A MICROCOMPUTER ENVIRONMENTAL

DATA BASE SYSTEM

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PART 1

INTRODUCTION

INTRODUCTION

1.0. The Problem: The Difficulties of Using Environmental Data for Emergency Oil-Spill Response, Oil-Spill Contingency Planning, and Regional Assessments

This document describes an environmental data base system developed 1) to minimize the impacts of marine and coastal oil pollution by aiding emergency response, and 2) to provide information for oil-spill contingency planning and for regional environmental assessments.

1.0.1. Marine and Coastal Oil Pollution

In a global context, it is useful to recall that although everyone agrees that petroleum is too valuable a source of energy to waste by fouling the ocean with it, and that every possibility for reducing its introduction into the ocean must be explored, an estimated 6 to 12 million cubic meters of crude oil and refined hydrocarbons reach the sea annually (National Academy of Sciences, 1975).

Oil at sea and on shorelines immediately suggests dramatic events such as the grounding of the "Torrey Canyon" on March 18, 1967 (13,680 m^3 of crude oil released northeast of the Scilly Islands); the "Arrow" on February 4, 1970 (11,500 m^3 of Bunker C, Chedabucto Bay, N.S.); the "Metulla" on August 9, 1974 (62,000 m^3 of crude oil in the Strait of Magellan); the "Golden Robin" on September 14, 1974 (160 m^3 of Bunker C, Baie des Chaleurs, P.Q.);

the "Amoco Cadiz" on March 17, 1978 (256,000 m^3 of light crude, Brittany); the "Lee Wang Zing" on December 25, 1978 (1,150 m^3 of fuel oil, Dixon Entrance, B.C.); or the "Kurdistan" on March 15, 1979 (7,700 m^3 of fuel oil in Cabot Strait).

A closer examination of statistics like the above reveals that 1) spills due to tanker accidents are occurring less frequently in recent years (Smets, 1983); and 2) although spectacular, these tanker accidents (of which 3,183 took place worldwide between 1969 and 1973; Gerlach, 1981) account for less than 3% of the total input of hydrocarbons into the oceans (National Academy of Sciences, 1975). River and urban runoff contributes the most (31%), normal tanker operations (excluding accidents) contribute 22%, all other transportation modes 10%, natural seepage and atmospheric fallout about 10% each, coastal oil ports and refineries 13%, and offshore petroleum exploration and production 1%. The resulting environmental damage depends not only on the absolute amounts and on the source of the oil, but also on the existing environmental conditions.

1.0.2. Governmental Regulatory Requirements: Environmental Assessments and Contingency Plans

Despite their low contribution to the overall ocean pollution, oil companies involved in offshore petroleum exploration can cause severe concentrated impacts and must operate within strict environmental restrictions. In Canada, since 1975, all oil companies proposing to drill offshore must submit a major document generally called "Environmental

Assessment" or "Environmental Impact Statement". These documents describe the physical, biological, and human characteristics of the region surrounding the proposed drilling site; the potential environmental and socio-economic effects of both routine drilling activities and possible accidents; and the mitigating measures that will be implemented to reduce all undesirable impacts. Environmental assessments, besides reflecting the philosophy and policies of individual companies, are also compilations of all available pertinent publications and, when possible, the results of unpublished research programs related to the area of interest. In areas where there are important data gaps, the proponent may be asked to carry out field studies programs before resubmitting its environmental assessment or impact statement.

These field programs can be of considerable importance and may involve several companies with joint interests or, if the issues are of national importance, a joint government-industry effort. Two recent examples of major field studies are the Offshore Labrador Biological Studies (OLABS) program (3.4 M$, 1978 to 1982, 13 oil companies), and the Eastern Arctic Marine Environmental Studies (EAMES) program (12 M$, 1976 to 1980, government - 4 oil companies; Arctic, 1982).

Before commencing drilling, the proponent must also submit to the offices of the Canadian Oil and Gas Land Administration (Energy, Mines and Resources) copies of detailed contingency plans. These plans describe in detail the procedures that would be followed in the event of a number of possible accidents, ranging from the loss of a supply vessel or support aircraft to a full scale blowout with the loss of well control and possible ensuing oil-spill. Like impact statements, these contingency plans are based on the compilation of a large number of environmental and logistic data.

Oil companies also have a staff of experts whose responsabilities include emergency oil-spill response. These persons must be able to review rapidly large numbers of the most complete and up-to-date environmental data within their field of expertise, for all areas in which their company is active in the offshore. Their competence and ability to respond rapidly is tested yearly during unannounced governmental exercises simulating real oil-spills.

The importance of environmental data bases to oil companies should be clear from the above. It can even be said that offshore exploration activities depend largely on the ability of oil companies to acquire, maintain updated, and use efficiently complex environmental data bases.

1.0.3. Deficiencies of Non-Computerized Environmental Data Bases

All present non-computerized environmental data bases consist essentially of maps and reports. These maps and reports are often associated with three major problems: 1) they are all difficult and costly to produce and maintain updated, 2) they do not lend themselves to conducting rapid regional evaluations or assessments, and 3) maps are often limited because of their scale.

The cost of producing and the difficulties of keeping data bases updated are due to the way they are prepared. Maps require a lot of time to be drafted and are invariably very expensive to print. Reports are generally not updated, instead, new ones are usually produced only after sufficient new information is obtained. After several years, data bases that have been kept updated become very complex and disjointed. New maps may replace old ones completely or only in parts, sometimes more recent studies are more detailed and their results are displayed using a different scale or projection.

These characteristics and the complexity of the information make maps and reports very difficult to use for regional assessments, contingency planning, and more importantly, for emergency oil-spill response. In general, one uses data differently for regional assessments and contingency planning, than for emergency oil-spill response. In the first case, one needs to know, usually in a relatively leisurely manner, which characteristics are important, and where they are located within a large area such as Labrador, the Eastern Arctic, or the West Coast. The situation is very different in the case of an oil-spill response. Even in the event of a very large oil spill, the oil would threaten only part or parts of the overall region for which a data base exists. Consequently, in an emergency situation, one needs to be able to focus immediately on the threatened area or areas and review their corresponding environmental data very rapidly.

In both cases of regional assessments and oil-spill response, the user has specific questions in mind. To obtain the answers to these questions, he will have to undertake a time-consuming search through atlases, maps, their updated additions or deletions, and numerous reports. Such an exercise often results in restraining one's curiosity and in discouraging the user from formulating new questions. In the case of regional assessments, these difficulties lead to a lack of an overall understanding of the characteristics of the region. These difficulties become much more critical in the event of a spill when questions must be answered and decisions must be made sometimes within minutes.

The last problem associated with present non-computerized data bases, that of scale, is much less obvious but much more frustrating. In preparing maps to illustrate the distribution of environmental data, one has to decide on a scale. The choice of a scale is governed primarily by the amount, complexity, and level of detail of the information to be displayed; the overall size of the region to be mapped; and the maximum number of maps that can be produced and handled conveniently. This last point depends very much on the personnel and budgetary resources allocated to the project. In general, limitations on these resources or, more simply, the need to restrict the number of maps for reasons of convenience force the mapper to select as small a scale as possible. Unfortunately this results in a reduction of the level of detail and quality of data.

The following example illustrates this point. One excellent approach (low-altitude coastal videotaping; APOA Review, 1982) used to analyse shorelines for oil-spill response allows the interpreter to describe very accurately the characteristics of coastal segments as short as 10 to 50 meters. Although short, such coastal segments may have very important consequences in an oil-spill response; they may be characterized by an excellent sea access to the shoreline or may consist in a very good helicopter landing site. At a scale of 1 : 50,000 a 50 m shoreline segment occupies 1 mm on a map. At a scale of 1 : 250,000 such a coastal segment occupies only 0.2 mm on a map and it becomes impossible to describe features in such a small amount of space. Yet, if the overall study area is large, one may have to use a 1:250,000 scale to restrict the number of maps. To overcome this problem, the present practice consists in grouping together adjoining coastal segments until their combined length exceeds a predetermined minimum mappable size. This map unit is then described in terms of the average characteristics of its components and the value of the original information is lost. In studies covering large regions, this results in a series of relatively vague descriptions of long (in the field) coastal segments when in reality, these segments are made up of shorter units of known contrasting characteristics.

The need to restrict the number of maps also imposes another very fundamental drawback, that is, the necessity to let boundaries of map units denote a transition in more than a single parameter at a time. For example, in producing a coastal map, one may wish to describe the features of the hinterland, those of the backshore, the foreshore, and the nearshore. Ideally, each of these categories of data should be described by a separate set of maps. In practice however, because this would require too many maps, one has to 1) group the data parameters together, and 2) use a subjective evaluation to define the boundaries of map units based on the variations of these data parameters. From that point on, individual map units imply a certain amount of subjectivity which may or may not suit particular applications or uses of the map.

These difficulties are illustrated in Figure 1-1. In this case, because the overall region (Labrador) is large, the author has selected a scale of 1 : 250,000. To display the information in a legible manner, short consecutive and often very different coastal segments have been grouped together to form units (deep red, pale red, and green) that can be mapped and displayed conveniently at this scale. The descriptors of these units reflect this grouping, for example mU-cBg:wIbb means a moderately sloping unconsolidated backshore with 20 to 80% of continuous gravel beach and more than 80% of wide intertidal flat with a boulder barricade. Maps like this one present not the original data but a subjective compilation of the original information. As such, they may be well suited to obtain a general understanding of a large study region. However, for emergency oil-spill response, where one needs information about as many different aspects of the coastline in as much detail and precision as possible, this type of map is of limited usefulness.

The coding of descriptions used on maps can also present a problem. In Figure 1-1, the situation is not too bad because the coding system is mnemonic and, with a bit of learning, one can read and understand the codes easily. Other systems, as the one illustrated in Figure 1-2, are hopelessly complicated and a considerable amount of time is required to decode the coastal descriptors. In this particular example, an accompanying document of 25 pages is required to understand the codes used as

Figure 1-1

Example of a typical shoreline geomorphology map. See text for discussion.

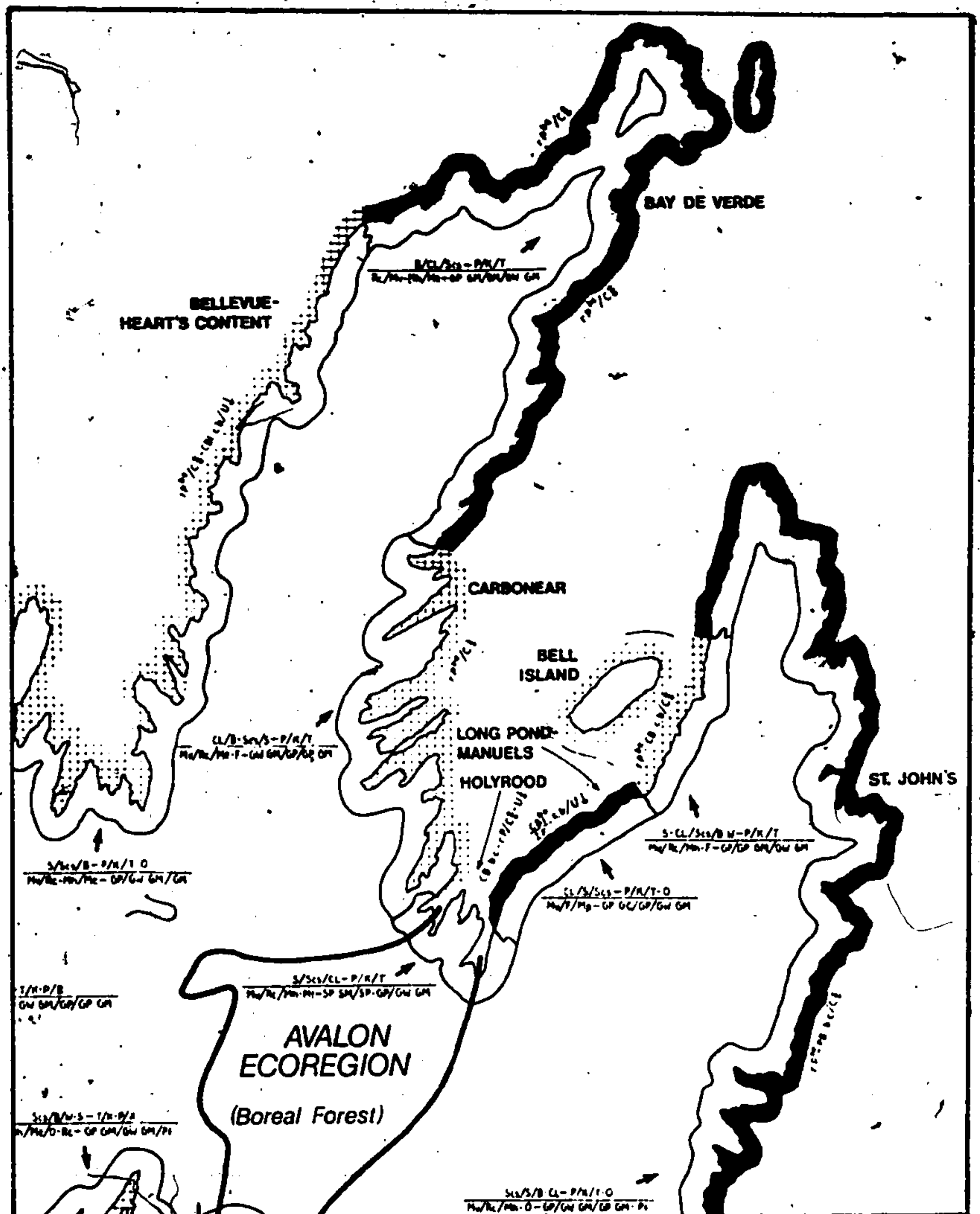


Figure 1-2

Example of coastal map. See text for discussion.

descriptors. This system is definitely not well suited for emergency spill response, and may be of questionable value for many other applications.

1.1. Purpose and Scope of Present Work

This study describes a microcomputer environmental data base system that alleviates the problems of high cost, lack of resolution, and difficulty of use associated with maps and reports. The system was designed specifically for emergency oil-spill response, oil-spill contingency planning, and the compilation of regional assessments.

The primary objectives of this system were defined early during the work. These objectives are: 1) the data base must be truly geographical in nature, that is, one in which environmental data can be stored, displayed, updated, and retrieved according to their spatial location defined in Universal Transverse Mercator (UTM) or latitude-longitude coordinates (see section 2.0.1.); and 2) it must overcome the difficulties associated with maps and reports.

For emergency oil-spill response, the following options were implemented:

1) A subset of any size or location within a larger region can be defined according to its UTM or latitude-longitude limits and displayed rapidly on a moderate resolution color monitor. The display consists in all coastlines, shorelines of inland lakes, and if requested, topographic or bathymetric contours of the area selected. A UTM or latitude-longitude grid can be superimposed

on the image.

2) A complete list of only those environmental parameters that are present in the area specified is displayed on a separate cathode-ray-tube (CRT) terminal. This list is displayed as a series of menus for the use of the operator.

3) Parameters from this list can be selected either singly or in any combination using the logical operators AND, OR, and NOT. Once selected, their spatial distribution can be superimposed on the shorelines displayed on the color monitor. Textual material, if present can also be retrieved and displayed on the CRT terminal, or printed on paper.

For oil-spill contingency planning and regional assessment, the data base system can be used essentially as above in order to:

1) examine the presence, spatial distribution, and interrelationships of the different data parameters of any subarea or of the complete study area;

2) use the capability of the system to combine information using logical operators and to display the results on a color monitor to compose maps that best illustrate the environmental conditions of the region under study;

3) produce good quality maps directly from the data base by the use of a plotter; and

4) perform analyses of relative abundance (as defined by the frequency of occurrence, total length, or total area) of different data parameters taken either singly or in combination, as well as measurements of degree of association between individual parameters.

1.1.1. Hardware

To meet the objectives described above, the hardware selected has to satisfy the following requirements:

1) A large amount of external memory is needed to store the geographical and environmental data. This external memory should be capable of being expanded.

2) A rapid data transmission (including storage and retrieval) is required to access data efficiently.

3) Moderate resolution, multi-color graphic capabilities are required to display complex images.

4) The computer itself should have good computational power, fast response for interactive use (Hathaway and O'Connell, 1983; Hantman, 1970) and should be easy to interface with the peripherals required for this project (color monitor, CRT terminal, printer, digitizer, and plotter).

These requirements and the relatively low budget that could be allocated to this project (funded solely by the author) led to the selection of a dedicated microcomputer as opposed to using a large mainframe or minicomputer. A detailed survey of the systems available was undertaken at the beginning of this project to evaluate their capabilities, potential for expansion, graphic capabilities, reliability, and costs.

This survey indicated that the Apple II microcomputer, and other similar ones, have low hardware cost. However, they also have limited computational and graphic capabilities, low graphic resolution, borderline response time, and limited expandability.

Representatives of somewhat more sophisticated systems are the Cromemco System III and the North Star Horizon. The Cromemco is expandable, it offers a wide selection of peripherals and software packages, and has good graphic capabilities. It is however relatively expensive, and it has a limited graphic resolution. In fact, the resolution of its graphics depends entirely on the number of colors required, each time the number of color is doubled, its resolution decreases by half.

The North Star Horizon system was finally selected because of its fast response time, ease of interfacing with any peripheral compatible with S-100 bus microcomputers, and capability to produce excellent graphics when used in conjunction with a Scion Microangelo color graphic system.

The hardware selected consists of a North Star Horizon, four megahertz, Z80A based microcomputer with two quad density, five and a quarter inch diskette drives, 64 Kbytes of random access memory, and an 18 Mbytes Winchester disk drive. A Soroc IQ120 terminal and a Houston Instrument Complot 7048 digitizer were selected to input data. Initially, an Epson MX-100 dot matrix printer, an Hitachi 19 inch red-green-blue (RGB) monitor, and a Scion Microangelo graphic system were selected to display the data. The graphic system is expandable and it was obtained first with four colors including a color mixer board and two Z80A based microcomputer boards with 32 Kbytes of display memory each.

The use of this data base system was contracted early in its development (Strong, 1982) and income generated by these contracts enabled further expansion. A North Star 13.4 Mbytes tape backup system was selected to provide a secondary means of storing information normally handled by the hard disk. This was necessary as it soon became evident in the course of this work that the hard disk alone would be insufficient to store the geographical and environmental data of the various regions under consideration. A second North Star Horizon computer system was selected as back-up for the first main one to provide the required assurance that the system could be used in the event of an emergency. A Calcomp 945 beltbed plotter was selected to produce good quality multicolor maps and the graphic capabilities were expanded by obtaining a light pen and six additional Scion Microangelo boards. The light pen enables the operator to interact with the color monitor and the additional graphic boards can display simultaneously 256 colors from a choice of 16 million possibilities. The graphic system also allows data to be displayed as eight separate transparencies.

1.1.2. Software

Several operating systems and programming languages are available for the North Star Horizon microcomputer. The CP/M and HDOS disk operating systems were selected for this project. All system programming and alterations were done in CP/M assembler and the software for the system itself was programmed in Fortran-80.

1.2. Existing Approaches

Although computers have been used to process and display geographic information only during the last 20 years (Douglas, 1982), a very large amount of work and research has been done and has been reported in a number of journals such as the American Cartographer, Cartographica, The Cartographic Journal, Geo-Processing, Computers and Geosciences, Journal of the International Institute for Aerial Survey and Earth Sciences; textbooks; and numerous conference proceedings.

It is possible to distinguish two major types of endeavours: one in which computers are used to automate or assist in the production of maps (computer assisted cartography); and one in which computers are used to store, analyse, and display spatially ditributed data (computer mapping or geographic information processing) (Taylor, 1980 a; Tomlinson, 1975 a).

In the first case, the intent is to use computers to control the production of maps which are essentially not different in style, design, or content from those produced by conventional methods. For example, computer assisted cartography is often used to speed up the production of topographic maps (Harris, 1973 a and b); nautical charts (Evangelatos, 1983, 1981; Gean, 1983; Strewig et al, 1983; and Furuya, 1973); or cadastral maps (Bradley, 1984, 1981; and Somers, 1984).

In the second case, the emphasis is on the analysis and manipulation of data rather than on the production of maps. High standards of precision are not always desired when maps are produced; however, the computer enables the manipulation and analysis of geographic data to answer specific questions. This type of endeavour has been used for many applications, including coastal assessment (Ader and Stayner, 1982); environmental assessment (Audet and Galanos, 1983; Batkins and Gustafson, 1982;

Ehler et al, 1982; Rowland et al, 1982; and Spencer and Krebs, 1982); analysis and display of socio-economic (Cote, 1983; Dupont et al, 1983; Porter, 1983; Marx, 1982; Mounsey, 1982; and Taylor, 1980 b) and statistical data (Rhind et al, 1984; Meehan, 1982; and Statistics Canada, 1972); and geoprocessing (Mark, 1982; Bauer and Juhasz, 1982; Gardiner, 1982; Robertson, 1982; Wastenson, 1982; and Burrough, 1980).

It is also possible to distinguish two main approaches for the encoding and processing of geographic data using gridding, including such things as quad trees and simple raster technique, and vector methods. The raster approach, which uses a grid based representation of spatial information, is advantageous because it lends itself well to current graphic devices suitable for high speed computer input and output of geographic data (Douglas, 1982; Peuquet, 1981 a and b). Algorithms for processing cartographic data in raster mode do exist (Callahan, 1983; Comeau and Holbaek-Hanssen, 1983; Goodchild and Grandfield, 1983; Edwards and Batson, 1980; and Peuquet, 1979) and are well suited for certain applications (Monmonier, 1983; and Miller, 1982). Also, a number of translation techniques enable raster based systems to process data using the more familiar vector concepts (Harris et al, 1982; Hsu and Huang, 1982; Theis, 1982; Peuquet, 1981 a and b, 1979; and Siekierska, 1980).

Traditionally, the representation and storage of spatial data has followed a vector-based method. This is partly because many features in geography are linear and hence can be well represented by series of vectors (Adams, 1982). It has also been argued that the analysis of information is best done when the information itself is structured according to the phenomenon it represents (Douglas, 1982; and Mark, 1982). This document describes a geographic information system that uses a vector mode for the input, manipulation, and output of data.

There are presently a large number of geographic information systems in existence. Some systems are of a modest scale, many are available commercially (Synagraphic Mapping System: Dougenick and Sheehan, 1975; Odyssey: Broekhuysen and Dutton, 1983; Morehouse and Broekhuysen, 1982; Gimms: Waugh and Chulvik, 1982; Waugh, 1977), and some were developed as university or government research programs (Douglas, 1983; Donnay, 1983; Statistics Canada, 1972). Because of the large number of systems in existence, only a few examples will be outlined here. These examples are geographic information systems that the author has encountered during the course of this work.

1.2.1. Canada Land Data System

The Canada Land Data System is a computer data base system that can store, manipulate, analyse, and display land resource information mainly to facilitate effective land-use planning and management at the national level. The original purpose of this system, which was initiated in 1962, was to store arable land data gathered by the Canada Land Inventory. Between 1971 and 1979, the system ceased to be solely concerned with inventory and evolved into an analysis facility with the implementation in 1974 of interactive graphic subsytems. Today the system provides advanced statistical program packages, interactive graphics enquiry facilities through a network of terminals across Canada, and improved hard-copy graphic output capabilities (Crain and MacDonald, 1983; Tomlinson, 1975 b, 1973; and Environment Canada, 1973).

1.2.2. Canadian Coastal Data Base

This system has been under development since 1981 at the Atlantic Geoscience Centre (Energy, Mines and Resources), Bedford Institute of Oceanography in Dartmouth, Nova Scotia. Its purpose is to provide a means of storing and retrieving coastal data for the whole of Canada, specially with respect to sediment availability and sediment transport. Its geographic component manipulates shorelines in terms of vectors of several tens of kilometers in length, defined by their bearing and mid-point latitude and longitude. Various types of data can be associated with these vectors (Dr. D. Forbes, Atlantic Geoscience Centre, pers. com., 1984; Dr. J.M. Sempels, Petro-Canada, pers. com., 1984).

The concept of defining shorelines in terms of vectors is probably a good approach to use when considering all coastlines of Canada. It is however too rigid and insufficiently precise to be used for spill response and regional assessments.

1.2.3. Labrador Environmental Data Archive

The Labrador Environmental Data Archive is an IBM mainframe data base system that was developed by Petro-Canada (C. Ro, Petro-Canada, pers. com., 1982; L. Davidson, Seaconsult Ltd., pers. com., 1982). This system was designed to store and retrieve engineering types of observations of ice, meteorology, and sea conditions for offshore Labrador. It provides a means of standardization of engineering observations that are subsequently used in the design of offshore drilling vessels and to model oil slick trajectories of simulated blowouts.

1.2.4. Future Trends

At present there appears to be two trends in the development of data base systems. The first trend is the idea of a mega system that will do it all. In the past, this attitude has sometimes led to the development of extremely large, expensive, complicated, and cumbersome data bases that are used only with great difficulties. The second trend results from the declining price and increasing capabilities of recent micro and minicomputers (Gerola and Gomory, 1984). This progress has enabled the creation of smaller, specific, and efficient data base systems.

PART 2

THE GEOGRAPHICAL COMPONENT OF THE DATA BASE

THE GEOGRAPHICAL COMPONENT OF THE DATA BASE

2.0. Introduction

Maps of environmental parameters show two things: 1) the nature of the data displayed, and 2) its geographical or spatial distribution. Part of the usefulness of the present microcomputer data base system is due not only to its ability to store and recall environmental data but also to its ability to associate the information with its spatial distribution.

The geographical component of the system provides the spatial framework with which the environmental data can be associated. It is created by digitizing the necessary information (the distribution of coastlines, and, if required, the shorelines of lakes and selected topographic or bathymetric contour lines) from appropriate topographic or bathymetric maps, refered to in the following sections as base maps.

The scale of the base maps together with the selected digitizing increment define the resolution of the geographical component of the data base. To avoid undesirable distortion of the base maps during digitization, copies are made on a stable mylar material by a photographic process, and these mylar copies are used on the digitizer.

To arrive at a consistent and convenient system of spatial reference, the digitizer machine coordinates are transformed to UTM and latitude-longitude coordinates (see section 2.0.1.), the two most commonly used reference systems.

Base maps made of paper always show some degree of distortion from the moment they are made. This is because the fibers making up paper shrink or expand in response to changing temperature and humidity conditions. Although physically small, these distortions can, depending on the scale of the map, introduce errors of hundreds of meters or even kilometers in the real location of geographical features. To minimize this, it is necessary to readjust the data using a series of rotations and calibrations.

Once adjusted as best as possible, the UTM coordinates forming the geographical component of the data base must be verified to ensure that they do not fall outside of the map area and that they form acceptable transitions between adjacent map sheets. Some degree of compromise is often required at this point as it is not rare to find that coastlines do not match properly across original adjacent map sheets.

To enable and optimize the selection and display of environmental data according to their spatial distribution, it is necessary to organize the list of UTM coordinates into suitable files. This is done by formatting the list of sequential UTM coordinates into a series of random access records and by creating files of indices denoting blocks of data. Similarly, to speed up the search for information, index files denoting the spatial extent of individual map sheets are also created for each major region.

2.0.1. Latitude-Longitude and Universal Transverse Mercator Coordinates

One method of specifying the location of a point on the surface of the earth consists in stating its latitude - longitude coordinate. According to this system of terrestrial coordinates, the latitude of a point can be defined as the angle between a line joining the point and the centre of the earth, and a line joining the centre of the earth and the equator; with the two lines lying in a plane that also contains the north-south axis of the earth. Latitude is normally expressed in degrees, minutes, seconds, and decimal fractions of seconds; with the suffix north or south as an integral part of the description.

The longitude of a point at the surface of the earth can be defined as the angle betwen two planes, one containing the point and the north-south axis of the earth, and the second containing the north-south axis of the earth and Greenwich, England. The intersection of planes containing the earth's axis and the surface of the earth form meridians, and the meridian passing through Greenwich is used by definition as prime meridian of longitude 0 degree. Longitude, like latitude, is expressed in degrees, minutes, seconds, and decimal fractions of seconds, from 0 to 180 degrees east or west of the prime meridian (Maloney, 1978).

Latitude - longitude coordinates are both useful and well known. Because they form a terrestrial system of reference, they impose no distortion on geographical features. However, their use for drawing maps based on a rectangular system of reference requires some form of projection or transformation of spherical coordinates into corresponding rectangular coordinates (McDonnell, 1979).

Because the earth is spherical, any representation of its surface on a flat piece of paper involves some degree of distortion (Green and Austin, 1969; Greenhood, 1964). This basic fact has given rise over the years to a large number of geometrical schemes, known as map projections, each with some advantages and some disadvantages.

One type of projection consists in dividing the earth into a number of north-south strips and projecting these strips onto a plane. In the Universal Transverse Mercator (UTM) projection, 60 such strips are used to cover the earth from latitude 80 degrees south to 84 degrees north. As the earth is 360 degrees in circumference, such a division yields zones that each have a width of six degrees of longitude. By convention, the UTM zones are numbered 1 to 60 and start at the longitude 180 degrees west. Sixteen of these zones, bearing numbers 7 to 22 cover Canada from the Pacific to the Atlantic.

Once projected onto a plane, each zone can be subdivided into a set of map sheets of convenient size. Each sheet can then be subdivided further into sections and each section is published as a map of a larger scale. In Canada, this approach yields the 1:250,000; 1:125,000; 1:50,000; and 1:25,000 map scales of the National Topographic System. By convention, the edges of most maps are selected such that they fall along parallels of latitude and meridians of longitude.

To facilitate the identification and referencing of geographical features, a rectangular grid is superimposed on each UTM zone. As these grid lines are superimposed on the zones after their projection onto a plane, the grid lines are straight and undistorted. All vertical grid lines are set parallel and all horizontal ones perpendicular to the central meridian of the zone.

Two systems are in use to specify the location of geographical features with respect to these rectangular grid lines. One is the Military System and will not be described here. In the second one, called the Civilian System, horizontal lines are designated by their distance in meters from the equator. As the southernmost point of Canada is about 4,620,000 m from the equator, all horizontal grid lines in Canada have a northing value greater than this figure. Vertical limes are measured from an imaginary line lying 500,000 m west of the central meridian of the zone. As zones never attain the full width of 1,000,000 m, no geographical location has a zero or negative easting value. In practice, this also means that the central meridian of a zone coincides with the 500,000 m easting grid line. Points to the left of this line have easting values less than 500,000 m; those to the right have easting values greater than 500,000 m.

Using this system, the full location of a point can be specified by the number of the zone in which it occurs, and its easting and northing values in meters. This approach is straightforward and as it uses only numbers, it is well suited for computer applications. Its disadvantage, however, is that it requires the use of large numbers.

2.1. Selection of Resolution

Although digitized coastlines can be obtained from several agencies (Edson, 1984; and Burkhart, 1981), the necessity for a high resolution (one point every 10 to 20 m in the field) made it necessary to implement digitization as required for specific projects.

The process of digitization allows lines to be represented by a series of Cartesian coordinates. During digitization, these coordinates are in machine units and refer to the axes of the digitizer. Unless an infinite amount of time and care could be spent in aligning the base maps onto the digitizer, the reference axes of the base maps and those of the digitizer never correspond in practice.

The resolution or distance between consecutive points of the digitizer, when used in an incremental mode (Scott, 1982), can be controlled and it is important to understand the implications of this. At its maximum resolution, the digitizer used for this work is capable of differentiating between two points separated by a distance of 0.025 mm. This distance is so small compared to the accuracy involved in the digitization itself that it is never used. A much more reasonable and appropriate increment may be 0.5 mm. Digitizing the coastlines of a map with a scale of 1:50,000 using a digitizer increment of 0.5 mm yields one point every 25 m in the field. If the scale of the map is 1:10,000, the same digitizing increment yields one point every 5 m in the field. It can be seen that the resolution of the geographical component of the data base can be controlled by the combined effects of digitizer increment and map scale.

The resolution required for a given project depends on two main factors: 1) the nature of the environmental data, and 2) the anticipated applications of the data base. For very detailed shoreline geomorphic analyses, for which accurate data exist, a resolution of 10 to 20 m in the field is commonly used. Such a resolution is not required, or for that matter justified, when the information is of a broader, less precise nature as in the case of fishing zones or migration routes. In this case, a resolution of hundreds of meters in the field may well suffice.

