Marine resource mapping: an introductory manual

FAO FISHERIES TECHNICAL PAPER

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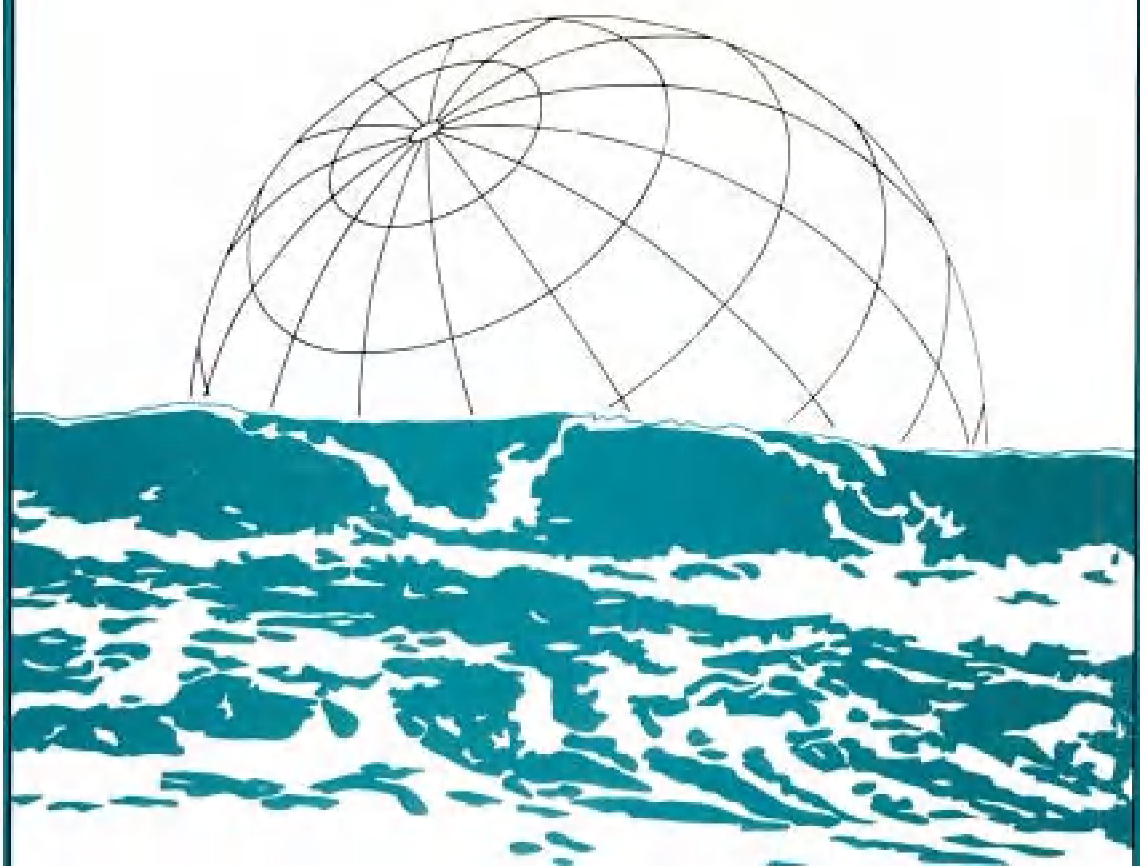

FOOD AND AGRICULTURE ORGANIZATION

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by

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CORRIGENDUM

In the document:

Extended Economic Zone (EEZ)

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Exclusive Economic Zone (EEZ)

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PREPARATION OF THIS DOCUMENT

The preparation world-wide of accurate maps and charts showing coastline configurations and the bathymetry of coastal waters, has been an objective of maritime nations since at least the 16th century, and many navigational charts now in common use still rely heavily on naval data collected in the 18th and 19th centuries. Now we recognize that in addition to their value for navigation purposes, accurate charts are essential for proper planning in support of multiple usage of maritime resources within national waters. Fisheries is not the least important of these activities: reserved areas for marine aquaculture and underwater parks, as well as the demarkation of fishery closure and access zones for various purposes, all require various specialized maps and charts to be prepared. This is especially true since declaration of Extended Economic Zones (EEZ's) by coastal states offers them the benefits of EEZ resources, as well as the need for accurate geographical information for a wide range of purposes.

The present report is aimed at those officers in the fisheries and marine services of government, and those concerned with coastal planning, by offering a national autonomous approach to cartographic applications. The text follows through the basic concepts underlying preparation of both maps and charts. Attention is paid also to collection of geographical information in fisheries, and to those graphics techniques that improve information transfer from cartographic representation to the end user.

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ABSTRACT

Practical guidelines and theorical principales of cartography are explained with particular relevance to mapping data of relevance to fisheries, especially for developing countries. The concepts of scale and relief as they apply both to coastal planning and to interpretation and display of marine and fishermen's charts are outlined. Design criteria are suggested for preparing maps and other visual displays, including basic questions of visual clarity, ease of interpretation, and the use of colour and alphanumeric information. The use of supplementary graphics together with thematic mapping is encouraged in providing an integrated approach to display of geographic and other types of information of relevance to fisheries and marine activities. Some guidelines equipment and procedures are suggested for graphics, drafting, and reproduction of illustrative material. Work plans and interview formats are suggested for field collection of basic data, as well as some suggestions for the use of aerial photography and for photointerpretation.

Twelve case studies discussing the approaches used to prepare existing marine resource maps are given and analysed. A short directory of training institutes in related fields is provided.

PREFACE

The preparation of accurate charts and maps showing coastline configurations and the bathymetry of coastal waters has been an objective of maritime nations since at least the 16th century, and many navigational charts now in common use still rely heavily on naval data collected in the 18th and 19th centuries. A current review of coastal zone mapping may be found in a special edition of the journal Cartographica (Volume 23, 1986), edited by Roland Perrotte for the International Cartographic Commission on Oceanic Cartography. In addition to their navigational value, accurate charts now are considered essential for proper planning in support of multiple usage of maritime resources within national waters. The introduction of Extended Economic Zones (EEZ's) increases the marine resource potential available to the coastal states. This in turn increases the need for accurate geographically referenced information and data which are required for the exploitation and management of the resources.

This manual is designed for personnel from departments of fisheries and other resource agencies who wish to produce and utilize marine resource maps as an aid to the development and management of marine resources under their jurisdiction. National resource development is becoming increasingly dependent on cartographic services not only to catalyze the process, but also to promote efficiency and economy in its management.

The manual does not assume that the reader has extensive fisheries or cartographic knowledge, hence, following the introduction (Section 1), and a review of the potential benefits of marine resource mapping to developing and developed nations alike (Section 2), considerable effort is devoted to understanding maps per se. Section 3 considers the concept of scale and the shape of the earth (Geodesy), which logically leads to a brief review of a complex topic, namely, map projections. A chart of map projections is included as an insert. The techniques of locating a point on the earth's surface and its accurate representation in terms of both the horizontal and vertical datum are described in Section 4. The content and construction of base maps are considered in some detail in Section 5, because they constitute the foundation on which resource (thematic) information is overlaid. In Section 6 map design fundamentals are reviewed as an introduction to thematic manuscript preparation (Section 7), the primary subject of this training manual. Figure I portrays the sequence of tasks which may be involved in this process in addition to map production alternatives. Section 7 not only considers the relevant cartographic principles but more importantly it describes tested procedures for the collection of meaningful resource information from the field. Aerial photographs, their acquisition, interpretation and relevance to the production of both base and thematic maps, are described in Section 8. Section 9 is devoted to a review of graphics, the visual techniques by which a cartographer communicates selected information clearly and easily to the map reader. The use of colour (Section 10) is presented as another communication aid. A colour chart is included as a second insert. Section 11 considers the procedures and materials associated with the production of "artwork", the term commonly used to define the cartographic end-products used for reproduction. The mechanics of various graphic reproduction techniques are then described in Section 12.

Section 13 reviews a wide range of marine resource mapping projects which can result from the cartographic process, be it the most basic of procedures or the most sophisticated of cartographic technology. Twelve of the mapping projects were selected for detailed analysis and constitute the case studies. Each case study includes one (or more) map sample and an associated critique of its design, production and contents. The variety of map types portrayed in the case studies will provide the user of this manual with a reasonably comprehensive survey of current marine resource mapping formats and techniques. Section 14 considers the future status of marine resource mapping in terms of advanced technology, and for those who may desire formal training in Cartography, Section 15 identifies the major international and national training institutes. A glossary of cartographic terms and the bibliography conclude this introductory manual to marine resource mapping. The manual does not presume to be all-inclusive; reference to specialized texts should be made whenever supplemental information is required.

A final and important point of information: it is not essential for the aspiring marine cartographer to fully digest all of the Sections herein prior to undertaking a marine resource mapping project. Section 7 (Thematic Manuscript Preparation) and Section 13 (Marine Resource Mapping and Case Studies) provide sufficient information to the reader of this manual to commence such a task. Practice will soon identify the theoretical concepts which are required to achieve the full potential of resource mapping; these fundamentals are reviewed in the other Sections of this manual; a broad schematic of procedures and elements involved in mapping fisheries data are shown in Figure 1.

Figure 1

DATA COLLECTION, COMPILATION AND MAP PRODUCTION

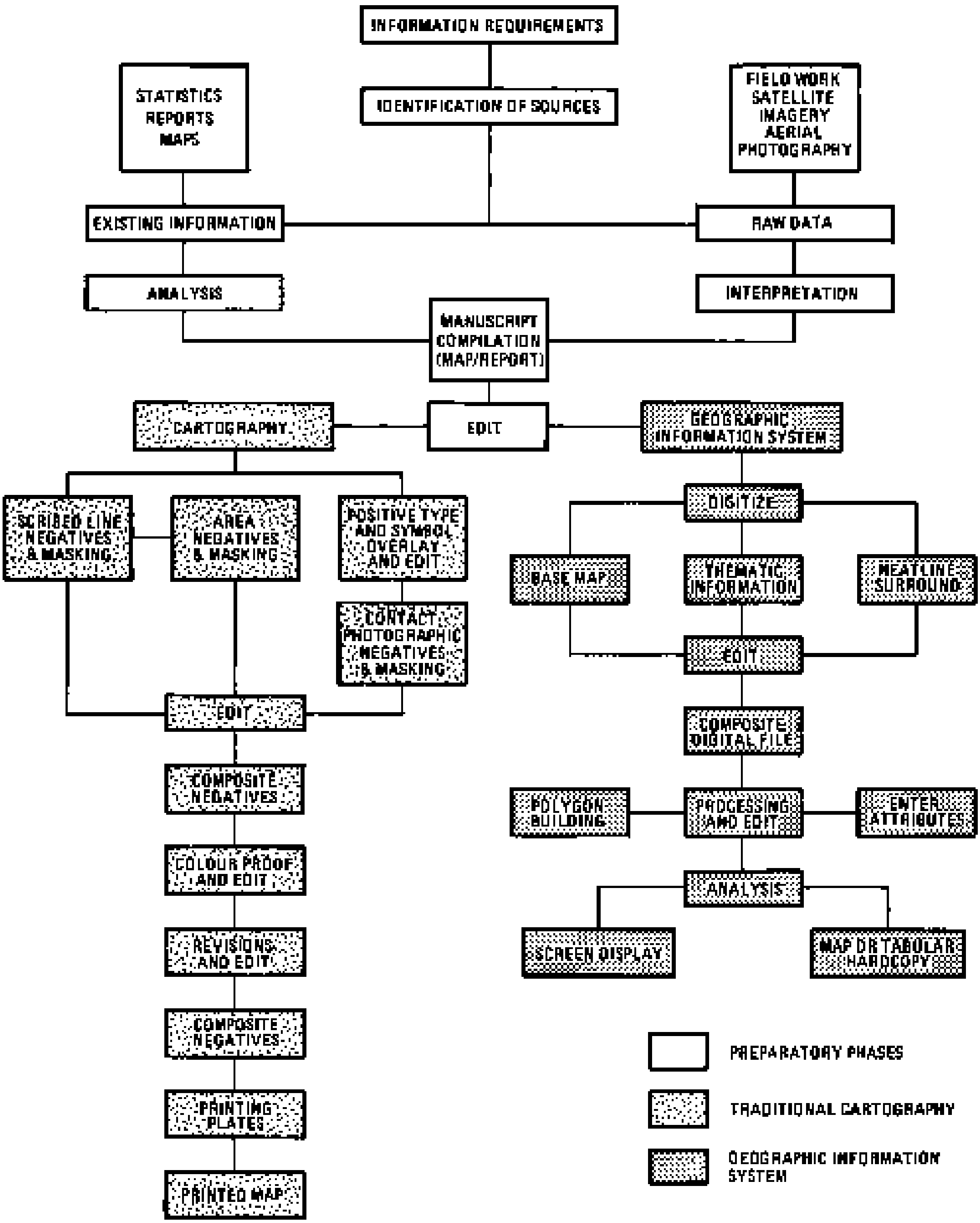


TABLE OF CONTENTS

Page

Page

Page

LIST OF FIGURES

LIST OF TABLES

SECTION 1

1. INTRODUCTION TO CARTOGRAPHY AND CLASSIFICATION OF MAPS AND CHARTS

1.1 Overview of Concepts

This manual is concerned with cartography, the art and science of making maps and charts. Those who practice this profession will be referred to as cartographers even though their actual titles may vary from map draftsman to graphic artist or from fisheries officer to scientific assistant.

A cartographer is a specialist in graphic communications who uses mapping as the main tool. The fundamental function of mapping is to provide accurate, clear and unambiguous information about the occurrence of various phenomena on or near the surface of the earth. A well drawn map is far more than a reduction of the area being studied; it is a carefully designed instrument that records, analyzes and displays the inter-related factors of the area in their true relationships to each other. In order to pass on this complex mass of information the cartographer must make effective use of graphics to illustrate a wide variety of concepts and ideas. In addition to the map format, cartographic personnel spend a large portion of their time producing such related graphics as display material, report illustrations, presentation graphics, statistical and scientific illustrations and hosts of charts, graphs and diagrams. Many of these items are frequently incorporated into maps or are substituted for them. For planning in general and resource management in particular, maps and other graphics have no equal.

Cartography exists as a field of applied graphics because words have proven to be inadequate when describing complex spatial relationships. It is vitally important that the map content be assembled in a logical and obvious manner so that the user can easily understand the information being shown. When producing maps or graphics that illustrate scientific studies a cartographer may require the advice of a scientific authority in the field to ensure the correct interpretation and portrayal of information. Relevant statistics or data alone will not necessarily supply the information required. In many decision-making processes the truly useful information is often that which is obtained from studying the overall relationship of all the data. Graphics and graphical techniques can present these relationships in a manner in which even casual observers can readily appreciate the implications.

Cartography can play a major role in socio-economic development, but the cartographer must first identify, compile and analyse the most up-to-date and accurate spatial information available. Also of importance is the selection of the most appropriate cartographic techniques to display this information, which may include both traditional presentations and those dictated by the increasing availability of relatively inexpensive computers. The essential point is to select the most appropriate methodology for each situation rather than applying a particular technique because of its familiarity. The design, equipment and techniques have to be tailored to the requirements of the specific product. There is no reason to produce an expensive multi-coloured map using the latest techniques and materials if the same subject matter can be effectively represented by a simple pen and ink drawing.

One of the intentions of this manual is to show a number of alternatives, both in design and in production techniques, so that the most appropriate can be selected for each given situation. It should be stressed that the most appropriate alternative is the simplest solution that will give the required detail, accuracy and clarity. The nature of the graphics should be governed primarily by the user's requirements.

1.2 Map Classification

There is no universally accepted classification of maps, map graphics and related products. The following categories are introduced to provide a framework for discussion and the beginning of a working language for practitioners. Broadly speaking, maps can be divided into two categories, the first being general purpose or reference maps, the second being special purpose or thematic maps.

1.2.1 General purpose or reference maps

The objective of general purpose or reference maps is to portray the relationships of a selection of different geographical features in an accurate and representative manner. Such features as roads, railways, settlements, water courses, elevations, coastlines and boundaries are typically displayed. These maps are usually produced in a series of individual sheets, and carefully constructed by photogrammetric methods (refer to Section 5). Great attention is paid to positional accuracy of features so that in some cases these maps have the validity of legal documents. They are the typical products of major national mapping agencies and may be considered the foundation on which other mapping and related studies are built.

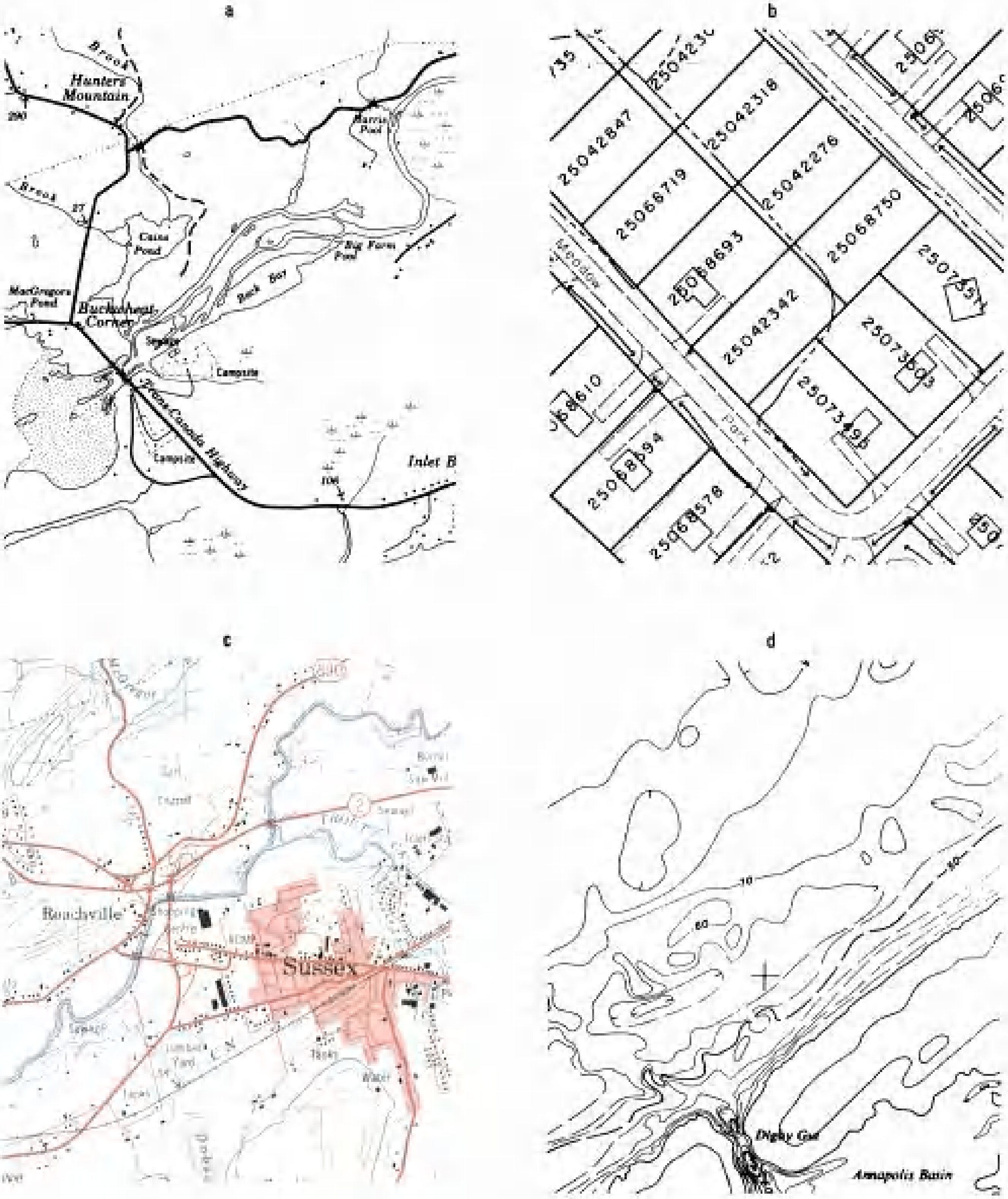
General purpose maps are fundamental to organizing and planning national and regional development. They are considered a basic national resource and are a foundation for further development. The main types of general purpose maps are as follows:

1.2.1.1 Planimetric maps: These show the horizontal position of selected features without elevations or water depths. They are often used as base maps on which to compile data for the production of special purpose or thematic maps (Figure 1.1 a).

1.2.1.2 Cadastral maps: These show the boundaries of land subdivision, often with bearings and measurements and are used to record property ownership (Figure 1.1 b).

1.2.1.3 Topographic maps (Hypsometric maps): In addition to the planimetric details of cultural and physical features that have been selected, these maps portray the shape and elevation of the terrain. This is usually done by contours, form lines, shading, colour gradients or hachures. National series mapping is normally composed of topographic maps.

Figure 1.1 Examples of general purpose (reference) maps: (a) planimetric; (b) cadastral; (c) topographic; (d) bathymetric.



Topographic maps are widely used for a multitude of purposes including selection of industrial sites, planning highways or settlements, routing power and telephone or pipelines, selecting dam sites, military planning, hunting, fishing, hiking and camping. They are thus true general-purpose vehicles and are considered to be fundamental to the economic and resource development of a region. In addition, topographic maps are frequently used as base maps for specific studies because they are often the only available accurate mapping of a region (Figure 1.1 c). Potential problems of this particular usage will be discussed in Section 7 of this manual.

1.2.1.4 Bathymetric maps: These show water depths and underwater topography. Uniform depths at specific intervals are usually connected by solid lines called bottom contour lines (Figure 1.1 d).

1.2.2 Special purpose or thematic maps

This second broad category includes all the map variants designed to fulfill a specific purpose which can be clearly identified in advance. Special purpose mapping is the fastest growing segment of the cartographic field because of its relevance to developmental activities. It is the area where a broad knowledge of design, technology and, in particular, the intended map user and use are required.

Thematic maps are composed of two major elements: the background or base map and the specific information being presented. The base map is prepared by directly or indirectly using information taken from general purpose or reference mapping. Additional base information and thematic data is derived from field work, image analysis, scientific studies, published statistics or existing maps. It is plotted onto the base map using appropriate cartographic techniques. Normally the creation of a thematic map involves a process of compilation which includes the collection and manipulation of data from a variety of sources to produce a new product.

Thematic maps are also called distribution maps. They are a kind of "geographical essay", emphasizing single or multiple themes such as geology, oceanography, climatology, vegetation, soils, crops or social and cultural aspects of the population. Cartographers use these maps extensively to show, for example, such details as harbour installations, pollution sources, climatic variation, and fish distribution and migration patterns. These distributions may be shown by many different methods (refer to Section 9).

Transportation mapping is the largest sub-group within the thematic category, including Nautical and Aeronautical Charts, Road Maps and Tourist and Recreational Maps. Most of these are specialized forms of topographic mapping and have been re-designed to suit a more specific purpose.

1.2.2.1 Nautical charts: These are published primarily for mariners although they serve a wider public in many related ways. These charts are designed to provide all available information for safe marine navigation including soundings and bathymetric contours, obstructions, hazards, prominent landmarks and navigational aids such as buoys and lighthouses.

The accuracy of these charts is of major importance in coastal regions because of the potential for marine accidents. The charts are constantly updated to keep abreast of natural and man-made changes (Figure 1.2 a).

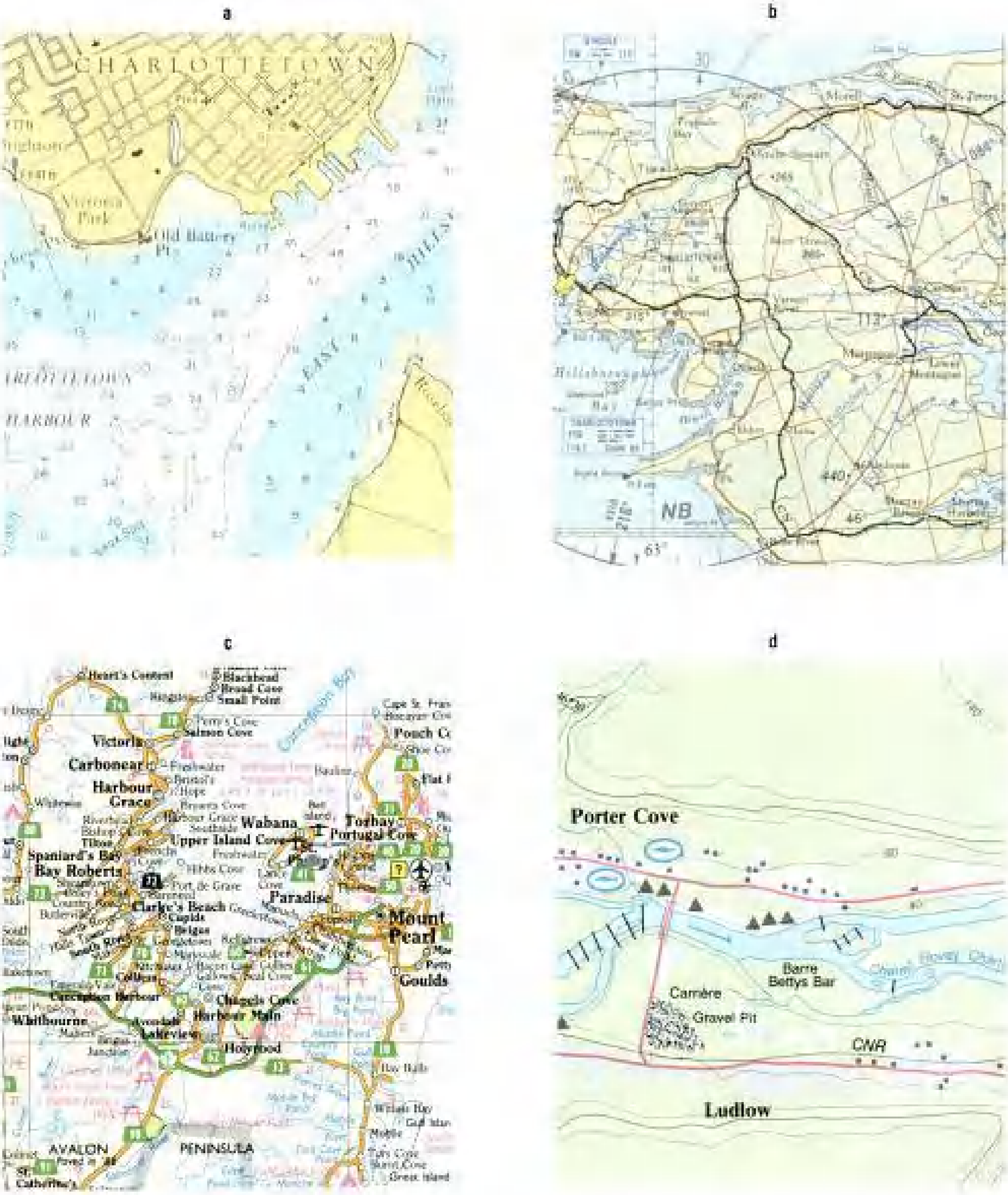
Variations of these charts include: Small Craft Charts - designed for recreational use of inshore and harbour waters; Harbour Charts - details of anchorage areas, harbours and smaller waterways; Waterways Charts - details of canals and navigable water systems; Coastal Charts - designed for inshore navigation; Sailing Charts - primarily used by navigators to fix positions as they approach the coast from the open sea.

1.2.2.2 Aeronautical charts: These are designed for air navigation, therefore emphasis is given to features of the greatest aeronautical significance. Major efforts are made to locate prominent landmarks including population centres, distinctive natural and cultural landmarks, railways and major roads. Topographic information is often shown by spot elevations, contours and layer tints, the latter practice becoming increasingly common so that relief information can be seen at a glance. Aeronautical information is generally displayed in bold size, magenta coloured symbols to give emphasis to this critical aspect of the chart. As with nautical charts, mapped aeronautical information requires frequent revisions, therefore the compilation date should be carefully noted (Figure 1.2 b).

1.2.2.3 Road maps: These are usually published by national, provincial or regional authorities to facilitate transportation over relatively long distances. Road maps indicate direction, distance and the quality of highways. Some may give related transportation information such as railways and airports. The map information is highly selective and in some forms, the map itself becomes more schematic than planimetrically accurate (Figure 1.2 c).

1.2.2.4 Tourist and recreational maps: The large market for map products generated by the increasing numbers of tourists and travellers has fostered competition amongst both private and governmental map producers. Many of the resulting products are modified topographic or planimetric maps. They show improved systems of road classification plus locations of hotels, hostels, camp sites, historic places, beaches, museums, mountain refuge huts, ski lifts, ferries, etc. Some maps use hill-shading and layer tinting to accent sites for climbing, camping, skiing, trekking and viewing. The maps of large towns may be schematic and resort to pictures and drawings of significant locations to aid the user (Figure 1.2 d).

Figure 1.2 Examples of special purpose (thematic) maps: (a) nautical; (b) aeronautical; (c) road; (d) tourist and recreational.



SECTION 2

2. MAPPING AS AN AID TO DEVELOPMENT

In most developing countries topographic mapping has preceded all other types and has formed a foundation for subsequent mapping programs. Usually geological surveys are built onto these topographic bases and become the planning vehicle for mineral resource development. This is followed by such important studies as road and railway development, improvement in regional agriculture, development of water supplies and hydro-electric power from dam construction, large-scale cultivation of new crops and other aspects of national planning required prior to undertaking major capital projects. Other major mapping projects built on a topographic base have included: tourism planning and development; census studies; forestry management; industrial plant location; land ownership; land usage; environmental hazards; ecological studies; transportation; archaeological and anthropological studies; investigation, control and use of water resources; cadastral surveys; urban studies; sea defences; soil surveys; economic assessments; health investigations; irrigation systems; land reclamation; mosquito control in marshes; airport siting; housing developments; vegetation classification; etc. There have also been many schemes implemented because of military and internal security considerations and significant boundary disputes.

To the obvious economic and security aspects listed above must be added a number of benefits which are difficult to quantify. These would include the significance of mapping in education and a variety of recreational activities.

A reading of the above list will show that many of the subject areas have a direct impact on the marine environment. In fact, the division of the natural world into terrestrial and marine aspects is an artificial one as each affects the other.

2.1 Mapping Requirements in Developing Countries

The economic welfare of a nation or region is directly dependent on the resources available to it and on the ability of the people to use these resources to their benefit. Inadequate knowledge often results in resources being over-exploited or even destroyed before they are truly appreciated. These resources include all of the exploitable minerals, soils, vegetation, wildlife and water. To derive benefits from a resource, it must first be identified and then managed. The map is the most efficient method of displaying the necessary resource information.

Many emergent nations begin by establishing a geodetic survey network to construct an effective topographic mapping series. Not only are these maps vital for recording and planning of any kind, but also they are an economic investment that produces a major, though highly diversified return. They create economic benefits by preventing a great deal of unnecessary measurement, by eliminating an enormous amount of expensive field work and by shortening the time required to assess a developmental proposal.

Once the basic frame of the survey control network for topographic or planimetric maps is in place, it can become the base on which special studies both on land and in the marine environment can be built. This is not to infer that mapping is impossible without a survey control network; in fact some aspects of this manual will concentrate on simple mapping techniques using readily available sources of information. Once the overview or reconnaissance phase is over, however, accurate measurements tied to survey control networks are usually necessary if major development is to take place.

Despite the benefits of national standard mapping, the current coverage of world topographic mapping is far from complete. Only 42% of the countries of the world are mapped at the scale of 1:50,000, considered to be the most useful scale available. At present rates initial coverage won't be complete until the year 2000. A recent study by the International Hydrographic Office found that only 40% of the marine area covered by the Exclusive Economic Zone (EEZ) of the 39 countries it surveyed was adequately charted.

Standardized mapping tends to have a long life. Topographic maps, for example, are typically in circulation for 15-20 years before they are updated. Many potential users and uses for such a product cannot be foreseen. Some hydrographic charts have been in continuous usage, through regular updates, for 70-100 years and their economic, social and convenience benefits can hardly be overstated. Such maps will easily return their cost many times over during their useful life and some will make possible a return on investment and human benefit unmatched by virtually any other developmental expenditure.

Maps have a catalytic effect on development and prevent the main source of haphazard planning which is the lack of easily understood information. In relation to the development and exploitation of marine resources, a mapping program can address critical information needs concerning, for instance, fisheries, oceanography, geology, navigation, coastal development and local political realities. In addition, such important topics as education and training can be addressed.

SECTION 3

3. SCALE AND PROJECTIONS

3.1 The Concept of Scale

All maps, aerial photographs and satellite images are a small representation of a portion of the earth's surface. It is their smaller than life size which is responsible for their convenience as a method for illustrating the world. If these products are to be at all useful, the relationship between the size of the graphic and the real size of the same region of the earth must be known. This fundamental concept, known as scale, is one of the most important design considerations in the field of cartography.

Establishing a scale for a map is an important design decision. Among other things, the following items are controlled by scale:

i) the amount of data or detail which can be shown;
ii) the size of the graphic and its suitability for production utilizing available materials and equipment;
iii) the cost of reproduction;
iv) the readability of any product which is an enlargement or reduction of an existing map;
v) the regional extent of the information shown;
vi) the degree and nature of the generalization carried out (refer to Section 7);
vii) the suitability of an available base for a specific purpose;
viii) the ease of use by the intended market;
ix) the amount of time a cartographer must spend on a project.

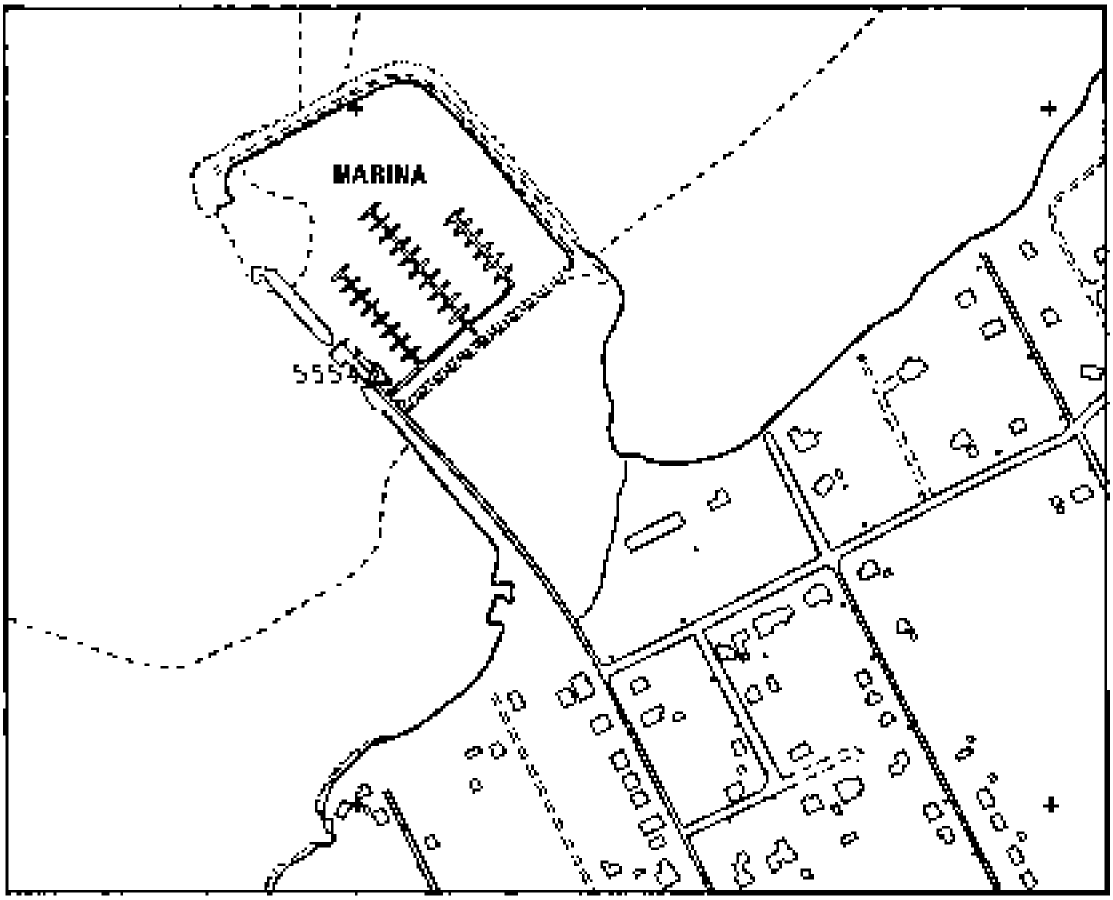
Specifically, scale is the ratio of map distance to ground distance and its selection depends primarily on map purpose. The cartographer must also consider convenience and economy, striking a balance between the area covered, map size and the amount of detail required. Scales are often a compromise.

The use of the relative terms large-scale and small-scale can cause considerable confusion and must be carefully addressed. To understand the concept clearly, compare two maps of the same area but of significantly different scales. Select a common feature such as an airfield, a bay or an island. The map which shows the feature drawn relatively large is the large-scale map. By contrast, the map which shows the same feature as being distinctly small is by definition a small-scale map (Figure 3.1).

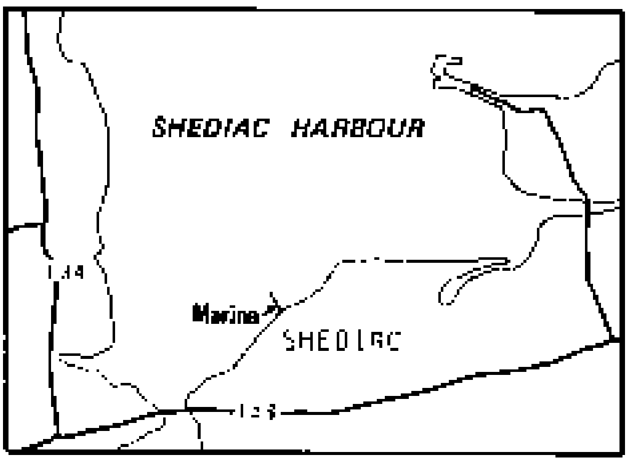
Small-scale maps cover large areas with little detail while large-scale maps show great detail and only cover a small area. Most maps will be a compromise between the required detail and the area of coverage. Sometimes the needs are incompatible, as when a large area must be covered but with some parts requiring great detail. This may be solved by producing more than one map or by using portions of the map as insets at larger scales. The latter solution allows variation in scales and greater detail in critical areas.

Figure 3.1 A comparison of a large and a small-scale map.

LARGE-SCALE MAP



SMALL-SCALE MAP



3.2 The Forms of Scale

Generally, once it is calculated, the scale of a map may be shown in three different standard forms. These are representative fraction, scale statement and graphic or bar scale. Other scale variations are sometimes used in addition to the standard forms.

3.2.1 Representative fraction

Representative fractions (R.F.), also known as scale ratios, relate the size of the map, or portion thereof, to its actual size on the ground. Thus an R.F. of 1:10,000 means that one unit on the map is equivalent to 10,000 units on the ground. A major advantage of this system is that it is not tied to a specific measurement system; the ratio works as well in metric as in imperial or any other convenient unit of measurement.

Comparatively low numbers after the colon are associated with large-scale maps while comparatively high numbers after the colon are associated with small-scale maps. The International Cartographic Association, in an attempt to standardize the terminology, has suggested the following:

i) R.F. larger than 1:25,000, i.e. numbers less than 25,000: large-scale maps;
ii) 1:50,000 to 1:100,000: medium-scale maps;
iii) R.F. less than 1:200,000, i.e. numbers greater than 200,000: small-scale maps.

3.2.2 Scale statement

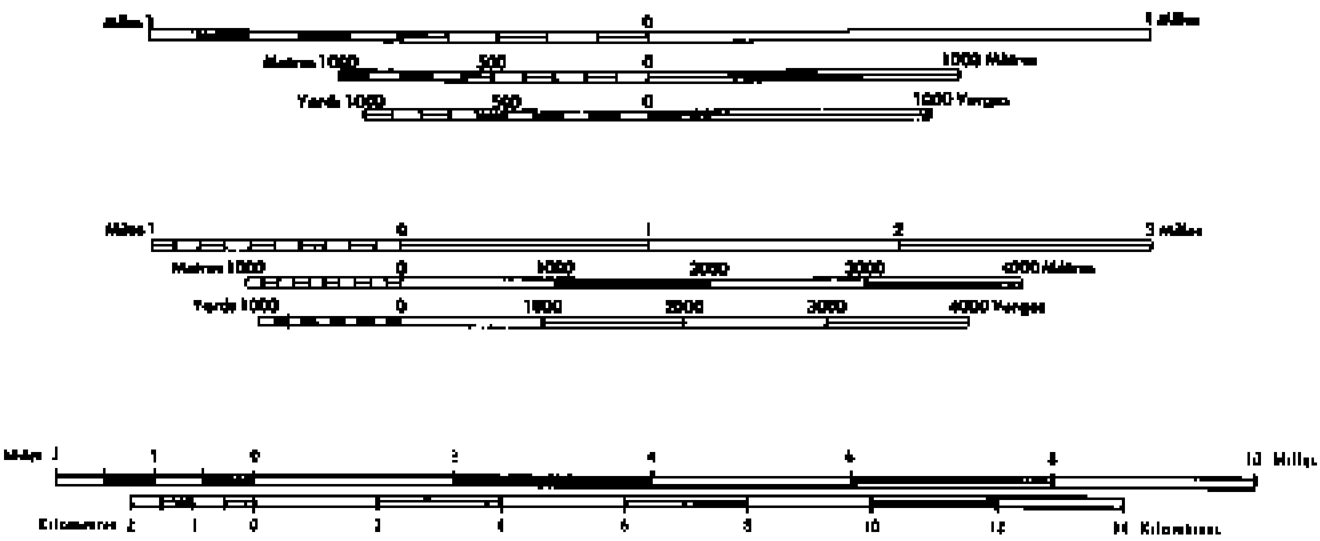
This is a written statement of map distance in relation to earth distance, for example, 1 inch equals 1 mile or 1 centimetre equals 1 kilometre. An R.F. could also be considered a scale statement since, for example, 1:1,000,000 could also be written as 1 centimetre equals 10 kilometres or 1 millimetre equals 1 kilometre. If this version of a scale is chosen, avoid confusion by not mixing metric and imperial units in one statement.

3.2.3 Graphic or bar scale

This device is the most common and the most useful method of depicting scale on a map or chart. It consists of one or more straight lines which are subdivided into units of ground distance or whatever the scale is designed to show (Figure 3.2). It has the considerable advantage of remaining correct even if the map is enlarged or reduced, which is not true for the other scale variants, the R.F. and scale statement.

The cartographer must remember that the scale must be designed for the user and not for the convenience of the cartographer. The subdivision units must be selected to be as even and useful as possible, whatever the R.F. For example, the common older map scale of 1 inch equals 1 mile with an R.F. of 1:63,360 should be converted by the cartographer if a metric scale is desired. By taking the original scale units of 1 inch and plotting them according to their metric scale equivalent, each

Figure 3.2 Examples of graphic or bar scales.



subdivision unit of 1 mile would represent an inconvenient 1609.35 metres. In this case a basic subdivision unit of 1000 metres or 1 kilometre might be deemed appropriate. A calculation reveals that each unit representing 1000 metres will be 1.578 centimetres long. This is difficult to plot but is the effort the cartographer must make for turning out a useful and professional product.

3.2.4 Graphic scale variants

Most graphic or bar scales are designed in traditional linear measurements such as feet, miles, nautical miles, metres and kilometres. Many land sub-division systems, however, were carried out in rods, chains, furlongs and leagues. Similarly both British and American cable lengths and even fathoms have been used and may occasionally be appropriate.

Direct reading scales in units which are not purely linear are sometimes useful. Many tourist maps, for instance, incorporate walking scales calculated at an average person's pace in units of five or more minutes. Military maps have shown scales in terms of the distance a troop of marching men will cover in a given time period. Highway maps may show elapsed time travelling at a set speed. Biological maps have shown how far a migratory bird, animal or fish will travel in a particular time. These scales are sometimes more useful than the standard scale formats.

3.2.5 Grids

Grids are a system of vertical and horizontal reference lines, drawn on many maps, which enable a point to be identified by a coordinate or reference number (refer to Section 4).

Grids, however, can also be used as a scale indicator on a variety of graphics. A grid of squares having sides of known length, such as a kilometre or a mile, extended over the drawing permits an easy identification of size, area, etc. In a series of related maps such a grid provides a ready method of comparison and identification. A grid must be drawn with fine lines or it will dominate the drawing because of its geometrical, and therefore, visible nature.

3.2.6 Comparison shapes

On some mapping products which illustrate an unknown or unfamiliar geographic area a useful scaling device is the inclusion of insets of a more familiar region and the study area at the same small scale. Travel maps have long used this method, for example "London at the same scale" on a map of Tokyo.

3.2.7 Spacing of parallels

Parallels of latitude are a set of east-west lines running parallel to the equator. They are a geographic constant which can always be translated into measurements of kilometres or miles.

In latitude:

i) 10° = 1111.111 kilometres = 600 nautical miles = 691.72 statute miles;
ii) 1° = 111.11 kilometres* = 60 nautical miles = 69.172 statute miles;
iii) 1' = 1852 metres = 1 nautical mile = 1.15 statute miles.

Thus a difference of 4° in latitude must have the same length in any region of the globe (240 nautical miles), and can be used as a scale indicator or base for calculations, unless supreme accuracy is needed.

*This is a convenient average figure corresponding to 45° latitude. It varies from 110.57 kilometres at the Equator to 111.699 kilometres at the Pole.

3.2.8 Scale factor

Since the earth is essentially spherical, the only consistently accurate method of showing a large region of it is by constructing a globe which can then be given a single scale. To transfer the globe shape to a map on a flat surface requires an organized and consistent method of controlling the inevitable distortions. These mathematical and graphical techniques are known as map projections and are discussed later in this section. The employment of any map projection, however, results in the scale actually varying in different locations on the same map.

The labelled representative fraction (R.F.) on the map is referred to as the principal scale while the local scale caused by projection distortion effects is known as actual scale and will vary from place to place. The scale factor (S.F.) is a ratio of one to the other, thus:

$$\text{Scale Factor} = \frac{\text{Actual Scale}}{\text{Principal Scale}}$$

The scale factor is 1.0 on a globe, that is the actual scale is equal to the principal scale, and is close to this figure on most large-scale maps. On small-scale maps it can easily vary from 0.5 to 2.0; this translates into a range of scales from 1:5,000,000 to 1,20,000,000 on a map whose stated scale is 1:10,000,000. On the widely used Transverse Mercator projection the S.F. of a 6° longitude zone varies only from 0.99960 to 1.00158. Similarly on the Mercator projection, much used for charting, the S.F. is limited to 1.016 in the zone between 10° North and South of the Equator.

The scale factor (S.F.) is seldom, if ever, stated on a map but it can have significant effects. The control of the scale factor is, therefore, a consideration in choosing a suitable map projection.

3.2.9 Area scale

It is sometimes necessary to construct a map so that all area proportions are correctly represented, i.e. one unit of area on the map (square centimetre, square inch, etc.) represents a particular number of the same square units on the earth. Here again, the cartographer must first select a relevant map projection which will allow this function. To prevent confusion area scales are shown graphically rather than numerically. Thus the explanation will include a square which represents a stated number of square kilometres or miles, acres, etc.

3.2.10 Variable scale

As discussed earlier, no flat map can exhibit true distance from all points in all directions simultaneously. In some map projections the distance distortion is systematic and a variable scale can be constructed to enable accurate measurements to be taken. This is particularly true on those maps containing a Mercator projection, such as some nautical and aeronautical charts. This permits the determination of scale in latitude or longitude despite the vast range in scale distortion.

3.2.11 Other scales

Ratio, nominal, ordinal, interval, value and logarithmic scales are discussed in Section 9. The scale of aerial photographs is described in Section 8.

3.3 Scale Changing

When a map or graphic is reduced or enlarged, the scale will change proportionately. If a drawing at a scale of 1:100,000 is reduced to 50% of its original size, the scale will change to 1:200,000. Similarly if it is enlarged to 200% of the original size, the 1:100,000 graphic will now have a scale of 1:50,000. All scales, and especially a scale statement or an R.F., must be carefully calculated and labelled for the reproduction scale. The amount of reduction or enlargement, if required, must be known precisely at the design stage. For this reason the cartographer must work closely with both the author and the printer when making preliminary design decisions.

Cartographic artwork may be photographically reproduced at 100%, reduced or enlarged. The scale change must be clearly identified if enlargements or reductions are required. It is best to use the designation which is built into most process cameras, the devices which are used to do the reproduction. On these instruments an identically sized reproduction is marked as 100%. To obtain a 25% reduction in size the camera must be set to 75%, and the latter is what should be specified. "Reduce to 75% of original" prevents the obvious error of setting the camera to 25%, and obtaining a drawing where every line would be 1/4 of its original size.

Similarly, to enlarge, the percentage on the camera setting should be specified. Thus, if a drawing is required where each dimension is twice that of the original, the statement "Enlarge to 200% of original" and not "100% enlargement" should be noted.

If there is still a possibility of confusion, provide the operator with a simple bar scale to place on the camera. Include two lines (lines AB and AC) of carefully measured lengths on the drawing. The instructions should read "Reduce (or enlarge) AB to AC exactly". This prevents any confusion and enables the operator to physically check the enlargement or reduction.

3.4 Geodesy - The Form of the Earth

The fact that the earth is neither flat nor round has historically posed a problem for cartographers, particularly when producing extensive chart or map series, at small or large scales, which cover extensive geographic areas. The exact shape of the earth now becomes a major consideration. For large-scale individual maps, however, particularly those of a thematic nature, the variations are not significant.

Satellite images have ensured that the roughly spherical shape of the earth is now accepted by most people and is no longer a subject for dispute. The exact shape is, however, of distinct interest and is still actively under study. As is well known, the earth has become slightly flattened at the poles because of the effects of its rotation. The distortion is not obvious - if the earth were reduced to a globe 1 metre in diameter, the amount of polar flattening would be only about 3.5 millimetres.

Surveyors must also contend with the fact that the mass of the earth is not evenly distributed. This creates variations in the strength and direction of gravity, which controls the local horizontal and vertical surfaces with which the surveyor must work. Scientists have thus postulated in theory an irregular spheroidal shape which takes the gravity variations into account; it is called the geoid. The geoid shape is higher under the continents because of the presence of a large rock mass above sea-level, as seen in Figure 3.3.

The geoid is often described as a hypothetical surface to which the ocean would conform (i.e. sea-level) if free to adjust to the earth's gravitational attraction and the forces of centrifugal rotation. Gravity studies using satellites have now revealed that the earth's gravitational field has some distinct humps and depressions. The largest hump is near New Guinea, being some 81 metres high, while a major depression south of India dips 110 metres below reference surface.

For mapping purposes an irregular surface is highly undesirable, so the information must be transferred to a regular geometric shape which can be calculated and which closely approximates the geoid. This shape is known as the ellipsoid and is a three-dimensional reference surface (Figure 3.3). No single ellipsoid is considered to be suitable for all surveys and mapping throughout the world. For historical and political reasons a number of different figures of the earth are in current usage (Table 3.1).

Recently the International Association of Geodesy has adopted new dimensions for a reference ellipsoid, called the Geodetic Reference System 1980 (GRS80). This is the basis for a new reference mapping system, the North American Datum 1983 (NAD83).

Figure 3.3 **The relationship between the regular ellipsoid surface and the irregular geoid surface under continents and over ocean basins. (After W.A. Heiskanen, 1958)**

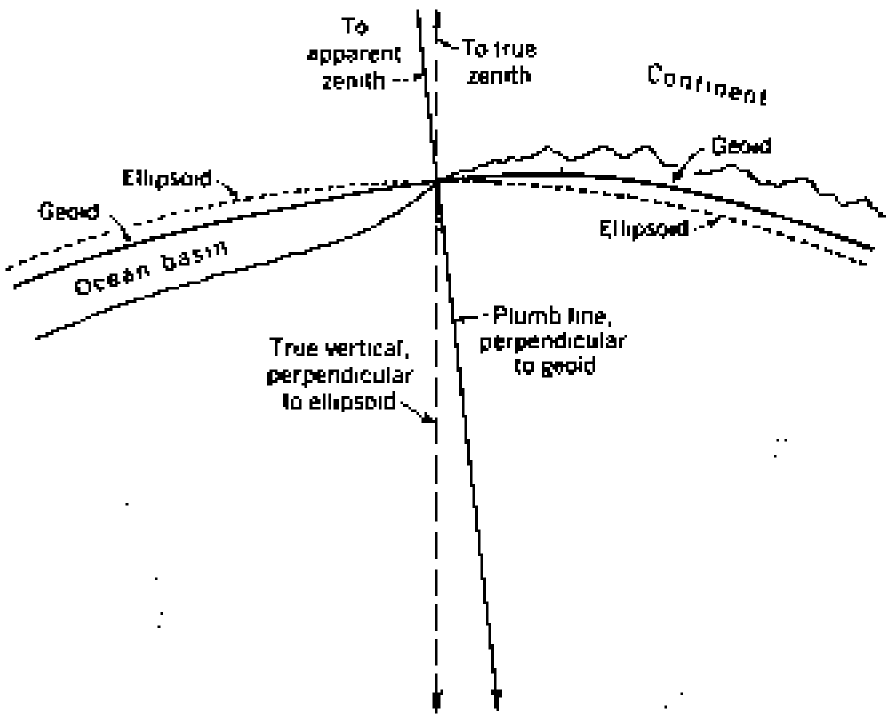


TABLE 3.1

REFERENCE ELLIPSOIDS AND THEIR DIMENSIONS

ELLIPSOID	EQUATORIAL RADIUS (Metres)	FLATTENING	USER
Everest (1830)	6 377 276	1/300.80	India
Bessel (1841)	6 377 397	1/299.15	Japan, Germany
Airy (1844)	6 377 563	1/299	Great Britain
Clarke (1860)	6 378 249	1/293.47	France, S.Africa
Clarke (1866)	6 378 397	1/294.98	North America
International (1924)	6 378 388	1/297.00	International
Krasovsky (1940)	6 378 245	1/298.30	U.S.S.R.
Astronomical Union (1965)	6 378 160	1/298.25	
IUGG* (1979)	6 377 563	1/298.26	North America/ International

*International Union of Geodesy and Geophysics

DIMENSIONS OF THE EARTH (Based on GRS80)

	KILOMETRES	STATUTE MILES (U.S.)
Equatorial diameter	12 756.3	7 926.4
Polar diameter	12 713.5	7 899.8
Equatorial circumference	40 075.1	24 901.5
Radius of the sphere	6 371	3 949
Area of the earth	510 064 500 km^2	196 936 000 mi^2

3.5 Map Projections

The cartographer makes use of map projections to present the three-dimensional nature of the earth's surface in the two dimensions available on a map or chart. As discussed earlier, for the purposes of medium and small-scale graphics the basic shape of the earth can be assumed to be spherical. A small area of a large-scale map or chart can be drawn without appreciable error but for those products showing large areas, and particularly for series mapping, a projection system is vital.

Projections can be created purely graphically by projecting the earth's curved surface onto flat surfaces or developable surfaces such as cones or cylinders which can be flattened. They can also be created mathematically or by a combination of the two methods.

The ideal projection would provide correct shapes, correct areas, correct scale, correct bearings, a good overall "fit" and ease of construction. Obtaining all or even most of these properties is impossible so the cartographer must select whichever feature is the most important for a particular map, or choose a compromise projection, often one of the so called "minimum error" types.

Correct shape is a characteristic of conformal (orthomorphic) projections. It should be noted that it is only possible to keep shapes correct over small areas. Conformal projections preserve true angles and a constant scale in all directions about a given point because the parallels and meridians cross each other at right angles. This is an essential characteristic for navigational charts. Both the Mercator and the Lambert Conformal Conic are conformal projections and are widely used both for sea and for air navigational charting. As these projections preserve angles locally, they also may be used for graphics showing data based on angular measurements. These might include tidal streams, lines of gravity and magnetics, direction of surface-water movements, migrations, and bathymetry. Navigational charting using conformal projections has been undertaken for centuries, providing a ready source of data for use as base map information. This simplifies the cartographer's task.

Equal area is also known as equivalence. This property can be preserved on a map constructed from a projection such as Bonne's, but only at the expense of distorted shapes. This projection can be of great value for displaying spatial relationships and distributions. When the cartographic symbolization requires an area or quantitative symbol, such as water volume movement, an equal area projection is needed.

The attainment of full equidistance, i.e. the preservation of scale at all points on a projection, is impossible. On any projection the actual scale is continuously variable; it can vary from point to point and may also vary in different directions. It is possible, however, to maintain correct scale where a projection surface meets the sphere from which it is derived. Selection of those points in a careful manner can reduce scale errors to a minimum. Equal distance can be preserved on Zenithal projections. Equidistant projections are a useful compromise between conformal and equal area projections and they are often used for general reference graphics. The area scale changes on equidistant projections are less dramatic than those on a conformal projection and the angular errors are less than those of an equal area projection.

Map projections may be classed in several ways which are summarized in the insert included with this manual.

SECTION 4

4. LOCATION AND RELIEF

4.1 Location

On the curved surface of the earth, position is defined by the universal system of latitude and longitude. All international and most national geographic gazetteers use this system for locating listed features. Small-scale maps and marine charts usually display a graticule (network) of meridians and parallels to assist in locating features using their geographical coordinates.

Marine chart graticules are based on points whose latitude and longitude have been fixed by astronomical or satellite observations. In contrast, topographic maps are surveyed and tied to the local national geodetic datum which is a reference network for horizontal locations. This sometimes results in a discrepancy in the position of the graticule shown on a coastal marine chart as compared to that shown on a topographic map. This is one of the main reasons for the current efforts to develop a world geodetic datum based on satellite observations.

4.2 Horizontal Control

Establishing the primary, horizontal control network requires the determination of the latitudinal and longitudinal positions of the control points through a process known as triangulation (Figure 4.1). This involves defining a starting line, called a baseline, and finding the latitude and longitude of its end points. From this baseline a network of straight lines is extended to the desired control points. The angles formed throughout this network are measured, and trigonometrical calculations are used to determine distances and locations within the network. Corrections must be made for the curvature of the earth through calculations based on spherical trigonometry.

The network that is measured to the highest level of accuracy is called the first-order or primary network. Once this is established, second and third-order networks can be built up within it. These new networks provide a denser array of control points as needed for local surveys. Usually first-order surveys are measured to an accuracy of 1 part in 25,000, second-order to 1 in 10,000, and third-order to 1 part in 5,000. Less accurate fourth-order measurements are used if they do not result in appreciable map error.

