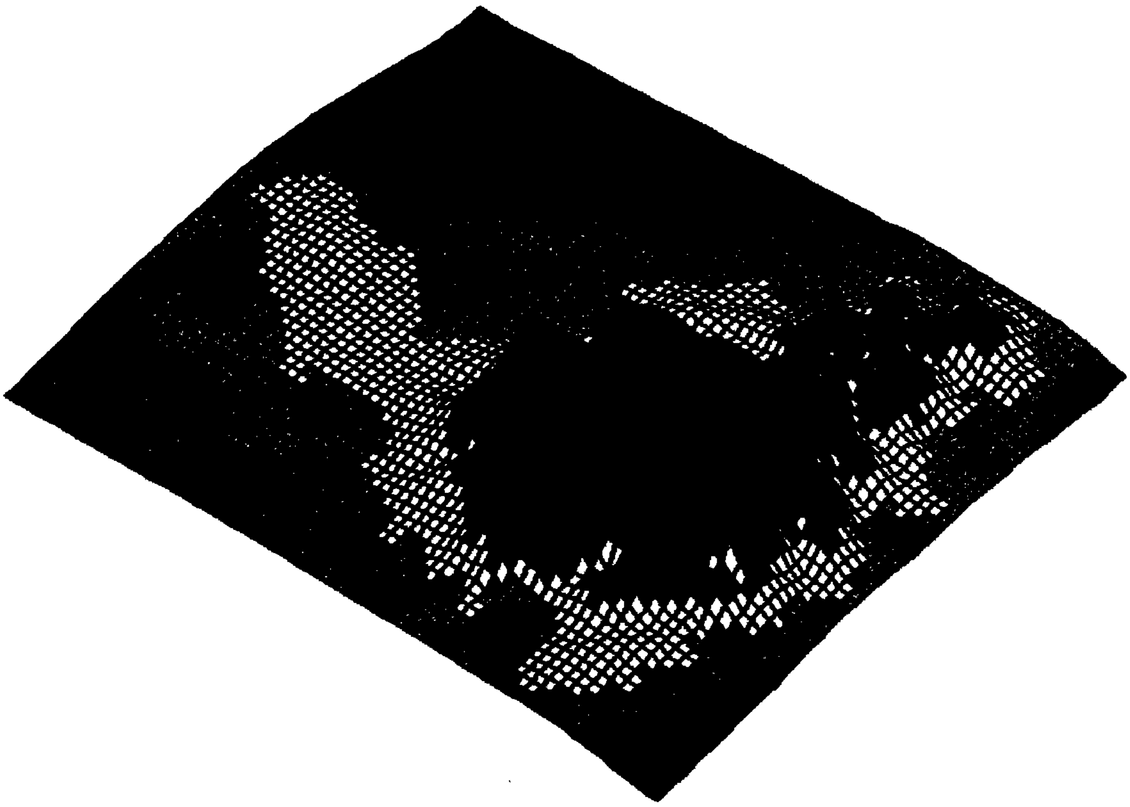

Fig. 4: Relief of the modelled Island.

With the initial land use shown in Figure 5 (top), and based on a hypotheses of stagnant or declining external demand, we have run the Island-model under different scenarios as regards to climatic change. As an example, we show on the right side of Figure 5, maps representing three stages in the 40-year evolution of the island under conditions of rising temperature (+ 2 °C) and sea level (+ 20 cm). Under this scenario, some beach area is lost, leading to a loss and partial relocation of tourism activities and the associated employment. These changes, together with increased population (up by some 56%), cause a substantial increase in subsistence agriculture activities. From the maps it is clear that the relocation and expansion of activities that are relatively strong in terms of value added per unit area (tourism, commerce, industry and residential activities) is pushing subsistence agriculture onto the steep marginal lands of the highlands.

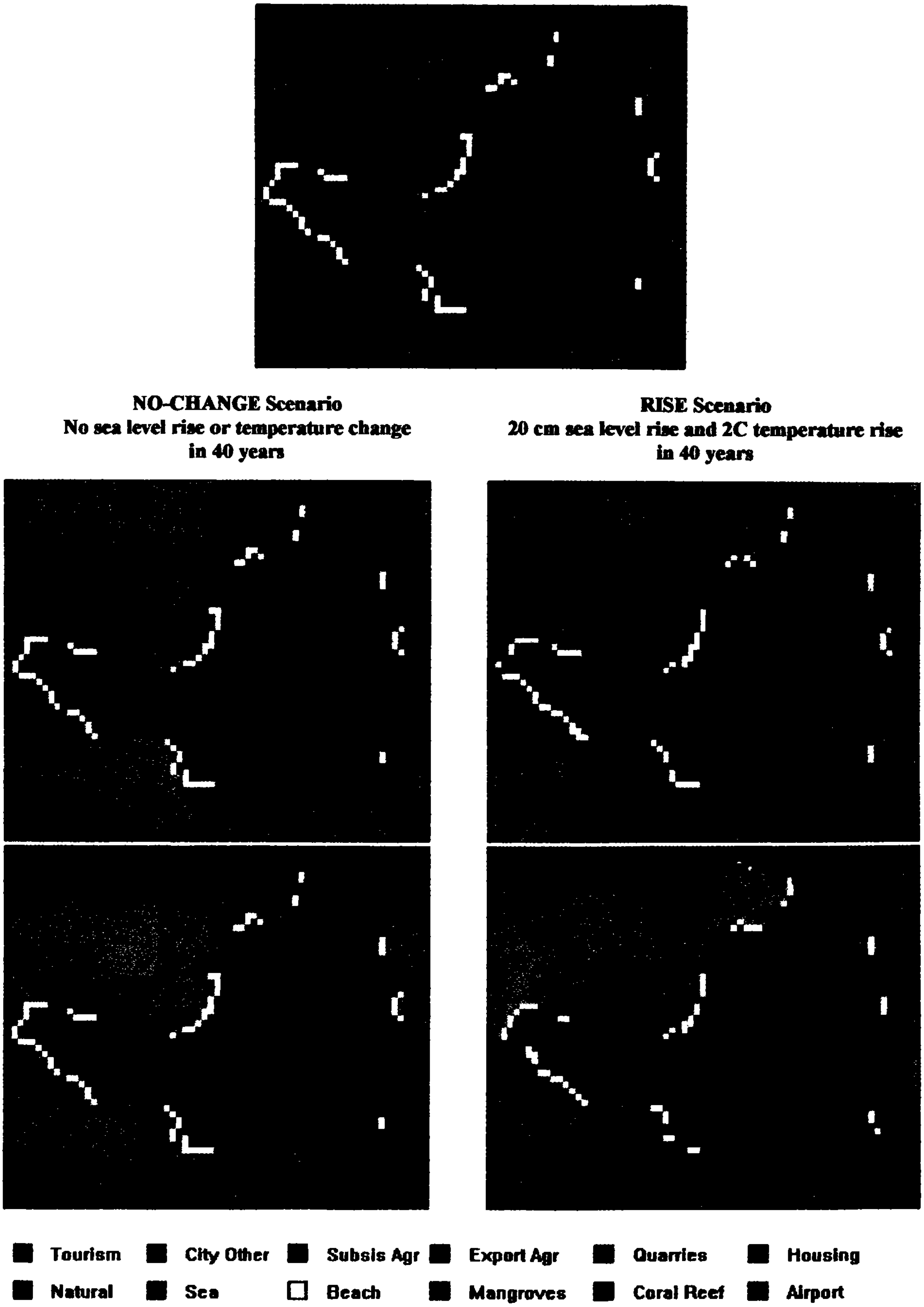

Fig. 5: Evolution of land-use on a Caribbean Island as the result of a NO-CHANGE (left) and a RISE (right) scenario. The initial condition (top) is the same for both scenarios.