The selection of an appropriate resolution to suit both the nature of the data and the anticipated applications is very important. This is because the resolution controls the number of points and accordingly, the time involved in all subsequent operations. In general, most applications of this data base system required from 6,000 to 20,000 points for each map sheet to describe adequately the geographical distribution of coastlines and other major features. Applications of this data base system for areas of Labrador required 25 map sheets; for areas of the Gulf of St. Lawrence, Nova Scotia, Cape Breton, and Newfoundland 35 map sheets; and areas of the Queen Charlotte Islands, Dixon Entrance, Hecate Strait required 40 map sheets.

To ease subsequent operations, it was found useful to work at two levels of resolution for each of these major areas: a very detailed one for very accurate information (location of houses, warfs, fish plants, sea plane bases, anchorages, marshes, good shoreline access points, bird colonies...), and a more general one for regional types of data (fishing zones, migration routes, harvesting areas...).

2.2. Digitization of Base Maps

A distinct program is used to digitize shorelines, including those of islands and inland lakes, present on each base map. This program creates a file of machine coordinates corresponding to the shorelines.

In order to transform machine coordinates of the digitizer into UTM coordinates of the map, it is necessary to know the coordinates, in both systems, of at least two distinct control points. To do this, the origin of the digitizer is relocated to coincide with an origin selected arbitrarily on the base map. The UTM easting, northing, and zone of this point are then requested by the program. A second coordinate, located as far as possible from the origin, is digitized and verified for transmission errors. In the event of an error, the program requires that the operator redigitize this point. Its UTM easting, northing, and zone number are also requested by the program.

The origin and the second UTM coordinates are used to calculate the rotation angle and its direction, and the calibration factor required to translate individual machine coordinates into their corresponding UTM coordinates. The rotation is necessary because, in practice, the axes of the digitizer and those of the base map never correspond.

If the origin and the second coordinate are not digitized accurately, the entire file of coastal coordinates are affected during their transformation to UTM coordinates. In order to verify the accuracy, four test points with known UTM coordinates are digitized and their easting and northing values are requested by the progam. The easting and northing values of these four test points are calculated using their digitizer coordinates, the rotation angle, its direction, and the calibration factor. If the real UTM coordinates of these four test points as read from the base map are not sufficiently close to their calculated values, the origin, the second UTM point and the four test points can be redigitized until an acceptable accuracy has been reached.

The four corners of the base map are then digitized and their degrees, minutes, and seconds of latitude and longitude, rather than their UTM coordinates, are stored for later use. This is because the boundaries of maps are selected to coincide with specific parallels of latitude and meridians of longitude, rather than with the UTM grid lines.

The shorelines of the mainland, islands, and lakes of the base map can then be digitized. For the subsequent use of the data, it is necessary to recognize whether or not two consecutive points are part of the same entity. For example, is one point part of the mainland and the second one the beginning of an island; or are they both consecutive points of a coastline? To recognize such differences, a tag is associated with each coordinate. Each tag value corresponds to one of the twelve buttons that are present om the cursor of the digitizer. These arbitrarily selected tag values have the following significance:

6 - Coordinates with tag 6 are ignored but indicate that all subsequent data (until another tag 6 is encountered) will be considered as a block of data (see

section 2.4.3). This is useful later to break up larger amounts of data into more manageable sections.

4,5 - A coordinate with a tag 4 denotes the beginning of a transition, that is, the first point on a segment of shoreline that extends on an adjacent map sheet (in effect, on 'entering' a map sheet). All segments of shorelines which extend on adjacent map sheets are called transitions in this document. A tag 5 is used to denote the last point of a transition before 'leaving' the map sheet.

7,8 - A coordinate with a tag 7 denotes the beginning of a closed area on a map sheet, such as an island or a lake. A coordinate with a tag 8 denotes the end of such a closed feature. The coordinate of this last point will later be replaced by the coordinate of the last occurring tag 7 to close the area perfectly.

1,2,3- A coordinate with one of these tags denotes that it is part of the same coastal segment as the previous one.

9 - A coordinate with tag 9 denotes the inland end of digitization of a river. The next coordinate (with tag 1, 2, or 3) is on the opposite bank of the river. For most applications, it is unnecessary to digitize the course of rivers up to their origin.

0 - A coordinate with tag 0 indicates that the previous point and this one must be deleted because of an error made while digitizing.

- A coordinate with tag # indicates that the operator

has made an error during digitizing, and the following actions will be taken during the verification of digitizer coordinates (see section 2.3.1.): the coordinate with tag # will be ignored, and the next coordinate will be used to find among the previous 50 points, the one closest to it. This option is useful when the operator makes a mistake but does not recognize it immediately.

* - In order to minimize disk access time, the coordinates generated by the digitizer are stored temporarily in a buffer. When this buffer is full, or when a coordinate with tag * is read, the content of the buffer is sent to the output file. If the buffer is empty and a coordinate with tag * is read, the digitizing is terminated.

At this point, the digitizer machine coordinates are ready to be verified, transformed into UTM coordinates, and adjusted as necessary.

2.3. Transformation of Digitizer Machine Coordinates to Universal Transverse Mercator Coordinates

To arrive at a final series of correct UTM coordinates, it is necessary to verify the digitizer coordinates, to convert them to UTM coordinates, to adjust them to compensate for the distortions inherent in all base maps, and to verify them with respect to the limits of the base maps.

2.3.1. Verification of Digitizer Coordinates

A second distinct program is used to verify the digitizer coordinates and their associated tags. The verification performed by this program consists in the detection of transmission errors (between digitizer and computer) and of invalid sequences of tags. Deletion of some coordinates also takes place when a tag 0 or # is encountered. When a coordinate has passed these verifications successfully, it is placed in a circular buffer (Taylor, 1983) illustrated in Figure 2-1. Two pointers are used to denote the beginning and end of data in the buffer. If the buffer is full, the first element is sent to the output file, and the pointer denoting the beginning of the data is incremented, thus freeing one position in the buffer.

The machine coordinates of the points digitized are transmitted to the computer with the format shown in Figure 2-2. The program verifies that each record has 19 characters and that each field of these records are acceptable. The first character must be any one of 0 1 2 3 4 5 6 7 8 9 or #. The second and eleventh characters must be commas. The third and twelfth characters are the signs of the X and Y coordinates and must be either + or -. Characters 4 to 10, and 13 to 19 make up the X and Y values respectively, and all must be digits from 0 to 9 inclusively. If any of the above verifications fails, the coordinate containing the error is deleted from the file.

Transmission errors, although rare, can occur when the operator moves the cursor too fast while digitizing. To help in this event, the coordinates are displayed on a CRT terminal as

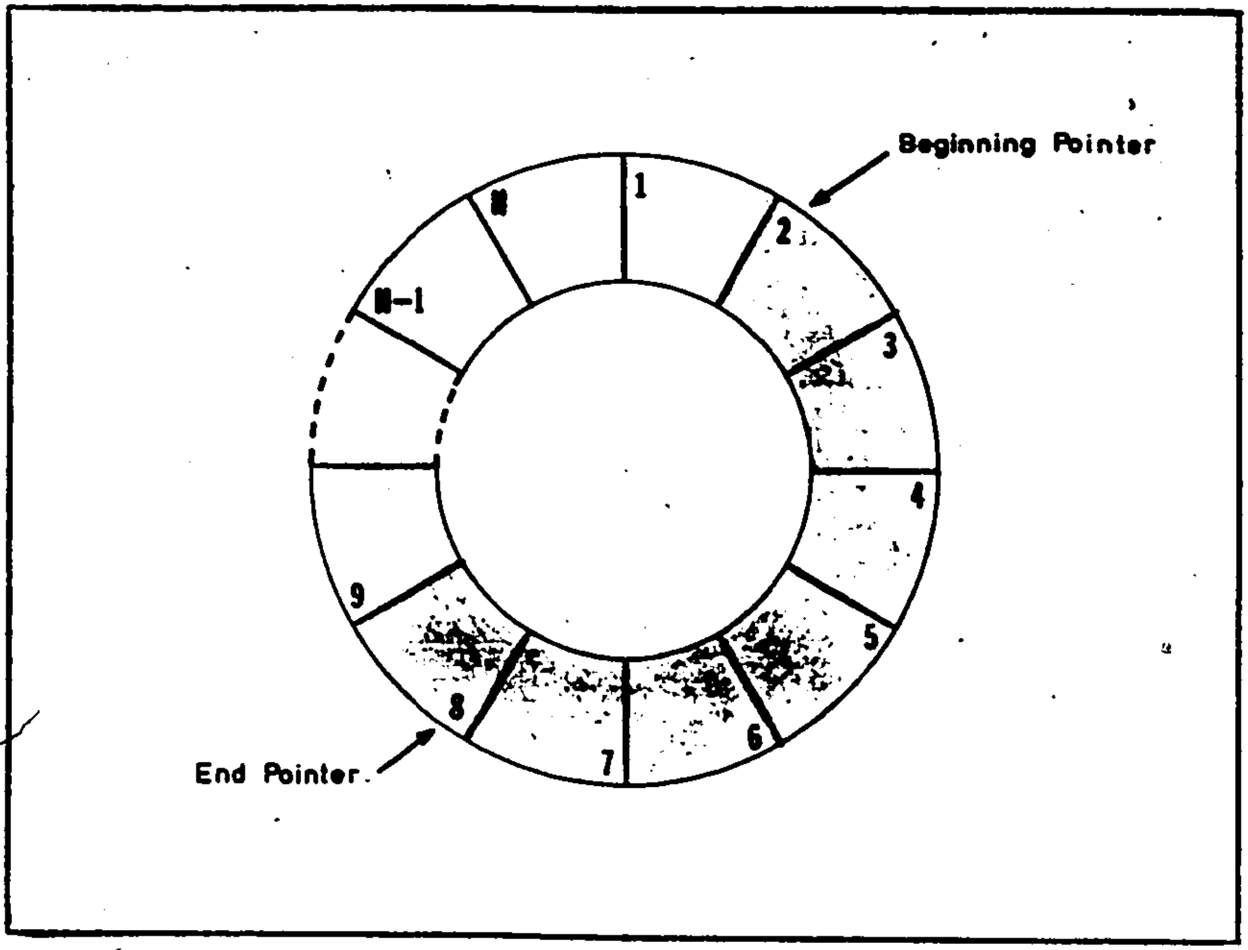


Figure 2-1

Circular buffer used in the verification of digitizer coordinates. Shaded areas indicate positions occupied by data.

tag	,	+ −	value on X axis	,	+ −	value on Y axis

Figure 2-2

Format of a coordinate as sent from the digitizer to the computer. See text for explanation of each field.

they are received from the digitizer. The operator can glance occasionally at the terminal and slow his movements when coordinates appear to be incomplete.

Two types of circumstances arise frequently when digitizing coastlines of a base map (Figure 2-3). Some lines represent limits of closed areas like islands. In this case, the first and last coordinates are almost at the same location. Other lines, called transitions, represent coastlines which continue on adjacent map sheets. These possible circumstances require that the digitizer coordinates appear in a sequence that obeys certain rules. The allowable sequence of tags is governed by the following considerations:

1: All line segments must be part of either a closed area or be located within a transition, that is, a section of coastline that continues on an adjacent map sheet.

2: When a closed area or a new transition begins, it must be terminated before another closed area or transition can be digitized.

3: Coordinates with tags 1 2 3 or 9 cannot appear between islands or between transitions.

4: Coordinates with tags 6 0 or # can appear anywhere.

These rules not only provide a framework for digitization but also define the following possible error conditions:

1: a data point (tag 1 2 3 or 9) found neither in an island nor in a transition,

2: a beginning of transition found in an island,

3: a beginning of transition found in a transition,

4: an end of transition found neither in a transition nor in an

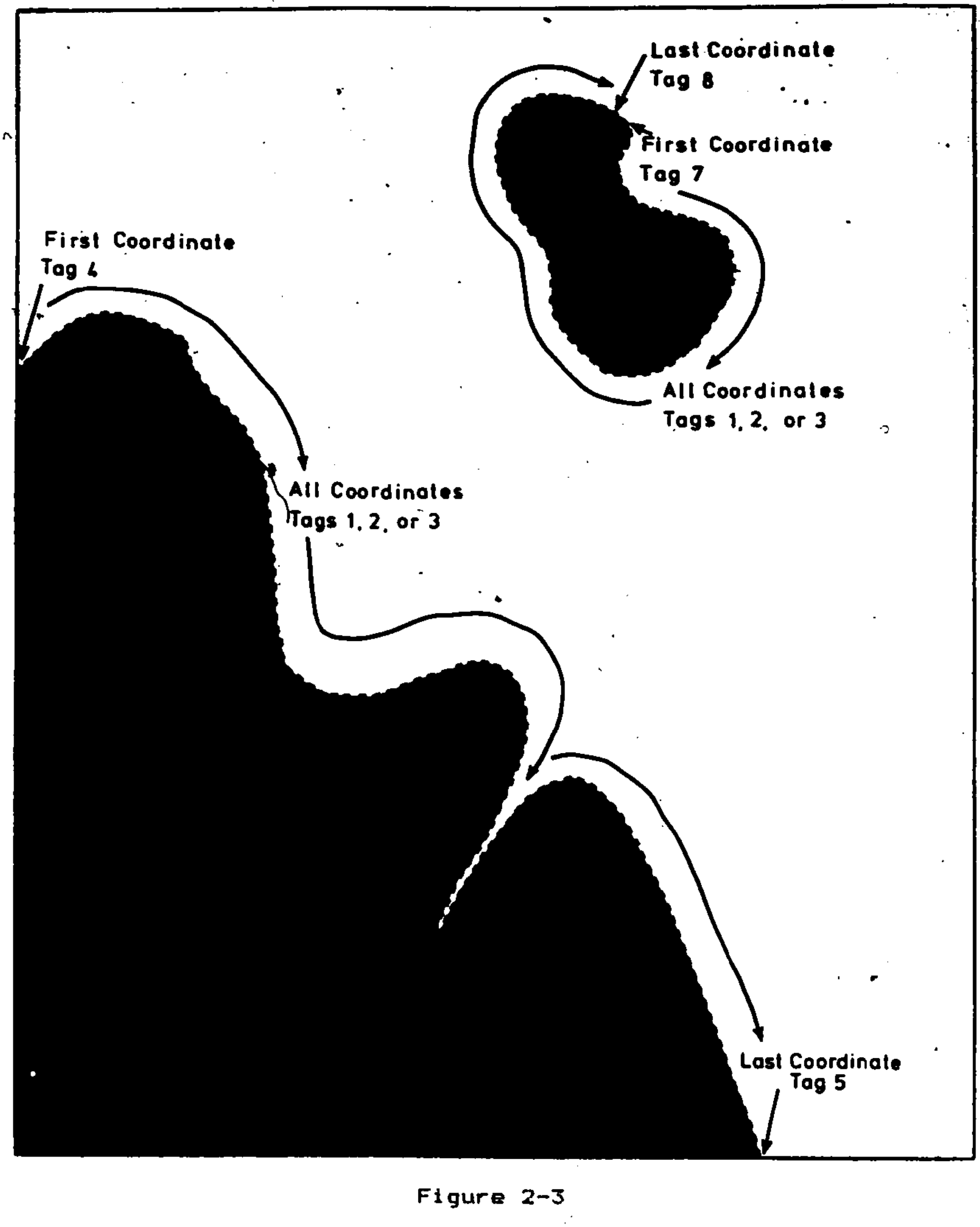


Figure 2-3

The two types of lines encountered during digitization and their associated tag values. Closed areas like islands must begin with a tag 7 and end with a tag 8. Transitions, or segments of shorelines continuing on adjacent map sheets must begin with a tag 4 and end with a tag 5.

island,

5: an end of transition found in an island,

6: a beginning of an island found in an island,

7: a beginning of an island found in a transition,

8: an end of an island found neither in an island nor in a transition, or

9: an end of an island found in a transition.

When any such error is detected, the five preceding coordinates, the point in which the error was detected, and the next point to be processed are displayed on a CRT terminal, along with their UTM coordinates and distances from each other. Based on this information, the operator must then instruct the computer to perform any one of the following corrective actions:

1: change tag of point being processed,

2: change tag of last point of the buffer,

3: delete point being processed, or

4: delete last point of the buffer.

Coordinates with tags 0 or # are ignored and indicate that a certain number of previous points must be deleted because of an error made during digitization. When a tag 0 is encountered, the last coordinate in the buffer is deleted. This is done by decrementing the end-file pointer illustrated in Figure 2-1. However, before deleting this point, its tag must be examined. If it denotes the beginning or the end of an island, or the beginning or end of a transition, an appropriate tag replacement is performed. When a tag # is encountered, it is ignored and the next valid coordinate is examined. The program then calculates the distances between this point and all the coordinates in the buffer, starting at the end of the buffer and proceeding towards its beginning. These calculations continue until a coordinate with tag 4 5 6 7 8 or 9 is found or until the entire buffer has been examined. The coordinate with the minimum distance to this point is then reset to indicate the end of the buffer and all intermediate points are deleted. This procedure enables the correction of errors such as digitizing the wrong line. In many instances, it is easy to confuse topographic contour lines or lines denoting nearshore reefs with the actual coastline, specially on monochrome mylar copies of colored original maps.

All digitizer coordinates are verified one by one in the manner discussed above before being sent to an output file. This output file contains only those coordinates that have valid tags, no error, and are ready to be converted to UTM eastings and northings.

2.3.2. Transformation of Verified Digitizer Coordinates to Universal Transverse Mercator Coordinates

When digitizing a base map, two systems of reference are present (Figure 2-4): the digitizer axes and the axes of the base map. All points digitized refer to the axes of the digitizer and must be transformed into UTM coordinates. The following variables are used to perform this transformation:

O O - coordinates of the origin, in the digitizer system of reference,

EO NO - easting and northing of the origin in the UTM system of reference,

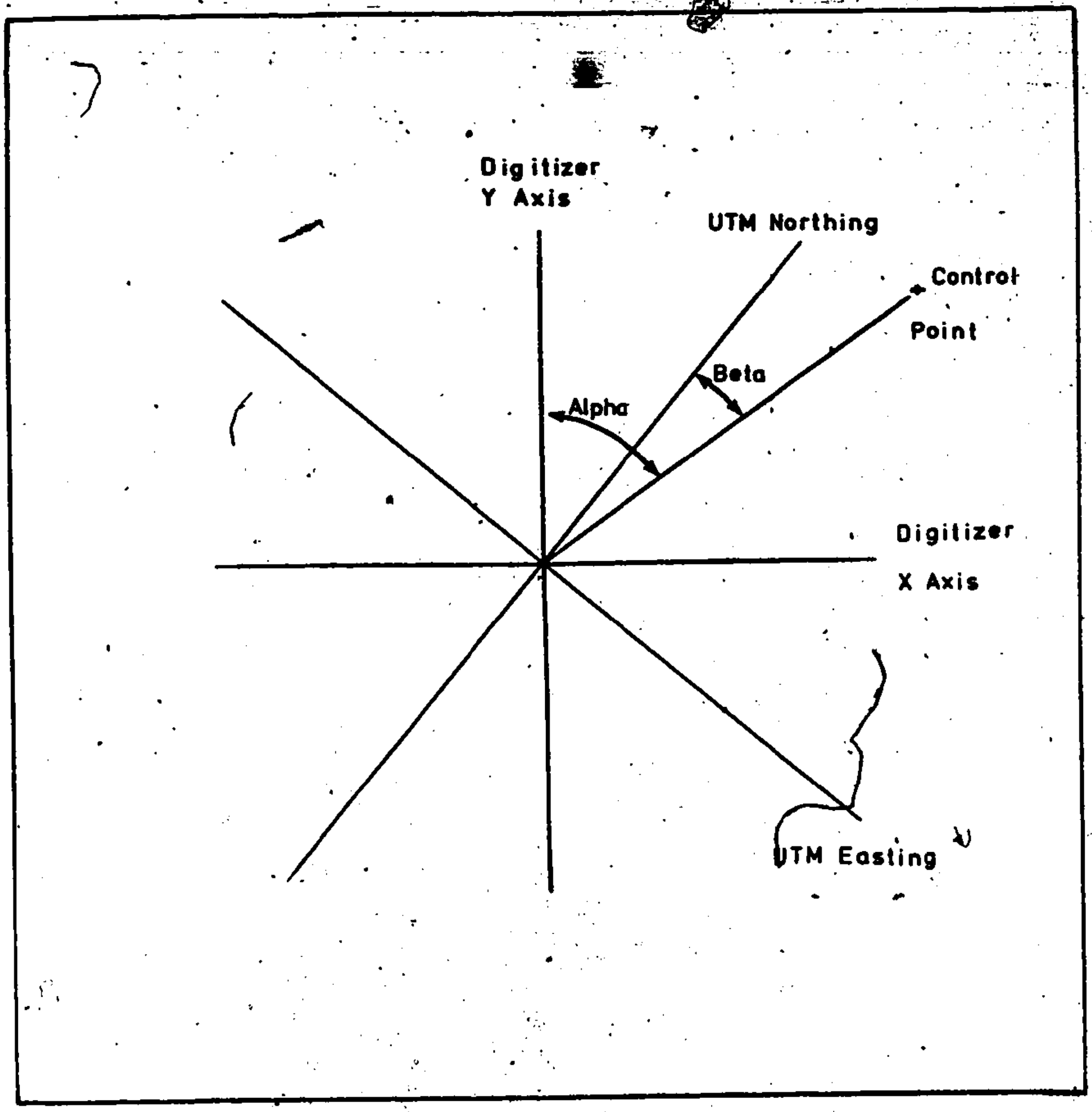


Figure 2-4

Example of a possible relative orientation of the digitizer and UTM reference systems. See text for explanation of symbols.

X1 Y1 - coordinate of the control point in the digitizer system of reference,

E1 N1 - easting and northing of the control point in the UTM system of reference, Alpha - angle between the lines joining the control point (X1,Y1) and the origin (0,0), and the Y axis of the digitizer system of reference,

Beta - angle between the lines joining the control point (E1,N1) and the origin (E0,N0); and the Y axis or the northing grid line of the UTM system of reference,

Angle - angle between the digitizer axes and the UTM axes. In practice, four cases can be present:

1) If Alpha and Beta are both in the first quadrant of their system of reference, then Angle = Alpha - Beta, and Angle can have either a positive or negative value. If it is negative, an anticlockwise rotation of the data must be performed. If positive, a clockwise rotation must be performed.

2) If Alpha and Beta are both in the fourth quadrant of their system of reference then Angle = Alpha - Beta, and if Angle is positive, an anticlockwise rotation must be performed. The converse is required if Angle is negative.

3) If Alpha is in quadrant 1 and Beta in quadrant 4 of their respective system of reference, then Angle = Alpha + Beta and a clockwise rotation must be performed.

4) If Alpha is in quadrant 4 and Beta is in quadrant 1 of their respective system of reference, then Angle = Alpha + Beta, and an anticlockwise rotation must be performed.

Sine Cosine - these variables are the sine and cosine values of Angle defined above. When an anticlockwise rotation is desired, the value of Sine is reset to -Sine before calculating the calibration factor Calfac.

In the sequence of operations required to transform digitizer machine coordinates to UTM coordinates, the two angles Alpha and Beta are first calculated as follows:

Alpha = Arctan { [|X1| / SQRT (X1**2+Y1**2)] / SQRT (1.-[|X1| / SQRT (X1**2+Y1**2)] **2) }

Beta = Arctan { [|E1-E0| / SQRT ((E1-E0)**2 + (N1-N0)**2)] / SQRT (1.-[|E1-E0| / SQRT ((E1-E0)**2+(N1-N0)**2)] **2)}

Where |X1| indicates the absolute value of X1, and SQRT denotes the square root function. The calibration factor (Calfac) is then calculated as follows:

Calfac = [SQRT ((E1-E0)**2 + (N1-N0)**2)] / [SQRT ((X1*Cosine -Y1*Sine)**2 + (X1*Sine+Y1*Cosine)**2)]

After the calculation of Alpha, Beta, and Calfac, each digitizer coordinate (X,Y) can be transformed into its UTM equivalent (E,N) by using the following equations:

E = (X * Cosine - Y * Sine) * Calfac + E0

N = (X * Sine + Y * Cosine) * Calfac + N0

These UTM coordinates are then ready to be adjusted in order to minimize the effects of the distortion inherent in all original base maps.

2.3.3. Adjustment of Universal Transverse Mercator Coordinates to Minimize Distortion of Base Maps

The real eastings and northings of the four corners of the map can be calculated from their latitude and longitude values, previously saved in the digitizer coordinate file. The eastings and northings of the same points can also be calculated from their digitized coordinates. Because of the distortion present in all maps, the two sets of coordinates rarely coincide and the series of UTM coordinates forming the complete geographical component of the data base must be adjusted to minimize this effect.

This distortion effect is illustrated in an exaggerated manner in Figure 2-5, where the ideal locations of the map corners (R1 to R4) and the locations of the calculated digitized corners (C1 to C4) are displayed. In this illustration, it is important to remember that both sets of coordinates (R1 to R4 and C1 to C4) are in the same system of reference, that is, they are both in UTM values.

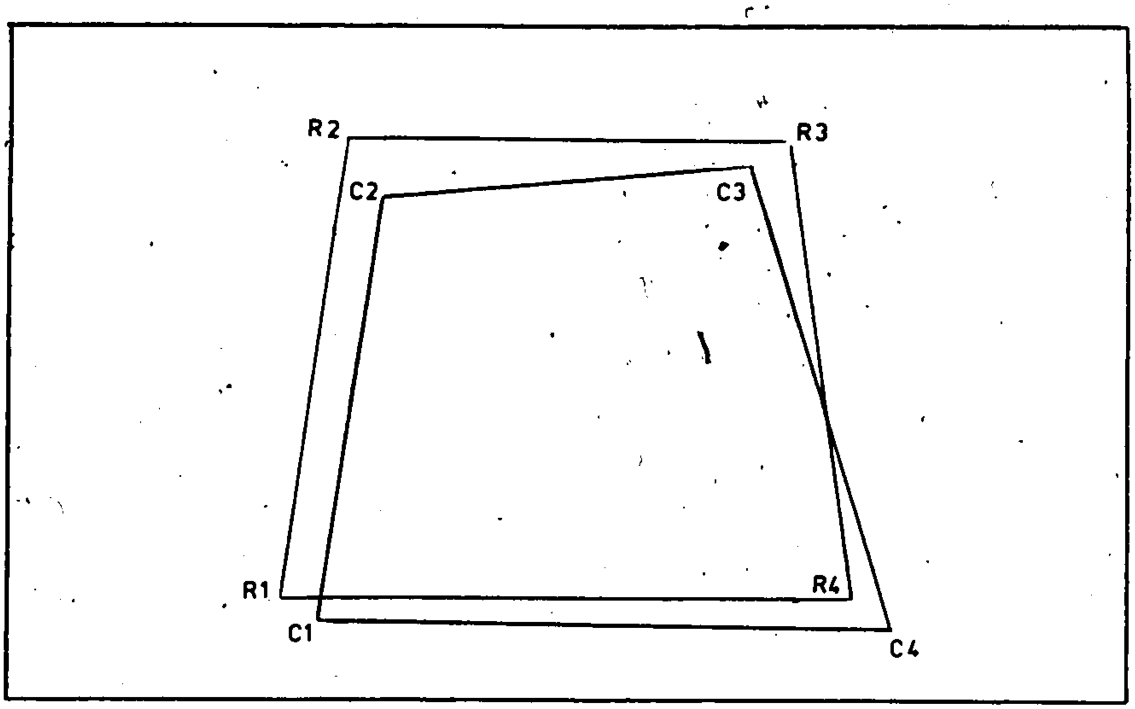


Figure 2-5

Example of the possible location of the ideal corners of a map (R1 to R4), and the calculated corners (C1 to C4) before adjustment. The poor matching of corners is due to the distortion of the base map.

The adjustment of the four calculated digitized corners to match, as best as possible, the four ideal corners of a map is performed according to the following sequence of operations:

1) A translation is performed in order to move C1 to the position of R1 (see Figure 2-5). C1 is then reset as an origin to facilitate subsequent operations.

2) Using C1 as origin, a rotation is performed such that C2 falls on a line that passes through R2 and is parallel to the northing axis.

3) The calculated northings are calibrated to move corner C2 onto R2 without altering the northing of corner C1.

4) The calculated eastings are calibrated such that corner C3 falls on a line that passes through corner R3 and is parallel to the northing axis, without altering the location of corners C1 and C2.

5) The calculated northings are calibrated to move corner C3 onto the ideal corner R3, without altering the locations of corners C1 and C2.

6) The calculated eastings are then calibrated to move corner C4 onto a line passing through corner R4, parallel to the northing axis, without moving corners C1, C2, and C3.

7) The calculated northings are calibrated to move corner C4 onto the real corner R4 without moving corners C1, C2, and C3.

These adjustments are performed on the calculated UTM coordinates of the four corners and on all UTM points forming the geographical component of the data base.

2.3.4. Verification of Universal Transverse Mercator Coordinates Near Borders of Maps

Because of subsequent adjustment of geographical data, it is difficult to be absolutely certain during digitization that no UTM coordinate falls outside of the borders of the map. It is convenient to begin digitizing coastlines slightly outside map borders and to delete UTM points falling outside of these borders.

To do this, when considering maps of the northern part of the western hemisphere, the boundaries of the maps digitized are always set such that 1) the minimum latitude is equal to the latitude of corners 1 and 4 (see Figure 2-5); 2) the maximum latitude is equal to the latitude of corners 2 and 3; 3) the minimum longitude is equal to the longitude of corners 3 and 4; and 4) the maximum longitude is equal to the longitude of corners 1 and 2. Maps other than of the northern part of the western hemisphere would require modifications to the above convention.

To verify if a point falls inside or outside the map area, each UTM coordinate is transformed into its equivalent latitude-longitude coordinate and compared with those of the map borders. UTM coordinates falling outside of the map area are deleted from the file but their tags are reassociated with the first point, on the same line segment, that falls inside or on the map borders.

To ensure that adjacent map sheets have matching shorelines, the program that performs the above verification also enables the user to specify the value of the first or last UTM coordinate, or both, of any transition. Using this option, it is possible to replace the first UTM coordinate of a shoreline segment of a map by the last UTM coordinate of the same shoreline segment of a previously digitized adjacent map. This requires some bookkeeping during verifications of adjacent maps, but it allows perfect matching of lines that extend onto adjacent map sheets. To do this, some degree of interpretation is generally required as it is not rare to find shorelines that do not coincide at the transitions of adjacent original map sheets.

2.4. File Structure and Management

To be used efficiently, the geographical component of the data base must include more than a large list of UTM coordinates and their associated tags. One can perceive, when looking at maps, the presence of a varying degree of texture. This texture may be due for example to the continuity of shorelines; the closed nature of islands; the amount and distribution of islands; or the degree, magnitude, and shape of indentations in the coastline. The structure of the data must be designed to take both this texture and the intended uses of the data base into account.

2.4.1. Data Structure

Let us consider first the relationship that exists between the various elements of the data. Once digitized and processed, each map sheet consists in at least zero, one, or more islands and zero, one, or more transitions as defined above. Each island consists in a 'beginning-of-island' UTM coordinate with tag 7; a certain number of 'shoreline' UTM coordinates with tag 1, 2, or 3; and an 'end-of-island' UTM coordinate with tag 8. Similarly, each transition consists in a 'beginning-of-transition' UTM coordinate with tag 4; a certain number of 'shoreline' UTM coordinates with tag 1, 2, or 3; and an 'end-of-transition' UTM coordinate with tag 5. The coastlines of both the mainland and the islands are thus represented by a series of discrete UTM coordinates which can be organized into a linear list (Knuth, 1973). When a map is drawn, it is created by joining together with a line these discrete UTM coordinates. It is however necessary to know which points must not be joined by a line, as in the case of going from one island to another or going from the mainland to an island.

The structural relationships between geographical data points can be defined by determining which coordinate is first in the list, which is last, which coordinate precedes and which coordinate follows a given one. The UTM coordinates of each island and each transition can be organized into a linear list as illustrated in Figure 2-6. The first coordinate in a given list must have a tag 7 (beginning of island) or 4 (beginning of transition). The subsequent coordinates making up the island or the transition are placed in the list in the same order as they were digitized such that joining these by a line will recreate the coastline. The last element of the list must have a tag 8 (end of island) or 5 (end of transition).