4.3 Coordinate Systems

The rotational motion of the earth spinning on its axis provides two natural points, the poles, upon which to base coordinate systems. These systems are networks of intersecting lines (graticules) inscribed upon the globe to permit the precise location of surface features. They are a method of organizing the concepts of direction and distance so that a comprehensive system of relationships can be established. Two types of systems are in general usage for reference mapping: a geographical

Figure 4.1 The principle of triangulation. (After A.N. Strahler, 1963)

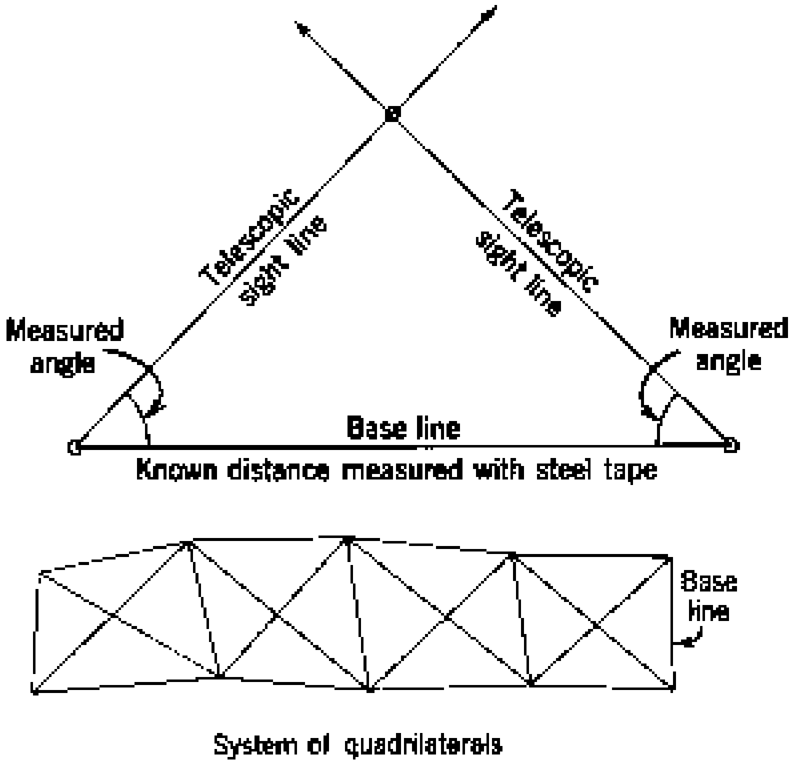
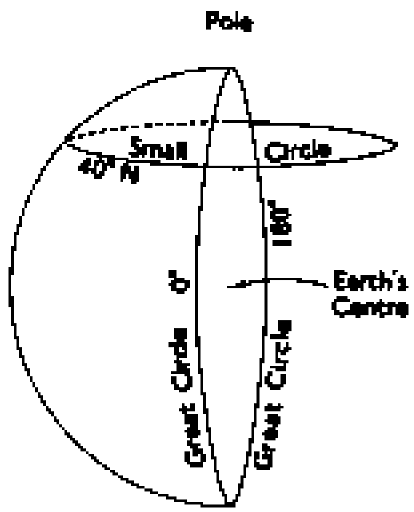


Figure 4.2 A great and a small circle. (After H.S. Roblin, 1969)



coordinate system which uses lines of longitude and latitude to fix positions, and a rectangular coordinate system, such as the Universal Transverse Mercator (UTM) Grid System, which uses eastings and northings as the locational technique. Navigation charts, in contrast to their terrestrial partner, the topographic map, may be overlaid with another geo-referencing system, the Loran-C network lattice (refer to Section 5.2.3).

The terminology associated with coordinate systems includes the following:

i) Great circle: A plane passing through the centre of the earth cutting the surface in a great circle (Figure 4.2), e.g., all meridians and the equator. An arc of a great circle is the shortest distance between two points on the earth's surface;

ii) Small circle: A plane passing through the earth, other than through the centre (Figure 4.2), e.g., parallels of latitude;

iii) Poles: Terminii (north and south) of the earth's axis;

iv) Meridians (lines of longitude): A set of north-south lines connecting the poles. Each meridian is half a circle. Two opposite meridians make a great circle (Figure 4.3);

v) Equator: The only great circle perpendicular to the earth's axis, and dividing the earth into northern and southern hemispheres;

vi) Parallels (lines of latitude): A set of east-west lines running parallel to the equator (Figure 4.3);

vii) Latitude: The angle (north and south) subtended by two imaginary straight lines, one extending from a given place inwards to the earth's centre, and the other from the earth's centre to the equator (Figure 4.4);

viii) Longitude: The angle (east or west of the prime meridian) subtended by two imaginary straight lines, one extending inwards to the earth's axis, and the other from the earth's axis to the prime meridian (PM), i.e. the meridian chosen for 0° which passes through Greenwich, U.K. (Figures 4.4 and 4.5). Going east from the PM, the meridians are numbered up to 180° East (the eastern hemisphere). Going west from the PM, the meridians are numbered up to 180° West (the western hemisphere) (Figure 4.4). Because the meridians converge at the poles, the 1° longitude interval decreases from 111 kilometres at the equator to 56 kilometres at 60° North or South and zero kilometres at the poles (Table 4.1);

ix) Graticule: A network of lines representing parallels and meridians on paper, i.e. geographic coordinates which are defined in degrees, minutes and seconds;

x) Grid: Two sets of parallel lines crossing at right angles to form squares, i.e. grid coordinates.

Figure 4.3 (a) Meridians; (b) parallels. (After A.N. Strahler, 1963)

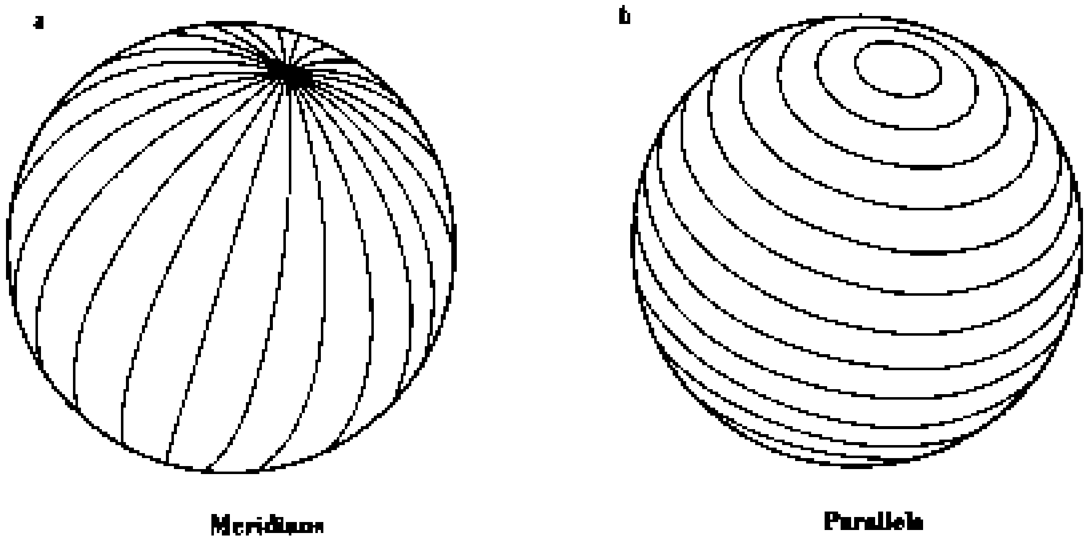


Figure 4.4 The geographic grid of parallels and meridians. Point A has a latitude of 50 North and a longitude of 75 West. (After A.N. Strahler, 1963)

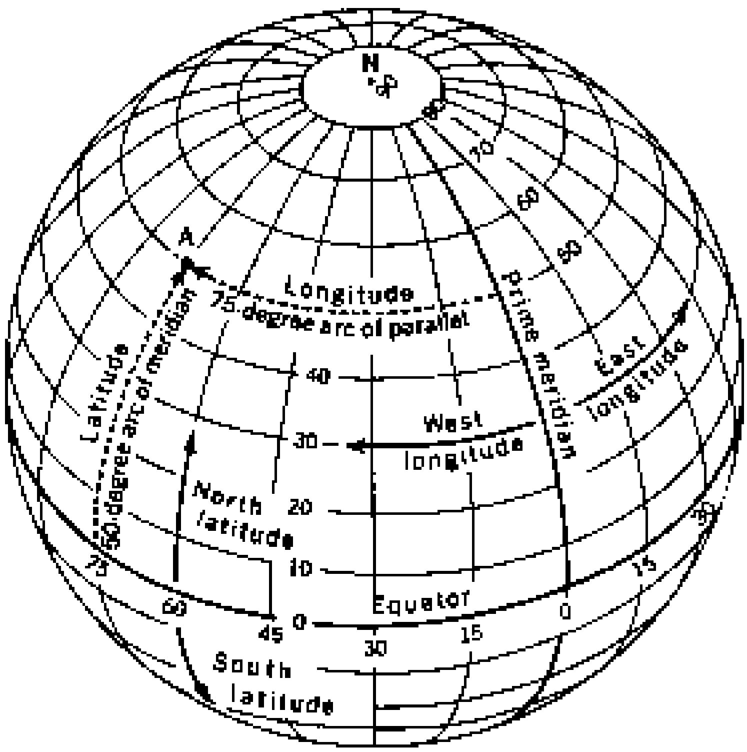


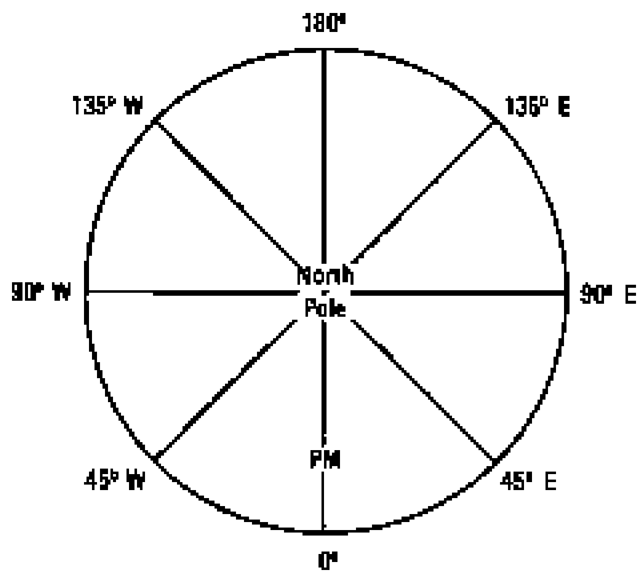
TABLE 4.1

THE LENGTH OF 1° INTERVALS OF SELECTED LATITUDES AND LONGITUDES

	LENGTH OF 1° OF LATITUDE		LENGTH OF 1° OF LONGITUDE	
Latitude (Degrees)	Statute Miles	Kilometres	Statute Miles	Kilometres
0	68.704	110.569	69.172	111.322
5	68.710	110.578	68.911	110.902
10	68.725	110.603	68.129	109.643
15	68.751	110.644	66.830	107.553
20	68.786	110.701	65.026	104.650
25	68.829	110.770	62.729	100.953
30	68.879	110.850	59.956	96.490
35	68.935	110.941	56.725	91.290
40	68.993	111.034	53.063	85.397
45	69.054	111.132	48.995	78.850
50	69.115	111.230	44.552	71.700
55	69.175	111.327	39.766	63.997
60	69.230	111.415	34.674	55.803
65	69.281	111.497	29.315	47.178
70	69.324	111.567	23.729	38.188
75	69.360	111.625	17.960	28.904
80	69.386	111.666	12.051	19.394
85	69.402	111.692	6.049	9.735
90	69.407	111.700	0.000	0.000

Based on Clarke ellipsoid of 1866, from U.S. Geological Survey Bulletin 650, "Geographic Tables and Formulas" by S.S. Gannett, 1916, pp. 36-37. (After A.N. Strahler, 1975)

Figure 4.5 The prime (0°) and other meridians from the perspective of the North Pole. (After A.R. Grime, 1978-80)



4.3.1 Geographical coordinate system

The geographical coordinate system was developed from concepts originated by Greek philosophers before the Christian era. It is the primary system used for basic locational reckoning, such as navigation and surveying. The system is basically one of spherical coordinates, the meridians and parallels being neither straight nor equally spaced. It is useful for mapping large areas and the measurement of distances and directions in angular measure of degrees, minutes and seconds. A rectangular coordinate system which is far simpler in construction and usage may be superimposed on the geographical coordinate system.

4.3.2 Rectangular coordinate system

The Universal Transverse Mercator (UTM) Grid System is an international system which provides rectangular grid zones for the globe between latitude 80° South and 80° North. Poleward of 80°, the Universal Polar Stereographic Grid System is used. These systems are named after the map projections on which they are based. The UTM Grid System consists of 60 grid zones, each 6° of longitude in width (Figure 4.6). The origin (0°) of the grid zone is the intersection of the central meridian and the equator, both straight lines. The grid is a network of 1,000 metre, 10,000 metre or 100,000 metre squares, each identified by the grid coordinates of its lower left hand corner. In stating grid coordinates, the number of metres east or eastings (right) is given first, followed by the number of metres north or northings (up). The procedure for reading UTM grid coordinates is explained in Figure 4.7. In order to have all eastings increase towards the right across the entire zone, the central meridian is given the arbitrary value of 500,000 metres east. The equator is given the value of 0 metres north as the reference line for northings increasing up to the 80th parallel north. For the southern hemisphere, the equator is given the arbitrary northing of 10 million metres north, so that northings begin with their lowest value at 80° South latitude and increase northward to attain that figure at the equator. The Universal Transverse Mercator Grid System has now been widely adopted for topographic maps, referencing of satellite imagery, natural resource data bases and similar applications which require precise positioning.

4.4 Vertical Datum and Control

The first step in setting up a vertical control network is the determination of a starting level, or datum. The most desirable level for this purpose is the surface of the geoid; if there were no tides, the surface of the ocean would provide the required surface. For this reason, measurements that eliminate sea level variations due to tidal action are used to establish the sea level datum. The establishment of this level or datum requires the recording of tidal levels every hour over a 19 year period. These readings are then averaged to establish a mean datum known as Mean Sea Level. The North American Datum based on Mean Sea Level has so far been adjusted twice, in 1929 and again in 1983. Mean Sea Level (MSL) is in fact a datum which fluctuates according to atmospheric pressure changes, winds, tidal forces, etc. Variations of up to one metre have been noted. Despite this, MSL has been adopted by most countries as their topographic vertical reference datum.

Figure 4.6 The UTM grid zone near the equator and at 45° North. (After A.N. Strahler, 1969)

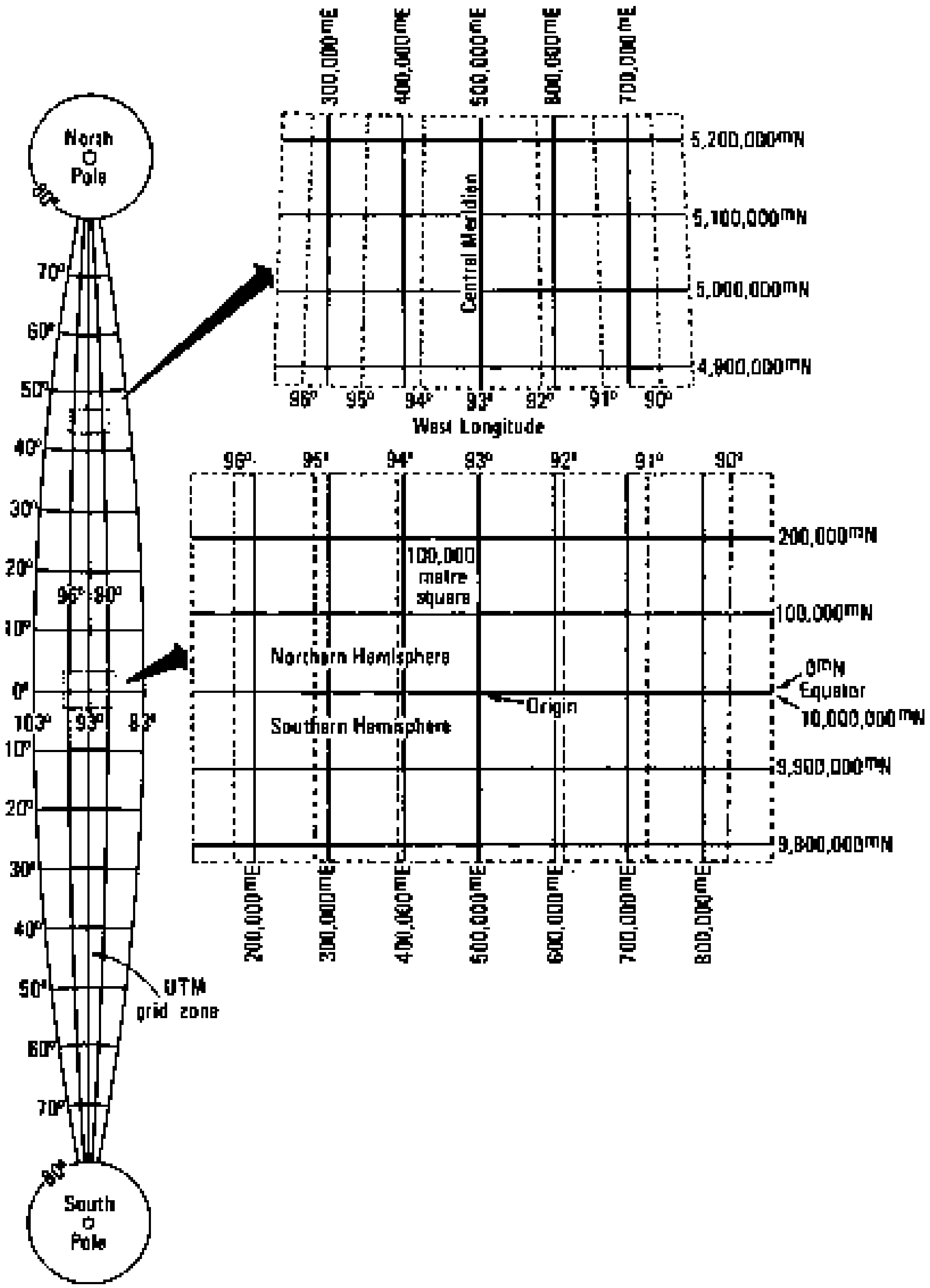
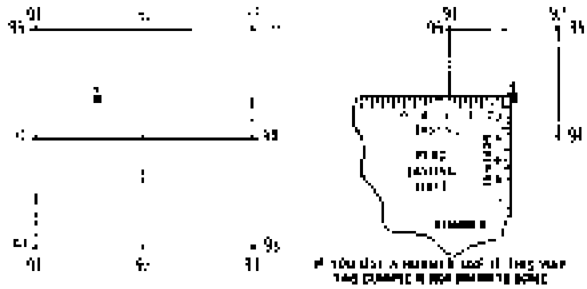


Figure 4.7 The procedure for reading UTM grid coordinates. (After Canada, Department of Energy, Mines and Resources, n.d.)

ANYONE CAN READ
MAP REFERENCES
QUICKLY AND ACCURATELY



SCALE 1:50 000

To find Map reference of ⍋ proceed as follows

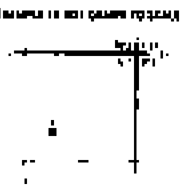
1. Find Number of Grid Line West of ⍋ (91)
Ascertain number of tenths ⍋ is East of (91)
This is observed to be 6.
Set it down thus. 916. This is known as EASTING

2. Find Number of Grid Line South of ⍋ (94)
Ascertain number of tenths ⍋ is North of (94)
This is observed to be 4.
Set it down thus. 944. This is known as NORTHING

The Map reference of ⍋ is therefore 916944

Note. Such map references repeat every 100 Kilometres. You should quote the map name if there is chance of ambiguity.

ALWAYS MEASURE OVER TO THE EAST AND THEN UP TO THE NORTH. IN OTHER WORDS FIND THE EASTING, THEN THE NORTHING



Note- When using a reference on the 1:250 000 map give the letters of the large square concerned.

Map reference on 1:250 000 scale is NT9393

In contrast to topographic maps, marine charts must show heights and depths above and below the water surface at any given time. Thus marine charts use two datums other than MSL to meet these requirements.

The most important information on a marine chart is the minimum depth of water at any given point. Therefore the primary reference datum used for marine charts is Lowest Normal Water Level. Depths below this level are known as soundings. In the intertidal zones, heights are measured upwards from the same level and are normally underlined on the face of the chart. Some charts use the word "dries" next to these figures and refer to them as drying heights.

The other datum is chosen to identify the land areas on these charts. The phenomenon of spring tides, the twice monthly peak of tidal range, is generally used to determine this datum. It may be labelled as Higher Water Ordinary Spring Tides, Mean High Water Springs, Highest Astronomical Tide, Mean Higher High Water, etc. The variety of mapping and charting datums is illustrated in Figure 4.8.

On lake charts, the horizontal datum, projection and grid are usually identical to surrounding topographic maps. As with sea charts, however, the lowest water level must be adopted as datum for vertical control. Many lakes have a wide seasonal variation, particularly those with no outlet. The elevation of this datum above Mean Sea Level should always be quoted. The choice of chart datum is usually more difficult in inland waters than coastal waters because the former lack the stabilizing influence the ocean exerts on the mean water level. Because a river descends from its source to its mouth, chart datum must slope similarly to the water surface of the river at low stage to avoid constant datum variations throughout the length of the river.

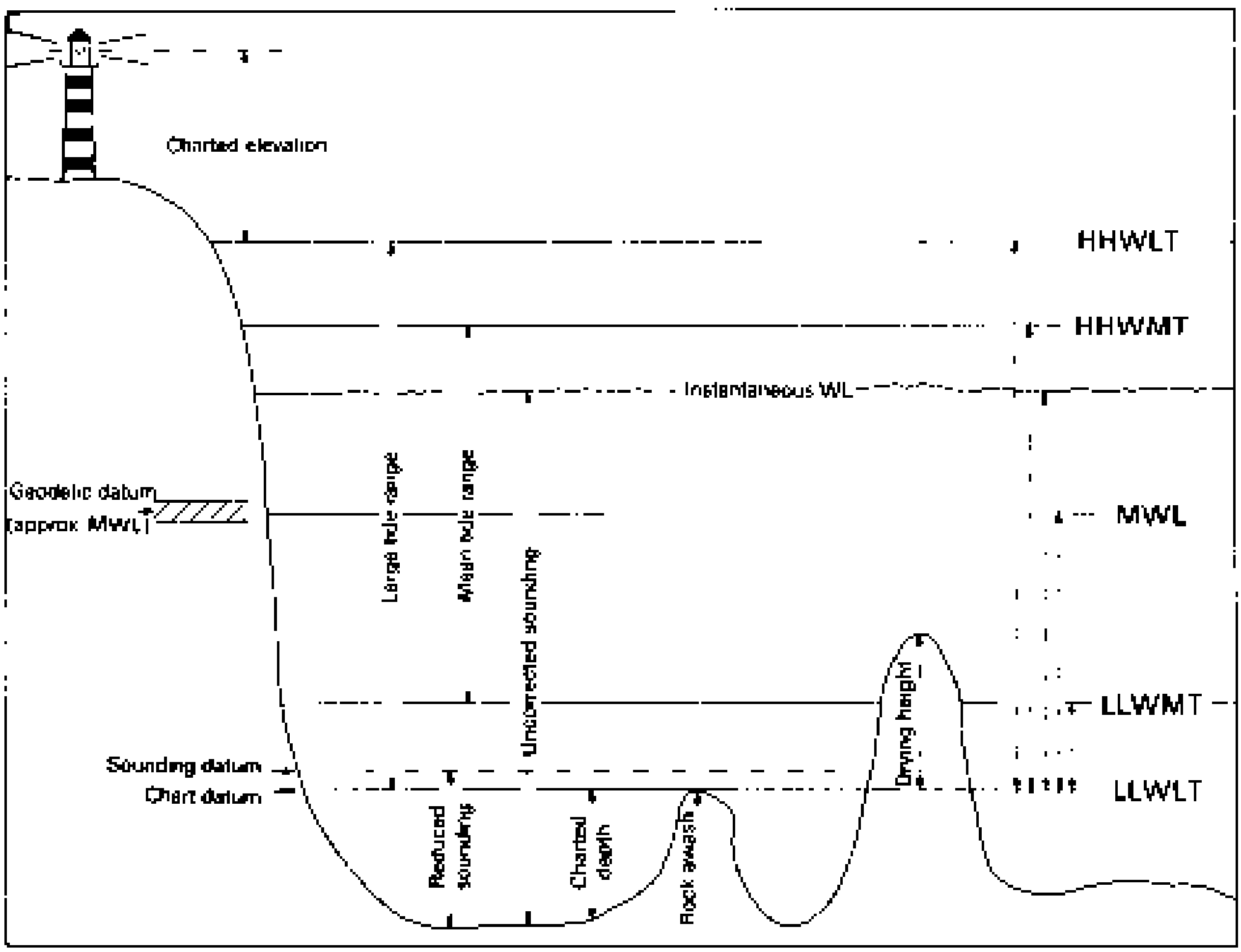
In contrast to depth measurements, the elevations of prominent targets (e.g., beacons) and clearances under obstacles (e.g., bridges) are referred to the datum for elevations (Figure 4.8). On most Canadian charts this is the HHWLT (Higher High Water, Large Tide).

Benchmarks (BM) are fixed elevation markers. In Canada, the Geodetic Survey of Canada locate geodetic benchmarks in relation to the national geodetic datum. Similarly the Canadian Hydrographic Service is responsible for hydrographic benchmarks which identify locally the elevation of the physical surface used as chart datum. Although it is not necessary for charting purposes, it is desirable that chart datum be referenced to geodetic datum, so that the geodetic elevation of chart datum can be supplied to surveyors and documented on charts.

4.5 Relief - The Third Dimension

Most people think of location only in horizontal terms, being unaware of the important third dimension of our environment - the vertical. For certain applications the vertical dimension is an important and sometimes critical factor which cartographers must portray within their two-dimensional graphics. In the marine environment, huge and unwieldy ships must maneuver a scant few metres above unseen and potentially lethal terrain. An up-to-date nautical chart will show a navigator the topography of the

Figure 4.8 Relation between tidal surfaces, charting datums and physical features. (After W.D. Forrester, 1983)



MWL — mean water level — average of all hourly water levels over the available period of record.

HHWLT — higher high water, large tide — average of the highest high waters, one from each of 19 years of predictions.

HHWMT — higher high water, mean tide — average of all the higher high waters from 19 years of predictions.

LLWMT — lower low water, mean tide — average of all the lower low waters from 19 years of predictions.

LLWLT — lower low water, large tide — average of the lowest low waters, one from each of 19 years of predictions.

LNT — lowest normal tide — in present usage it is synonymous with LLWLT, but on older charts it may refer to a variety of low water chart datums.

ocean bottom so that he can safely navigate the underwater valleys and ridges.

4.5.1 Spot values

The simplest representation of surface elevation is the use of spot values to indicate the measurement of height or depth which applies at that particular point. The spot is represented by a small point symbol with a number beside it indicating the height or depth above or below a reference value or datum. On topographic maps and aeronautical charts the measurement of height is relative to Mean Sea Level; on marine charts depth and height are relative to the selected chart datum.

On topographic maps, spot values known as spot heights, are shown for some physically monumented bench marks on the ground. Other significant locations such as hilltops, mountain passes and road intersections are also given spot heights (Figure 4.9). On nautical charts, depth soundings are spot values that show the depth of water (Figure 4.10). Spot heights and depth soundings are very simple and are accurate for the specific point chosen. They do not, however, provide a graphic effect of shape, nor do they indicate values located between the spots. Because of this limitation the map viewer cannot easily visualize the characteristics of the surface being displayed. Spot heights and depth soundings are most often used as an information supplement to some other technique of showing surface elevation.

Nautical charts have traditionally shown a large number of depth soundings, in addition to isolines or depth contours, to indicate to the mariner the reliability of the information from which the chart was derived. With the increased accuracy of detail of modern marine surveys, however, many marine charting organizations are now dropping this practice which simplifies both the production and usage of these visually more appealing products.

4.5.2 Contours

Contours, or isolines, are by far the most widely used method of portraying relief or depths on maps and charts (Figure 4.9). They may be defined as lines of constant elevation or depth; they are imaginary but they appear on the map as real lines.

Contours can be obtained in several ways, including:

i) traditional surveying techniques;
ii) hydrographic surveying;
iii) interpolation from spot heights or depth soundings;
iv) photogrammetric plotting;
v) dropline techniques in orthophoto production;
vi) conversion from other mapping.

Unfortunately, it is rarely possible to determine the origin and nature of contours on a given map. In particular, the reliability of interpolated or sketched contours will vary from map to map and with the skills of the map maker. Contours on many older maps should be treated with

Figure 4.9 Relief as portrayed by contours. (After Canada, Department of Energy, Mines and Resources, n.d.)

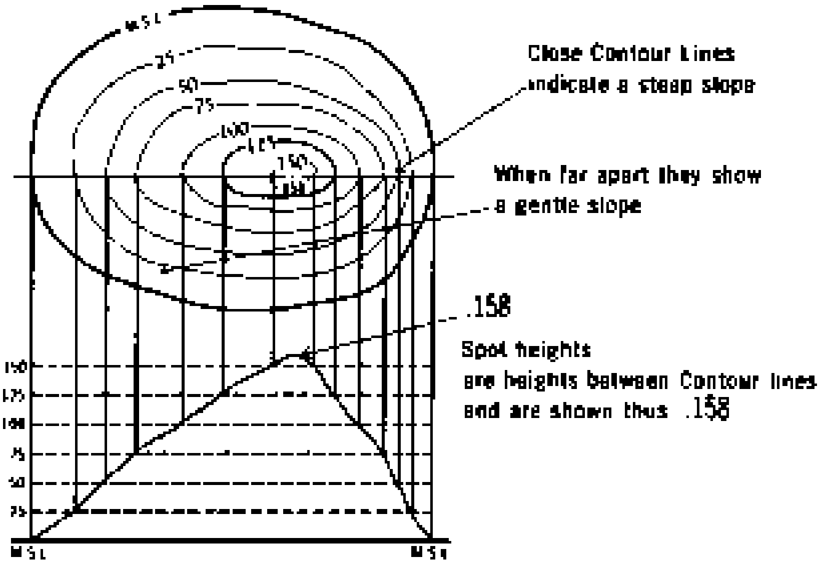


Figure 4.10 Nautical chart showing depth soundings. (Canadian Hydrographic Service, Chart no. 4332)

suspicion unless details of the accuracy are provided. Obtaining accurate contours by traditional survey techniques is tedious and will often double the cost of a given survey. Hence, many contours have been interpolated from minimal survey data. Generally speaking, modern photogrammetrically plotted contours are drawn with a large amount of detail, therefore their accuracy will often reveal the errors existing on older mapping.

4.5.2.1 Marine contours (Figure 4.11): Surveying the ocean floor is still subject to considerable difficulty, as boats and water surfaces are normally in motion during a survey. Accuracy of positions at sea, until the advent of satellites, depended on the distance from shore. High seas positioning historically depended on astronomic observations using sextants, which were not noted for their accuracy.

Depth measurements are taken relative to an artificial datum surface because the actual sea level is constantly fluctuating. There are also several different reference datums in usage, for example, those used by Britain and France vary by 0.6 metres. For reasons of safety the French use the Approximate Lowest Low Water, while Britain has used one which is 0.6 metres below Low Water Mean Spring Tide.

Most nautical charts are notable for the density of spot depths, but the spots are not evenly distributed, being concentrated along navigation routes, at river mouths and shallow areas (Figure 4.10).

It is important to note that hydrographic charts, designed for navigation, and bathymetric charts, designed to depict marine topography, will be contoured differently using the same data. Hydrographic charts emphasize shallow water zones as a deliberate safety factor. Bathymetric charts are the marine equivalent of topographic maps; the interpolation of contours is based strictly on the spot depth values and the distance between them.

The accuracy standards of marine mapping are even more varied than that of land mapping. In general, the continental shelves of the world have been poorly mapped by modern standards. In Canada, for instance, only 50% of those areas carrying commercial maritime traffic are up to modern mapping standards, and in Arctic waters it is less than 20%.

4.5.2.2 Vertical or contour interval: This is the vertical distance between two adjacent contour lines. It is usually a constant unit on topographic maps whereas many hydrographic charts utilize a number of differing intervals. This latter system is of great benefit to the map user because it is the vertical interval which largely controls the effectiveness of contours in representing the terrain. Any feature whose height is less than the vertical interval will probably not be identified by the contour pattern, therefore a great deal of "micro-relief" information that may be of interest to some people is lost on standard topographic mapping. Selecting a smaller contour interval in areas of low relief is an obvious solution which is not used enough in these days of standardized presentations. Conversely, in mountainous regions the contour interval should be kept larger to prevent overcrowding. Since varying contour intervals could lead to consistency problems in series mapping, a system to select contour spacings for various map scales is necessary. The most comprehensive system for that purpose was developed by the noted German cartographer, Eduard Imhof. See Table 4.2.

Figure 4.11 Example of bathymetric contours. (Canadian Hydrographic Service, Chart no. 15062)

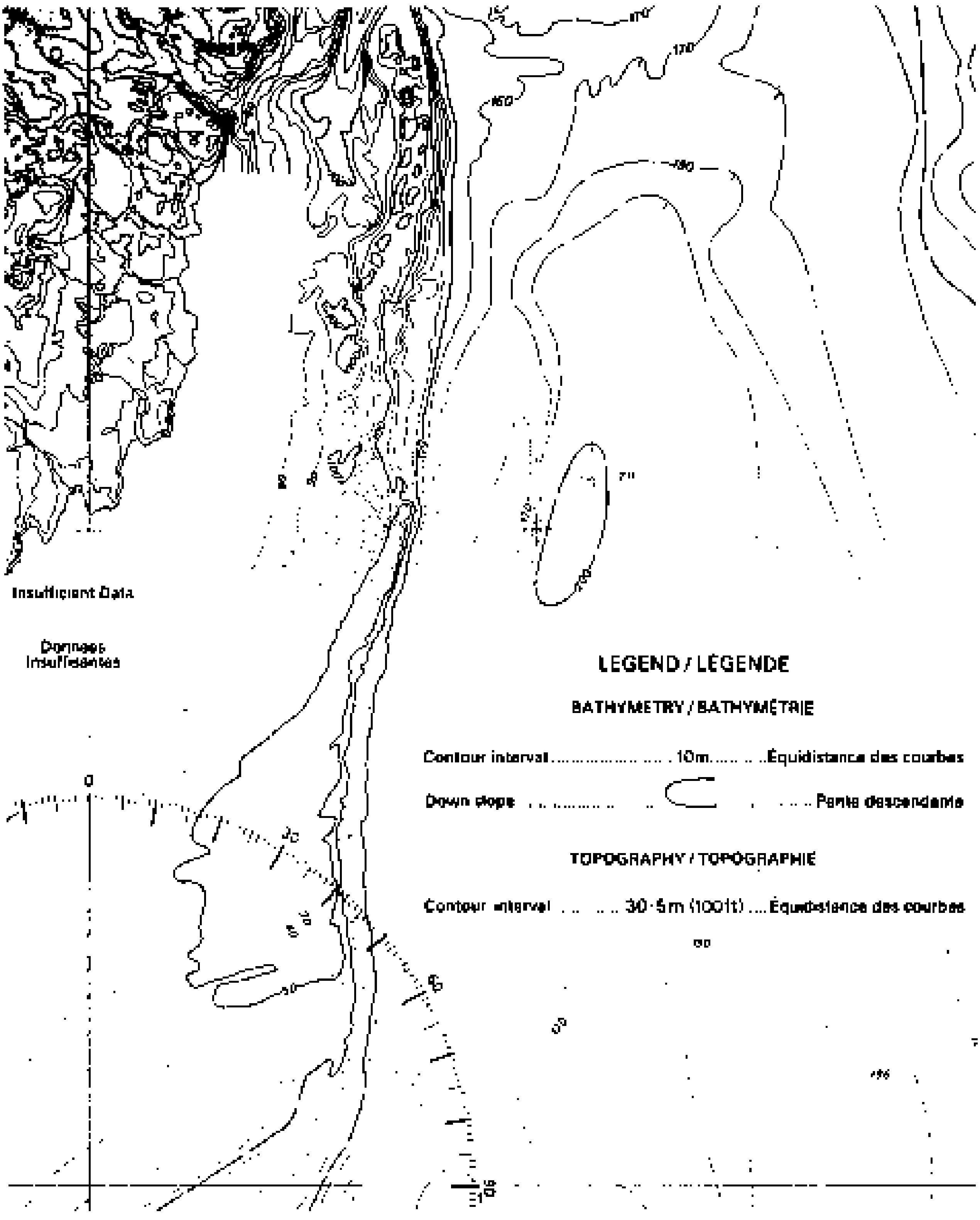


TABLE 4.2

CONTOUR SPACINGS FOR VARIOUS MAP SCALES (After E. Imhof, 1965)

	A					B	C
SCALE	1	2	3	4	5	6	7
1:2,000	1.0	2	2.7	2	1.0	1.0	0.5
1:5,000	2.5	5	5.7	5	2.5	2	1.0
1:10,000	5.0	10	10	5	5	5	2
1:25,000	12.5	10.2	19	20	10	10	2.5
1:50,000	25	20.25	29	20	10	10	5
1:100,000	50	50	47	50	25	25	5
1:250,000	125	100	85	100	50	50	10
1:1,000,000	500	200	200	200	100	100	20

contour spacings in metres

Key:

A: STEEP RELIEF (slopes up to 45°)

1. Smallest contour interval for ease of drawing.
2. Most commonly used vertical interval.
3. Theoretical contour interval based on empirical formula.
4. Recommended interval for principal contours.
5. Recommended interval for intermediate contour where those are necessary to depict features which would normally be omitted.

B: MEDIUM RELIEF (slopes up to 26°)

6. Recommended contour interval.

C: LOW RELIEF (slopes up to 9°)

7. Recommended contour interval.

Intermediate or auxiliary contours are a solution to the problem posed above. They are inserted between contours of standard vertical intervals to illustrate significant minor features. To ensure that their non-standard nature does not confuse the reader, they are drawn with broken or dotted lines or, occasionally, in another colour.

A contour line is of little use to a map reader unless its value can be easily identified. Numerical values are placed in short gaps in the appropriate line and aligned with the local orientation of that line. Two different conventions have been developed for numbering contours:

i) the "top" of the number indicating the up-slope direction (upslope);

ii) numbers placed such that they can be easily read from the normal base viewing position of the map (upright).

There is no rule which controls the number of contour numbers on a map sheet. The only guide is that the map user must be able to obtain the accurate relevant information required with a minimum of effort. The frequency of the number placement must be judged accordingly. The visual ladder effect created by long strings of numbers should be avoided because it is highly disruptive. In contrast, totally random number placement is difficult for map readers to interpret.

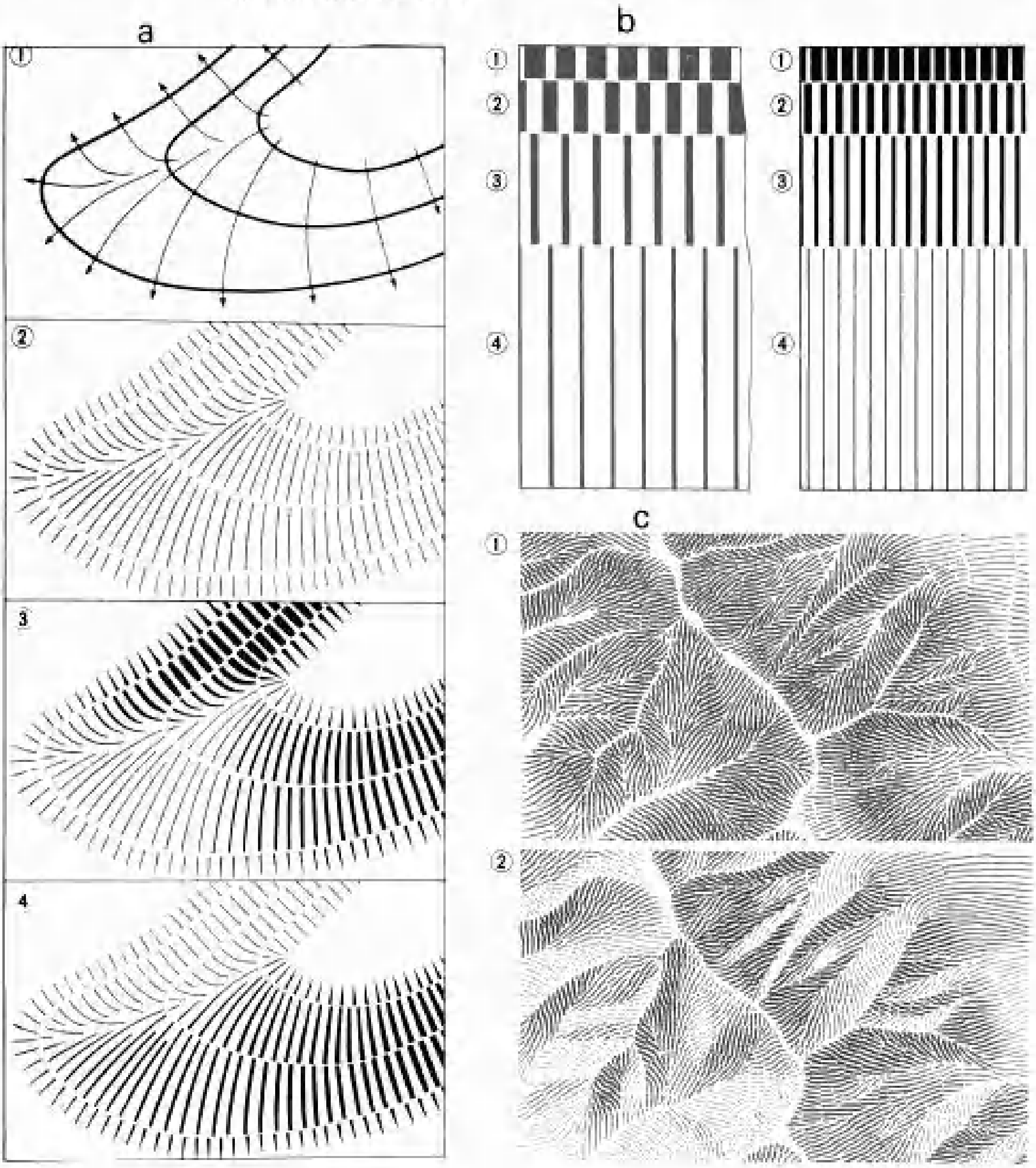
4.5.2.3 Index lines: Many maps have a high density of complex isolines or contours. Without a visual aid the reader can become disoriented and misinterpret the information. Convention has every fourth or fifth line drawn visibly wider to aid in interpretation. The selection of the fourth or fifth line as the index depends on the contour interval. The most rounded and convenient contour interval should be selected, for example, a map with 25 metre contour intervals would show the fourth or 100 metre line as an index.

4.5.2.4 Contour accuracy: As indicated earlier this is not easy to ascertain. The most reliable contours are normally those derived photogrammetrically, although their standards can vary widely. In North America the absolute accuracy standard specifies that contour lines must be positioned within a band representing one half the contour interval above and below the true elevation. This is adequate for most engineering purposes but contours cannot show true slope or variation in the terrain, unless the interval is much smaller than the absolute accuracy standard. Intermediate contours should not be interpolated between the contours of an existing topographic map because the land does not necessarily slope evenly between two contours.

4.5.2.5 Contour characteristics: The following is a list of contour characteristics:

i) Contours are always horizontal and perpendicular to the dip of the land, i.e. the direction in which water would run at that location;

Figure 4.12 Hachures construction. (After International Cartographic Association, 1984)



a HACHURE DRAWING

① Relation of contours and direction of maximum slope angle. ② Draw hachures along the direction of maximum slope angle. ③ Hachure width depends on the maximum slope angle Vertical illumination. ④ Hachure width depends on both the maximum slope angle and the direction of slope surface — Oblique illumination.

b SPACING OF HACHURES

Hachure width depends on the slope angle at ① 30°, ② 20°, ③ 10°, ④ 5°. The left drawing: 20 lines per 10 mm. The right drawing: 40 lines per 10 mm. Both are enlarged 10 times.

c EXAMPLES OF HACHURES

① Vertical illumination, ② Oblique illumination.

ii) All contours are closed lines, unless cut off by the margin of the map;

iii) Contours become closer as the slope of the terrain steepens;

iv) On crossing rivers, contours will point upstream except on a few alluvial fans;

v) If the contour interval is too large, low relief will not be recorded;

vi) Neighbouring contours do not cross or touch each other, with the exception of cliffs and overhangs.

4.5.3 Hachures

Hachures have historically been a very important and common method of showing relief and slopes (Figure 4.12). They consist of short (often tiny) lines arranged so that they face "downhill". Each hachure line lies in the direction of the steepest slope. On steep slopes they are short but close together, and on flatter slopes they are longer but further apart. They can also be drawn with a variety of line widths, heavier lines indicating steeper slopes.

These techniques can be quite precise and produce a good visual impression of relief. They are, however, extremely time consuming, and cartographers need considerable practice to use the technique effectively. Also the black hachure lines on the map face tend to hide other detail. For most applications the cost and time involved in producing these symbols are prohibitive, especially as there are better methods of showing relief.

4.5.4 Other techniques for showing relief

There are a growing variety of shading techniques, such as illuminated contours, hill shading and step surface shading, which are replacing hachures as a means of showing relief. Complex terrain can also be portrayed by illustrative techniques, for example, rock drawing and the use of physiographic and landform symbols. Details of these relatively sophisticated cartographic techniques can be obtained from more specialized texts.

SECTION 5

5. BASE MAPS AND THEIR CONSTRUCTION

Before thematic or marine resource mapping can proceed it is essential to understand the content and construction of base maps which constitute the foundation on which thematic information is overlaid. Base maps are generally in the form of topographic maps or hydrographic charts.

5.1 The Topographic Map

5.1.1 Function

The topographic map presents the cultural and physical features of the land, usually in various colours, and gives their exact geographic location in terms of latitude, longitude and elevation above sea level. Features on a topographic map may be classified into four main divisions: water, relief, culture and vegetation (refer to Section 1).

5.1.2 Scale

Three methods are commonly used to express scale on maps (refer to Section 3). They may be summarized as follows:

i) representative fraction, which is the proportion of map distance to true distance expressed as a mathematical ratio, e.g., 1:250,000;

ii) scale statement, which is a written statement of map distance in relation to true distance, e.g., 1 centimetre = 10 kilometres;

iii) bar scale, which consists of one or more graduated straight lines which are subdivided into units of ground distance.

Topographic maps are commonly produced in one of five scales:

i) 1:25,000 - 4 centimetres to 1 kilometre or approximately 2 1/2 inches to the mile;

ii) 1:50,000 - 2 centimetres to 1 kilometre or approximately 1 1/4 inches to the mile;

iii) 1:125,000 - 1 centimetre to 1 1/4 kilometres or approximately 1/2 inch to the mile;

iv) 1:250,000 - 1 centimetre to 2 1/2 kilometres or approximately 1/4 inch to the mile;

v) 1:1,000,000 - 1 centimetre to 10 kilometres or approximately 1/16 inch to the mile.

Many countries, however, still use older mapping at 1:63,360 or 1 inch to 1 mile, and 1:15,840 or 1 inch to 1/4 mile.

5.1.3 Geographic coordinate system

In Canada, for example, the National Topographic Series uses the Transverse Mercator projection as the geographical coordinate system of latitudes and longitudes on which is superimposed the UTM Grid System; Canada is divided into sixteen North-South strips or zones of 6° longitude (refer to Section 4.3 and Figure 5.1). These strips are part of the world-wide UTM Grid System of 60 zones.

5.1.4 Production

The key stages of topographic map production are as follows:

5.1.4.1 Aerial photography of area to be mapped: An aircraft equipped with a special aerial survey camera, flying at a specific speed and an altitude of 5,000 to 10,000 metres, takes a succession of photographs of the terrain in parallel strips with 20-40% overlap laterally and 60% in the direction of flight (Figure 5.2). Thus each portion of land appears at least twice in the photo series, a necessity for producing a three-dimensional visual model (image) from which the map information is derived. Aerial photography is repeated regularly to provide up-to-date information for the revision of topographical mapping.

5.1.4.2 Giving the aerial photograph a geographic location: An aerial photograph provides only a visual two-dimensional representation of the terrain. It does not show the height of mountains, depths of valleys, etc. The following are the procedures required to establish the exact geographic location of each photograph so that the features of the photograph can be accurately transferred to a map:

i) each photograph is given a grid to permit interrelation with adjacent photographs;

ii) field surveys establish primary control points by measuring their exact latitude, longitude and height above sea level.

Primary control points established by surveyors in the field include the following two types:

i) vertical control points, or bench marks, which provide a precise height above sea level;

ii) horizontal control points which provide precise latitude and longitude coordinates.

The primary control points are marked with a white cross and photographed by an aircraft flying directly above at a predetermined altitude. This operation ties some of the aerial photographs to a precise ground location, a primary control point. Approximately one in ten aerial photographs is positioned by this method.

Figure 5.1 UTM zones and central meridians for Canada. (After Canada, Department of Energy, Mines and Resources, 1976)

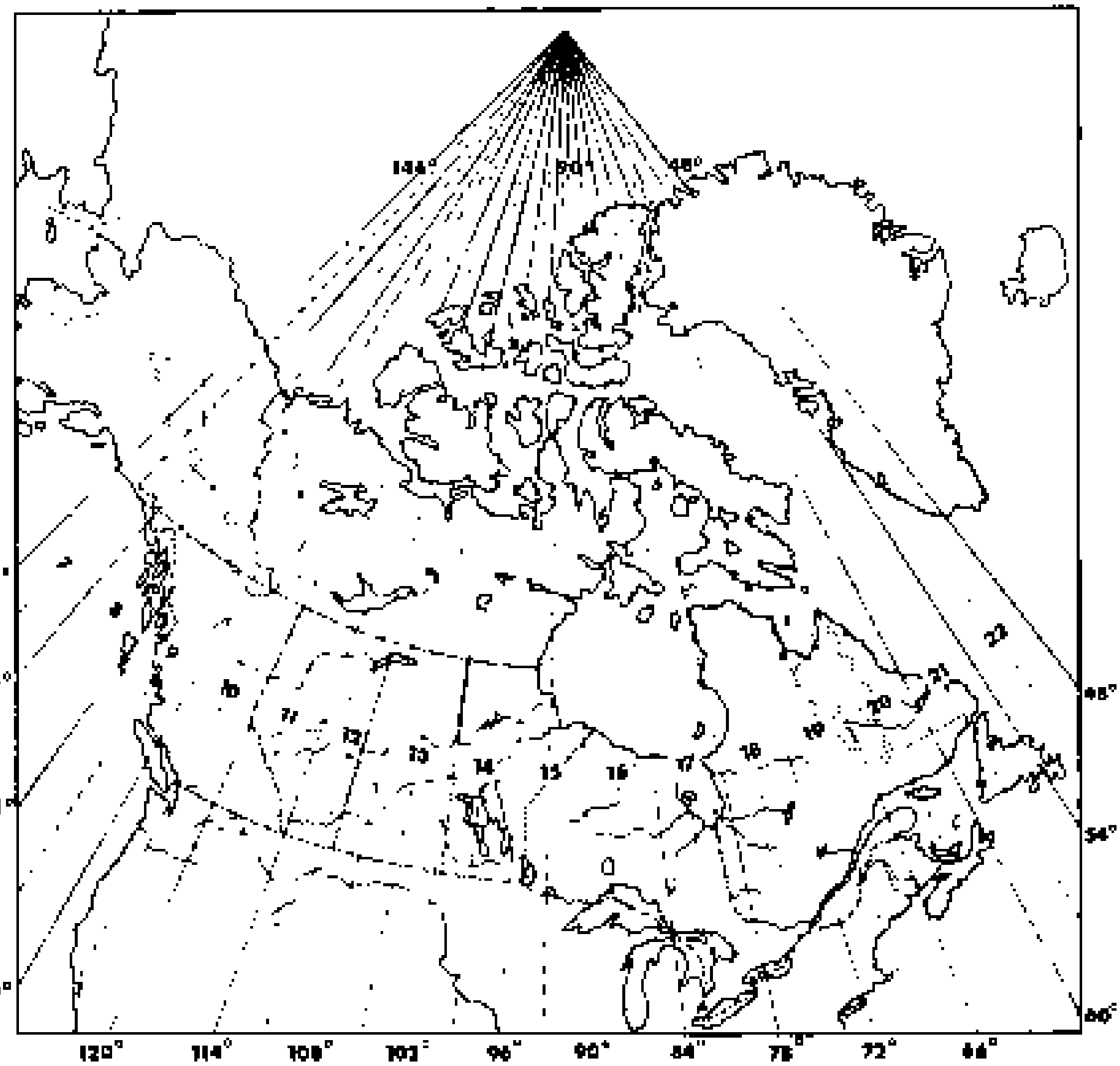
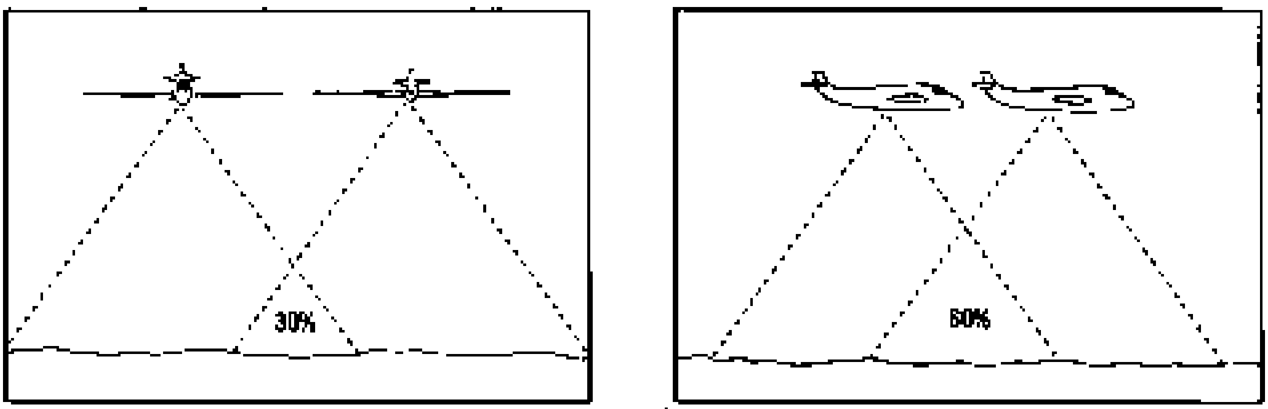
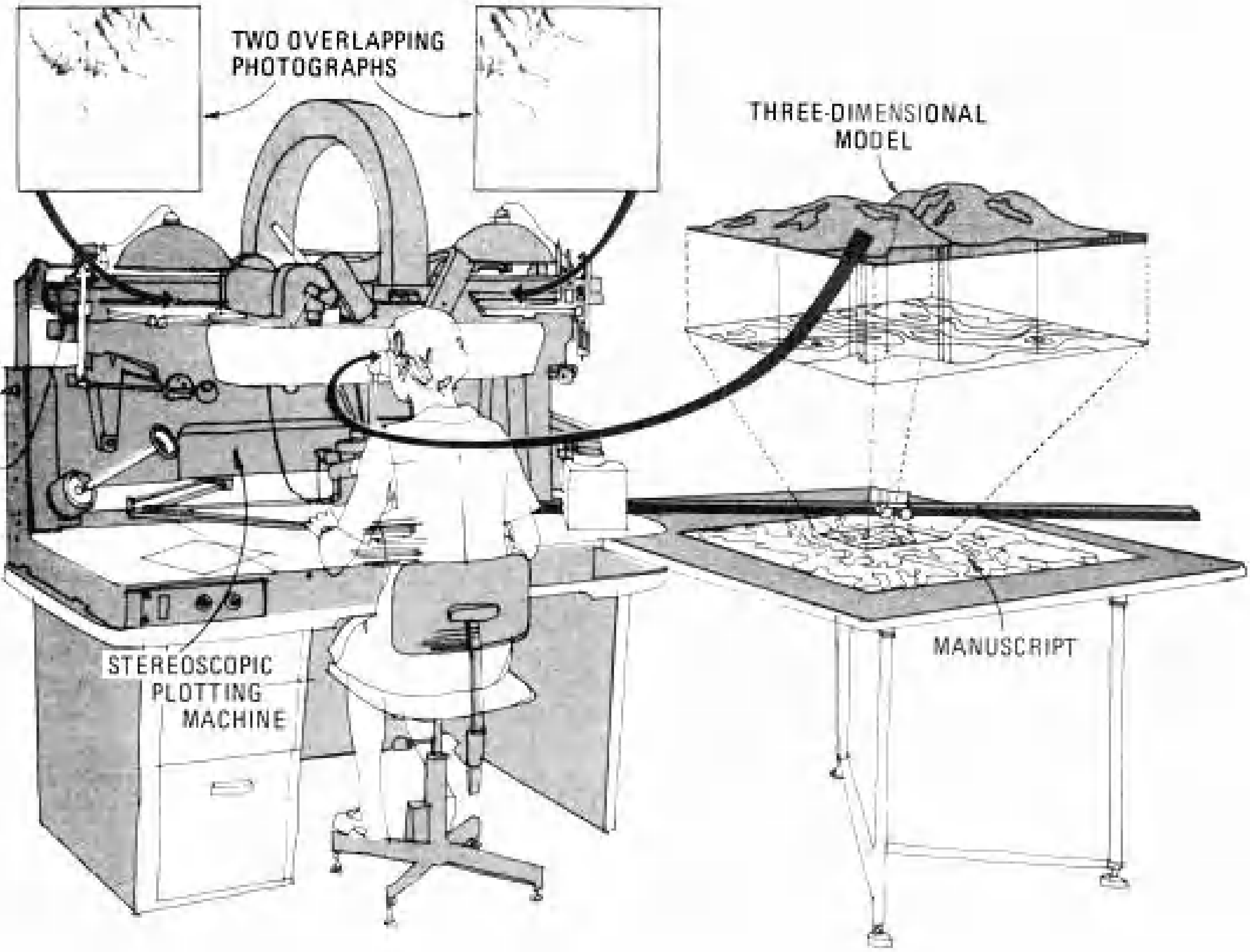


Figure 5.2 Lateral and forward overlap of aerial photographs. (After Canada, Department of Energy, Mines and Resources, 1976)



Lateral overlap. Forward overlap.