In comparison, the left side of Figure 5 shows results generated under a similar scenario but with no climate change this time. There is less spatial reorganization of the activities and there is less out migration of the population due to higher levels of economic activity, especially in the tourism sector. But the pressure on the natural and marginal land is similar. For many small Caribbean islands, such evolution is realistic and has been observed.

Agricultural expansion has been reported to damage natural ecosystems and habitats, both terrestrial and marine, to jeopardize sweet water reserves and aquifers, to contaminate rivers and to pollute beaches and coastal waters (Blommestein, 1993). It generates high levels of flooding and erosion, but also droughts that damage the system even further.

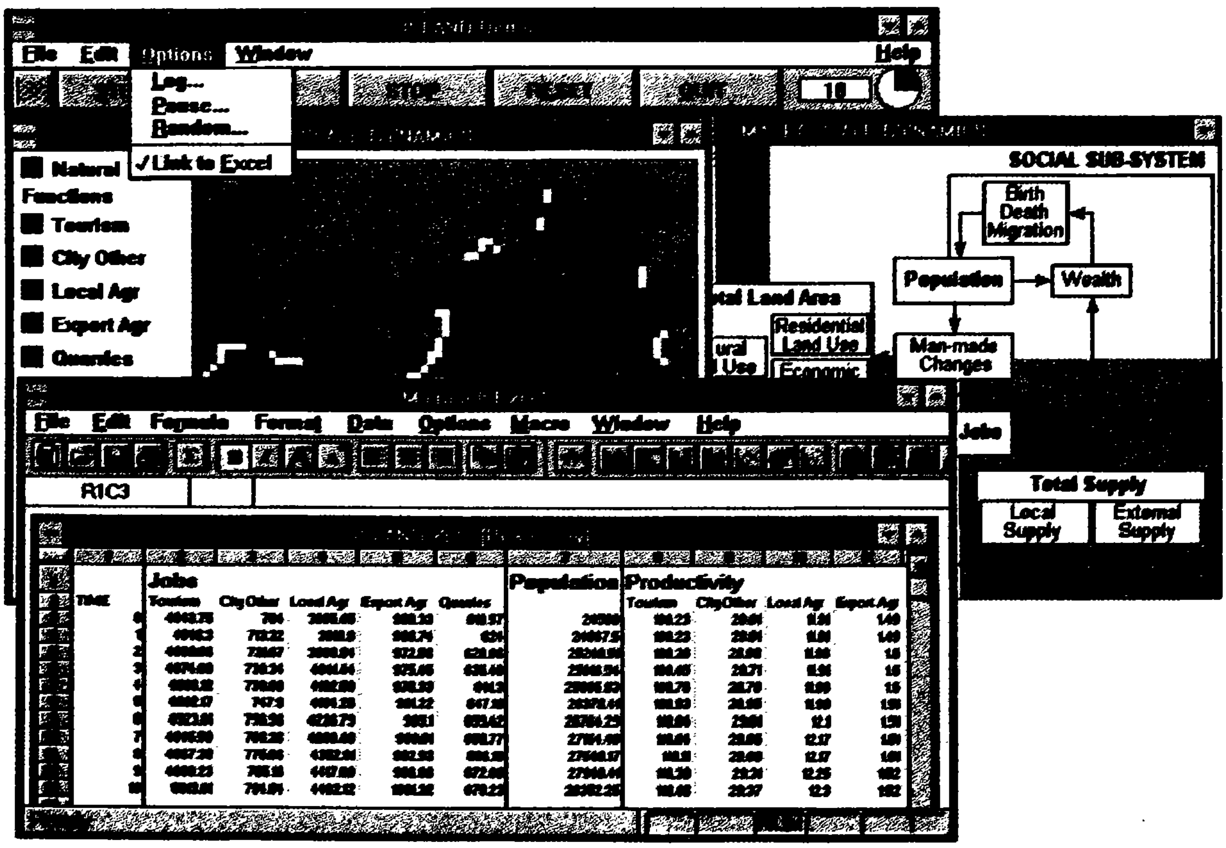

Fig. 6: A view of the graphical user interface of the decision support shell. Menus allow the user to manipulate simulation files and to use the different tools of the system. Once a simulation file is opened, the micro- and macro-level models will appear in separate windows. A control panel allows for the control of the simulation. The open architecture of the decision support shell allows for a DDE link with MS Excel.

In order to control this sort of evolution and direct the system onto a more sustainable development path, a thorough analysis of different scenarios representing the effects of possible policy measures is essential. The Island-model is designed to provide this kind of policy support.

Modelling, Simulation and Decision Support.

The modelling framework has been incorporated into a generic computer shell running under Windows 3.1 on PC compatible machines. The shell is equipped with a graphical user interface (Figure 6), which makes the system transparent and accessible both to researchers with extensive modelling experience and to users with little expertise in computers or modelling.

For the first group, the interface tools permit users to deal interactively with the technical issues of interest to them. They can enter new applications, modify existing models, or change parameter values, as well as compare and evaluate simulation experiments. For the second group, a number of decision support tools permit questions of policy to be addressed in a systematic, comprehensive way, without the user being bothered by the highly technical nature of the instrument. The most important of these tools are text and graphical editors, "what-if?" and scenario editors, and facilities for the display and mapping of results, as well as tools for pattern analysis. Also available are instruments for performing multiple criteria, multiple objective evaluation of the various policies that have been simulated, in order to facilitate the choice of the most effective policy.

The shell makes extensive use of Interprogramme Communication Protocols (DDE, DLL and OLE) and is thus capable of exchanging on-line information with other software packages (Figure 6). This capability has permitted the shell to be integrated into an Intelligent Tutorial System for geography (Engelen et al, 1994), thus making it available for a third group of users.

Further research

The system presented in this article is being further developed into a generic decision support system for use in small islands and coastal areas. As a first step, it is being applied to the island of St. Lucia, one of the Windward islands in the Eastern Caribbean (Figure 7), and to the metropolitan region of St. John's, Newfoundland, Canada.