Let us consider now the uses and types of operations that will be performed with this geographical data. One obvious

```
 ------------     ------------     ------------     ------------
| 7 | E | N | -> | 1 | E | N | ::: | 1 | E | N | -> | 8 | E | N |
 ------------     ------------     ------------     ------------
```

Figure 2-6

Example of a linear list of the UTM coordinates making up an hypothetical island. The letters E and N denote the easting and northing of the UTM coordinate. The first symbol of each coordinate, in this case the numbers 7, 1 and 8, denote the tags.

operation consists in recreating a map for a certain area. The area may consist in a complete region or any subset of any size. All applications of this data base (Labrador, East Coast, West Coast) have required dozens of individual map sheets, each made up of 6,000 to 20,000 UTM coordinates. When a map of a complete study area is requested, it is sufficient to read and process all lists of UTM coordinates described above. When a map of a subset of a complete study area is requested, the limits of this subset are specified in terms of minimum and maximum easting and northing or minimum and maximum latitude and longitude coordinates. The file made up of the lists of UTM coordinates of the complete study area can then be searched to find the coordinates that occur within the specified limits. It is obviously very time consuming to search through hundreds of thousands of coordinates to find the ones that describe the specified area, therefore a data structure that will facilitate such a search is not only desirable, but necessary.

One method of optimizing such a search would be to organize all geographical data in a list of points with sorted UTM northing and easting values. The ordered list could then be searched using, for example, a binary searching approach (Martin, 1976). This approach would speed things up considerably, and could be used if coastlines could be represented adequately by a series of discrete points. However, for the purpose of this data base, coastlines must be represented as continuous lines and it is essential to know which coordinate precedes or needs to be joined to another one.

An ordered linked list could be created such that every coordinate has an associated pointer whose purpose is to indicate the address of the next coordinate to be joined. This list could be searched as described above, but the connecting points would also have to be found and verified. Such an approach would be very inefficient.

Consider now a file made up of all the lists, as illustrated in Figure 2-6, corresponding to all islands and all transitions of a given overall study area. To draw the coastlines of a given subarea, it is necessary to perform a serial search of all elements of the complete file to find all UTM coordinates making up the specified subarea. This requires a considerable amount of time but has the advantage of implicitely denoting which coordinates must be joined together. The problem of searching time can be reduced considerably by using a neighborhood locatability technique (Flores, 1970), which defines immediately in the overall file, a neighborhood in which to concentrate the search.

Instead of creating a single geographical data file for an overall study region, a separate file is created for each map sheet. Each of these geographical data files is subdivided further into a number of blocks of data. The purpose of these blocks is to speed up the search for coordinates falling within specified areas. It is convenient to use blocks of approximately 500 coordinates. The area covered by a block depends on the scale of the map and the resolution used during digitization. To access the information efficiently, a directory is created for each geographical data file. It specifies the UTM boundaries (maximum and minimum eastings and northings) of each block, and its starting and ending addresses in the file. This directory, refered to in the following sections as a block index file, indicates which blocks of data of a given map sheet must be examined for any given search. Similarly, a master directory, refered to in the following sections as a map index file, is created and used to indicate which maps of the overall study area need to be considered in a search.

2.4.2. Map Index Files

For each overall study region, a map index file is created and used as a master directory. This file has a record for each map of the overall study region. These records contain the following information: 1) a seven character alphanumeric code denoting the identity of the map, 2) the UTM and latitude-longitude boundaries of the map (minimum and maximum easting, northing, latitude, and longitude) and its UTM zone number; 3) the year of compilation of the map, 4) a flag to indicate the presence or absence of digitized lakes, and 5) 83 other flags to indicate the existence of various types of environmental data. Records of this master file are sorted first by decreasing minimum latitude then within each latitude increment, by decreasing maximum longitude. These records are easily updated, deleted, inserted, or appended to the map index file.

There is a single map index file or main directory for each overall study region. Each base map specified in this map index file has, however, its own block index file and geographical data file. When a givon subarea is requested, its limits in UTM or latitude-longitude coordinates are compared to those of individual map sheets in the map index file. This indicates which base maps need to be examined and guides the search to the appropriate block index files.

2.4.3. Block Index Files

For each base map that is digitized, a block index file is created and used as a directory. The geographical extent of blocks of data are defined before digitizing. An example of a division of a base map into a number of blocks is illustrated in Figure 2-7. In practice, this map would be digitized as follows: the first point digitized has a tag 6 to denote the beginning of a block. Its UTM coordinate is not considered. Next, the shorelines of island 1 and transition 1 are digitized. The section of shoreline that is part of both transition 2 and block 1 is then digitized. At the point where transition 2 crosses into block 2, a coordinate with tag 6 is digitized to indicate the beginning of block 2, and the remaining part of transition 2 is

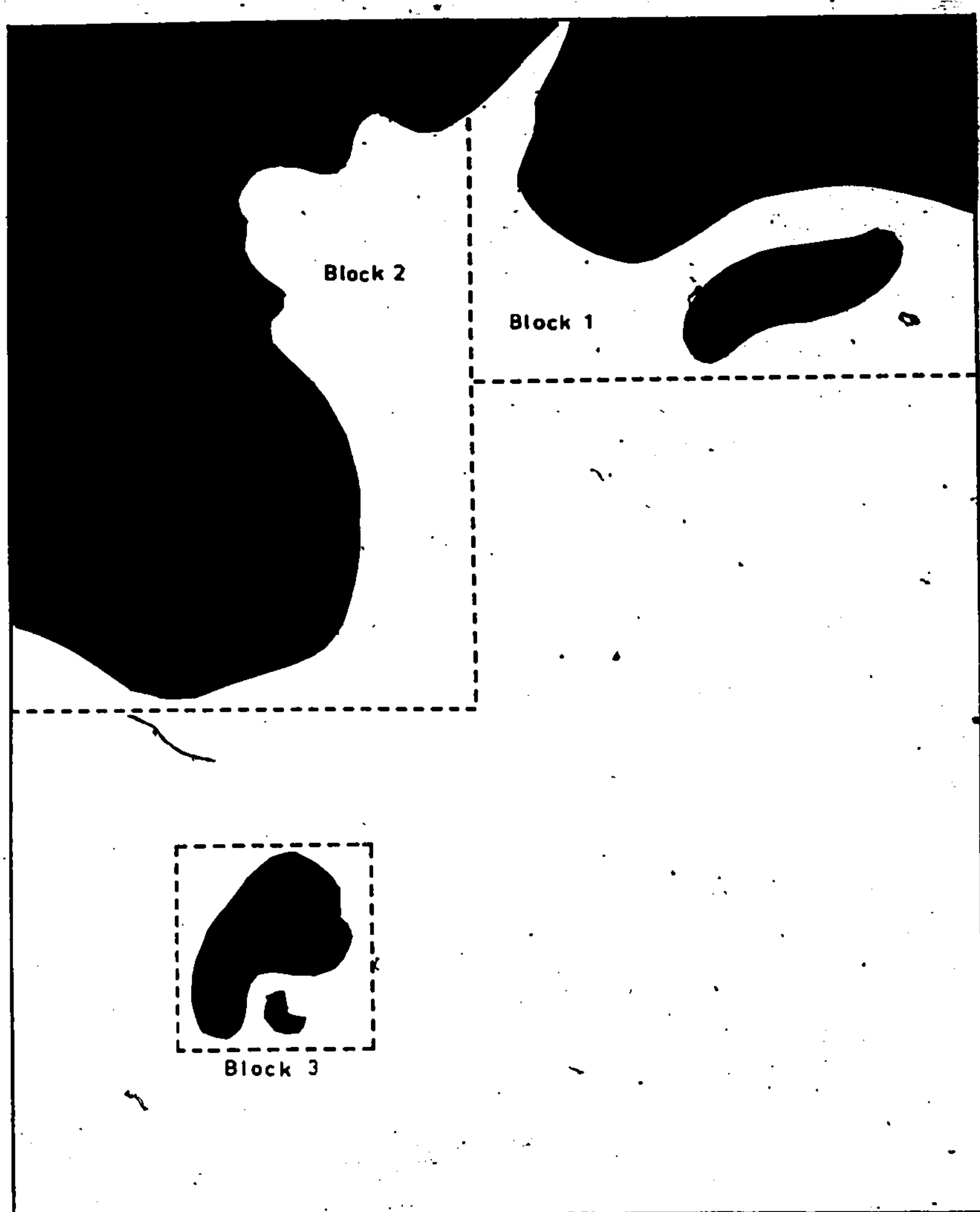


Figure 2-7

Example of a base map subdivided into three data blocks, ready for digitizing. See text for explanation of symbols.

digitized. The beginning of the third block of data is denoted by a coordinate with tag 6 and the two islands of this block are then digitized.

The block index file includes the following information for each block: 1) the minimum and maximum eastings and northings of the block, 2) the address of the first coordinate of the block in the geographical data file, and 3) the address of the last coordinate of the block in the geographical data file.

In practice, if the required area includes the southwestern part of the map illustrated as example in Figure 2-7, the number of the appropriate map is obtained from the map index file, and the block index file would indicate that only the geographical data corresponding to block 3 must be searched further. Similarly, if the requested area consists of the southeastern part of the map of Figure 2-7, the appropriate map number is obtained from the map index file, and the corresponding block index file would indicate that there are no geographical data in that particular area. In this case, the geographical data file does not need to be searched at all.

2.4.4. Geographical Data Files

The block index file indicates the address of the first and last coordinate of each block in the geographical data file. If the requested block begins at the nth coordinate of the geographical data file, and the file is accessed sequentially, n-1 coordinates must be read before the desired block is reached. This access time is reduced by organizing the geographical data file into a random access file. In this case, the nth record, or any other record, is reached as rapidly as the first one.

In order to minimize the memory space required for the geographical data file, consecutive coordinates are grouped together into a record of predetermined length. Each of these records occupies 128 bytes of memory and each coordinate is defined by three fields: the tag, the UTM easting of the point in meters, and the UTM northing of the point in meters. Each coordinate can have zero, one, or more pointers associated with it. Each pointer links the geographical coordinate to a certain type of data (see section 3.1.). Since the number of pointers for each coordinate varies with the regions under study, the number of coordinates grouped in a record can differ from one region to another.

As described above, the block index file denotes the address of specific coordinates. In practice, this address is the number of the random access record of the geographical data file that contains the required coordinate, and the position of the coordinate within this random record. Within each random access record, the data must be read sequentially.

The map index file, the block index files, and the geographical data files are created as described above to optimize the access and search of the geographical data files, and to minimize the amount of memory required by the geographical component of the data base.

PART 3

THE ENVIRONMENTAL COMPONENT OF THE DATA BASE

THE ENVIRONMENTAL COMPONENT OF THE DATA BASE

3.0. Introduction

It has been found by experience that the environmental data normally considered for emergency oil-spill response, oil-spill contingency planning, and regional assessments could be consistently grouped into two main categories. The first major group is one where the information itself needs to be associated with its corresponding coastal UTM coordinates. Examples of this type of data are the distribution and extent of marshes, river outlets, estuaries, deltas, rock platforms, intertidal flats, boulder barricades, shoals, reefs, beaches; or good sea, land, or air access points. The second major type of data is one where the information requires its own spatial definition, that is, where the information has a distribution that is independent of the location of shorelines. Examples of this type of data are the location of settlements, individual buildings, roads, airstrips; or biological features such as shellfish harvesting areas, fish traps, spawning areas, or migration routes.

This natural distinction leads to the grouping of all environmental data into these two distinct major types. These two major types are refered to, in the following sections, as data associated with coastal UTM coordinates, and data independent of coastal UTM coordinates.

3.1. Environmental Data Associated with Coastal Universal Transverse Mercator Coordinates

The geomorphology of coastlines is a type of information that is essential for oil-spill response. It is also an excellent example of data that are associated with coastal UTM coordinates.

Coastlines can be subdivided, moving from the land to the sea, into the following sections: 1) the hinterland or section of the land adjacent to the shore but not affected by marine processes; 2) the backshore or part of the coast that extends from the inland limit of marine processes to the high tide level; 3) the intertidal zone or section of shore lying between the high and low tide levels; and 4) the nearshore zone extending between the low tide level and the first seaward break in slope of the bottom surface. Each of these zones can be described in terms of a large number of characteristics such as amount and type of vegetation, type of substrate, slope, morphology, and special features. Each of these zones and each of their characteristics can vary independently of the others in a direction parallel to the shoreline. For example, the amount of vegetation of the hinterland can differ considerably at two separate locations, but it may remain similar next to a section of shoreline that has a highly variable backshore or intertidal zone.

To keep a record of all possible variations in the geomorphic description of the shoreline alone would require the digitization of a very large number of points or lines. The number of coordinates required to identify all these variables and their limits would probably exceed the number of coordinates required to describe the geographical distribution of the coastlines themselves. If each characteristic of each shoreline zone was digitized separately and stored into a distinct file, a very large amount of memory and of time would be required to access the information. This approach becomes totally impractical when one considers the amount of information that needs to be associated with the location of shorelines.

In order to minimize the amount of memory and access time, each coastal UTM coordinate of the geographical data file is associated with a certain number of pointers. One of these pointers is the number of a record that contains, in a separate file, the complete geomorphic description of the coast at that particular point along the coast.

3.1.1. Assignment of Pointers to Coastal Universal Transverse Mercator Coordinates

As mentioned in section 2.4.4, when the geographical data files are created by grouping several coordinates into a single record, each coordinate is assigned a number of pointers, all initialized to the value zero. After the creation of the geographical data files, it is possible to change the value of these pointers by the use of a separate program.

The sequence of operations performed by this program is as follows. First, the limits of the area in which pointers need to be modified are requested by the program. It is possible to modify the pointers associated with coastal UTM coordinates of complete map sheets or of subareas of any size. The limits of the area or region to work with are specified in terms of UTM eastings and northings and are used to search in the appropriate block index files and geographical data files for all enclosed coordinates. A map of the area requested is displayed on the color monitor with each coastal coordinate drawn separately and not joined to any other one. Green and white points are used to represent coastal coordinates that are associated with specific pointers of non zero and zero value respectively.

The program used to assign or modify specific pointer values then performs the following operations:

1; a red cross is drawn over the point under consideration on the color monitor;

2: the easting and northing of the coordinate; the current value of the pointer specified; and the current value of the pointer if it is not zero, otherwise the value assigned to the pointer of the previous coordinate, are displayed in three separate columns on a CRT terminal.

3: If a zero or a carriage return is entered on this terminal, the pointer value displayed in the last column is assigned to the coordinate under consideration. This feature is useful in the case of a long section of coastline associated with an unchanging pointer value as it avoids having to retype this value for each coordinate.

4: If an integer greater than zero is entered, it is assigned as pointer value to the coordinate under consideration.

5: A value of -1 entered on the CRT terminal indicates that the coordinate under consideration has no data for the pointer specified.

6: After assigning a value to the pointer, the red cross is moved to the next coordinate on the color monitor and the point is redrawn in a color other than green or white to indicate that it has been processed.

This program is used initially to describe, by the use of pointers, environmental data associated with coastal coordinates; and can be used later to modify or update the information as frequently as necessary.

3.1.2. Random Access Environmental Data Files

Each pointer associated with each coastal coordinate is in fact the number of a random access record in an environmental data file. If a coastal coordinate has more than one pointer, each pointer refers to a specific environmental data file.

Let us consider for example the environmental data file associated with the first pointer of coastal coordinates in one of the study areas for which this data base has been used (Labrador). In this case, each record of the environmental data file consists of 14 individual variables with the following meaning:

1: the number of the videotape that covers the coastal coordinate under consideration,

2: the general elevation and slope of the hinterland,

3: the extent and type of vegetation cover of the hinterland,

4: the slope and nature of the backshore,

5: any other features of the backshore,

6: the nature of the upper intertidal zone, 7: the texture of the upper intertidal zone,

8: the nature of the middle and lower intertidal zone,

9: the texture of the middle and lower intertidal zone,

10: any other features of the middle and lower intertidal zone,

11: any nearshore features,

12: the accessibility of the shore from land and from air,

13: the ease of sea access to the shore, and

14: the appropriate data source.

Each of these items, being a variable, can also have a number of possible values. For example, in the case of Labrador, variable number 5 denoting other features of the backshore may be assigned a value between 0 and 9, each having the following meaning:

0: unknown,

1: scattered trees,

2: grassy,

3: wide (>50 m) continuous marsh,

4: narrow (<50 m) discontinuous ma[illegible]assy,

5: eroding,

6: stable,

7: lagoon with marsh in the backshore,

8: barren,

9: no feature.

Similarly, variable number 13 denoting sea access to the shore zone may be assigned a value from 0 to 4 with the following significance:

0: unknown,

1: impossible or extremely difficult,

2: difficult, access restricted to very small crafts,

3: relatively good access for small crafts,

4: excellent sea access to the shoreline.

The approach used for environmental data associated with coastal UTM coordinates is summarized in Figures 3-1 and 3-2. Each record of the geographical data file (Figure 3-1) contains several elements (see section 2.4.4), each made up of a tag (T), a UTM easting (E), a UTM northing (N), and a predefined number of pointers (P1,P2,...,Pp). Each pointer is the number of a record in a specific environmental data file (Figure 3-2) that corresponds to a major category of data (for example, geology or fetch). The number of pointers and of corresponding environmental data files vary according to the complexity of the region under study.

Each record of the environmental data file contains a list of variables, V1 to Vn in Figure 3-2, each denoting a distinct subcategory of data. In the case of Labrador, each record of the geology environmental data file contains the 14 variables denoting the subcategories listed above. The individual values of the variables of this record indicate the exact data parameter in that subcategory. For example, the geology (category) of a certain coastal location of Labrador may be characterized by a backshore (subcategory) made up of a wide continuous marsh (data parameter).

This approach is both efficient and flexible because 1) it requires a minimum storage space for the environmental data, 2) it already links the various types of environmental data and their geographical locations, 3) it is possible to have as many

```
Record              GEOGRAPHICAL DATA FILE
Number
        ---------------------- ::: ----------------------
     1 :       Element 1       :   :      Element i      :
        ---------------------- ::: ----------------------
       :                       :   :                     :
       :                       :   :                     :
       :                       :   :                     :
        ---------------------- ::: ----------------------
     k : Element ((k-1)*i)+1   :   : T : E : N : P1 : P2 :
        ---------------------- ::: ----------------------
       :                       :   :                     :
       :                       :   :                     :
       :                       :   :                     :
        ---------------------- ::: ----------------------
     m : Element ((m-1)*i)+1   :   :    Element m * i    :
        ---------------------- ::: ----------------------
```

Figure 3-1

Example of a geographical data file of m records. Each record contains i elements. Each element is made up of a tag (T), the UTM easting (E) and northing (N) of the coordinate, and a certain number of pointers. In this example, only two pointers (P1 and P2) are illustrated.

pointers, hence data categories, as required, 4) it is possible to have as many variables or subcategories as required, and 5) it is possible to use as many values (data parameters) as required within each subcategory.

The variables making up each record of the environmental data file can have different values assigned to them by the use of a distinct program. This program can create new records, update existing ones, or print the contents of an existing environmental data file. The updating option enables the user to append records at the end of a file, to insert records between existing ones, to delete records, and to modify the contents of a record.

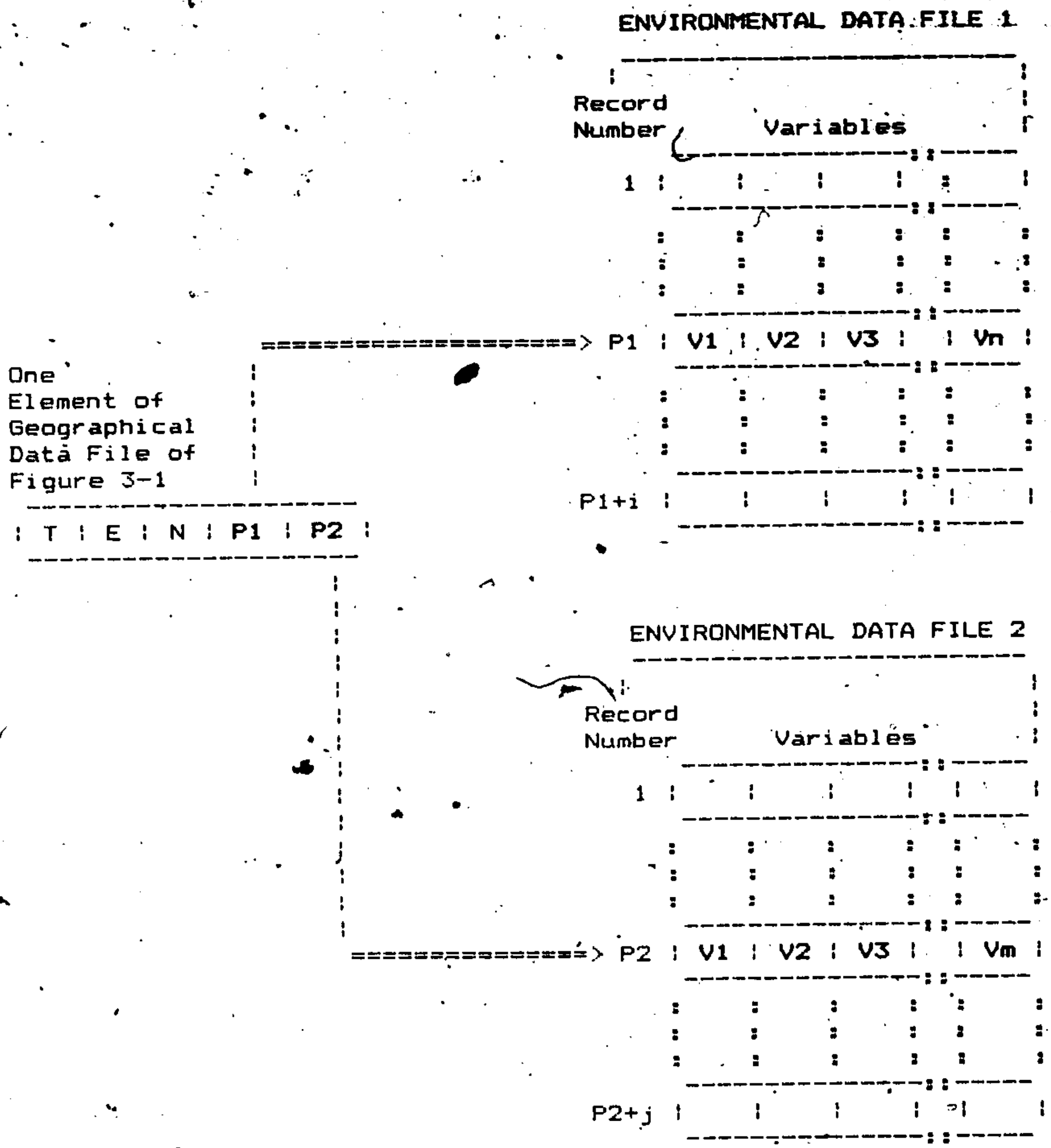


Figure 3-2

Relationship between one element of the geographical data file and the environmental data files of parameters associated with coastal UTM coordinates. In this example, only two pointers and two environmental data files are illustrated. In practice, the number of pointers and environmental data files is a function of the complexity of the region under study.

3.2. Environmental Data Independent of Coastal Universal Transverse Mercator Coordinates

Many types of data normally considered for oil-spill response and contingency planning are not directly associated with coastal UTM coordinates and require their own spatial definition. Data about fisheries, biological resources, tourism, or recreation are generally of this type. In this case, the creation of the environmental data files requires the use of both the digitizer to specify the spatial distribution of the information, and a CRT terminal to enter textual material, if present.

3.2.1. Digitization of Environmental Data and Verification of Digitizer Coordinates

It has been found by experience that the information that is independent of coastal UTM coordinates always fall into one of the following categories:

1: A single UTM coordinate denoting the location of a point in space without textual information (for example, the location of a house, helipad, fishing camp, or fish plant).

2: A single UTM coordinate associated with textual information (for example, the location and name of a settlement).

3: A single coordinate associated with numeric data (for example, the location and quotas of a lobster pound).

4: A single coordinate associated with an alphanumeric code and textual information. An example of this is illustrated in Figure

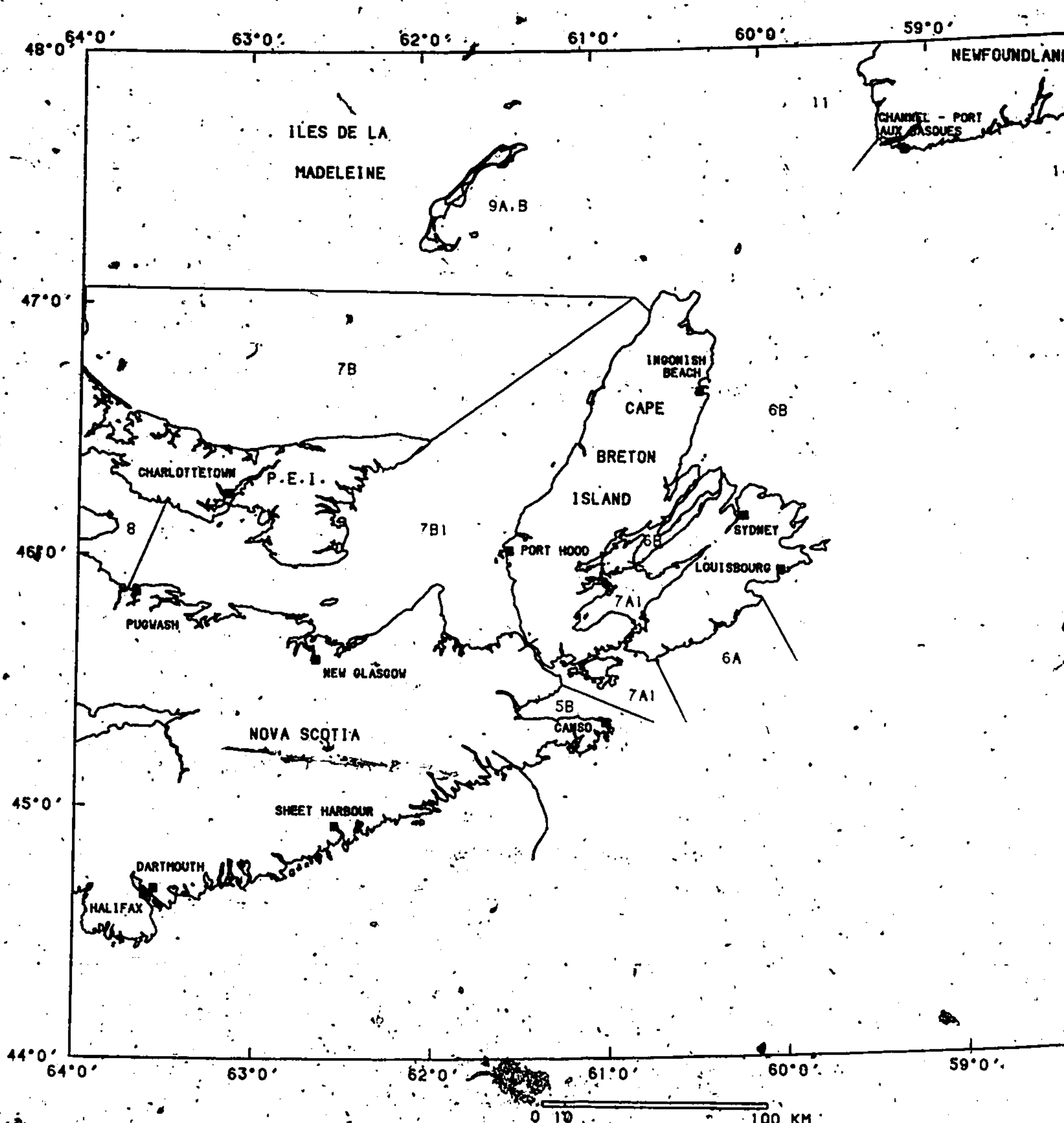
3-3, where the coordinate is the location of the district number in the map, the alphanumeric code is the district number itself, and the textual information describes the dates of operation of the district. The alphanumeric code is printed within the boundaries of the map and provides a link with the textual information printed to the right of the map.

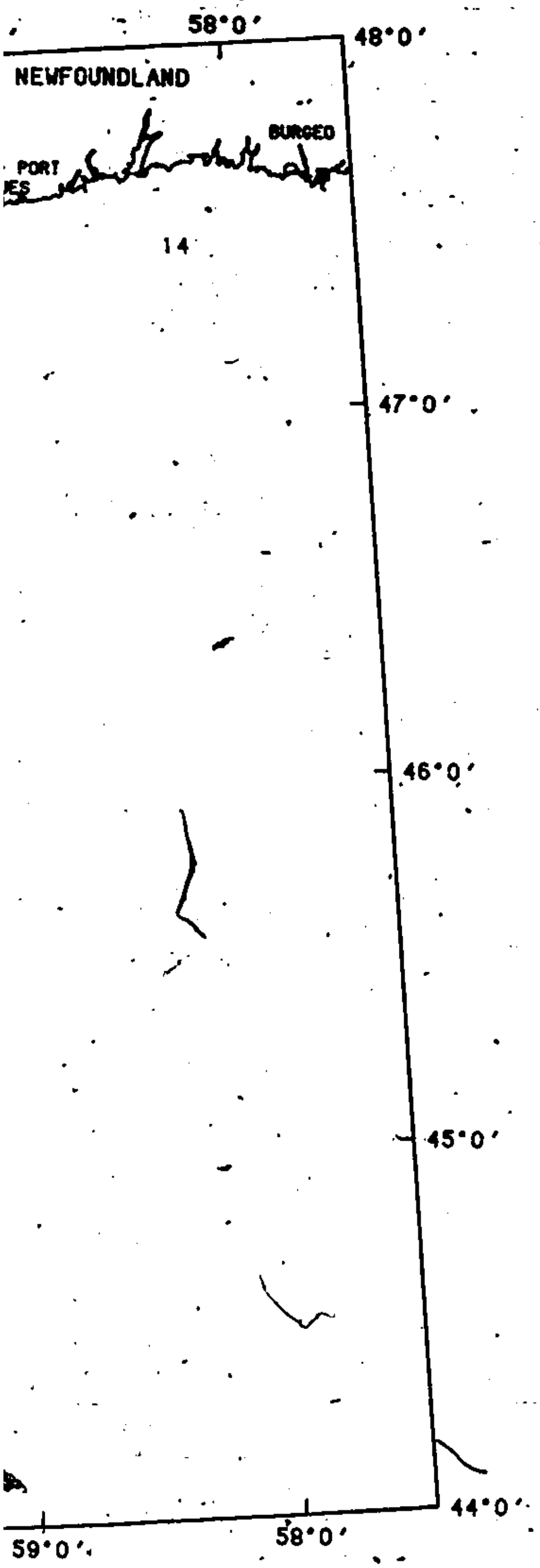
5: A line segment with no textual information (for example, the district boundaries of Figure 3-3).

6: A closed area such as the zone of major concentration of fishing efforts illustrated in Figure 3-4, and

7: areas along coastlines. These areas can be of three types as illustrated in Figure 3-5: 1) an area along the shoreline with only one boundary line to be digitized (Figure 3-5, area A), 2) an area between two sections of coastlines with two boundary lines to be digitized (Figure 3-5, area B), and 3) an area that includes more than two boundary lines to be defined properly (Figure 3-5, area C).