Figure 5.3 Photogrammetry: the mapmaker viewing two overlapping photographs stereoscopically to produce a three-dimensional model. (After Canada, Department of Energy, Mines and Resources, 1976)



Secondary control points, such as buildings, river junctions, headlands, etc., are chosen to fix the position of the remaining photographs. These control points, identified by surveyors in the field, may include the following two types:

i) tie points, used to mathematically tie together the adjacent photographs;

ii) pass points, which are only used in aerotriangulation to assist in the mathematical adjustment of measurements for the whole area.

Measurement of latitude, longitude, and height above sea level for the secondary control points is established by aerotriangulation. In this system the grid of the aerial photograph is used to provide grid coordinates for the secondary control points that occur in the photograph. With the aid of a computer and coordinate geometry, the individual grids of each aerial photograph are combined into one common grid for the whole area to be mapped. The latitude, longitude and elevation for the secondary control points are then calculated, based on their position relative to each other and the precisely surveyed primary control points.

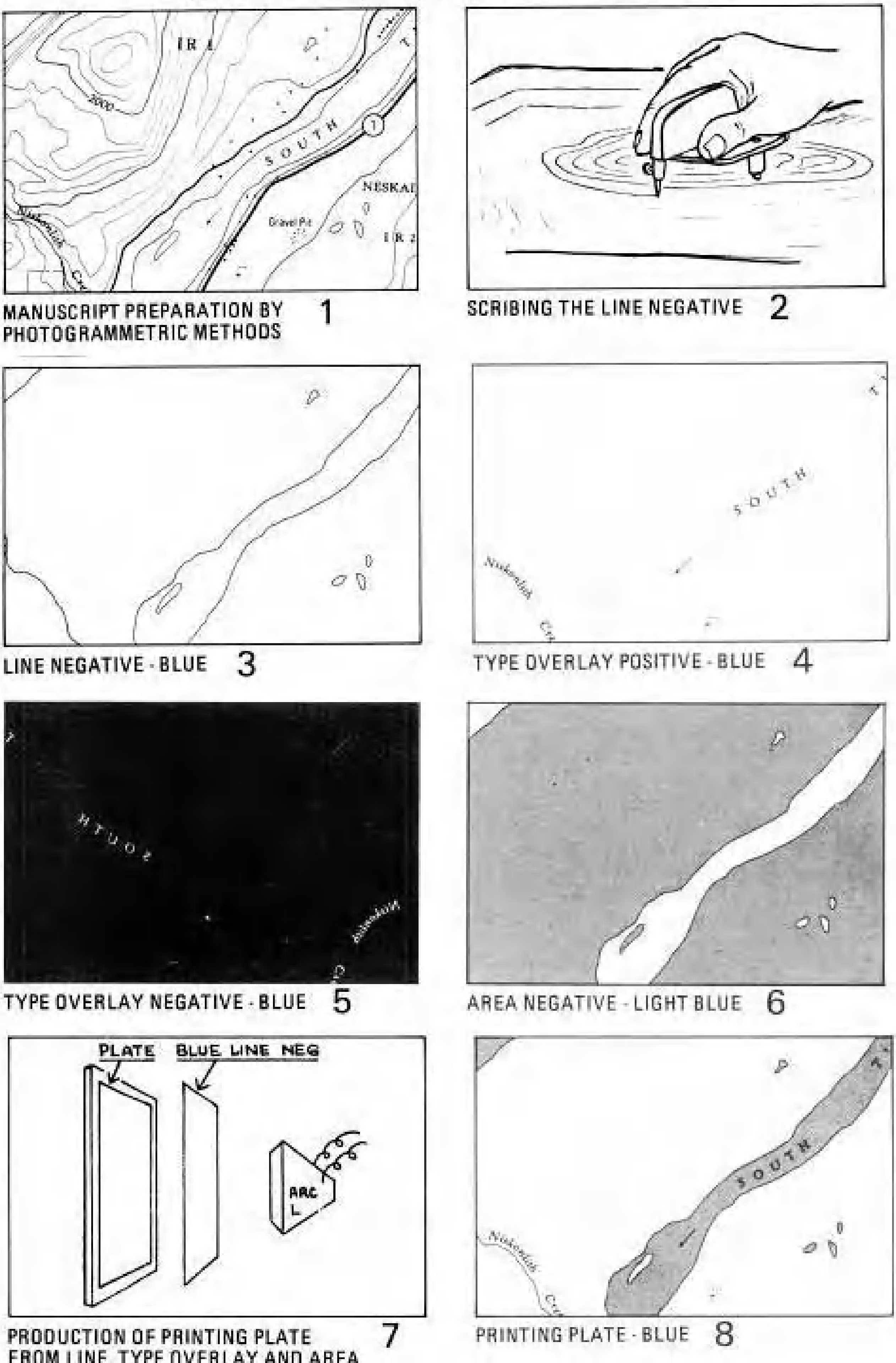
5.1.4.3 Plotting the map (Photogrammetry): Photogrammetry is a process by which information is transferred from the aerial photographs to the map manuscript. The process consists of a number of phases:

i) The photogrammetric compiler first produces a three-dimensional visual model by viewing two overlapping aerial photographs of the same area taken from different camera stations in a stereoscopic plotting machine (Figure 5.3). The model is positioned and expanded or contracted to fit the required scale according to the secondary control points, i.e. the two aerial photographs in the stereoscope are levelled to correct horizontal or vertical displacement due to the tilt or heading of the photographic aircraft;

ii) A manuscript is produced by tracing the required features on a sheet of translucent plastic. The photogrammetric equipment has a small floating mark in its viewer that the compiler moves throughout the model to trace any feature. A drawing stylus on a connecting drafting table follows the movement of the floating mark and sketches fine lines across the manuscript. For contour lines, the compiler sets the vertical height reading of the equipment at a selected elevation. The mark is then moved through the visual three-dimensional model so that it always appears to be in contact with the ground at that level, thus plotting a path of equal elevation, a contour line. The initial manuscript information shows cultural features, water, vegetation and contours. The information on the manuscript is verified by ground checking. Additional names, appropriate symbols, etc., are now added. The manuscript is then edited and inspected before the cartographic process begins.

5.1.4.4 The cartographic process: This process transforms the initial manuscript information into separate negatives from which printing plates for each printing colour are made for map reproduction (Figure 5.4). Six

Figure 5.4 Phases of topographic map production. (After Canada, Department of Energy, Mines and Resources, 1976)



MANUSCRIPT PREPARATION BY PHOTOGRAMMETRIC METHODS 1

SCRIBING THE LINE NEGATIVE 2

LINE NEGATIVE - BLUE 3

TYPE OVERLAY POSITIVE - BLUE 4

TYPE OVERLAY NEGATIVE - BLUE 5

AREA NEGATIVE - LIGHT BLUE 6

PRODUCTION OF PRINTING PLATE FROM LINE, TYPE OVERLAY AND AREA 7

PRINTING PLATE - BLUE 8

basic colours are normally used in topographic map making:

i) black, for cultural features;
ii) blue, for water systems and grid;
iii) brown, for contours;
iv) red/orange, for road systems;
v) green, for vegetation.

Three types of negatives are produced to make the printing plates for each colour:

i) Line negatives (refer to Section 11): The manuscript base sheet is photographed or contacted to negative form. Using the negative, a guide image is reproduced on scribing film by a photo-chemical method. Scribing film is clear plastic with a coloured coating which is scribed or engraved (Figure 5.5) along the guide lines produced by the negatives on the coating. The end result is a line negative;

ii) Type overlay negatives (refer to Section 11): These show geographic names, labels, elevations, figures and bordering information which may appear on the final map in more than one colour (e.g., black for land features, blue for water features and brown for elevation numbers on contour lines). Separate type negatives are, therefore, produced for each colour. Each type item is given a type style and size. The type is positioned on a plastic overlay sheet in the place it will appear on the map, using a line positive of the base as an outline guide. The type overlay is then converted to a type negative by the contact process. For relatively simple jobs a single type overlay and single type negative are usually sufficient. This saves considerably on reproduction costs and also makes checking easier. Colour separation of the names is accomplished with masks;

iii) Area negatives (refer to Section 11): Normally called "peel coats", these are also termed "open window" or "artificial" negatives. They are used to produce areas of solid or tinted colour, e.g., blue area for water. The linework image on a sheet of scribing film or line negative is etched photomechanically onto sensitized peelable material. The coating is then peeled from the area to be coloured or shaded, so that it becomes a clear plastic window.

Composite negatives for each of the printing colours are then produced. Alignment of the individual negative components is assured by punching registration holes in each negative which are fitted to metal pins or bars. The cartographer then prepares a colour proof (refer to Section 12.1.11) of the map, from all of the composite negatives, for editing purposes.

5.1.4.5 <u>The printing plates:</u> A colour plate for each of the printing colours is produced by exposing the image onto a light sensitive printing plate. This is achieved by shining an arc light through the composite negative for that particular colour in contact with the plate. The

Figure 5.5 Scribing. (After International Cartographic Association, 1984)

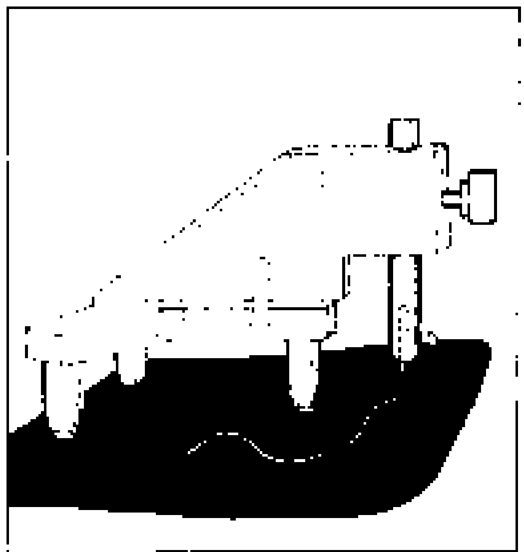
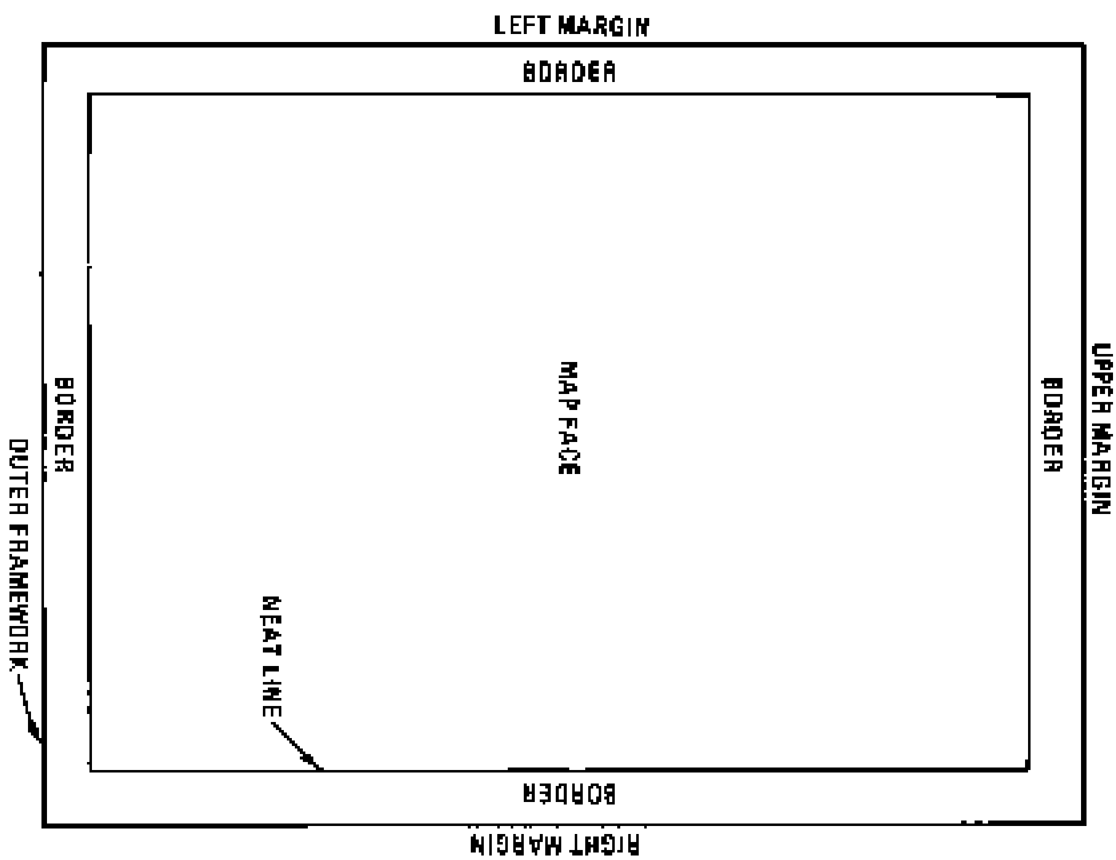


Figure 5.6 Map borders and margins. (After A.J. Kers and P.J. Oxtoby, 1977)



lacquered areas on the printing plate which show the map image retain ink and repel water; the non-image areas retain water and repel ink. The plate is pliable so that it can be shaped around a cylinder. Single paper sheets are then passed through the press and printed with the basic colour images and their tint variations (refer to Section 12).

5.1.4.6 Automated cartography: All information that appears on a map can be digitized, i.e. converted into the computer's numerical code form. It can then be filed as computer data on magnetic tape or on hard or floppy disk for selection by the map maker. Digitized data can be fed into an automatic plotting machine to be reproduced as a map (refer to Section 14).

Information can be digitized directly from the photogrammetric plotter, thus avoiding the steps of preparing an initial map manuscript and manual digitization. After checking and editing, it can be automatically scribed on scribing film for the production of printing plates, or the information may be reproduced by a photo-head plotter on photographic film.

5.1.4.7 The finished product: In addition to showing the features of part of the earth's surface within a given framework (graticule or grid), topographic maps contain marginal and border information. The type and position of this information has been standardized as follows (Figure 5.6):

i) Margin: the area of paper surrounding the outer framework of the map;

ii) Neat line: the line (graticule or grid) enclosing the mapped area;

iii) Border: the area between the neat line and the outer framework of the map;

iv) Map face: mapped area enclosed by the neat line.

The following is a list of items regarded as essential information for inclusion in the topographic map margin (Figure 5.7) and may be useful as a checklist when designing maps in general:

i) sheet name or title;
ii) series number;
iii) sheet number;
iv) edition designation;
v) identification panel (contains 2nd, 3rd and 4th items above);
vi) date of aerial photography used for map compilation;
vii) date of aerial photography used for map update;
viii) area of coverage of the series (series title);
ix) representative fraction scale;
x) graphic bar scale;
xi) unit of elevation used, e.g., metres or feet;
xii) contour interval and unit, e.g., 2 metre contour interval;
xiii) conventional signs (legend);
xiv) elevation tint box;
xv) index to adjoining sheets;

xvi) notes concerning grid(s);
xvii) instructions on the use of the grid reference system;
xviii) declination diagram (information on the relationship between true, grid and magnetic north);
xix) projection and datums;
xx) names and boundaries disclaimer note, e.g., "This map is not an authority on international boundaries";
xxi) publication note, e.g., name of publishing agency;
xxii) history note, e.g., type of production and list of sources on which map is based;
xxiii) copyright note;
xxiv) printing note and printer's imprint, i.e. distinct from publisher's name.

The following is a list of items regarded as essential for inclusion as map border information (Figure 5.8):

i) geographical coordinates of the sheet corners;
ii) values of graticule lines or ticks;
iii) grid values;
iv) destination of road or railways;
v) that portion of a name which overlaps into the next sheet.

Optional marginal and border information may include the following:

i) compilation diagrams;
ii) glossary of terms;
iii) boundaries diagram;
iv) conversion diagrams, e.g., metres to feet;
v) reliability diagram;
vi) representation of relief diagram;
vii) other items which may be required in specific instances.

5.2 The Marine Chart

5.2.1 Function

A marine chart is essential for safe navigation and the practice of surveying and charting water for the purpose of navigation is known as hydrography. Marine charts are important to a number of economic sectors including:

i) commercial shipping;
ii) fishing fleets;
iii) aquaculture operations;
iv) offshore and coastal oil and gas industry;
v) coastal mines and industrial plants;
vi) recreational sailing.

Figure 5.7 Marginal information for a topographic map. (After J.S. Keates, 1973)

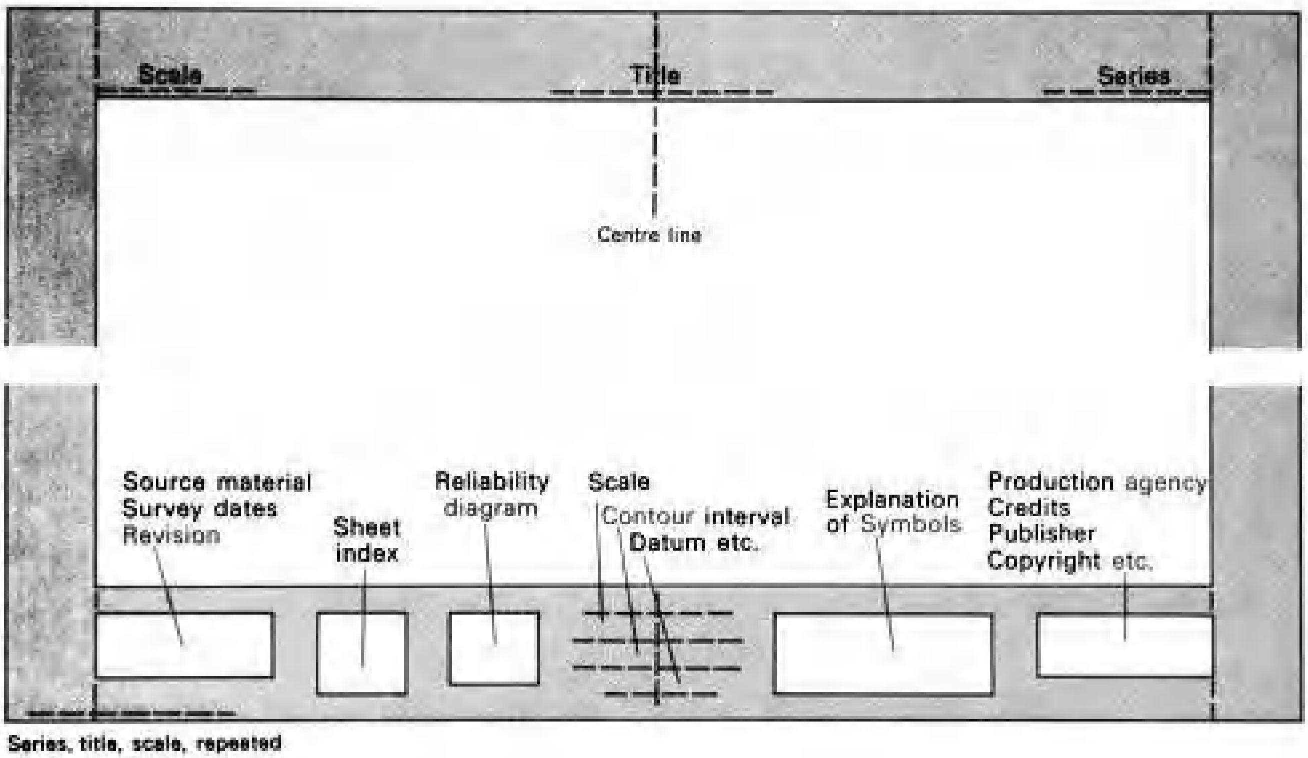
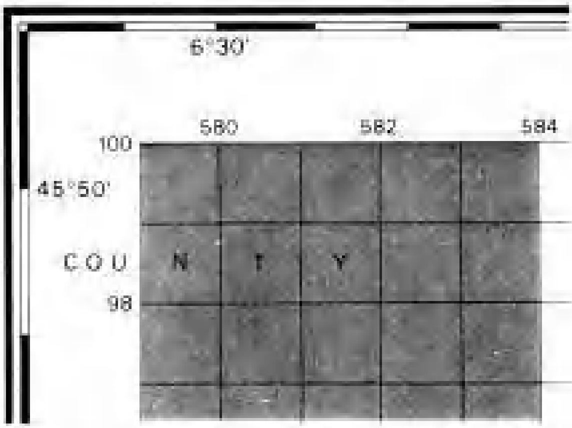


Figure 5.8 Border information for a topographic map. (After J.S. Keates, 1973)



5.2.2 The hydrographic survey

The fundamental operation in hydrographic surveying is sounding, that is, measuring water depths. These are indicated on a chart by the following conventions:

i) depth soundings represented by a point symbol with a number beside it indicating the depth;

ii) contour lines, referred to as bathymetric lines in marine charts which join soundings of equal depth;

iii) colour coding, which indicates an increase or decrease in depth by the use of varying tints of a colour.

For centuries soundings were obtained by a lead weight tied to a line lowered over the side of a ship. This method, while accurate, is time-consuming and does not give a continuous profile of the ocean. For detailed large-scale surveys of confined areas, and for shoal examination, however, the leadline method is still used today.

Most modern surveys are carried out with an instrument known as Sonar (So̲und Na̲vigation and R̲anging), also called an acoustic depth finder, echo sounder or fathometer. Depths are determined by measuring the time required for a sound wave to travel from a transducer mounted in the hull of a survey ship to the ocean bottom and back to the ship. The ocean bottom reflects sound as a mountain face reflects sound in air, producing an echo. In fact echos are more easily obtained from the sea bottom. Because of lower absorption, sound in water will travel many times as far as it will in air. The properties of sea water also ensure reasonably constant velocities of sound - about 1440 metres per second.

Sonar distances are obtained by measuring a signal's round trip travel time, dividing by two and multiplying by the velocity of sound in sea water. A measurement that previously took hours using the leadline method can now be obtained in seconds using sonar. Modern echo sounders continuously and automatically record signals, creating a continuous profile of the bottom relief along the ship's track.

5.2.3 Positioning

Soundings must be located precisely on a chart. In former days when surveys were normally conducted within sight of shore, the geographic location of these soundings was measured with a sextant, an instrument for measuring angles. A typical sextant reading is obtained by simultaneously measuring two angles between three clearly marked "stations" on shore, the positions of which are known from previous measurements. From this, it is possible to plot the exact position of the vessel at the time the angles were measured (Figure 5.9 and Table 5.1). Today the sextant has been replaced with a number of electronic systems. With the exception of satellite systems there is an inevitable trade-off in positioning systems between range and accuracy. The systems developed for shorter range are normally more accurate than those used for long ranges.

Figure 5.9 Shipboard positioning. (After Canada, Department of Fisheries and Oceans, 1979)

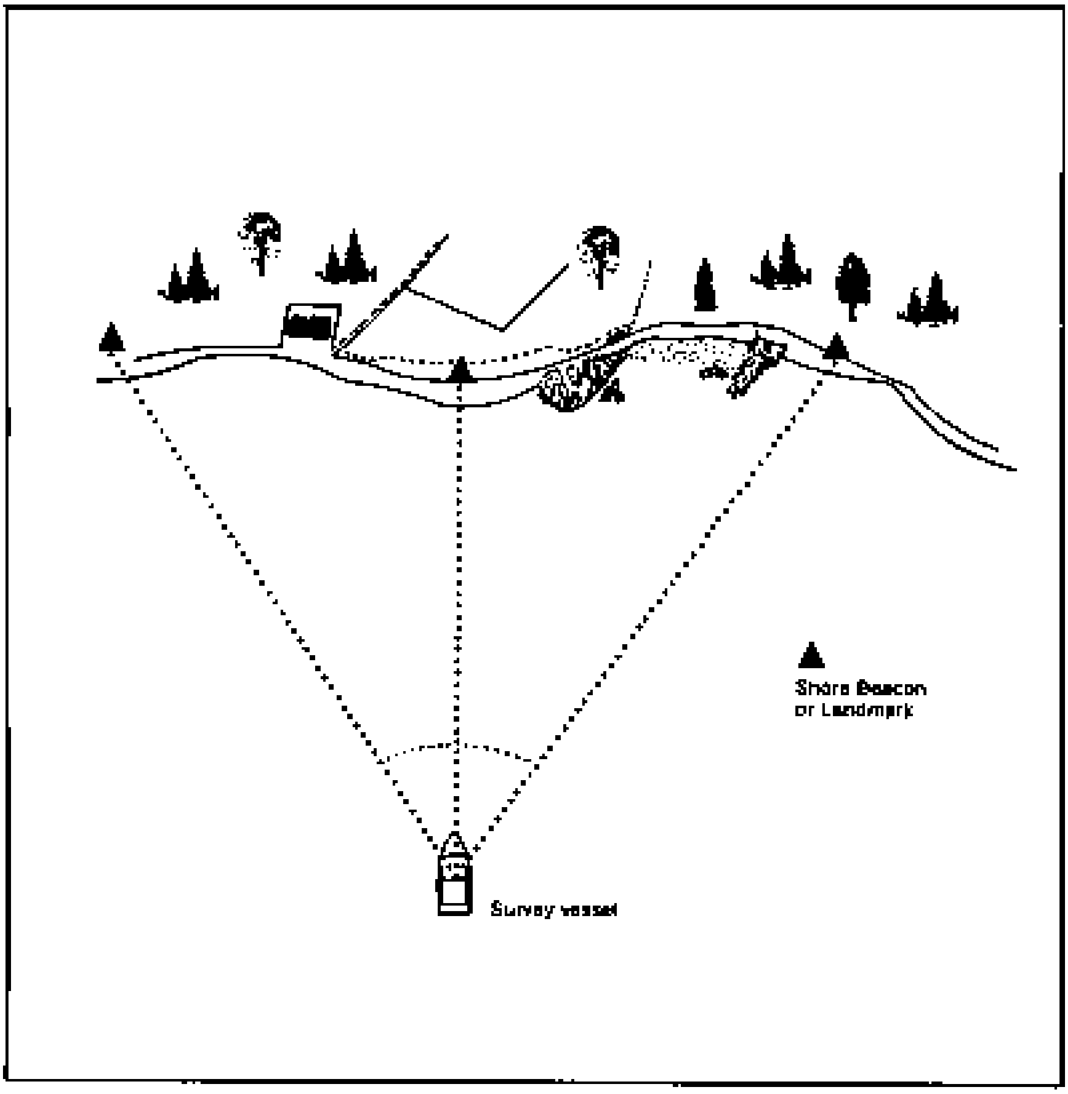


TABLE 5.1

FEATURES REQUIRED FOR POSITION FIXING
(After M. Schmidt, 1979)

POSITION FIXING	Charts used for:							
	overseas navigation			coastal navigation				
	ocean	marginal sea	inland sea	offshore	inshore	approach	entrances, channels	port
Graticule	x	x	x	x	x	x	x	
Magnetic variation	x	x	x	x	x	x	x	
Coastal configuration[2]					x	x	x	x
Land topography[2]					x			
Detailed land topography						x	x	
Landmarks visible from afar		x	x	x				
All landmarks					x	x	x	
Soundings[1]	x	x	x	x				
All depth data					x	x	x	
Nature of bottom and depth data for echo soundings		x	x	x				
Nature of bottom					x	x	x	
Selected marks on land or at sea		x	x					
All marks on land or at sea				x	x	x	x	x
Leading lines				x	x	x	x	x
Radar conspicuous objects				x	x	x	x	
Selected maritime radio, radio navigation and radio determination stations		x	x	x	x	x	x	
Radiobeacons					x	x	x	
Limits of radar stations						x	x	x
Hyperbolic navigation grids	x	x	x	x	x	x	x	

1. Soundings and depth contours must be selected so that their depiction permits the mariner to draw conclusions regarding the density of the surveys. Even very deep soundings must be shown on charts since areas without depth data will suggest incomplete surveys. The depth data must be shown for the whole area and not be limited to certain channels.

2. Coastal configuration and land topography are essential elements for position fixing and cannot be omitted, notwithstanding modern navigational methods. Topographic features extending inland from the coastal area may become necessary in the case of particularly conspicuous landmarks visible over a great distance, the depiction of spot heights alone being insufficient.

Some modern positioning systems include the following:

i) Short range systems (in sight of land) - microwave frequencies, e.g., Miniranger or Tellurometer MRD - accuracies of 10 metres, restricted to line of sight;

ii) Medium range systems - medium frequencies, e.g., Hi-Fix 6 or Argo - accuracies of 20-50 metres, 100-200 kilometres from shore;

iii) Long range systems - pulsed, low frequency:

a) LORAN-C is a pulsed, low-frequency, long range hyperbolic radio navigation system. It combines features of both LORAN-A and DECCA, two systems of navigation accepted throughout the world.

Hyperbolic navigation systems operate on the principle that the difference in time of arrival of signals from two stations, observed at a point in the coverage area, is a measure of the differences in distance from the point of observation to each of the stations.

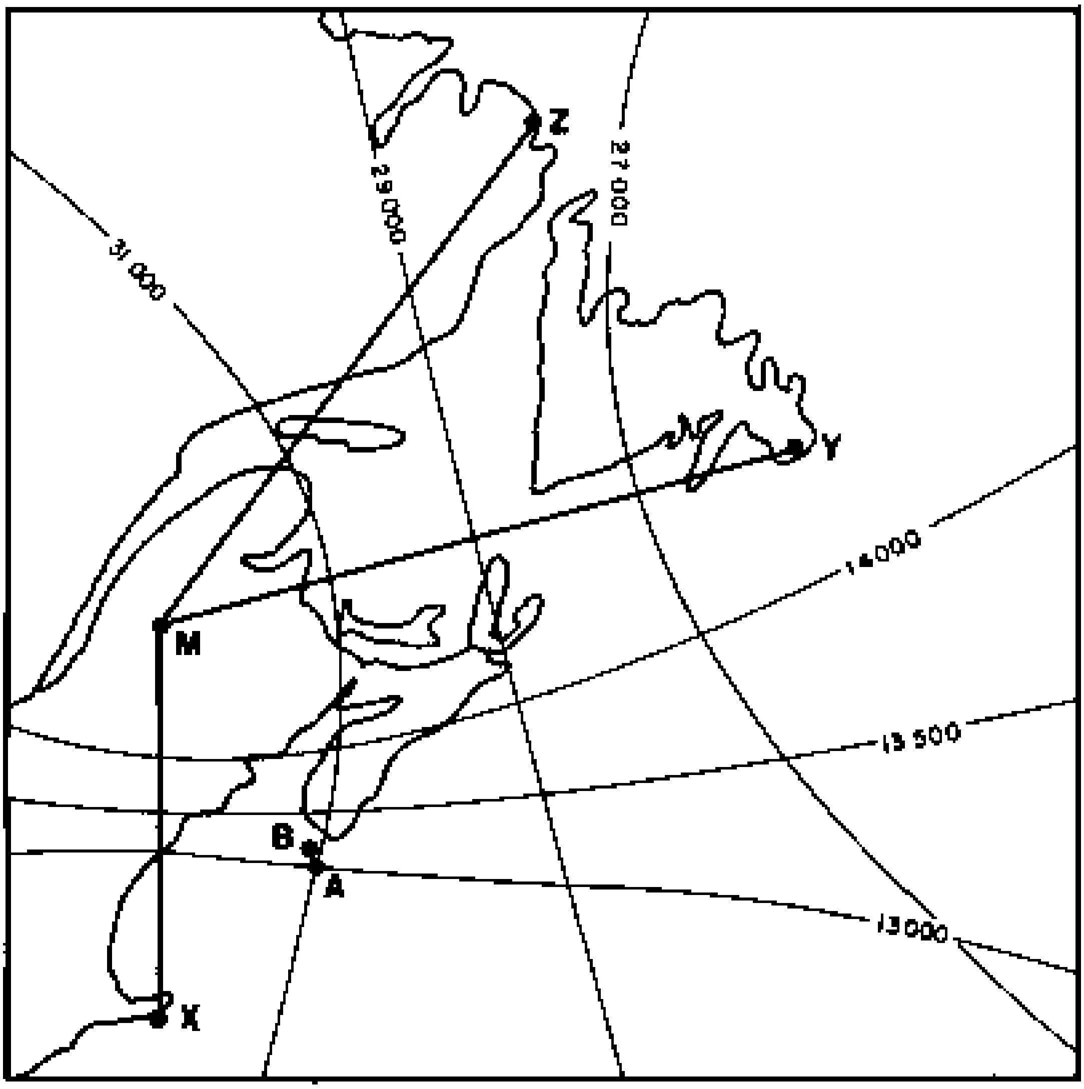
LORAN-C stations are located on land and are grouped to form a "chain"; one station is labelled the Master (designated M) and the others are called secondary stations (designated W, X, Y, or Z). Signals transmitted from the secondaries are synchronized with the master signal.

As an example, in Figure 5.10, the master station (M) and the secondary station (X) transmit synchronized pulses at precise time intervals. The on-board LORAN-C receiver measures the slight difference in time that it takes for these pulsed signals to reach the ship from this pair of transmitters. The time difference (TD) is measured in microseconds, or millionths of a second, and is then displayed as one readout on the receiver. When at position "A", the time difference displayed is 13,000.0 microseconds. This time difference can be plotted on a LORAN-C latticed chart on a line-of-position (LOP). With just this one number, the vessel could be located somewhere along the "13,000 line-of-position".

Next a TD measurement is taken from the master station (M) and another secondary (in this case Y). The LORAN-C receiver then displays the TD between M and Y. Continuing with the same example, the TD displayed is 31,000.0 microseconds. Again the TD is plotted as a LOP and the vessel's position is located somewhere along the 31,000 LOP. Where the two LOP's intersect is the vessels exact location (position "A" in Figure 5.10).

b) The OMEGA system, developed by the U.S. Navy, provides world wide all-weather positioning of ships, aircraft and submarines (submerged) with a nominal accuracy of one mile in daytime and two miles at night. It is now widely used by non-naval vessels. OMEGA is a global system of eight land-

Figure 5.10 A typical LORAN-C chain off the east coast of Canada. (After Canada, Department of Transport, 1981)



based transmitting stations, so located that a user will receive signals from at least three stations. Any two signals can be used as a pair to establish a line-of-position (LOP).

As with LORAN-C, OMEGA is a very low frequency hyperbolic radio navigation system, but it uses phase difference measurements rather than a time-difference principle.

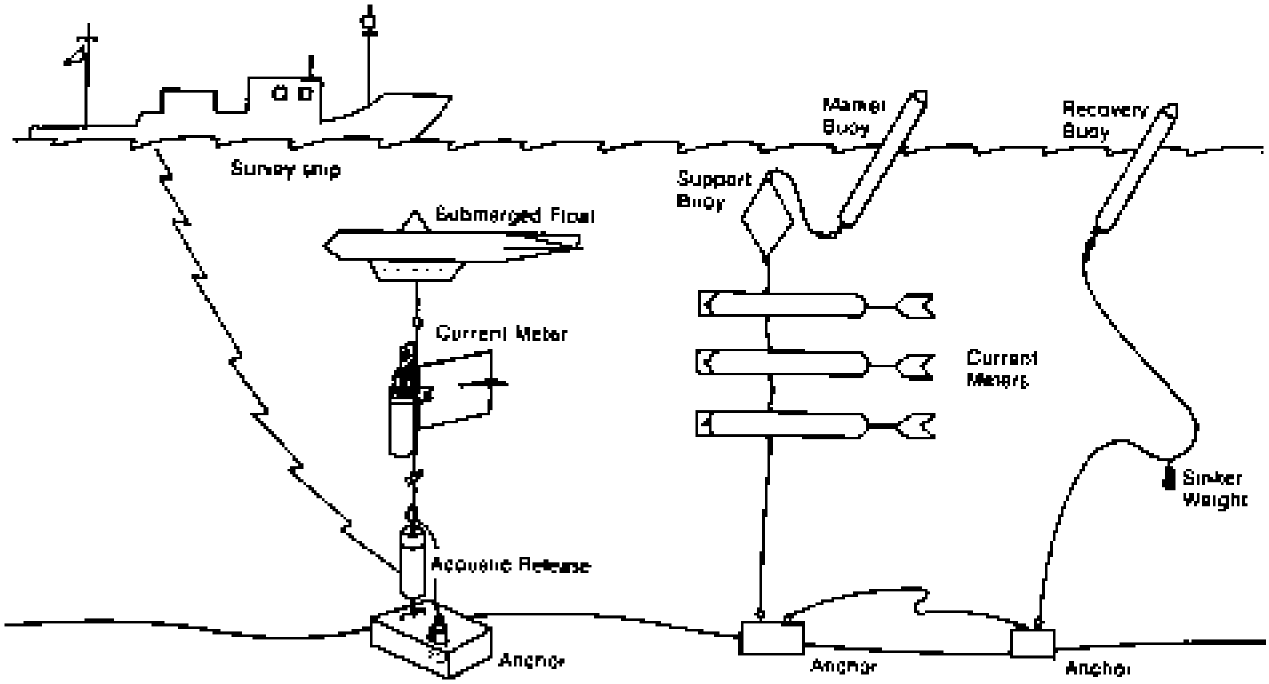
iv) Satellite systems (overlapping both medium and long range systems):

The Navy Navigation Satellite System (NAVSAT) was also designed for the U.S. Navy and was released for civilian use in 1967. It is suitable for any size of vessel, when it is economically justified, but the shipboard receivers and related equipment are considerably more expensive than other systems such as LORAN and OMEGA. The NAVSAT System consists of one or more satellites, each in a circular polar orbit at an altitude of about 1100 km. Only one satellite is used at any given time to determine position. The apparent change in frequency of the radio waves received when the distance between the source of radiation (Satellite) and the receiving station (ship, aircraft, submarine, etc.) is increasing or decreasing is termed the Doppler Shift. By means of this phenomenon, it is possible to calculate the location of the receiver on earth to within 10 metres if the satellite orbits are known, together with the speed and direction of the surface vessel.

5.2.3.1 <u>Tides:</u> Accurately positioned soundings must be specified on a chart as the depths below a reference level (chart datum, refer to Section 4). Selection of a suitable chart datum depends on a number of factors, including a detailed knowledge of past fluctuations in water levels, hence the installation of permanent and temporary water level gauges. Traditionally, float-operated water level gauges have been installed in harbours etc. Submersible, self-contained pressure gauges are located offshore. In addition to charting and navigational applications, water level information is used for coastal engineering studies, resource planning, etc.

5.2.3.2 <u>Currents:</u> A navigator requires information on the horizontal movement of water (currents) in addition to tidal information. The usual method of obtaining the data is to suspend several current meters, which automatically record speed and direction of currents, at specific depths on a single mooring line. The line is anchored to the sea bed and supported by a submersible buoy. Two of the methods used are illustrated in Figure 5.11. The current meter (left side of figure) is equipped with an acoustic release device which can be activated by a signal from the survey ship, allowing the float to rise to the surface. On the right side of the figure is an array of current meters set at different depths and utilizing surface buoys to assist in the recovery of the meters. Data is recorded automatically on magnetic tape and the meters can be left submerged for up to 12 months.

Figure 5.11 Techniques for measuring current speed and direction. (After Canada, Department of Fisheries and Oceans, 1979)



5.2.4 Production

Other than the data and its mode of collection, the production phases of a hydrographic chart are identical to those of the topographical map, namely:

i) collection of soundings etc., by a survey vessel;

ii) collation of this information in the hydrographic operations centre of the survey vessel, where data is checked for accuracy;

iii) plotting the soundings on a field sheet of the area surveyed;

iv) transference of field sheet data to a compilation copy of the nautical chart. (In the compilation process the field sheets and other source data are photographically reduced to chart size. Once a mosaic of this source data has been prepared, cartographers select the data to be shown on the chart.);

v) digitizing of the graphic data, i.e. conversion into computer compatible form for automatic drawing by a computer controlled plotter. (The plotter produces high quality negatives for each colour shown on the chart. The negatives are passed to the printing units for platemaking and printing.);

vi) amendment of chart catalogues to indicate coverage of new areas or update of previously mapped areas. (In the latter case "Notices to Mariners" are distributed.)

The size of the area to be surveyed and the scale of the chart to be produced are carefully coordinated. The largest scale surveys are generally those for harbour charts which show more detail than general navigation charts. More general surveys and smaller scales are used for extensive offshore areas in which hazards to navigation are few.

5.3 Marine Charts and Topographic Maps: A Comparison

The nautical chart and the topographic map constitute the primary forms of mapping which may be used as base maps or from which base maps can be derived. Base maps constitute the skeletal structure on which thematic information is overlaid to produce thematic maps.

From the previous section it will be appreciated that nautical charts and topographic maps differ in a number of important respects, some of which have relevance to thematic base map preparation:

i) Projection: Nautical charts generally use Mercator, whereas, topographic maps use Transverse Mercator (refer to Section 3);

ii) Symbology: Different in most respects (Figure 5.12 a-d);

iii) Coordinate system: Nautical charts have parallels of latitude and meridians of longitude, and sometimes a Loran and/or Decca lattice. Topographical maps have parallels of latitude, meridians

Figure 5.12 a Nautical chart symbols. (After Canada, Department of Fisheries and Oceans, 1981)

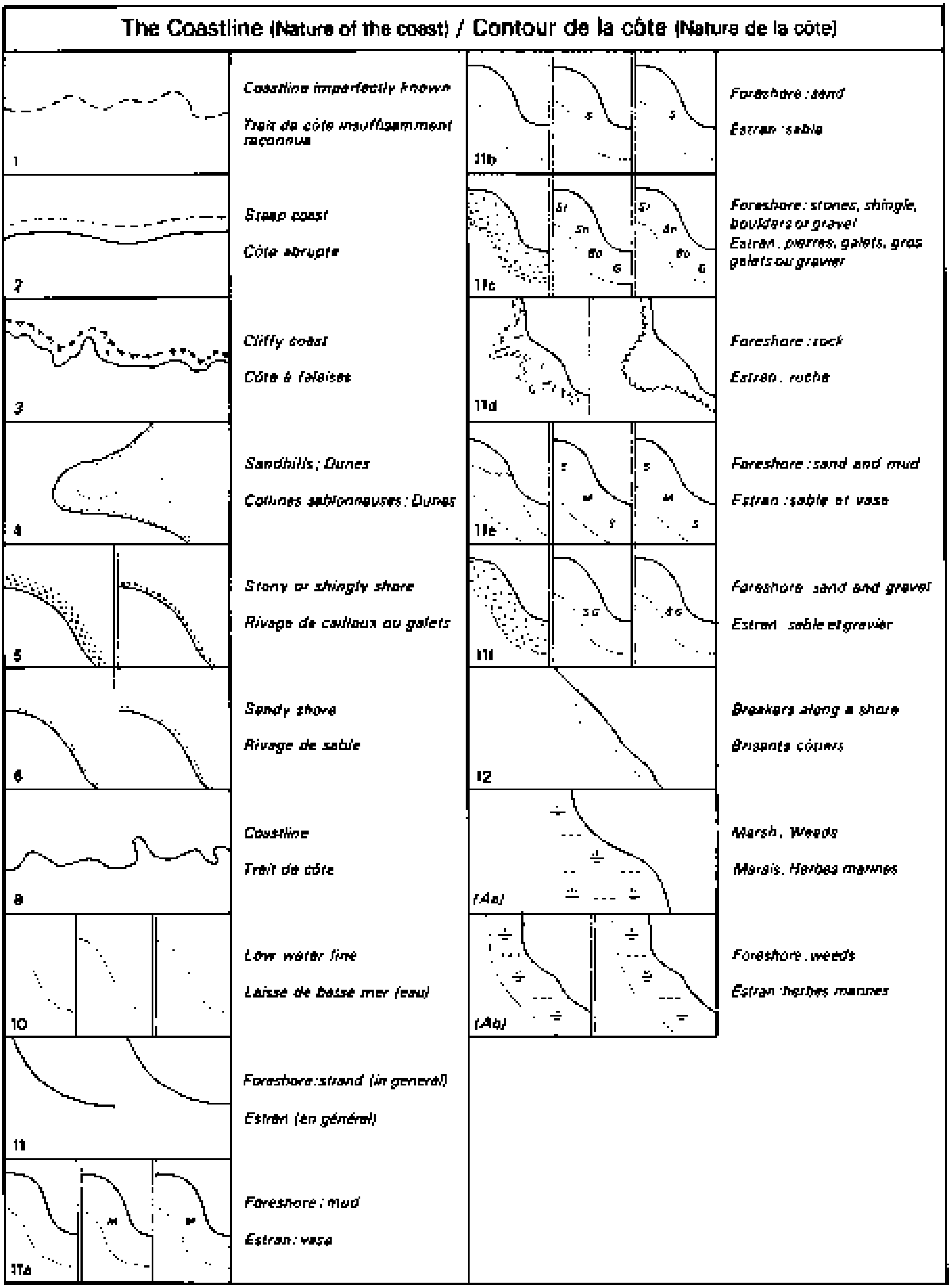


Figure 5.12 b   Nautical chart symbols. (After Canada, Department of Fisheries and Oceans, 1981)

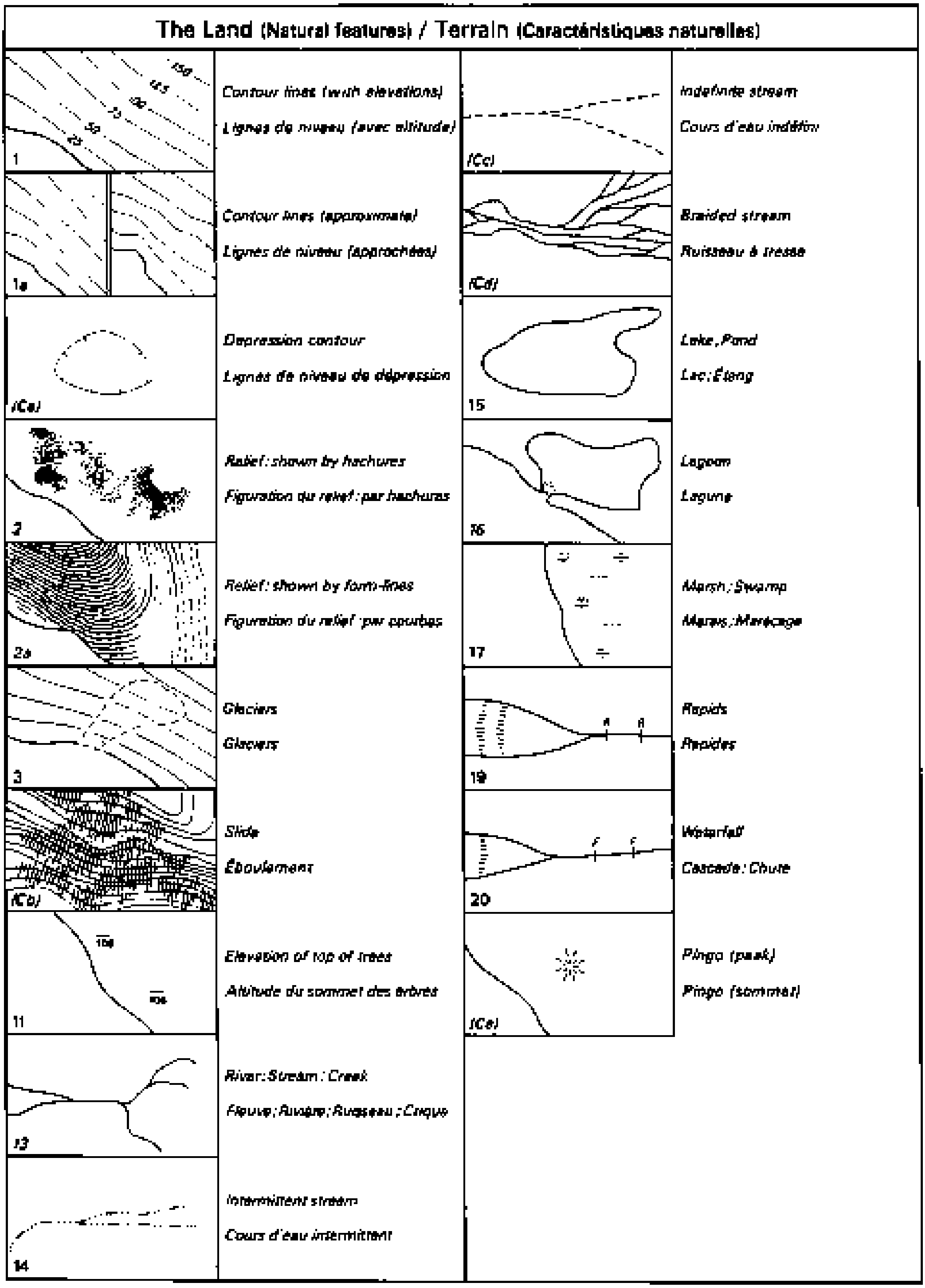


Figure 5.12 c   Nautical chart symbols. (After Canada, Department of Fisheries and Oceans, 1981)

Dangers/Dangers

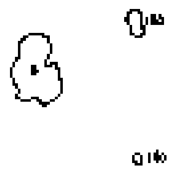
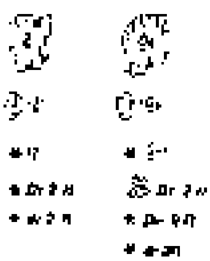
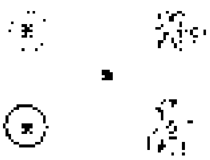
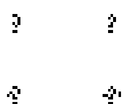
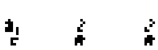
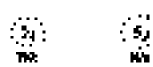
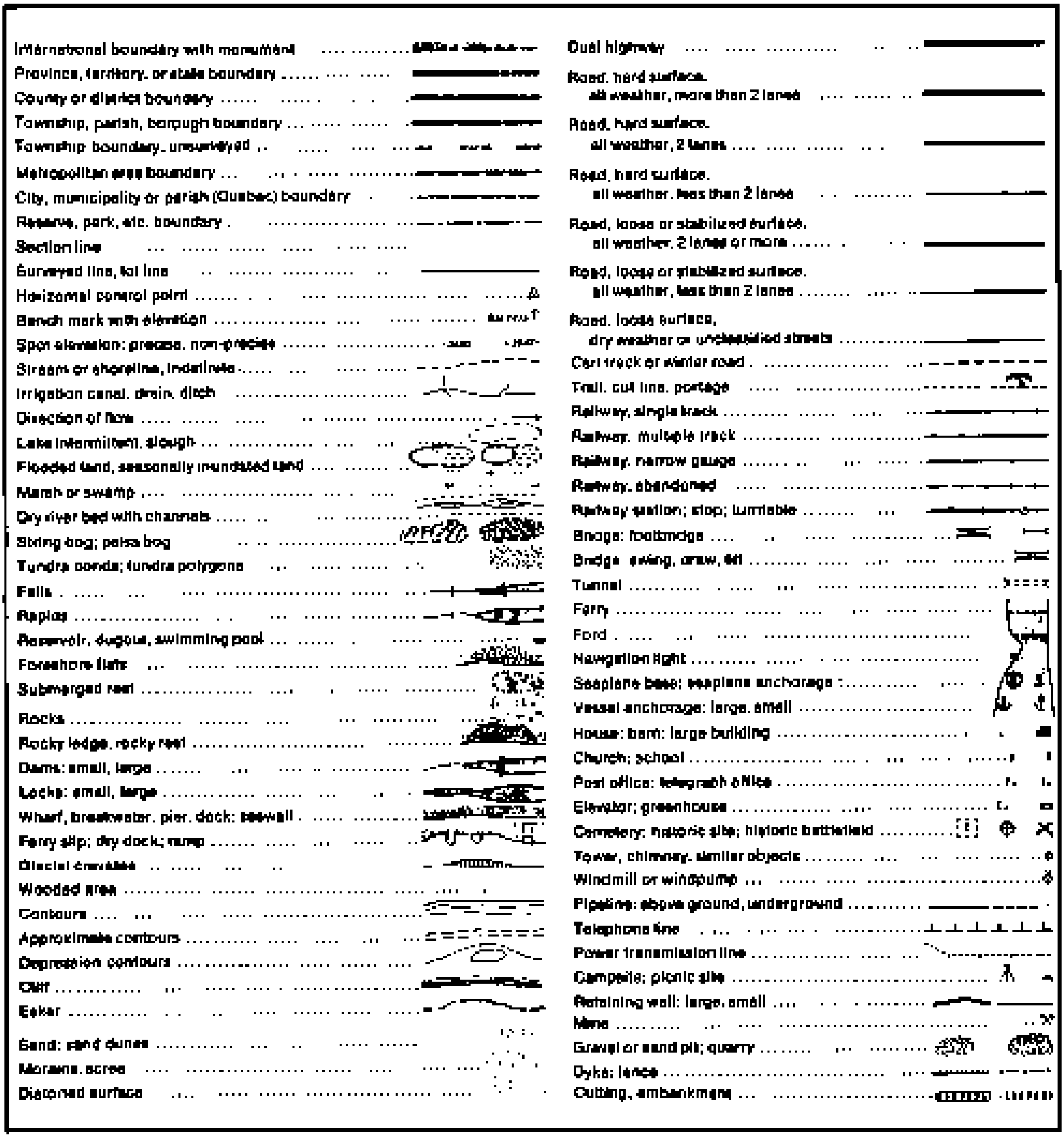
No.	Symbol	Description
1		*Rock which does not cover with height (see general remarks)* *Roche ne couvrant jamais avec hauteur (voir remarques générales)*
2		*Rock which covers and uncovers (dries) with height (see general remarks)* *Roche couvrant et découvrant (assèche) avec hauteur (voir remarques générales)*
3		*Rock awash at the level of chart datum* *Roche à fleur d'eau au niveau de réduction des sondes*
(Oa)		*Awash* *À fleur d'eau*
4		*Underwater rock 6 ft (2 m) or less or dangerous to surface navigation* *Roche submergée 6 pi (2 m) ou moins ou dangereuse pour la navigation de surface*
5		*Shoal sounding on isolated rock* *Brassiage d'une roche isolée*
(Ob)		*Underwater rock with depth* *Roche submergée avec profondeur*
6a		*Underwater danger with depth cleared by wire drag* *Danger submergé avec profondeur vérifiée à la drague hydrographique*
(Oc)		*Known depth over an artificial feature* *Profondeur connue couvrant une construction artificielle*
11		*Stranded wreck showing any portion of hull or superstructure* *Épave échouée montrant une portion de la coque ou de la superstructure*
12		*Wreck of which the masts only are visible* *Épave dont les mâts seuls sont visibles*
13		*Old symbols for wrecks* *Anciens signes conventionnels pour les épaves*
14		*Sunken wreck, dangerous to surface navigation* *Épave submergée dangereuse pour la navigation de surface*
15		*Wreck over which depth is known* *Épave de profondeur connue*
15a		*Wreck with depth cleared by wire drag* *Épave avec profondeur vérifiée à la drague hydrographique*

Figure 5.12 d Topographic map symbols. (After C.L. Blair and R.I. Simpson, 1979)



of longitude, and grid squares (refer to Section 4);

iv) Distance: In nautical charts, which generally use Mercator projections, one minute of latitude is always equivalent to one nautical mile (1852 metres or 6080 feet). In topographical maps, various other projections are used so there is no constant equivalence (refer to Section 3);

v) Bearings: Nautical charts have two or three compass roses (Figure 5.13) in contrast to a declination diagram of the three norths on topographical maps (Figure 5.14). This illustrates the relatively greater importance of the compass in a marine environment;

vi) Terminology: Variation, the angular difference between true north and magnetic north on hydrographic charts, is termed declination on topographic maps;

vii) Coastlines: Coastlines are naturally of critical importance to marine mapping. Their compilation for small-scale maps is relatively simple because they usually require so much simplification that detail is of little consequence. When compiling medium and large-scale maps, however, the major difficulties facing the cartographers and hydrographers include the following:

a) Datums: Hydrographic charts use low water reference datums (refer to Section 4.4), whereas, topographic maps use Mean Sea Level. As a result, the shape of the coast will differ, particularly in areas of high tidal amplitude;

b) Colouring: There are a number of inconsistencies when utilizing both charts and maps, e.g., marshland, definitely not navigable, is likely to be coloured as land on a chart, whereas a low-lying swamp on a topographic map is likely to be coloured blue as water;

c) Geomorphological changes: In some areas of the world, the shape of the coast changes rapidly due to erosion or deposition (refer to Section 13.6.12). These changes may be monitored by the comparison of historical and current aerial photography and satellite imagery;

d) Scale: In some conventional projections the scale varies considerably over the map, particularly in the higher latitudes, giving certain areas of the coast undue emphasis.

Figure 5.13 Compass rose.

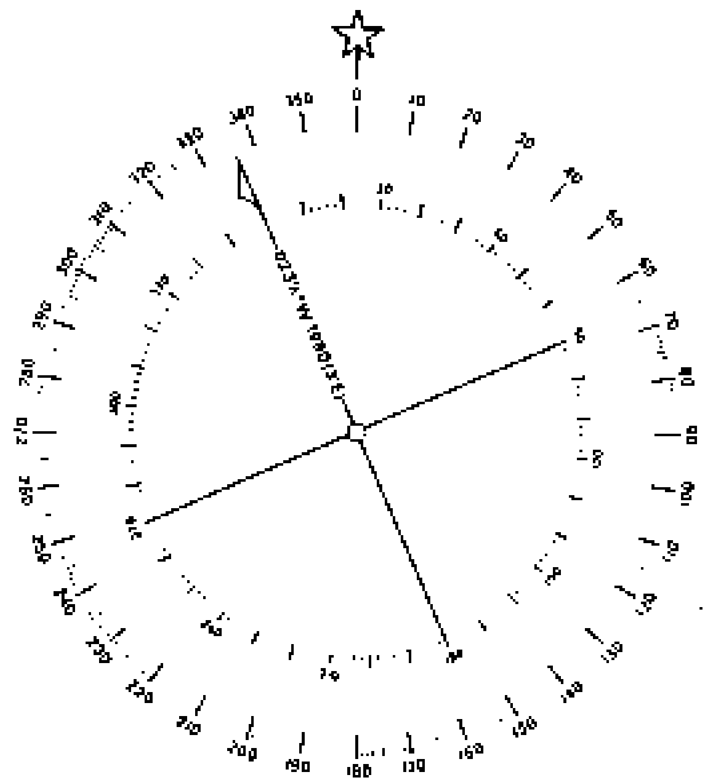
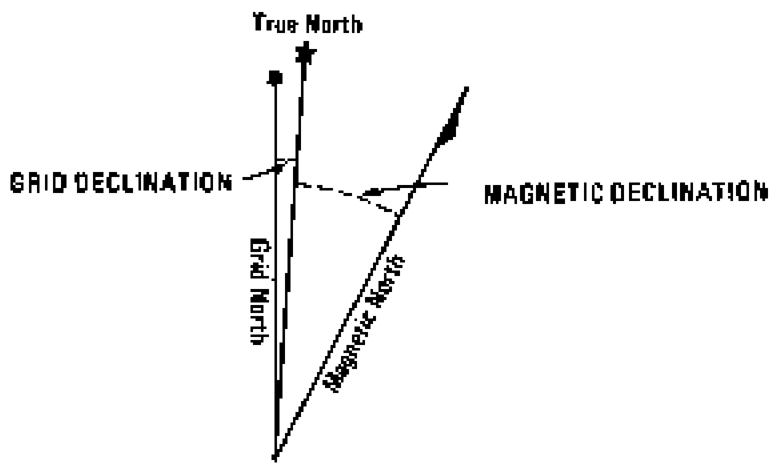


Figure 5.14 Declination diagram. (After C.L. Blair and R.I. Simpson, 1978)



SECTION 6

6. DESIGN FUNDAMENTALS

6.1 Principles of Cartographic Design

Basic map design decisions must be made in order to communicate information and data clearly, accurately and economically to users having a minimum of map reading skills. Factors which affect the design process include: the map user's requirements, his/her ability and knowledge of maps, the complexity of the information to be mapped, the available methods of map reproduction and costs. An understanding of the natural or cultural environment being mapped is also necessary to present a balanced reproduction of that region of the world.