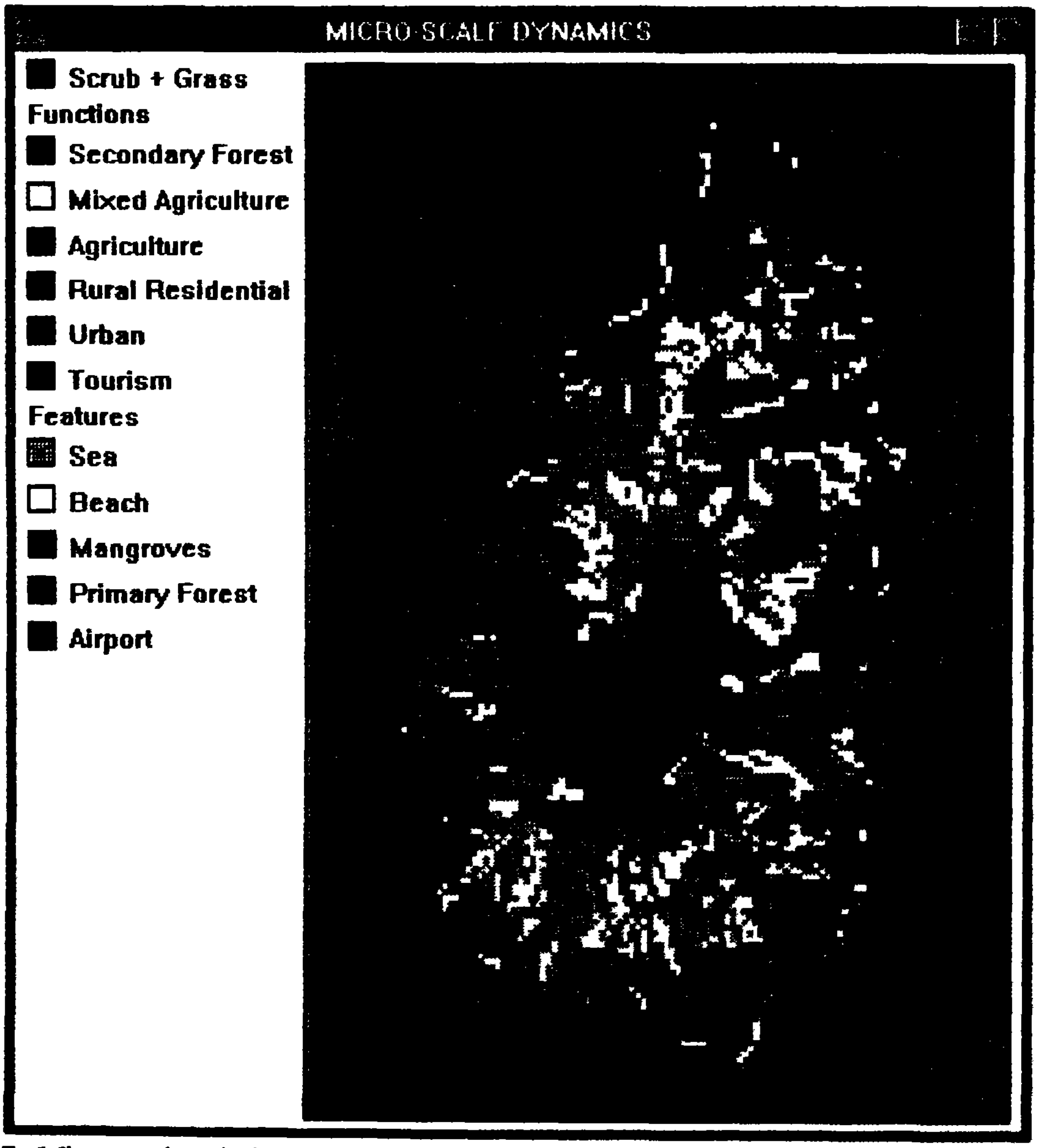

Fig. 7: Micro-scale window of the modelling framework applied to the island of St. Lucia (West Indies).

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Relevant Technology Development Directions for Small Island States

By:

Giulio Maffini

Key Technology Development

- Reducing The Cost Of Where
- Capturing The Data
- Using The Data

Reducing The Cost of Where

- Small Form Factor
    - PCMCIA cards
    - RS232 attached hand helds
- Low Cost ($500)
- 10 to 30 meter accuracy
- Rapid capture of geo coordinates
- GUI based PC software now available for transparent data capture into applications

Portable Environmentally Tolerant Computers (PETC)

- Physically Tolerant
- Pen Enabled
- Docking Station, Dial Up, or Wireless Capable
- GPS Attached
- MS WINDOWS Field GIS Software now available (Pen Metrics, Bentley Systems, Buers)

PETC Pen Tablet Computers

- 3 to 6 pounds
- 80386, 80486, and PowerPC processors
- 4 to 32 megabytes of RAM
- 40 to 105 megabytes of hard disk
- 4 foot drop to concrete
- -25 C to 55 C
- Full sunlight to full darkness
- PCMCIA
- Keyboard and docking station expansion
- Sealed - water proof and salt water resistant
- $3595 to $5995

Multitasking GUI Operating System Environments For PETC

- MS-WINDOWS

- MS-DOS 4.0 (late 1994)
- Chicago (June 1994)
- Cairo (1995)
- AIX
- OS/2
- General Magic

PETC Operating Environments

- PETC devices are ideal for use in:
  - cars
  - boats
  - jeeps
  - trucks

PETC and GPS technology promise a time in the near future when the knowledge of "where" the user is transparently collected while using the PETC.

PETC Pen Tablet Vendors

- TUSK
- Kaleida
- Norand
- Telxon
- Micro State

All can withstand common elements of the island environment:

* Sand
* Dust
* Salt Water
* Heat & Full Sun

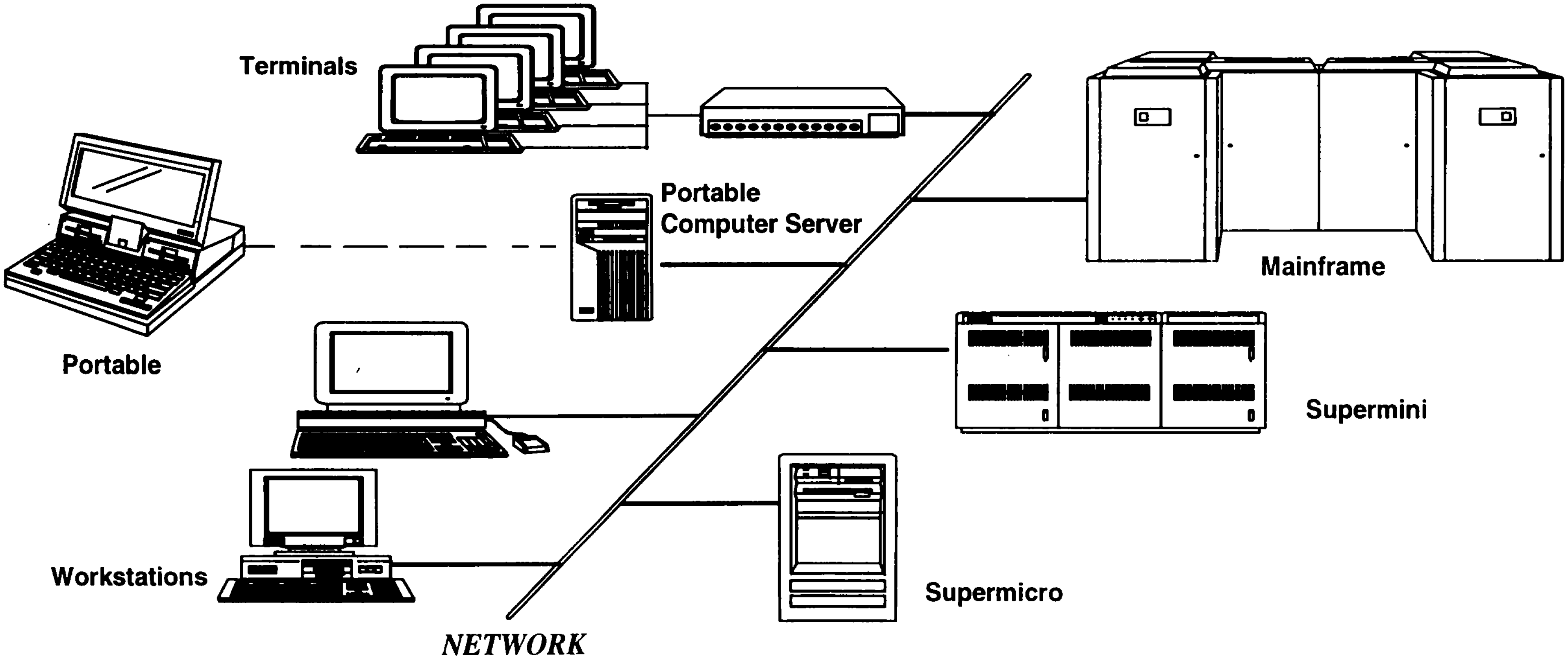
Client/Server Defined

" A CLIENT is a single user workstation, providing the user with presentation services and the appropriate computing, connectivity and database services and interfaces relevant to the business need;
A SERVER is one or more multi-user processors with shared memory, providing the user with computing, connectivity and database services and interfaces relevant to the business need;
CLIENT-SERVER COMPUTING is an environment in which the business need is satisfied by an appropriate allocation of the application processing between the client and server processors. The environment will typically be heterogeneous"

Client/Server Data Management

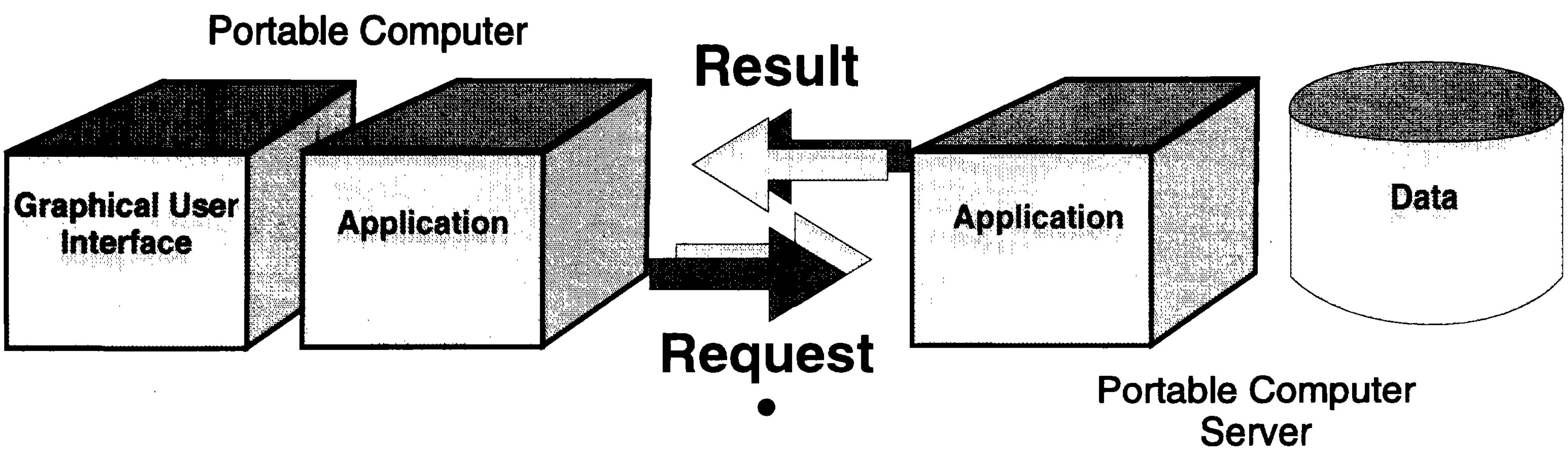
- Client/Server Topology
- Object Wrappers
- OSQL
- Object Relational Data Base Management Systems
- ODBC

Enterprise Client/Server Architecture With Field Computers



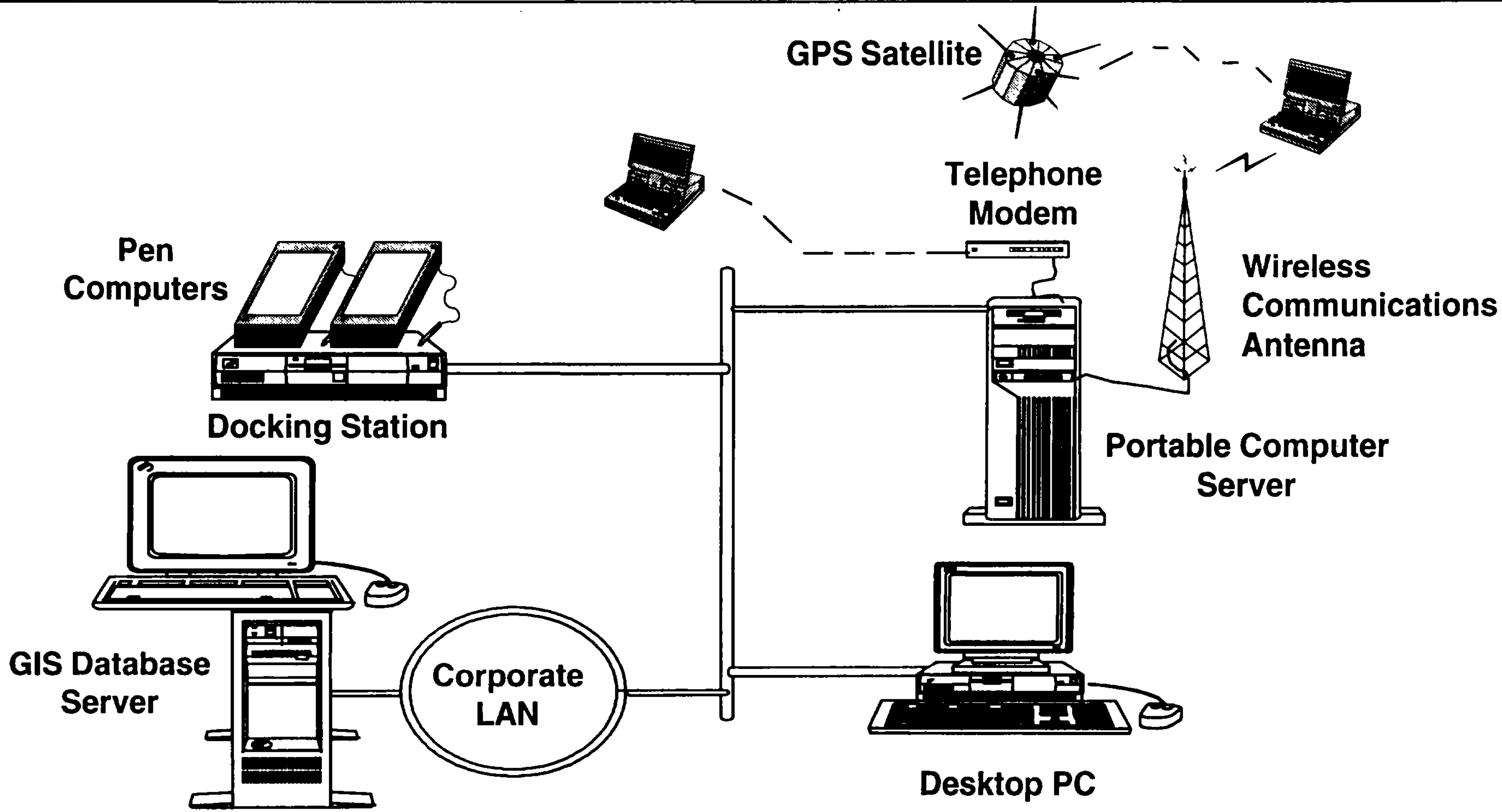
International Workshop: GIS in CZM of SIDS, Barbados '94