It is important to understand why it is necessary to distinguish between the cases 5, 6, and 7 above. At present, coastlines can only be drawn as lines either with the plotter or on the color monitor. In the future, the methods of displaying data will be improved to include shading of distinct areas. In order to accomplish this, it is essential to recognize the different line segments making up the boundaries of a given area. Futhermore, all line segments are digitized in a consistent manner, that is clockwise with respect to the area under consideration. Following this convention, the line segment denoting the limits of area A in Figure 3-5 would be digitized


48°0'
64°0'
63°0'
62°0'
61°0'
60°0'
59°0'
NEWFOUNDLAN
11
CHANNEL - PORT AUX BASQUES
ILES DE LA
MADELEINE
9A,B
47°0'
7B
INGONISH BEACH
CAPE
BRETON
ISLAND
6B
CHARLOTTETOWN
P.E.I.
8
7B1
PORT HOOD
SYDNEY
LOUISBOURG
7A1
PUGWASH
NEW GLASGOW
6A
7A1
5B
CANSO
NOVA SCOTIA
45°0'
SHEET HARBOUR
DARTMOUTH
HALIFAX
44°0'
0 10
100 KM



PETRO-CANADA CABOT STRAIT ENVIRONMENTAL DATA 1983

INVERTEBRATE FISHERIES

LOBSTER DISTRICTS AND SEASONS

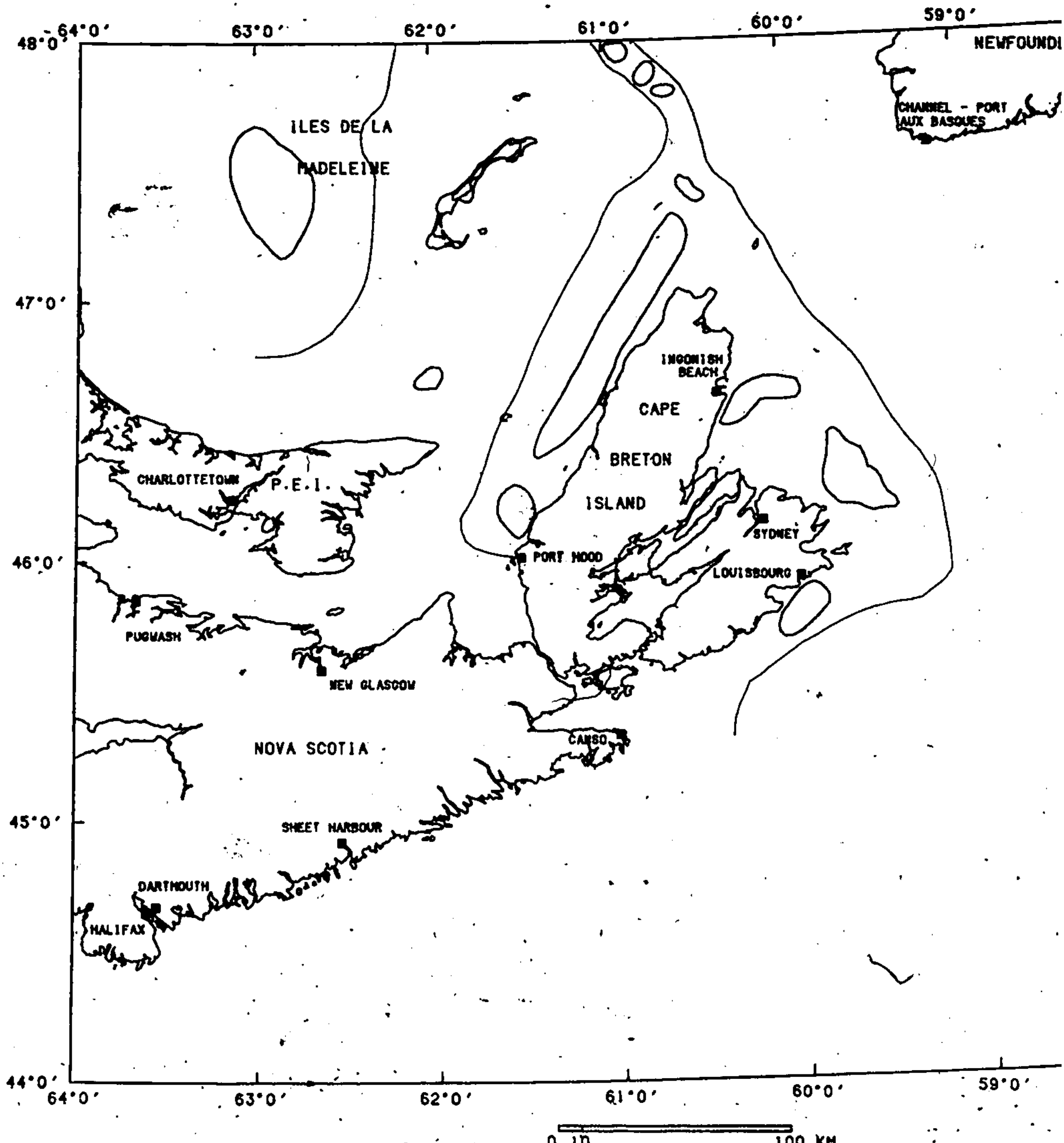
DISTRICT NUMBER - OPEN SEASON

5B	-	APRIL 20 TO JUNE 20
6A	-	MAY 20 TO JULY 20
6B	-	MAY 16 TO JULY 15
7A1	-	MAY 1 TO JUNE 30
7B	-	MAY 1 TO JUNE 30
7B1	-	MAY 1 TO JUNE 30
8	-	AUGUST 10 TO OCTOBER 10
9A,B	-	MAY 10 TO JULY 10
11	-	APRIL 20 TO JULY 5
14	-	APRIL 20 TO JUNE 30

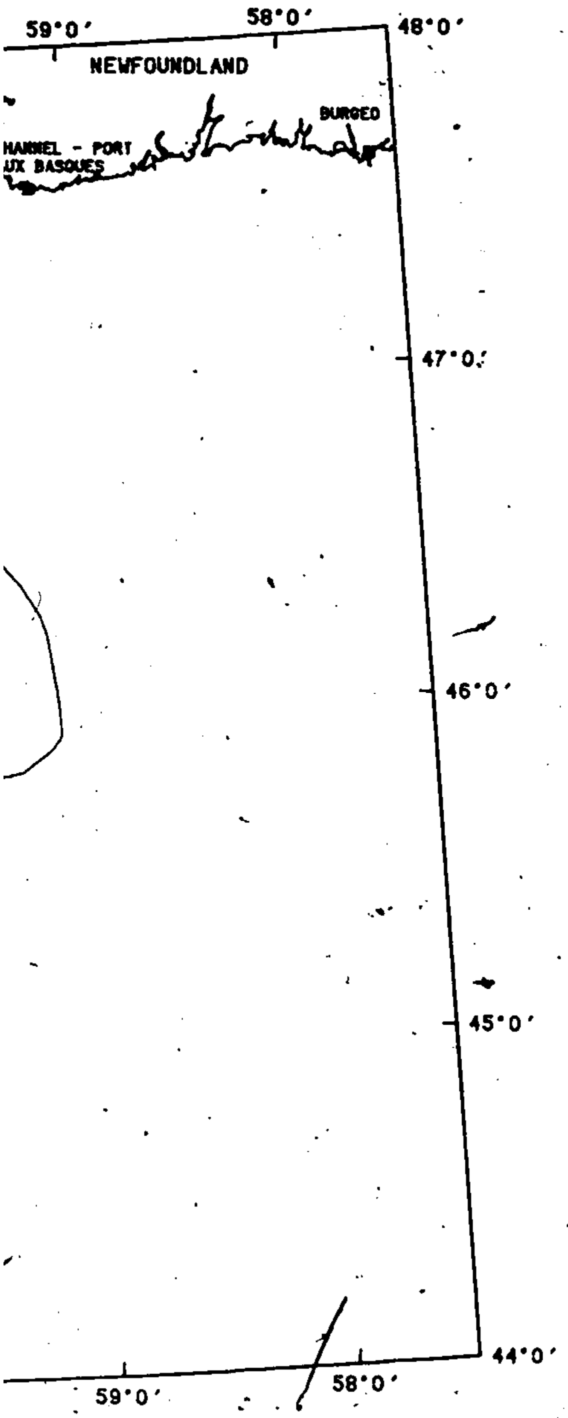
REFERENCE: APPENDIX I

Figure 3-3

Examples of single coordinates associated with an alphanumeric code (district number) and textual information (district numbers and seasons); and of line segments without textual information (district boundaries).



48°0′
64°0′
63°0′
62°0′
61°0′
60°0′
59°0′
NEWFOUNDI
CHANNEL - PORT
AUX BASQUES
ILES DE LA
MADELEINE
47°0′
INGONISH
BEACH
CAPE
BRETON
ISLAND
CHARLOTTETOWN
P.E.I.
SYDNEY
PORT HOOD
LOUISBOURG
46°0′
PUGWASH
NEW GLASGOW
CANSO
NOVA SCOTIA
45°0′
SHEET HARBOUR
DARTMOUTH
HALIFAX
44°0′
0 10
100 KM



PETRO-CANADA CABOT STRAIT
ENVIRONMENTAL DATA
1983

INVERTEBRATE FISHERIES

SNOW (QUEEN) CRAB

GENERAL DISTRIBUTION
OF THE POPULATION

AREAS OF MAJOR CONCENTRATION
OF FISHING EFFORTS

POTENTIAL FISHING AREA

REFERENCE: APPENDIX I

Figure 3-4

Example of closed areas (major concentration of snow crab fishing efforts).

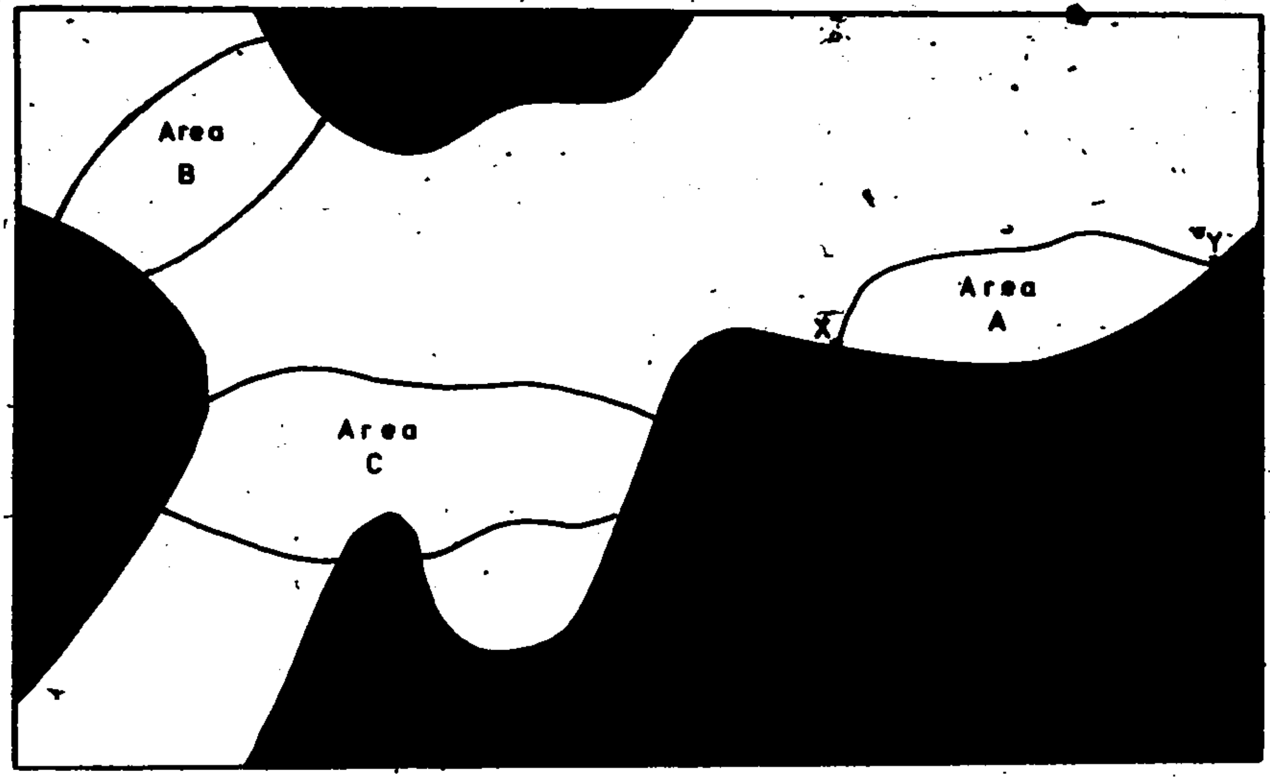


Figure 3-5

Three cases of data represented by areas along the coastline. The red lines are digitized to represent the seaward limits of the areas.

from point X to point Y. This consistent approach will enable to differentiate between the inside and outside of given areas, a condition necessary to shade land masses, the sea, and areas of data using different colors.

Environmental data not associated with coastal UTM coordinates are digitized using a distinct program. As in the case of the geographical data themselves, each UTM coordinate is assigned a tag value. These tags are then used to distinguish among the seven main possibilities described above, the particular case under consideration.

Each time a coordinate is digitized, this program verifies the validity of the tag value as well as the remaining part of the data record received from the digitizer, as described in section 2.3. The program also verifies the validity of the sequence of tags. For example, when a closed area (case 6) is digitized, an 'end-of-closed-area' coordinate must be encountered before any other operation can begin. If the digitizer coordinate or the tag is not acceptable, the program requests that the last point be redigitized. Coordinates that are valid are placed in an output file, along with any textual material entered using the CRT terminal. To simplify subsequent operations, different data parameters are digitized and stored in distinct data files.

3.2.2. Transformation of Verified Digitizer Coordinates to Universal Transverse Mercator Coordinates

All valid digitizer coordinates of all files containing environmental data independent of coastal UTM coordinates are then transformed into UTM coordinates. This is accomplished using an approach that is similar to the one described in section 2.3.2. These UTM coordinates are also adjusted to eliminate, as much as possible, the distortion of data maps. The adjustment is performed in a manner similar to the one described in section 2.3.3.

The adjusted UTM coordinates and the associated textual information are stored in a series of separate environmental data files. One data file is created for each data parameter for each map sheet. These files are differentiated by their names, which includes a seven character code number for the map sheet to which they apply, and a three character code number to identify the data parameter.

PART 4
DATA ORGANIZATION ACCORDING TO GEOGRAPHICAL REGIONS

DATA ORGANIZATION ACCORDING TO GEOGRAPHICAL REGIONS

4.0. Introduction

One important characteristic of the present environmental microcomputer data base system is the flexibility with which it can accept the wide variety of information that needs to be considered for oil-spill response, contingency planning, and regional assessments. To arrive at this flexibility, it is neccessary to allow a variable number of pointers to be associated with geographical data. The number of pointers assigned to the coordinates of the geographical data files is constant within an overall region, but it varies from region to region. The environmental data files associated with these pointers have not only different contents but also a different input-output format for each region. Furthermore, the pointers themselves may require a different format, according to their value. The contents of the environmental data files which are not associated with the pointers of the geographical data base can also differ considerably.

It is obvious that all programs which need to access the geographical data files must know the number of pointers associated with each coordinate and the format of these pointers before being able to read any of these records. Similarly, all programs which access the environmental data files must know the name of the data file, the number of variables in each record of the file, and their input-output formats in order to read the information.

Several options could be implemented to handle all possible variations of data types and formats. One option would be to create a different version of all programs that access the data according to each major region. A second option would be to write a large program that could be used for all regions, with different sections designed specifically for each region. Both options have serious disadvantages. The first one would require the use of a large number of programs that would occupy a large amount of valuable disk storage space. The second option would most likely require the use of programs that would be too large for the limited amount (64 Kbytes) of random access memory available on the microcomputer used for this work.

To solve this problem, all programs which need to access the geographical or environmental data files start their execution by reading a regional setup file. These setup files describe the organization of the data for each major region and contain all the information required to allow programs to access the appropriate data files.

In the following sections describing the nature and use of these setup files, data associated with coastal UTM coordinates, are refered to as Type 1, and data independent of coastal UTM coordinates are refered to as Type 2.

4.1. Regional Setup Files for Type 1 Data

A setup file for Type 1 data is created for each region and is used to access both the geographical data files made up of UTM coordinates and their pointers, and the environmental data files corresponding to these pointers. The regional setup files for Type 1 data always contain the following information:

1: the number of UTM coordinates grouped into each random access record of the geographical data files,

2: the number of pointers associated with each UTM coordinate, and

3: the formats required to read correctly the random access records of the geographical data files.

If at least one pointer has been associated with the UTM coordinates of the geographical data files, then for each set of pointers, the regional setup file also contains the following information:

1: the name of the environmental data file associated with the pointer,

2: the number of variables in the random access records of this environmental data file,

3: the type (integer or real numbers) and range of values for each of these variables,

4: the format of the random access records making up this data file,

5: the name of the menu file (see section 4.2.) that lists the individual data parameters represented by the different values of the variables of the environmental data file, and

6: all formats required to create, update, or print this environmental data file. These formats include those of lines to be displayed on the CRT terminal as guides to be followed when entering new data, those used to input data from the CRT terminal, those used to print the titles of data files, and those used to print the data themselves.

4.2. Menu Files for Type 1 Data

In the regional setup files described above, two file names are assigned to each set of pointers. The first one is the name of the environmental data file associated with the given set of pointers. The second one is the name of a menu file which contains a description of the contents of the environmental data file. Each menu file consists of the following:

1) A main title specifying the general type or category of data contained in the corresponding environmental data file.

2) For each variable stored in a record of the environmental data file: a title describing the data subcategory, and a flag to indicate whether or not this variable can have multiple values. If it can, the flag is set to 1.

3) For each variable for which flag = 1, a title describing the data represented by each possible value of the variable.

Let us consider for example the first pointer associated with the geographical coordinates in the case of Labrador. The main title in the menu file associated with this pointer is GEOLOGY, indicating that all data in the environmental data file associated with this pointer consist of the geological description of the shorelines. The records of the environmental data file contain data for 14 different variables. The titles describing these variables are:

1: videotape numbers,

2: coastLand - general elevation and slope of the land, 3: coastland - extent and type of vegetation,

4: backshore - slope and nature,

5: backshore - other features,

6: intertidal zone - nature of upper intertidal zone,

7: intertidal zone - texture of upper intertidal zone,

8: intertidal zone - nature of middle and lower intertidal zone,

9: intertidal zone - texture of middle and lower intertidal zone,

10: intertidal zone - other features of middle and lower intertidal zone,

11: nearshore features,

12: access - land and air access to the shore zone,

13: access - sea access to the shore zone,

14: data source.

The flag associated with each variable is set to 1 for all variables except for the first one which is set to 0. This is because in this example, each value of variable 1 does not represent different data parameters, but only a different videotape number.

Variable 2 has seven possible values, each representing different data. These values are associated with the following titles in the menu file:

0: unknown,

1: low elevation (<10 m), horizontal or gently sloping (0-20 degrees),

2: moderate elevation (10-50 m), horizontal or gently sloping,

3: moderate elevation, moderately sloping (20-45 degrees),

4: moderate elevation, steeply sloping or cliffed (45-90 degrees), 5: high elevation (>50 m), horizontal,

6: high elevation, steeply sloping or cliffed.

The titles contained in the menu file describe textually the data categories, subcategories, and individual data parameters that are present in the study region and help the user to make a selection to be displayed on the color monitor. Menus consisting of lists of these titles are displayed on a CRT terminal during the normal course of operations and each title represents a data category, subcategory, or parameter which can be selected by the user. The menus available for the different regions covered by this data base are listed in appendices I to IV.

4.3. Regional Setup Files for Type 2 Data

A regional setup file for data not associated with coastal UTM coordinates is assembled for each major study area. These files along with their associated menu files define which Type 2 data are present in each overall study area. The setup files include for each general category of data: a main title; the number of subcategories of data whithin this main category; and for each subcategory: a title, and the name of the menu file associated with it.

Let us consider for example the Cape Breton - Cabot Strait region. The menus for this region are listed in Appendix II. The main categories of Type 2 data are: anthropogenic features, tourism and recreation, and biology. Each of the first two categories are made up of a single subcategory with similar titles. The biological data are grouped into six subcategories:

seaweed harvesting areas, invertebrate fisheries, estuarine fisheries, demersal fisheries, pelagic fisheries, and mammals. Each subcategory is associated with a menu file, the name of which is given in the regional setup file.

4.4. Menu Files for Type 2 Data

The menu files for Type 2 data describe the data parameters included in each subcategory specified in the setup file. Each menu file includes the number of data parameters in the particular subcategory under consideration; and for each data parameter, a title describing the information, and the name of the environmental data file that contains the information. For example, the menu file for the seaweed harvesting areas subcategory indicates that there are four data parameters in this particular subcategory: irish moss, dulse, rockweed, and kelp. Each one of these data parameters is associated with an individual environmental data file.

The regional setup files and the menu files for Type 2 data do not contain input-output formats. This is because all files containing Type 2 environmental data are accessed using the same formats. The tag of each coordinate indicates whether or not it is accompanied by textual or numeric information (see section 3.2.1). These tags are used to select the appropriate formats.

PART 5

APPLICATIONS

APPLICATIONS

5.0. Introduction

This environmental data base system was used, up to the time of writing this document, for four major regions of Canada. These regions are: 1) a part of Labrador centered around the town of Cartwright; 2) a region centered on Cabot Strait including southwestern Newfoundland, Magdallen Islands, Prince Edward Island, Cape Breton Island, and the eastern half of Nova Scotia; 3) a region including the Queen Charlotte Islands, Dixon Entrance, Hecate Strait, and the adjacent mainland coast; and 4) a smaller but more detailed area of the Queen Charlotte Islands centered on Louise Island and northeastern Moresby Island.

The system was developed for a number of specific purposes. The most immediate purpose is to help in the event of an oil-spill. The improvement of oil-spill contingency planning and regional assessments are equally important objectives. The nature of the system also makes it particularly valuable for carrying out research on coastal characteristics and processes.

The ability to respond to two very basic questions seem to underly the three first applications: emergency oil-spill response, contingency planning, and regional assessments. These two questions are: 1) given a certain area or location in a study region, what are the prevailing environmental characteristics; and 2) given a certain environmental characteristic or combination of characteristics, what is its distribution throughout the area under study (Bertin, 1983).

This system was developed to be able, among other things, to answer these two basic questions. After defining the area or location of interest within the study region, the environmental part of the data base is searched to find the information present in this specified area. A list of these data parameters is then displayed as a series of menus. This answers the first basic question: given a certain area, what is there? Using these menus, it is then possible to request a map showing the distribution of the selected environmental parameters to be displayed on the color monitor or to be plotted on paper. This process answers the second basic question: given a certain data parameter or combination of parameters, what is its distribution?

Reseach on coastal characteristics and processes requires a somewhat different approach. In this case, calculations are performed on individual parameters or on combinations of parameters to obtain quantitative measurements of abundance. The influence of geographical location on abundance of coastal characteristics and the degree of association that exists between parameters can also be measured quantitatively.

Early in the development of this system, the author realised that, in general, environmental data could be subdivided into two groups: site specific and regional. This is purely a reflection of the nature of the data themselves. The distribution of warfs cannot be displayed in a meaningful manner on a map with a scale of 1:500,000 if the intent is to show their exact location. Similarly, it would require many 1:10,000 map sheets to display the major fishing zones of the Gulf of St Lawrence - Cabot Strait region. It is also evident that displaying large detailed areas using a very large scale requires a large amount of time. To be able to handle both site specific and regional information in a meaningful manner, it was decided that coastlines would be digitized twice where necessary: once with a high resolution (for example 1:25,000 or 1:10,000) for site specific data, and once with a much lower resolution (for example 1:500,000) for regional information. For this reason, each of the four major study regions has two series of geographical data files and associated block index files, map index files, and environmental data files.

The system is designed such that only site specific data can be plotted on high resolution detailed maps, but both site specific or regional information can be plotted on regional maps. This is because there can be cases where viewing detailed information at a regional scale can be of use. For example, a display of the locations of warfs throughout Labrador does not indicate their precise geographical distribution, but it does give at a glance an indication of where they are concentrated within the overall region. A good deal of common sense is required here in order to formulate meaningful requests.

5.1. Oil-Spill Emergency Response

In the event of an emergency oil-spill situation, the user is required first to define the area of interest. Once defined, the environmental part of the data base is searched to find and list the data parameters that are present within this area. These lists enable the user to gain an appreciation for the conditions, characteristics, and sensitivities of the area, even without displaying any of the information in map form. For example, knowing that the area of importance includes a large marsh, a few low energy sections of shorelines, and bedrock cliffs is sufficient to formulate a ranking with respect to shoreline geomorphic sensitivity. The user can then require a map of the area with the location and extent of the marsh displayed according to his specifications. The user could also request a map showing the geographical location of the marsh and the low energy sections of shorelines. Within a few minutes, the user has been informed of 1) what is present (as a list of parameters) in the area he has specified, and 2) where these parameters are located within the area specified (as a map on the color monitor). The processes involved in answering these two basic questions are described in detail in the following sections.

5.1.1. Creation of Geographical Maps on the Color Monitor

The first requirement for emergency oil-spill reponse is to draw a map of the shorelines of an area whose limits have been defined by the user. There are no restrictions on the selection of this area, neither with respect to its size nor with respect to its location within the overall study region. The area of interest may consist in only part of an original map sheet, it can extend over several adjacent map sheets, or it can even extend over adjacent UTM zones.

Before using the color monitor, it is necessary to initialize the Microangelo graphic system by defining a screen organization. This screen organization can be defined by the user or a default organization can be read from a file. In either case, it is done by defining:

- the number of transparencies (1 to 8);
- the number of bit planes (1 to 8) making up each transparency, remembering that the total number of bit planes cannot exceed 8. The number of bitplanes for each transparency defines the maximum number of colors which can be displayed on that transparency. One bit plane can be used to display simultaneously two colors, two bit planes can display four colors, three bit planes can display 8 colors, and so on.
- The colors assigned to each transparency, as defined by their proportion of red, green, and blue.
- The order of precedence of transparencies. If transparency 1 precedes transparency 2, then drawings on transparency 2 will be hidden where overlapped by drawings present on transparency 1.
- The presence or absence of fusion. Fusion of colors is used to highlight overlapping drawings by displaying the overlap in a different color. If fusion is to take place, the resulting color has to be defined.

Since there are several study regions, each with two levels of resolution, the user must specify the particular study region and level of detail he wishes to access. After specifying these two, the user must define the area of interest by specifyng its boundaries in terms of UTM or latitude - longitude coordinates. Several variables must then be calculated before a map can be displayed on the color monitor. These variables are:

1) The distortion factor inherent in the Microangelo graphic

system. This distortion is due to the different maximum number of addressable points in an horizontal and vertical direction, for equivalent distances on the color monitor. Without this distortion factor, a map of a square area would have a rectangular outline.

2) The calibration factor. All UTM coordinates present within the area specified must be converted to appropriate machine coordinates of the graphic system. This calibration factor is always calculated such that the area specified will fill, as much as possible, the entire screen of the color monitor.

3) A displacement factor. This factor is used for esthetic reasons to center the map of the specified area on the screen of the color monitor.

At this point, the computer is ready to begin the creation of a geographical map of the specified area. The map index file is searched to find which map sheet or map sheets are part of the specified area. For each of these map sheets, the block index file is then searched to verify which part or parts of the geographical data file needs to be examined. The UTM coordinates that fall within the boundaries of the specified area are then converted to graphic coordinates by the use of the distortion, calibration, and displacement factors. They are then plotted on the color monitor, either as separate points or as points joined by lines as necessary to display a correct map of the coastlines of the area. If the area displayed on the monitor is not exactly what the user wanted, he can respecify new limits and the process described above is repeated.

At this time, a temporary file is created to contain for each map sheet belonging to the specified area the number of the map sheet and the addresses in the corresponding geographical data file of the first and last coordinates of the sections of coastlines within the selected area. This temporary coordinate address file is used to save time in subsequent reaccessings of the data base for the same specified area.

5.1.2. Creation of Menus

After creating a map of the specified area on the color monitor, a series of menus are created using the regional setup files and the menu files for both Type 1 and Type 2 data (data associated with coastal UTM coordinates and data independent of coastal UTM coordinates). The complete menus for the four major study regions are listed in appendices I to IV.

These menus are complete lists of all parameters that are present in the four major study regions. It should be clear however that it is unlikely to have all parameters of a region present simultaneously in a subarea. A simple list of all parameters present in an overall study region is not an efficient approach to examine a subarea. If a user has no idea of which data is present or absent in the area he has specified, he can waste valuable time requesting displays of the distribution of parameters that may not be present.

This problem is eliminated by searching the environmental data files and by indicating to the user which data parameters out of the lists presented as menus are present in the area he has specified.

To do this, the environmental data files associated with the coastal UTM coordinates (Type 1 data) are searched first. The temporary coordinate address file described in section 5.1.1. is used to reaccess efficiently the appropriate sections of the geographical data files. The elements of the appropriate sections of the geographical data files are examined one by one and their pointers are used to verify the corresponding environmental data files. A matrix of flags indicating the presence or absence of individual data parameters is created for each set of pointers and is used in conjunction with the menus to indicate which data parameters are present in the area specified.

The files containing environmental data independent of coastal UTM coordinates (Type 2 data) are verified next, and a series of matrices of flags are used to indicate the presence or absence of parameters in a manner similar to the above one.

When all relevant environmental data files have been searched, a first menu refered to as LEVEL 1 is displayed on a CRT terminal. Two additional lines, not present in the appendices, are displayed at the end of each menu on the CRT terminal. The first line indicates which data categories, subcategories, or parameters are present in the specified area. This is done by listing the number of the appropriate options. If an option number is not listed in this line, the program will not let the user select it. For example, consider the LEVEL 1 menu for Labrador:

SELECTION OF DATA TYPES - LEVEL 1:

```
************************************************
1: REDEFINE STUDY AREA
2: REVIEW OR MODIFY SCREEN GRAPHICS ORGANIZATION
3: REVIEW OPTION(S) SELECTED
4: DISPLAY OPTION(S) SELECTED
5: STOP PROGRAM
************************************************

6: ANTHROPOGENIC FEATURES
7: RESOURCE HARVEST AREAS OF COASTAL LABRADOR
8: GEOLOGY
```

If no resource harvest data are present in the selected area, but both anthropogenic and geological information do exist, the line "OPTIONS AVAILABLE: 6, 8" will appear at the end of the menu. If the user tries to select option number 7, the same menu is redisplayed. The option numbers listed between the two lines of stars are not repeated in the list of available options because they are always available. The second additional line listed at the end of each menu consists of "ENTER OPTION NUMBER:".

5.1.3. Selection and Monitor Display of Environmental Data

The LEVEL 1 menu lists the control options and the main data categories for the area selected. The main control options are:

1) REDEFINE STUDY AREA. If the user wants to examine a new study area or modify the limits of the one he is working with, this option allows him to redefine new boundaries. A geographical map of the coastlines of the new area will be displayed on the color monitor and new menus corresponding to this area will be displayed on the CRT terminal.

2) REVIEW OR MODIFY SCREEN GRAPHICS ORGANIZATION. This option allows the user to review or modify the screen graphics and data graphics organizations. If the screen graphics organization is to be reviewed, the system displays on the CRT terminal: the number of transparencies presently defined, the number of bit planes for each transparency, the colors assigned to each transparency, which colors are to be fused, and the order of precedence of the transparencies. The user can then modify any of these or redefine a completely new graphics organization. If the data graphics organization is to be reviewed, the system displays on the CRT terminal the data parameters previously selected, the colors with which they are associated, and the transparencies on which they are displayed. Any of these can then be modified or deleted.

3) REVIEW OPTION(S) SELECTED. It is possible that the user may want to examine the distribution of several data parameters simultaneously. For example, he may want to display all coastlines that include a horizontal or gently sloping unconsolidated backshore, AND a wide marsh, AND a wide intertidal flat. If the user wants to review the options he has selected, the system will display on the CRT terminal both the data parameters selected and the logical operators used in formulating his choice. The logical operators available to the user are AND, OR, and NOT. At present, operators AND and OR cannot appear together in the same list of data options, and operators AND and NOT can only be used with data associated with coastal UTM coordinates (Type 1 data). The use of this option allows the user to modify the list of data parameters he has selected or to modify the logical operators used in his list of

data parameters.

4) DISPLAY OPTION(S) SELECTED. When the data parameter or combination of data parameters has been selected, the user must specify on which transparency and with which color his choice should be displayed. The system warns the user in the event of a duplication of color on a transparency. The data parameter or combination of data parameters is then displayed in conjunction with the geographical map on the color monitor. The LEVEL 1 menu is redisplayed after the execution of any of the first four control options.

5) STOP PROGRAM. This option is used to terminate the current program.

When one of the main data categories is selected from the LEVEL 1 menu, the system displays the corresponding LEVEL 2 menu. This LEVEL 2 menu lists the subcategories of data that are available and that make up the option selected from the LEVEL 1 menu. The process is repeated after selecting a particular data subcategory from the LEVEL 2 menu, and a LEVEL 3 menu is diplayed on the CRT terminal. This LEVEL 3 menu lists the individual data parameters that make up the selected data subcategory. These three levels of menus are sometimes unnecessary. Some categories of data are such that subcategories are not required and, in that case, the system will go directly from the LEVEL 1 to a LEVEL 3 menu.