6.1.1 Design approach

The cartographer should work in a similar manner to the artist, beginning with a general plan and progressing to finer details. Based on the objective of the map, a design concept should be developed which takes into consideration the desired information content and symbolization. This concept, which controls the choice of a scale, should be tested on various parts of the map and adjusted as necessary.

6.1.2 Visual levels

All map designs should aim at producing more than one visual level. Information selected to be the foreground of the product will be the most obvious to the user and must be chosen carefully to fulfill the major objectives of the map. Examples of major objectives include the cultural features of topographic maps, the depiction of economic ore zones on geology maps, and rocks, reefs and other hazards on navigational charts.

Supporting information should be treated as background material and given a lower visual level by decreased size, colour intensity, contrast and, therefore, decreased overall importance. This information is often ranked by relative importance to the map subject. Information which does not support the subject of the map is visual clutter and should be eliminated.

6.1.3 Contrast and balance

As a general rule, the initial design should employ the minimum degree of contrast needed to ensure that all symbols are readable and that dominant symbols appear as such. Excessive contrast used at the outset results in a rapid buildup of heavy lines, large type and strong colour.

6.1.4 Symbol categories

On all maps the subject matter should be organized and displayed in categories of similar items. Subdivisions of any one category should be shown by symbols representative of their relative importance within the category. The most obvious road on the map and in the legend, for example, should be the most important road in the category identifying the various classes of roads. Other roads will be treated in order of diminishing importance and with less visual impact. Related categories and their subdivisions should follow one another in the legend in order of importance.

6.1.5 Basic identification elements

A map user is first concerned with identifying the region covered by the map. The information used to do this will initially include the title, subtitles, key map and scale, followed by an examination of the map face.

The general arrangement of land and water, the depiction of relief and the general shapes of cultural and vegetated areas are the basic elements which provide a reader with a mental impression of the region depicted by the map. A clear visual distinction between land and water is the single most valuable item providing the map user with a fundamental orientation. The land and water areas should be clearly differentiated by the use of colour, tone or pattern over either surface.

Similarly, pale tones or subtle colours may be used to separate the prime map area from the surrounding region. Often the background of the crucial map area is left white so that small type and fine symbols can be seen more easily. The surrounding map area is given a tone or pale colour, often a neutral grey, to subdue it. This treatment creates an optical "window" allowing the reader to concentrate his attention on the prime map area. On less complex maps of a thematic nature, the reverse treatment is sometimes more effective. The critical area is given a light tone or colour to visually hold it together and to differentiate it from the surrounding information. This is particularly effective on informal maps which lack the common devices of ruled lines, borders, blocks or more formal placement of their various elements.

6.1.6 Clarity of linear symbols

On most maps, the greatest volume of information is shown by a variety of line symbols. In areas where different line symbols cross each other there is a high probability of confusing the map reader. A common cartographic task is, therefore, the clarification of line symbols. This is most often done by placing a tone, pattern, or colour within the area for which a particular line symbol acts as a boundary. Geological and other scientific maps commonly use this technique to clarify what would otherwise be a confusing complexity of lines. The area tones, patterns and colours should be pale and subtle. If heavy tints are used the lines or symbols which must show through the colours or tones in these areas will have to be drawn more heavily. The result will be poor legibility (refer to Section 13, case study 45).

6.1.7 Emphasis

On many maps the most interesting or most crucial features are often relatively small in comparison to the total map area. These items can be made more visible by the deliberate use of emphasis or visual impact.

Prominent colours or obvious patterns and darker tones should be restricted to small-size features. The colours red, orange and purple/violet are ideally suited to draw attention to small regions surrounded by light backgrounds. Black and dominant patterns are also used to give emphasis to small areas. Every tone, colour, pattern, and symbol selected must be evaluated for its effect in relation to the overall design.

6.1.8 Basic proportions

The surface area used for the map face (the area within the neat lines) should be visually dominant. A good rule of thumb is to keep the map area to about 2/3 of the total area, with the remaining 1/3 for notes, surround, etc.

The oldest known and most extensively used "pleasing proportion" is the ancient Greek standard called the "Golden Section" which is a ratio of approximately 5 units to 3 units. This proportion can be used both for overall map sheet proportions and for such details as blocks within the overall design. The ratio 3:2 is probably the most used for legend blocks, being very close to the proportion of the "Golden Section". These ratios are also appropriate for maps which will be photographed to 35mm slides.

In general the square should be avoided when the intent is to produce aesthetically pleasing artwork. It can, however, be effectively included as an inset within the overall "Golden Section" map face. The optical square which should be used is a slight modification of the true square, being 3% wider then high. It is aesthetically more pleasing but still appears "really square".

6.2 Map Design Guides

6.2.1 Map titles and sub-titles

This should be the single most obvious item on the map to permit easy recognition of the subject. The title should appear in the largest and/or boldest type used anywhere on the map without being too dominating. It should also be short in length and describe the area or subject portrayed. Such redundant terms as "Map of" and "Chart of" should be avoided.

When extra information such as District, Region, Province, State, etc., is added to the main title as a sub-title, it should be smaller in lettering size and weight than the main title. Type styles should be the same or be compatible with controlled spacing between lines of type.

6.2.2 Key plan or location map

The purpose of a key plan is to locate the map area geographically in relation to a larger context. It should only have enough geographic detail to ensure that the average reader will recognize the area easily. The primary map area must be outlined and labelled for ease of recognition within the location map.

6.2.3 Bar scales

An important feature of any map or plan is an accurate bar scale from which a range of measurements may be obtained. To be of maximum utility a cartographic bar scale has one primary sub-division placed to the left of "0", all others being to the right of "0". This single unit is in turn sub-divided into smaller, exact, convenient units which are appropriate for the scale and map use.

Scales should be neither too long nor too bold to avoid dominating the map. On a double line bar scale alternate sub-divisions should not be filled in as this dramatically increases the visibility of the scale and tends to make the alternate sub-divisions visually long and short.

The representative fraction, scale statement and graphic bar scale should be located together.

6.2.4 Direction

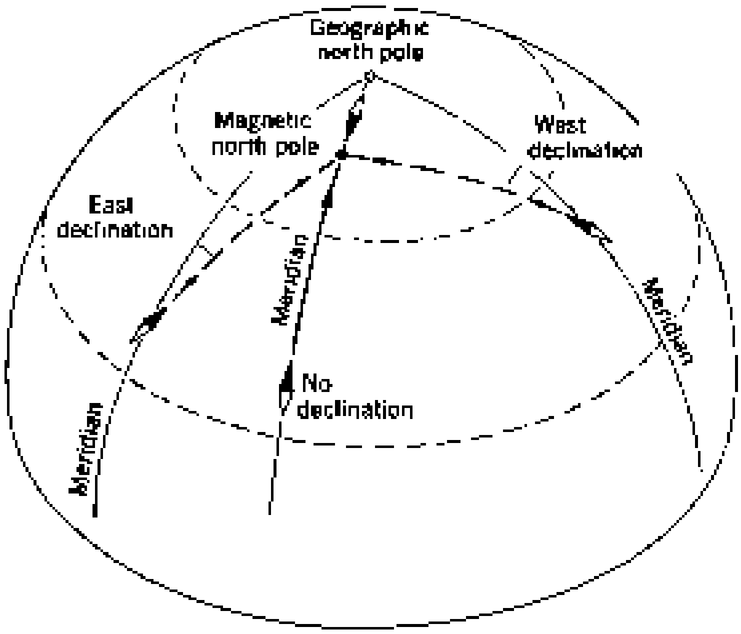
North arrows should be simple, accurate and unobtrusive. Unless otherwise noted, it is always assumed that the direction referred to by a north arrow is true north or geographic north (Figure 6.1), established by reference to the graticule. Standard mapping conventions dictate that the direction of true north coincide with the vertical edge of a map; this should be followed whenever possible to avoid confusion. Maps oriented in the planned direction of travel are exceptions to this rule, e.g., orienteering, canoeing or cross-country skiing maps.

There are other north directions in common usage, probably the best known being magnetic north (Figure 6.1) which is seldom identical to true north. The needle of a magnetic compass aligns itself with the direction of the local variations of the earth's magnetic field. The needle will tend to point to the north magnetic pole, which is currently located in Northern Canada 1400 kilometres from the geographic pole. The difference between true and magnetic north is known as the declination (Figure 6.1). A north arrow system showing this difference is a declination diagram, a common feature of most reference maps (Figure 5.14). As the magnetic field changes slowly, a useful declination diagram will include the correct declination, the year of its measurement, and the amount of annual change. In this way magnetic north can be easily converted to true north, and vice-versa, throughout the useful life of the map.

It should be noted that magnetic declination can be very significant and thus of major importance on any chart designed for navigation. In the continental United States, the angle ranges from 22° East to 22° West while in the Canadian Arctic it ranges from 0-180°.

A detailed isogonic chart, showing lines of equal magnetic declination and equal amounts of annual correction, should be referred to when constructing a declination diagram. Many coastal or marine maps can usefully incorporate a miniature isogonic chart as part of the valuable surround information.

Figure 6.1 Magnetic declination. (After A.N. Strahler, 1963)



The declination diagram also frequently incorporates a third north called grid north (Figure 5.14). This refers to the direction of the grid lines that are added to many maps and charts. When a grid such as the Universal Transverse Mercator grid is used in areas far from the equator the divergence between grid lines and meridians becomes very noticeable. The meridians converge on the pole while the grid lines remain equidistant. Thus, the declination diagram (Figure 5.14) should also show grid declination, the angle between grid north and (true) geographic north.

6.2.5 Legends

An important element of the surround of many complex graphics or maps is an explanation of symbols which have been used and are not immediately self-explanatory. These explanations are variously called Legend, Symbols, Key, Reference, Explanation, Conventional Signs, etc.

The organization of the legend needs particular care. The first consideration is always the manner in which the map or graphic reader will actually use the product. After consulting the title or possibly the key map, most people refer directly to the map face or diagram detail. When they see a symbol, pattern, colour or abbreviation which is unfamiliar or unclear, they seek an explanation in the surrounding notes. In keeping with the convention of reading from left to right and from top to bottom, the explanations should be laid out in a similar manner. The symbol should be on the left, and the notes explaining it to the right of the symbol.

People using the legend have to rely on their memory of the unfamiliar symbol to locate it in the list provided for them. This results in a number of design limitations, including the following:

i) The symbol in the list must be exactly as shown on the graphic, i.e. it must be identical in size, shape and colour. Many presentations are made with the actual symbols contained in rectangular boxes, followed by an explanation. These boxes represent a small portion of the map or graphic. Linear symbols contained in such legend blocks should run across the block to represent their continuing nature on the actual map face;

ii) Legends must be organized or ranked. All symbols which need an explanation must be organized into logical and closely related groups and sub-groups. Thus all forms of contour or isolines will be in one grouping; closely related species may be in another, etc. Within each grouping the symbols must be ranked so that normally the most important (to that map or map user) is listed first, and the others are then shown in descending order of importance;

iii) Symbols which do not appear on a product should not be listed in the legend. For series mapping, however, cross-referencing, economics and speed of production may dictate otherwise;

iv) Type (lettering) used for explanations must be simple and small. The lettering size should be the smallest which can be read by people of less than average eyesight, under realistic usage conditions;

v) Explanations should not be placed on separate pages of a report, particularly when the pages must be turned to read the explanations. Avoid printing legends on the back of maps for the same reason.

It should be noted that wherever possible items should be identified or labelled on the map face rather than including them in the legend, which is a relatively inefficient communication device.

6.2.6 Name placement

The reading and quality of any map or graphic is greatly affected by the positioning of the names and lettering used upon it. When it is properly placed, the lettering will clearly identify the feature to which it refers without ambiguity.

The following set of guidelines may result in conflicting requirements in the production of a complex map. These must be resolved by the cartographer choosing the alternative which gives the greatest clarity:

i) Maps are normally read (viewed) from the bottom. Most names, numbers and labels should, therefore, be positioned so that they are either horizontal, or parallel to the lines of latitude on the map. The major exceptions to this rule are linear features and area names;

ii) Linear features such as rivers, canals, roads, etc., are named close to, parallel to, and normally on top of the feature. Lengthy features should be named more than once rather than relying on excessive letter spacing;

iii) Labels on linear features can be greatly improved by attention to the flow or alignment of the lettering. Names should be placed parallel to a straight section or smooth curve of the feature. Avoid all irregular or zigzag placements. The names for such natural features as bays, rivers, linear lakes, ridges, etc., should be aligned on broad areas or easy curves following the overall trend of that feature. Contour numbers are placed on breaks in the line and are aligned precisely with that section of the relevant line;

iv) The placement of vertical names (along meridians, grids and borders) needs attention. On small-size maps such names are normally oriented to read south to north so that they can be read looking from the right or east side of the map. On large-size maps the viewing position is taken to be the centre of the south edge. Letters will read south to north on the west edge and north to south on the east side;

v) Letters should not be placed so that they are upside down when viewed from the south map edge or the planned viewing position.

For the purpose of definition the term "upside down" includes any angle past the vertical;

vi) Lettering should not be placed in a straight line on any diagonal, unless it parallels a linear feature. It is excessively obvious and visually disruptive, interfering with the readability of the rest of the product;

vii) The naming of adjacent features at angles close to the vertical needs particular attention. Frequent changes of direction should be avoided wherever possible;

viii) In naming areas (lakes, estuaries, basins, mountains, counties, regions, etc.) the name is placed within the feature if at all possible. When such features are irregular the names should be placed on smooth curves whose alignment broadly follows the trend of the feature. Letter spacing is often used to better indicate the extent of the feature named. Short names which apply to long areas may have to be repeated;

ix) As a general rule names should be placed so they do not cross marked changes in background colour or tone. Thus in coastal regions names are placed either on land or in the water, not across the coast or waterline;

x) Names take priority over all map symbols and details except area colours and tones. Lines and other map symbols must, therefore, be broken or eliminated beneath a name. As this obviously affects the continuity of information and may also result in the loss of essential details, point xi becomes a fundamental consideration;

xi) Names should be placed so that they do not interrupt other map information. If this is not possible the name must be placed to cause the absolute minimum interruption and loss of detail. If a name must cross a line or run into it, there is much less disruption if it crosses the line at right angles rather than at a shallow angle;

xii) The most common class of names used in mapping are those which are applied to point symbols. These names must be applied so that the point symbol and the initial letter of the name coincide as closely as possible. As people normally read from left to right, the ideal location for the name is immediately to the right of the point symbol, and slightly above or below its alignment;

xiii) If the positioning in xii is not possible, an acceptable position is immediately to the left of the point symbol, and again slightly above or below it;

xiv) If neither xii or xiii is possible the name can be centered slightly above or below the point symbol. The above position is usually considered superior as there are fewer letters in the alphabet with descenders (descending limbs such as "g") then there are with ascenders (ascending limbs such as "d"). This will tend to ensure closer name placement to the point symbol and better name identification;

xv) Aligning a name precisely with any point symbol should be avoided as this can often create visual confusion, especially on those maps with unfamiliar names or terminology;

xvi) There must never be any doubt as to which point or feature a name refers. Names for point symbols should be placed a distance approximately equivalent to half the height of a capital letter from the symbol name. Rules xii, xiii and xiv should be used to manipulate complex areas to ensure points are labelled without ambiguity;

xvii) When applying names to point symbols located on linear features such as coastlines or rivers, the name should be placed so that it is not separated from the point symbol by the linear feature. Names of towns on rivers should be on the same side of the river as the symbol;

xviii) Coastal names can rarely be placed horizontally because of the usually complex shape of the coastline. A pleasing solution is to place many of the names seaward of the coastline and to curve them into the point to which they refer. Attempt to curve as many of these names as possible in the same direction and with similar curves;

xix) Names should not cross one another unless no other solution is possible;

xx) Names which must cross each other must be clearly differentiated by either the use of letter spacing or a change in the style or size of lettering that is used;

xxi) In general, use letter spacing as little as possible;

xxii) The entire sequence of letters in a letter-spaced name must be easily seen and read without error. It is often necessary to move point symbol names to clarify regional letter-spaced names in the same area;

xxiii) All letter-spaced names must have equal-appearing intervals or spaces, according to the visual perception of the cartographer. The spaces should not be measured mechanically.

6.2.7 Lettering basics

The fundamental methods of lettering any graphic must follow the normal guidelines used to produce text (written) material:

i) Lower case letters are the norm and communicate more effectively than upper case letters;

ii) Capital letters are more obvious because of their increased size and angular nature but are less efficient than lower case. They should, therefore, be used sparingly and only be selected for the most important items to which particular attention is desired;

iii) Identifying land features by upright letters and water features by italic or slanted lettering has become a widespread convention. This should be followed unless an overriding reason prevents it, such as charts of entirely marine environments;

iv) The size and visual weight of a name should reflect the importance of that feature on the map. The smallest and least important information must be easily read and reproduceable. The remaining class sizes are chosen with the subsequent smallest increment in size and weight of letter that will be clearly seen by the average reader;

v) Most punctuation marks are omitted from the face of a map for simplicity and to avoid confusion with other map symbols. Textual material in the surround is punctuated normally. The period is not used. The apostrophe is never used to indicate possession; thus "Harpers Ferry" and "Pikes Peak" are correct, and not "Harper's Ferry" or "Pike's Peak". The apostrophe is used only for legal spelling, such as "O'Brien Creek". The hyphen is used only to conform to legal spelling, e.g., "Geneva-on-the-Lake" and "Shut-In-Cove", or for separating the two parts of joint names, e.g., "Bell-Johnson Channel".

SECTION 7

7. THEMATIC MANUSCRIPT PREPARATION

7.1 Base Map Considerations

Special purpose, scientific or thematic mapping must be plotted onto accurate geographic information of the study region which acts as a reference. This geographic information is a base map and is normally obtained directly or indirectly from available reference mapping, with hydrographic charts and topographic maps being the most common sources. In some studies the thematic information is added directly to available reference mapping. This is an economical and rapid approach, but one which can lead to excessively complex or cluttered presentations.

A better but more costly and slower approach is to create a base map designed specifically to display the thematic information by redrawing those geographic features which are significant to the subject and eliminating or simplifying the remaining features. Occasionally aerial photographs or satellite images are substituted as a simple base or photogrammetric techniques are used to derive a base map from these sources.

In general, base map information should be obtained at larger scales than that planned for the product to avoid the random filtering effect of generalization. The level of information, symbolization and accuracy of small scale maps are unsuitable for significant enlargements.

Some fundamental considerations for base maps include the following:

7.1.1 Purpose

The level of base map detail is dependent on the purpose for which the derived map is required. Available reference maps are often too complex to be used directly as base maps.

7.1.2 Accuracy

The known or probable level of accuracy of the reference map must be given consideration and must suit the accuracy requirements of the new product. Standards should be checked and publication dates noted. Reliability diagrams or notes should be carefully inspected.

7.1.3 Projections

Projections can have a considerable impact on the suitability of base map material and on the economics of a whole project. Obtaining usable base material on a suitable projection is sometimes difficult but well worth the effort. A common problem is that thematic information must be plotted on available reference mapping which is based on a totally different projection. This necessitates knowledge of the characteristics of both projections and the time and capability to transform one into the other. The information required to perform this task may not be readily available, such as the location of the chosen parallels. In general these concerns are relevant to small-scale mapping. On medium and large-scale maps the consideration of projections is not normally a major problem.

The cartographer should remember that there can be a great range of scales within a small-scale map due to the map projections. The Mercator projection is a good example: a given symbol is four times larger in map area at 60° latitude than it would be at the equator. For that reason, attention must be given to the level of symbolization and compilation carried out in tropical zones in comparison to higher latitudes.

7.2 Examples of Small-Scale Base Maps

The following is a list of readily available small-scale base maps:

i) the General Bathymetric Chart of the Oceans (GEBCO) at a scale of 1:1,000,000 (Figure 7.1);

ii) the International Map of the World (IWM) at a scale of 1:1,000,000;

iii) aeronautical charts (ONC, WAC) at a scale of 1:1,000,000;

iv) the International World Map at a scale of 1:2,500,000;

v) maps in reference atlases generally at scales varying between 1:25,000,000 and 1:10,000,000 or smaller. Examples of these atlases include the following:

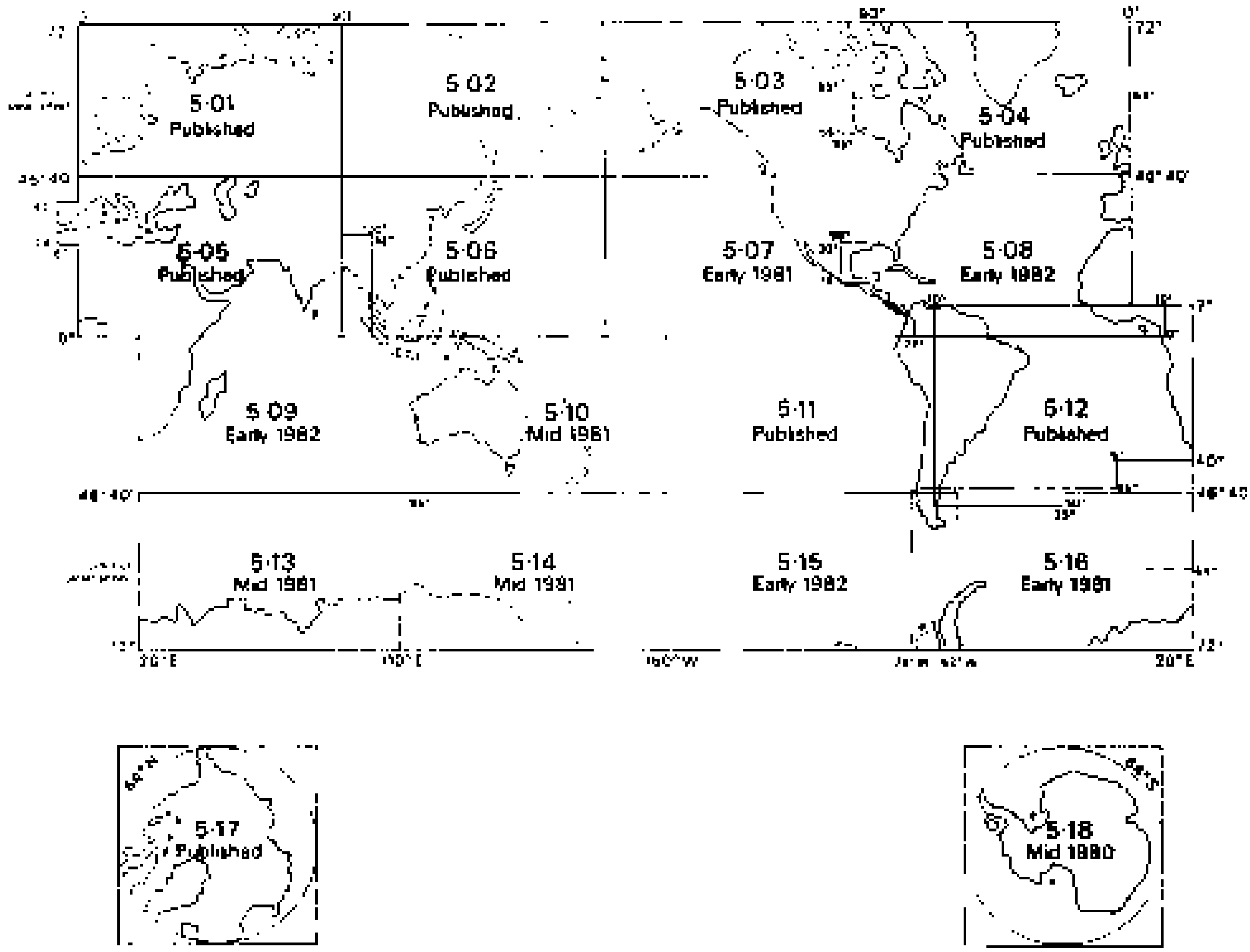
- a) Times Atlas of the World (London);
- b) Atlas Mira (Moscow);
- c) series maps of the world at a scale of 1:5,000,000 published by the American Geographical Society (AGS), and by the Institut Géographique National (IGN) in France;
- d) series of maps of the world at a scale of 1:10,000,000 published by the IGN.

7.3 Base Map Sources

Sources of base map information on any complex map product should always be identified, particularly when several sources of varying accuracy have been used. If permission has been obtained to use copyrighted materials the credit must be given exactly as specified by the copyright holder. The following are possible sources of base maps or base information:

i) In many countries the major mapping agencies can supply printed or film copies of hydrographic and topographic products in single colour format (black and white). Film positives are particularly useful as diazo copies (refer to Section 12) can then easily be produced for use as base maps for plotting data, trial interpretations and design studies. As mentioned earlier, overprinting thematic information directly onto these products is economical but results in the visual conflict of two different data sets;

Figure 7.1 Assembly diagram for GEBCO sheets. (Intergovernmental Oceanographic Commission and International Hydrographic Organization)



ii) Orthophoto or photo maps (refer to Section 6) can sometimes be used as base maps. These can be economical to produce, and they have an implicit accuracy which many people do not attribute to line mapping because of the possibility of bias, error or manipulation in the production of the latter. The photo imagery must be reproduced in a light tone in order to allow the thematic information to be clearly visible. Photo base mapping has become popular for public presentations and tourist mapping;

iii) Satellite imagery, Landsat for example, can often be used for small-scale base mapping if its geometric distortion is not a problem. It can be treated in the same way as photo mapping. These images have a "high tech" connotation which can be a useful asset in many kinds of presentations. The images are widely available and current. Inquiries for information regarding satellite imagery may be addressed to: Earth Observation Satellite Company, 4300 Forbes Boulevard, Lanham, Maryland 20706, U.S.A.;

iv) Portions of published hydrographic charts or even topographic maps can be used directly. A negative of the map sheet is obtained from the mapping agency concerned, and unwanted detail is simply opaqued or masked. Photographic scale adjustment can also be carried out. The negative can be used to produce a new base map onto photographic film on which minor adjustments and line touch-ups can be made with an ink pen;

v) Single aerial photographs can often be used as base maps, particularly for small area/larger scale studies. The photograph, or a portion thereof, can be enlarged to a suitable approximate scale. For display work or report illustrations a system of transparent overlays with coloured symbolization can be produced cheaply by diazo techniques. For thematic mapping the photograph can be reproduced onto scribing film for use as a guide image; the thematic information is scribed in the usual way. A halftone tone version of the aerial photograph becomes the base map and the thematic information is then overprinted in the desired colour. The scale accuracy is normally poor, but this is often offset by the ease with which geographic relationships can be seen.

7.4 Generalization of Base Information

Every map is a reduction of reality. It is the resulting compression of detail which requires a systematic approach to the selection of information through the process of generalization. Maps, even those at large scales, can not possibly show all the details of an area in their correct relationships. This limitation becomes highly restrictive as scales get smaller. For example, taking information mapped at a scale of 1:25,000 and reducing it to a scale of 1:100,000 will result in a new map occupying only one sixteenth the area of the original. This reduction allows only a limited portion of the original information to be portrayed at the smaller scale. Thus the smaller the scale the greater the amount of generalization required. Successful generalization results in the retention of the distinguishing characteristics of the mapped features so that they are effectively represented despite the restrictions of scale.

The various operations, which together make up the subject of cartographic generalization, are normally discussed under four categories or elements: simplification, classification, symbolization and induction.

7.4.1 Simplification

The fitting of information to the selected scale of the map and the maintenance, as far as possible, of the essential geographic characteristics of the mapped area are the two primary objectives in mapping. The information must be simplified by judiciously selecting the necessary classes of information to be shown and by reducing its complexities and detail. The information to be discarded or retained is determined by the relative importance of each item, the relation of the data to the map objective and the graphic consequences (to other data, symbols, etc.) of retaining each item.

7.4.2 Classification

This is a process of grouping a large, variable mass of information in a relatively orderly and simple manner. For example, fish species could be classified into groupings of genera or families depending on space availability. The number of classes should be fewer and broader on smaller scale products.

7.4.3 Symbolization

This procedure occurs after the processes of simplification and classification have been carried out. Some symbols are highly generalized (the dot) while others are not (latitude and longitude lines). Codes are also used to represent the data and identify its location. Good symbolization enhances the effectiveness of other aspects of generalization; however, it can also infer an unjustifiable degree of precision if derived from poor information. These aspects are discussed later in this section.

7.4.4 Induction

This is the process of extending the information content of a map, in areas of limited data availability, by means of logical inference. Isolines drawn through point data measurements are the most common examples. For instance, water temperature and salinity can be inferred from relatively few samples. This process is quite common in the marine environment where sampling is a widely used procedure for observation and measurement. Since extensive inference affects map accuracy, a reliability diagram or statement should be included.

7.5 Map Layout

The creative freedom of cartographers is often limited by a number of overlapping restrictions, such as the requirement for economical reproduction, restrictions due to regional geographic shapes, map projections and grids, and allowances for items in the map margin or surround. Nevertheless, there is a definite place for artistic sensibilities and consideration. An attractive map is more likely to be read and in general will be taken more seriously as a professional product.

7.5.1 Balance

All major map elements should be placed within the available space in an organized and visually pleasing manner. A formal balance calls for symmetrical balancing of similarly sized and shaped elements in relation to a balance point. This is the approach usually taken by the organizers of series mapping. Typically the title is centred either at the top or the bottom, the latter being visually more stable and preferable. Practically, however, it is often necessary to use the former position. The scale is normally centred at the bottom, and the notes are arranged evenly around the perimeter of the map.

Formal balance is often considered stilted and uninteresting for single maps which are not part of a series. The features shown are unlikely to be symmetrical and the shape of the region governs the locations for the title, legend, scales, etc., in convenient open areas. Thus an informal balance of the elements is required.

In informal balance the visual weight of each element must be considered individually and in relation to the whole design. The various elements must be placed so that there is a general balance. Often a large item such as the title or the legend can be visually offset by two or more smaller elements.

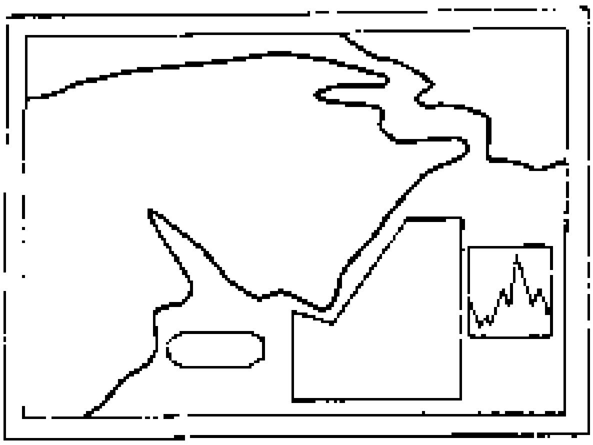
The various possibilities of layout should be first tested in a series of simplified miniature drawings followed by a full-scale dummy which shows outlines of the major elements without detail. It is not possible to create effective designs if major elements must be fitted in at the last moment (Figures 7.2 and 7.3).

7.6 Manuscript Compilation for Marine Applications

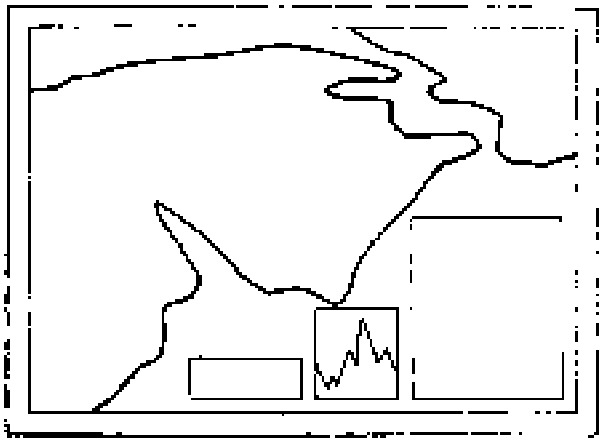
In cartography the term compilation means the process of organizing, assembling and fitting together all of the various geographical and thematic data which will be included in the map. The various kinds of data must all be located in their proper planimetric position according to whatever projection system and scale have been chosen. The compilation manuscript becomes the guide for construction of the map and is necessary no matter what technique or equipment is used to create the final product.

The compiling of data may require the use of several information sources including maps at varying scales, published material in both textual and tabular form, field surveys of various kinds, "raw" data derived from aerial photographs, satellite imagery and digital records. Each of the maps may be on different projections and have varying accuracies and scales. Similarly the textual and digital material may exhibit a wide variety of characteristics. It is the task of the cartographer to select appropriate information with which to create the final map, with the intended use of the end product kept firmly in mind. Reliable maps cannot be created from poor or inadequate data sources, regardless of the compilation techniques used.

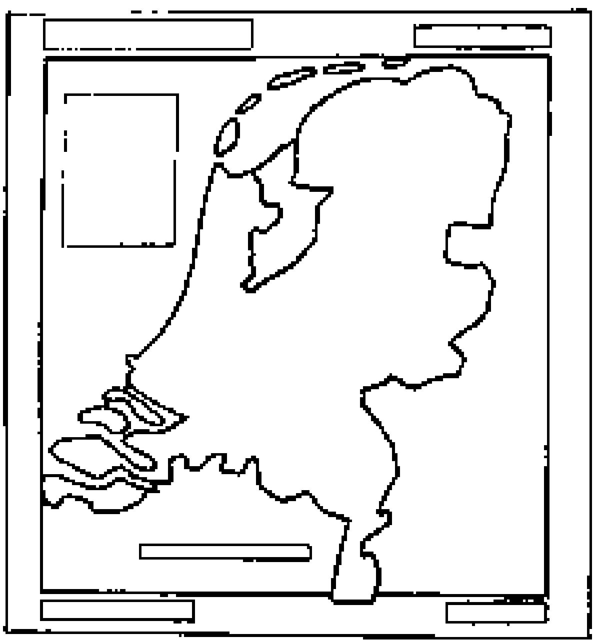
Figure 7.2 Good and bad solutions to map layout design. (After R. Bertrand and P.J. Oxtoby, 1980)



Too many different shapes

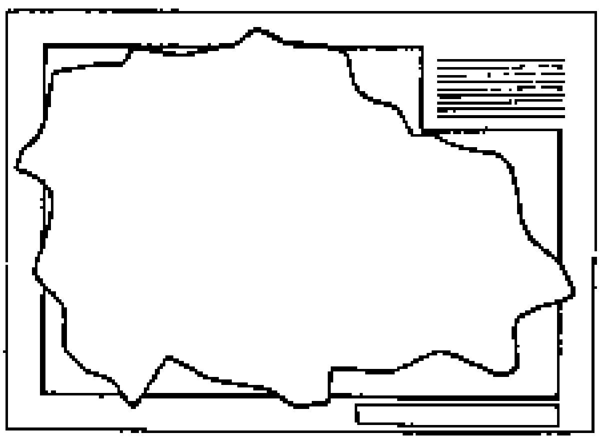


Same shapes, better balanced



Unneccessary frame

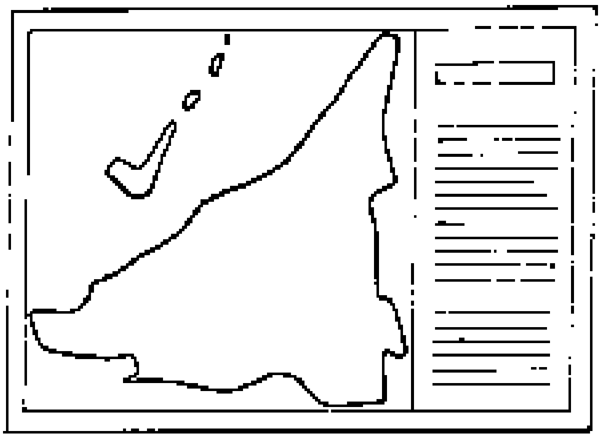
Without frame, more possibilities in arrangement



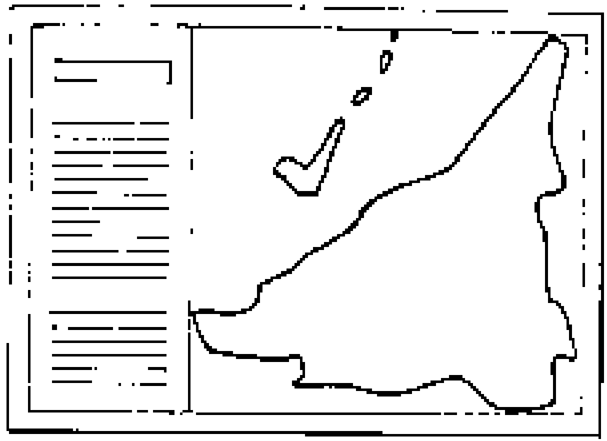
Frame too small and broken

Nearly the whole map is enclosed by the frame

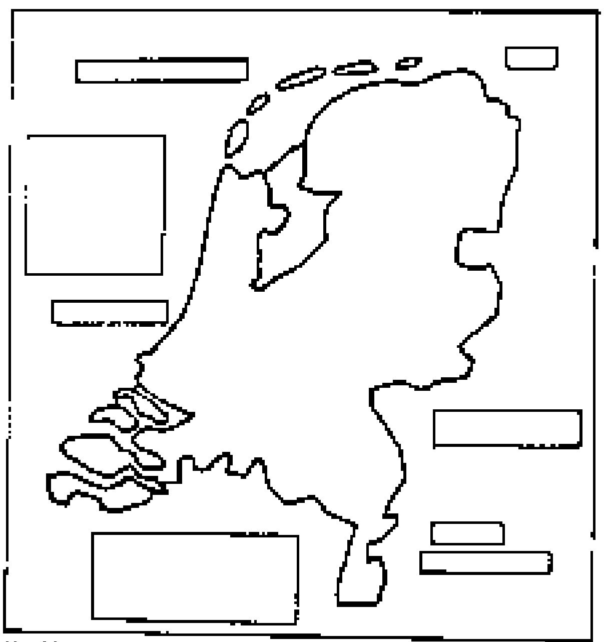
Figure 7.3 Good and bad solutions to map layout design. (After R. Bertrand and P.J. Oxtoby, 1980)



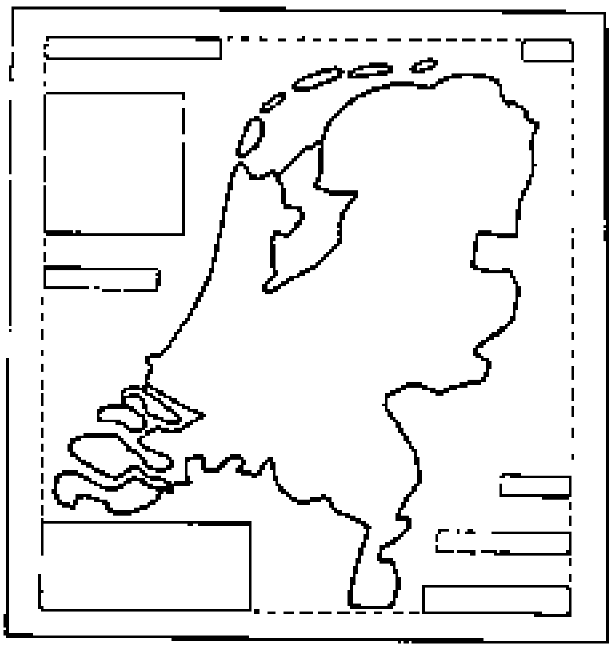
Overbalanced to the right



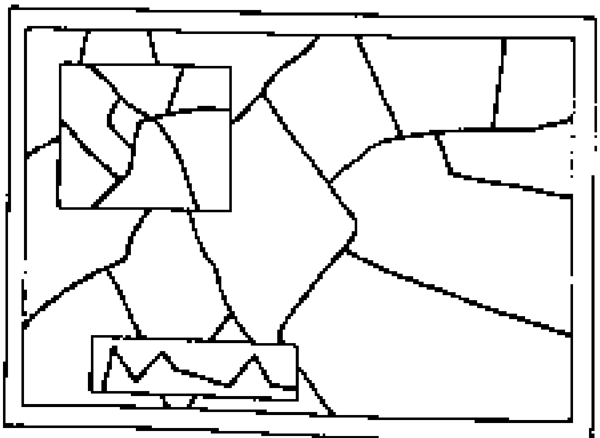
Evenly balanced



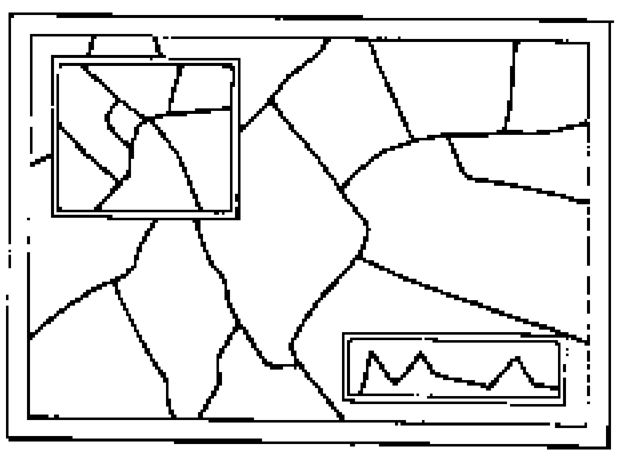
Untidy arrangement



Tidy arrangement



Insets do not stand out from the main map



Insets made to stand out

7.6.1 Work plan: Survey strategy for a developing nation

Surveys of the status of fisheries and marine related information within developing nations often indicate a dearth of such data, at least in a form which can be utilized for management purposes. This state of affairs, invariably due to a lack of manpower, money or expertise, confirms the requirement for fisheries resource mapping with an emphasis on the collection and presentation of marine information in its most basic form. The major source of such information in developing nations is often the fishing community, rather than the research and management agencies associated with industrialized fishing nations. The understandable desire to fund the acquisition of new remotely sensed data (from aircraft and satellites) and to computerize the developing data base should be dependent on the success of data collection and subsequent thematic mapping.

A survey should include the following phases:

i) The formulation of a small project team. Additional expertise or manpower can be called upon as required;

ii) An invitation to selected fisheries personnel to visit an appropriate institution in order to:

a) become familiar with the array of technologies associated with resource mapping;
b) formulate an acceptable data collection strategy;
c) develop a program itinerary and schedule;

iii) The preparation of large-scale base maps of national waters (inshore) and small-scale base maps of the area as a whole (the 200 mile Extended Economic Zone) on which to collect information;

iv) The field testing of the techniques and logistics of data collection and, accordingly, their refinement;

v) The reviewing of existing data from the sources indicated in Section 7.6.3.

7.6.2 Information categories

A typical literature review and interview process might include the following marine information categories:

i) Physical features:

a) bathymetry;
b) currents (surface, bottom);
c) temperature;
d) salinity;
e) tidal range;
f) meteorological characteristics;
g) coastal morphology (e.g., beach);
h) near-shore geomorphology;

ii) Type of bottom (habitat):

a) location of coral reefs;
b) sand bottom;
c) mangroves or turtle grass beds;

iii) Resource location by species areas and seasons:

a) reef fish;
b) lobster;
c) conch;
d) turtles;
e) flying fish and other small pelagics (plus baitfish);
f) tunas;
g) other large pelagics (e.g., rainbow runners, kingfish and billfish);

iv) Fishing areas by species, season, boat and gear type:

a) troll fishing;
b) hand lining;
c) fish traps;
d) seining (purse and shore);
e) foreign fishing vessel sightings (by country), distinguishing vessels of adjacent countries from distant water fleets;
f) sport fishing;

N.B. Areas fished by nationals, which are outside their area of national jurisdiction, should be indicated.

v) Other marine activities:

a) location of fishermen's communities;
b) number of fishermen, boats and gear types;
c) principal handling and trans-shipment points and harbours;
d) tourist development areas;
e) marine parks and conservation areas;
f) shipping routes;
g) main sources of domestic and industrial pollution;
h) areas designated for aquaculture development;
i) identification of Ciguatera zones.

7.6.3 Identification of information sources

The identification of information sources for the preparation of a manuscript is a critical phase of any thematic mapping program. In relation to fisheries, jurisdictional conflicts between the numerous national authorities associated with the coastal zone often result in relevant data being housed in the unlikeliest of locations.

Potential sources of information include some or, ideally, all of the following categories:

i) published scientific literature;
ii) unpublished scientific material;
iii) library collections of papers on special topics;
iv) government department reports and automated data bases;
v) consultant reports;
vi) commercial bibliographic data bases, e.g., ASFA (Aquatic Sciences and Fisheries Abstracts - an FAO data base);
vii) questionnaire results (sent and received by mail);
viii) interview material;
ix) conventional aerial photograph repository;
x) map collections;
xi) satellite imagery (generally the responsibility of a government or international agency).

7.6.4 Collection of information

This phase may employ a variety of techniques from relatively simple and inexpensive data gathering activities, such as the deployment of field personnel equipped with coloured felt markers and accurate base maps, to the complex operations associated with data collection from remote sensing platforms (satellites, fixed wing aircraft and helicopters). The information collected can be stored either in the conventional manner on hard-copy maps, or it can be entered into a geographic information system (GIS) and stored in digital form in a computer (refer to Section 14). Utilization of these more advanced techniques is certainly not essential; they should, however, be considered since the more elaborate data collection procedures are becoming commonplace in many developing countries.

The phase of manuscript compilation which involves collection of information in the field is often critical to the success of a marine resource mapping program. It should be carried out sequentially as follows:

7.6.4.1 <u>Design of interview format:</u> The precise format and interview strategy should be prepared in cooperation with fishery officers familiar with the locale, the fisheries and, most importantly, with the fishing community. The format should be simple and unambiguous. A field tested procedure for conducting interviews is as follows:

i) the provision of large-scale base maps of national waters and small-scale base maps of the region as a whole for data collection;

ii) the interviewing of fishermen, fishery officers and other interested and qualified persons (e.g., coast guard and naval personnel, harbour masters, etc.) utilizing the above maps to plot the acquired marine information using felt markers. Sufficient maps should be used to ensure accuracy and comprehension;

iii) the provision of unmarked maps for each person interviewed, identified with his/her name and profession and the name of the interviewer, the date and place. This is important, particularly when interviewing fishermen, to avoid bias caused by seeing the results of previous interviews with other fishermen. The base maps should be filled in, as an integral part of the interview, by the person interviewed, but if need be with the assistance of the interviewer(s). Figure 7.4 is an example of information portrayed by the simple felt marker technique.

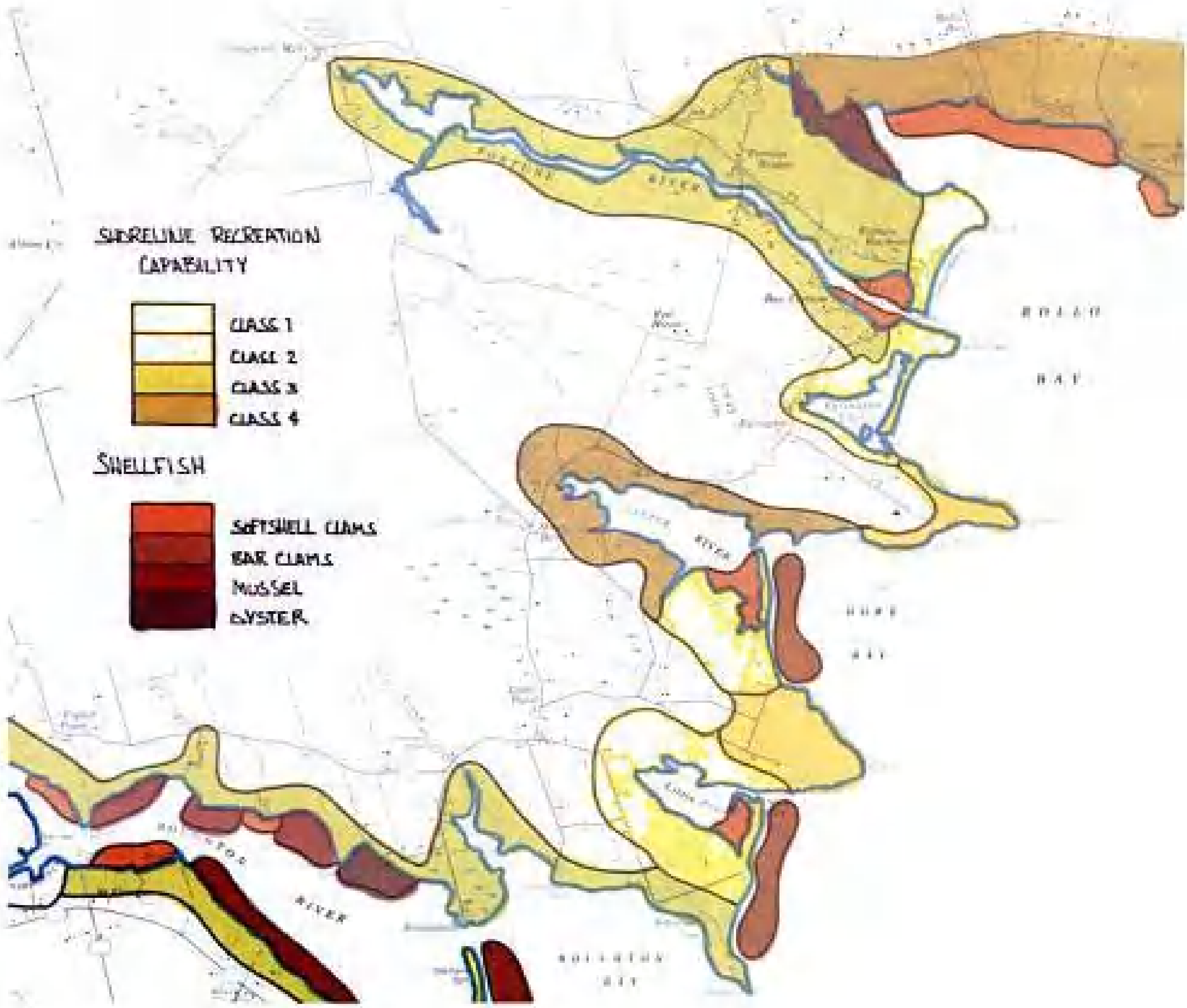
7.6.4.2 Interview process: The majority of current marine resource information is obtained from those personnel most directly concerned with its exploitation, management and scientific research. The actual interview process will vary according to the individual or group being interviewed:

i) Fishermen: It is advantageous to interview fishermen individually to avoid bias, as previously mentioned. The rationale of the program and the benefits which will be derived from it by the fishing community should be particularly emphasized, as fishermen are generally the most skeptical of the subjects to be interviewed. The considerable effort required to overcome such skepticism and cynicism is most certainly justified by the wealth of information usually obtained. In contrast to many of the species they catch, the fishing community is perhaps the most under-exploited marine resource in the context of information retrieval. This information must, however, be critically assessed in terms of its accuracy;

ii) Fishery officers: When possible, group sessions are recommended for fishery officers. After an initial briefing by a member of the resource mapping team, the officers should be queried about the subject under review. While one or two team members take notes, the other(s) should encourage the officers to draw distribution patterns, etc., on the base maps previously affixed to the walls or tables. The team members must be "animators" and encourage discussion, which pre-supposes a personal knowledge of the local fisheries. Controversy between the officers concerning marine information can often improve the quality of the final product, if the point of controversy can be resolved. The team should attempt to methodically follow the list of topics to be reviewed and at all times record the name of the person who provided particular information, either on the base maps or in the notes. A plentiful supply of coloured markers and unmarked base maps is essential for a successful interview session;

iii) Scientists: It is advisable to interview scientists on an individual basis, partly because of the inherent professional jealousy that results when scientists meet in groups, but also because of the real, and perceived, proprietary nature of their information. A manuscript map, containing information previously obtained from the fishermen and fishery officers, should be the focus of discussion. It will probably elicit criticism, which is required to ensure accurate and verifiable data. It is not possible to elicit much informed opinion, in a short space of time (generally a critical factor), unless a manuscript is available to stimulate

Figure 7.4 Example of information presented with the aid of felt markers.



and focus the criticism.

When the information, collected from the above three groups, has been analyzed and collated with other sources of data, another manuscript map should be prepared. At this point it is essential to arrange a "check session" with the key information providers to ensure that their contributions have not been misinterpreted. This session is also a valuable part of the "feedback" process and will increase the confidence of the participants in the worth of the thematic mapping program. The thematic map, as an end product, must be seen to contain reliable and accurate information, otherwise the credibility of the whole program will be lost.

7.6.4.3 Interview protocol: In all cases basic civilities are a prerequisite to a successful interview. Unless these civilities are observed, future efforts to obtain information or cooperation will be jeopardized. These include the following:

i) Prior consultation should take place to ensure that the rationale for the program is clearly understood and, particularly, that the benefits to be derived from the program are identified; the latter will often facilitate cooperation;

ii) The interview format and topics of interest should be circulated in advance. The interview process is unfamiliar to many persons, professional and otherwise, and can be a little forbidding, hence the need to alleviate any fears;

iii) It is essential to establish a precise time and date for the interviews. Unlike other professions, fisheries are often seasonal and are carried out at different times of the day and night. Thus a time should be selected when fishermen and fishery officers are not in the midst of their peak activities, i.e. exhausted personnel are not ideal subjects to interview and the information obtained suffers accordingly;

iv) All arrangements should be confirmed, by letter or by telephone, well in advance of the interview. Another communication a few days prior to the agreed upon date may also help to avoid embarrassment;

v) The location in which the interview is to take place should be chosen with care. Most people feel more relaxed in their home or work environment, rather than in some alien institutional setting. This is particularly true for the fishing community: a fishing boat, dockside or the fisherman's home are ideal settings, assuming prior permission has been arranged;

vi) Awareness of political realities is another prerequisite. The fishing community and personnel from the Department of Fisheries rarely agree on any topic, especially fisheries management and within the fishing community itself there are normally a variety of firmly held opinions. Hence the interviewer must beware of jeopardizing his primary task of collecting information by an injudicious choice of words or reference to a currently volatile topic. Diplomacy is thus essential;

vii) The parties interviewed are naturally aggrieved if they do not see the end results of the program, i.e. a map and/or report. Personal copies are particularly appreciated but the cost of the item is obviously a factor. Acknowledgement of their contribution also is essential, both in the form of a letter of appreciation and in the appropriate acknowledgement section of the end product.

7.6.5 Organization, analysis and evaluation of information

The information and data collected from the numerous sources must now be categorized according to the desired use of the end product, the thematic map(s). The integration of data and its portrayal as thematic information will normally occur within clearly defined categories, i.e. pelagic fisheries, demersal fisheries, habitat, fleet distribution, port infrastructure, etc. Utilization of these various categories, either individually or in combined form, will depend on the map design (refer to Section 6) which in turn will reflect the ultimate use of the map, its management role.

The acceptance of marine resource mapping as a management tool is dependent on the reliability of the contained information. The importance of accurate mapping cannot be overestimated, for instance, in acqua-culture leases and development sites, location of artificial reefs and, more generally, coastal zonation and multiple use delineation of nearshore areas. Thus the analysis and evaluation of the categorized data should be thorough and scientifically acceptable. For this reason, all information utilized in the thematic mapping process must be clearly identified with the aid of an "Audit Trail", to give users of the map(s) the opportunity to check the authenticity of the sources and the credibility of the mapped information. This is particularly important for thematic maps as the original data may have been transformed and integrated with information from other sources.

Under certain circumstances it may be desirable to assess the informa-tion in relation to its perceived accuracy. This may be done by graphical means or in accompanying text. Whichever technique is used, it will be open to public scrutiny and may cause considerable concern to the original information providers, particularly if the assessment of their contribu-tion is not complimentary.

The collected information and data to be reviewed and selectively integrated may include not only written material and graphics (maps), but also aerial photography and satellite imagery which will require inter-pretation. It may be used to update old information or provide new information. The role of aerial photo interpretation, satellite image analysis and geographic information systems (GIS) are considered in general terms in Sections 8 and 14.