Mobile Computing Client/Server Architecture



-
- Docking Station
- Dial Up
- Wireless

Client/Server Mobile Computing Connections



International Workshop: GIS in CZM of SIDS, Barbados '94

Wireless Computing

GIS has historically ended at the office door. With the new technologies discussed here, full functionality GIS can be deployed to the field. These functions include:

- System access with map and data read/view only capabilities
- System access with map and data read/view and annotation capabilities
- System access using pen based computer interface and input forms
- System access with read/view, annotation, write, and modify capabilities;
- Full engineering tool set, including work order generation

Wireless Computing Options

	Advantages	Limitations
Traditional	• Ubiquitous	• Limited throughput
Cellular	• No restrictions	• Congestion in urban areas
CDPD	• Enhanced cellular data (more reliable) • Integrated voice and data	• Not yet deployed • Lack of applications development
Dedicated	• Reliable	• Data only
Packet-Switched	• Short call setup time	• Require specialized wireless modems
Mobile Networks	• Bill by message size • Integrated applications and communications	• Limited packet size • Limited coverage
Specialized Mobile Radios	• Voice and data	• Vehicle based • Limited coverage
Satellite-Enabled Networks	• Geographic reach	• Expensive
Paging	• Alphanumeric messaging capability • Economical message broadcast	• One-way transmission only • Limited message size

Two Approaches To Building the Database

- Layer/Theme Model
- Feature/Object Model

Layer Theme Model

- Map Makers Model
- Open Ended by Definition
- No Explicit Structure Implied
- Ambiguous/Redundant

Feature/Object Model

- Database Builders Model
- Formally Defined At Outset

- View Of Themes Can Be Generated
- Effort Required To Define Robust Structure

Migrating From Layers to Features

- Explicit Definitions Required
- Ambiguity Removal Process/Procedure
- Complexity Reduction
  - Unique Conditions
  - PATN

Digital Still Photography

- Cameras Today:
  - 600 dpi
  - 64 shades of gray
  - 350 grams
  - serial port export
  - $695

- Cameras In The Next Two Years:
  - 1200 dpi
  - 16.8 million colours
  - 300 grams
  - serial port export
  - PCMCIA storage/transfer
  - $795

Voice Recognition

- In the next two years we will have:

  - 2000 word vocabulary or more
  - Speaker independence
  - 80 words per minute input recognition rate
  - user definable vocabularies for vertical applications
  - background noise filtering
  - context sensitivity with real time dictionary look-up
  - low cost PC solution $500 - $1,000

Geographic Data Agents

- What They Are
- Why We May Need Them
- Examples Of What They May Achieve

Just Imagine....

- Using a pen computer underwater while updating a map of a coral reef...
- Walking down a beach with a portable computer and updating a map of beach erosion...
- Taking digital pictures of recreation areas and potential land development areas...
- And then transferring this information to your GIS database without using a single piece of paper....

Stop Imagining! Its here today....

Current Status and Future Development of Remote Sensing and GIS at the South Pacific Applied Geoscience Commission (SOPAC)

Notes prepared for the Workshop on GIS Applications in Coastal Zone Management of Small Island States Barbados 20-22 April, 1994

PURPOSE OF NOTES

To provide information on the background, current status, and future developments of Remote Sensing and Geographic Information Systems at SOPAC.

BACKGROUND

Remote Sensing is the acquisition of images of the earth by aerial or space borne vehicles with various types of sensors and a Geographic Information System (GIS) is the application where the data from remote sensing is most effectively stored and manipulated. A GIS should contain and relate both the spatial and tabular data and should provide users with the ability to obtain information by the query of spatial and tabular objects.

GIS have become essential tools for member governments where accurate and timely information is needed to assist in the resource management and policy development.

Remote sensing is closely linked with GIS and in many cases they cannot be separated.

REMOTE SENSING

Several pilot projects have been undertaken at SOPAC to process satellite imagery and hardware and software has been acquired and developed over the last two years where the processing of such imagery is now a routine task.

The major constraint in acquiring satellite images from the main suppliers such as SPOT and EOSAT is the cost of each image which is of the order of US $2,500. A Remote Sensing User Group with representatives from the regional organisations and other groups (FFA, SOPAC, SPC, SPREP, SPT and LATICAL) has been meeting regularly via PEACESAT during the last 6 months to determine a cost effective method of data procurement and sharing as well as provide a catalogue of existing images.

Discussions with both SPOT and EOSAT have determined that a user group comprising the regional organisations could purchase a single image and share that image for an additional 15% or US $375 approx. Payment of this same 15% would enable the sharing of existing images where there are currently in excess of 50 images held by SPT in Tahiti and LATICAL in New Caledonia where SPT has data from Fiji, while LATICAL has data from Vanuatu and New Caledonia.

SOPAC has been providing assistance to Forestry, Agriculture and Mineral Resources Department in Fiji as well as arranging remote sensing workshops for the member countries. It is anticipated that future satellite imagery will be processed and made available to member countries as additional GIS data.