The selection of data parameters to be displayed on the color monitor is always done from a LEVEL 3 menu. The following rules apply to the selection of data parameters:

1) In the case of data associated with coastal UTM coordinates,

it is possible to use the logical operator NOT with any data parameter. To select this operator, the user types a minus sign in front of the LEVEL 3 option number of the data parameter to be displayed. This logical operator can also be used in conjunction with LEVEL 1 (data categories) and LEVEL 2 (data subcategories) option numbers.

2) When selecting a combination of data parameters, the system prompts the user for the logical operator after the second parameter has been identified.

3) Only one of the logical operators AND and OR can be specified within a combination of data parameters.

4) The logical operator AND can only be used with data associated with coastal coordinates.

5) The logical operator OR can be used with data associated with coastal UTM coordinates (Type 1 data), with data independent of coastal UTM coordinates (Type 2 data), or with a combination of the two.

6). When the logical operator AND is used, the system verifies that the data parameter selected is of Type 1 and that the combination requested is permissible. It is not possible to display two data parameters belonging to the same subcategory using the logical operator AND. For example, the system will not allow a user to request a data combination consisting of gently sloping backshore AND steeply sloping backshore, since both cannot occur simultaneously at the same location.

If the data parameter or combination of data parameters is associated with coastal UTM coordinates, the system uses the temporary coordinate address file described in section 5.1.1. to reaccess the UTM coordinates belonging to the requested area. In the case of the selection of a single data parameter, each coastal UTM coordinate of the requested area is read and its appropriate pointer is used to access the corresponding record in the environmental data file. This record is verified for the presence or absence of the data parameter selected from the LEVEL 3 menu. If the data parameter is present, the UTM coastal coordinate is transformed to a graphic coordinate and is drawn on the color monitor using the color and transparency specified by the user. In the case of a combination of data parameters, the system examines the environmental data files for the presence of all selected data parameters when the logical operator is AND, and for the presence of at least one of the selected data parameters when the operator is OR. When all coastal coordinates of the specified area have been processed, the LEVEL 1 menu is redisplayed on the CRT terminal to allow the user to continue his work.

If the data, to be displayed are independent of coastal coordinates, only the environmental files containing parameters selected and in the general vicinity of the specified area are considered. Every UTM coordinate in these files is examined, and if it is within the specified area it is transformed into its corresponding graphic coordinate. It is then drawn on the color monitor following the specifications of the user with respect to data graphics organization.

If the data to be displayed are a combination of Type 1 and Type 2 and the logical operator is OR, the system performs the operations described above for each data parameter.

The approach described above fulfills the requirements of emergency oil-spill response. The user can define any subarea he wishes to examine. He can then gain an overall appreciation of the conditions and characteristics of this subarea by examining the lists of environmental parameters present. The lists of data parameters present in the specified area guide the user in deciding on which parameters to concentrate first. The geographical distribution of parameters of his choice can then be displayed on the color monitor, superimposed on a map of the coastlines of the area specified.

The main disadvantage of the present system is the relatively slow speed with which these operations are performed (an average of 1 to 3 minutes is required to examine a typical subarea of about 400 square km). This is particularly severe when the specified area is large and of high resolution. The time required to verify the presence or absence of individual parameters is not a waste as it prevents the user from formulating impossible requests later on. This relatively slow response is due partly to the use of a microcomputer to perform all these operations, and partly to the large number of operations that need to be performed. Ways of improving this disavantage are discussed in section 6.

5.2. Contingency Planning and Regional Assessments

For oil-spill contingency planning and regional assessments, the system must provide, in addition to the ability to define subareas as required and to review their environmental data rapidly, a means of producing maps of good quality. This is necessary for meeting regulatory requirements and to demonstrate the complete contents of the data base. In many cases, it is very useful to compose the maps with the help of the screen display option, before actually plotting them on paper.

5.2.1. Reviewing Environmental Data Using the Color Monitor

To review the contents of the data base for a particular region, the user follows the steps discussed in section 5.1. The overall region and the level of detail are selected first, then the limits of a subarea of interest are defined. The appropriate menus are created and displayed on a CRT terminal, along with the lists of data parameters present in the subarea of interest. The user can then select data parameters and display their geographical distribution on the color monitor.

This ability to preview maps of environmental data is very useful. It saves time that would otherwise be spent in trying various combinations directly with the plotter. When the user is examining environmental data in order to compose a map, he must take into account the basic differences that exist between the color monitor and the plotter. In general, it is preferable to keep the number of colors to a minimum for each map. Failing to do this can produce maps that are difficult to understand.

5.2.2. Creation of Environmental Maps Using the Plotter

It has been found by experience that it is both convenient and more efficient to subdivide the task of producing environmental maps into two components. This is particularly true when a large number of maps of the same area or region have to be produced as in the case of atlases. The first component is the creation of what could be called the base part of the map, the second is the overlaying of the environmental information. In this context, the base part of an environmental data map is the graphic information that remains mostly identical from one map to another. It may include:

1) a series of main titles such as the name of the overall region, the name of the project, or the name of the company for which the work is done,

2) the scale of the map,

3) an optional latitude-longitude or UTM grid within the borders of the map or, if preferable, short marks along the outer borders of the map where they intersect with UTM or latitude - longitude grid lines,

4) if required, the location and names of provinces, cities, or other prominent geographical features, and

5) if the environmental data is of Type 2, all coastlines of the area.

The data part of the map may include:

1) the geographical distribution of the environmental data,

2) any associated textual information, and

3) the titles required to identify the data category,

subcategory, or parameters displayed on the map.

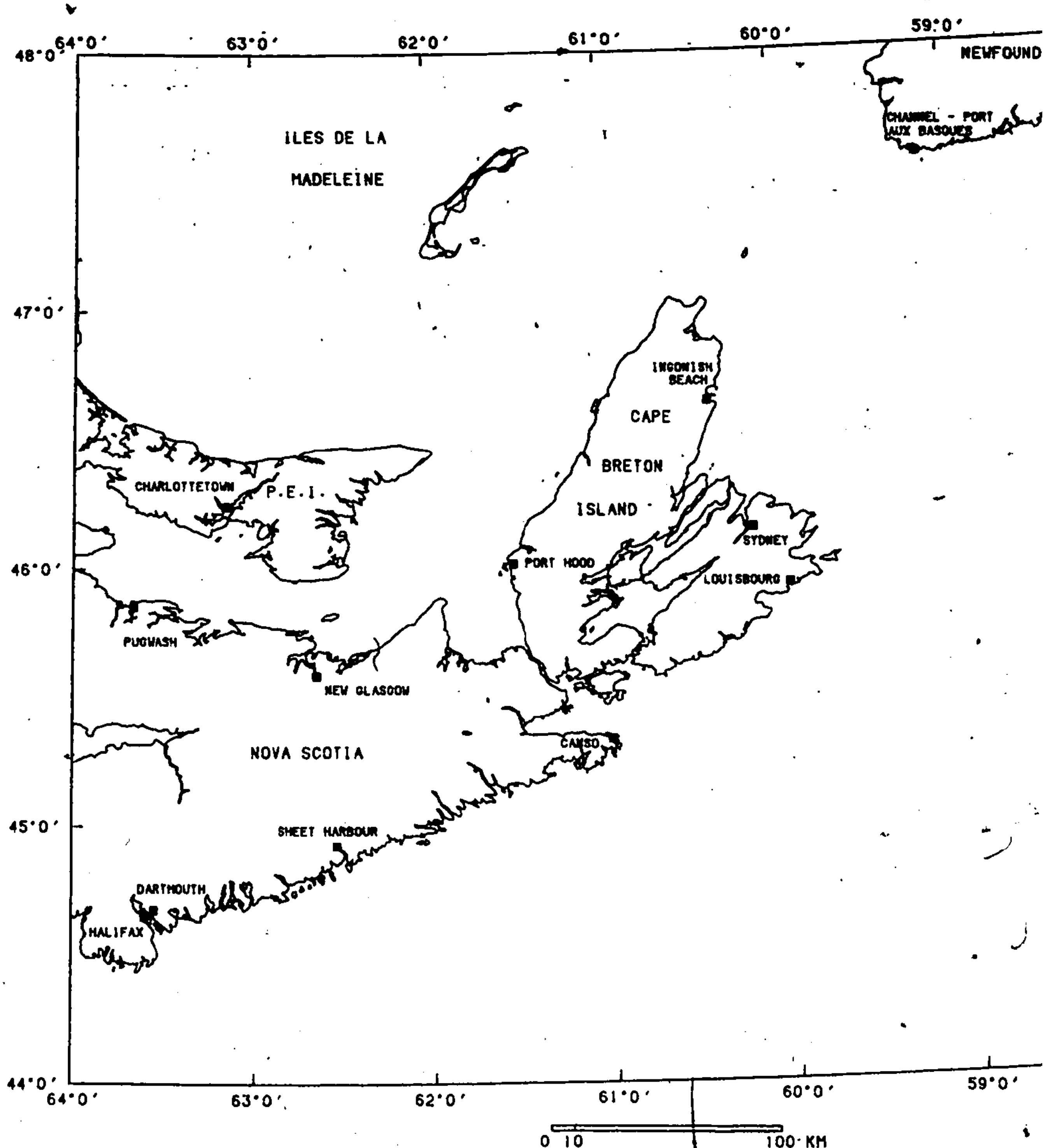
Since it is generally necessary to produce several copies of each map sheet, all plotter commands and variables required to produce the final maps are stored in disk files. A copy of a particular map sheet can then be made by superimposing the contents of the base map file and the data map file. As the base part of the map can be identical for a large number of different maps, this approach saves having to recreate the shorelines, main titles, scale, and grid lines of the maps.

5.2.2.1. Creation of Base Part of Environmental Maps

The base part of an environmental map includes those features that are generally identical from one map to another. Shorelines are normally part of the base map except when the information displayed consists of Type 1 data, that is data associated with coastal UTM coordinates. In this case, the environmental information is generally displayed by drawing the appropriate sections of shorelines using different colors. Figures 5-1 and 5-2 are examples of the base part of maps without shorelines (to be used in conjunction with Type 1 or both Type 1 and Type 2 data) and including shorelines (to be used in conjunction with Type 2 data only).

The program used to create the base part of environmental maps performs the following tasks:

1) It prompts the user for the overall region to be used, the level of detail (regional or site specific), the limits of the specific area to be displayed, the width and length of the sheet


64°0'
63°0'
62°0'
61°0'
60°0'
59°0'
48°0'
47°0'
46°0'
45°0'
44°0'
NEWFOUND
CHANNEL - PORT AUX BASQUES
ILES DE LA
MADELEINE
INGONISH BEACH
CAPE
BRETON
ISLAND
CHARLOTTETOWN
P.E.I.
SYDNEY
PORT HOOD
LOUISBOURG
PUGWASH
NEW GLASGOW
CANSO
NOVA SCOTIA
SHEET HARBOUR
DARTMOUTH
HALIFAX
0 10
100 KM

PETRO-CANADA CABOT STRAIT
ENVIRONMENTAL DATA
1983

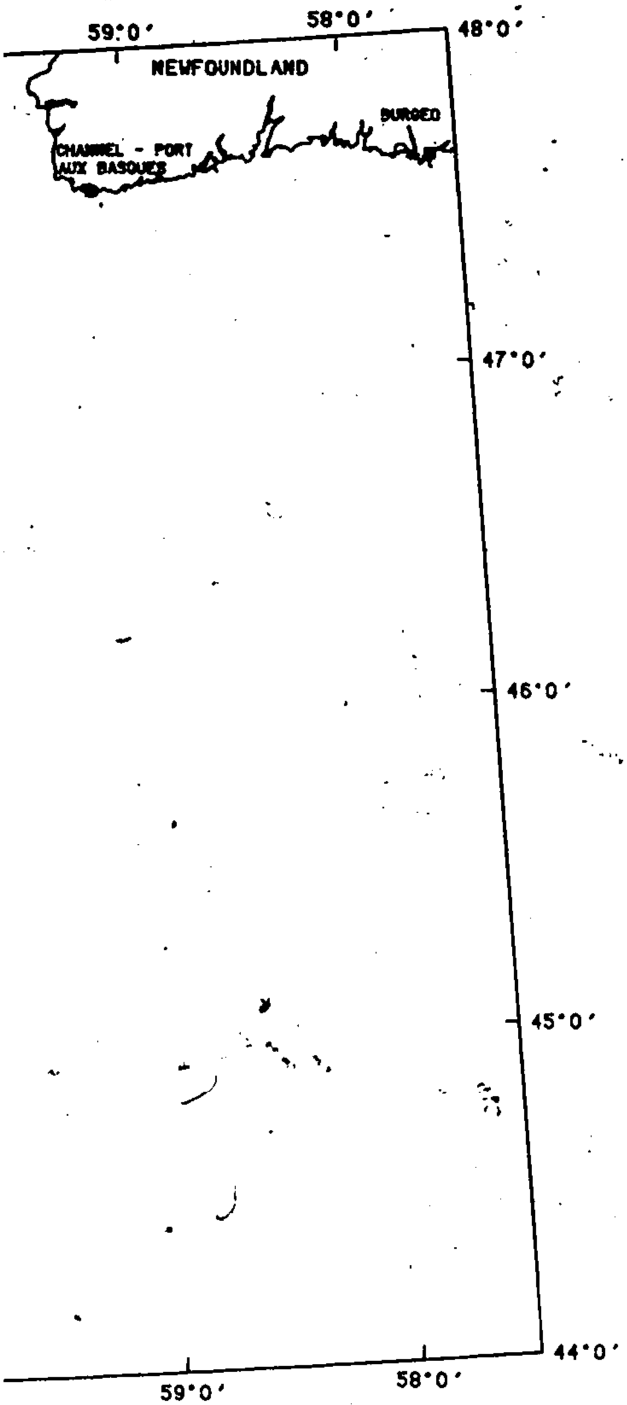


Figure 5-2

Example of a base map including shorelines.

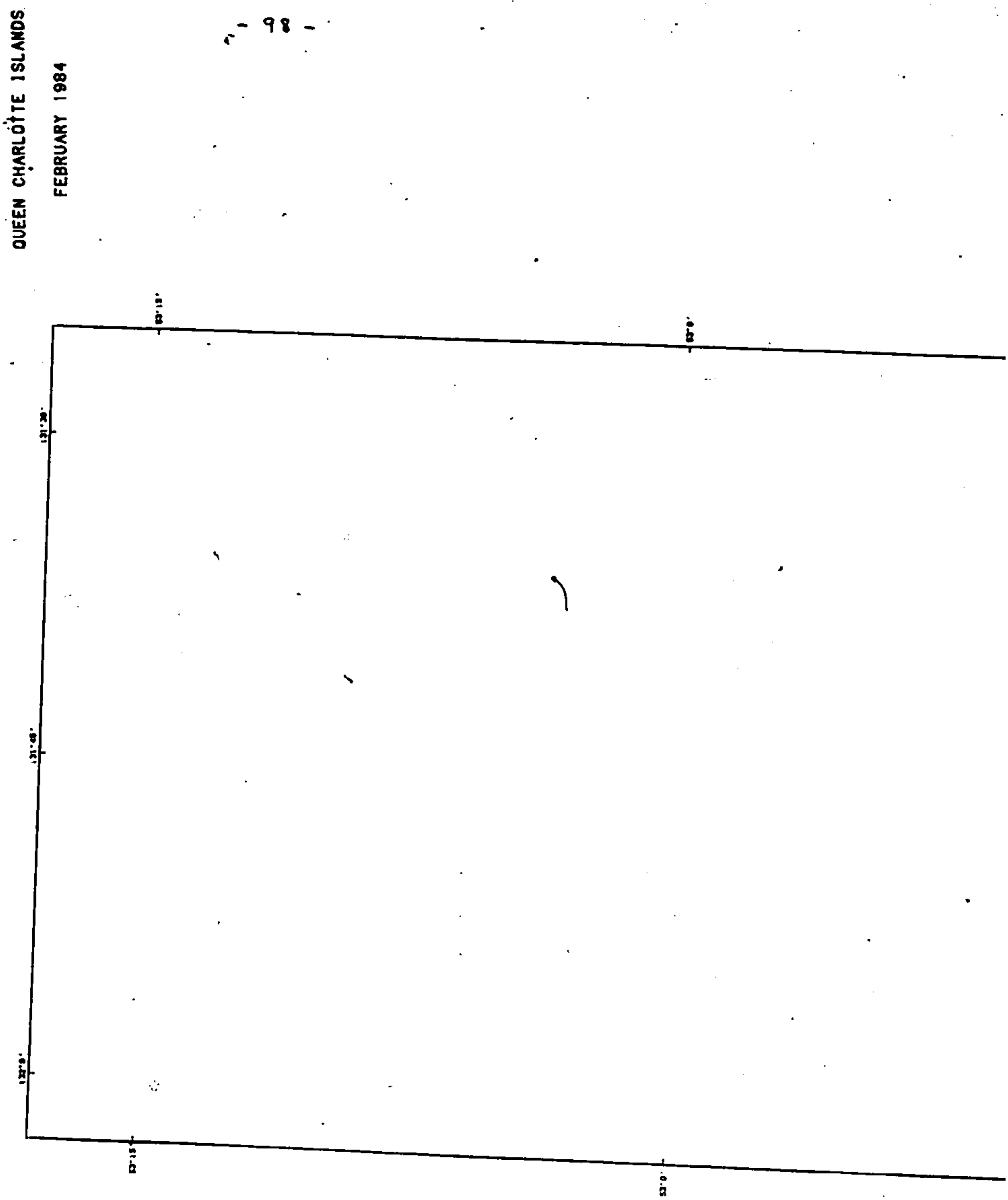
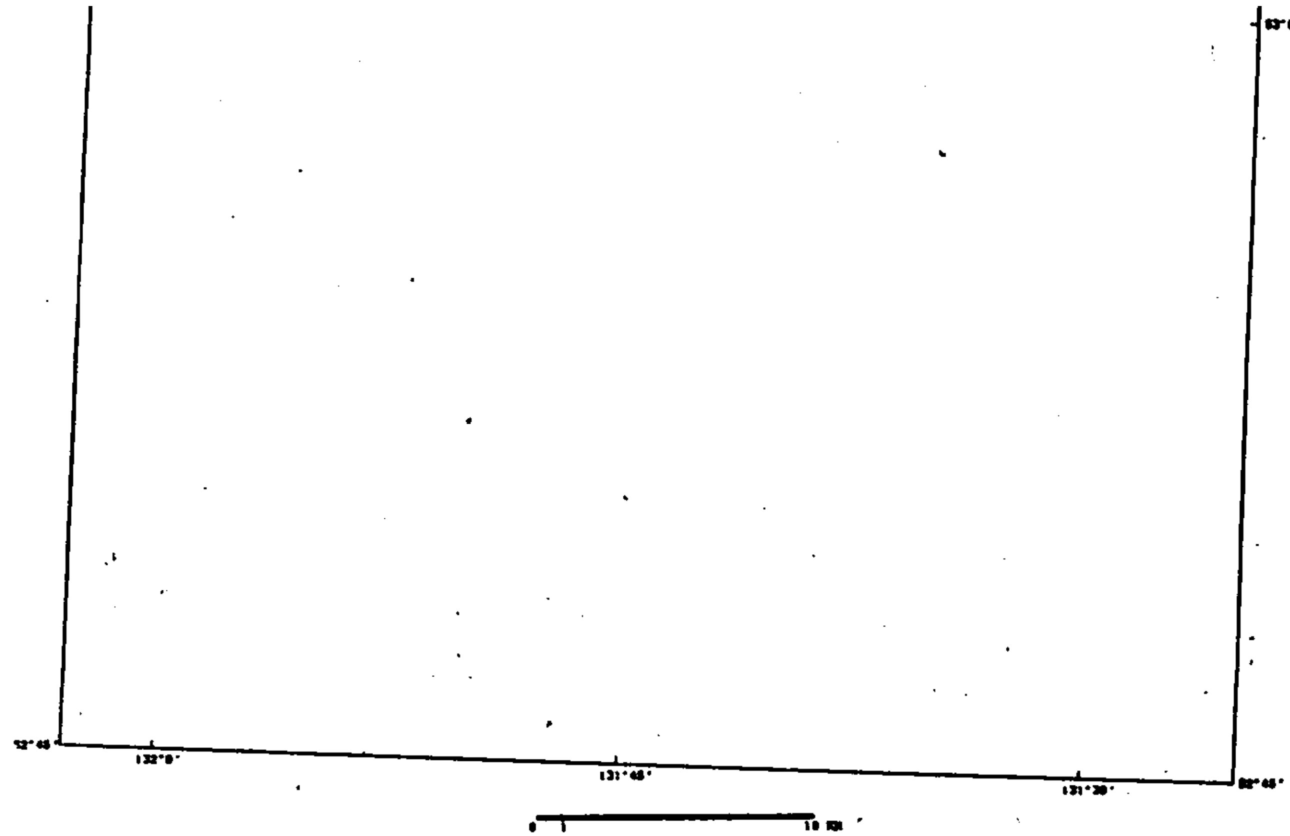


Figure 5-1

Example of a base map without shorelines.


53°0'
52°45'
132°0'
131°45'
131°30'
52°45'
0 1 10 KM

of paper on which the map will be plotted, the width of the margins, and the width of the area reserved for textual information.

2) A calibration factor and a displacement factor are calculated to translate the geographical UTM coordinates into plotter machine coordinates and to center the map, including the legend on the sheet of paper.

3) The main titles to be plotted and their size are defined by the user and the commands to plot them are sent to the base map file.

4) The scale of the map is calculated using the calibration factor and the commands to plot a bar scale at the bottom of the map are generated and sent to the base map file.

5) The latitude-longitude or UTM grid lines are calculated and sent to the base map file. If the grid is not required, the border lines only are generated. The latitude-longitude or UTM values are displayed at intervals that depend on the overall extent of the area to be displayed.

6) If the user wishes to include the shorelines of lakes, the appropriate map index file, block index files, and geographical data files are searched to find all coordinates of shorelines of lakes present in the area required. These UTM coordinates are transformed into plotter coordinates and sent together with the commands to draw them to the base map file.

7) When coastlines are to be included on a map, a similar process is used to find and transform all coastal UTM cordinates into plotter coordinates. The plotter coordinates and the commands to draw them are sent to the base map file.

8) When requested by the user, the locations and names of provinces, cities or other geographical features are sent, along with their size and commands to draw them to the base map file.

Along with the base map file, a base map layout file is created to store the variables required to create the data part of the environmental maps. These variables include the calibration and displacement factors, the size of the sheet of paper, the width of the margin where textual information will be written, and the distance from the origin of the map to the last title line.

5.2.2.2. Creation of Data Part of Environmental Maps

A separate program is used to generate the file containing the plotter instructions and the variables required to draw environmental data maps using the plotter. This program begins by first performing the three following tasks:

1) The user specifies with which base map file the data map will be associated.

2) All variables stored in the base map layout file associated with the base map specified are read. These variables are necessary to generate the data map.

3) If a page number is required, as in the case of atlases, the user specifies it and the size of the characters that should be used. The plotter commands required to plot this page number are generated and sent to the data map file.

A series of menus is then created, as defined in section 5.1.2. The LEVEL 1 menu is displayed on a CRT terminal. The control options of this menu are different than those created for use with the color monitor. For example, the plotter LEVEL 1 menu of the Cape Breton - Cabot Strait region is as follows:

```
SELECTION OF DATA TYPES - LEVEL 1

**********************************
1: CREATE A NEW DATA MAP
2: CHANGE PLOTTER PENS
3: REVIEW OPTION(S) SELECTED
4: PLOT OPTION(S) SELECTED
5: STOP PROGRAM
**********************************

6: ANTHROPOGENIC FEATURES
7: TOURISM AND RECREATION
8: BIOLOGY
9: GEOLOGY
```

The control options perform the following tasks:

1) CREATE A NEW DATA MAP. The present data map file is closed and control returns to the beginning of the program. The user can then create a new data map file.

2) CHANGE PLOTTER PENS. The pen carriage of the plotter used in conjunction with this system (a Calcomp 945) can hold only four pens simultaneously. If the user wants a plot with more than four colors, he must select this control option when pens have to be changed. The user specifies which pens (color and type) he wants, and in which position they should be mounted in the pen carriage. The appropriate plotter commands are then sent to the data map file. When these commands are executed, the plotter pauses and a message is displayed on the CRT terminal and on the plotter console itself. This message informs the operator in which positions the various pens requested should be mounted. When all pens are loaded as required, plotting can be resumed by a

response on the plotter's console.

3) REVIEW OPTION(S) SELECTED. This option is used if the user wants to review the data parameters he has selected. The system displays on the CRT terminal the parameters and the logical operators used. The logical operators available are AND, OR, and NOT: At present, the operators AND and OR can only be used with data associated with coastal UTM coordinates (Type 1 data). The use of this control option also allows the user to modify the list of data parameters he has selected and to modify the logical operators used in his request.

4) PLOT OPTION(S) SELECTED. When a data parameter or combination of data parameters has been selected, titles describing this choice can be specified and will be plotted in the right margin of the map. The user defines the titles, the size of their characters, and the colors to be used in plotting them. The plotter commands required to plot these titles are then sent to the data map file. For site specific data such as dwellings, warfs, shoreline access points, or possible helicopter landing sites, the user can define which symbols should be used to denote their location. The size and color of these symbols are also specified by the user. Once these variables have been specified, the appropriate map index file, block index files, geographical and environmental data files are searched to find the location of the specified data parameter or combination of parameters within the area of interest. The search is performed as described in section 5.1.3. The UTM coordinates of the data to be plotted are transformed to plotter coordinates using the calibration and displacement factors. The plotter coordinates and commands

required to draw them are then sent to the data map file.

5) STOP PROGRAM. The data map file is closed and the execution of the program stops.

The LEVEL 1 menu is redisplayed after the execution of any of the first four control options. The user selects the data parameter or combination of parameters to be plotted, as described in section 5.1.3. The same rules apply to the selection of data parameters wether they are to be displayed on the color monitor or using the plotter. The user can map as many data parameters as he wants at one time, however, in general, it is better to make maps simple and easy to understand.

An example of a data map showing the distribution of a single data parameter is illustrated in Figure 5-3. In this data map, all segments of coastlines including a beach have been requested as data parameter to be displayed in red. Since this data parameter is associated with coastal UTM coordinates (Type 1 data), the appropriate segments of coastlines are displayed in red, and the rest of coastlines are diplayed in black. This data map is ment to be associated with the base part illustrated in Figure 5-1 to produce a meaningful image.

An example of a map showing the distribution of three data parameters is illustrated in Figure 5-4. In this case, the three parameters, major identified lobster grounds, major lobster fishing areas, and secondary lobster fishing areas, are independent of coastal UTM coordinates (Type 2 data). The data part of the map does not include the coastlines present in the area. This data map is ment to be associated with the base map illustrated in Figure 5-2 to produce a meaningful image.

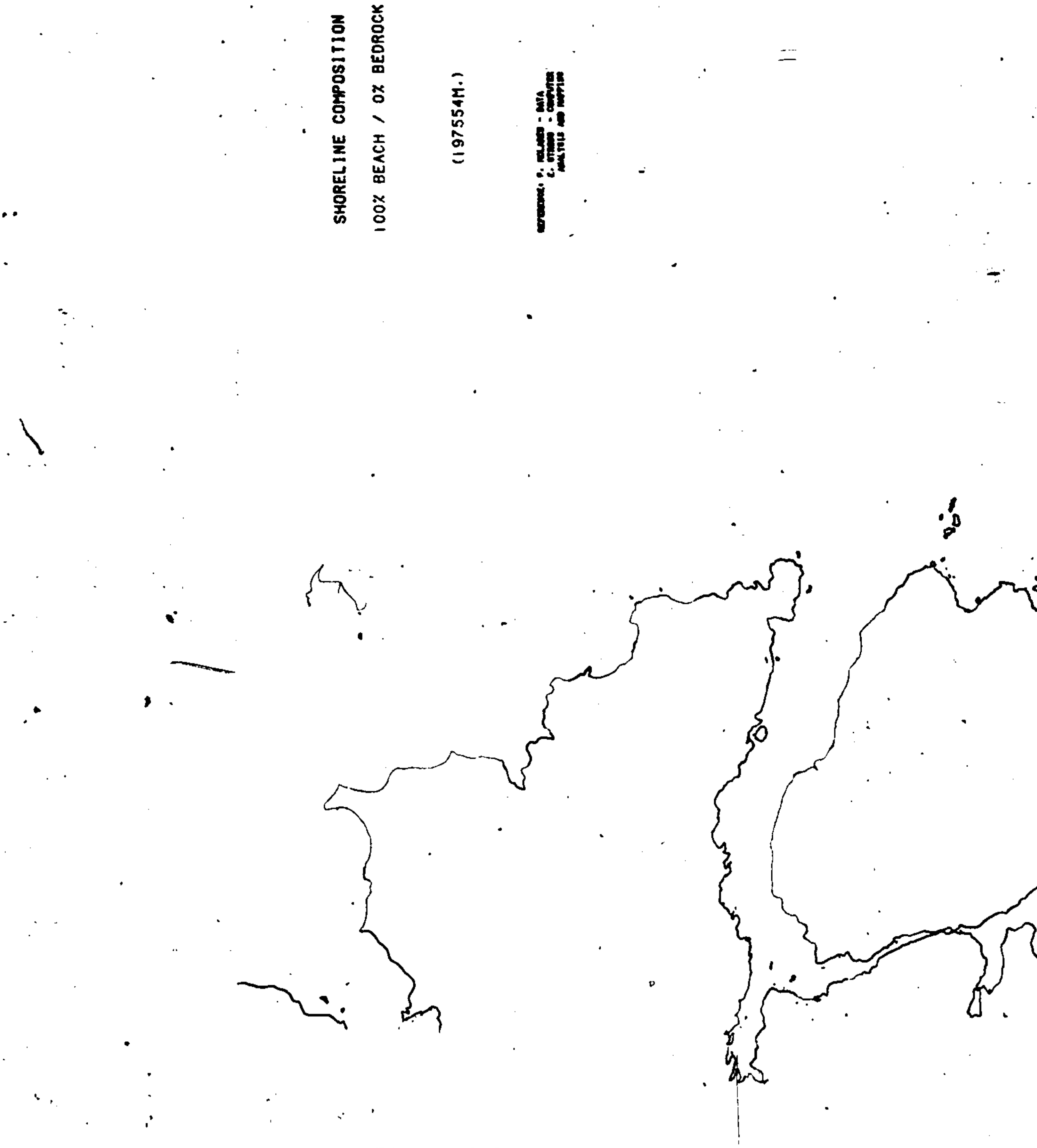


Figure 5-3

Example of data part of map displaying a single parameter. In this case, this data parameter is associated with coastal UTM coordinates (Type 1 data).

meter.
al UTM

E
three
(Type

INVERTEBRATE FISHERIES

LOBSTER

MAJOR IDENTIFIED LOBSTER GROUNDS

AREAS OF MAJOR CONCENTRATION
OF FISHING EFFORTS

AREAS OF SECONDARY CONCENTRATION
OF FISHING EFFORTS

REFERENCE: APPENDIX I

Figure 5-4

Example of data part of a map showing the distribution of three data parameters, all independent of coastal UTM coordinates (Type 2 data).

5.2.3. Plotting Environmental Data Maps

Having the base part and the data part of the environmental maps stored on disk means that plotter copies of these maps can be generated without having to recreate the image. In order to generate these plotter copies, the following operations are performed.

The appropriate pens must be mounted in the pen carriage of the plotter. A variety of pen types can be used: liquid ink drafting pens, liquid ~~ink~~ ball points, pressurized ball points, or nylon tip pens. Pens of different types can be place together in the pen carriage. The operator enters the pen type and its position in the carriage using the plotter console. The pressure, maximum acceleration, and maximum velocity of individul pens can be specified or their default value can be selected.

A scaling factor (1/9999 to 9999) and a rotation factor (0 to 359 degrees) can also be selected using the plotter console. A de-skewing value and media compensation factor can be used to compensate for the misalignment between the axes of the plotter and those of the paper and for the distortion of the paper. These features are used only when plotting on a pre-existing topographic or bathymetric map to ensure perfect matching of the image and the map.