7.6.6 Plotting techniques and equipment

Having collected and organized the resource information in the form of a manuscript, it may be necessary to plot this information onto another map at a different scale. There are a variety of manual, mechanical and optical techniques and equipment available to reduce or enlarge a map for this purpose:

i) Grid square or Union Jack method: A grid of squares is drawn on the map which is to receive the information. Increased accuracy can be achieved by drawing the diagonals (hence the term "Union Jack" method). The larger/smaller format is divided up into the same number of squares. Detail is now copied by hand from each square (or triangle) onto its counterpart at the required scale (Figure 7.5). A similar method can be used to transfer detail from aerial photographs to a map;

ii) Similar triangles: This method is particularly well suited for the compilation of linear detail such as contour boundaries, etc. It can be used for both reduction or enlargement. The method is shown in Figure 7.6;

iii) Proportional dividers: These instruments can be valuable for manual compilation; they greatly reduce the amount of time required to perform the two previous procedures. They consist of modified dividers having two equal legs pivoting about a milled wheel attached to a slide piece (Figure 7.7). If the slide piece is moved in the control slot the proportion of one set of legs to the other is changed. Scales are graduated on each of the legs, although these are only an approximate guide. Exacting scales are usually determined after a few minutes of trial and error. The variable proportion makes it possible to measure a distance on one map with one end of the dividers, turn the instrument over and plot onto the manuscript directly with the other end. Most proportional dividers have scales graduated for planimetry on one side and circles on the other, increasing their versatility;

iv) Parallelogram pantographs: These various devices make use of simple geometric ratios, based on the properties of parallel lines, to change scale. They consist of a system of rigid arms, hinged or sliding, forming a parallelogram with extensions. At certain points are mounted a pivot (which does not move), a tracing point and a drawing pencil. When these three loci are adjusted correctly for the required scale change, and the tracing point is used to trace the original map, the pencil draws the map at the new scale (Figure 7.8);

v) Photography (refer to Section 12): The only serious problem with this technique is ensuring that the correct scale change has been obtained. This can be checked with the grid square method;

vi) Specialized projectors: A map can be projected, enlarged or reduced, as required, onto paper laid over a glass screen. Once the correct setting is obtained (check with the grid square method) the lines of the map are drawn on the paper. Examples of these projectors include:

Figure 7.5 Grid square method for enlargement or reduction. (After C.L. Blair and R.I. Simpson, 1978)

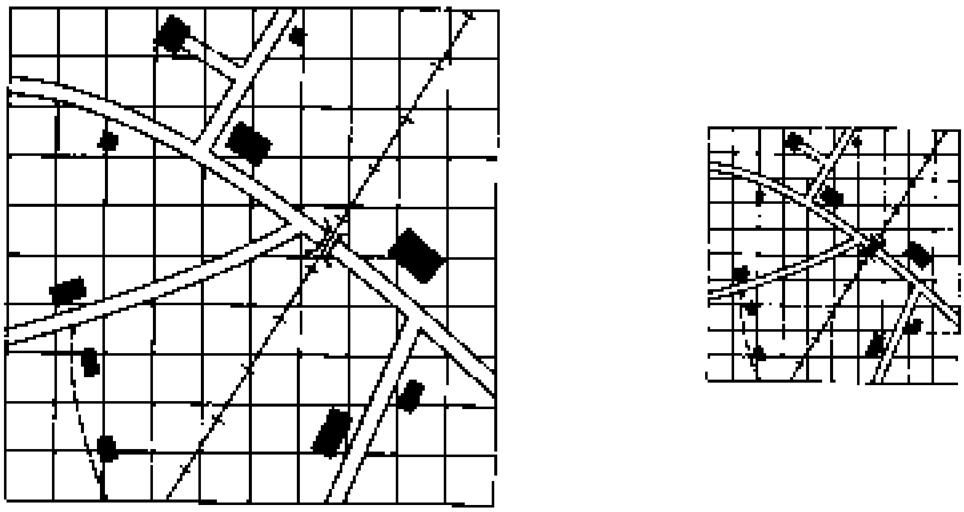


Figure 7.6 Triangle method for enlargement or reduction. (After P.J. Oxtoby and A. Brown, 1976)

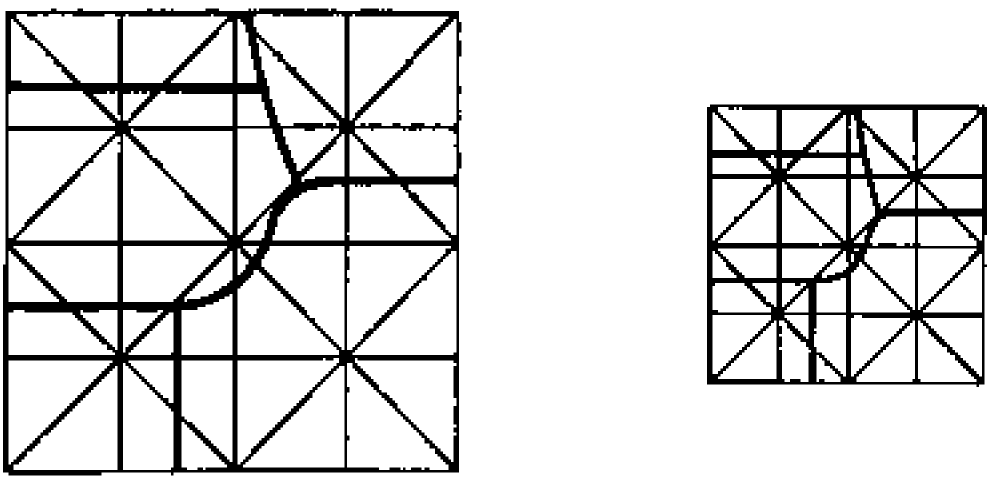


Figure 7.7 Proportional dividers. (After International Cartographic Association, 1984)

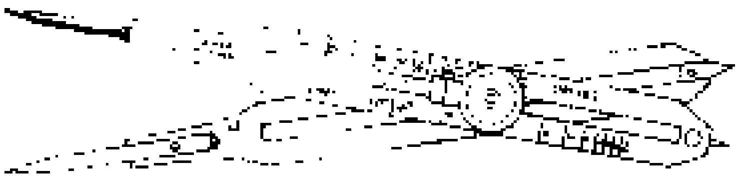
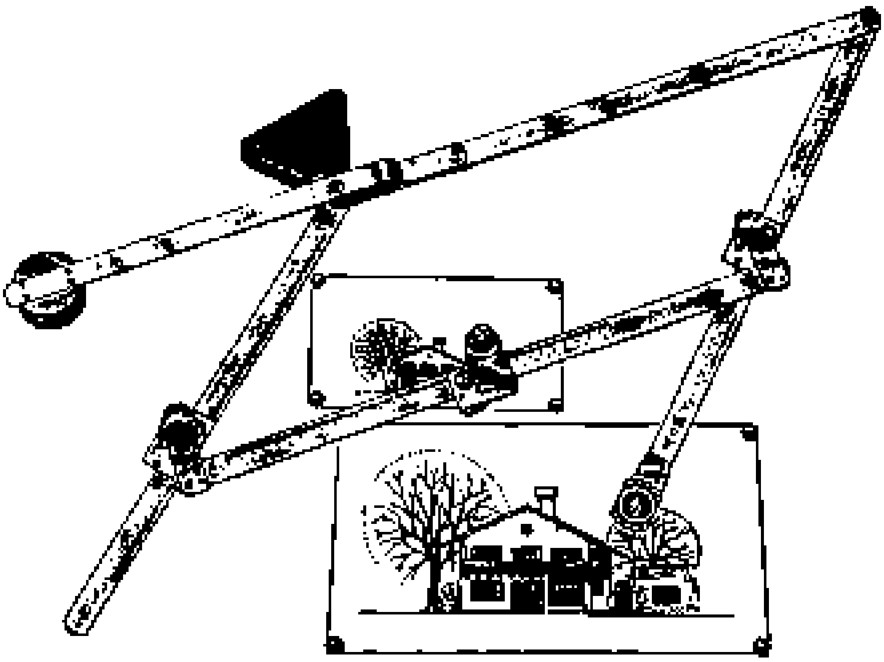


Figure 7.8 Parallelogram pantograph. (After R. Graham, 1968)



a) Grant projector;
b) Klimsch Antiskop;
c) Map O'Graph;
d) Kail projector;

vii) Slide projector or epidiascope (overhead projector): These are crude methods for scale changing and only enlargements can be easily produced. A slide or transparency of the original must be available for projection. To avoid distortion, the axis of projection and the paper onto which the map is to be drawn, must be at right angles. Once again, the grid square method is an appropriate method to check correct scale change. It is possible to reduce an image with an overhead projector if the subject is brightly lit in a darkened room. The stage of the projector can be used as a small tracing table, and in this case, no transparency is necessary.

SECTION 8

8. AERIAL PHOTOGRAPHS AND THEIR INTERPRETATION

Aerial photographs are an invaluable source of information for the study of the nature and characteristics of the coastal and terrestrial environment. Vertical aerial photographs can be used to update existing base maps and to produce new base maps in the form of individual photographs or several photographs in assembled format known as mosaics (refer to Section 8.9).

Various simple transfer instruments (sketch master and zoom transferscope) are available for correcting the horizontal distortion (x and y) inherent in aerial photographs and may be used to transfer the necessary photo information to line maps with a reasonable degree of accuracy. The amount of information extracted from these aerial photos depends upon the skills of the photo interpreter. To correct for height displacement (z), a complex and expensive photogrammetric plotting instrument is required, e.g., Wild A10.

8.1 Types of Aerial Photographs

There are two major classes of aerial photographs:

i) Verticals: the survey camera lens points vertically downwards producing a view resembling a plan of the ground;

ii) Obliques: the survey camera lens axis points at an angle to the ground. If the horizon is included the photograph is defined as a high oblique; if not, it is a low oblique.

Depending on the photo information required, more than one film type may be necessary. In this situation, the use of multiple survey camera installations will reduce flying costs. In Figure 8.1 the twinned and triple camera installations are indicated.

8.2 Acquisition of Aerial Photographs

An aircraft taking systematic air photo coverage of an area does so by making successive passes back and forth across it, usually in an east-west direction. This flight line ensures consistency in orientation and sun angle, which aids in photo interpretation. The orientation of the prints is at 90° to that of the flight lines. To permit stereoscopic and photogrammetric analysis there is usually a 60% forward overlap between successive photographs in the same flight line and 20-40% lateral overlap between adjacent flight lines (Figure 8.2). Considerable variation in the format size of photographs exists, although the most common size is 23 X 23 cm (9 X 9"). Scales may vary from 1:1,000 to 1:80,000 depending on the photo interpretation requirements. For example, forest inventory photography is commonly at 1:10,000 whereas the analysis of geological features may only require photography at a scale of 1:50,000. An annotation, usually located along the southwest corner of the photographs, should contain all relevant information such as the roll number, print number,

Figure 8.1 Twinned (a); and tripled (b) survey camera installations. (After G.C. Dickinson, 1969)

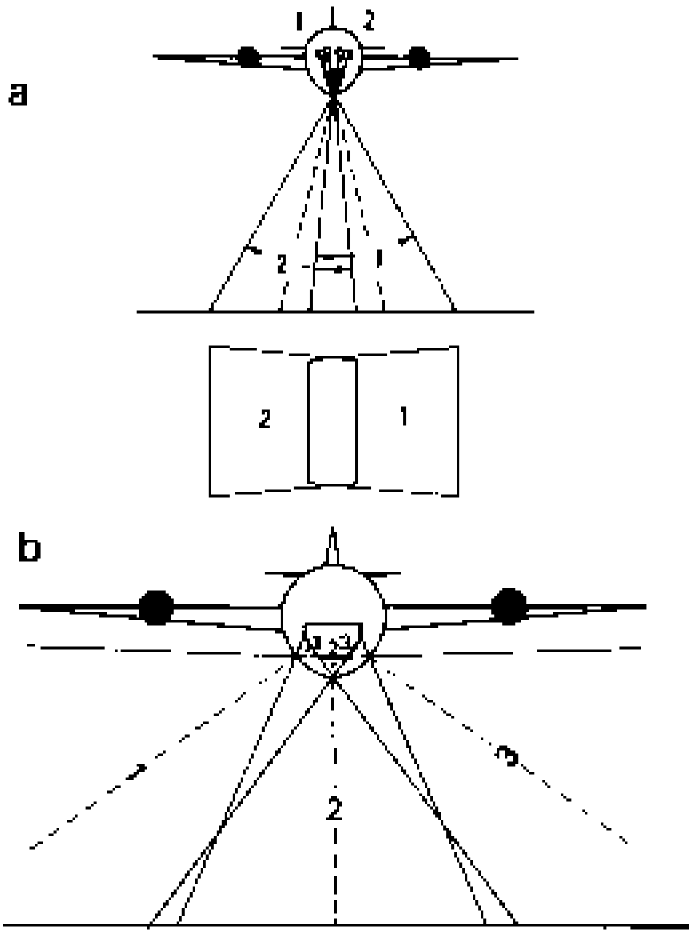
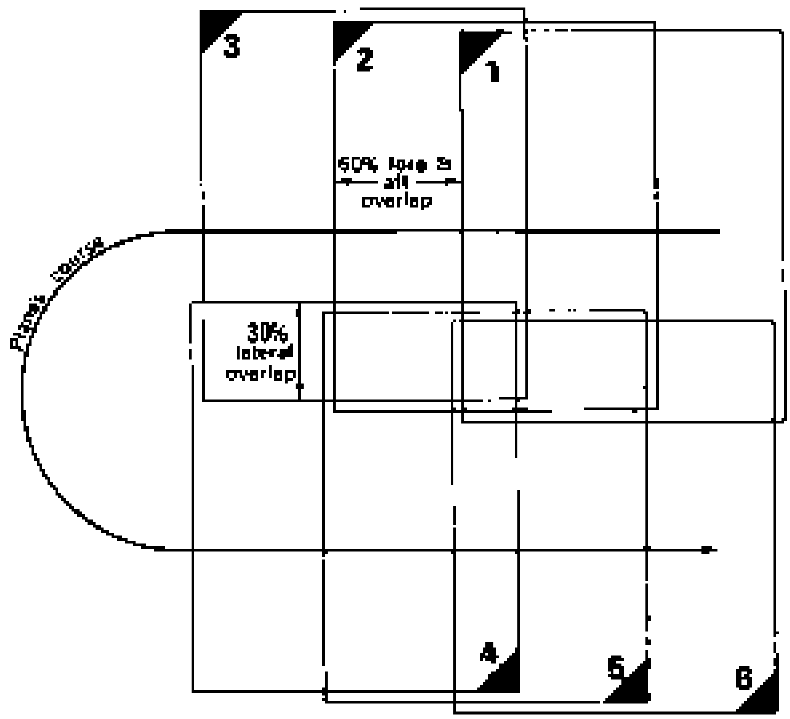


Figure 8.2 Lateral and forward overlap of aerial photographs. The top left-hand corner of each photograph is indicated. (After G.C. Dickinson, 1969)



time and date of photography, etc.

8.3 Terminology of Aerial Photographs

Basic terminology associated with aerial photographs includes the following:

i) Format: the size of the photo;

ii) Focal plane: the plane in which the film is held in the camera for photography (Figure 8.3);

iii) Principal point (PP): the exact centre of the photo or focal point through which the optical axis passes. This is found by joining the fiducial or collimating marks which appear on every photo (Figure 8.4);

iv) Conjugate principal point: image of the principal point on the overlapping photograph of a stereo pair;

v) Optical axis: the line from the principal point through the centre of the lens. The optical axis is vertical to the focal plane (Figure 8.4);

vi) Focal length (f): the distance from the lens along the optical axis to the focal point (Figure 8.3);

vii) Plane of the equivalent positive: an imaginary plane at one focal length from the principal point, along the optical axis, on the opposite side of the lens from the focal plane (Figure 8.3);

viii) Flying height (H): height of the lens above sea level at the instant of exposure. The height of a specified feature above sea level is designated "h" (Figure 8.3);

ix) Plumb point (Nadir or vertical point): the point vertically beneath the lens at the instant of exposure (Figure 8.5);

x) Angle of tilt: the angle subtended at the lens by rays to the principal point and the plumb point (Figure 8.5).

8.4 Properties of Aerial Photographs

The majority of photogrammetric techniques are based on the three basic properties of aerial photographs: scale, displacement and radial property.

8.4.1 Scale

The scale of a truly vertical photo of perfectly flat terrain would be nearly the same as an accurate line map (refer to Section 3). The occurrence of relief, however, causes variations in scale because of the perspective view of the camera lens (Figure 8.6). These differential variations in scale preclude the tracing of information from photographs directly to large-scale maps. The amount of displacement, however, can be

Figure 8.3 The focal length, focal plane, plane of the equivalent positive and flying height of aerial photographs.

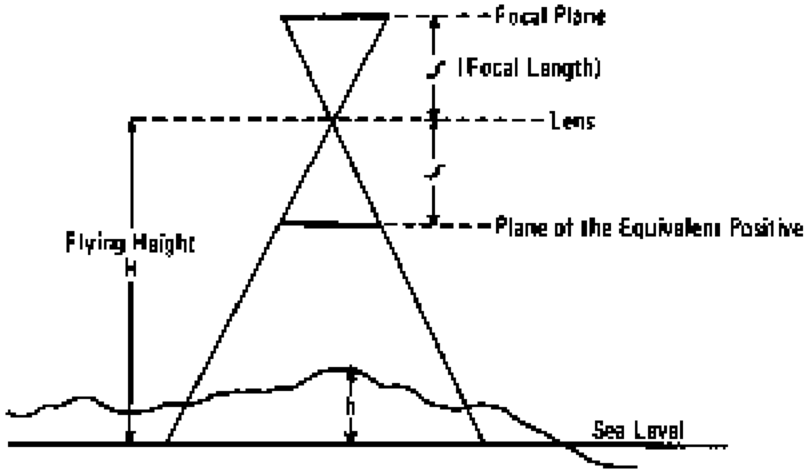


Figure 8.4 The principal point, fiducial marks and optical axis of aerial photographs.

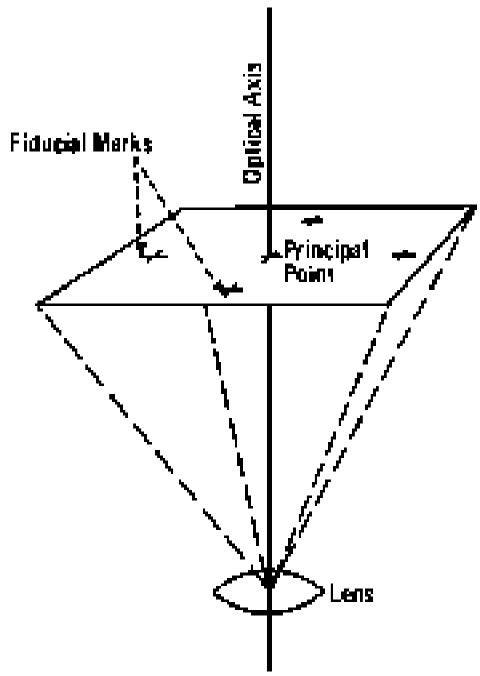


Figure 8.5 Plumb point and angle of tilt of aerial photographs.

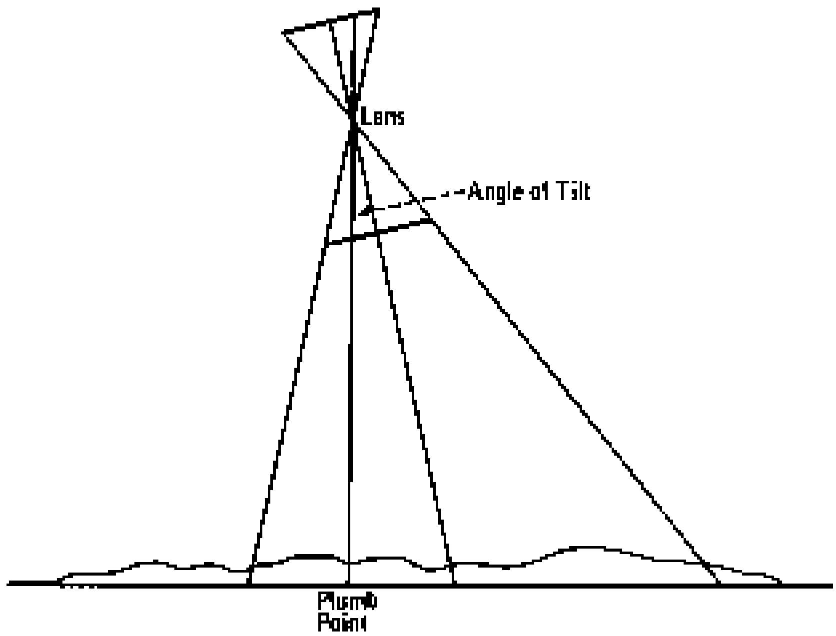
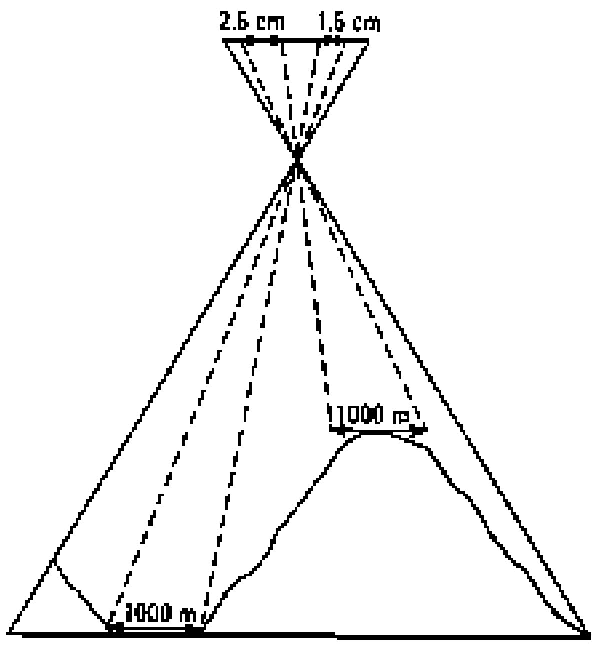


Figure 8.6 The effect of topography on photo scale: photo scale increases with an increase in elevation of terrain.



measured.

The overall scale is the ratio of the focal length of the camera lens to the elevation of the camera lens with respect to some specific features on the landscape; it follows that this ratio will not be correct for any other elevation,

$$\text{e.g., R.F.} = \frac{0.5}{10,000} \text{ or } 1:20,000$$

8.4.2 Displacement

Relative to one level of terrain, higher points are displaced away from the centre of the photograph and lower points towards the centre. The amount of displacement increases as the height of the object and the distance from the centre of the photograph increases. As the altitude of the camera increases, displacement is less. This is the reason why high altitude vertical photography is used for the construction of mosaics or as an effective and inexpensive base map substitute.

The displacement of objects on aerial photographs produces parallax, which is the apparent change in position of an object due to a change in the point of observation. This apparent change in position is the principal reason for our ability to view two photographs to produce an illusion of a third dimension. The algebraic difference of the parallax on two overlapping photographs is used to determine elevations using stereoscopic plotting instruments.

8.4.3 Radial property

In a vertical photograph the radial directions from the centre are true. Thus bearings measured from the principal point are true, whereas distances are not.

8.5 <u>Scale of Aerial Photographs</u>

The scale of a photo affects its use in the revision of line maps, i.e. a photo with a nominal scale of 1:50,000 should not be used to revise a map with a scale of 1:10,000. Photos at the same scale or larger should be used to insure that the resolution of the photograph matches the degree of precision required for the revised information.

8.5.1 Determining the scale

There are four basic methods of determining the scale of an aerial photograph which, in decreasing order of accuracy, are as follows:

i) the relationship between two points on the ground of known distance, and the same two points on the photo. (Note that the scale may vary for other locations on the same photograph if there is significant relief variation);

ii) the relationship between two points on the map and the same two points on the photo;

iii) the relationship between an object on the ground, whose dimensions are known and the same object on the photograph;

iv) the relationship between the focal length of the camera lens and the altitude of the camera lens,

e.g., focal length (f) = 15 cms, altitude (H) = 1,500 m;

$$\text{therefore scale} = \frac{15}{1500 \times 100} = 1:10,000.$$

8.5.2 The effect of tilt and height displacement

The scale of an aerial photo changes from point to point due to tilt of the camera lens (i.e. aircraft attitude) and changes in height of the terrain unless the terrain is absolutely flat (Figure 8.7). The top of a high mountain, therefore, will be at a larger scale than a valley because it is nearer the camera lens when photographed (unless the photo has been rectified). Figure 8.8 a shows a rectangle of roads in absolutely flat country photographed with a perfectly vertical camera. There is no distortion so they appear on the photo as they would in a line map. Figure 8.8 b shows the distorted appearance of the roads on a tilted photo; Figure 8.8 c shows the appearance of the information after rectification, i.e. the roads are restored to their proper shape but the print itself is no longer square. When hilly country is photographed there is no means of completely removing the effects of tilt and the differences of terrain height in one photo. Differential rectification, however, minimizes these effects.

8.6 <u>Plotting Techniques</u>

The following simple techniques may be used for plotting detail from aerial photographs onto line maps without the use of sophisticated equipment (refer to Section 7):

i) Transfer-by-eye sketching: If the line map shows considerable detail it may be possible to add further information by visual referencing with a satisfactory degree of accuracy;

ii) Direct transfer after reduction or enlargement of the photograph to the line map scale: The photograph is projected at the appropriate scale onto the line map to be revised; photo detail is then drawn on the map. To minimize distortion, the enlargement/-reduction factors should be calculated only for small areas at a time. Instruments such as the Kail projector and Map O'Graph may be used for this task (refer to Section 7.6.6);

iii) Transfer by grids, triangles, etc. (Figure 8.9): These are methods derived from the basic principle that a straight line on the ground will appear as a straight line on the photograph if the terrain is relatively flat. Height distortion, however, will introduce small errors in vertical photographs and excessive errors in obliques. All methods require that at least four points be identified on both the photograph and the existing line map (refer to Section 7.6.6);

Figure 8.7 Variations in scale in relation to aircraft attitude. (After C.H. Strandberg, 1967)

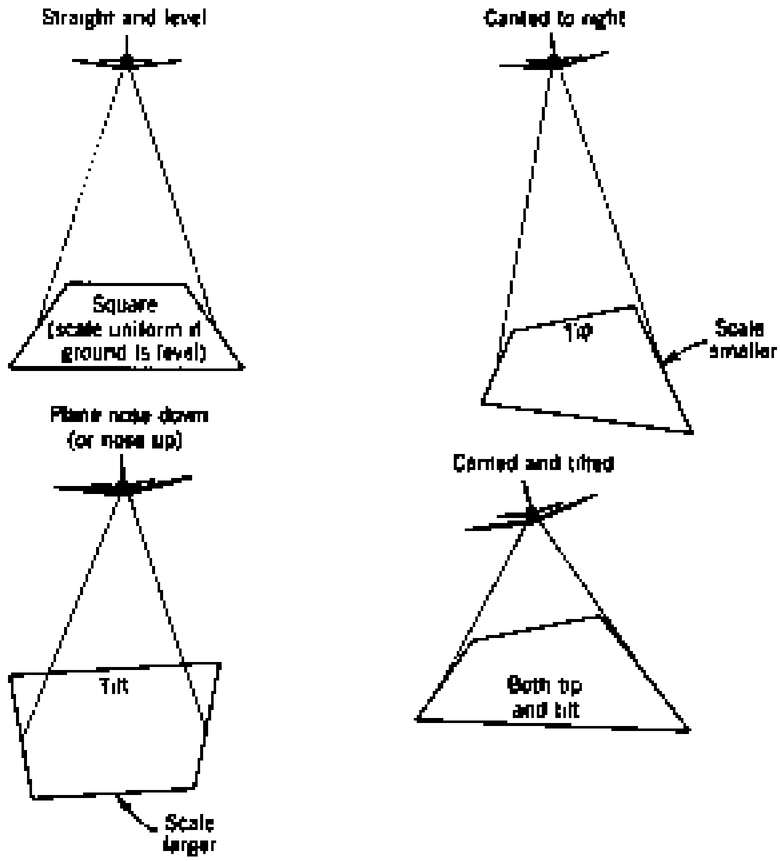


Figure 8.8 An undistorted aerial photograph (a); distorted (b); and rectified (c). (After P.J. Oxtoby and A. Brown, 1976)

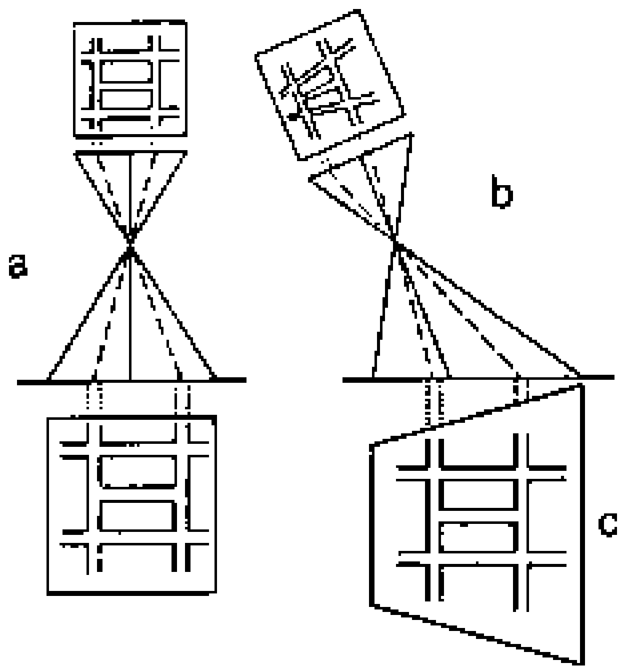
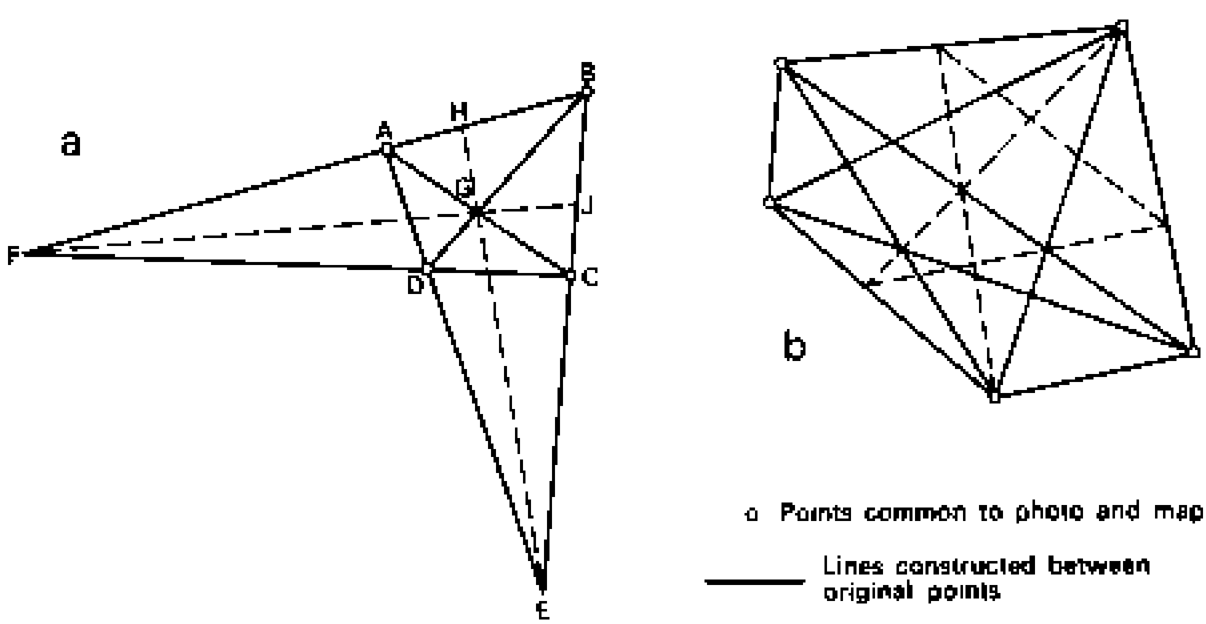


Figure 8.9 Grids for transference of detail from an aerial photograph to a map: (a) polar grid; (b) polygonal grids. (After G.C. Dickinson, 1969)



a) Polar grid (Figure 8.9 a): Identical grid constructions are drawn on the line map and the photograph:

- the four points used may be A, B, C and D;
- AD and BC are extended to meet at E;
- AB and CD are extended to meet at F;
- Through G, the intersection of AC and BD are drawn EGH and FGJ.

Detail can now be copied from any triangle on the photograph onto the corresponding triangle on the map;

b) Polygonal grid (Figures 8.9 b): When more than four common points can be identified on the photo and line map, extended points as in the polar grid need not be drawn. The points are simply plotted on both line map and photograph and the area within the resultant polygon subdivided by joining each point to all the others.

8.7 Interpretation

Using normal vision "on the ground" an object can be distinguished by a combination of the three processes of observation:

i) size and shape;
ii) colour;
iii) features with which it is associated.

The same processes are used by photo interpreters but with different conditions and emphasis within each group:

i) Size: may be the deciding factor when distinguishing between objects alike in shape. Measuring may be necessary;

ii) Shape: the general form (which includes the three-dimensional stereoscopic view) may be the single most reliable evidence for identification;

iii) Tone: variation in tone results from differences in the reflective qualities of objects, e.g., light, dark, etc.;

iv) Texture: when changes in tone are too small to be discernable, texture may assist identification, e.g., stippled, granular, rough, smooth, etc.;

v) Shadow: provides a ground view of the object, hence an important clue. Lengths of shadows can be used to determine heights of objects if the surrounding terrain can be assumed to be flat;

vi) Pattern: the arrangement on the landscape of physical and cultural features is often distinctive and may be useful for recognition and evaluation;

vii) Site: the location on the landscape can contribute to identification, e.g., particular vegetation may appear in specific locations only;

viii) Associated features: features commonly found adjacent to the object under investigation. These have a characteristic appearance and so immeasurably assist photo interpretation, e.g., rocks and soil, water, vegetation (woods, grasslands, crops), roads, railways, towns and historic sites.

8.7.1 General rules for photographic interpretation

In general photographs should be interpreted from the whole to the part, i.e. broad distinctions defined first. Interpretation should be approached systematically:

i) A literature review is a necessary part of any study and as much information as possible should be obtained from these sources;

ii) The photograph should be orientated. This may be possible with the aid of shadows. Many air photographs are taken near mid-day for optimum light conditions resulting in the shadows pointing between north-east and north-west in the northern temperate latitudes;

iii) A pattern or shape should be selected on the photograph which will be easily identified on the line map, e.g., coastline. An apparent match should be confirmed by supporting evidence;

iv) Photographic "keys" or file photos of significant features are extremely useful as aids to current investigation and as "memory joggers" in complex situations.

8.7.2 Stereoscopes and stereoscopic vision

Aerial photographs convey only a weak impression of relief unless a stereoscope is used to produce a three-dimensional image. The three-dimensional impression which is obtained in normal vision is due to the fact that with two eyes set about 6 cms apart, each eye is able to present to the brain a slightly different perspective of the object that is being observed. From the differences in perspective between these two images, the brain is able to assess depth and build up a three-dimensional picture. This is the basic principle involved in the use of two adjacent aerial photographs with considerable overlap (a stereo pair) and a stereoscope to produce a three-dimensional image.

There are a number of types of stereoscopes, including:

i) Pocket stereoscope (Figure 8.10);

ii) Mirror stereoscope (Figure 8.11): This type uses pairs of parallel mirrors to "spread" the line of sight, thus increasing the three-dimensional area under view at one time. Detachable binoculars give greater magnification;

Figure 8.10 Pocket stereoscope. (After G.C. Dickinson, 1969)

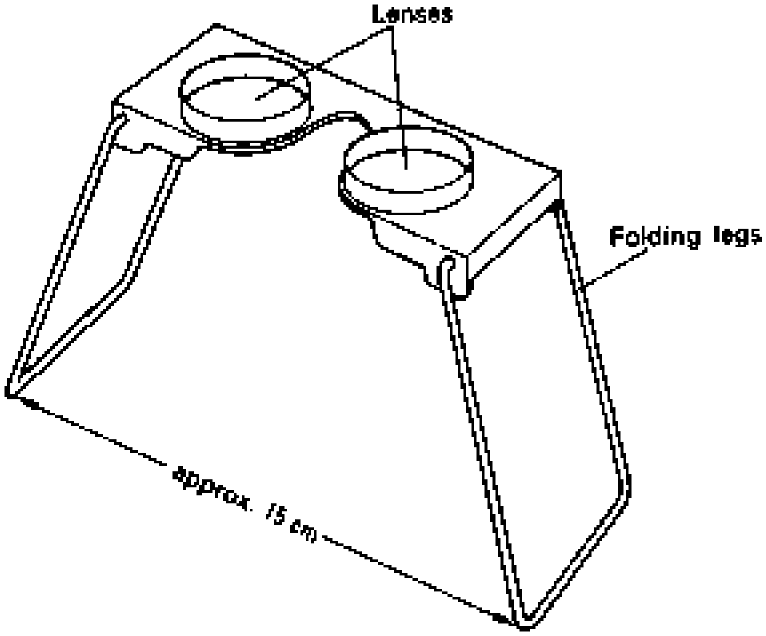
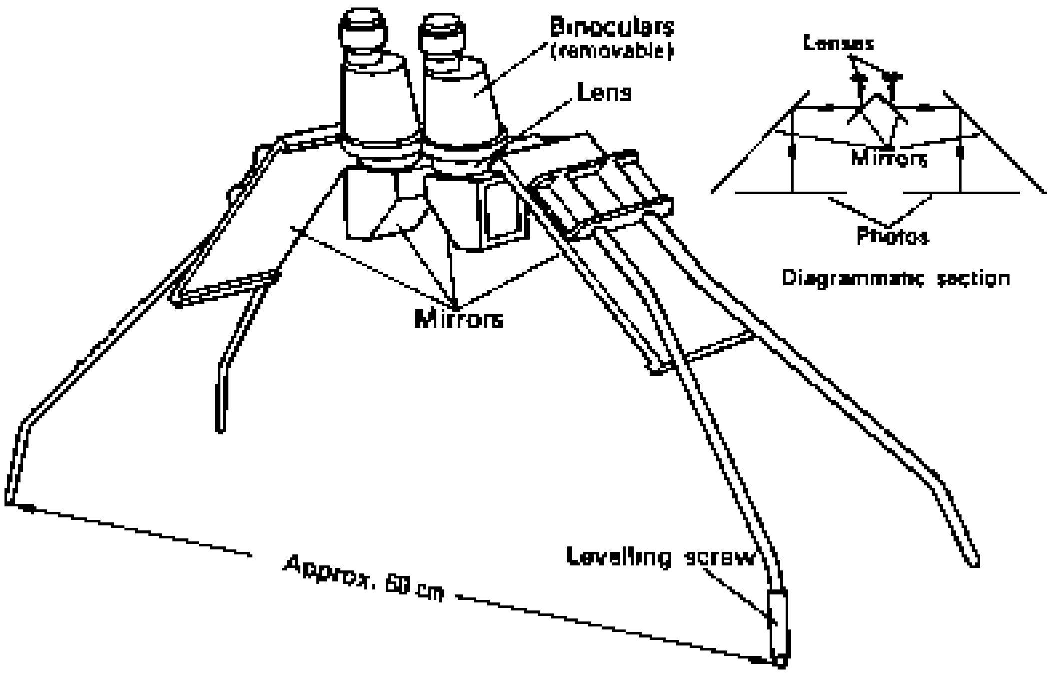


Figure 8.11 Mirror stereoscope. (After G.C. Dickinson, 1969)



iii) Twin stereoscope: This modified mirror stereoscope enables two interpreters to view the same photograph simultaneously, a considerable advantage.

8.8 <u>Orthophotographs</u>

The perspective image of a photograph can be changed to an orthogonal projection with the aid of an orthophotoscope which removes scale distortion caused by height variation. All points are thus in their correct relative locations, scale is constant and angles are true.

The most common method of producing an orthophotograph is as follows: the projection of a three-dimensional stereoscopic image produced by a stereoscopic plotter is exposed to photographic film through a very small opening moved across the stereoscopic model. As the tiny aperture moves along a narrow strip, the film remains stationary in its horizontal position but is moved in the vertical dimension to keep the aperture "in contact with the surface" of the three-dimensional image. After the aperture has moved across the model once, it is moved sideways a distance equal to the width of the opening, and the operation is repeated. More recent instruments electronically scan photographs and after correction by a computer, display the image on a video terminal.

Because of the great amount of detail on photographs, orthophotographs can be more useful than a topographic line map for compilation in the field.

8.9 <u>Mosaics</u>

Photographs can be assembled into mosaics, which can then be overprinted with selected thematic information to produce photo maps.

Since a photo is a perspective view (projection), objects may not appear in their true horizontal position; this tendency is accentuated the further the object is from the photographic centre. Therefore, only the central parts of photographs usually are used in mosaics to reduce the amount of error due to relief displacement. The central areas are carefully trimmed along line features so that joints between components of the mosaic can be easily camouflaged upon assembly.

Orthophotos can also be assembled to form a mosaic, which can be overprinted with thematic information to produce an orthophoto map. The orthophoto map has the advantage of accurate scale, in contrast with photo maps prepared from mosaics of conventional photographs, which suffer from displacement, hence scale discrepancies.

Mosaics are of three types, according to the extent of geometric control:

i) Uncontrolled: the sections of photographs are laid in place by matching the images;

ii) Semi-controlled: mosaics constructed with limited ground control are semi-controlled mosaics. With the aid of a rectifying projector, line features such as rivers are "stretched" or "shortened" for best fit to an existing map;

iii) Controlled: prior to photography, precise horizontal locations are marked on the ground and plotted on an existing accurate base map (thereby providing control). The photographs are then positioned so that the photo images of the control points coincide with the plotted control points on the base map. Ratioed and rectified prints are used to correct for perspective displacement of features.

8.10 Types of Aerial Photographic Film

There are numerous types of aerial photographic film available. The following is a partial list of films and some of their uses and advantages:

i) Colour transparency film, used for depth penetration, location of subsurface features, etc.:

- less expensive than colour negative film which requires the production of paper prints;
- good resolution (detail);
- excellent visual presentation aid;

ii) Colour negative film, used for land typing, etc. The colour prints produced from this film are:

- easy to use in stereoscope;
- excellent text illustration;

iii) Colour infrared film, used for shoreline classification, vegetation analysis etc.:

- excellent for comparison with normal colour films;

iv) Colour video film, used for depth penetration, etc.:

- quick turnaround and relatively cheap;
- suitable for monitoring dynamic parameters;

v) Black and white film, used for land typing, etc. The black and white prints made from this film are:

- less expensive than colour prints;
- useful for general coastal studies;
- easy to reproduce;
- make excellent base maps.

SECTION 9

9. GRAPHICS

Graphics are a means by which the cartographer communicates selected information clearly and easily to the map reader or data user. The information can be contained in various graphics such as maps, charts, diagrams and graphs, and aided by related textual material.

9.1 Characteristics of Graphics

The following characteristics are necessary to produce effective graphics:

i) Simplicity: The graphic should be easy to learn, remember, apply and interpret;

ii) Conciseness: The graphic should provide concise identification of the data portrayed;

iii) Uniformity: Identical graphics should be provided for similar data within the limits of the study;

iv) Informativeness: The graphics should convey enough information concerning an area to allow an immediate evaluation of its characteristics;

v) Reproducibility: The graphic should be designed for easy and economical reproduction;

vi) Talkability: The graphic units must be distinctive, easy to identify and easy to use in conversation and publications. They thus communicate an immediate and clear idea of the subject matter.

9.2 Graphic Design Guidelines

The following graphic design guidelines should be considered:

i) Measured lines should be shown by continuous (solid) line symbols in contrast to interpolations (estimates) which should be shown by interrupted (broken) line symbols;

ii) Symbols, which may be defined as a point, a line or an area (refer to Section 9.7), should be selected for ease of identification on the graphic, rather than in the legend or colour chart. This is particularly important in statistical presentations which use a single symbol repetitively, changing only one aspect, such as size, to represent a different level of data;

iii) A single graphic should not include more than three variables (refer to Section 9.5);

iv) Information that does not contribute directly to the message should be removed from the graphic;

v) The subject should be separated clearly from the background;

vi) A single colour graphic should contain a total amount of black ink that ranges from 5-10% of the figure area. This prevents the creation of designs that are too light or too dark;

vii) In general, cross hatch patterns and similar dominant designs should be avoided. Dominant patterns, common in commercially available transfer films, have a tendency to create visually disturbing and "vibrating" graphics (Figure 9.1);

viii) Dark or solid tones and intense colours should be reserved for small areas of the most significant information. Lighter tones and colours should be used for secondary information;

ix) In any statistical graphic the data may be designed for its perceived visual effect or for the ability to take accurate physical measurements from the graphic;

x) In the graphical representation of data the visual thresholds should be taken into consideration: perception, separation and differentiation (Figure 9.2).

Figure 9.1 The vibration effect obtained when graphic elements are in a 50% relation to the white background. (After International Cartographic Association, 1984)

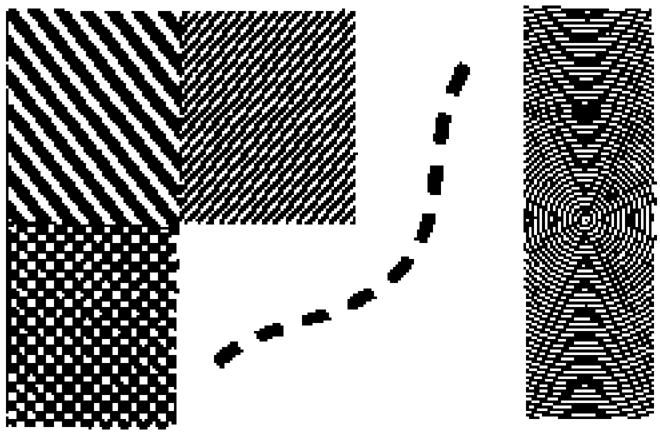
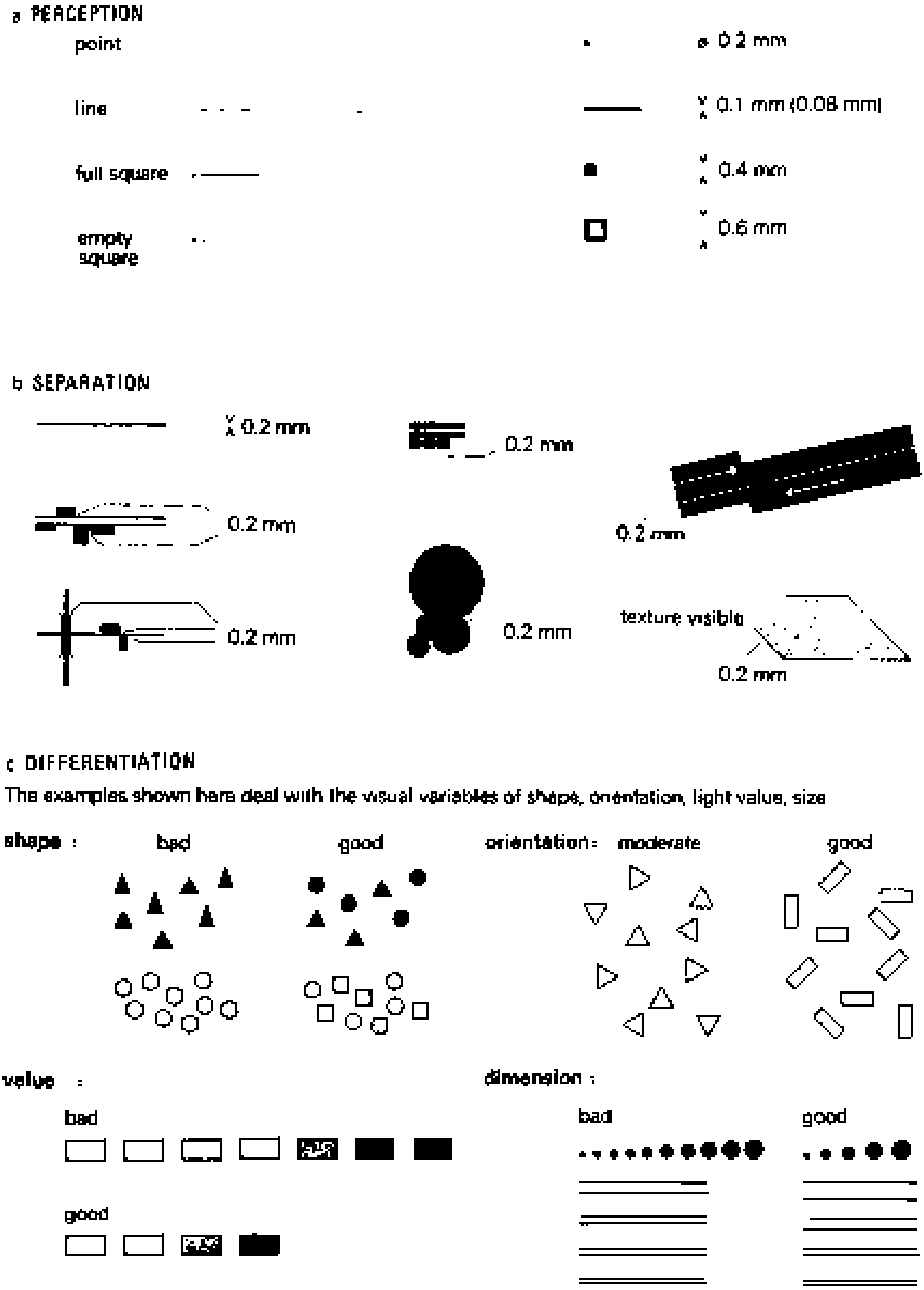


Figure 9.2 The thresholds of graphic representation: (a) perception; (b) separation; (c) differentiation. [After International Cartographic Association, 1984]



9.3 Graphic Design Checklist

Well designed graphics are easy to look at and easy to obtain information from. The following are some of the characteristics of "User Friendly" and "User Unfriendly" designs:

User Friendly	User Unfriendly
Words are spelt out. Unusual and elaborate encoding avoided.	Abbreviations abound, i.e. the viewer must sort through text to decode abbreviations.
Words run from left to right, normal for occidental languages.	Words run vertically, especially on Y-axis. Words run in several different directions.
Short messages help decode data.	Graphic is cryptic, requires repeated references to text material.
Elaborately encoded patterns, shades, tones and colours are avoided. Labels are placed on the graphic itself. No legend required.	Obscure codings require going back and forth between legend and graphic.
Graphic attracts viewers and provokes curiosity.	Graphic is repellent, i.e. filled with redundant decoration and other embellishments.
Colours are chosen so that the colour-deficient and colourblind can make sense of the graphic (blue can usually be distinguished from other colours).	Design insensitive to colour deficient viewers. Red and green used for essential contrasts.
Type is clear, precise, modest. Lettering may be done by hand.	Type is heavy, complex and unclear. The effect is overbearing.
Type is upper and lower case.	Type is all capitals.

Modified from "The Visual Display of Quantitative Information" by Edward R. Tufte, 1983.

9.4 Graphic Organization

Graphics can be subdivided into three visual levels of organization: the qualitative, ordered and quantitative levels. These levels are not mutually exclusive and many graphics can use two or even all three of the visual levels available:

i) The qualitative level includes illustrations of two or more different concepts - two different species, colours, products, trades, etc. These can be displayed as either "this is similar to that" or "this is different from that";

ii) The ordered level is a systematic arrangement of elements into a well recognized ranking, such as temperature from hot to cold or size from small to large;

iii) The quantitative level illustrates measurable or counted information, "This is twice that", "This is exactly what we measured here," etc.

9.5 Graphic Variables

There are eight variables (dimensions that can be manipulated) which are available to the cartographer to differentiate aspects of the graphic: the two dimensions of the plane, plus variations in size, value, texture, colour, orientation and shape. These variations are used to create visible marks, signs or symbols on graphics and maps. An effective design will use more than one of these variables; several if not all will be incorporated into complex products. Used alone variations in value usually prove to be the most effective. The commonly used variations in orientation and shape, often with colour, are less efficient in communicating information. To emphasize a message, "graphic redundancy" may be employed by using two graphic variables simultaneously. For instance, in traffic signals the vital stop light is larger in size in addition to being differentiated by colour. A more detailed explanation of the eight variables is as follows:

9.5.1 The two dimensions of the plane

This refers to the x and y dimensions along a sheet of paper, with information being plotted against one or both of these axes. This is the common graph and its many variants such as matrices.

9.5.2 Size

Any graphic or map symbol can be created in a variety of sizes using length, area or volume measurements. These various sizes can be ranked or ordered. A cartographic convention dictates that bigger symbols represent larger or more important features, regardless of whether the symbol is a simple point, a line or a complex symbol. Many thematic products apply a scale to the sizes of symbols shown to indicate detailed quantitative information.

9.5.3 Value

Value, also known as "lightness", refers to the variation in intensity of light as seen by the eye. On black and white drawings, this ranges from white to black as shades of grey (Figure 9.3). As this is a measurement of the amount of light reflected from a surface the notion of value applies equally to coloured graphics and maps. The colours, or hues, yellow and yellow-green reflect more light than red, brown or purple and are thus seen as lighter in value. This variation and its control are important in most graphic applications.

9.5.4 Texture

This effect is also called grain (Figure 9.4). It is closely related to value and is a reflection of the size of repeated symbols. When a pattern is photographically enlarged or reduced the value (relationship of white to dark elements) remains unchanged but the texture is affected. Varying the amount of ink in the pattern or changing the frequency of the elements will also change the value, a useful effect in many graphics.

9.5.5 Colour

Colour, more accurately termed hue, traditionally has been a much used graphic tool (refer to Section 10). The colour or hue refers to the dominant wavelength of light reflected from the graphic or map surface. Symbols produced in full-strength colours are seldom as obvious on the map or graphic as might be predicted from the colour samples used for their selection. Again it is the control of contrast which is vital; each colour must be visible against the actual background on which it will appear. Many dark colours are virtually indistinguishable from each other, particularly when overwhelmed by a strong background. Colour is a very useful tool but attention must be given to its application. If subdued tones or light tints are reserved for extensive areas, small areas of solid colour will become highly visible if superimposed on or adjacent to the light tints.

9.5.6 Orientation

The angle of any distinct symbol (except fine dot or line patterns) can be rotated and that angle given a significance or change in meaning. This can be a useful design element, particularly when combined with another graphic variable. Used alone repeatedly, it can also produce graphics which are visually disturbing and extremely hard to understand. Extensive areas of fine ruled lines and similar patterns are usually not seen as aligned symbols but as a tone. The same symbol at various angles creates the same tone, hence visual confusion. Again it is contrast which is the desired dominant effect. For the same visual reasons ruled pattern lines should not be drawn through a line symbol because the boundary will disappear.

9.5.7 Shape

Ideally the shape of a symbol should clearly represent the feature being shown. This is seldom possible because so many maps and graphics

Figure 9.3 Variation in "lightness". (After International Cartographic Association, 1984)

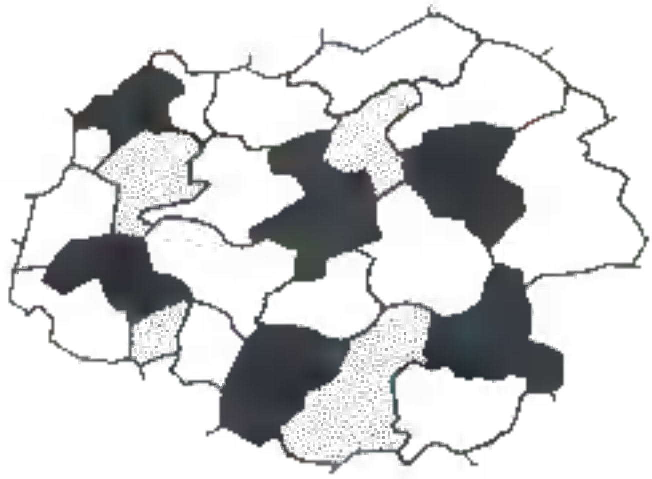
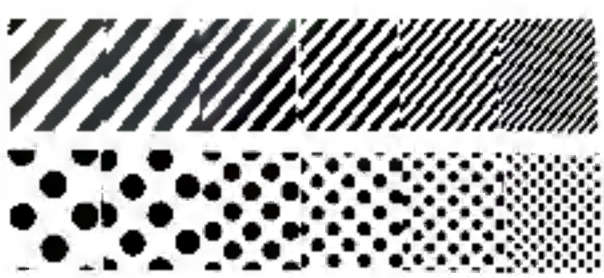


Figure 9.4 Variation in grain or texture. (After International Cartographic Association, 1984)



are produced at small scales where the true size of the object would be close to that of a small point. Many symbols, therefore, must be exaggerated in size and simplified in design in order to be visible.

The most common error is to design a large number of small symbols, approaching points in size, which vary only in shape. Against most backgrounds these minor variations are not apparent to many users. Shape, therefore, should be combined with another element, most often a change in size.

9.6 Scaling Graphic or Map Data

Graphic or map data may be scaled in four levels of measurement. They are as follows, in increasing order of precision:

i) Nominal scaling: a division of data based on qualitative considerations, e.g., a wharf, a lighthouse;

ii) Ordinal scaling: a differentiation of data within a class on the basis of rank but without any numerical value, e.g., large and small ports;

iii) Interval scaling: a ranking of data in exact standard units with differences between classes expressed in multiples of that unit. The zero point is arbitrary as in the centigrade scale, where 20 °C is not twice as warm as 10 °C, merely 10 °C warmer;

iv) Ratio scaling: as with interval scaling classes are exactly defined but in contrast the zero point is absolute, e.g., weight, distance.

9.7 Symbol Classification

In order to simplify their design or selection, symbols can be subdivided into three different classes: point, line and area. Variations of these classifications are made possible by subtle increments of the factors previously described in graphic variables (refer to Section 9.5).

i) Point symbols are individual signs such as dots, triangles, small crosses, etc., that are used to represent positional data such as towns, reefs, sample locations, soundings;

ii) Line symbols are variations on the theme of a single line representing a wide variety of data. The information can be both linear or non linear. Commonly, lines of communication (roads, railways), boundaries, rivers, etc. are drawn in this manner, in addition to flow lines, contours, depths and many forms of volumetric data;

iii) Area symbols indicate that an area has a common characteristic, which is commonly shown by the use of a tone, colour or pattern throughout the designated area.

9.8 Statistical Graphics

Statistical graphics may be subdivided into two categories (Figure 9.5):

i) graphics showing relationships between quantities;

ii) graphics indicating the portion of the whole formed by several component parts.

9.8.1 Graphics showing relationships between quantities

i) Line graph (Figure 9.6): The independent variable is normally plotted on the horizontal scale and the dependent variable on the vertical scale;

ii) Bar graph (Figure 9.7): The bar graph is similar to the line graph, but directs attention to the actual quantities, whereas the line graph emphasizes the rise and fall of the values. Bar graphs are often "turned on their side" with horizontal bars; this provides more space for names, values, etc;

iii) Circular graph [Polar chart, Clock graph] (Figure 9.8): The circular graph can be used to denote a series of values which relate to a recurrent state of affairs, a continuum;

iv) Logarithmic graph (Figure 9.9): This graph is used to indicate a rate of increase rather than the amount of increase. It will show equal rates of change by lines of equal slope, whatever the numerical basis of that change may be;

v) Scatter graph (Scatter diagram) (Figure 9.10): The scatter graph is used to investigate the relationship which exists between two variables occurring over a wide area. The relationship can be expressed mathematically by means of regression analysis, with a straight or curved line drawn through the points on the graph.