The *Fiji User Group Remote Sensing and GIS Newsletter* was started in November 1993 to provide a forum for exchange of ideas and information for users in Fiji and the region. It is compiled, edited and produced at SOPAC every month with a current mailing list of 300 within the region which includes regional organisations, member country representatives, other interested parties and members of Fiji's user group who meet monthly . It is anticipated that it will be an ongoing activity

GEOGRAPHIC INFORMATION SYSTEM

SOPAC has developed an organisation-wide GIS which includes the following data: coastlines, bathymetry, EEZ boundaries, survey vessel tracks, beach surveys, satellite imagery, aerial photographs, and wave energy. Some of these data sets such as vessel tracks are themselves part of management databases and include further information containing magnetic, gravity and shot point seismic data as well as catalogues of off-line mass storage media containing the actual acquired data.

All ACP member countries have been provided with the necessary computer equipment for operating and developing GIS and extensive data sets have been included with their equipment.

New and updated data will be provided on an ongoing basis and in particular there are plans to supply additional equipment so that member countries can receive the large bathymetric data sets from the SOPACMAPS survey where this data will be in a readily accessible GIS format.

There has been close cooperation with other regional organisations, in particular with the Forum Fisheries Agency in the Exclusive Economic Zone delimitation program as well as Fiji Government departments of Agriculture, Forestry, and Mineral Resources.

ASSISTANCE TO MEMBER COUNTRIES

SOPAC provides assistance to member countries in resources assessment and management, and applied environmental geoscience in ocean, coastal, and onland areas, and includes resource inventory acquisition, resource management, and coastal zone management. Field work, data management, training, and technology transfer are an integral part of most projects.

A major project has been the South Pacific Marine Resources Program which comprises seabed mapping and equipment support. The project has been funded under Lorne III of the European Community and is part of an ongoing program to assist the member countries in resource management and sustainable development.

The seabed mapping project named SOPACMAPS covered some 340,000 square km of ocean in the waters of Fiji, Solomon Islands, Tuvalu and Vanuatu and has provided imagery, bathymetry, gravity, magnetism and seismic reflection data. The data will be received at SOPAC during April and May 1994, and will be integrated with the existing GIS, and distributed to the member countries where it will be used to assist in evaluating marine minerals and hydrocarbon potential, fishing industry development, improved navigation, map production, and natural disaster prediction.

Another component of the South Pacific Marine Resources Program has been the provision of appropriate computer equipment to the member countries and together with suitable training will enable the countries to better manage their resource and related data through the use of GIS.

The data from SOPACMAPS will be distributed on CD-ROM to the member countries and other organisations and CD-ROM readers and upgraded software will be provided under an additional subproject. This new equipment will further enhance the capabilities of the member countries where funding for the sub-project has been provided by the EC.

COMMUNICATIONS

Effective communications are vital in the region where international telecommunications circuits are expensive and national telecommunications often unreliable. SOPAC plans to install a PEACESAT terminal in 1995 which will allow connection to the existing network as PEACESAT terminals are already installed in all member countries.

PEACESAT is a non commercial communications network which provides 9 simplex voice and full duplex voice/data circuits and utilizes obsolete weather satellites and low cost 3 meter dishes. The headquarters are in Honolulu and there are currently 35 ground stations throughout the Pacific. There are no transmission charges and the current cost of a ground station is US $28,000. There are plans to upgrade the service in 1995 to more effectively utilize the available bandwidth of the satellite. The 3 meter dishes will be upgraded to provide more voice and data circuits and a new series of 6 metre hubs is planned which will offer multiple sessions at the ground station and feature video and packet switching.

HARDWARE AND SOFTWARE

SOPAC has an organization-wide network which connects all users to the main file server. Users are provided with 386 and 486 PC desktops and field officers with 486 notebooks. The file server has Novell Netware 3.11 as the network operating system while users have Windows for Workgroups 3.11. This configuration allows sharing of corporate and group data and provides resource sharing. The corporate standard software is Microsoft Office and the corporate database is Microsoft Access which is connected to MapInfo as the mid level GIS. The high end GIS is Arc/lnfo and ERDAS. All software with the exception of Arc/Info and ERDAS is Microsoft Windows based and other tools include AutoCAD, Corel Graphics and Surfer.

A SUN workstation is used for data conversion and has peripheral devices which accept all major mediums including CD-ROM, tapes, cartridges.

The system is extremely flexible and as an example, a user in one section can query the central GIS and send output to a colour printer in another section.

The equipment provided to member countries are PC desktop computers with identical software to that utilised at SOPAC where Maplnfo is the GIS of choice.

SUMMARY

SOPAC has been actively involved in remote sensing and acquiring and processing satellite images over the past two years as well as developing and operating a comprehensive GIS. This organization is assisting member country governments and other regional organisations as well as the commercial sector in the development of this technology and provision of services. Specialist areas include coastal zone management, offshore minerals, offshore hydrocarbons, survey cruise coordination, and map and publication production. The focus of future direction is sustainable development and climate change monitoring.

The main points are:

(i) SOPAC has developed an organization-wide information system, of which GIS is a major component. This information system named the SOPAC Regional Data Centre is currently accessible to all staff and is planned to be accessible to the member countries in 1995 through the PEACESAT communications network.

(ii) The Wave Energy Program has provided ocean wave data from waverider buoys located at six locations in the Pacific. These data were collected by satellites and stored daily by ARGOS in its databank in Australia from where it was downloaded by SOPAC.

(iii) Deepsea mineral surveys have been undertaken and data have been analyzed by SOPAC and maps produced.

(iv) Several member countries have been supplied with equipment and training. The equipment includes 486 PCs and mid range GIS.

(v) SOPACMAPS swath seafloor survey has been completed and data will be received during April and May 1994 from the contractor and integrated into SOPAC's GIS. Selected data will then be distributed on CD-ROM to member countries and other organisations. Member countries will receive equipment upgrades.

(vi) A GIS and Remote Sensing Newsletter is published monthly to serve the needs of the Fiji and the South Pacific Region.

(vii) A formal user group consisting of representatives from FFA, SOPAC, SPREP, SPC, LATICAL and SPT is being established to purchase satellite images, with an additional copyright being paid so that the image becomes shared among the community of users.

ACRONYMS

EC	European Community
EOSAT	Earth Observation Satellite Company (Landsat data)
FFA	Forum Fisheries Agency
JICA	Japanese International Cooperation Agency
LATICAL	LAboratoire de Traitement d'Image CALédonien
NORAD	Norwegian Agency for International Development
SOPAC	South Pacific Applied Geoscience Commission
SPC	South Pacific Commission
SPOT	Système Pour l'Observation de la Terre
SPREP	South Pacific Regional Environment Program
SPT	Station Polynésienne de Télédétection

CONCLUDING REMARKS BY THE HONOURABLE SENATOR HARCOURT LEWIS, MINISTER OF THE ENVIRONMENT, HOUSING AND LANDS BARBADOS, APRIL 22, 1994

Mr. Chairman, Representatives of the Government of Canada, the Intergovernmental Oceanographic Commission (IOC) and the United Nations Environment Programme (UNEP), Participants, ladies and gentlemen:

Let me first extend a warm welcome to you all on behalf of the Government and people of Barbados, even though this workshop is now approaching its final stages. I wish to assure you that my Government is heartened by the decision of the organizers of the programme to convene the workshop here, for I am sure that the outcome of your deliberations will assist in the design of strategies geared to the achievement of sustainable development. And as you are all aware, this will be the focus of our activities over the next two weeks, when the Global Conference on SIDS takes place here in Barbados.