After mounting the plotting media itself (different types of papers, acetates, and mylar materials are used according to the requirements of specific projects), the program used to plot maps is executed. The plotter commands stored in the appropriate base map file and data map file are sent to and executed by the plotter. An example of the image produced by superimposing the contents of the base map file and the data map file is illustrated in Figure 5-5. In this case, the data part of the map illustrated in Figure 5-3 has been superimposed on the base part of the map illustrated in Figure 5-1. This map is also an example of detailed information (segments of shorelines including a beach), and covers Louise Island and the northeastern part of Moresby Island of the Queen Charlotte Islands. The original map had to be scaled down to approximately one quarter of its size in order to fit the paper on which it is plotted in this document. This reduction explains the overly small size of the characters of the legend.

The superimposition of the base map illustrated in Figure 5-2 and the data map illustrated in Figure 5-4 is shown in Figure 5-6. In this case, the information is regional and the map covers the Cape Breton - Cabot Strait study region. It is reproduced here in its original size, using liquid ink ball point pens.

The ability to select a subset of an overall study region is displayed in Figure 5-7. Here the area specified covers the northeastern part of Cape Breton Island, from Bay St Lawrence in the north to Wreck Cove in the south, a subset of the overall region illustrated in Figure 5-6. This map also illustrates the ability to associate data with textual information, in this case, printed to the right of the map.

These examples demonstrate how this data base system, when used in conjunction with a plotter, enables the user to create maps according to his requirements. The ability to use the color monitor to preview combinations of data parameters allows the

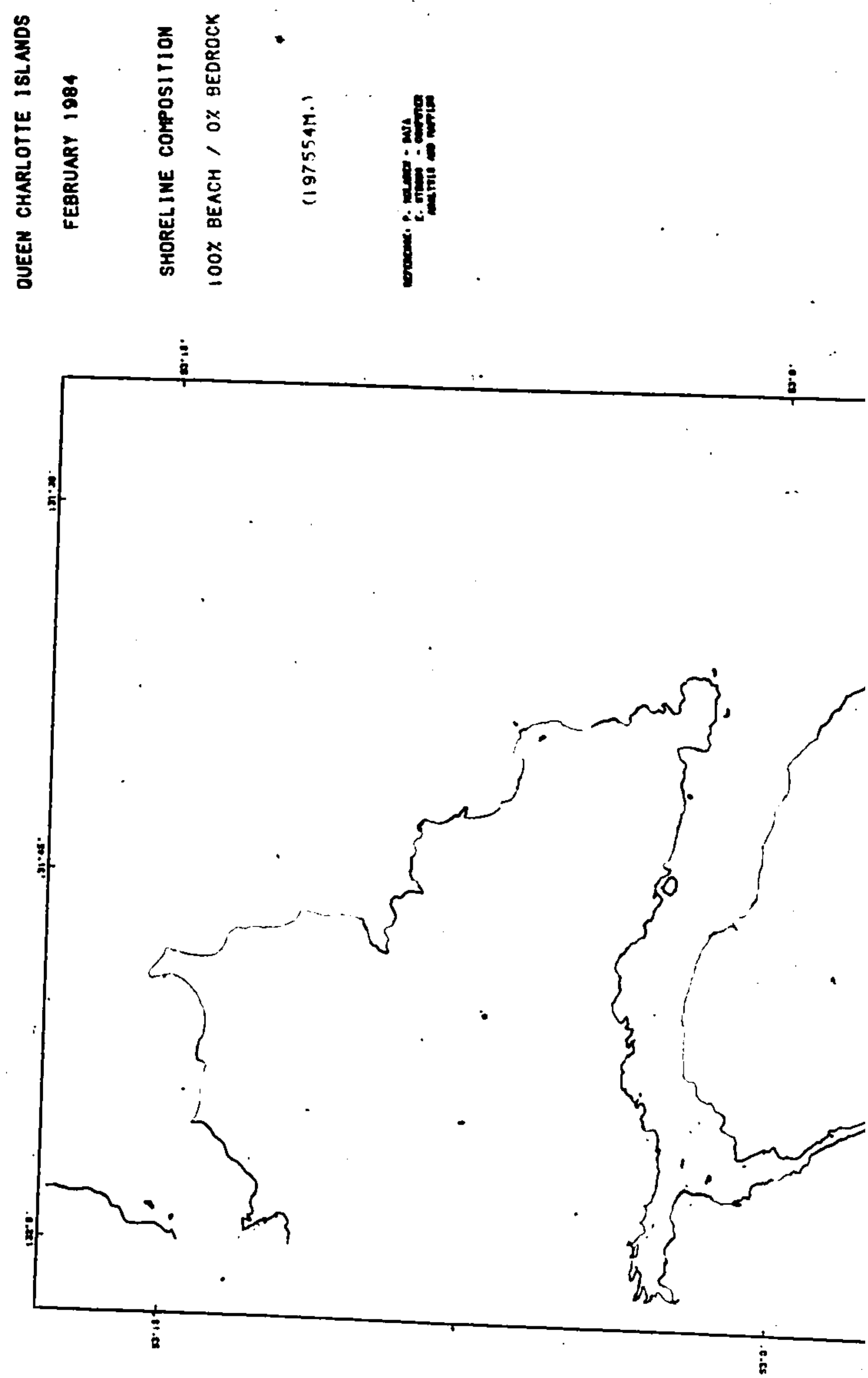
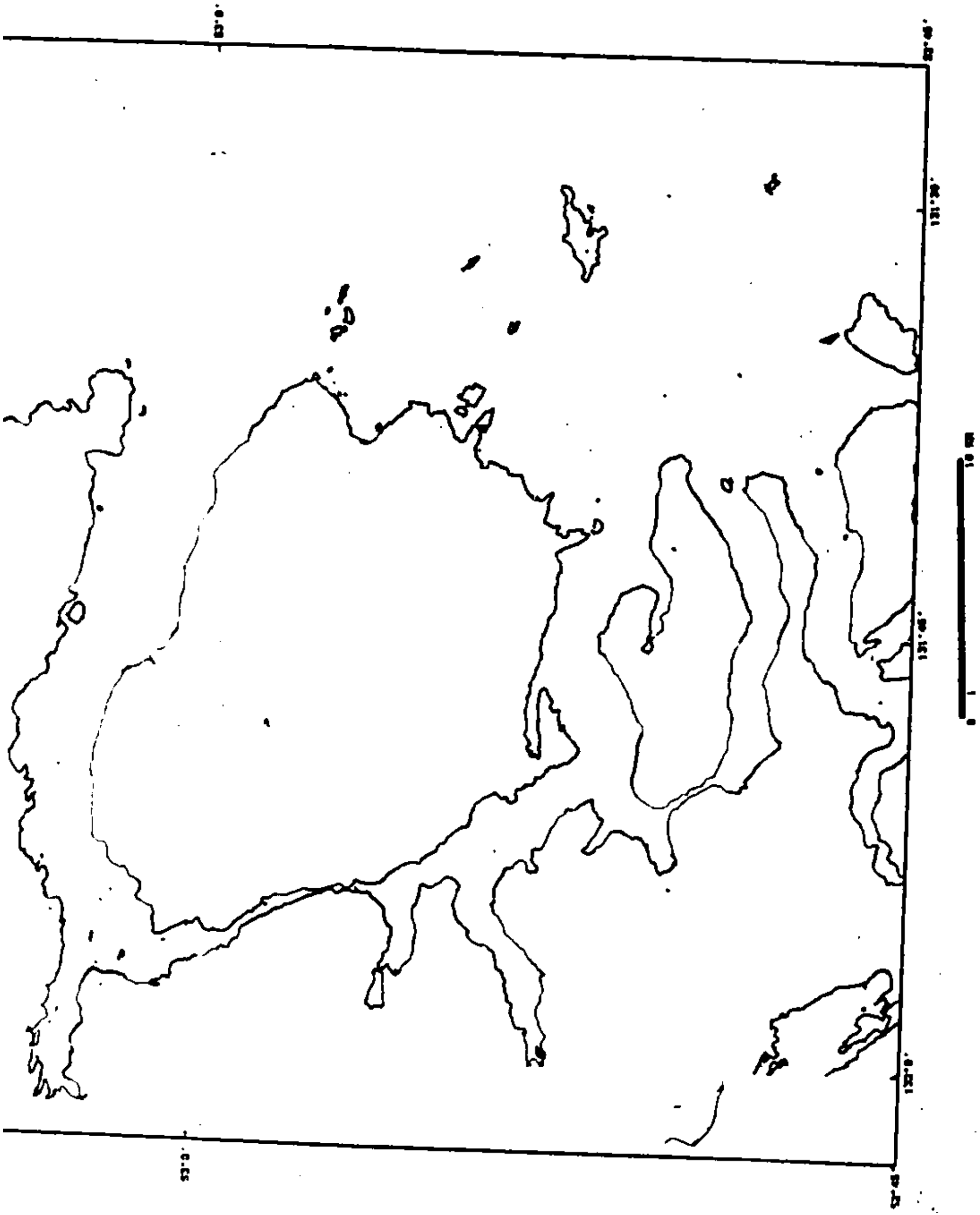
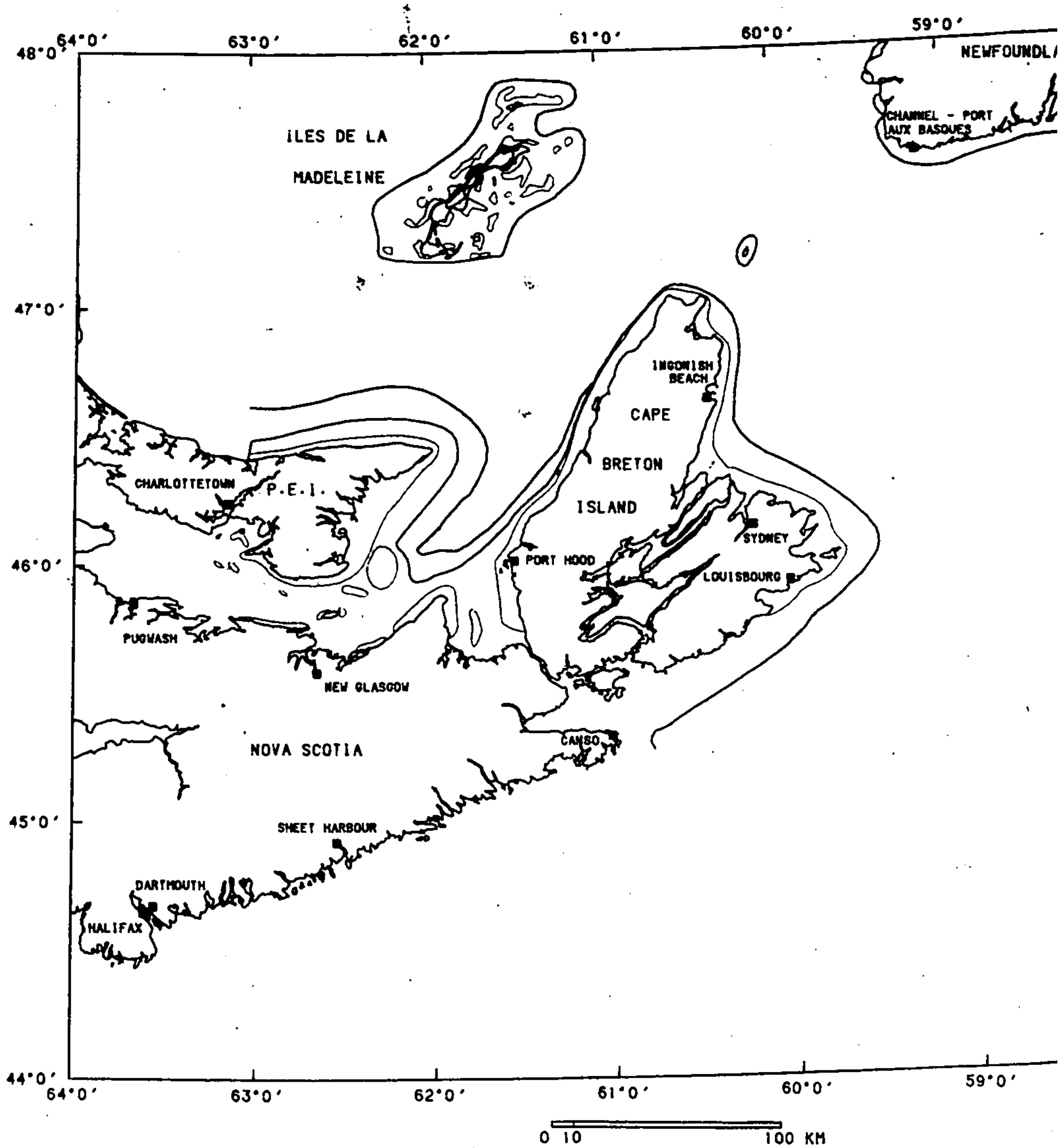


Figure 5-5

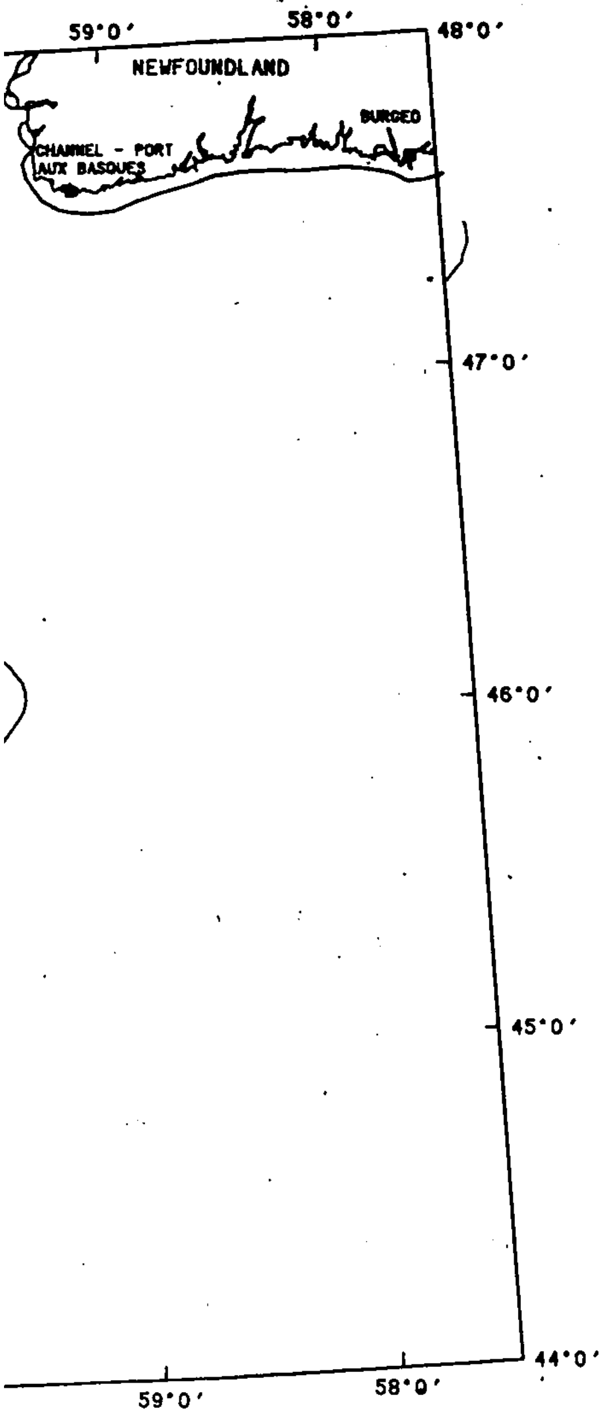
Shorelines including a beach, of Louise Island and northeastern Moresby Island, part of the Queen Charlotte Islands study region. This map is made up of the base part illustrated in Figure 5-1 and the data part illustrated in Figure 5-3.



· Island and
.rlotte Islands
t illustrated
ıre 5-3.



64°0′
63°0′
62°0′
61°0′
60°0′
59°0′
48°0′
47°0′
46°0′
45°0′
44°0′
NEWFOUNDL
CHANNEL - PORT AUX BASQUES
ILES DE LA MADELEINE
INGONISH BEACH
CAPE BRETON ISLAND
CHARLOTTETOWN
P.E.I.
SYDNEY
PORT HOOD
LOUISBOURG
PUGWASH
NEW GLASGOW
NOVA SCOTIA
CANSO
SHEET HARBOUR
DARTMOUTH
HALIFAX
0 10
100 KM



PETRO-CANADA CABOT STRAIT
ENVIRONMENTAL DATA
1983

INVERTEBRATE FISHERIES

LOBSTER

MAJOR IDENTIFIED LOBSTER GROUNDS

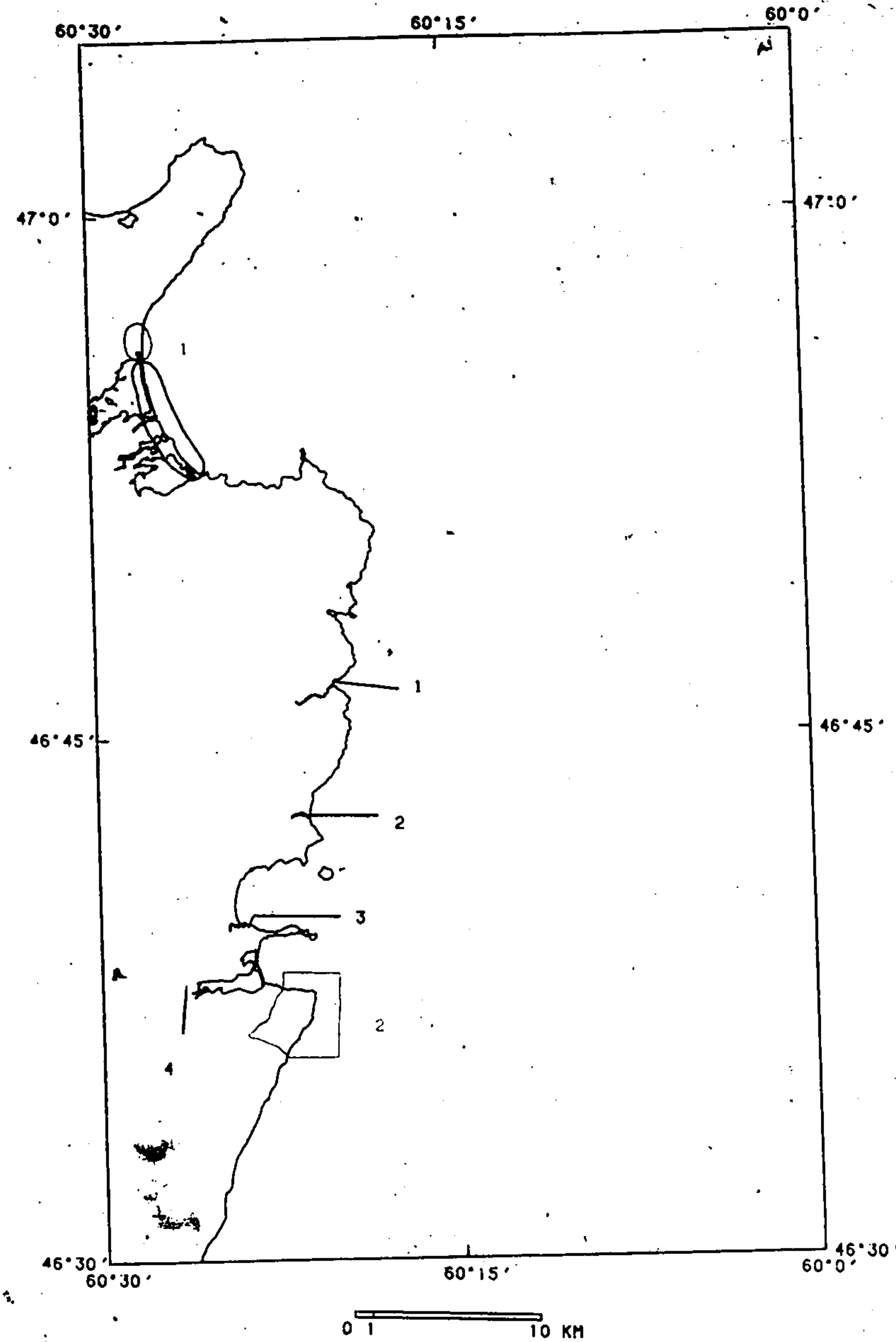
AREAS OF MAJOR CONCENTRATION
OF FISHING EFFORTS

AREAS OF SECONDARY CONCENTRATION
OF FISHING EFFORTS

REFERENCE: APPENDIX I

Figure 5-6

Lobster fishing areas of the Cape Breton - Cabot Strait study region. The information displayed here is regional in nature. The map is composed of the base map part illustrated in Figure 5-2 and the data part illustrated in Figure 5-4.


60°30'
60°15'
60°0'
47°0'
47°0'
1
1
46°45'
46°45'
2
3
2
4
46°30'
60°30'
60°15'
46°30'
60°0'
0 1
10 KM

CABOT STRAIT
ENVIRONMENTAL DATA
1983

TOURISM AND RECREATION

0'

PROVINCIAL PARKS

1 - PICNIC AREA.
HISTORICAL SIGNIFICANCE (CABOT'S LANDING)
2 - PICNIC AREA.
COASTAL HIKING

PARK RESERVE - BARRIER BEACH

CAMPGROUNDS

5°45'

1 - BLACK BROOK CAMPGROUND. PARKS CANADA.
0-SERVICED. 187-UNSERVICED UNITS
2 - BROAD COVE CAMPGROUND. PARKS CANADA.
83-SERVICED. 197-UNSERVICED UNITS
3 - INGONISH BEACH. PARKS CANADA.
0-SERVICED. 108-UNSERVICED UNITS
4 - SMOKEY RIDGE PARK. PRIVATELY OWNED.
82-SERVICED. 100-UNSERVICED UNITS

REFERENCE: APPENDIX 11

46°30'
0'

Figure 5-7

Example of a map displaying a subarea of the overall study region illustrated in Figure 5-6. The map covers the northeastern part of Cape Breton, from Bay St Lawrence in the north to Wreck Cove in the south. Textual information, printed to the right has been associated with the contents of the map.

user to compose maps that best illustrate the environmental conditions of the area under study.

5.3. Research on Coastal Characteristics and Processes

This system has also been used to carry out research on coastal characteristics and processes. Its usefulness for research comes from its ability to determine quantitatively the abundance of coastal parameters or combinations of parameters in any specified area. The interrelationship and interdependence of individual data parameters can also be measured by the use of this system. In the past, these analyses had to be kept to a very simple level because of the large amount of manual labour involved in measuring all individual parameters (Sempels, 1982). Some examples of this type of research are outlined in the subsequent sections.

5.3.1. Determination of Abundance of Individual Coastal Parameters

The total length of coastlines present in any specified area can easily be determined by adding the distances that are present between consecutive coastal UTM coordinates. Of course, one must verify the tags of the coastal coordinates to avoid adding incorrect distances such as that present between the end of a coastal segment and the beginning of an island. The same procedure can be performed on data parameters, selected by the user. It is a simple matter, once these lengths are calculated, to print their values on paper or on a CRT terminal, either as coastal lengths or as percentages of the total length of coastlines present in the area specified.

An example of such calculations is presented in Table 5-1. In this table, the lengths and percentages of coastlines occupied by a series of variables are reported for the entire Queen Charlotte Islands study region. This table indicates that geological and fetch information was not associated with all shorelines of the region that is, there were some data gaps in this region. Incidentally, fetch is the distance of open water over which the wind can blow. It is used as an indication of the maximum wave energy level that can reach the coast, a very important factor for oil-spill response and contingency planning. The percentages of shorelines with geological data, with fetch data, and with both are calculated with respect to the total length of coastlines of the overall region. The percentages of individual data parameters are calculated with respect to the total length of coastlines for which information of that type exists. It may be noted that the sum of the lengths of coastlines associated with the four fetch data parameters is equal to the length of coastlines for which fetch information does exist. The same is not true for geology, the sum of the lenghts of coastlines associated with the seven data parameters is greater than the length of coastlines for which geological information does exist. This is not an error, it simply reflects the fact that in this case, not all geological parameters of the study region are mutually exclusive.

LIMITS OF STUDY AREA:

EASTING: 564393 M (ZONE 9) TO 614841 M (ZONE 8)
NORTHING: 5742756 M TO 6066176 M

OVERALL STATISTICS:

TOTAL LENGTH OF COASTLINES:	7896 KM
LENGTH OF COASTLINES WITH GEOLOGICAL DATA:	6249 KM (79.15%)
LENGTH OF COASTLINES WITH FETCH DATA:	6848 KM (86.72%)
LENGTH OF COASTLINES WITH BOTH TYPES OF DATA:	6249 KM (79.15%)

LENGTHS AND PERCENTAGES OF COASTLINES WITH GEOLOGICAL DATA:

GEOLOGY	LENGTH (km)	PERCENTAGE (%)
No Data	1646	n/a
Bedrock	5551	88.8
Beach	3180	50.9
Sand	342	5.5
Mixed Sediments	1815	29.1
Gravel	1022	16.4
Intertidal Boulders	1745	27.9
Delta	51	0.8

LENGTHS AND PERCENTAGES OF COASTLINES WITH FETCH DATA:

FETCH (KM)	LENGTH (KM)	PERCENTAGE (%)
No Data	1048	n/a
<10	2141	31.3
10-100	2496	36.4
100-100	1203	17.6
>1000	1008	14.7

Table 5-1

Lengths and percentages of coastlines associated with individual geological and fetch data parameters.

Percentages of shorelines as those listed in Table 5-1 can also be reported in the form.of histograms produced by the plotter as illustrated in Figures 5-8 and 5-9, or reported directly on maps of geomorphic data as illustrated in Figure 5-10.

5.3.2. Interdependence of Coastal Parameters of Different Data Categories

This data base system can also be used to determine the relationship between coastal parameters of different data categories. For example, how frequently is a given geomorphic parameter encountered in conjunction with a certain fetch parameter? Answers to questions like these can be found by adding the length of coastlines associated with both data parameters simultaneously. The results of such an analysis performed on the area used in Table 5-1 are displayed in Tables 5-2 and 5-3. In Table 5-3, the percentages are calculated with respect to the length of coastlines that include both geological and fetch data. These results can be appreciated better when they are displayed in the form of histograms produced by a statistical packge such as SAS (<u>Statistical Application System</u>: Meehan, 1982), as illustrated in Figure 5-11.

5.3.3. Interdependence of Combinations of Parameters

Type 1 data can also be analysed to determine the relative abundance and interdependence of combinations of parameters. One

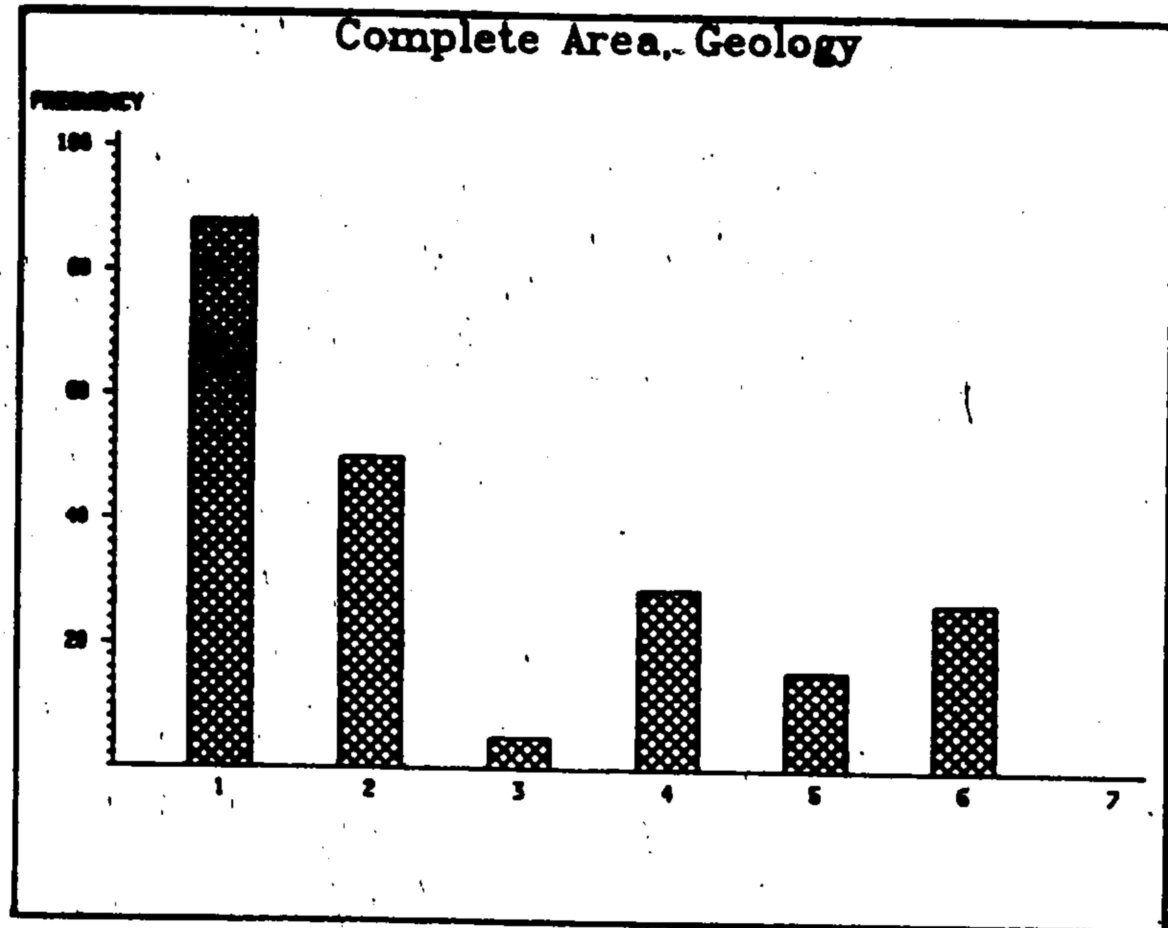


Figure 5-8

Relative abundance of the seven geomorphic data parameters, within the overall study region of the Queen Charlotte Islands.

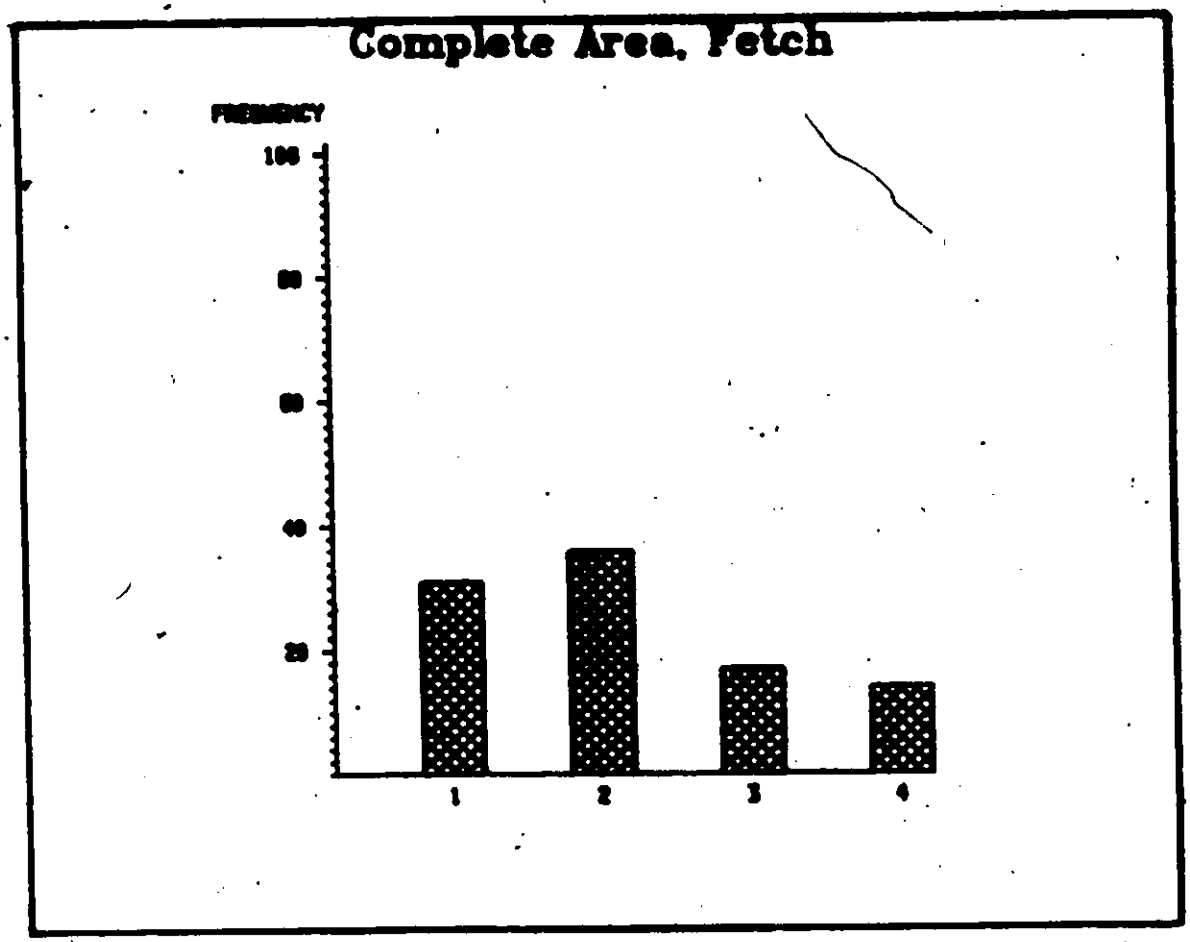


Figure 5-9

Relative abundance of shorelines associated with the four fetch data parameters within the overall study region of the Queen Charlotte Islands.