9.8.2 Graphics showing proportions formed by constituent parts

Several of these graphics are modifications of those already described:

i) Compound line or bar graph (Figure 9.11): This is used to subdivide the area beneath the line, or contained within the bar, into any number of components if the vertical line commences at zero;

ii) Divided circle or pie graph (Figure 9.12): This is the commonest statistical diagram. The total quantity concerned is represented by a circle which is divided into segments proportional in size to the components. Comparison can be made between variations in these components in two or more examples if a circle, subdivided in this way, is drawn for each of the total quantities. Circles varying in size proportionally to the total quantity which they represent can also be used;

Figure 9.5 Graphical techniques for portraying statistical information. (After G.C. Dickinson, 1973)

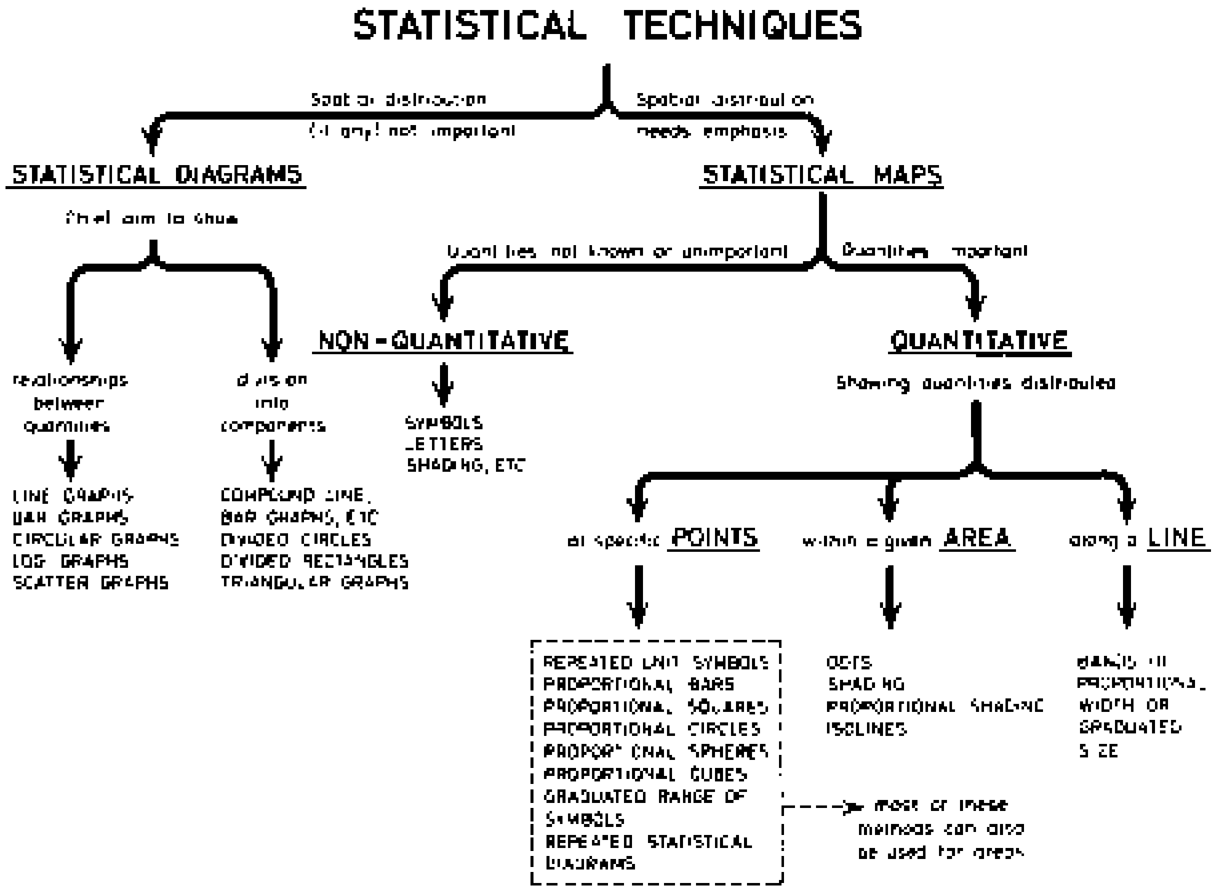


Figure 9.6 Line graph showing herring landings from 1948-78 for two Statistical Districts. (After S.N. Messieh *et al*., 1981)

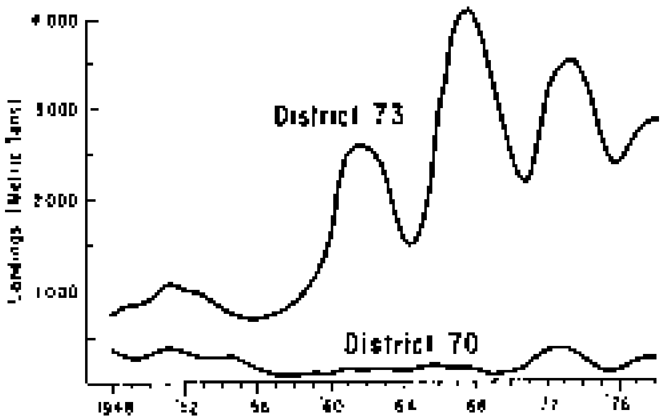


Figure 9.7 Bar graph showing the potential catch per unit effort using gillnets by Statistical Area. (After D.G. Reddin and P.B. Short, 1981)

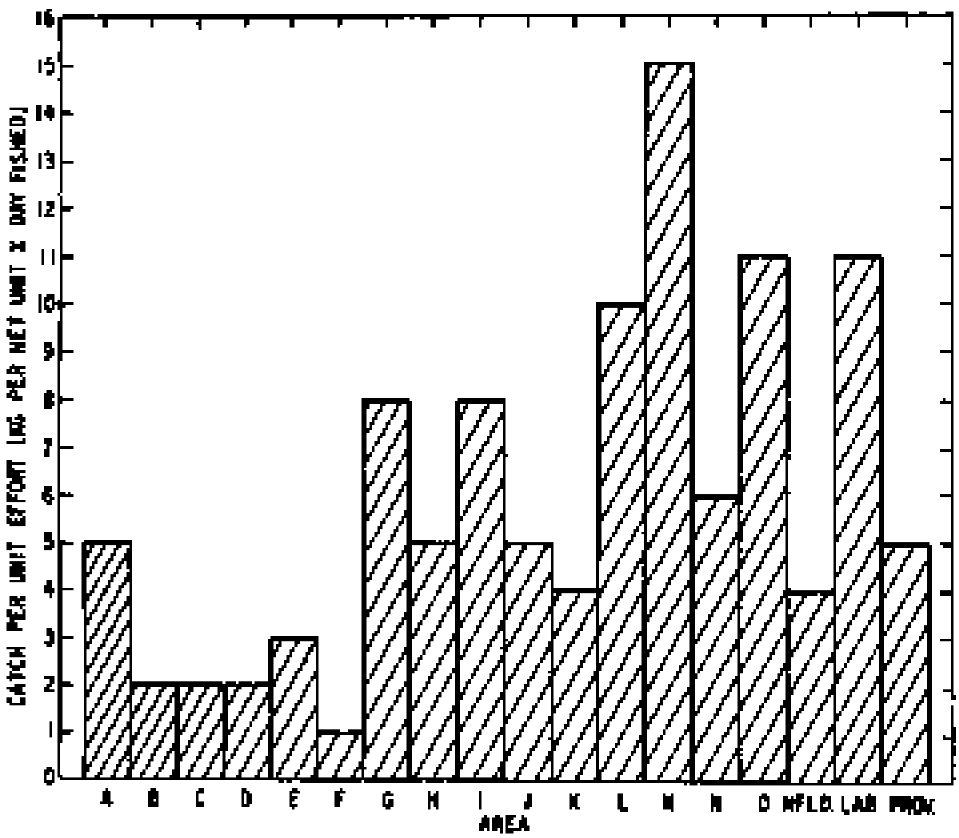


Figure 9.8 Circular graphs showing wind characteristics on a monthly basis. (After MARTEC Limited, 1982)

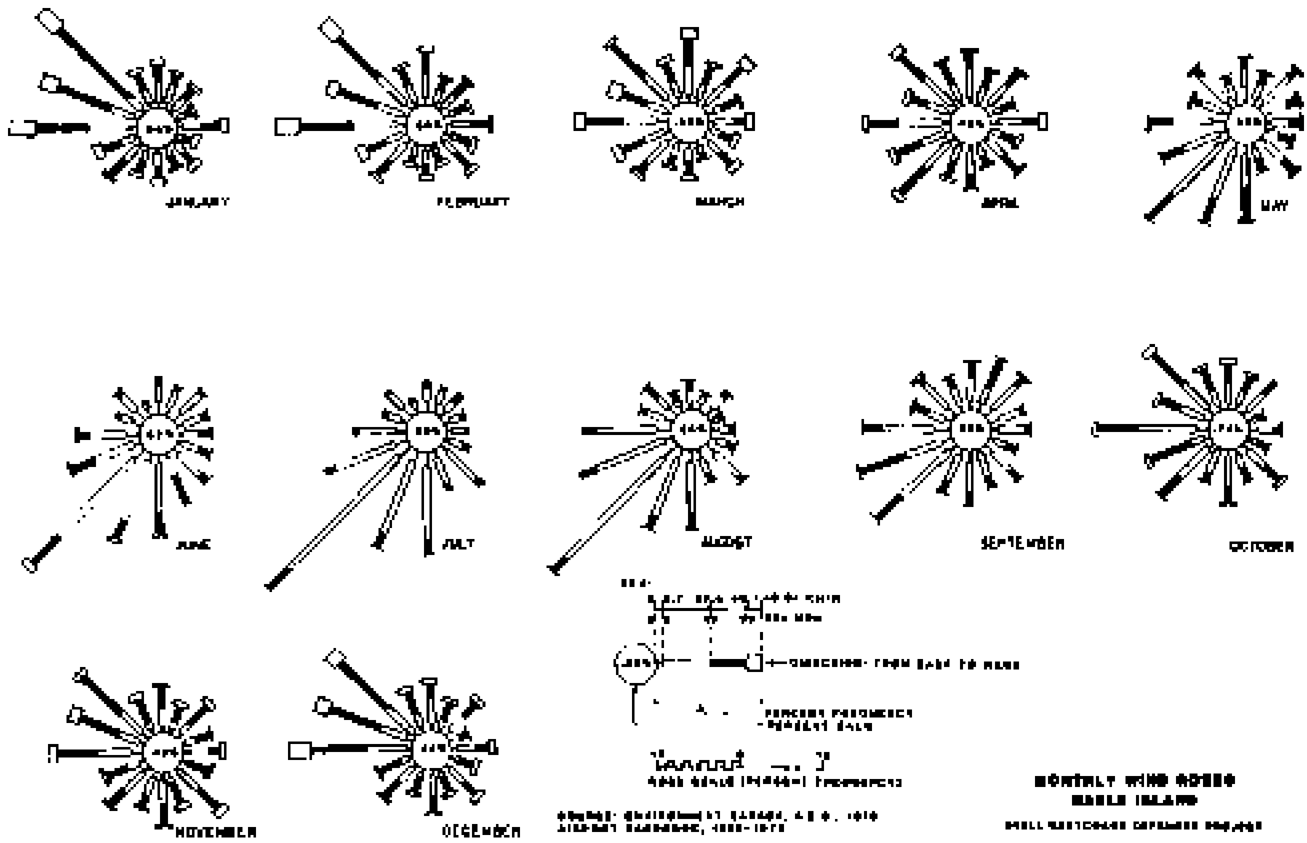


Figure 9.9 A normal line graph (a); and its logarithmic equivalent (b). (After G.C. Dickinson, 1973)

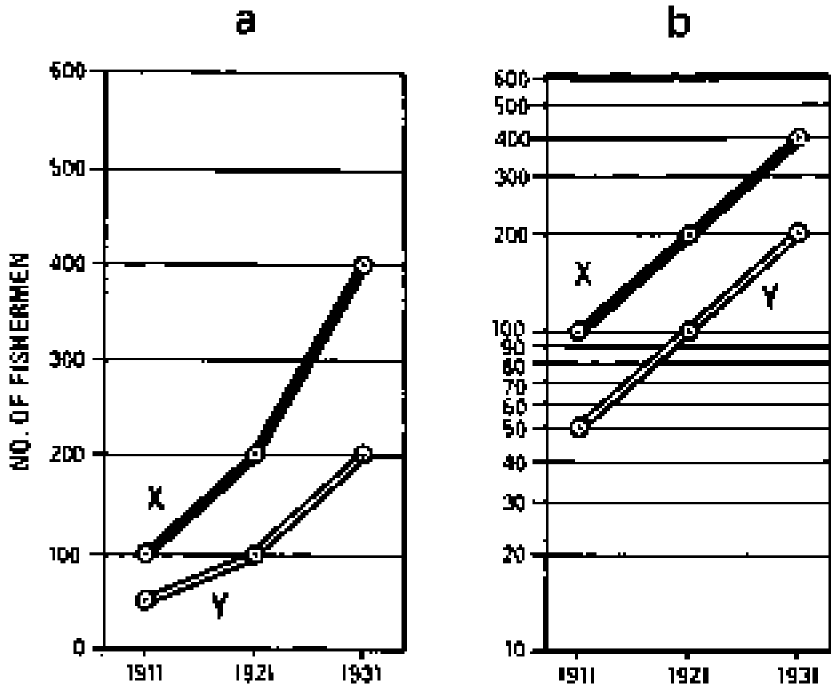


Figure 9.10 Scatter graph showing the relationship between observed and estimated year-class size of cod (After P.F. Lett, 1980)

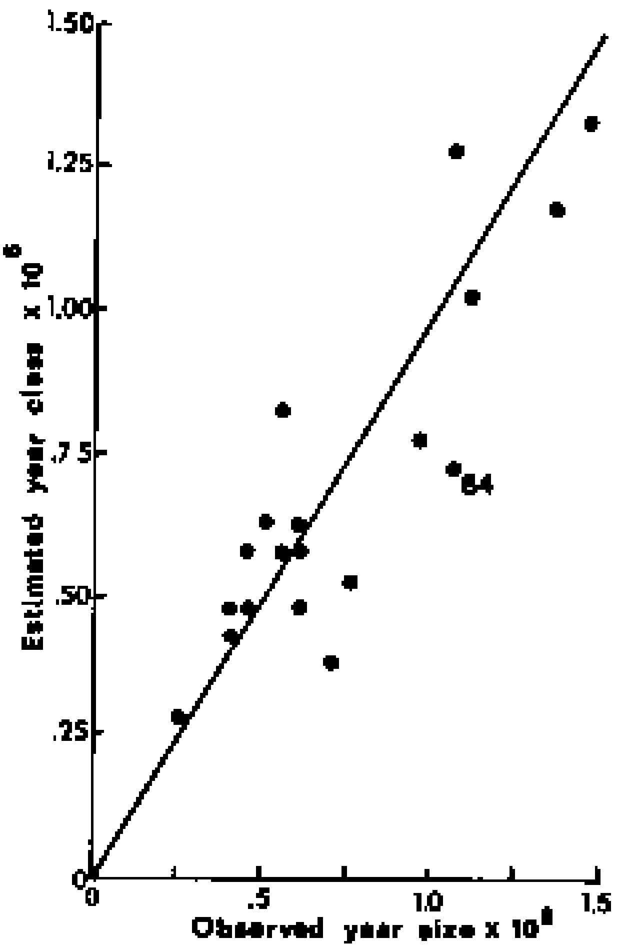


Figure 9.11 Compound bar graph showing value of Canadian exports of fishery products 1955-72. (After Canada, Department of the Environment, 1974)

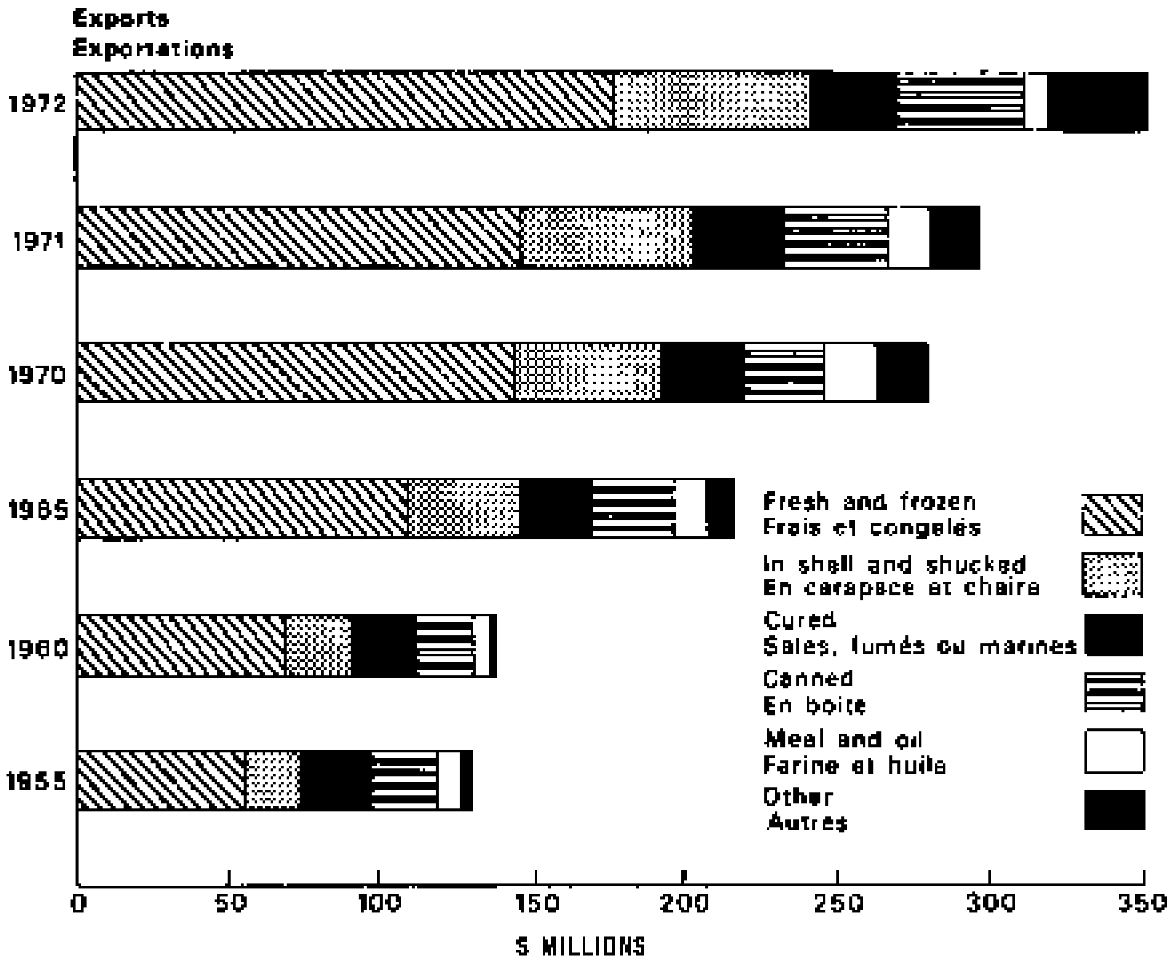
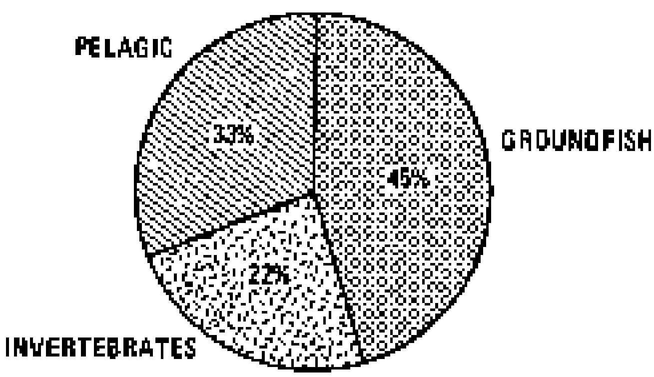


Figure 9.12 Divided circle showing percentage of total catch (weight) by major group.



iii) Divided rectangle (Figure 9.13): The rectangle, whose area may be proportional to the total quantity, is used in a manner similar to the circle and can be subdivided into layers, each representing one of the components;

iv) Triangular graph (Figure 9.14): This graph may show three variables; in both interpretation and use it has strong affinities to the scatter graph. The graph consists of an equilateral triangle with sides 100 units long, each carrying a scale running from 0 to 100.

9.9 Statistical Maps

The important element of position in statistical maps forces the cartographer to work within rather finer limits than with statistical graphics. The space available for display of any detailed information depends not only on the overall size of the whole map, but on the area of the map within which the information can be placed and still be associated with the appropriate geographic area or feature. The statistical information may be shown by non-quantitative or quantitative techniques (Figure 9.5):

9.9.1 Non-quantitative statistical maps

These maps indicate the places or areas where features of interest occur, without the need to differentiate according to size or importance (Figure 9.15). Their merit lies in their ability to summarize a situation.

9.9.2 Quantitative statistical maps

There are three main types of statistical techniques used to show quantitative distributions according to size or importance: a series of points, given areas and a series of lines.

9.9.2.1 Quantities distributed at a series of points: The following techniques are used to show quantities distributed at a series of points:

i) Repeated symbols (Figure 9.16): The symbols can be geometric, pictorial or descriptive in nature. The appeal of this quantitative method is its simplicity; quantities can easily be deduced by counting symbols and if the symbol used is representative in nature, the pictorial device makes its message easily understood;

ii) Proportional bars (Figure 9.17): The bars are simple to draw, flexible to arrange in congested areas and, because of the simple linear form, easy to estimate visually;

iii) Proportional circles (Figure 9.18): The area of the circle is proportional to the quantity represented. Since the area of the figure is proportional to the square of the radius, a symbol 100 times the amount of the other is only 10 times as large; hence, a great range of values can be represented if distinct visual steps in size are carefully chosen;

Figure 9.13 Divided rectangle showing percentage of total catch (weight) by major group and species composition within each major group.

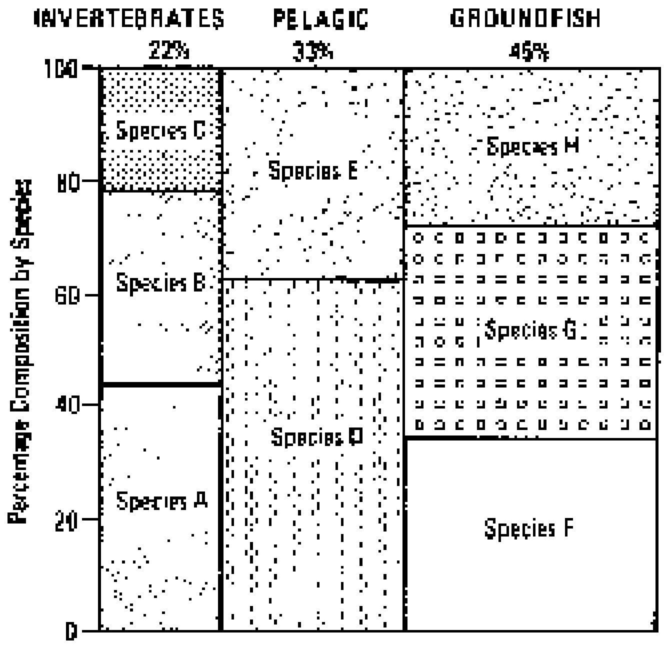


Figure 9.14 Triangular graph showing the nomenclature of sediment types. (After F.P. Shepard, 1954)

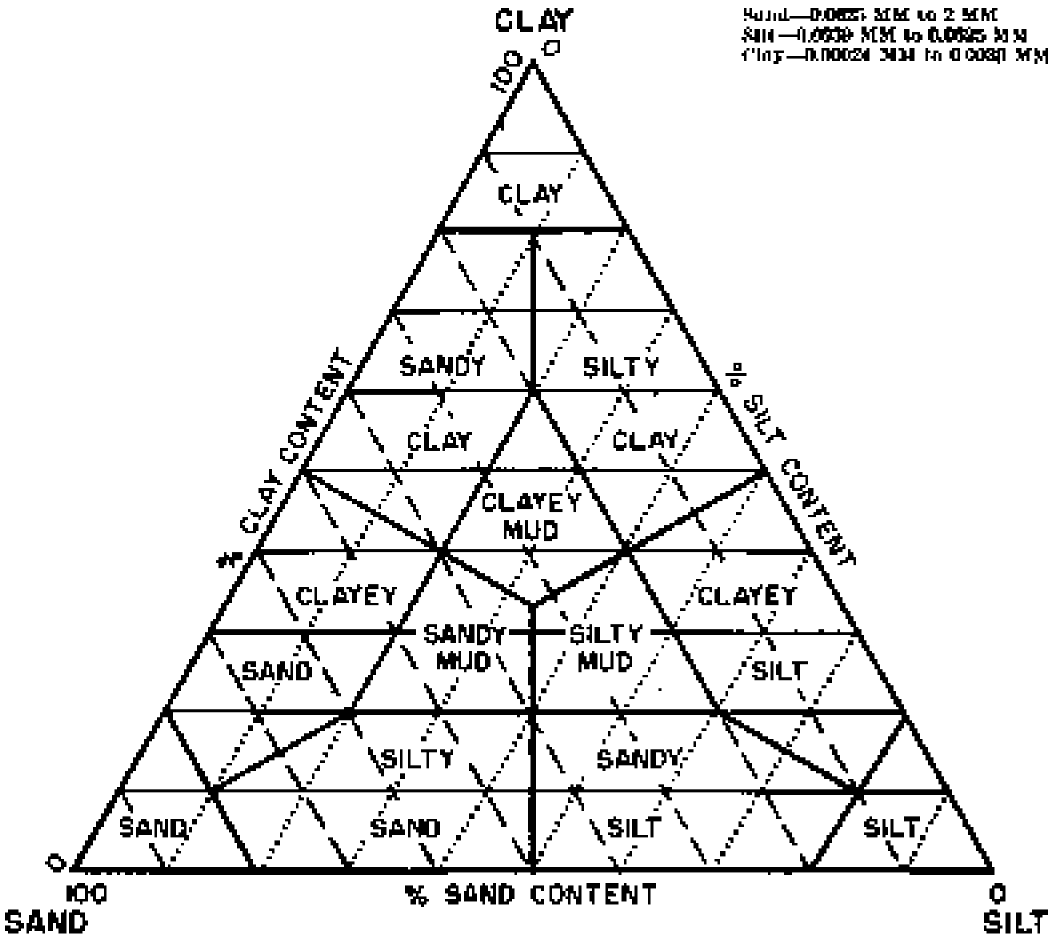


Figure 9.15 Non-quantitative statistical map. (After Maritime Resource Management Service Inc., 1986)

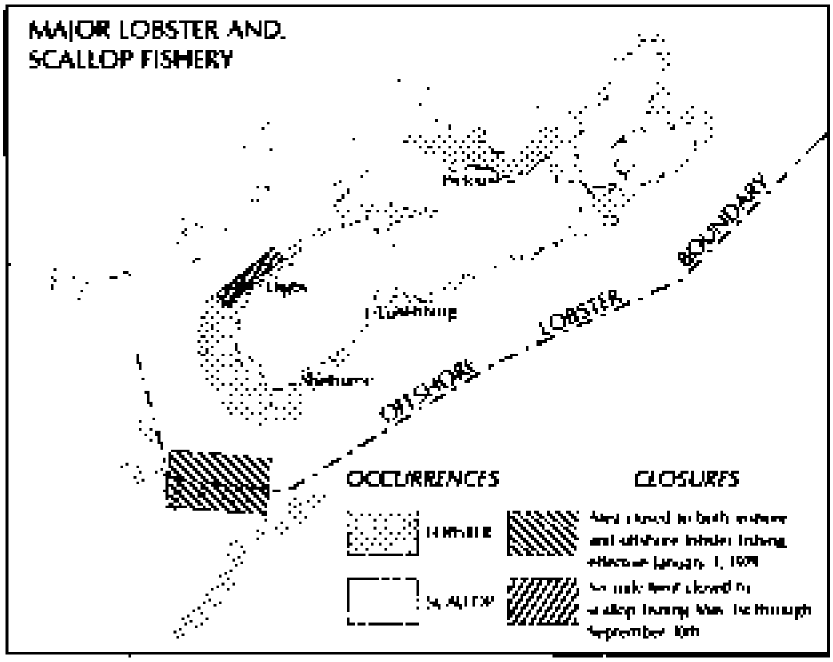


Figure 9.16 Quantities distributed at a series of points using repeated symbols. (After Canada, Department of Fisheries and Oceans, 1981)

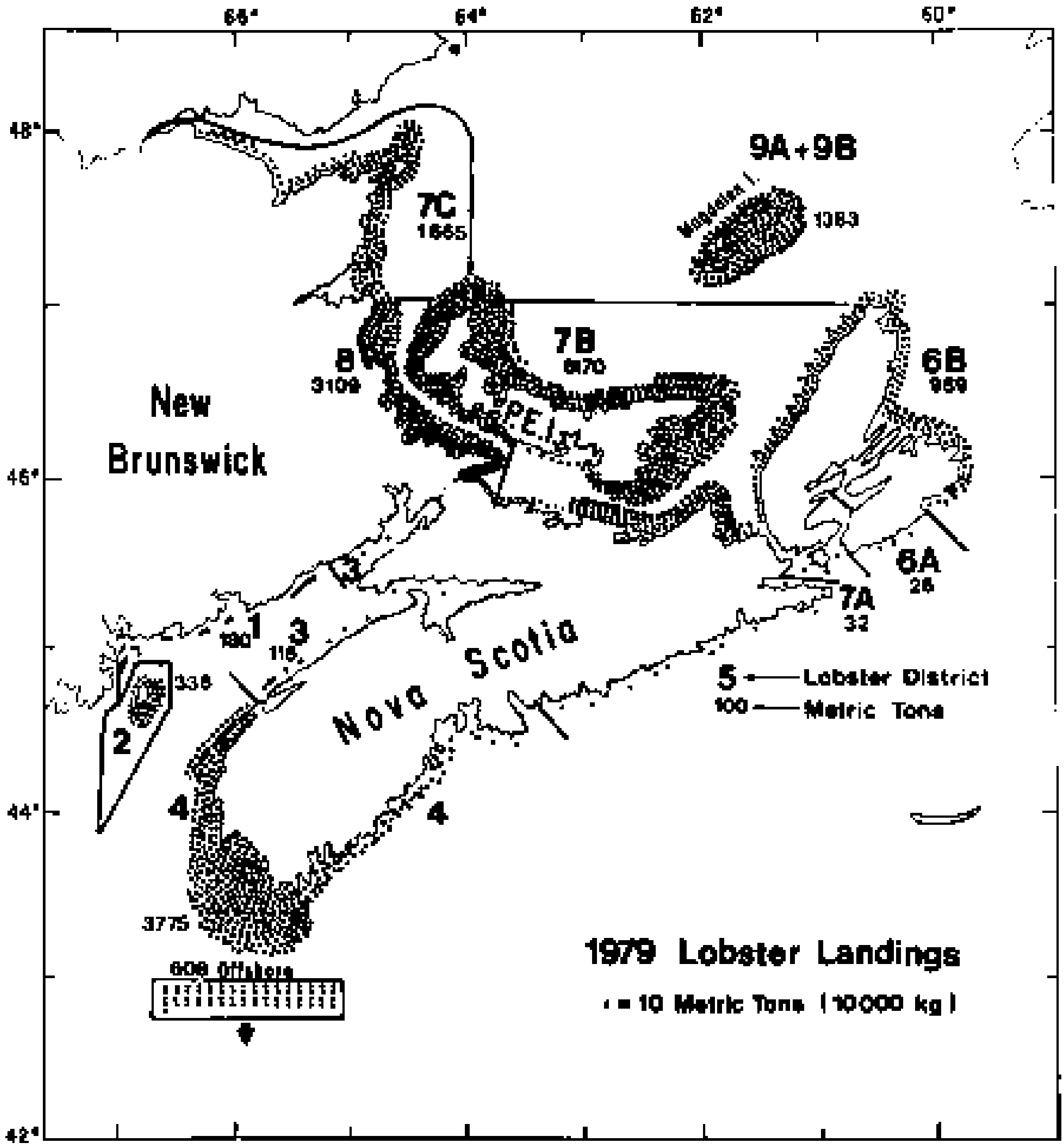


Figure 9.17 Quantities distributed at a series of points using proportional bars (simulated data).

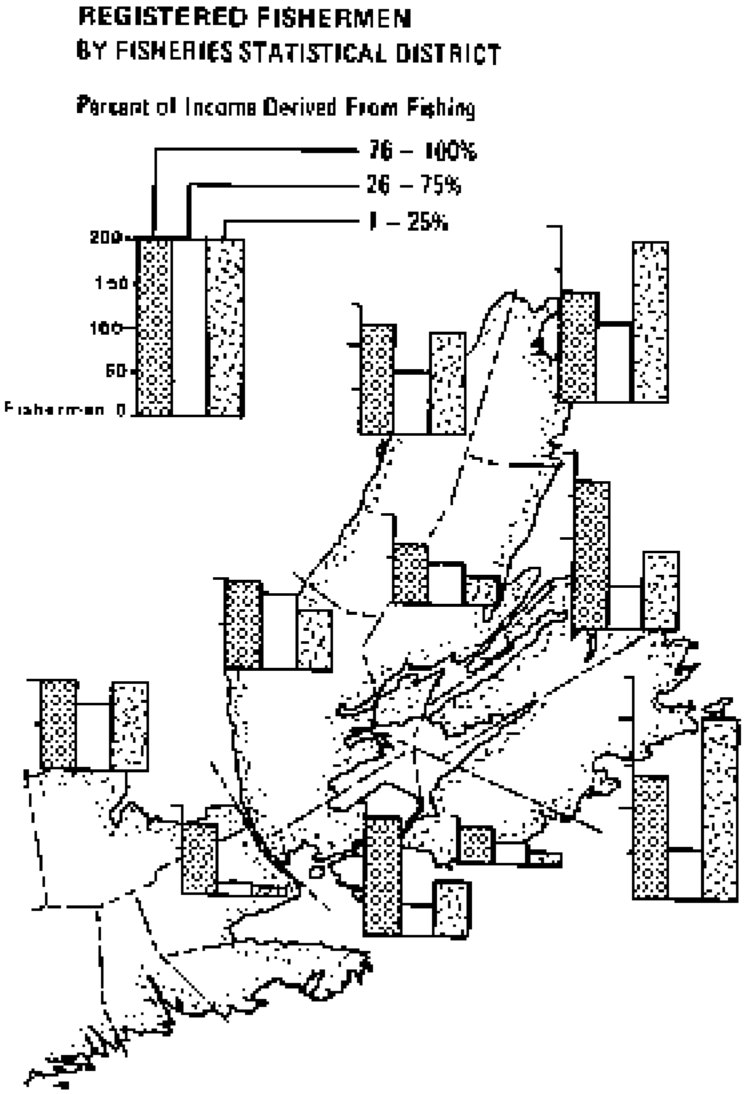
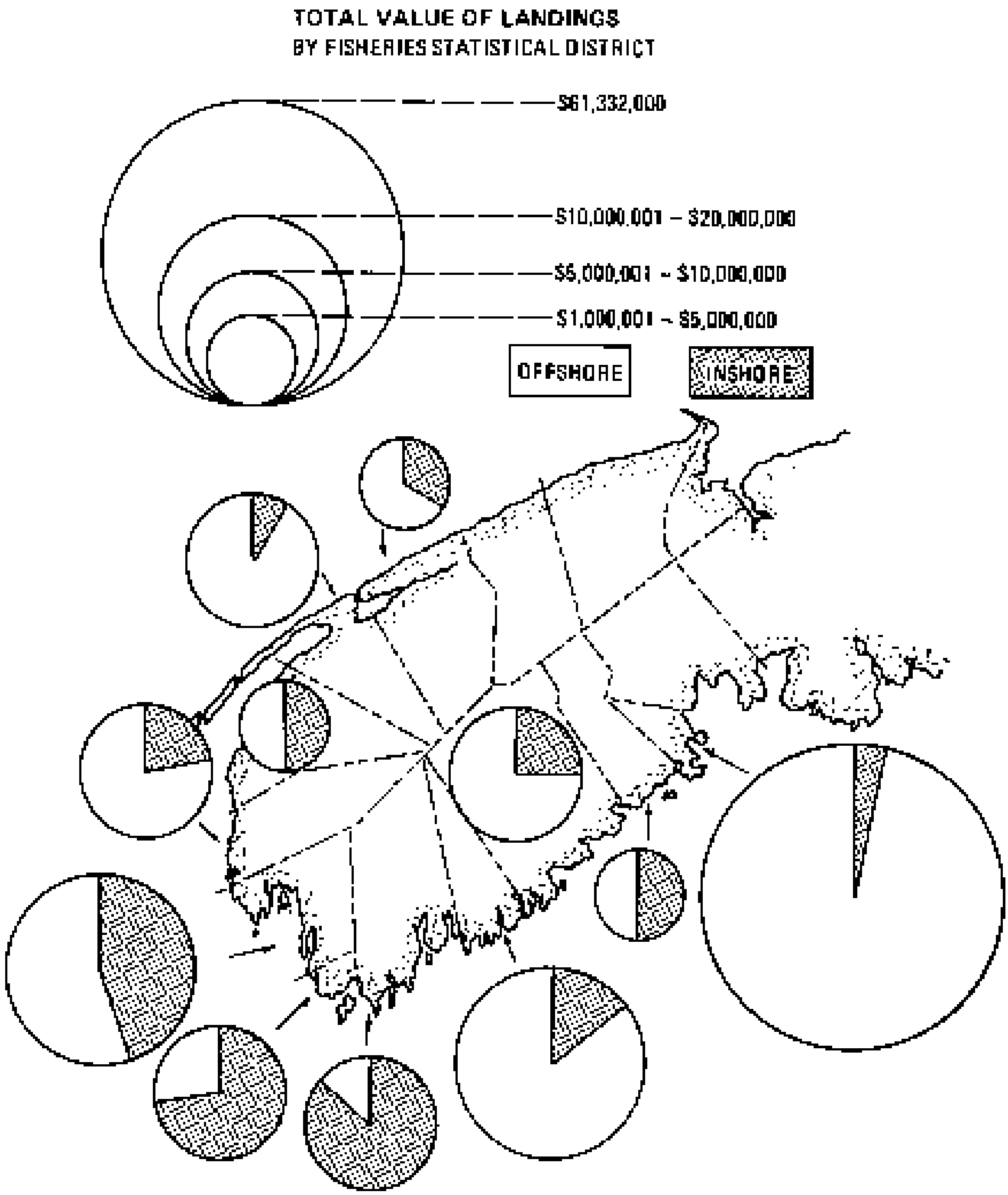


Figure 9.18 Quantities distributed at a series of points using proportional circles (simulated data).



iv) Proportional spheres and cubes (Figure 9.19): By adding a third dimension the range of value that can be considered is increased tremendously. The value of these symbols is proportional to the cube of their radius or length of side; a symbol 10 times larger than another will represent a value 1,000 times greater. (N.B. the information contained in these graphics is extremely difficult to visualize and will create interpretation problems for many users);

v) A range of graduated symbols (Figure 9.20): Each symbol represents a specific group of values, the symbols increasing in size as the quantities they represent get larger. These are preferable to proportional circles for most uses.

9.9.2.2 Quantities contained within given areas: This method of showing quantitative distribution is more common than any other type. The statistics simply indicate that within a given boundary line a certain number of features is to be found although the arrangement of features is not indicated. The following techniques are used to show quantities contained within given areas:

i) Dot maps (Figure 9.21): Although simple in principle, this technique raises design questions which need to be answered before mapping can begin:

   a) How much or how many should each dot represent?
   b) How big should each category of dot be drawn?
   c) Should the dots overlap, coalesce or be otherwise differentiated in busy areas?

ii) Shading maps (Choropleth map) (Figure 9.22): Shading methods presuppose uniform distribution of the quantity throughout the given area which is often unjustified. Each shade will represent a different density per unit of area. If colours are available it is advisable to limit the number to two or three and build up variety by using tints of each colour;

iii) Proportional shading maps (Figure 9.23): This technique not only places a value within a range but actually represents it "true to scale". Although these maps may be constructed to absolute statistical accuracy, they are usually inefficient at imparting their information. They often suffer from the common distracting defect of "visual vibration" caused by alternating black and white bands;

iv) Isoline maps (Figure 9.24): As with shading techniques, average densities are shown for each unit but this value is regarded as being typical of, rather than confined exactly to, the areas under consideration. It thus avoids the "unreal" effect which boundary lines produce on shading maps;

v) Repeated statistical graphics (Figure 9.25): Statistical graphics, previously described in Section 9.8, are used to illustrate variations in several factors throughout an area.

Figure 9.19 Quantities distributed at a series of points using proportional cubes (simulated data).

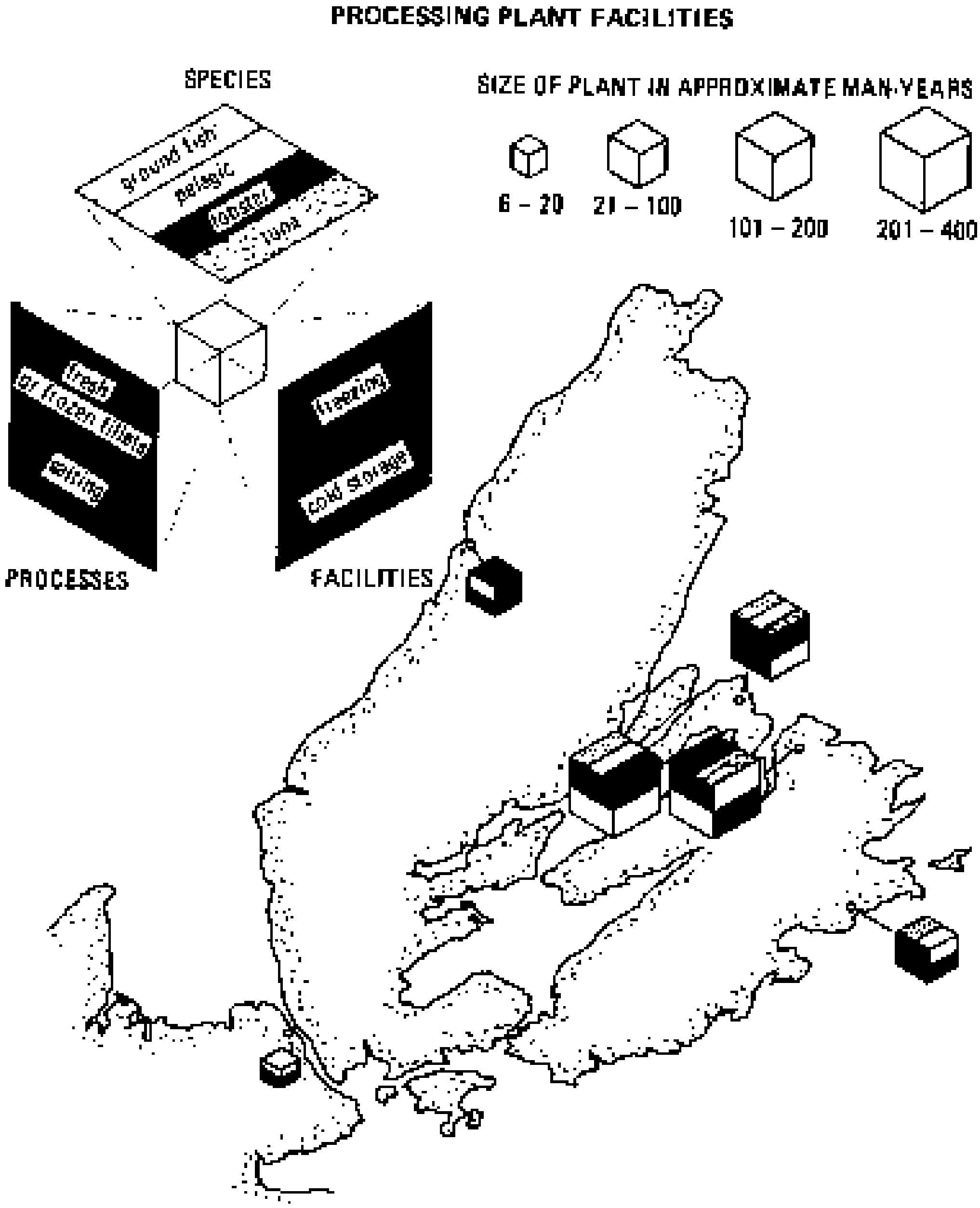


Figure 9.20 Quantities distributed at a series of points using graduated symbols. (After Nova Scotia Department of Development, 1973)

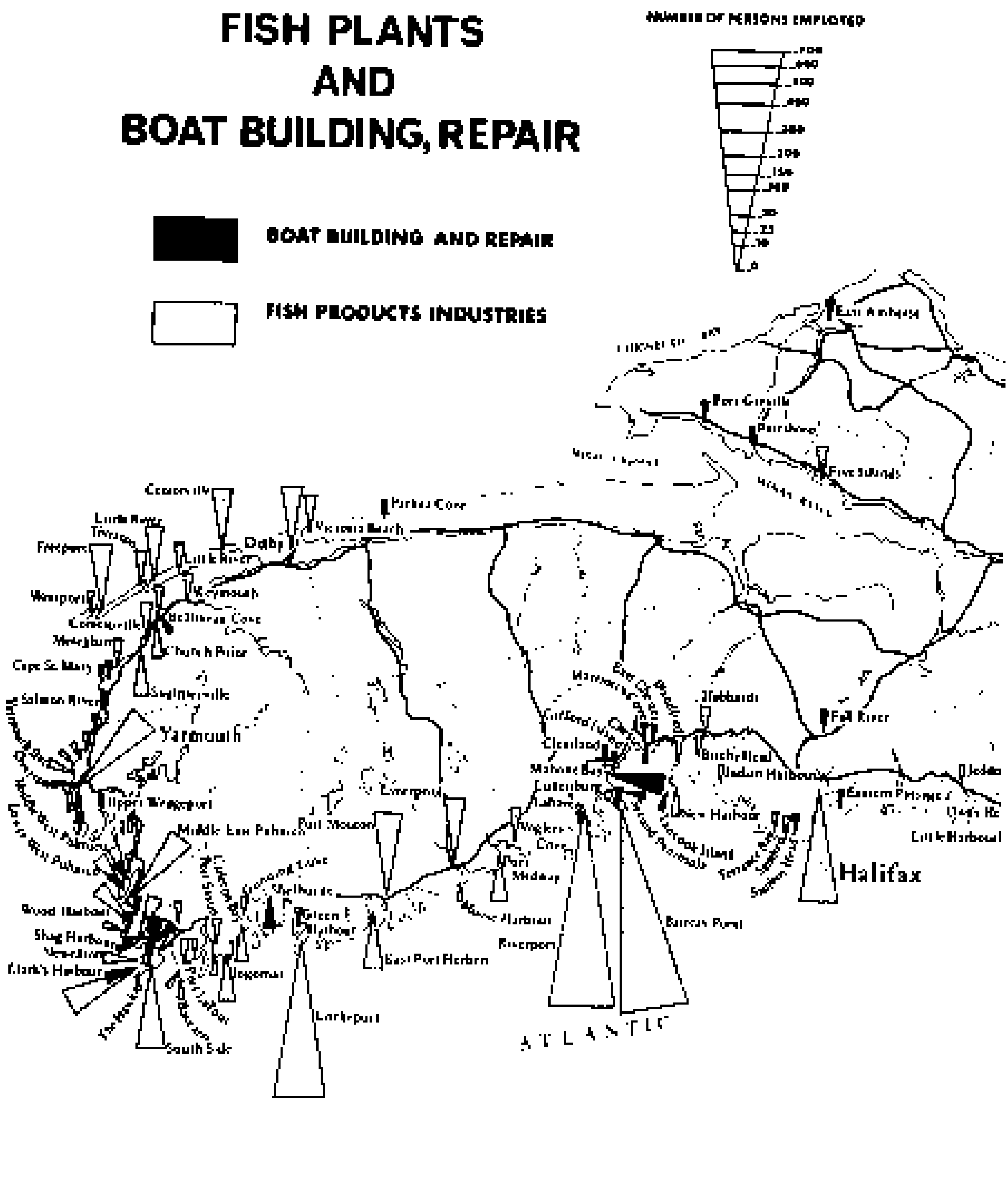


Figure 9.21 Dot map showing unit area boundaries, and the geographical distribution and relative magnitude of scallop landings. (After G.S. Jamieson *et al.*, 1981)

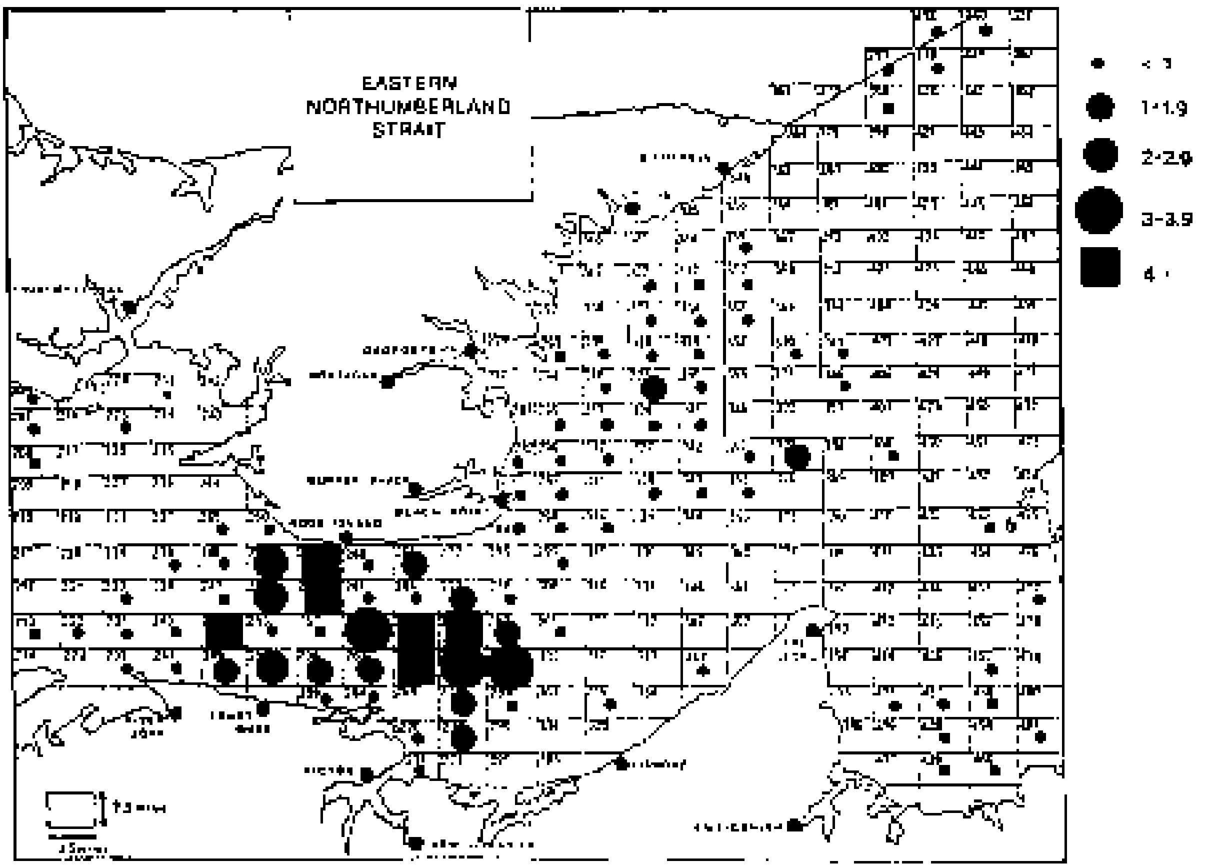


Figure 9.22 Shading map showing distribution of pelagic fish on the delta area of Burma. (After T. Stromme et al., 1981)

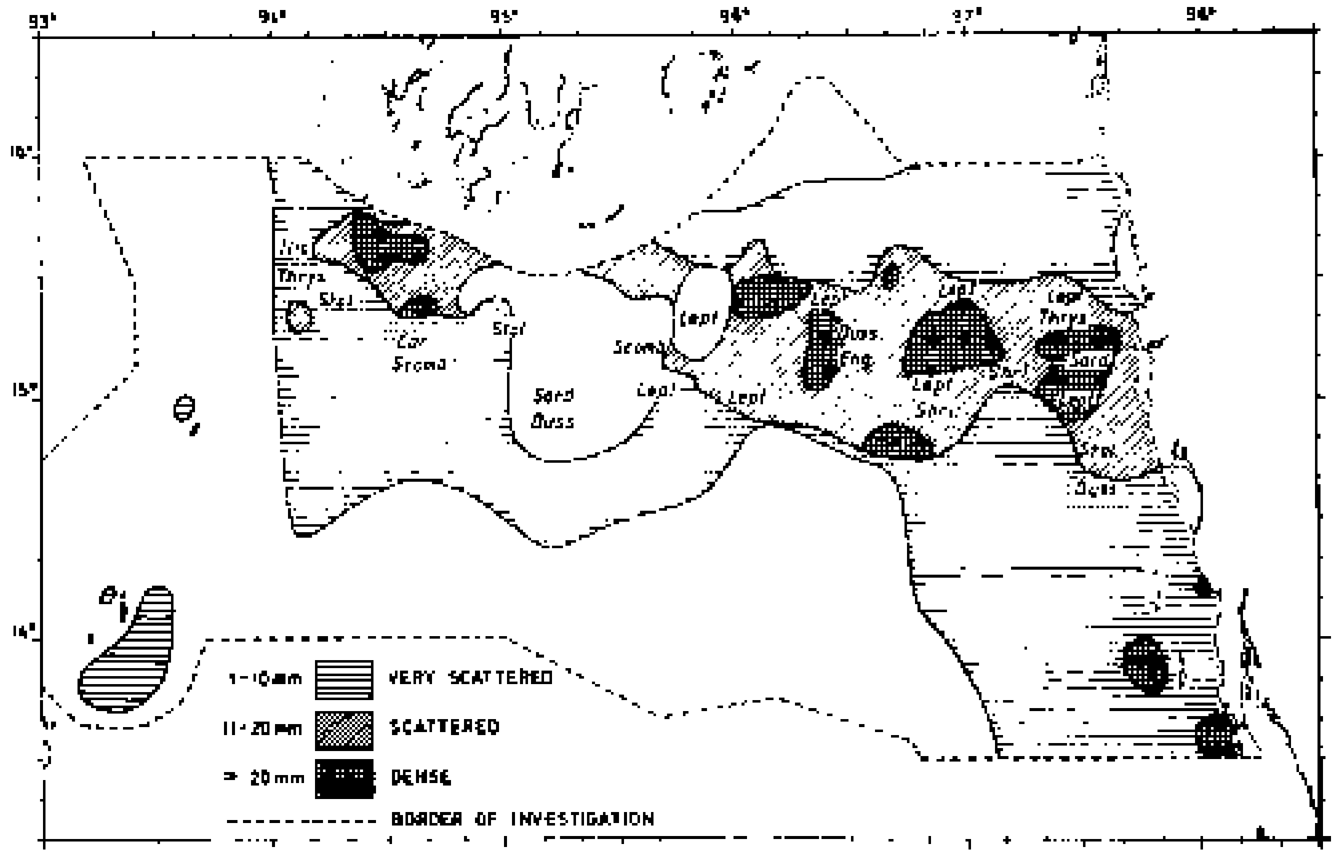


Figure 9.23 Proportional shading map. (After G.C.Dickinson, 1973)

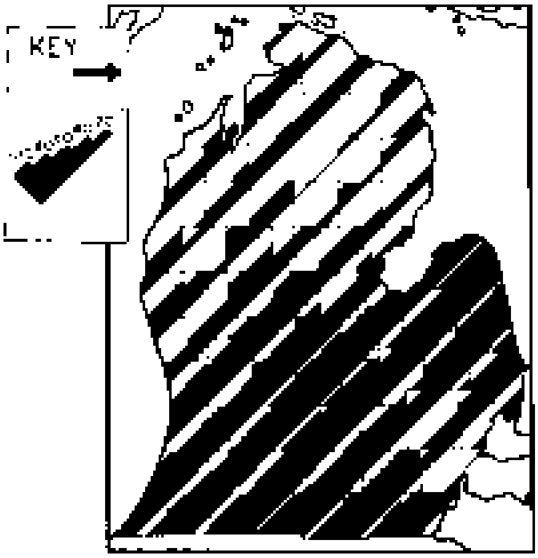


Figure 9.24 Isoline map showing abundance of herring larvae (number under an area $10m^2$) in Miramichi Bay, New Brunswick, Canada. (After S.N. Messieh et al., 1981)

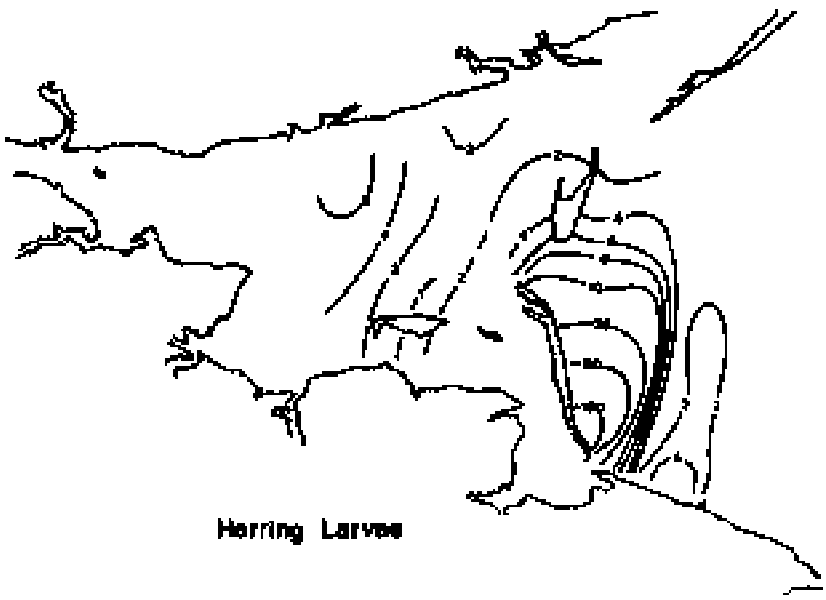
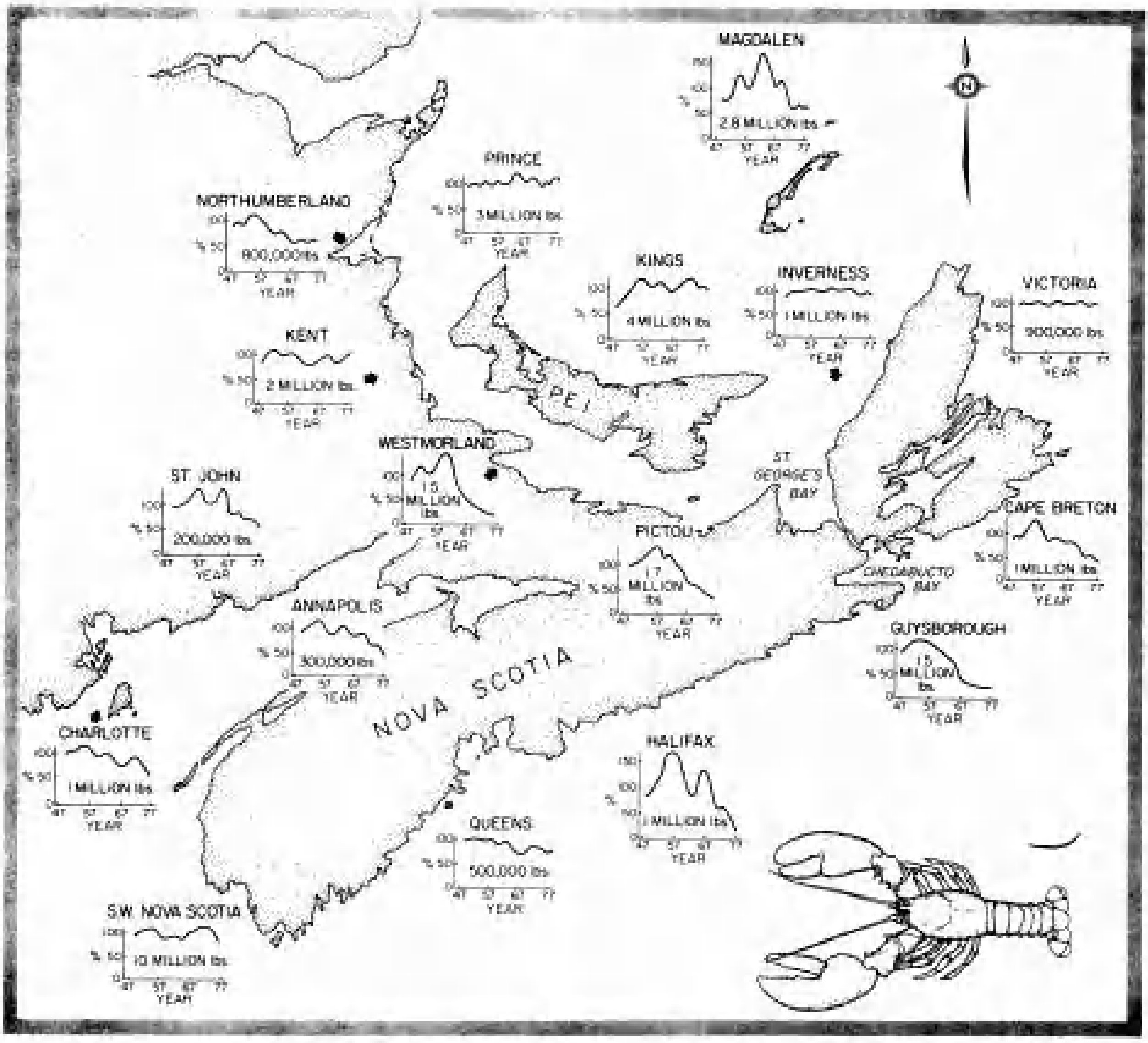
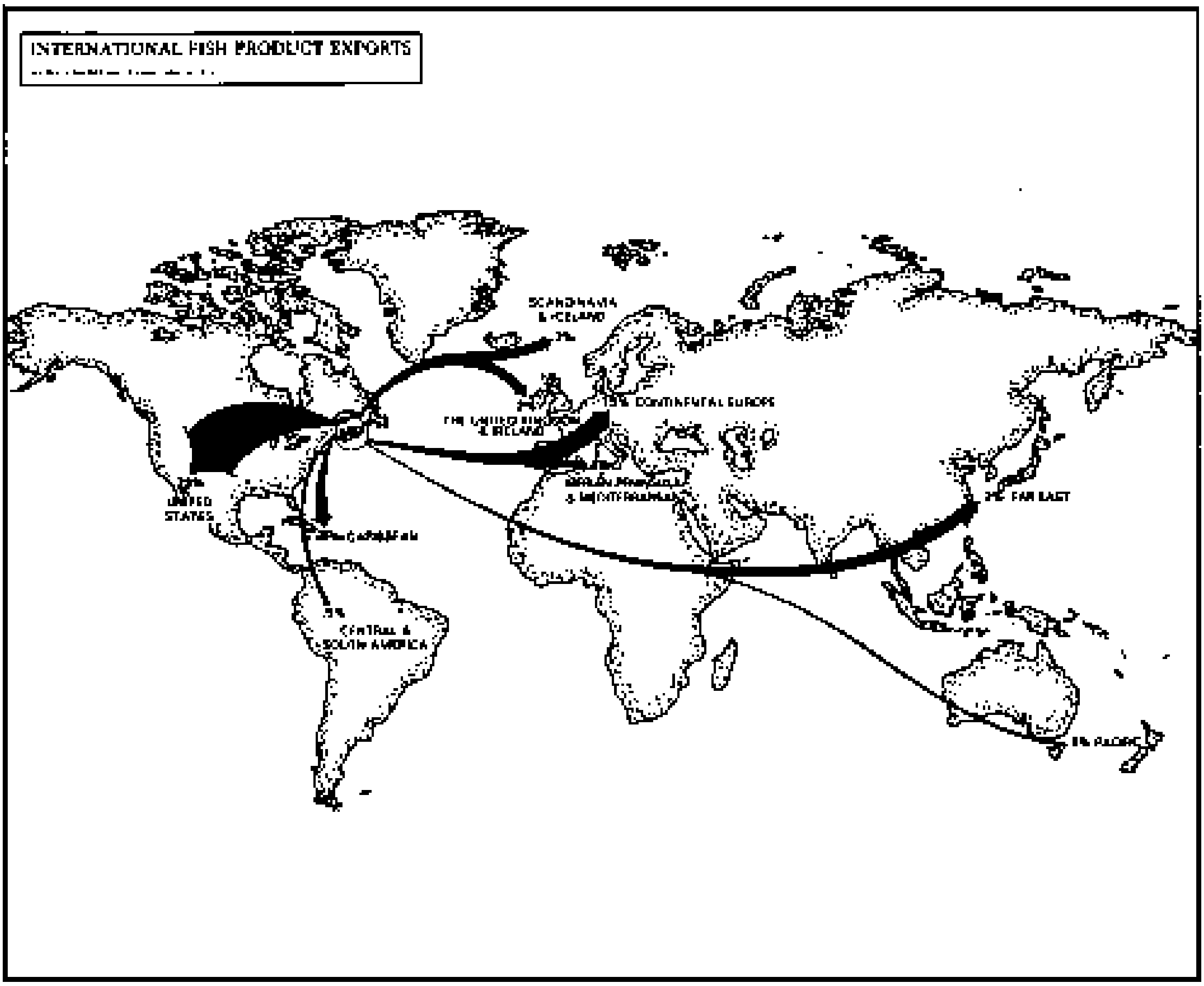


Figure 9.25 Repeated statistical graphics showing lobster landings from 1947 to 1977 in selected counties of Nova Scotia, Prince Edward Island, and New Brunswick expressed as a percentage of the mean landings during that period. (After Canada, Department of Fisheries and Oceans, 1981)



9.9.2.3 Quantities distributed along lines: The technique for showing quantities distributed along lines is commonly used in relation to traffic flows along route-ways of various kinds, e.g., line width is proportional to the quantity of traffic passing on the route (Figure 9.26). It can equally be applied to such topics as migratory routes, current flows, sediment transport, etc.