This workshop could not therefore have been convened at a more opportune time. For more and more, it is becoming abundantly clear that our survival depends on prudent management of all of our resources, both natural and man-made. And in this process, we must employ the best available tools, as long as they are appropriate and relevant to our circumstances. It is for this reason that I am firmly of the view that state-of-the-art tools such as Geographic Information Systems have a vital role to play in the improvement of our data management capability, and in the provision of decision-making support.

I am particularly pleased that the theme of the workshop is GIS applications in coastal management of small island states. As in the case of any other small island developing state, Barbados is fully aware of the importance of its coastal resources to national economic and social development. We exploit our coastal and marine zone in a variety of ways: for fishing, housing, industry (e.g. flour milling, cement manufacture, rum and petroleum refining), tourism and recreation, to name a few. In addition, critical infrastructure such as our air and sea ports are located on the coast.

It is against this background that my Government has been actively seeking to ensure, that the resources of this country are exploited and managed in a sustainable way. And this is precisely why the Government has committed a substantial body of resources for the implementation of a comprehensive coastal zone management project for the island. The current phase of that programme, which commenced in 1991, is being funded jointly by the Government of Barbados and the Inter-American Development Bank to the tune of approximately US $7.3 million. This programme has four main components:

- (i) A technical, scientific study of various processes and phenomena which impact on the coastal system:
- (ii) The construction and evaluation of selected pilot projects, to determine their effectiveness and applicability as coastal protection measures, in the context of our local conditions;
- (iii) An institutional strengthening component which evaluates the efficiency of the current arrangements for coastal resources management, including existing legislative provisions. Indeed, at the present time the Attorney General's Chambers are currently in the process of finalising a Coastal Zone Management Bill and a Marine Pollution Control Bill, for submission to Parliament.
- (iv) The preparation of an effective, implementable Coastal Zone Management Plan for Barbados.

Ladies and Gentlemen, I would be the first to admit that like many other states, both developed and developing, we could have been more careful in the exploitation of our coastal resource base. We have knowingly and unknowingly contributed to the loss of some of our coral reefs and most of our coastal wetlands; and in the last few decades we have witnessed some degree of erosion of some of our finest beaches. To reverse these processes, we require a reliable, wide-ranging, scientific information base, for prudent decision-making. We can think of no potentially better tool than the Geographic Information System, as a means of storing, retrieving and processing the required mass of data, efficiently. Thus, it is my earnest hope that this workshop will be regarded by all participants, as an integral part of the process of capacity building and technology transfer, in small island developing states. Indeed, Agenda 21 of the Rio Declaration specifically identifies the application of appropriate Geographic Information Systems and remote sensing technologies, as vital components of sustainable development strategies. In a sense, we are therefore witnessing positive action in your workshop to implement that commitment given at Rio.

Permit me however, to sound a note of caution at this point. While we recognize the versatility of the technology, let us not forget that it does not constitute an end in itself, but simply a means to an end. We must still continue to focus on quality research, using 'traditional' methods, as our primary means of obtaining reliable data that can withstand rigorous, scientific scrutiny. However useful a tool the Geographic Information System might be, it will not enhance the quality of decision-making, if it is fed data of dubious quality. I therefore wish to suggest that any such technology transfer and capacity building in small island developing states, must be pursued on two fronts. For while training in the use of the 'new' technology proceeds, there must be a simultaneous commitment to improvement in data quality control. Experience in Barbados has taught us that this is the sensible route to travel .

I suspect that by now you would have realised that Geographic Information Systems technology has been warmly embraced by my Ministry. We are acutely aware that Government's commitment of taxpayers' money is based firmly on the conviction that there will be a better quality product. In these tough economic times and with a growing list of priorities, Government must allocate funds where it will be assured of getting best value for its money. Happily, in the case of the Coastal Conservation efforts, our confidence has been well placed. The Arc CAD system which the Coastal Conservation Unit currently uses, had become a functional and indispensable tool for routine data management, analysis, modelling and graphic presentation of spatial information. In fact, I wish to take this opportunity to extend an invitation to all who will be remaining for the SIDS conference, to view the Unit's exhibit and GIS slide show, at the Village of Hope at the Community College.

Ladies and Gentlemen, it is heartening to note the large number of issues you have dealt with during the last three days. They cover areas ranging from data management needs, evaluation of GIS systems, strategies for building and maintaining GIS data bases to capacity building and technology transfer. But what I think is most gratifying, is the fact that the discussion has remained focussed on the needs of small island developing states. I therefore urge you to use appropriate, available fora to ensure that the critical recommendations of this workshop are disseminated during the coming two weeks, and beyond.

Ladies and Gentlemen, it is my understanding that all the main objectives of the workshop have been achieved, some to a lesser extent than others. I have been further informed that it was never the expectation of the organizers, that you could become a graduate class of 'GIS and Coastal management experts', after only three days. Nevertheless, I am confident that you are now in a much better position to evaluate critically the relevance and applicability of the available tools to your own individual island situations.

This alone will be useful, since as resource managers you will all be faced inevitably with the problem of allocating scarce resources for maximum effect.

Finally, I believe that we in the Caribbean region, as well as our colleagues from the Pacific who are present with us, owe a debt of gratitude to the Department of Fisheries and Oceans, Canada, for taking the initiative to convene this workshop. I confidently expect that this exercise will be the beginning of a process, that will prove beneficial to all parties. Sustainable development is a goal that can best be achieved through the exchange of ideas and relevant experiences, because, through this medium, costly mistakes can be avoided, especially by countries which can least afford them.

Ladies and Gentlemen, I thank you.