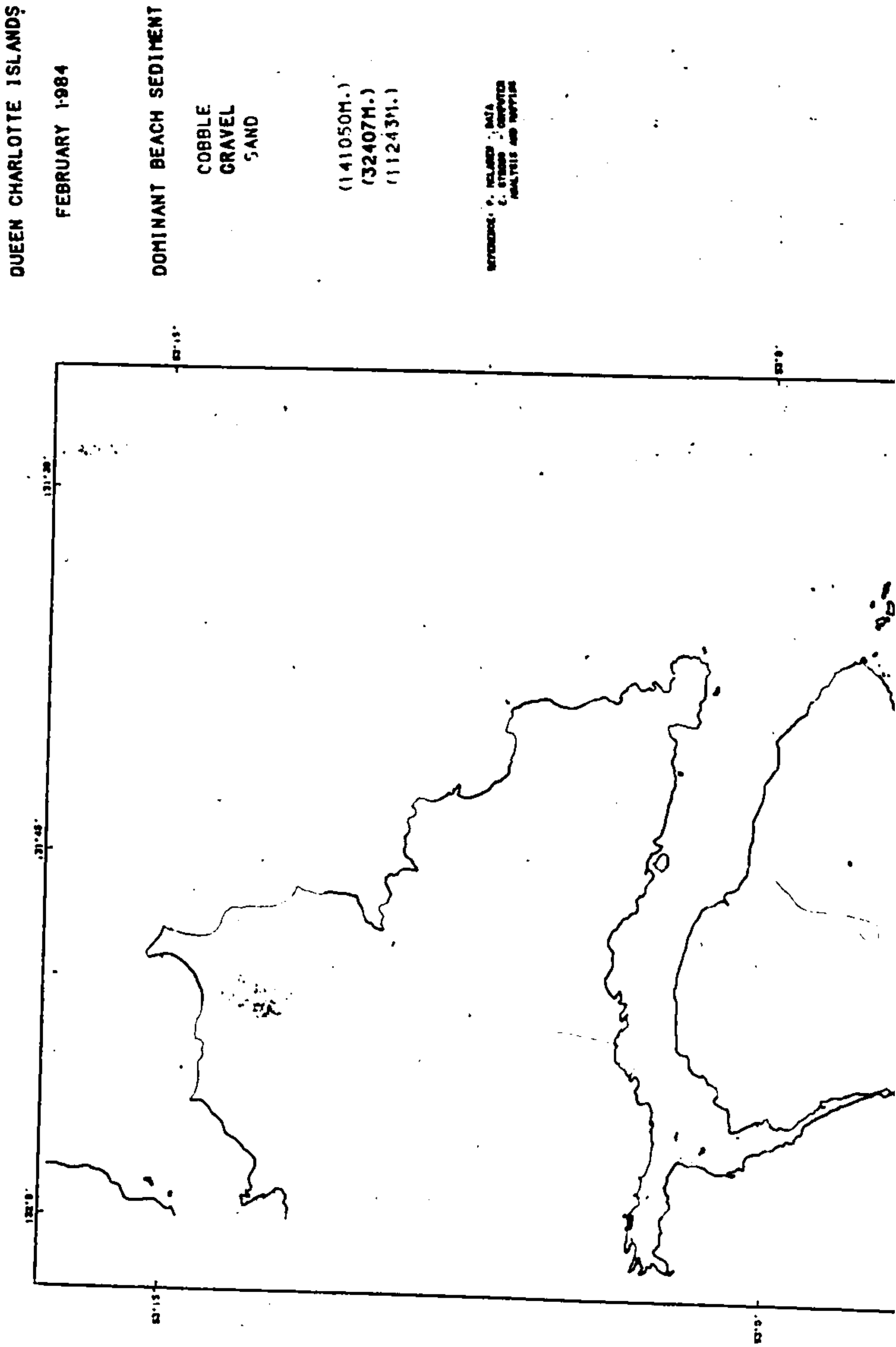
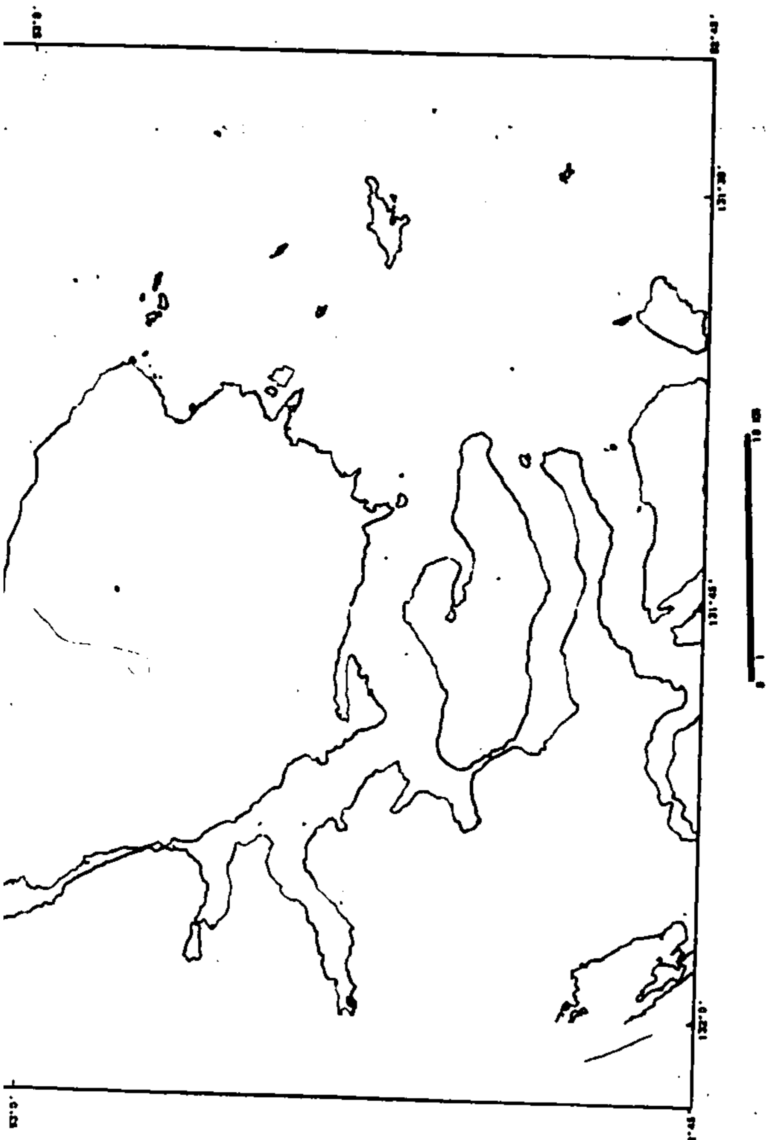


Figure 5-10

Map of Louise Island and northeastern Moresby Island illustrating the distribution of three data parameters. Note the total length of coastlines associated with each data parameter.



and
the

GEOLOGY \ FETCH (KM)	NO DATA	< 10	10 TO 100	100 TO 1000	>1000	TOTAL
NO DATA	1048	292	117	74	114	1645
BEDROCK	0	1660	2210	846	835	5551
BEACH	0	955	892	669	665	3181
SAND	0	161	77	102	2	342
MIXED SEDIMENTS	0	594	533	484	204	1815
GRAVEL	0	200	281	82	459	1022
INTERTIDAL BOULDERS	0	378	533	286	548	1745
DELTA	0	27	21	0	3	51

Table 5-2

Lengths of coastlines associated with individual geological and fetch parameters.

GEOLOGY \ FETCH (KM)	< 10	10 TO 100	100 TO 1000	>1000	TOTAL
BEDROCK	26.56	35.36	13.53	13.37	88.82
BEACH	15.28	14.27	10.70	10.64	50.89
SAND	2.58	1.23	1.64	.03	5.48
MIXED SEDIMENTS	9.51	8.53	7.74	3.26	29.04
GRAVEL	3.20	4.50	1.32	7.34	16.36
INTERTIDAL BOULDERS	6.05	8.53	4.58	8.76	27.92
DELTA*	.43	.34	.00	.04	.81

Table 5-3

Percentages of coastlines associated with individual geological and fetch parameters.

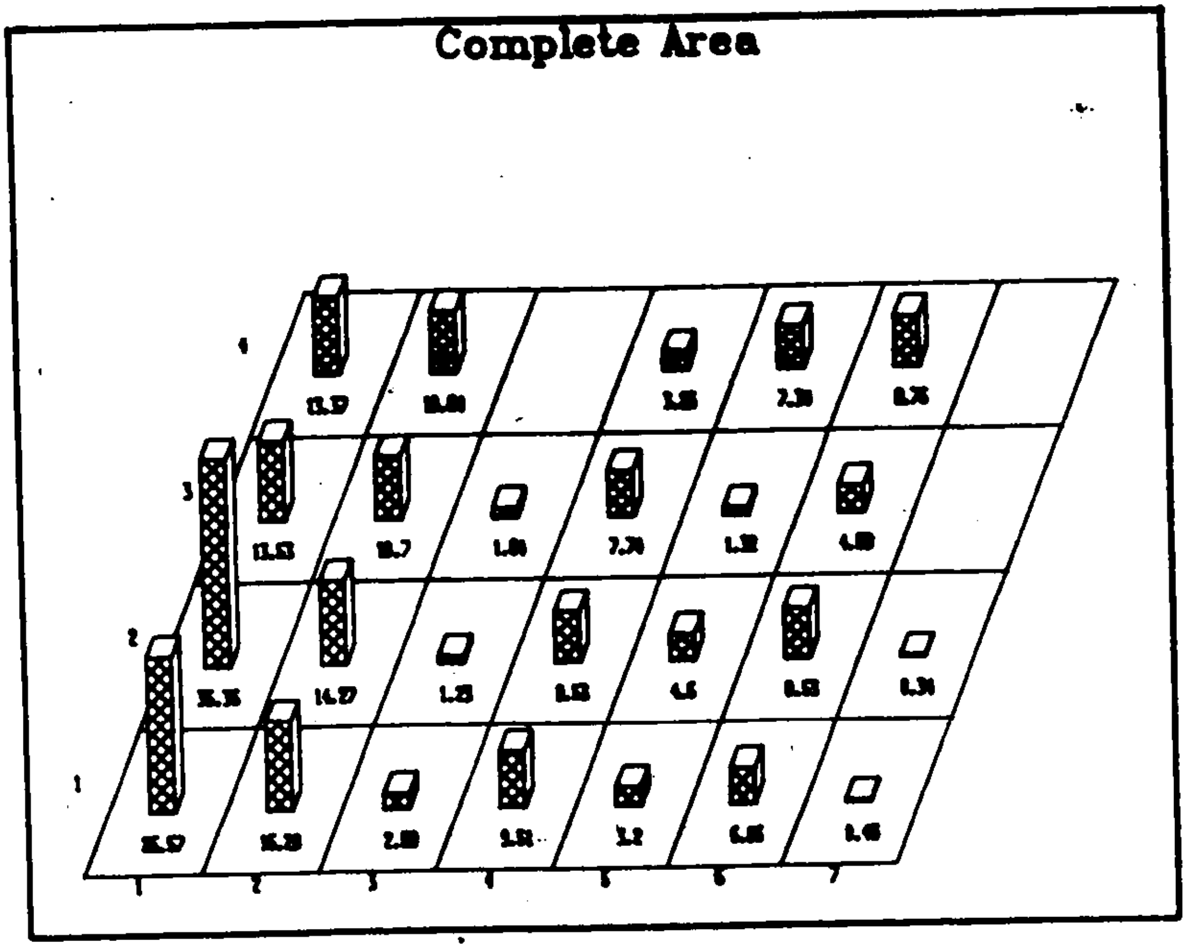


Figure 5-11

Histogram of percentages of coastlines associated with individual geological and fetch data parameters. Values less than 0.1 % are not shown.

approach to this is to examine the length of coastlines associated with the various pointer values. As described previously, the pointers assigned to the coastal UTM coordinates are in fact, the number of records in accompanying environmental data files. Each record of these environmental data files contains a series of variables, each representing a data parameter. In the study region of the Queen Charlotte Islands, each record of the geological data file contains seven variables (excluding the no data) as listed in Table 5-1. Each record also describes a unique combination of the seven parameters as it has been observed in the field. Although the total number of possible permutations of these seven variables is large, in reality, only 17 such combinations are found to exist in this region. It follows that the environmental data file has only 17 records, each describing a unique combination of seven coastal characteristics as they occur in the field. The abundance of each of these combinations can be found by adding the length of coastlines in which they occur.

The results of such an analysis are displayed in Figure 5-12. In this histogram, each unique combination of the seven geological parameters has been called a geological unit, as the name implies exactly what it is: a naturally occuring combination of features. It can be seen that unit number 1 is the most abundant in this region. This particular unit consists in a segment constructed entirely of bedrock. Unit number 4 is the next most abundant one. It is made up of a bedrock backshore, with a beach of gravel, and intertidal boulders.

The lengths of coastlines associated with each of these 17

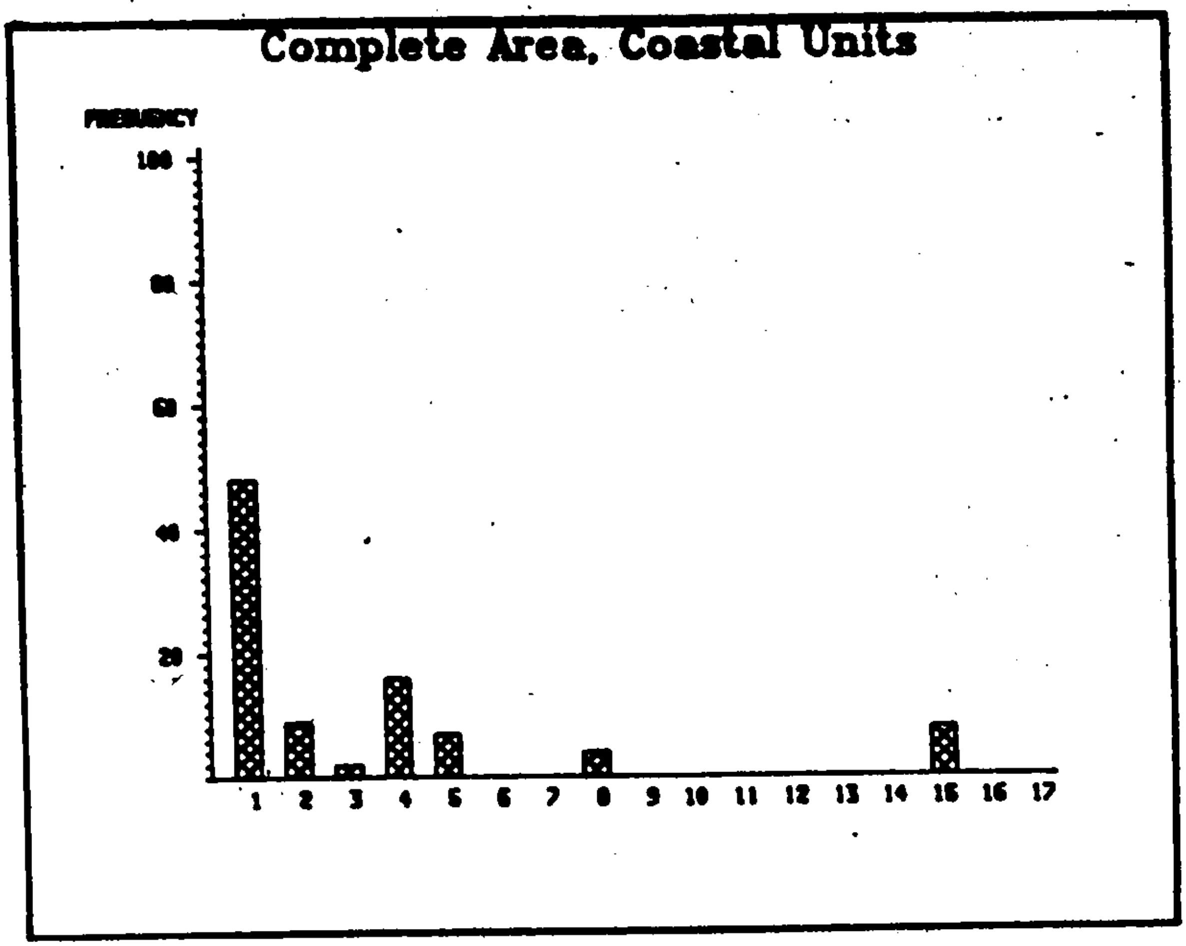


Figure 5-12

Histogram of percentages of coastlines associated with geological units 1 to 17.

coastal units and associated with a given fetch parameter are listed in Table 5-4. These same results are expressed as percentages in Table 5-5, and as histograms in Figure 5-13. These tables and this figure demonstrate that the most abundant geological-fetch combination is between unit 1, a coastline constructed of bedrock and fetch unit 2 (10 to 100 km).

5.3.4. Effects of Geographical Location on Relative Abundance

The analysis described in the above sections can be performed for an overall study region or for any subarea. When these analyses are performed for selected subareas it becomes possible to compare the effect of geographical location on the abundance, interrelationship, and interdependence of data parameters or combinations of data parameters.

An example of such an analysis is illustrated if Figure 5-14. In this case, the percentages of coastlines associated with geological coastal units 1 to 17 are calculated for the overall region and for two subareas. The overall region is the one used in previous examples (Table 5-1), that is the Queen Charlotte Islands and the adjacent mainland coast. The first subarea consists in the eastern part of the Queen Charlotte Islands and the second subarea consists in the western part of the adjacent mainland coast. It can easily be seen that the relative abundances of the various geological coastal units differ according to their geographical location.

A similar analysis can be performed to determine the effects of geographical location on the interdependence of data

GEOLOGY \ FETCH (KM) UNIT NO.	NO DATA	< 10	10 TO 100	100 TO 1000	>1000	TOTAL GEOL.
NO DATA	1048	292	117	74	114	1646
1	0	882	1463	460	228	3033
2	0	266	165	118	54	603
3	0	37	46	99	0	182
4	0	197	281	74	450	1002
5	0	142	122	179	56	498
6	0	6	1	0	0	7
7	0	0	13	0	0	13
8	0	153	75	82	0	311
9	0	0	0	20	0	20
10	0	0	0	3	6	9
11	0	2	7	0	0	9
12	0	0	0	5	0	5
13	0	4	2	0	0	6
14	0	12	11	0	0	23
15	0	141	192	88	95	517
16	0	3	0	0	2	5
17	0	3	0	0	3	6
TOTAL (FETCH)	1048	2141	2496	1203	1008	7896

Table 5-4

Lengths of coastlines associated with geological unit numbers 1 to 17 and fetch units 1 to 4.

GEOLOGY UNIT NO. \ FETCH (KM)	<10	10 TO 100	100 TO 1000	>1000	TOTAL GEOL.
1	14.11	23.41	7.37	3.65	48.54
2	4.26	2.64	1.89	.86	9.65
3	.59	.74	1.58	.00	2.91
4	3.15	4.50	1.18	7.20	16.03
5	2.26	1.95	2.87	.89	7.97
6	.10	.02	.00	.00	.12
7	.00	.21	.00	.00	.21
8	2.45	1.21	1.31	.00	4.97
9	.00	.00	.32	.00	.32
10	.00	.00	.05	.09	.14
11	.03	.11	.00	.00	.14
12	.00	.00	.09	.00	.09
13	.07	.03	.00	.00	.10
14	.19	.18	.00	.00	.37
15	2.26	3.08	1.41	1.52	8.27
16	.06	.00	.00	.03	.09
17	.04	.00	.00	.04	.08
TOTAL (FETCH)	29.57	38.08	18.07	14.28	100.00

Table 5-5

Percentages of coastlines associated with geological units 1 to 17 and fetch units 1 to 4.

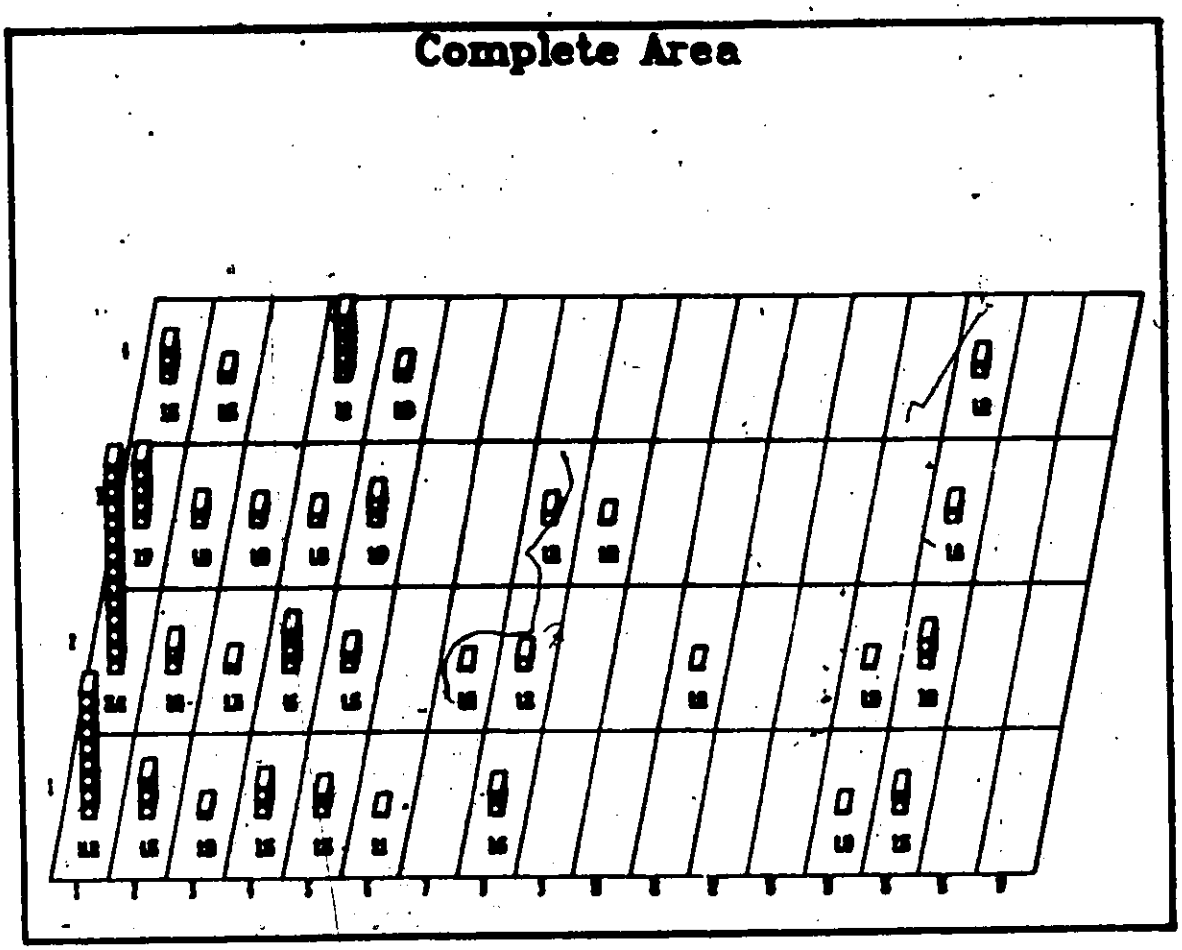


Figure 5-13

Histogram of percentages of coastlines associated with geological units 1 to 17 and fetch units 1 to 4.

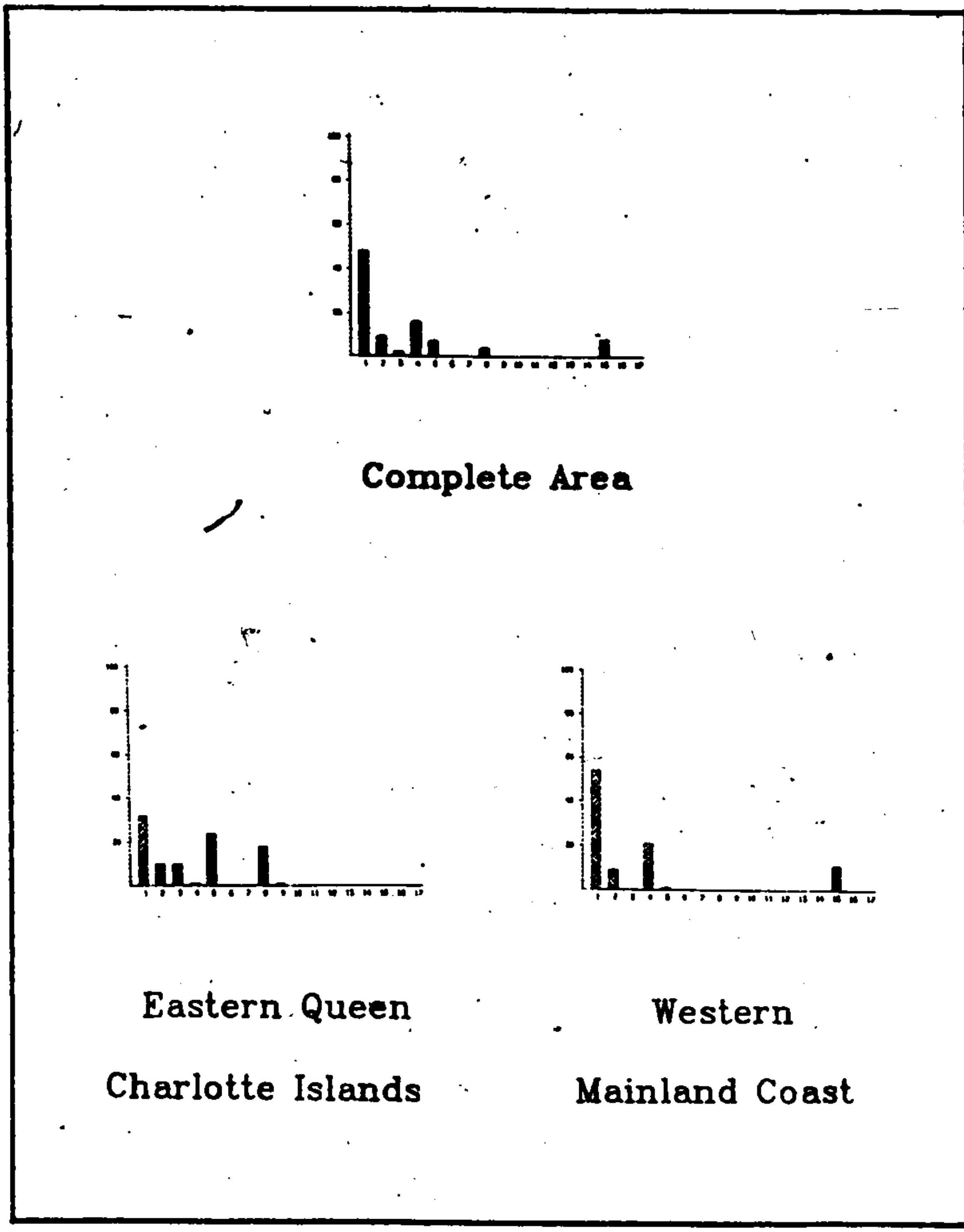


Figure 5-14

Effects of geographical location on the relative abundance of shorelines associated with coastal unit numbers 1 to 17.

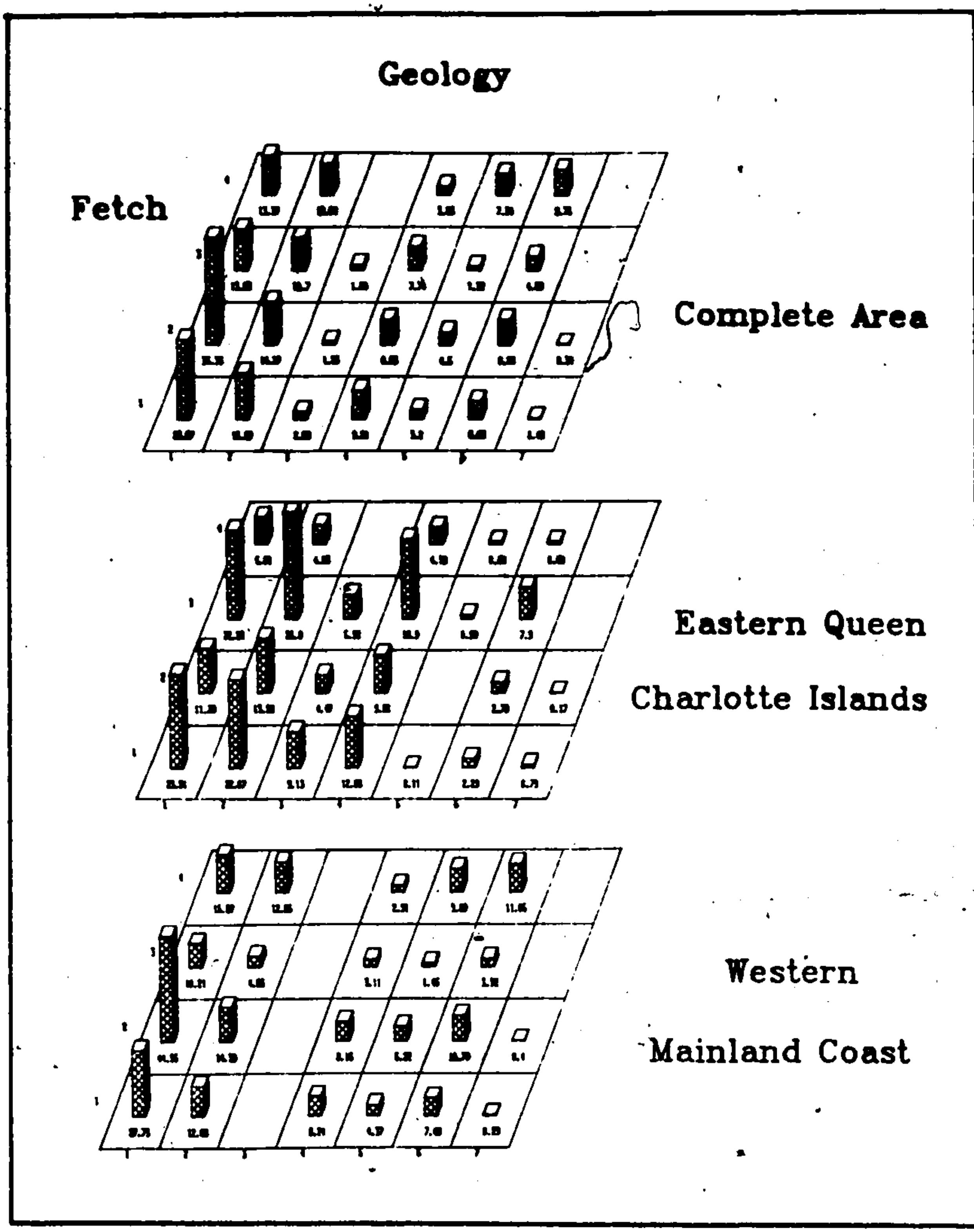


Figure 5-15

Effects of geographical location on the relative abundance of combinations of data parameters.

parameters. This is illustrated in Figure 5-15 where the relative abundance of coastlines associated with a given fetch and a given geomorphology are determined for the overall study region and the two same subareas.