Figure 9.26 Quantities distributed along lines showing international fish product exports from Nova Scotia, Canada. (After Maritime Resource Management Service Inc., 1982)



SECTION 10

10. COLOUR BASICS

Colour exists on a map or graphic for the purpose of communication. The use of colour is of special relevance to marine and navigational charts, topographic maps and thematic maps whose primary purpose is to create a mental image of some of the characteristics of the region.

Communication in colour is more effective if the colours used are appropriate. Individual colours often have widely different cultural connotations with which the cartographer must be familiar. The colour blue, for example, can symbolize coolness, wetness, truth, constancy, loyalty, wisdom and despondency; in China it is the colour attributed to the dead. Similarly, red, which is an emotion-compelling colour, can symbolize heat, love, valour, energy, fire, cruelty, danger, wrath and sin; in China it is the colour of the living.

Colour is both used and abused widely. The psychological aspects of colour are commonly exploited in the fields of advertising and propaganda. A careful study of successful local advertising techniques in the cultural "target market" will often result in an appreciation of appropriate colour responses.

10.1 Colour Characteristics

10.1.1 Hue

Hue refers to the specific wavelength zones of the electromagnetic spectrum and is the unique quality of a colour referred to by name, e.g., blue, greenish-blue, etc. Most natural and man-made colours are composed of combinations of wavelengths which approximate the spectral hues of a rainbow as seen when white light passes through a prism and is split into its component parts.

10.1.2 Value, lightness or brightness

This refers to the relative lightness or darkness of a colour and is a measurement of the extent to which the colour reflects light. Thus brown and red are dark colours in comparison to yellow which is light. Value is considered to be the most significant aspect of colour, because it is a primary factor in the recognition of graphic variations. In the absence of colour, value ranges from white to black through intensifying shades of grey. Untrained eyes can readily perceive five steps in value from white to black.

10.1.3 Intensity, chroma or saturation

This refers to the strength or fullness of a colour in comparison to a neutral grey, as described by the terms "brilliant" blue or "dull" green. A spectrally-pure colour is fully saturated; if the colour is diluted by the presence of other wavelengths of light as happens when it is screen tinted onto white paper, a desaturated hue results. Thus pink, which is created by screen tinting red, can be thought of as a desaturated red.

10.2 Evaluating Colour Characteristics

The three basic characteristics of colour discussed above do not occur separately.

Value is the critical dimension of colour from the point of view of perceptibility. In contrast, hues arouse emotions or reactions, the most obvious being the warm-cool connotations already mentioned.

Intensity would seem to be the least significant of the three characteristics of colour, but it is a useful cartographic tool. The ability to differentiate between different saturations of the same hue is strongly affected by the area of the images and the spatial separation of the units. Adjacent legend blocks having the same hue with varying saturations can be easily identified. The differences, however, will not be as apparent if the coloured areas are widely separated on the graphic.

Against the normally complex background of a typical map with its varied symbols, text and area tints, fine lines of different colour appear identical. Fine discriminations in hue, saturation and value are only possible if there are no other distractions such as adjacent dominant colours. A fine line is the cartographic symbol most difficult to differentiate by colour, because it approaches the limits of perception. Differentiation by hue alone is the most common cartographic error in colour usage. Many different hues have visually the same darkness or lightness value and are therefore hard to differentiate. This is particularly true of fully saturated intense colours. Contrast effects are greatly improved when pastel shades or desaturated hues are employed for larger background areas. Thus if differentiation of fine lines by colour is necessary a second variable such as line width will ensure a clearer distinction. The same considerations apply to the use of small point symbols. Graphic redundancy again makes symbol differentiation clear (refer to Section 9.5). Maximum clarity occurs when hue, value and intensity are all manipulated deliberately to accentuate the vital aspects of the graphic and to subdue the related or background material.

10.3 Screen Tints and Halftone Screens

Most coloured maps will be reproduced by printing on an offset or similar press (refer to Section 12), using inks which deposit a pigment onto the paper. The colour or hue of the selected ink is fully saturated when printed as a solid colour; desaturation of the solid colour, resulting in a colour tint, can be achieved by the use of photomechanical screen tints. Screen tints are reproduced on film or glass and consist of highly precise, closely spaced dots of a given size arranged in a rectangular pattern. The dot spacing on a particular tint screen is identified by the number of lines of dots per inch. A 65 line screen tint having relatively few large dots is considered coarse in comparison to a fine 150 line screen tint having many small dots. A fine screen tint will produce an even tonal effect in contrast to a coarse screen tint.

As the reflectance of light from a white surface is higher than from any coloured surface, a screen tint will increase lightness and decrease saturation. Screen tints are identified by the tone resulting from their use. A 10% screen tint will produce a light tone with only 10% of the surface area being covered with ink. Conversely an 80% screen tint will produce a strong, dark colour or tone. Usually screen tints are available in increments of 10% giving a large number of gradations of a single colour on one plate (Figure 10.1). Recent developments in the graphic arts industry are computer-controlled laser platemakers which are capable of producing any desired size and density of dot. This gives complete control over colour saturation and makes possible subtle gradations and colour mixtures very difficult to obtain by conventional methods. The cartographic potential of these machines is considerable.

The use of screen tints can result in considerable cost savings in colour printing. By using only two coloured inks and combining them using screen tints, a range of several colour variations may be achieved. Even if a number of these colour combinations or individual tints is discarded as not visually distinct, two coloured inks have considerable potential for the economical and attractive display of information. Many graphic products in the field of marine resources could easily be produced with such a simple combination as black and blue. Printing one or two coloured inks onto coloured paper is another economical solution.

In contrast to screen tints, which are used to represent selected areas in uniform grey or coloured tones, halftone screens are used to represent continuously changing ranges of tones or "continuous-tones" such as those found in hill shading or aerial photographs. Halftone screens are introduced in the photomechanical process because the printing process cannot easily reproduce continuous-tones. In contrast to screen tints which reproduce dots of consistent size, halftone screens produce dots which vary in size depending on the amount of light that reaches the film. The darker areas on the original reflect little or no light and produce large clear dots. The lighter areas reflect more light and produce smaller clear dots. This results in a negative of the original composed of dots of varying sizes.

10.4 Colour Spectrum

Light is the small zone of the electromagnetic spectrum which is visible to our eyes (Figure 10.2). This zone is measured in wavelengths ranging from approximately 0.4 to 0.7 micrometres (one thousandth of a millimetre or one millionth of a metre). If a beam of white light is passed through a prism, the different amount of refraction of the various wavelengths causes it to split into its component parts. The same effect occurs when light passes through rain creating the rainbow. In the case of the prism we refer to the series of different spectral hues or colours displayed which the human eye can discern as the visible spectrum.

The shorter, higher energy wavelengths are the violet-blues near the 0.4 micrometre end of the spectrum. The longer, lower energy, wavelengths are the reds near the 0.7 micrometre region of the spectrum. The order of the spectral hues, known as spectral progression is violet, blue, blue-green, green, yellow-green, yellow, orange, and red in decreasing energy

Figure 10.1 Examples of screen tints expressed in 10% increments. (International Cartographic Association, 1984)

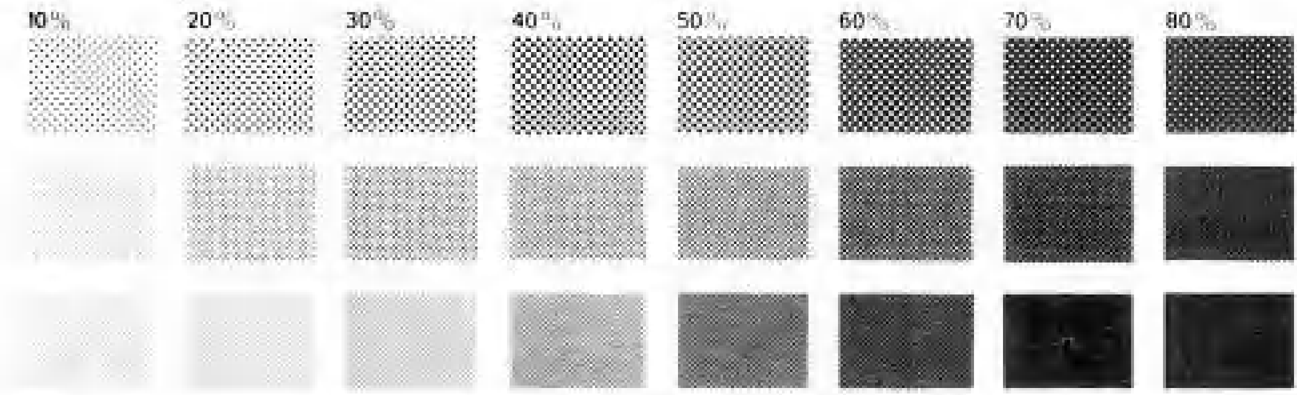
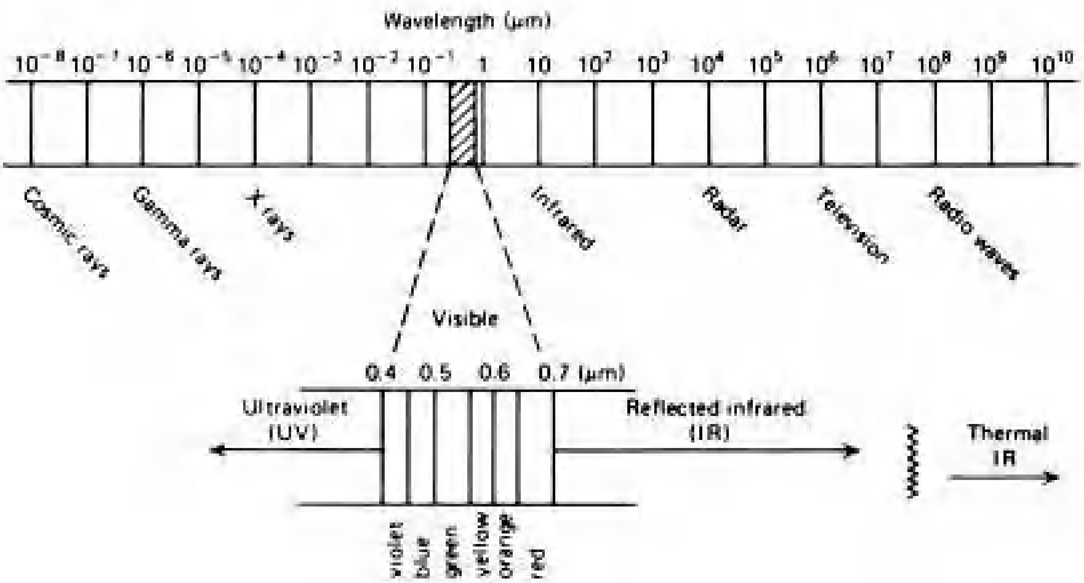


Figure 10.2 Electromagnetic spectrum. (After D.P. Paine, 1981)



levels or lengthening wavelengths. This sequence, being a natural and familiar one to most people, is a logical choice when colours must be arranged in an ascending or descending manner.

Examination of the human eye has shown that it is most sensitive to coloured light at wavelengths of 0.55 micrometres, that is the yellow-green zone which occurs in the centre of the visible spectrum. The sensitivity drops off rapidly on both sides of this point, the lowest sensitivity being at the violet and red extremes of the spectrum. The perceived lightness or darkness of various colours is a measure of our visual sensitivity to the light received. Thus violet-blue and red are perceived as dark because of our relative visual insensitivity to these wavelengths. In contrast the yellow-green region of the spectrum is perceived as being light due to our relative visual sensitivity to these wavelengths. For example, in many regions of the world emergency fire-fighting vehicles were originally painted intense red, the most emotion provoking colour. In recent years, however, most of these vehicles have been repainted a yellow-green colour which has proved to be highly visible against the dark background of our cities. In some areas the accident rate of these vehicles dropped dramatically after the colour change.

10.5 Colour Contrast

For any pair of colours, maximum contrast occurs when hues of varied value are selected to maximize this effect. The following list ranks contrasting colours in a decreasing order:

Black on Yellow (most contrast)
Green on White
Blue on White
White on Blue
Black on White
Yellow on Black
White on Red
White on Orange
White on Black
Red on Yellow
Green on Red
Red on Green
Blue on Red (least contrast)

Both extremes of the list are worthy of note. Yellow on black is far more visible than the conventional white on black. Red on green and blue on red are combinations of dark colours with low relative contrast which will create a visibility problem. The red/green combination is also the one which people with colour deficiencies have the greatest trouble differentiating.

10.6 Primary Colours

Primary colours are those used to create other colours. Some special colours cannot be produced by mixing the primaries. Special coloured inks are printed for this purpose, for example, the brown colour in Figure 13.9. There are three conventions in common cartographic usage for defining primary colours:

i) artistic primaries;
ii) additive primaries;
iii) subtractive primaries.

The additive and subtractive primaries are sometimes referred to collectively as optical primaries.

10.6.1 Artistic primaries

Artistic primaries are commonly defined as blue, yellow and red. From these colours, most other colours can be created with inks or paints. Thus mixing yellow and red produces orange, red and blue results in violet and blue and yellow gives green. Intermediate colours are obtained by varying the strengths of the hues. Artistic primaries are based on the subtractive principle (refer to Section 10.6.3). Each tint or pigment absorbs some part of white light and the perceived colour is what is left over. Artistic primaries are used in mechanical colour separation, the conventional cartographic method of obtaining various colours. Their use has the disadvantage of requiring many separation overlays but the resulting colours can be easily controlled.

10.6.2 Additive primaries

The blue, green and red bands may be referred to as one-third colours, each comprising approximately 1/3 of the visible spectrum. When white light passes through a prism, the blue, green and red colours cannot be further subdivided, hence the term primary colour. When correct proportions of blue, green and red light are projected together, the other known colours can be created. Also, in the correct proportions, a mixture of all three produces white light. Thus the one-third colours blue, green and red are known as the additive primaries. A complete colour system is possible from the three additive basic or primary colours.

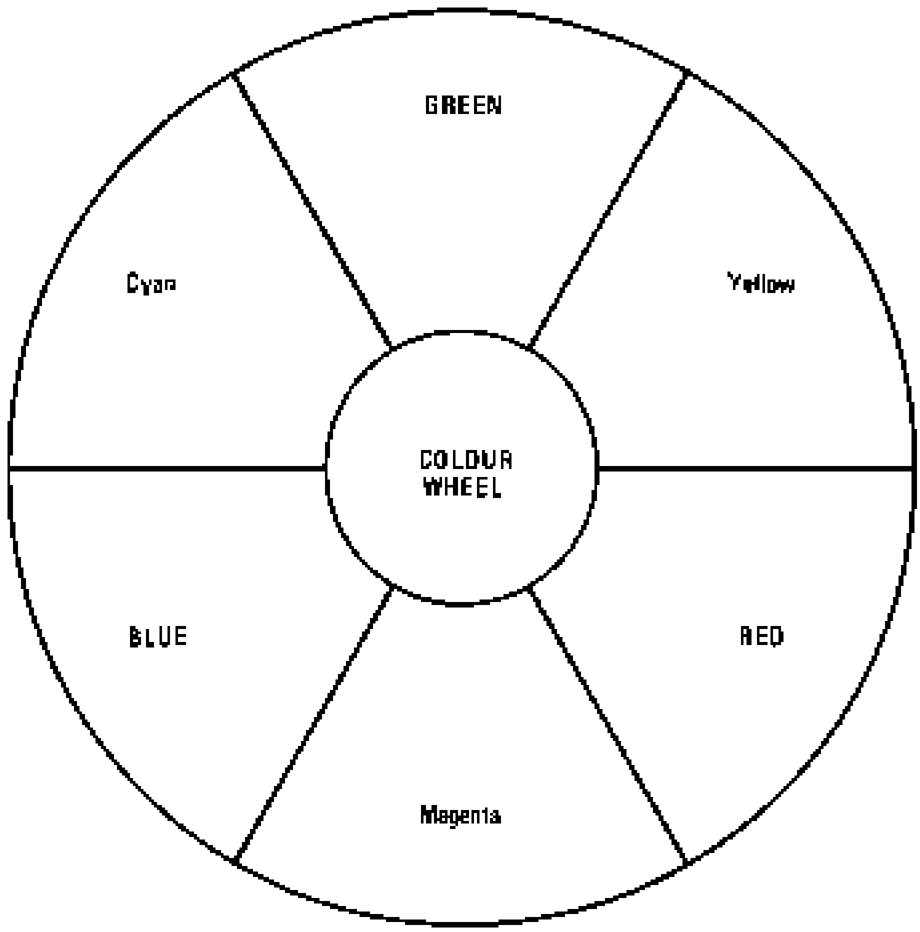
Projecting two of the one-third primaries together creates new colours which are of distinct interest. Red added to blue projected light creates magenta. Blue added to green projected light creates cyan and red added to green projected light produces yellow. Cyan, yellow and magenta are known as two-thirds colours, each containing wavelengths equivalent to 2/3 of the visible spectrum. Thus the full sequence of optical colours is red-yellow-green-cyan-blue-magenta and back to red in a circular fashion (Figure 10.3).

Additive primary colour mixing is the basis for optical colour separation used in the reproduction of full-colour originals which are used increasingly in cartography. It is also the basis for preparing transparencies for use as projected overlays onto a screen and as the basis for colour television.

10.6.3 Subtractive primaries

Cyan, yellow and magenta, the two-thirds colours, are the subtractive primary colours. Superimposing filters of these colours over a white

Figure 10.3 Colour wheel showing duos and triads of complementary colours with additive (caps) and subtractive (lower case) primaries.



light source selectively eliminates parts of the spectrum, in contrast to the additive process described above. A combination of cyan and yellow filters used to filter white light produces a green hue. Magenta and cyan filters result in a blue hue, and magenta and yellow filters superimposed in a similar manner produce a red hue. Thus by subtracting light (filtering), the additive primary colours are created. Using cyan, magenta and yellow filters together will remove all available light resulting in black.

The subtractive system is the basis for printing with the process colours cyan, yellow and magenta used together with black to sharpen the image. It is also the principle used in mechanical separation, the conventional cartographic method of creating colours on maps and graphs. As with artistic primaries, the subtractive primaries have the disadvantage of requiring many separation overlays but the resulting colours can be easily controlled.

10.7 Colour Harmony

Colour harmony, a visually pleasing arrangement of colours, can be achieved by the use of complementary, analogous or monochromatic colours:

10.7.1 Complementary colours

Colours complement one another when they contain approximately equal visual amounts of each of the three pigment primary colours. A colour wheel is a considerable aid to their identification and will be referred to throughout this section (see insert). The sequence of colours on a colour wheel is itself considered to be harmonious and may form the basis of useful colour scales. Two colours (duos) are harmonious and complementary if they lie opposite each other on the colour wheel. Thus we have the following duos of complementary colours with the artistic primaries (Figure 10.4):

Yellow - Violet
Yellow-orange - Blue-violet
Orange - Blue
Red-orange - Blue-green
Red - Green
Red-violet - Yellow-green

The same principle holds for groups of three colours on the wheel (triads) (Figure 10.4). Thus we have the following triads of complementary colours:

Yellow - Red - Blue
Yellow-orange - Red-violet - Blue-green
Orange - Violet - Green
Red-orange - Blue-violet - Yellow-green

The principle of harmonious and complementary duos and triads of colours in relation to the artistic primaries can also be applied to the additive and subtractive primaries (Figure 10.3). These colour duos and triads are more harmonious if the colours are lightened by white, darkened by black or similarly toned down to a pastel shade by adding equal amounts of grey. Pastels or subdued colours are considered to be visually more pleasing than pure colours.

Brown, a fundamental cartographic colour, is not listed above but is often used in many mapping products. Brown essentially consists of yellow and red plus a small amount of blue. Harmonious colours for browns are found in those colours in which the dominant pigment is weakest in the brown. Thus we have the following complementary colours for brown:

Yellowish brown - Blue-violet
Reddish brown - Blue-green

10.7.2 Analogous colours

This system of obtaining harmony between colours is extremely valuable to the thematic cartographer who wishes to produce a scale of colours for related features, e.g., the depiction of varying levels or densities of a species.

Analogous colours use one quadrant section of the colour wheel, moving from one extreme steadily through each neighbouring hue to the other extreme (Figure 10.4). Thus a scale of harmonious colours might include green, yellow-green, yellow and yellow-orange. These scales are often adjacent to the subtractive primary colours magenta, yellow or cyan. When using this system, extending beyond 1/3 of the wheel will result in unharmonious colour combinations.

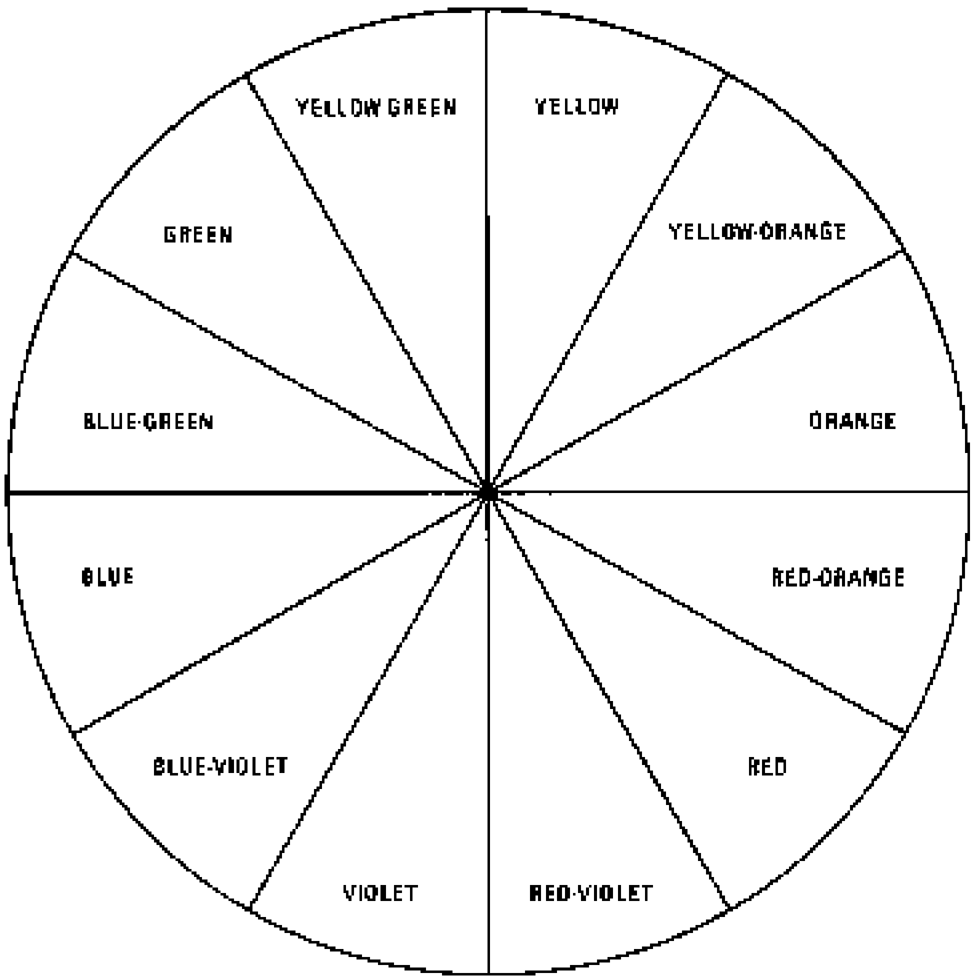
This system is useful as an economic solution to costly colour printing. Using only two basic colours in varying saturations and over-printing them can create a useful scale of related colours.

10.7.3 Monochromatic colours

This is an economical colour system based on a sequence of several continuously graded colours of a single hue. These gradational sequences are achieved by the addition of white, grey or black, resulting in desaturated, pastel or shaded series of colours.

The system is suited to displaying continuously variable data such as water depth in relation to bottom topography.

Figure 10.4 Colour wheel showing duos and triads of complementary colours with the artistic primaries.



SECTION 11

11. ARTWORK PREPARATION

The quality and often the complexity of a map or graphic is dependent on the nature of the original artwork. Photographic reduction and high contrast photography can improve the quality of linework on reproductions although most flaws and all errors will still remain.

Basically artwork can be prepared in positive or negative formats, or in a combination of the two. The reproduction method chosen, the economics of the situation and the availability of equipment and materials dictate the format utilized. Both positive and negative artwork are normally produced as colour-separated plates, overlays or components. This requires a pin registration system so that the images on the various overlays retain their correct relationship when a composite negative or positive of the overlays is made. This also demands the use of stable-base materials, as artwork produced on unstable materials will shrink or expand with variations in temperature and humidity. Thus stable, polyester-based, plastic films are a requirement for all graphics which are not simple, single colour designs produced on one overlay. These plastic films are also more permanent and of consistent quality. Erasures and changes can be made relatively easily. For these reasons tracing papers, art papers and similar materials are not used in most mapping operations except for minor projects, internal planning or display work.

11.1 General Guidelines

The following general guidelines and work habits should be followed for the production of artwork:

i) The accuracy of the final product is dependent on the accuracy of the original manuscript and the accuracy of the subsequent drawing or scribing;

ii) Cleanliness is vital. The following work habits should be followed:

a) Hands should be clean at all times. Many people use linen or cotton gloves to avoid staining the artwork;

b) All instruments such as scales, triangles, straight edges, etc., should be cleaned regularly;

c) The work table should be cleaned before use. All work should be covered when not in use, as well as the overlays not currently being worked on. On complex pen and ink work, only the small area currently being drawn should be uncovered;

iii) The work area should be kept clear of clutter. When not in use, opened bottles should not be left on desks to avoid spillage;

iv) A good source of even lighting is necessary for cartographic work; it should provide a high level of illumination without glare or strong shadows.

11.1.1 Positive artwork

Until recently, positive artwork such as the pen and ink drawing was the only method of producing original artwork. It remains a common procedure for short run, illustrative and relatively quickly produced graphics with which much of this manual is concerned. Normally, traditional drafting techniques using modern graphic aids are used for producing positive artwork. Automated plotting devices and other forms of computer technology can also produce positive artwork.

Positive artwork is associated with the following reproductive processes:

i) Artwork produced on translucent material at the intended reproduction scale can be used to produce a negative or positive copy by the contact method in a vacuum frame. It can also be used for direct reproduction by a positive working contact method such as diazo;

ii) Artwork produced on opaque (white) material at the desired final scale can be viewed directly and optically reproduced by a process camera, xerography, etc. The total effect of any revision made to the artwork can be seen immediately;

iii) Artwork produced at a larger scale than that intended for reproduction can be optically reduced by a process camera. Graphic symbols and complex details are easier to construct at a larger scale. Reduction sharpens the image, removes small irregularities and generally improves registration of the overlays. The reduced size of lines, symbols and lettering must be considered when drafting the original artwork.

11.1.1.1 <u>Cartographic drafting:</u> This is a flexible method of producing artwork, using a wide range of materials, inks, pens and equipment:

A. Materials: The following factors should be considered when selecting drafting materials:

i) Costs: Material costs are usually a minor part of the total cost of cartographic products; using the appropriate material, however, can usually save a great deal of time in this labour intensive field. To minimize costs, expensive stable-based materials should not be used when their characteristics are not required;

ii) Dimensional stability: Temperature and humidity variations cause shrinking and stretching of all paper-based products. All image separated graphics should be drawn on stable-base polyester films. As the size of the graphic increases so should the thickness (and stability) of the drafting material;

iii) Tooth: This is the technical term given to the slightly roughened surface of polyester plastic films to ensure ink will adhere to the surface, creating a good image. A smooth surface will not accept ink; a rough surface will provide a poor image and wear out drawing instruments;

iv) Translucence: Translucence is the state of transmitting light without being transparent. This dictates the ease with which you can see through the drafting material on a light table. Vital for tracing purposes, translucence also eases the comparison of separated layers of a graphic;

v) Erasability: Changes are often necessary on original artwork. The drafting material should permit erasure several times without damaging, smearing or ghosting;

vi) Strength: Drafting material should withstand a great deal of wear and handling;

vii) Absorbency: Drafting materials should not be absorbent. Paints and inks contain a great deal of liquids. Any material which absorbs these liquids will distort, curl and tear easily.

B. Inks: In cartography, coloured inks are used only to produce display products. The colours in maps and graphics which will be reproduced by the printing process are drawn with black, high density inks (refer to Section 12).

A wide range of black drafting inks is produced by such manufacturers as Pelikan, Koh-l-Noor, Higgins, etc. Temperature and humidity variations cause changes in the flow characteristics of all inks. It is unlikely that a single product will suffice for all drawing instruments and conditions which are encountered in a drafting office. Thus it is advisable to experiment with the various types available to determine their suitability. A new ink product from Koh-l-Noor uses a latex base instead of the usual lacquer base. This not only produces a dense black image but also minimizes the clogging of technical pens. All inks have a finite shelf life.

C. Technical pens (Reservoir pens, Tubular nib pens): Technical pens have become the most widely used drawing instruments. They can be used both freehand or with a mechanical guide. Their ease of use and the consistency of the linework are the major reasons for their popularity.

The ink, contained in a reservoir, supplies a round replaceable drawing point via a feed mechanism. Each line width requires a different size pen point, hence a wide range of point sizes is available. Normal steel points wear out rapidly when used on plastic drafting materials; more durable jewel points are available for this purpose at a higher cost. Tungsten carbide points are also available but are most suitable for use with plotting machines. All pens will clog if left opened or filled for long periods of time without regular cleaning. The quality of linework is reasonable for most purposes although lines tend to be grey unless an opaque ink is used.

D. Other pens: Technical fountain-type pens such as Pelikan Graphos have replaceable nibs for each specific line width. The pen nibs are made of a mild steel and thus wear out rapidly when used on plastic drafting materials. These pens are best suited for straight line work using a straight edge, making them ideal for borders, neat lines, etc. The quality of linework is superior to that of technical pens. The cleaning and changing of pen nibs, however, is a messy process.

Ruling pens have been largely replaced by technical pens. They still are the most versatile and economical drawing instruments available as individual pens are adjustable and thus capable of producing varying line widths. They can be re-sharpened when worn so a quality instrument can last for years. Considerable effort is required, however, to learn how to use these pens. They can produce a dense, high quality line but need to be continually refilled and cleaned.

A contour pen is essentially a ruling pen with a swivel handle. Unlike the ruling pen it is primarily used freehand, especially for drawing contours and other isolines. It is the drawing instrument which produces the smoothest freehand curves but considerable practice is required to master its use.

Quill pens (crowquill pens, dip pens, straight pens) consist of flexible metal nibs mounted in wooden or plastic handles. These are the least expensive drawing instruments available. Replaceable nibs should be obtained in a variety of sizes and stiffness. Quill pens are the only pens which allow the drawing of lines of varying widths from a single nib.

E. Equipment: The following good quality equipment is required to produce professional products:

i) The most basic item required is a sturdy, flat drafting table sized to accommodate the largest maps which will be produced. A light table which contains an adequate illumination source is also required. Access to both a drafting table and a light table is ideal although many cartographers work exclusively on light tables;

ii) T squares are used for horizontal alignment and drawing straight lines. They can only be properly used if one side of the drafting table is perfectly straight and rigid;

iii) Steel straightedges are useful for drawing straight lines. They should not be used as a cutting edge to avoid damage caused by a slipped knife blade;

iv) Parallel rules consist of straightedges which are attached to the drawing board by guide wires, and are useful for drawing straight lines and general layout work;

v) Rolling rules are short straightedges with a wheel insert that keeps them straight. They are an excellent aid as they can be moved easily about the drawing;

vi) Drafting machines consist of two scales or straightedges at right angles that can be rotated through 90° by a control device similar to a protractor. Widely used in engineering drafting, they are useful for plotting angular measurements, drawing straight lines and as a base for lettering guides;

vii) Line-up tables consist of a light table with two moveable guide arms mounted at right angles to each other. They are a precise layout tool;

viii) Drafting triangles made either of acrylic or of steel are aids for angular plotting and for use as short straightedges;

ix) French curves are indispensable aids for drawing smooth curved lines and a variety of curved shapes;

x) Ships curves are precisely engineered curves which are useful for precision curved work of all types. Railroad curves are similar to ships curves;

xi) Spline curves are flexible curves used for drawing long smooth projection curves. They consist of a flexible plastic spline and heavy hooked lead weights which keep the spline smoothly curving through pre-determined points;

xii) Beam compasses are large radius compasses often necessary for drawing large circles, arcs, etc.;

xiii) Proportional dividers are useful for the mechanical changing of scales (refer to Section 7);

xiv) Spacing dividers have eleven points hinged together like an accordian. They are used to divide a line into any number of equal parts from two to ten. They are useful for dividing bar scales, plotting coordinate positions, etc.;

xv) Swivel knives are used for cutting irregular shapes on pre-printed patterns sheets, masks, shading films, etc.

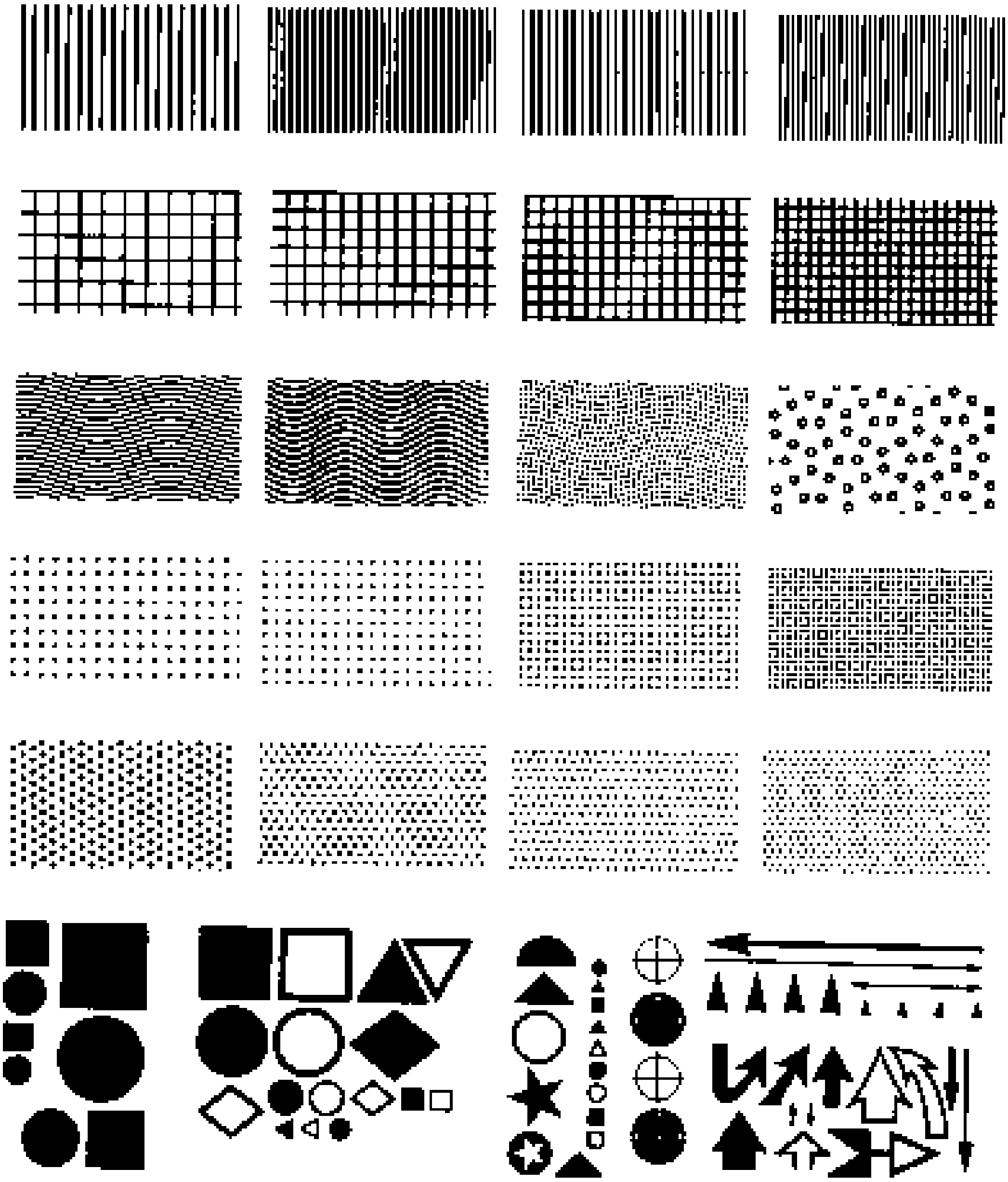
11.1.1.2 Text (Lettering): Text may be produced by any of the methods listed in Table 11.1. It may be used directly on artwork or photographically reproduced onto photographic paper, stripping film, image transfer or sticky-back materials for use on overlays. These positive overlays can also be photographed or contacted in a vacuum frame to component negatives for use in the production of composite negatives. A precision grid, which consists of a clear polyester film base having an image of fine, closely and evenly spaced horizontal and vertical lines, may be used to align the text or lettering on the map or graphic.

11.1.1.3 Point symbols: A wide variety of symbols can be produced by any of the methods listed for producing text (refer to Table 11.1 and Figure 11.1). Photographic reproduction of any of these symbol sources can greatly increase the size range of available symbols. They can be photographically reproduced onto such materials as stripping film, image transfer, diffusion transfer (sticky-backs) or photographic paper in a variety of sizes for use on overlays. Hand-drawn symbols should be drawn larger than required and then photographically reduced to sharpen the image.

TABLE 11.1 - LETTERING (TEXT) AND POINT SYMBOL METHODS

METHOD	ADVANTAGES	DISADVANTAGES
Hand Lettering	Least complex system. Very economical. No special equipment or materials necessary. Flexible. Curved and spaced names are easily laid out. Can produce very small sizes.	Needs considerable skill and practice to achieve professional results. Non-standardized results. Few styles achievable.
Template (e.g., Wrico-Unol	Simple. Minimal skills necessary. Uniform letters. Equipment is inexpensive.	Spacing and alignment difficult. Limited styles available. Shapes often unattractive. Small sizes not available. Curves hard to control. Slow.
Pantograph - Small (e.g., Leroy)	Long life equipment. Skills easily learned. Good spacing easily attained. Attractive standardized letters. Good selection of sizes in small to mid range. Widely available. Height/slant control scriber gives variations of styles.	Relatively slow. Many templates needed for a range of lettering. Non standard styles are expensive. Hard to produce curved lettering. Poor for headline or display use.
Pantograph - Large (e.g., Varigraph)	Basic set produces wide range of styles. Excellent for display or title work. Single template can produce many variations of sizes and slanted letters. Long life equipment. Relatively inexpensive.	Small sizes not available. Cumbersome for detail work. Basically used for headlines. Slow.
Dry-Transfer	Wide range of styles, sizes and colours available. High quality. Highly uniform. No special equipment needed. Clean and dry. Curved and spaced names are easily laid out.	Expensive to maintain a "useful supply". Products have shelf life. Slow. Standardized sheets are wasteful.
Typewriter (e.g., Varityper, IBM Composer)	Relatively inexpensive and quick. Several styles available.	High quality paper needed. Only limited variation in sizes available.
Photo type composition	Fastest method. High quality. Requires few manual skills. Uniform spacing. Wide range of sizes and styles available. Names can be easily moved. Excellent for blocks of text.	Expensive equipment. Equipment needs regular maintenance and servicing. Photographic reproduction material costly (stripping or sticky-back film). Darkroom needed.

Figure 11.1 Examples of preprinted pattern, area and point symbols. (After J. Campbell, 1984)



11.1.1.4 <u>Area symbols (Patterns, Tones):</u> Pattern and area symbols are available in two basic forms: the pressure-sensitive, rub-down variety and a more commonly used cut-out type (Figure 11.1). In the latter kind the required area of the pattern or tone is cut out with a swivel knife. The portion required is removed from its backing sheet, placed into position on the artwork, trimmed to the exact shape and then burnished into place. There is a wide variety of patterns available in lines, dots, and other shapes.

As a general rule, finely textured patterns must be selected so that small areas on the map receive enough elements of the pattern to make them easily recognizable. Screen tints should not be finer than 120 lines per inch to avoid problems in reproduction. Similarly, if a tone is required, tints that are coarser than 75 lines per inch are generally seen as patterns and not tones and should be avoided unless the artwork is photographically reduced.

Preprinted cut-out solid colour and pattern materials are useful for displays and artwork prepared for slides or optical colour separation. If photomechanically reproduced, red colour material can be used wherever an area of solid black is needed. Using red material instead of black is easier, as the former is actinically opaque but visually transparent, allowing the underlying artwork to be viewed.

The major problems in the use of cut-out area patterns or colours are cleanliness and smooth burnishing. The adhesive backing of these materials will easily pick up dirt such as lint or hairs. Air bubbles and areas of weak adhesion will show up distinctly on many reproductions, as will smearing and ghosting. Care must be taken when cutting the adhesive film over inked lines on a drawing. The knife blade may easily damage the linework and trimmed excess material may also remove part of the image when it is stripped off. The tone of identical tints will vary from sheet to sheet, making it difficult to maintain even tones in large areas. Many commercial products have a grey or thin black image, rather than a dense black one, which is difficult to reproduce photomechanically. It is a relatively slow process to cut out complex shapes. A few of the manufacturers of cut-out area symbols include Artype, Letratone, Zip-a-Tone, Para-Tone, etc.

11.1.2 Negative artwork

It is difficult to obtain precise, quality and permanent images by pen and ink drawing, i.e. positive artwork. The level of manual skill required for excellent positive artwork is high and it takes a considerable period of time for even talented people to develop consistent abilities. In contrast, negative artwork is more easily prepared and less skill is required to produce quality products.

11.1.2.1 <u>Scribing process:</u> This process is used extensively in modern map production; it produces directly the equivalent of a line photographic image. Accurate, sharp and consistent lines can be produced by a person with relatively little experience. Scribed linework is produced more quickly, easily and cheaply than drafted linework. Scribing produces high contrast negative artwork which eliminates a considerable amount of photomechanical processing. Scribing is also normally produced at the reproduction scale, avoiding the need for photographic reductions so common in positive artwork.

Scribing film consists of a clear base of dimensionally stable polyester, covered by an actinically opaque or translucent scribable coating. Examples of scribing film include Scribe Coat produced by Keuffel and Esser Company and Scribe Base produced by Kimoto USA Inc. Some scribing films are available with a pre-sensitized coating to which the base map or worksheet is exposed in a vacuum frame to provide a guide image (refer to Section 5.1.4.4) for scribing. These coatings are often diazo sensitized and must be developed in ammonia fumes. Others have a photographic emulsion. These scribing films are relatively expensive and have a short shelf life. Refer to Table 11.2 for a description of various scribing film types.

A guide image can also be simply reproduced by wiping a diazo or bichromate solution on regular scribing film at any desired stage of production. Diazo images are positive acting and require positive worksheets if positive guide images are needed. In contrast, bichromates are negative acting and require negative worksheets if positive guide images are required. Both types of solutions are available in several colours so a multi-coloured guide image can be achieved by successive applications and exposures.

An alternate and relatively economical method of scribing is to produce the entire image wrong-reading or reversed (refer to Figure 12.1). When photomechanically contacted, emulsion to emulsion, this will produce the required right- reading image on the printing plate directly. Manufacturers such as Keuffel and Esser Company produce reversed lettering transplates for this purpose.

TABLE II.2 - SCRIBING FILM TYPES

COLOUR TYPE	USAGE	COMMENTS	CHARACTERISTICS
Rust	On a light table.	Most common variety.	Excellent actinic opacity (impervious to photographic light).
Green	On a light table.	Easiest colour on the eyes.	Good actinic opacity.
Yellow	On a light table.	2nd easiest colour on the eyes.	Excellent actinic opacity.
Red	Light table may not be necessary. Trace scribing.	Translucent, guide image not necessary.	Excellent actinic opacity.
(White on green or white on rust)	Automated plotters. No light table required.	Scribed linework is highly visible.	Double coated.
Scribe n' Peel	Scribing linework and producing open-window negatives.	Film useful for two separate applications.	Excellent actinic opacity. Scribe layer over transparent peelable layer.
Duplication Scribing Film	Revision work.	Diazo sensitized.	Good opacity.
Contone	Continuous-tone and line combination products.	Both contact and projection speed reproduction.	Photographic emulsion on scribing film. Reproduces air photos. White and rust surface.

A wide range of scribing tools is available, some of which are shown in Figure 11.2. Generally scribing points or needles are mounted in a tripod support perpendicular to the scribed surface. Some tools use sharpened blades rather than points. As the scriber (tripod) is moved across the scribing film using a small amount of vertical pressure, the needle, point or blade penetrates the coating and scrapes it away from the transparent base. Too much pressure, will gouge the underlying polyester base resulting in a poor photographic image. Corrections and revisions are simple to make using an opaque substance specifically formulated for this purpose although rescribing may be difficult.

The scribing process removes part of the coating as loose particles. This debris is actinically opaque and if left on the film will cause gaps in lines and broken images; it will transfer to any contact frame or other material with which it is in contact. It is also highly abrasive and can rapidly wear out or seize up the ball feet of scribing tools. Most debris can be removed by frequent brushing with a soft bristle brush or by wiping with a damp cloth or tissue. The sticky side of drafting tape or tacky gum erasers may also be used for removing the loose particles. All linework must be checked frequently under a magnifier for traces of loose particles.

Points are available in various diameters ranging from 0.05 mm (.002 inch) upwards in regular increments; above a certain size they are chisel shaped to facilitate cutting the wider lines. Points are also available for scribing double lines, triple lines and combinations of thick and thin lines to represent road casings, special symbols, borders, etc.

Scribing tools are available in both freehand and rigid versions, the latter for use with a straightedge or french curves. There are also special scribers available for scribing dots, buildings, etc., as well as a wide variety of templates used for scribing symbols. Manufacturers of these tools include Roto Instruments, Keuffel and Esser, and Astrascribe.

11.1.2.2. <u>Scribe point characteristics:</u> The shape of scribe points and their associated advantages and disadvantages may be described as follows:

Type	Advantages	Disadvantages
Round	Can be used freehand. Easy to set up. Can be used in rigid or swivel head scribing tool.	Pressure needed increases with point size. Should not be used for square symbols.
Conical	Can be used freehand. Easy to set up. Can be used in rigid or swivel head scriber.	Needs rigid holder to keep tip perpendicular. Pressure needed increases with size. Should not be used for square symbols.
Chisel (point or blade)	Removes scribing film coating cleanly. Wide range of sizes and styles available.	Needs careful alignment and setting up. Needs swivel head scriber.

There are three primary materials used to construct scribe points: steel, sapphire and tungsten. Tungsten points are expensive, very hard and long wearing; they cannot be resharpened. Steel points are the cheapest and withstand rough handling; they tend to wear out quickly but can be resharpened. Jewel points (sapphire) are expensive, brittle and fragile and cannot be resharpened. They are, however, long lasting if handled with care.

11.1.2.3 Area symbols: Open-window negatives for area symbols can be prepared by using cut and peel techniques on strip masking or peelable materials such as Amberlith or Rubylith by Ulano Corporation or Kimoto Strip Coat by Kimoto USA Inc. They can also be produced photomechanically by an etch and peel process using sensitized peelable materials which consist of a thin ruby-coloured film coating on a transparent polyester plastic base. These materials are exposed in registration with a line negative of the boundary lines in a vacuum frame under high intensity ultraviolet light.

The peelable material is then developed and subsequently etched by a separate chemical process. Any unwanted boundary line can be masked by the use of an opaque formulated for that purpose. The desired open areas are peeled with tweezers or similar sharp instruments. A corner is carefully lifted and the rest of the area stripped off. If an opaque line remains at the edge of the open area this can be removed by swabbing with a moist material.

Sensitized peelable materials can be processed in normal room lighting. Patterns and tonal values can be added to a map by using contact screens or screen tints on the open-window negatives. Examples of sensitized peelable material include Peel Coat produced by Keuffel and Esser Company and Etch n' Peel produced by Kimoto USA Inc.

11.1.3 Masking

A mask is an area of opaque material on a clear overlay which prevents light from striking and therefore exposing an area on a negative or positive during the photomechanical process. Masks can be made by painting or opaqueing the area on a sheet of transparent plastic. They can also be hand cut on masking material which consists of a transparent polyester base coated with an actinically opaque thin film coating which is peelable such as Rubylith. The coating is normally transparent, allowing the artwork which requires masking to be viewed. Masks can also be produced by the photomechanical etch and peel process described in Section 11.1.2.3.

11.2 Economical Colour Systems

Occasionally a coloured graphic is required both quickly and economically, e.g., for internal usage within an organization or to illustrate a topic at a meeting. There are many simple and economical colour systems available to produce artwork for such graphics. Each system described may be used to produce multi-coloured artwork. If many colour copies are required the "artwork" can be optically colour separated for printing on an offset press.

11.2.1 Coloured pencils

Coloured pencils are the quickest and cheapest colour system. Normally considered unsuitable for reproduction they may be adequate for internal use.

The main problem in the use of coloured pencils is inconsistent colour. A great deal of streaking is normally evident in the most careful art-work. This can be largely overcome by means of the stomping technique. A stomp is a pencil-like device composed entirely of compressed paper with tapered ends. The tip of the stomp is moistened with ordinary lighter fluid and then rubbed gently over the coloured areas. It will soften and smoothen the coloured areas removing streaks and brightening the image. Lighter fluid, however, is flammable and should be used with care. Stomps are available from graphic arts suppliers. An example of stomping is shown in case study #5, Geology of the Island of Newfoundland, shown in Section 13.

11.2.2 Felt tip markers

These relatively inexpensive and convenient products are available in a wide variety of colours, tip widths and tip styles. When the markers are not in use, it is important to keep the caps on to prevent the solvents from evaporating, thus drying the markers.

Applying colour on large areas without obvious streaking is difficult. The use of a good quality art board is important as marker solvents easily penetrate inferior materials, such as diazo paper, resulting in colour bleeding or spreading. Plastics, having non-porous surfaces, have the opposite problem. The colour sits on the surface and is easily smeared. The use of an acrylic art spray prior to colouring the surface, however, can prevent this problem.

11.2.3 Coloured acetate film

Adhesive-backed coloured acetate film in both vivid and pastel hues can be applied to either side of both positive or negative transparencies. Similarly opaque paper artwork can be given vibrant colours by applying adhesive-backed colour tapes and symbols.

The area is cut out with a sharp knife and burnished into place on the artwork after necessary trimming has been carried out. Care must be taken to apply the colour correctly as the adhesive or colour may be damaged by repositioning.