No.	Title	Languages
52	SCOR-IOC-UNESCO Symposium on Vertical Motion in the Equatorial Upper Ocean and its Effects upon Living Resources and the Atmosphere; Paris, 6-10 May 1985.	E
53	IOC Workshop on the Biological Effects of Pollutants; Oslo, 11-29 August 1986.	E
54	Workshop on Sea-Level Measurements in Hostile Conditions; Bidston, UK, 28-31 March 1988	E
55	IBCCA Workshop on Data Sources and Compilation, Boulder, Colorado, 18-19 July 1988.	E
56	IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Cleveland, Australia, 24-30 July 1988.	E
57	IOC Workshop on International Co-operation in the Study of Red Tides and Ocean Blooms; Takamatsu, Japan, 16-17 November 1987.	E
58	International Workshop on the Technical Aspects of the Tsunami Warning System; Novosibirsk, USSR, 4-5 August 1989.	E
58 Suppl.	Second International Workshop on the Technical Aspects of Tsunami Warning Systems, Tsunami Analysis, Preparedness, Observation and Instrumentation. *Submitted Papers*; Novosibirsk, USSR, 4-5 August 1989.	E
59	IOC-UNEP Regional Workshop to Review Priorities for Marine Pollution Monitoring Research, Control and Abatement in the Wider Caribbean; San José, Costa Rica, 24-30 August 1989.	E, F, S
60	IOC Workshop to Define IOCARIBE-TRODERP proposals; Caracas, Venezuela, 12-16 September 1989.	E
61	Second IOC Workshop on the Biological Effects of Pollutants; Bermuda, 10 September-2 October 1988.	E
62	Second Workshop of Participants in the Joint FAO-IOC-WHO-IAEA-UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region; Accra, Ghana, 13-17 June 1988.	E
63	IOC/WESTPAC Workshop on Co-operative Study of the Continental Shelf Circulation in the Western Pacific; Bangkok, Thailand, 31 October-3 November 1989.	E
64	Second IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Phuket, Thailand, 25-31 September 1989.	E
65	Second IOC Workshop on Sardine/Anchovy Recruitment Project (SARP) int he Southwest Atlantic; Montevideo, Uruguay, 21-23 August 1989.	E
66	IOC *ad hoc* Expert Consultation on Sardine/Anchovy Recruitment Programme; La Jolla, California, USA, 1989.	E
67	Interdisciplinary Seminar on Research Problems in the IOCARIBE Region; Caracas, Venezuela, 28 November-1 December 1989.	E (out of stock)
68	International Workshop on Marine Acoustics; Beijing, China, 26-30 March 1990.	E
69	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Leningrad, USSR, 28-31 May 1990.	E
69 Suppl.	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Leningrad, USSR, 28-31 May 1990.	E
70	IOC-SAREC-UNEP-FAO-IAEA-WHO Workshop on Regional Aspects of Marine Pollution; Mauritius, 29 October - 9 November 1990.	E
71	IOC-FAO Workshop on the Identification of Penaeid Prawn Larvae and Postlarvae; Cleveland, Australia, 23-28 September 1990.	E
72	IOC/WESTPAC Scientific Steering Group Meeting on Co-Operative Study of the Continental Shelf Circulation in the Western Pacific; Kuala Lumpur; Malaysia, 9-11 October 1990.	E
73	Expert Consultation for the IOC Programme on Coastal Ocean Advanced Science and Technology Study; Liège, Belgium, 11-13 May 1991.	E
74	IOC-UNEP Review Meeting on Oceanographic Processes of Transport and Distribution of Pollutants in the Sea; Zagreb, Yugoslavia, 15-18 May 1989.	E
75	IOC-SCOR Workshop on Global Ocean Ecosystem Dynamics; Solomons, Maryland, USA, 29 April-2 May 1991.	E
76	IOC/WESTPAC Scientific Symposium on Marine Science and Management of Marine Areas of the Western Pacific; Penang, Malaysia, 2-6 December 1991.	E
77	IOC-SAREC-KMFRI Regional Workshop on Causes and Consequences of Sea-Level Changes on the Western Indian Ocean Coasts and Islands; Mombasa, Kenya, 24-28 June 1991.	E
78	IOC-CEC-ICES-WMO-ICSU Ocean Climate Data Workshop Goddard Space Flight Center; Greenbelt, Maryland, USA, 18-21 February 1992.	E
79	IOC/WESTPAC Workshop on River Inputs of Nutrients to the Marine Environment in the WESTPAC Region; Penang, Malaysia, 26-29 November 1991.	E
80	IOC-SCOR Workshop on Programme Development for Harmful Algae Blooms; Newport, USA, 2-3 November 1991.	E
81	Joint IAPSO-IOC Workshop on Sea Level Measurements and Quality Control; Paris, 12-13 October 1992.	E
82	BORDOMER 92: International Convention on Rational Use of Coastal Zones. A Preparatory Meeting for the Organization of an International Conference on Coastal Change; Bordeaux, France, 30 September-2 October 1992.	E
83	IOC Workshop on Donor Collaboration in the Development of Marine Scientific Research Capabilities in the Western Indian Ocean Region; Brussels, Belgium, 12-13 October 1992.	E
84	Workshop on Atlantic Ocean Climate Variability; Moscow, Russian Federation, 13-17 July 1992.	E
85	IOC Workshop on Coastal Oceanography in Relation to Integrated Coastal Zone Management; Kona, Hawaii, 1-5 June 1992.	E
86	International Workshop on the Black Sea; Varna, Bulgaria 30 September - 4 October 1991.	E
87	Taller de trabajo sobre efectos biológicos del fenómeno «El Niño» en ecosistemas costeros del Pacífico Sudeste; Santa Cruz, Galápagos, Ecuador, 5-14 de octubre de 1989.	S only (Summary in E, F, S)
88	IOC-CEC-ICSU-ICES Regional Workshop for Member States of Eastern and Northern Europe (GODAR Project); Obninsk, Russia, 17-20 May 1993.	E
89	IOC-ICSEM Workshop on Ocean Sciences in Non-Living Resources; Perpignan, France, 15-20 October 1990.	E
90	IOC Seminar on Integrated Coastal Management; New Orleans, USA. 17-18 July 1993.	E
91	Hydroblack'91 CTD Intercalibration Workshop; Woods Hole, USA. 1-10 December 1991.	E
92	Réunion de travail IOCEA-OSNLR sur le Projet « Budgets sédimentaires le long de la côte occidentale d'Afrique » Abidjan, Côte d'Ivoire, 26-28 juin 1991.	F
93	IOC-UNEP Workshop on Impacts of Sea-Level Rise due to Global Warming. Dhaka, Bangladesh, 16-19 November 1992.	E
94	BMTC-IOC-POLARMAR International Workshop on Training Requirements in the Field of Eutrophication in Semi-Enclosed Seas and Harmful Algal Blooms, Bremerhaven, Germany, 29 September - 3 October 1992.	E
95	SAREC-IOC Workshop on Donor Collaboration in the Development of Marine Scientific Research Capabilities in the Western Indian Ocean Region; Brussels, Belgium, 23-25 November 1993.	E
96	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; Zanzibar, United Republic of Tanzania, 17-21 January 1994.	E
96 Suppl. 1	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; *Submitted Papers* 1. Coastal Erosion; Zanzibar, United Republic of Tanzania 17-21 January 1994.	E
96 Suppl. 2	IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts; *Submitted Papers* 2. Sea Level; Zanzibar, United Republic of Tanzania 17-21 January 1994.	E
97	IOC Workshop on Small Island Oceanography in Relation to Sustainable Economic Development and Coastal Area Management of Small Island Development States; Fort-de-France, Martinique, 8-10 November, 1993.	E
98	CoMSBlack '92A Physical and Chemical Intercalibration Workshop; Erdemli, Turkey, 15-29 January 1993.	E
99	IOC-SAREC Field Study Exercise on Nutrients in Tropical Marine Waters; Mombasa, Kenya, 5-15 April 1994.	E