PART 6

CONCLUSIONS, FUTURE IMPROVEMENTS AND FUTURE DEVELOPMENTS

CONCLUSIONS, FUTURE IMPROVEMENTS AND FUTURE DEVELOPMENTS

6.0. Conclusions

The fact that this data base system fulfills a useful role has been demonstrated by a very positive response from oil companies. The author believes that this is mainly because the objectives of the system were defined very precisely in order to meet a certain number of specific requirements. The main positive features of this data base system are:

1) It is a truly geographical system in which environmental data are stored, retrieved, updated, displayed, or mapped according to their UTM or latitude-longitude coordinates.

2) The system is very flexible and undemanding with respect to data. It does not require precoding or formatting of information and the file structures and organization impose no limitation on the nature and quantity of environmental data.

3) For emergency oil-spill response, this system provides a means of accessing and displaying rapidly all environmental data of any subregion defined by the user. The displays on the color monitor may not be of very high resolution, but they are of a quality that is sufficient for this purpose.

4) For oil-spill contingency planning and regional assessments, the system provides analytical capabilities, a means of previewing the spatial distribution of environmental data, and a means of producing color maps of high quality.

5) The nature of the system makes it particularly useful for research on coastal geomorphology. This is because it is capable

of performing quantitative measurements of the relative abundance of parameters, taken singly or in combinations, and of the degree of association and interdependence that is present between parameters or groups of parameters.

The positive features of this system do not mean that it is perfect. A number of improvements and further developments are forseen. A brief discussion of some of these improvements and further developments is presented in the following sections.

6.1. Future Improvements

At present, the main disadvantage of this data base system is its relatively slow response time. Although this response time is not unbearably slow, the author believes that some improvements could be made (Foley and van Dam, 1983). It is clear that, after working with this system, this relatively slow response time is not due to the lack of computational capabilities but rather to the time required for disk access. This could be partly due to the way Fortran programs access the hard disk. The Fortran programs are run under the CP/M operating system. When a file is accessed, the CP/M operating system communicates with the Horizon Disk Operating System (HDOS) which in turn finds the appropriate file on the hard disk. It may be possible to modify CP/M to access the hard disk directly, without passing through HDOS in order to improve the disk access time.

It may also be possible to decrease the time required to access the environmental data associated with coastal UTM coordinates (Type 1 data). Presently, each coordinate in the study area must be read and its pointers must be used to access and examine the appropriate environmental data. When the study area includes a large number of coordinates, this method becomes very time consuming.

The following approach may be more efficient. For each category of Type 1 data, a table could be created such that:

1) it contains a record for each pointer value present in the study area, and

2) each record of this table includes the pointer value and, for each section of coastlines associated with this value, the address of the first and the last coordinate in the appropriate geographical data file. When the user requests a display of the geographical distribution of a data parameter, the system would find from the appropriate environmental data file the number of the records (or pointer values) containing the requested data. The table associated with the selected pointers would then be accessed and the appropriate sections of shorelines could be displayed immediately. In this case, the geographical data file would not have to be searched to display the shorelines associated with a given data parameter or with a combination of parameters.

The menus displayed on the CRT terminal and used to select data parameters or combinations of parameters could also be improved. Instead of having a line at the end of each menu to indicate options that are available in the area specified, the menus could be listed on the CRT terminal using different intensities. By convention, all data categories, subcategories, and parameters (from the LEVEL 1, 2 and 3 menus) that are present in the specified area could be listed using a high intensity on the CRT terminal. Conversely, all data categories, subcategories, and parameters not present in the specified area could be listed using a low intensity.

The menus could also be modified to include the relative abundance of data parameters, at least for those that are associated with coastlines. The lengths of coastlines associated with each data parameter could be calculated as described in section 5.3.1, and these lengths could be listed next to the parameter in question. These lengths could also be expressed in terms of percentages of total length of coastlines present in the specified area in order to give an accurate measure of their relative abundance.

6.2. Future Developments

The interactive graphics component of the system will be developed further to enable the use of a lightpen (van Dam, 1983). It will be possible to use this lightpen in several ways to identify information displayed on the color monitor. Some anticipated applications are:

1) Selecting the limits of the study area from a map of the overall region displayed on the color monitor. The user could indicate with the lightpen two opposing corners of the desired subarea on a map of the overall region.

2) Accessing textual information associated with a coordinate displayed on the color monitor. For example, if the user

indicates with the lightpen the location of a bird colony displayed on a map on the color monitor, textual material pertaining to this bird colony such as species of birds present, number of birds present, or dates of occupation of the colony could be listed on the CRT terminal. Similarly, the user could point to a specific location of shoreline and obtain a full list of all parameters present at this point.

3) The lightpen could also be used to review or modify the data graphics organization. The user could point to a certain color on the color monitor and the data parameter or data parameters associated with this color could be recalled on the CRT terminal.

The data base system is presently undergoing further developments to perform a greater variety of analyses for research on coastal characteristics and processes. These analyses include:

1) Calculation of basic statistics for all data variables. These basic statistics include measuring the shortest and longest length of coastline associated with each data parameter, and the mean and standard deviation of lengths of coastlines occupied by each data parameter.

2) Selection of data parameters based on the coastal length they occupy. One important characteristic of all data parameters is the coastal length they occupy. The ability to retrieve parameters according to their coastal length is a great advantage for subsequent analyses, specially for those analyses dealing with interdependence and association of parameters.

3) Production of matrices of association for all data parameters present in any given area. These matrices of association will

define much more clearly the interdependence and association present among all data parameters by determining associations not based on the total length of coastlines present in the study area, but based on the total length of coastlines associated with each data parameter. For example, although it is of interest to know that beaches are present in 50% of all shorelines of a given area, it is also of interest to know that for example, of all shorelines including a beach, only 10% are associated with a fetch greater than 100 km, and the remaining 90% are associated with a fetch less than 10 km.

The graphic component of this data base system will also be developed further to enable shading areas on the color monitor and on maps produced using the plotter. This feature will permit shading of land masses, of the sea, and of data parameters that occupy areas on a map or on the color monitor.

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APPENDIX I

LABRADOR ENVIRONMENTAL DATA

Appendix I

This appendix lists the Labrador environmental data as they appear on the CRT terminal during access to the data base. The LEVEL 1 menu allows the user to access the various main groups (categories) of environmental data. LEVEL 2 menus list the main options (subcategories) within the data category selected in LEVEL 1. LEVEL 3 menus are required in the case of complex information. They are used to access the various parameters present within the main options of LEVEL 2. During a real interaction with the computer, options present in the selected study area are always listed after each menu.

```
SELECTION OF DATA TYPES - LEVEL 1:

************************************************
1: REDEFINE STUDY AREA
2: REVIEW OR MODIFY SCREEN GRAPHICS ORGANIZATION
3: REVIEW OPTION(S) SELECTED
4: DISPLAY OPTION(S) SELECTED
5: STOP PROGRAM
************************************************

6: ANTHROPOGENIC FEATURES
7: RESOURCE HARVEST AREAS OF COASTAL LABRADOR
8: GEOLOGY
```

SELECTION OF DATA TYPES - LEVEL 3:

****
(CR): RETURN TO LEVEL 1
****

ANTHROPOGENIC FEATURES:

1: DWELLINGS (HOUSES, FISHING CAMPS, CABINS)
2: WARFS
3: ANCHORAGES
4: JETTIES
5: SLIPWAYS
6: LIGHTHOUSES
7: SEA PLANE BASES
8: AIRPORTS
9: HELIPADS

SELECTION OF DATA TYPES - LEVEL 2:

****
(CR): RETURN TO LEVEL 1
****

RESOURCE HARVEST AREAS OF COASTAL LABRADOR:

1: FISH
2: SEALS
3: BIRDS

SELECTION OF DATA TYPES - LEVEL 3:

****
(CR): RETURN TO LEVEL 2
****

RESOURCE HARVEST AREAS OF COASTAL LABRADOR: FISH

1: COD - GILL NETS
2: - TRAPS
3: - TRAWLS
4: - JIGGING
5: SALMON - GILL NETS
6: - SPAWNING AREAS
7: CHAR - GILL NETS
8: - SPAWNING AREAS
9: TROUT - SPORT FISHING AREAS

SELECTION OF DATA TYPES - LEVEL 3:

```
***********************************
(CR): RETURN TO LEVEL 2
***********************************
```

RESOURCE HARVEST AREAS OF COASTAL LABRADOR: SEALS

1: SEAL SHOOTING AREAS
2: SEAL NETTING AREAS

SELECTION OF DATA TYPES - LEVEL 3:

```
***********************************
(CR): RETURN TO LEVEL 2
***********************************
```

RESOURCE HARVEST AREAS OF COASTAL LABRADOR: BIRDS

1: BIRD SHOOTING AREAS
2: BIRD NESTING AREAS

SPECIES:

3: GULLS
4: DUCKS
5: PIGEONS
6: GEESE
7: TINKERS
8: TURRS
9: PUFFINS
10: STEARINS
11: LORDS AND LADIES

SELECTION OF DATA TYPES - LEVEL 2:

```
***********************************
(CR): RETURN TO LEVEL 1
***********************************
```

GEOLOGY:

1: VIDEOTAPE NUMBERS
2: COASTLAND - GENERAL ELEVATION AND SLOPE OF THE LAND
3: COASTLAND - EXTENT AND TYPE OF VEGETATION COVER
4: BACKSHORE - SLOPE AND NATURE
5: BACKSHORE - OTHER FEATURES
6: INTERTIDAL - NATURE OF UPPER INTERTIDAL ZONE
7: INTERTIDAL - TEXTURE OF UPPER INTERTIDAL ZONE
8: INTERTIDAL - NATURE OF MIDDLE AND LOWER INTERTIDAL ZONE
9: INTERTIDAL - TEXTURE OF MIDDLE AND LOWER INTERTIDAL ZONE

10: INTERTIDAL - OTHER FEATURES OF MIDDLE AND LOWER INTERTIDAL ZONE
11: NEARSHORE FEATURES
12: ACCESS - LAND AND AIR ACCESS TO SHORE ZONE
13: ACCESS - SEA ACCESS TO SHORE ZONE
14: DATA SOURCES

SELECTION OF DATA TYPES - LEVEL 3:

****
(CR): RETURN TO LEVEL 2
****

<u>COASTLAND: GENERAL ELEVATION AND SLOPE OF THE LAND:</u>

1: UNKNOWN
2: LOW ELEVATION (<10M), HORIZONTAL OR GENTLY SLOPING (0-20 DEG.)
3: MODERATE ELEVATION (10-50M), HORIZONTAL OR GENTLY SLOPING
4: MODERATE ELEVATION, MODERATELY SLOPING (20-45 DEG.)
5: MODERATE ELEVATION, STEEPLY SLOPING OR CLIFFED (45-90 DEG.)
6: HIGH ELEVATION (>50M), HORIZONTAL
7: HIGH ELEVATION, STEEPLY SLOPING OR CLIFFED

SELECTION OF DATA TYPES - LEVEL 3:

****
(CR): RETURN TO LEVEL 2
****

<u>COASTLAND: EXTENT AND TYPE OF VEGETATION COVER:</u>

1: UNKNOWN
2: DENSE, CONTINUOUS TREE COVER DOWN TO BACKSHORE
3: DENSE, CONTINUOUS TREE COVER NOT REACHING BACKSHORE
4: DENSE, DISCONTINUOUS TREE COVER, SOME CLEARINGS
5: DENSE, DISCONTINUOUS TREE COVER IN CLUSTERS
6: SCATTERED TREES, A FEW CLUSTERS
7: GRASSY
8: BARREN

SELECTION OF DATA TYPES - LEVEL 3:

****
(CR): RETURN TO LEVEL 2
****

<u>BACKSHORE: SLOPE AND NATURE:</u>

1: UNKNOWN

2: HORIZONTAL OR GENTLY SLOPING UNCONSOLIDATED
3: MODERATELY OR STEEPLY SLOPING UNCONSOLIDATED
4: CLIFF, UNCONSOLIDATED
5: HORIZONTAL OR GENTLY SLOPING SEDIMENTS OVER OR BETWEEN BEDROCK
6: MODERATELY OR STEEPLY SLOPING SEDIMENTS OVER OR BETWEEN BEDROCK
7: HORIZONTAL OR GENTLY SLOPING BEDROCK
8: STEEPLY SLOPING OR CLIFFED BEDROCK
9: RAISED BEACHES

SELECTION OF DATA TYPES - LEVEL 3:

****
(CR): RETURN TO LEVEL 2
****

<u>BACKSHORE: OTHER FEATURES:</u>

1: UNKNOWN
2: SCATTERED TREES
3: GRASSY
4: WIDE (>50M) CONTINUOUS MARSH
5: NARROW (<50M) DISCONTINUOUS MARSH, GRASSY
6: ERODING
7: STABLE
8: LAGOON WITH MARSH
9: BARREN
10: NO OTHER FEATURE

SELECTION OF DATA TYPES - LEVEL 3:

****
(CR): RETURN TO LEVEL 2
****

<u>INTERTIDAL: NATURE OF UPPER INTERTIDAL ZONE:</u>

1: UNKNOWN
2: NO SEDIMENTS
3: NARROW (<5M) DISCONTINUOUS BEACH
4: NARROW CONTINUOUS BEACH
5: WIDE (>5M) CONTINUOUS BEACH
6: BEDROCK
7: SEDIMENTS OVER BEDROCK
8: POCKET BEACHES

SELECTION OF DATA TYPES - LEVEL 3:

```
**********************************
(CR): RETURN TO LEVEL 2
**********************************
```

INTERTIDAL: TEXTURE OF UPPER INTERTIDAL ZONE:

1: UNKNOWN
2: MUD
3: SAND
4: PEBBLES AND COBBLES
5: BOULDERS OR BLOCKY RUBBLE
6: MIXED SEDIMENTS
7: MARSH
8: RAMP

SELECTION OF DATA TYPES - LEVEL 3:

```
**********************************
(CR): RETURN TO LEVEL 2
**********************************
```

INTERTIDAL: NATURE OF MIDDLE AND LOWER INTERTIDAL ZONE:

1: UNKNOWN
2: MODERATELY SLOPING
3: STEEPLY SLOPING
4: WIDE (>50M) INTERTIDAL FLATS
5: INTERTIDAL RAMP
6: INTERTIDAL PLATFORM
7: NARROW (<50M) INTERTIDAL FLATS
8: SCATTERED BOULDERS

SELECTION OF DATA TYPES - LEVEL 3:

```
**********************************
(CR): RETURN TO LEVEL 2
**********************************
```

INTERTIDAL: TEXTURE OF MIDDLE AND LOWER INTERTIDAL ZONE:

1: UNKNOWN
2: MUD
3: MUD WITH SCATTERED BOULDERS
4: SAND
5: SAND WITH SCATTERED BOULDERS
6: COARSE SEDIMENTS (PEBBLES, COBBLES)
7: BEDROCK
8: NO FEATURE

SELECTION OF DATA TYPES - LEVEL 3:

```
**********************************
(CR): RETURN TO LEVEL 2
**********************************
```

INTERTIDAL: OTHER FEATURES OF MIDDLE AND LOWER INTERTIDAL ZONE:

1: UNKNOWN
2: NO OTHER FEATURE
3: POORLY DEVELOPED DISCONTINUOUS BOULDER BARRICADE
4: WELL DEVELOPED CONTINUOUS BOULDER BARRICADE
5: SHORT, NON-ORIENTED BOULDER STRINGS
6: LONG, STRAIGHT OR CURVED BOULDER STRINGS, PERPENDICULAR TO THE COAST
7: LARGE PATCHES OF ALGAE
8: RIDGES AND RUNNELS
9: SCATTERED BOULDERS

SELECTION OF DATA TYPES - LEVEL 3:

```
**********************************
(CR): RETURN TO LEVEL 2
**********************************
```

NEARSHORE FEATURES:

1: UNKNOWN
2: NO FEATURE
3: SCATTERED BOULDERS, BEDROCK REEFS
4: LARGE SAND BANKS

SELECTION OF DATA TYPES - LEVEL 3:

```
**********************************
(CR): RETURN TO LEVEL 2
**********************************
```

ACCESS: LAND AND AIR ACCESS TO SHORE ZONE:

1: UNKNOWN
2: DIFFICULT EVEN BY FOOT
3: FOOT ONLY
4: DIFFICULT HELICOPTER (FLOATS) LANDING CAPABILITY
5: RELATIVELY GOOD HELICOPTER LANDING CAPABILITY
6: VERY GOOD HELICOPTER LANDING CAPABILITY
7: BACKSHORE AND COASTLAND SUITABLE FOR VEHICULES
8: ROAD ACCESS IN ADJACENT COASTLAND

SELECTION OF DATA TYPES - LEVEL 3:

****
(CR): RETURN TO LEVEL 2
****

ACCESS: SEA ACCESS TO SHORE ZONE:

1: UNKNOWN
2: IMPOSSIBLE OR EXTREMELY DIFFICULT
3: DIFFICULT, ACCESS RESTRICTED TO SMALL CRAFTS
4: RELATIVELY GOOD ACCESS FOR SMALL CRAFTS
5: VERY GOOD SEA ACCESS TO SHORELINE

SELECTION OF DATA TYPES - LEVEL 3:

****
(CR): RETURN TO LEVEL 2
****

DATA SOURCES:

1: TOPOGRAPHIC MAPS, LOW ALTITUDE OBLIQUE PHOTOGRAPHS AND LOW ALTITUDE OBLIQUE VIDEOTAPES, FIELD WORK AND INTERPRETATION BY J.M. SEMPELS, PETRO CANADA, SEPTEMBER 1982.
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APPENDIX II

CAPE BRETON - CABOT STRAIT ENVIRONMENTAL DATA

Appendix II

This appendix lists the environmental data of the Cape Breton - Cabot Strait region as they appear on the CRT terminal during access to the data base. The LEVEL 1 menu allows the user to access the various main groups (categories) of environmental data. LEVEL 2 menus list the main options (subcategories) within the data category selected in LEVEL 1. LEVEL 3 menus are required in the case of complex information. They are used to access the various parameters present within the main options of LEVEL 2. During a real interaction with the computer, options present in the selected study area are always listed after each menu.

```
SELECTION OF DATA TYPES - LEVEL 1:

*************************************************
1: REDEFINE STUDY AREA
2: REVIEW OR MODIFY SCREEN GRAPHICS ORGANIZATION
3: REVIEW OPTION(S) SELECTED
4: DISPLAY OPTION(S) SELECTED
5: STOP PROGRAM
*************************************************

6: ANTHROPOGENIC FEATURES
7: TOURISM AND RECREATION
8: BIOLOGY
9: GEOLOGY
```

SELECTION OF DATA TYPES - LEVEL 3:

```
************************************
(CR): RETURN TO LEVEL 1
************************************
```

ANTHROPOGENIC FEATURES:

1: LOBSTER POUNDS
2: SEA PRODUCTS BUYING STATIONS
3: SEA PRODUCTS PROCESSING PLANTS
4: SALT WATER INTAKES
5: CANNERIES
6: IRISH MOSS DRYING PLANTS

SELECTION OF DATA TYPES - LEEVEL 3:

```
************************************
(CR): RETURN TO LEVEL 1
************************************
```

TOURISM AND RECREATION:

1: INTERNATIONAL BIOLOGICAL PROGRAM SITES
2: PARKS CANADA
3: NATIONAL PARKS
4: PROVINCIAL PARKS
5: PARK RESERVES
6: MAJOR RECREATIONAL BEACHES
7: MAJOR PUBLIC SHORELINE ACCESS POINTS
8: MAJOR COASTAL HIKING TRAILS
9: CAMPGROUNDS
10: SCUBA DIVING SITES
11: MAJOR CONCENTRATION OF COTTAGES

SELECTION OF DATA TYPES - LEVEL 2:

```
************************************
(CR): RETURN TO LEVEL 1
************************************
```

BIOLOGY:

1: SEAWEED HARVESTING AREAS
2: INVERTEBRATE FISHERIES
3: ESTUARINE FISHERIES
4: DEMERSAL FISHERIES ACCORDING TO GEAR TYPES AND MAJOR SPECIES
5: PELAGIC FISHERIES
6: MAMMALS

SELECTION OF DATA TYPE - LEVEL 3:

```
**********************************
(CR): RETURN TO LEVEL 2
**********************************
```

SEAWEED HARVESTING AREAS:

1: IRISH MOSS
2: DULSE
3: ROCKWEED
4: KELP

SELECTION OF DATA TYPES - LEVEL 3:

```
***********************************
(CR): RETURN TO LEVEL 2
***********************************
```

INVERTEBRATE FISHERIES:

```
 1: SHELLFISH HARVESTING AREAS - SOFT SHELL CLAMS.
 2:                            - BAR CLAMS
 3:                            - RAZOR CLAMS
 4:                            - OCEAN QUAHAUGS
 5:                            - BAY QUAHAUGS
 6:                            - BAY SCALLOPS
 7:                            - BLUE MUSSELS
 8:                            - OTHER SPECIES OF MUSSELS
 9:                            - OYSTERS
10:                            - SPAT COLLECTIONS
11:          SCALLOPS    - DISTRICTS AND SEASONS
12:                      - MAJOR FISHING AREAS
13:                      - SECONDARY FISHING AREAS
14: SNOW (QUEEN) CRABS   - DISTRICTS AND SEASONS
15:                      - GENERAL DISTRIBUTION OF POPULATION
16:                      - MAJOR FISHING AREAS
17:                      - POTENTIAL FISHING AREAS
18: ROCK CRABS - FISHING AREAS AND SEASONS
19: SHRIMPS    - FISHING AREAS AND SEASONS
20: SQUIDS     - FISHING AREAS AND SEASONS
21: LOBSTERS   - DISTRICTS AND SEASONS
22:            - MAJOR IDENTIFIED LOBSTER GROUNDS
23:            - MAJOR FISHING AREAS
24:            - SECONDARY FISHING AREAS
```

SELECTION OF DATA TYPES - LEVEL 3:

****
(CR): RETURN TO LEVEL 2
****

ESTUARINE FISHERIES:

1: CAPLIN - SPAWNING AREAS
2: SALMON - SPAWNING AREAS
3: - FISHING AREAS
4: SALMONID CULTURE SITES
5: SMELT
6: MACKEREL AND HERRING
7: GASPEREAU
8: EELS
9: STRIPED BASS
10: FLOUNDER
11: TOM COD
12: BLOOD WORMS
13: SHAD
14: SILVERSIDES
15: RAINBOW TROUTS
16: OTHER SPECIES OF TROUTS.

SELECTION OF DATA TYPES - LEVEL 3:

****
(CR): RETURN TO LEVEL 2
****

DEMERSAL FISHERIES ACCORDING TO GEAR TYPES AND MAJOR SPECIES:

1: OTTER TRAWL
2: LONGLINE
3: DANISH SEINE
4: FIX GILL NETS
5: MULTIPLE GEAR

SELECTION OF DATA TYPES - LEVEL 3:

****
(CR): RETURN TO LEVEL 2
****

PELAGIC FISHERIES:

1: HERRING - MAJOR SPAWNING AREAS
2: - MAJOR FISHING AREAS
3: MACKEREL
4: BLUEFIN TUNA

5: SWORDFISH
6: BASKING SHARK
7: SALMON

SELECTION OF DATA TYPES - LEVEL 3:.

```
************************************
(CR): RETURN TO LEVEL 2
************************************
```

MAMMALS:

1: GREY SEAL ROOKERIES
2: DISTRIBUTION OF OTHER SPÊCIES OF SEALS

SELECTION OF DATA TYPES - LEVELS 3:

```
*************************************
(CR): RETURN TO LEVEL 1
*************************************
```

GEOMORPHOLOGY:

```
 1: AREAS COVERED BY LOW ALTITUDE OBLIQUE PHOTOGRAPHY
 2: AREAS COVERED BY LOW ALTITUDE OBLIQUE VIDEOTAPING
 3: SHORELINES WITH - ELEVATED AND STEEP BACKSHORES
 4:                 - LOW LYING AND GENTLY SLOPING BACKSHORES
 5:                 - BEDROCK CLIFF OR RAMPS WITH DISCONTINUOUS
                      POCKET BEACHES
 6:                 - NARROW BEACHES
 7:                 - WIDE BEACHES
 8:                 - BEACHES OF FINE SEDIMENTS
 9:                 - BEACHES OF COARSE OR MIXED SEDIMENTS
10:                 - MARSHES OR WITH MARSHES IN THE BACKSHORE
11: ALL ACCESS POINTS
```

APPENDIX III

NORTHEASTERN MORESBY ISLAND ENVIRONMENTAL DATA

Appendix III

This appendix lists the environmental data as they appear on the CRT terminal when working with the system for a region centered on Louise Island, and northeastern Moresby Island. The LEVEL 1 menu allows the user to access the various main groups (categories) of environmental data. LEVEL 2 menus list the main options (subcategories) within the data category selected in LEVEL 1. LEVEL 3 menus are required in the case of complex information. They are used to access the various parameters present within the main options of LEVEL 2. During a real interaction with the computer, options present in the selected study area are always listed after each menu.

```
SELECTION OF DATA TYPES - LEVEL 1:

*************************************************
1: REDEFINE STUDY AREA
2: REVIEW OR MODIFY SCREEN GRAPHICS ORGANIZATION
3: REVIEW OPTION(S) SELECTED
4: DISPLAY OPTION(S) SELECTED
5: STOP PROGRAM
*************************************************

6: BACKSHORE SLOPE, INTERTIDAL ZONE WIDTH, AND INFILLED BAYS
7: BEACH MATERIAL
8: INTERTIDAL MATERIAL
9: FETCH
```

SELECTION OF DATA TYPES - LEVEL 3:

****
(CR): RETURN TO LEVEL 1
****

BACKSHORE SLOPE, INTERTIDAL ZONE WIDTH, AND INFILLED BAYS:

1: BACKSHORE SLOPE
2: INTERTIDAL ZONE WIDTH
3: INFILLED BAYS

SELECTION OF DATA TYPES - LEVEL 2:

****
(CR): RETURN TO LEVEL 1
****

BEACH MATERIAL:

1: PERCENTAGE OF BEDROCK
2: PERCENTAGE OF SEDIMENTS
3: TYPE OF BEACH
4: DOMINANT BEACH SEDIMENT TYPE
5: SECONDARY BEACH SEDIMENT TYPE
6: OTHER FEATURES

SELECTION OF DATA TYPES - LEVEL 3:

****
(CR): RETURN TO LEVEL 2
****

PERCENTAGE OF BEDROCK:

1: UNKNOWN
2: 100 %
3: > 80 %
4: 20 - 80 %
5: < 20 %
6: 0 %

```
SELECTION OF DATA TYPES - LEVEL 3:

*********************************
(CR): RETURN TO LEVEL 2
*********************************
```

PERCENTAGE OF SEDIMENTS:

```
1: UNKNOWN
2: 100 %
3: > 80 %
4: 20 - 80 %
5: < 20 %
6: 0 %
```

```
SELECTION OF DATA TYPES - LEVEL 3:

*********************************
(CR): RETURN TO LEVEL 2
*********************************
```

TYPE OF BEACH:

```
1: UNKNOWN OR NOT APPLICABLE
2: CONTINUOUS
3: POCKET
4: VENEER
```

```
SELECTION OF DATA TYPES - LEVEL 3:

*********************************
(CR): RETURN TO LEVEL 2
*********************************
```

DOMINANT SEDIMENT TYPE:

```
1: UNKNOWN OR NOT APPLICABLE
2: BOULDERS
3: COBBLE
4: GRAVEL
5: SAND
6: LOGS
```

SELECTION OF DATA TYPES - LEVEL 3:

****
(CR): RETURN TO LEVEL 2
****

SECONDARY SEDIMENT TYPE:

1: UNKNOWN OR NOT APPLICABLE
2: BOULDERS
3: COBBLE
4: GRAVEL
5: SAND
6: LOGS

SELECTION OF DATA TYPES - LEVEL 3:

****
(CR): RETURN TO LEVEL 2
****

OTHER FEATURES:

1: UNKNOWN OR NOT APPLICABLE
2: DELTAS

SELECTION OF DATA TYPES - LEVEL 2:

****
(CR): RETURN TO LEVEL 1
****

INTERTIDAL MATERIAL:

1: PERCENTAGE OF BEDROCK
2: PERCENTAGE OF SEDIMENTS
3: TYPE OF BEACH
4: DOMINANT SEDIMENT TYPE
5: SECONDARY SEDIMENT TYPE
6: OTHER FEATURES

NOTE: The LEVEL 3 menus displayed for the intertidal material are similar to those of the beach material above and are not repeated here.

SELECTION OF DATA TYPES - LEVEL 2:

```
**********************************
(CR): RETURN TO LEVEL 1
**********************************
```

FETCH:

1: COASTAL BEARING TO NEAREST DEGREE
2: EFFECTIVE FETCH TO NEAREST 0.1 KM
3: MAXIMUM FETCH BEARING TO NEAREST DEGREE
4: DISTANCE OF MAXIMUM FETCH TO NEAREST 0.1 KM
5: FETCH WINDOW ANGLE TO NEAREST DEGREE
6: FETCH WINDOW BEARING TO NEAREST DEGREE
7: DISTANCE ALONG FETCH WINDOW TO NEAREST 0.1 KM

APPENDIX IV

QUEEN CHARLOTTE ISLANDS ENVIRONMENTAL DATA

Appendix IV

This appendix lists the environmental data as they appear on the CRT terminal when working with the system for the area of the Queen Charlotte Islands, Dixon Entrance, Hecate Strait and adjacent mainland region. The LEVEL 1 menu allows the user to access the various main groups (categories) of environmental data. LEVEL 2 menus list the main options (subcategories) within the data category selected in LEVEL 1. LEVEL 3 menus are required in the case of complex information. They are used to access the various parameters present within the main options of LEVEL 2. During a real interaction with the computer, options present in the selected study area are always listed after each menu.

```
SELECTION OF DATA TYPES - LEVEL 1:

**************************************************
1: REDEFINE STUDY AREA
2: REVIEW OR MODIFY SCREEN GRAPHICS ORGANIZATION
3: REVIEW OPTION(S) SELECTED
4: DISPLAY OPTION(S) SELECTED
5: STOP PROGRAM
**************************************************

6: GEOLOGY
7: FETCH
```

SELECTION OF DATA TYPES - LEVEL 3:

```
**********************************
(CR): RETURN TO LEVEL 1
**********************************
```

GEOLOGY:

1: NO DATA
2: BEDROCK
3: BEACH
4: DOMINANT BEACH SEDIMENT - SAND
5: - MIXED SEDIMENTS
6: - GRAVEL
7: INTERTIDAL BOULDERS
8: DELTAS

SELECTION OF DATA TYPES - LEVEL 3:

```
**********************************
(CR): RETURN TO LEVEL 1
**********************************
```

FETCH:

1: NO DATA
2: FETCH - LESS THAN 10 KM
3: - 10 TO 100 KM
4: - 100 TO 1000 KM
5: - GREATER THAN 1000 KM

ABSTRACT

This document describes a microcomputer environmental data base system that was developed specifically to improve emergency oil-spill response, oil-spill contingency planning, and regional assessments.

The data base is truly geographical, that is, environmental data can be stored, displayed, mapped or updated according to their spatial location defined in terms of Universal Transverse Mercator or latitude-longitude coordinates. For emergency oil-spill response, an area of any size or location within a larger region can be defined and its environmental data can be reviewed rapidly using a color monitor. For oil-spill contingency planning and regional assessments, medium quality color maps can be produced directly from this data base by the use of a plotter.

The nature of this system also makes it particularly useful for research on coastal geomorphology. In this case, measurements of lengths can be performed on coastal characteristics or combinations of characteristics to determine their relative abundance, their interdependence, and the variations in their abundance according to geographical location.

The decision to use a microcomputer to perform this work is based on two main factors: 1) cost; and 2) the use of a dedicated microcomputer, with suitable back-up components, guaranties its availability in the event of an oil-spill. The use of a microcomputer however imposes limitations that may not be encountered on larger systems, and care and ingenuity is required in the design of efficient file structures and management

approaches.

At present, this data base system fulfills a useful role with respect to oil-spill response, contingency planning and regional assessments. Nevertheless, further developmental work is on-going, mainly to improve its speed of response, its graphic capabilities, and its applications for research on coastal geomorphology.