The use of these films is slow but excellent results can be achieved on displays and artwork intended for photographic reproduction, e.g., overhead transparencies, slides, etc. Because they are easily damaged they are not suitable for diazo reproduction, long term usage or highly complex work.

11.2.4 Airbrush

This versatile instrument is one of the most common and valuable tools used by commercial artists. The airbrush is a precision, penlike spraying device approximately the size of a fountain pen. It is connected by a hose to a controllable air supply which forces light-bodied ink, liquid colours or paint from a small reservoir cup or bottle. The air supply is normally obtained from a small, portable electric air compressor. For casual usage, however, small bottles of compressed air can be economically obtained. Airbrushes are available in a wide range of prices and performance capabilities. The more expensive models are capable of spraying extremely fine jets of colour in small areas. The cheaper versions are useful for applying broad areas of colour or tone.

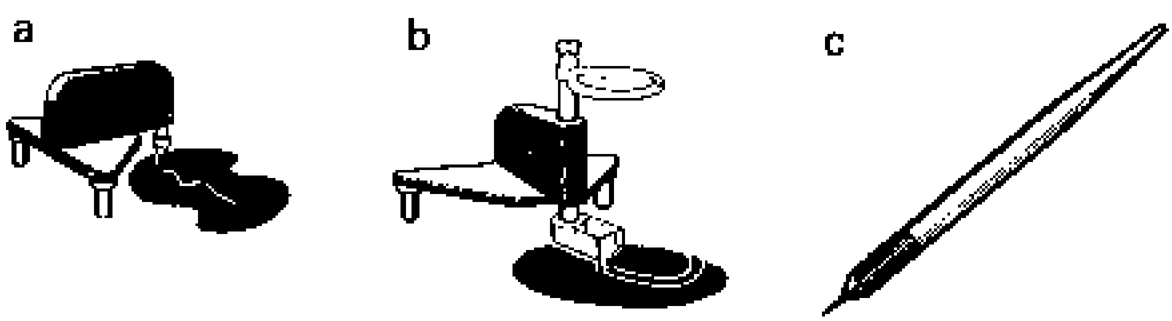
Airbrushes can apply precise amounts of tone or colour to almost any surface, whether opaque or transparent. They are superior in this regard to virtually any pen, brush or marker. Shading and blending of colours can be done with ease, making airbrushes particularly valuable for hill shading, hypsometric colouring, depth illumination, etc. Edges must be carefully masked to prevent colour from accidentally being added to the wrong area. Special "fisket" solutions are available to create paintable masks which are easily removed.

11.2.5 Aerosol spray colours

The aerosol container, with its fine spray, approximates the effects of an airbrush, though the amount of control is relatively limited. Most of the colours available are bright. Professional-looking graphics can be obtained on transparent or opaque materials. As in airbrushing, smooth edges can be created by masking the unwanted area with an adhesive mask.

A simple and effective mask can be created with rubber cement, suitably thinned, which is peeled off after the aerosol has been applied.

Figure 11.2 Examples of scribing tools: (a) rigid scriber and (b) swivel scriber, both of which are used for linework; (c) pentype scriber used for freehand work. (After A.H. Robinson _et al._, 1984)



SECTION 12

12. GRAPHIC REPRODUCTION

Cartographic products usually are designed to be reproduced, the number of copies ranging from one to hundreds of thousands. The quality of the copies is related closely to the nature and quality of the original artwork and also is determined by the selected reproduction process.

Every method of reproduction imposes limitations on the nature of the cartographic product thus the reproduction method must be considered during the initial planning process.

12.1 Limited-Copy Reproduction

These techniques are normally used when a small number of copies of the original graphic or map is required. Reproduction facilities often are not available or necessary. Economical and easily available techniques should be utilized whenever possible. Particularly useful are those methods which allow for rapid revision of data. A few of the many limited-copy reproduction methods and materials available are presented below. Some techniques and materials use commonly available equipment while others require specialized graphic arts facilities and darkrooms such as those found in larger mapping agencies.

12.1.1 Photomechanical reproduction

Although photomechanical reproduction facilities may not be available to all users of this manual, this subject is considered at the outset because the terminology and some of the processes described are often common to both limited and multi-copy reproduction. Photomechanical reproduction facilities are used extensively in all major mapping agencies to produce and reproduce complex products such as hydrographic charts, topographic maps, etc. For those who lack access to photomechanical facilities the simpler reproduction techniques should be considered (refer to Sections 12.1.2 to 12.1.11.4).

Most complex maps or graphics are mechanically colour separated as they are produced to show combinations of symbols, lines, and screen tint and halftone images in multiple colours. In mechanical colour separation, the basic photomechanical processes reproduce the coloured areas in black and white and grey tone images. These images are not converted to their intended hues until the stages of colour proofing and final printing.

The photomechanical reproduction processes may be defined under two categories: reflex and transmission. Artwork created on opaque material not easily penetrated by light can be reproduced by a reflex optical system, such as a process camera. Size changes are easily made. Translucent or transparent artwork with a light opaque image can be reproduced by transmission in contact with a sensitized material. The use of the transmission process often gives better quality control and results in lower costs; size changes, however, are not easily achieved.

The materials used in photomechanical reproduction processes consist of a base, which may be paper or plastic film, with a light-sensitive coating (emulsion) which is composed of silver salts (halides) in gelatin. The usual product of the photomechanical reproduction process is a negative in which the light portions of the original positive artwork are represented by dark deposits of silver, and the dark portions of the original artwork are clear (Figure 12.1). A positive print reproduces tonal values similar to those on the original positive artwork.

12.1.1.1 Reflex process: Graphic arts photography is used for the reproduction of artwork and is an integral part of the printing process. The major parts of a reflex process camera consist of a vacuum copyboard, lens, vacuum film holder and bellows (Figure 12.2). The artwork is placed in the copyboard and the unexposed film is placed on the filmboard of the camera. The bellows and copyboard extensions are then adjusted to obtain the required scale. The lens aperture is set and the exposure made through the shutter as the artwork is being illuminated by high intensity lights. This reflex process normally results in a film negative if the artwork being photographed is positive. If the artwork is negative the process is reversed and a film positive is produced.

12.1.1.2 Transmission process: Transmission by contacting is the most basic, common and essential method of reproduction in the mapping industry. Contact prints are made by placing a negative or positive over an unexposed sheet of film in a vacuum frame and exposing them to a light source. Negative prints can be made from positive originals, or vice versa. By using duplicating film, it is also possible to make duplicate copies, that is, negative copies of negative originals and positive copies of positive originals. Contact printing produces an image at the same scale as the original; size changes are difficult to achieve and are not normally attempted. All contact originals are normally translucent or transparent.

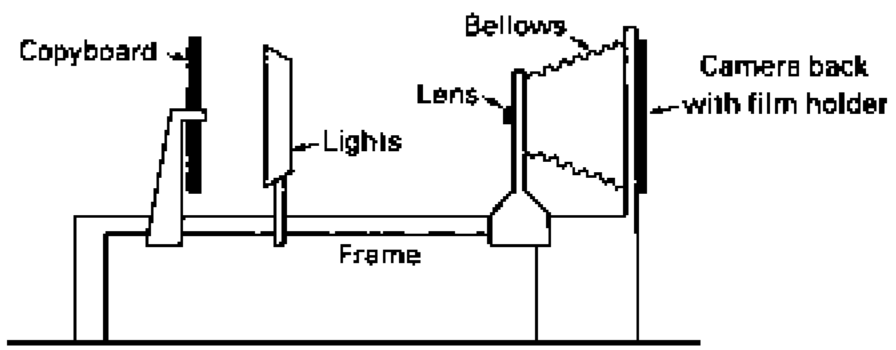
Combinations or "composite negatives" are an example of the capabilities of contacting. Several negatives or "components" of a particular printing colour are exposed in succession to a sensitized material to which they have been accurately pin registered. Some component negatives can be duplicated without modification, while others can be masked for selected information. Other negatives can be screened or tinted to increase the contrast of specific features, and so aid in their visual identification.

Applications for contact printing by the transmission process include the following:

i) duplicate a negative or positive image, e.g., type, text, logos, etc.;
ii) convert a negative to a positive or vice versa;
iii) record transitory or delicate artwork such as type overlays;
iv) provide a guide image for further processing, e.g., apply an image to scribing film;
v) produce etched images on sensitized peelable material;
vi) convert an image from wrong-reading to right-reading and vice versa (Figure 12.1);

Figure 12.1 Positive and negative photographic images. (After International Cartographic Association, 1984)

Figure 12.2 Components of a reflex process camera. (After J. Campbell, 1984)



vii) produce a composite negative or positive from several negative components;
viii) produce coloured overlays for display work;
ix) produce patterns or screen tints in open image areas;
x) produce accurate diazo copies;
xi) convert a continuous-tone image to a halftone image;
xii) produce colour proofs for editing and display;
xiii) produce plates for printing graphic images.

Contacting can also be used to produce some creative effects on art-work. For example, spacers consisting of transparent materials placed between the image and the recording material can create the following:

i) vignetting, a band of colour or tone which varies in density, normally used to visually reinforce a boundary or edge;

ii) fat masks, used to create a small clear area surrounding type or symbols which ensures detail does not interfere with type or symbols;

iii) double lines from single ones or outline type from solid letters using autoreversal film;

iv) heavy lines from thin lines or vice versa.

12.1.1.3 Comparison of light sources: Table 12.1 outlines the various light sources used in photomechanical reproduction:

TABLE 12.1 COMPARISON OF LIGHT SOURCES

SOURCE	CHARACTERISTICS	COLOUR	USES	PROBLEMS	NOTES
CARBON ARC	Continuous spectrum	Variable, similar to daylight. High ultra-violet.	Diazo-dichromates, photopolymers. Plate making, photoengraving.	Inconsistent output. Health problems from fumes. Needs frequent cleaning.	Source must be vented to outside. Best source for deep-etch plate making.
PULSED XENON	Continuous discharge. Constant output. Short start-up times.	5400°K Low ultraviolet.	Colour and black and white reproduction. Graphic arts photography, platemaking. Standard industrial applications.	Deficient in ultra-violet.	Long life: 300 - 1000 hours. Preferred source for colour separation.
TUNG-STEN	Continuous spectrum, which varies according to power level applied.	Variable, limited to 3000°K. Low in blue and ultraviolet.	Black and white reproduction, Point light applications for halftones.	Highly deficient in ultraviolet. Colour level and output decrease with age. High infrared output.	Short life - very hot. Replaced frequently to maintain control.
QUARTZ IODINE	Tungsten lamp in quartz with added iodine. Efficient.	2800 - 3400°K	Black and white reproduction. Platemaking. Graphic arts photography.	Not suitable for colour. Deficient in ultraviolet.	Long life - 1000 hours. Constant colour.
MERCURY VAPOUR	Discontinuous spectrum. Peaks at useful wavelengths.	Variable according to construction. Peaks at .36-.37 micrometres (ultra-violet and blue).	Diazo - dichromates. Platemaking.	Needs long warm-up and light integrator.	Largely replaced by metal halide.
METAL HALIDE	Discontinuous spectrum. Mercury lamp with additives. Extremely efficient.	.40-.41 micrometres (blue).	Ideal diazo light source. Black and white reproduction. Photopolymers, dichromates. Colour proofing. Platemaking.	High cost. Needs warm-up and light integrator.	Highly efficient: produces 2 X output of mercury, 3 X output of carbon arc, 4 X output of pulsed xenon.
LASERS	Monochromatic, Directional. Very powerful. Highly accurate. Narrow application range.	Selected for specific wavelength and application.	Scanning. Typesetting. Platemaking. Printing.	High cost. Computer dependent.	High quality reproduction. Short exposures. Direct printing of computer data.

12.1.1.4 <u>Characteristics of photomechanical reproduction materials:</u> Colour sensitivity, contrast and film speed are characteristics of photomechanical reproduction materials which affect their use and their processing:

A. Colour sensitivity: Although almost all photomechanical materials used in cartography and related graphics are black and white, each records a range of coloured hues present in the visible or non-visible spectrum. The various films have different levels of sensitivity to the colours present in light and will record different hues as different shades of grey.

B. Contrast: The way in which a film emulsion records the tones of a grey scale is referred to as the contrast characteristics of the emulsion. This grey scale is a strip of photographic film or paper with a distinct gradation of tones, ranging from black to white.

When high-contrast graphic film is exposed and processed normally it will record only the extremes of the grey scale; there are no tonal gradations. It is usually processed in an infectious developer to produce the required high contrast. It is widely used for line and halftone reproduction.

Medium or low-contrast films are normally referred to as continuous-tone. The grey scale can be reproduced to approximate the original. They are used for making colour separations from full colour originals.

C. Film Speed: Film speed is directly related to the light sensitivity of the film. For general photographic purposes, film speed is commonly defined by an ASA or ISO rating. In contrast, graphic arts films may be defined as either camera speed film or contact speed film, both of which are far slower than conventional photographic film and are not categorized according to an ASA or ISO rating.

Process camera speed films are generally high contrast lith type material specially designed for process camera work. They are available in all light sensitivities. Process camera speed films generally have the narrowest exposure range of all graphic arts materials, necessitating careful handling. Many of these films are not suitable for contact work because of their excessively thick anti-halation backing. They are also more light sensitive, leading to shorter exposures and reduced control.

Contact speed films are specifically designed for the contact printing process. They are usually in the form of blue-sensitive continuous-tone films; processing in an infectious developer, however, gives them the characteristics of a lith film. Being continuous-tone, they have a wide exposure range which is a useful feature. Contact film has a higher resolution than process camera film which is important for quality reproduction.

12.1.1.5 <u>Photomechanical reproduction materials:</u> The ever widening range of photomechanical applications and techniques has resulted in a growing list of available reproduction materials which vary according to their speed, contrast and spectral sensitivity. The following is a partial list of these materials:

A. Orthochromatic film (Lithographic film, Ortho film): These films have certain dyes added to their emulsion to increase their sensitivity to blue, green and yellow light. Because of their insensitivity to red light it is safe to use a red safelight in the darkroom.

Orthochromatic emulsions can also be obtained in duplicating film or reversal film. These films are the most important sensitized materials used in map making and related graphics. Their increased sensitivity means that they are "fast" and thus require relatively short exposure times. Their high contrast makes them ideal for processing inked or scribed line artwork. They are widely used for photomechanical separations and for masks and screens used in platemaking. Regular lithographic film is very sensitive to changes in temperature, development speed and type of developer while being processed; this provides the experienced operator with total control over quality.

Stabilization or direct access lith film is not affected by normal changes in processing and must be controlled solely by varying exposures. This reduces problems in processing but also reduces the versatility of the material.

The characteristic reaction of these emulsions to blue and red images has useful applications. For example, light blue guide lines on the artwork will not reproduce on the film and red registers the same as black, producing transparent areas.

B. Wash-off materials and autopositive films: Some of the more useful, high quality, and easily processed photographic products are the wash-off materials specifically developed for drafting. Wash-off materials are capable of reproducing a high-quality black image of the finest line or tint. Reproductions of pencil lines are denser than the original drawing. A reproduction on wash-off film will thus provide better reproduction than an original artwork drawn in pencil.

The high-contrast nature of wash-off films makes them ideal for reproducing lines in a drawing while eliminating smudges, discoloured areas and incomplete erasures. The emulsion can be removed easily with a damp eraser, leaving no ghosts or damaged areas. The base is mylar, ensuring dimensional stability and permanency. The chemicals required for development are incorporated into the emulsion, therefore only an activator is needed. Activating times ranging from 45 seconds to 5 minutes will produce a good print.

Wash-off films are exposed to negatives or scribed linework using an ultraviolet light source. A vacuum frame is ideal for reproduction but many simpler techniques can be substituted, such as daylight photo-floods, diazo, etc. The films are tolerant of normal room light for several minutes, so they do not need to be handled in a darkroom if reasonable precautions are taken. After activation the unhardened parts of the emulsion are simply washed-off with warm water and the film is dried.

Autopositive films are a related line of positive working photographic products which must be exposed through yellow sheeting superimposed on the light source.

Both product lines essentially have gelatine-based surfaces, and as such they are capable of accepting the coloured dyes used in proofing techniques. Wash-off materials are an excellent base for colour proofs and coloured display materials. These products are available from manufacturers of photographic films.

C. Room-light handling film: These films are special contact films which permit the operator to handle them under low levels of incandescent or fluorescent light. Typically they are not sensitive to visible light but are more reactive to ultraviolet light. They are not intended to be used with a point source light and are normally exposed in a vacuum frame. The light source should be pulsed xenon, mercury vapour or metal halide; all are high intensity and have a high percentage of ultraviolet light (refer to Table 12.1).

D. Colourblind film: These films record blue light as a dense area on the negative while reds, yellows and greens are very "thin". On a positive, this process is reversed. White or transparent areas on the positive correspond to blue images on the original and dark areas on the positive correspond to the other colours on the original. Because of its limited sensitivity to colour the film is called colourblind film, and can be safely handled with either a yellow, orange or red safelight during processing. It can be used for making both halftone and line images from black and white artwork and contact prints from positives or negatives.

E. Dylux: This is an economical product of the Dupont Company which is available in both paper and dimensionally stable plastics. The great advantage in its use is that an excellent image can be obtained with no chemical developing. It also self-fixes under normal room lighting conditions. The material produces a blue line image immediately upon exposure to any ultraviolet light source through either negative or positive artwork.

Initially there is a pale yellow background but this will disappear in an hour or so. Normally the material is exposed in a platemaker through a special ultraviolet blocking material. Best results are obtained with black-light fluorescent lamps. A considerable advantage is its ability to produce a positive image from a positive original. It is capable of rendering a wide range of tones, making the paper-based version a cheap and efficient method of proofing or reproducing artwork. As with all similar systems used in platemakers, the original artwork must be produced on transparent or translucent materials, with a dense or opaque image to block the light.

F. Panchromatic film: Panchromatic films have emulsions which contain additional dyes. These dyes make them sensitive to all visible wavelengths of light. Therefore, they can be handled safely only in total darkness before the material is fixed. These films are commonly notched on one edge. When the notch is in the upper right-hand corner the emulsion is towards the operator.

Panchromatic film (pan film) has more sensitivity than ortho film and requires less exposure. Pan film is commonly used to reproduce black and white aerial photographs and other continuous-tone artwork. In the graphic arts industry it is used for making colour separations of coloured originals.

12.1.2 Xerography (Electrophotography)

This is a non-chemical photographic process producing a dry positive copy from a clear or opaque positive original. It utilizes a light-sensitive, selenium-coated plate which carries a positive electrostatic charge. Where exposed to light the charge is dissipated, leaving a latent image to which negatively charged black powder toner will adhere. This powder image can be transferred to a positively charged surface such as ordinary paper, transparent film and even metal offset plates. The toner is fixed (actually fused) by being passed over a heat source.

A major advantage of xerography is that it is available in most offices at a reasonable cost. Also it does not involve wet chemicals, thus the time required for processing and drying is saved. The speed of production is relatively rapid for limited quantities. Because the image is projected through a lens, size changes are possible on many machines, varying from 50-200% of the original size. Some machines, however, have a built-in scale distortion in one direction. The quality of the reproduced copies is reasonably good if the lines on the original are sharp and black. Large areas of uniform tone on the artwork tend to "wash out" in the centre of the copies, resulting in a variation of tone. Ordinary paper can be used and so can preprinted sheets. Tracing papers and transparent overlays can receive an image, but in comparison to photographic images, the quality is poor.

In contrast to single-colour xerography which uses a single plate and toner, the more expensive full-colour machines reproduce multi-coloured opaque artwork by using separation plates. A different plate is used for each of the subtractive primaries (cyan, magenta, yellow), the colour separation being achieved through a lens and filter (red, green, blue) system. Although making colour copies is slower than black and white copying, the price per colour print is economical for limited quantities compared to most other methods of duplicating colour originals. The results, however, can be unpredictable.

Xerography machines in common usage have distinct size limitations. Often the size of the original is limited to 28 X 43 cm (11 by 17 inches) and the reproduction copy to 22 X 36 cm (8 1/2 X 14 inches). Machines are available with greater capacity.

12.1.3 Diazo

The diazo process is by far the most widely used silverless reproduction method in the graphic arts field. The diazo process dates from World War I when a serious shortage of photographic papers and films generated a need for a substitute reproduction process. It is one of the most flexible and comprehensive copy systems which, together with its wide availability and low cost, renders it a desirable reproduction method.

The legacy of the diazo process as a photographic substitute is apparent in its capability of producing copies of line and continuous-tone drawings, air photos and satellite images on various diazo products. These products include a wide range of papers, plastics, foils and plates. The diazo process is ideal for reproducing several copies of a base map which may be used, for example, to compile field information. The non-emulsion side of several diazo products is treated for drafting. The capability to update diazo prints also is an important feature. For this purpose the diazo image on the emulsion side of some products can be removed by bleaching while the diazo image on the emulsion side of non-chemical materials is conveniently moist erasable.

The diazo process allows the same size reproduction of originals. It is positive working, which means that a positive original is needed to produce a positive copy. It can also produce a negative copy of a negative - a useful checking procedure which eliminates darkroom time.

The diazo process involves the destruction of a diazonium salt coating by exposure to ultraviolet, violet or blue light. The original copy on a translucent or transparent base, having a light-absorbing image (ink, pencil, dye, photographic) is placed in contact with the diazo material and is exposed with the original facing the light source. Thus, light passes through the original copy and breaks down the diazonium in the non-image areas, effectively bleaching it. The remaining diazo image is transformed into a visible, stable diazo dye by chemical development. In the older two-component diazo process warm, moist ammonia fumes are used for development. The newer, thermal diazo products are dry processed and developed by heat after their exposure. The one-component diazo products are developed by pouring a phenol solution over the reproduction copy.

A diazo machine should be located in a room with subdued light levels. To produce a diazo copy of an original drawing, the diazo material and the original are fed in the machine together. The diazo material is placed emulsion up and the original is placed on top in the right reading position. Inside the machine the light source, which is high in ultra-violet rays, is located in the centre of a transparent tube. Both the diazo material and the original must be wrapped around this tube during the exposure. This wrapping is a source of potential trouble as some slippage may occur which can affect both the image size and quality.

Inevitably, the act of bending the materials around a tube creates a scale distortion in one direction. If this is a cause for concern, it is recommended that the diazo products should be exposed in a vacuum frame. Light sources used can be carbon-arc, mercury, pulsed-xenon or other high ultraviolet light sources. The newer metal-halide vacuum frames produce a superior product as their light output is ideally balanced for diazo. Vacuum frames enable the cartographer to hold the original drawing and the diazo copy in precise registration with the use of a pin-registration system, a considerable advantage over diazo machines.

An inexpensive, though cumbersome and slow method of exposure, is to place the original over the diazo product in a simple photographic print frame or under a sheet of plate glass, followed by exposure to a photo-flood lamp containing a daylight bulb. Any large transparent container which will hold both the exposed diazo material and a small container for the ammonia can be used for development. With care and experimentation, good results can be obtained at nominal cost.

Materials used on original drawings must also be stable under heat and ultraviolet light, which precludes the use of wax-based adhesive films. Rub-down lettering and symbols can also be easily damaged by the heat and should be given a protective spray. Adhesive tapes, white-outs and similar opaques cannot be used on the original drawing as these will be reproduced on the copy as dark areas.

The diazo process is both convenient and economical and dye line papers are inexpensive and are easily obtained. There are few size restrictions; machines that can reproduce copies up to 122 centimetres (48 inches) wide are readily available. The image, however, is not stable and will fade over a period of time, especially when exposed to light.

All diazo products have a limited thermal stability, particularly in the presence of moisture. Thus their normal shelf life is six to twelve months, possibly much shorter in warm, damp conditions. To alleviate this problem they should be kept in refrigerated storage areas which will greatly extend their useful life. If the materials become discoloured they should generally be discarded.

Most manufacturers produce a range of coloured transparency material with diazo coatings. Combined with pin or punch registration these are ideal sources for map and display overlays. A black base can be combined with several different coloured overlays to make an effective presentation. The diazo process is also used to apply images on scribing film and various colour proofing materials.

12.1.4 Diffusion transfer

This process is becoming extremely popular because of its speed, relative simplicity and the wide range of available products useful in mapping, graphic and display projects.

The basic diffusion transfer process normally begins with a sheet of light sensitive carrier material (which acts as a negative) being exposed in a process camera. Typically the material is orthochromatic so that it can be used under normal red safelights. Both line and continuous-tone materials can be reproduced easily. The exposed negative material is combined with the desired (positive) receiver material and both are fed through a simple processor which contains a single chemical activator.

The two materials are separated by the feeder system, moistened by the activator, and then forced together by the roller system. The result is a sandwich where the negative is in close contact with the receiver. The activator softens the unexposed portion of the negative which transfers the image to the receiver with which it is in contact. A catalyst in the receiver stimulates the breakdown of the silver halide into a visible silver image. The two materials are peeled apart, typically after one minute or so and the negative discarded. The receiver is then rinsed to remove the small amount of residual activator. Receiver materials can include the following: photographic paper; transparent film used to create overlays and overhead projection transparencies; adhesive film used for "cut and paste" artwork and type overlays; and paper and metal lithographic printing plates. Halftones can be created by using special contact screens during the exposure (refer to Section 10.3).

Most diffusion transfer materials are designed for use with a process camera, as camera ready artwork is normally prepared on opaque materials. Therefore a great variety of reproduction sizes is possible. If the final image is intended to be the same size as the original, exposure can take place in a vacuum frame if the artwork has been produced on translucent material.

The economics of diffusion transfer should be carefully evaluated. The materials themselves, particularly continuous-tone and "sticky-back" variants are relatively expensive. The lack of a re-usable negative can be costly when several copies must be made. There is, however, no need for a film negative or for the use of a film fixer or stop-bath. This reduces reproduction costs if only one or two copies are required. Washing requirements are minimal and no time is lost in drying. The activator is re-usable. In most operations, therefore, the use of diffusion transfer will show considerable savings over comparable photographic techniques.

Sizes are limited to the availability of standard materials and to the throat size of the available processor. Most commonly material sizes of 22 X 28 cm (8 1/2 X 11"), 26 X 31 cm (10 X 12"), 28 X 36 cm (11 X 14") and 31 X 46 cm (12 X 18") are processed in the standard 38 cm (15") wide processor. A larger, more expensive processor with a 53 cm (21") throat will process materials available up to 51 X 61 cm (20 X 24"). The most widely available systems are Kodak's P.M.T. (photomechanical transfer) and Agfa-Gevaert's Copyproof which are essentially the same, although the Agfa-Gavaert's product line includes the versatile "sticky-back" material so useful for type and symbol overlays and "paste-up" presentations. Both manufacturers now have full colour systems which are considerably more expensive.

12.1.5 Thermocopy (Thermal copy, Thermal transfer, Dry heat, Infrared)

This is the only copying process in which exposure and development are simultaneous. This simple operation involves only one step, namely the insertion of a specially coated film, plus the original artwork, into the exposure opening of the copying machine. The image is duplicated in only a few seconds onto one of several types of transparency materials. The process is designed for the production of transparencies for overhead projection. It can, however, be used to produce overlays for report size illustrations.

When the original, which can be fully opaque or translucent, and the thermocopy film are passed through the machine the heat from the infrared light source passes through the thermocopy film to the original. Metallic substances in the image absorb the infrared light, producing "hot" areas which form an image on the film where the two are in contact.

Normally acceptable images can be produced from carbon-base inks, most printing inks, lead pencil, liquid writing inks and typewritten copy. Quality is not generally as high as that obtained with photographic or even diazo systems but it is often acceptable for demonstration purposes. Single colour transparencies can be produced in positive or negative form. The size of the thermocopy materials and copying machines is usually limited to page size.

12.1.6 Photostabilization

This is a versatile reproduction system but of decreasing importance because of competition from xerography and continuous printing processes. Nevertheless it offers a speedy alternative to conventional processing methods for silver halide films and papers, which include the standard steps of developing, stopping, fixing and washing. Photostabilization reduces the processing steps to two; developing and fixing. Exposure can be obtained by any conventional photographic method; it then takes about ten seconds to obtain a stable line print or continuous-tone transparency.

All chemicals needed for development of the latent image are contained in the emulsion of the special films. An activator is applied to the film, converting the exposed silver halides to silver. A stabilizer solution then dissolves the undeveloped halides, stops development and fixes the film. These steps are usually carried out automatically in a single processing machine.

Most products are resin-coated to reduce the quantities of water and chemical products absorbed during processing. A more permanent print can be obtained by immersing the film in a fixing solution, followed by washing and drying. No darkroom is needed for this process. The emulsions created are thin and are not suitable for reproduction with photographic films. The background of poorly washed or fixed products will darken in time. Photostabilization processors have been produced in sizes ranging from 13 cm (5") to 107 cm (42") wide, though most are designed for page size reproduction.

12.1.7 Colour imaging

There are many methods of producing colour graphics. One of the most flexible and versatile is a colour imaging system. Colour imaging may be used as a colour proofing system for editing purposes or for the production of materials for display or short-run report illustrations. There are five main systems currently available: Letrachrome (Letraset), Creative Color (Mecanorma), Chromatec, Colourtech and Matrocolor. All produce quite similar results although the processes vary considerably.

Each of these processes is a one-off printing process capable of producing direct image prints or transfer type images from film negatives. Colours are applied individually by manually coating the base material with ink using a metal rolling rod. The ink is dried, usually with a simple hair dryer and then photomechanically exposed to a negative using a specially calibrated ultraviolet light source. The image is developed by removing the softer non-image areas. Exposures are carefully controlled by a calibrated light source.

There is a wide range of colours available. Inks can be mixed to provide colour control by experienced users. Sizes are normally limited to 48 X 63 cm (17 X 25") although some transfer materials are considerably smaller.

12.1.8 Image transfer

Image transfer products enable a cartographer to apply black and white or colour "rub-down" images to particular areas of the artwork.

A high contrast negative is exposed in contact to the image transfer material using an ultraviolet light. A special developer is applied, after which a transferable image is left attached to the base carrier sheet. The image can be burnished onto any desired area of the artwork. Custom type, symbols or images can be created and used whenever necessary. The cost per sheet is relatively high although it is cheaper than commercially available products and the potential for time saving is considerable. The best known product is 3M Image-N-Transfer (I.N.T.), recently acquired by Letraset.

12.1.9 Ink-jet printing

This is a plateless electronic printing method which can reproduce the data stored in digital form in a computer. As with all such techniques the image must be created each time it is reproduced so for 1000 copies the image must be composed from digital information 1000 times. This process is time consuming and subject to mechanical failure so these systems are appropriate for limited-copy production or display products only.

Ink jet printers create images by spraying jets of coloured fluids, similar to fountain pen inks, under pressure through a fine nozzle onto the printing surface. The ink breaks up into tiny droplets, often only .06 millimetres (.0025 inch) in size and at a rate of 100,000 droplets per second. These are charged electrically and directed by the computer to their correct image position. Many printers contain banks of nozzles so they can simultaneously print several colours. If process colour inks are selected the final result can look similar to that produced by lithography.

These machines are mechanically and technically complex and require regular maintenance. Ink jet printing can produce coloured artwork including transparencies relatively quickly and inexpensively. The quality of the image is adequate for many purposes but is inferior to those produced by photomechanical methods.

12.1.10 Laser printing

Laser printing is a plateless electronic printing method used for limited-copy reproduction. Laser printers are relatively expensive but are capable of producing high-quality products. The image is obtained from digital data in a computer which guides the laser beam. A modulator turns the laser beam on and off according to the digital instructions, while a mirror system and scanning prism direct the light beam onto a photosensitive drum. The image is built up line by line in a raster format.

The drum which now contains positive charges is dusted with a toner and a charged paper sheet rolled over it. The resulting image is heat fused in a manner similar to xerography.

Laser printed products excel in quality; there are machines available printing 90,000 dots per square inch, at which point the image approaches that of lithographic printing.

12.1.11 Proofing systems

Most complex graphics or maps are produced from more than one component or overlay. This is true for artwork intended for either single or multi-colour reproduction. These component pieces have to be fitted or registered accurately to each other to produce composite printing negatives which are used to produce printing plates. Proofing must be carried out prior to printing because errors detected at this stage are expensive to correct. Undetected errors may have serious consequences. Proofing systems permit the combination of the graphic components in a pseudo printing manner for editing purposes so that changes can be made before the expensive platemaking and printing processes occur. In many cartographic applications, the proof is the first visual representation of design decisions and construction efforts.

There are several proofing systems available; virtually all are designed for the graphic arts industry and may be unsuitable for some cartographic applications. Most graphic products are reproduced from optical separation negatives of multi-coloured artwork or photography. Therefore the process colours (subtractive primaries) cyan, magenta (red) and yellow, together with black, are used for printing such artwork (refer to Section 10).

Cartographic products, in contrast, may be reproduced in colours other than the process colours. For example a fine line, the most common cartographic symbol, may be coloured brown. In process reproduction, however, the colour brown would be a composite of the process colours and minor registration problems which occur in the printing stage would cause visible colour variations in brown linework. Therefore fine lines should be printed as a separate colour rather than a composite of the process colours. Cartographic proofing systems must have a wider range of colours than the process colours. They can also be considered as limited copy reproduction techniques as most proofs make excellent display or discussion products.

12.1.11.1 <u>Overlay systems:</u> These systems use a series of transparent overlays of different colours which are registered to each other to form a composite of the original artwork. An advantage of this technique is that any given overlay can be corrected, reproduced and refitted to the others without the need to produce an entirely new proof. The overlays also make excellent overhead projection transparencies. The systems are limited to relatively few layers because the intervening reflective layers of plastic degrade the lower images.

Overlay systems are versatile and can produce excellent results. They are available in both negative and positive working formats. The materials are exposed to a high ultraviolet light source in a vacuum frame. The film is developed with a simple single solution, washed and dried. It is possible to make a full colour proof in 20-30 minutes. The overlays are available in several popular colours and darkroom facilities are not required. Examples of overlay proofing systems include 3M Color Key and Polychrome Chrome-Guide. Coloured diazo film, however, is the most economical and widely available version of the overlay system. If the overlays are produced on a diazo polyester base in a vacuum frame and punch registered, they can be used to proof the registration as well as the information contained on the original artwork.

12.1.11.2 Lamination overlay systems: Lamination overlay systems are capable of producing high quality, colourful and attractive proofs which are excellent for promotional purposes. They are, however, expensive systems to purchase and to operate, hence they are unlikely to be considered by smaller agencies.

Lamination overlay systems produce colour proofs on sensitized, adhesive-backed and transparent materials. These materials are either pre-coloured or are given the appropriate colour during processing. Processing begins by laminating a sensitized overlay to the base material. The sensitized overlay is then exposed in contact with the appropriate film intermediate using an ultraviolet light source. The procedure varies depending on the process being used. Some processes are negative working while others are positive working. After developing, an appropriate coloured image remains and the process is repeated for each additional colour. Normally a colour proof can be produced in an hour. Equipment needed includes photomechanical items, a laminator and a toning console. Examples of these systems include Cromalin by Dupont and Transfer-Key by 3M.

Other lamination proofing systems use sensitized gelatin coatings. A proprietary white base material is softened in a special solution and the sensitized coating added in a transfer unit. A dryer is also required. The base is exposed to a negative, processed in an activator and washed. The process is repeated for each colour. Gevaproof by Agfa-Gaevert, an example of such a system, was primarily designed for four colour separation using black, cyan, magenta and yellow although a few other colours can be obtained. The proof is of excellent quality and can be used for display purposes.

12.1.11.3 Negative superimposition systems: Superimposition systems are widely used throughout cartography to produce proofs, plates and guide images on dense, stable-base materials. A light sensitive coating is applied to the base in a liquid form and allowed to dry. It is exposed to ultraviolet light in contact with a negative in a vacuum frame. Exposed areas are hardened, whereas non-exposed and therefore non-hardened areas can be removed by special developers or sometimes by water.

After developing, washing and drying, the process is repeated for each additional colour. An example of these systems is Kwik Proof by Direct Reproduction Corp. In general the processes are economical to purchase and produce an acceptable proof of virtually any size. Liquid coatings have a limited shelf life, therefore, the expiry date of these materials should be carefully noted. These processes are time consuming and the colours achieved are less intense than those which result from the use of lamination overlay systems. Actual printing colours are also difficult to match.

12.1.11.4 Positive superimposition systems: Positive superimposition systems produce a better quality proof than negative superimposition systems. A positive working dichromated colloid emulsion is added to a white opaque plastic base material, often polyvinyl chloride. The positive is exposed to the base under an ultraviolet light source in a vacuum frame and a coloured ink is then applied. The hardened emulsion areas wipe off with water. The process is repeated for each additional colour, thus producing one of these proofs is time consuming.

The positive superimposition system is ideally suited for proofing positive artwork such as line drawings, type overlays, rub-down pattern overlays, etc. An example of such a system is the Hausleiter system. The inks themselves are not light sensitive, thus the expiry date is not a problem. The liquid emulsion, however, has a relatively short shelf life.

12.2 Multi-Copy Reproduction

12.2.1 Basic printing processes

Multi-copy reproduction of images may be carried out by one of four basic printing processes [Figure 12.3]. These processes are distinguished by the nature of the printing surface of the intermediate image carrier, commonly called a plate. They include:

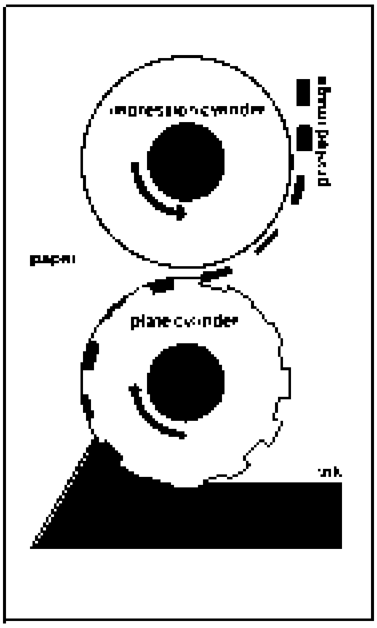
i) intaglio or gravure [Figure 12.3 a];
ii) relief or letterpress [Figure 12.3 b];
iii) planographic or offset-lithography (Figure 12.3 c);
iv) screen or stencil (Figure 12.3 d).

12.2.1.1 Intaglio printing [Gravure]: Image areas are etched into metal plates to form reservoirs for ink. The entire image area is screened with the depths of the reservoirs controlling the amount of ink being transferred, thereby controlling the density of tone on the paper. The etched gravure cylinder rotates in a fountain of ink, filling the reservoirs. A doctor blade then wipes the ink from the non-recessed, non-image areas of the plate. The image is then transferred directly from the plate onto the paper by the impression cylinder. Intaglio printing presses may be sheet-fed or roll-fed and provide quality reproduction on both smooth and textured surfaces. Intaglio printing is a relatively expensive process and is normally reserved for high-volume, high-quality products.

12.2.1.2 Relief printing (Letterpress): This process is the opposite of intaglio printing in that the image areas are raised above the non-image areas. The process uses metal type, engravings, combinations of both or duplicate plates to carry the image. The ink is applied by rollers to the raised surfaces and then transferred directly onto paper. Impression is sharp and clear but varies with the smoothness and texture of the paper.

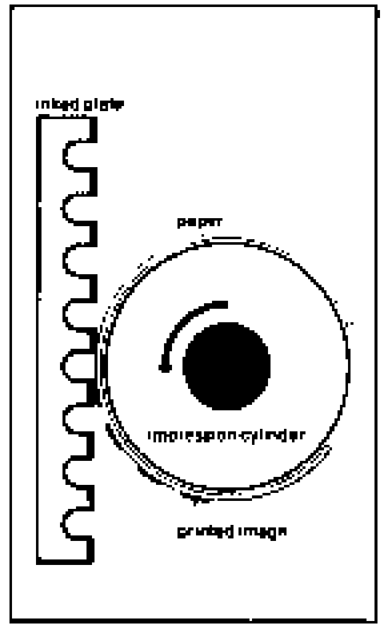
Figure 12.3 Basic printing processes. (After E.B. Eddy handbook of printing production, 1967)

a INTAGLIO OR GRAVURE



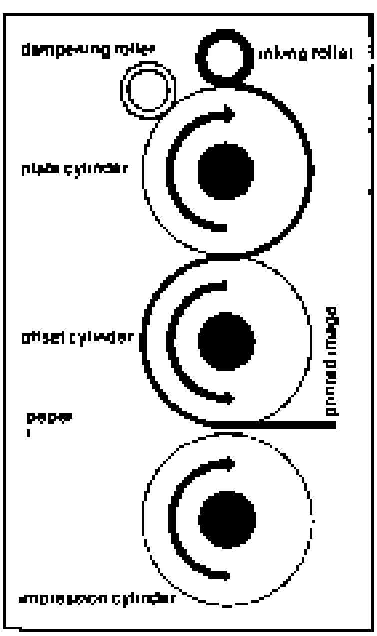
Example: rotogravure
Ink is transferred to paper from wells sunk in the surface of the cylinder. Non-printing areas are on the surface from which all ink is wiped by the doctor blade; depth of the individual wells determines the amount of ink transferred to paper.

b RELIEF OR LETTERPRESS



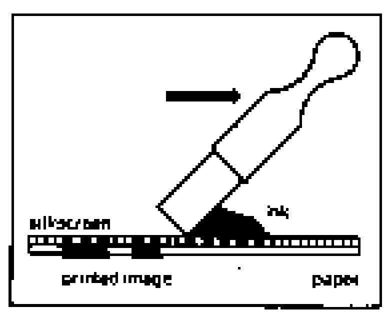
Example: letterpress
Ink is transferred to paper directly from the raised parts of type or illustrations. All other areas of the printing form are lower than the printing surface and therefore receive no ink.

c PLANOGRAPHIC OR OFFSET-LITHOGRAPHY



Example: offset
Ink is transferred from a flat plate, usually zinc (although other metals or even paper may be used) to a rubber blanket and thence to paper. Parts of plate which are to print are greasy, and therefore attract the ink, others are not and therefore attract water which repels the ink.

d SCREEN OR STENCIL



Example: silkscreen
Ink is transferred to paper by being squeezed through the open parts of the screen. Non-printing areas are chemically hardened and thereby solidify the screen at these points.

The relief process is somewhat dated and has been replaced by lithography in most major printing operations.

There are three general classes of letterpress or relief printing presses (Figure 12.4):

i) platen (Figure 12.4 a);
ii) flat-bed cylinder (Figure 12.4 b);
iii) rotary (Figure 12.4 c).

A. Platen press: The plate and paper are both carried on plane surfaces. Paper is sheet-fed into position on the platen which then presses against the inked image in the press bed.

B. Flat-bed cylinder press: The impression cylinder which also carries the paper is on a stationary axle. The press bed which carries the inked image moves back and forth. Impression is made under pressure as the cylinder revolves. Cylinder presses are sheet-fed.

C. Rotary press: Rotary presses have two cylinders that rotate at high speed in the same direction. One cylinder which carries the inked image transfers this image to the other cylinder which carries the paper. Paper may be sheet-fed or roll-fed.

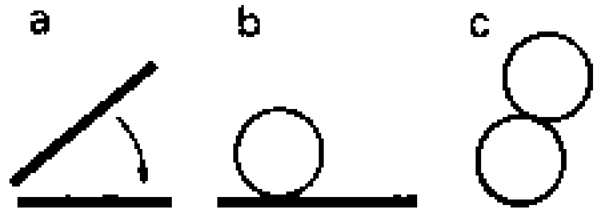
12.2.1.3 Planographic printing (Offset lithography): This method is based on the principle that water and oil do not mix. Offset lithographic plates carry both the image and the non-image areas on the same level. Image areas are photomechanically reproduced onto metal plates that are chemically sensitized to accept ink and repel water in the image areas. Non-image areas accept water and repel ink. In offset lithography, the plate first contacts rollers of water and then the inked rollers. The inked image is transferred from the plate onto a rubber blanket cylinder, and then onto the paper which is carried by a third cylinder. The resilience of the rubber blanket allows offset lithography on a wide range of surface textures. Paper may be sheet-fed or roll-fed. Multi-copy reproduction of most cartographic products is done on sheet-fed offset presses. Offset lithography is by far the most common printing process available and is normally used to reproduce cartographic artwork.

There are two techniques of forming an image on the lithoplate:

i) A negative is exposed in contact with the coated plate. The resultant image is based on the residual hardened coating; the unexposed (background) areas are soluble and removed;

ii) A positive is exposed in contact with the coated plate. The image itself, being soluble, is removed. Like the negative-made image, this technique forms a "surface" plate, but it can also provide a "deep-etch" plate, with the aid of acid etching, so producing an image which is slightly recessed.

Figure 12.4 Three classes of letterpress or relief printing presses: (a) platen; (b) flat-bed cylinder; (c) rotary. (After J.S. Keates, 1973)



12.2.1.4 Screen printing (Stencil): This process is one of the oldest and most widely used methods of reproduction. Traditionally screens consisted of porous materials, such as silk, mounted on a wooden frame. Modern day image carriers or screens are usually made of polyester fabric or stainless steel mesh. Printing is done by forcing ink through the image areas of the screen with a squeegee. The non-image areas of the screens are blocked by stencils which are hand-cut or produced by photo-mechanical methods.

Line, halftone and screen tinted artwork can be reproduced on virtually any surface. The screening, however, is relatively coarse by cartographic standards. The simpler systems make it difficult to register additional colours accurately. For this reason it is mostly limited to simple and bold reproductions, for example, posters, report covers, invitations, programs, etc.

Screen printing using traditional techniques is an inexpensive and versatile positive working system suited to limited-copy production. Commercial screen printing, however, is done on power-operated presses capable of producing 5,000 impressions per hour and is suitable for multi-copy reproduction. Paper may be sheet-fed or roll-fed.

SECTION 13

13. MARINE RESOURCE MAPPING AND CASE STUDIES

The following list of resource maps indicates the wide variety of cartographic techniques which may be used to portray marine information and data. Some of the maps are "one of a kind", others are one of a map series and still others are an integral part of a scientific report. Each of the twelve map projects selected from the listing as a case study is accompanied by a description of the map objectives and scale, and general comments concerning its format, colour, update capabilities, etc.

13.1 Small-Scale: International Atlases

i) Atlas of the Living Resources of the Seas. (Refer to FAO, 1972 in bibliography.)

ii) Serial Atlas of the Marine Environment. (Refer to American Geographical Society, var.d., in bibliography.)

13.2 Small-Scale: Regional Atlases

i) The Lancaster Sound Region: Data Atlas. (Refer to Dirschl, H.J., 1982 in bibliography.)

ii) Fundy Coastal Zone Study. (Refer to case study #1 and Hunter and Associates, 1982 in bibliography.)

iii) Gulf of St. Lawrence Water Uses and Related Activities: A Cartographic Presentation. (Refer to Simpson, W., 1973 in bibliography.)

iv) Canadian Atlantic Offshore Fishery Atlas. (Refer to Scarratt, D.J., 1982 in bibliography.)

v) Barbados Preliminary Data Atlas: Survey of Conservation Priorities in the Lesser Antilles. (Refer to case study #2 and The Eastern Caribbean Natural Area Management Program, 1980 in bibliography.)

vi) Bay of Fundy Resource Inventory. (Refer to case study #3 and McKay, A. et al., 1978 in bibliography.)

vii) Environmental Atlas of the Southern Gulf of St. Lawrence. (Refer to McGuire, B.E., 1979 in bibliography.)

viii) Nova Scotia Fisheries Atlas. (Refer to case study #4 and Maritime Resource Management Service Inc., 1982 in bibliography.)

13.3 Small-Scale: Regional Maps

i) Distribution, Migration and Spawning of the Main Fish Resources in the Northern CECAF Area. (Refer to Garcia, S., 1982 in bibliography.)

ii) Fisheries Atlas of the Western and Central Mediterranean. (Refer to Charbonnier, D. and S. Garcia, 1985 in bibliography.)

iii) Geology of the Island of Newfoundland: Preliminary version. (Refer to case study #5 and Newfoundland and Labrador Department of Mines and Energy, 1983 in bibliography.)

iv) 1983 Fishing Industry Synopsis - Gulf Region. (Refer to case study #6 and Maritime Resource Management Service Inc., 1983 in bibliography.)

13.4 Medium to Large-Scale: Regional Map Series

i) An Ecological Characterization of Coastal Maine. (Refer to U.S. Department of the Interior, 1980 in bibliography.)

ii) Demersal Fish Assemblages in Liberia, Ghana, Togo, Benin and Cameroon. (Refer to Villegas, L. and S. Garcia, 1983 in bibliography.)

iii) Strait of Canso Natural Environment Inventory. (Refer to Maritime Resource Management Service Inc., 1975 in bibliography.)

iv) Nova Scotia Estuarine and Coastal Resource Inventory. (Refer to case study #7 and Maritime Resource Management Service Inc., 1982 in bibliography.)

v) Marine Resource Pilot Study: Passamaquoddy Bay. (Refer to Maritime Resource Management Service Inc., 1982 in bibliography.)

vi) Small Craft Harbours and Facilities Directorate. (Refer to case study #8 and Maritime Resource Management Service Inc., 1985 in bibliography.)

13.5 Maps in Conjunction with Technical Reports

i) A Survey of the Coastal Fish Resources of Sri Lanka. (Refer to Blindheim, J. et al., 1979 in bibliography.)

ii) Peru: Acoustic Estimation of Ichthyomass and its Distribution in Lake Titicaca. (Refer to Johannesson, K. et al., 1981 in bibliography.)

iii) Regional Fishery Survey and Development Project, Demersal Resources of the Gulf and the Gulf of Oman. (Refer to case study #9 and FAO, 1981 in bibliography.)

iv) Coastal Resources Inventory and Mapping Program, St. Georges Bay Pilot Study. (Refer to case study #10 and Warren, R.A. and H.P. Anderson, 1975 in bibliography.)

v) A Remote Sensing Technique for Quantifying Lobster Fishing Effort. (Refer to case study #11 and Pringle, J.D. and R.E. Duggan, 1983 in bibliography.)

vi) Barbados Coastal Conservation Study. (Refer to case study #12 and Hunter and Associates et al., 1984 (unpublished) in bibliography.)

The publication entitled "A Review of Coastal Zone Mapping", edited by Roland Perrotte (1986), prepared under the auspices of the Commission on Oceanic Cartography (International Cartographic Association) complements the case studies. Unlike this manual, however, it is not confined to resource mapping per se.

13.6 Case Study Review and Analysis

The following case studies are intended to provide the reader with a range of thematic mapping applications and their various production methods:

13.6.1 Case study #1

Title:	Fundy Coastal Zone Study
Produced by:	Hunter and Associates, Mississauga, Ontario, Canada.
Produced for:	New Brunswick Department of Natural Resources Mineral Resources Branch, Fredericton, New Brunswick, Canada, 1982.
Scale:	Various
Objective:	The study was designed to provide the following information: - an inventory of marine beaches and terrestrial resources; - study of coastal processes; - study of coastal zone land uses and their influences on the coastal environment; - preparation of coastal zone management recommendations.
Description:	The study was prepared in two separate volumes, a Technical Report and a Map Atlas, and was printed in three colours. The example shown was taken from the Atlas (Figure 13.1 - White Head Island), one of 74 map sheets. The base map is a photo mosaic (refer to Section 8.9).
Commentary:	The maps are good examples of the use of a simple photo mosaic base overprinted with a variety of thematic subject matter. In this Atlas the treatment of each of the 74 maps is similar, hence a common legend was used for the entire Atlas. This type of presentation can be quickly and economically produced. For the user, the three available colours plus a detailed photo base ensured that data could be easily interpreted. Most of the thematics in this volume, however, could have been added directly to the photo base rather than to the additional line base map (Figure 13.2). The maps could also have been produced at smaller scales and therefore occupy less space and fewer pages.

Figure 13.1

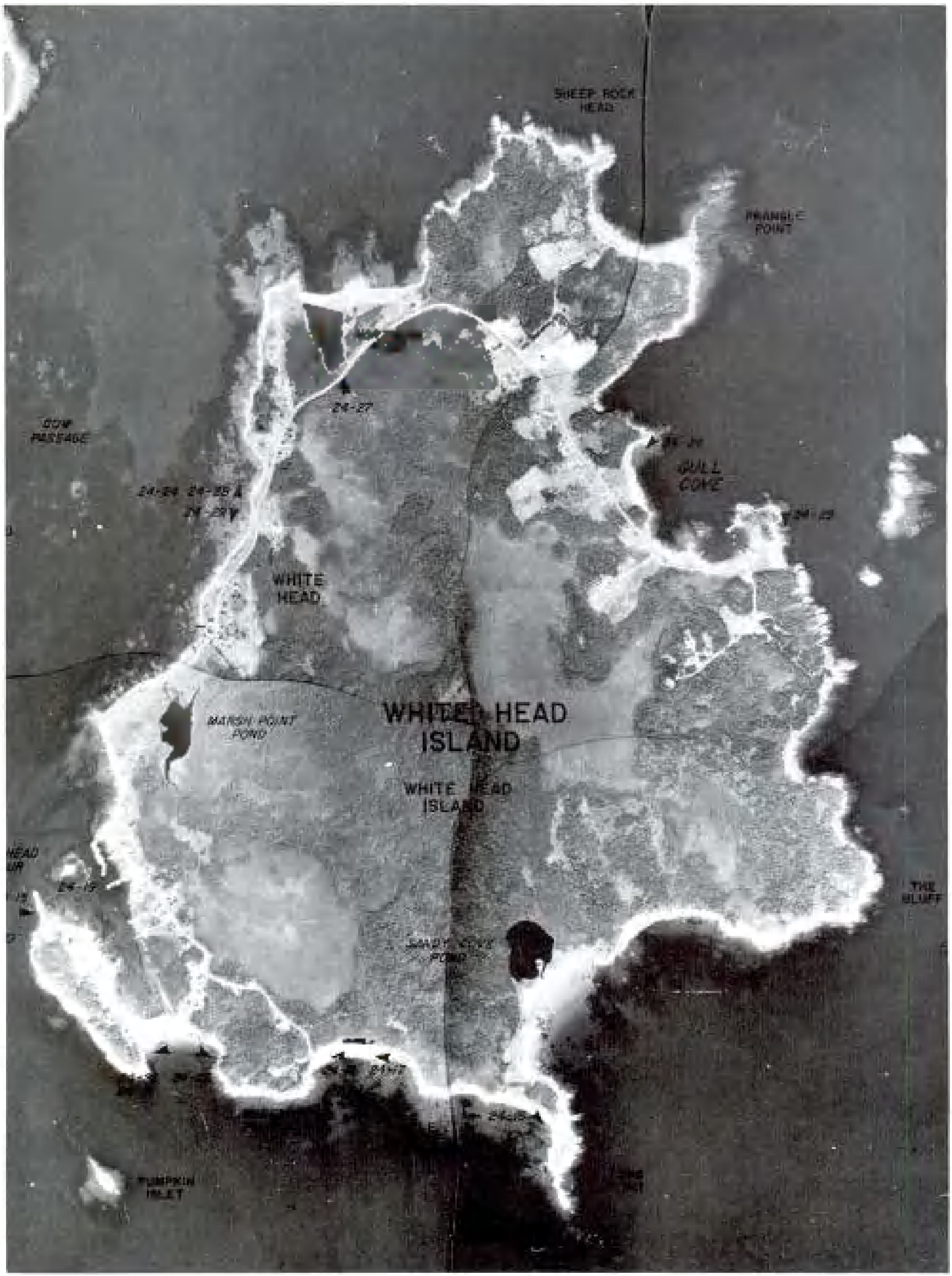

SHEEP ROCK HEAD
COW PASSAGE
24-27
24-24 24-25
24-28
GULL COVE
WHITE HEAD
MARSH POINT POND
WHITE HEAD ISLAND
WHITE HEAD ISLAND
THE BLUFF
24-19
PUMPKIN INLET

Figure 13.2


SGB/R
G/R
R
R·r
R
SG/R
bgs
B/R
R
GS
G/R
R
PCcb - TVS
R·r
Tm
bgs
Ww·Mv
R
CB/R
R
SGB/R
R
Mwv·O
R·r
GB/R
CB/R
R
B/R
R
R
R
O
GSM
SGB
R
O
R
GB/R
R
Mv·R·O
R·r
R·r
O
Mwv·O
R
WwvO
R
O
R
Mv·R
R·r
R·r
S
Mwv·O
O
R
S/R
R
GB/R
bgs
SG
R
S
R
R·r
SG/R
U·u
PCsh
bgs
+
GB/R
bgs
SGB/R
bgs
PCcb - TVS
R

13.6.2 Case study #2

Title: Barbados Preliminary Data Atlas
Survey of Conservation Priorities in the Lesser Antilles

Produced by and for: The Eastern Caribbean Natural Area Management Program (ECNAMP), St. Michael, Barbados. A cooperative effort of the Caribbean Conservation Association and the School of Natural Resources of the University of Michigan, 1980.

Scale: Various

Objective: To provide the ECNAMP with a co-ordinated information source in order to plan an effective conservation strategy throughout the Lesser Antilles.

Description: The Barbados Preliminary Data Atlas is one of a series of 26 Atlases, one for each of the islands or island groupings in the region. The size of the standardized presentation is 22 X 28 cm (8 1/2 X 11"), which dictated a wide variation in scales and graphic details. Each atlas covered the same sixteen parameters chosen as significant: Rainfall; Land Use Capabilities; Coastal Currents; Terrestrial Life Zones; Important Marine Habitats; Endangered and Locally Important Species; Population Density; Present Land Use; Marine Resource Use; Transport; Natural Attractions; Cultural Attractions; Population; Key Watersheds, Parks and Protected Areas; Land Ownership; and Conservation Synthesis.

Commentary: The use of a single base map and standardized page layout is often an economical and time saving solution, but with the disadvantage that several maps are drawn at an unsuitable scale. The amount of information shown on "Coastal Currents" (Figure 13.3), for example, is limited and could be depicted at a smaller scale. The constant scale, however, does have the advantage of enabling easy comparison of data from map to map, a significant consideration from the point of view of most users. It also would enable such information to be easily entered into a computerized data storage system should that become a necessity.

The artwork was produced with simple drafting techniques and commercially available shading patterns and symbols (Figure 13.4). Some symbols were hand drawn on other maps in the atlas as no suitable commercial symbols were available.

Graphic improvements might include the removal of the credit attribution repeated at the top of every page, and its replacement with a bolder map title.

Figure 13.3

Eastern Caribbean Natural Area Management Program
Survey of Conservation Priorities in the Lesser Antilles

RESOURCE DATA MAPS - BARBADOS

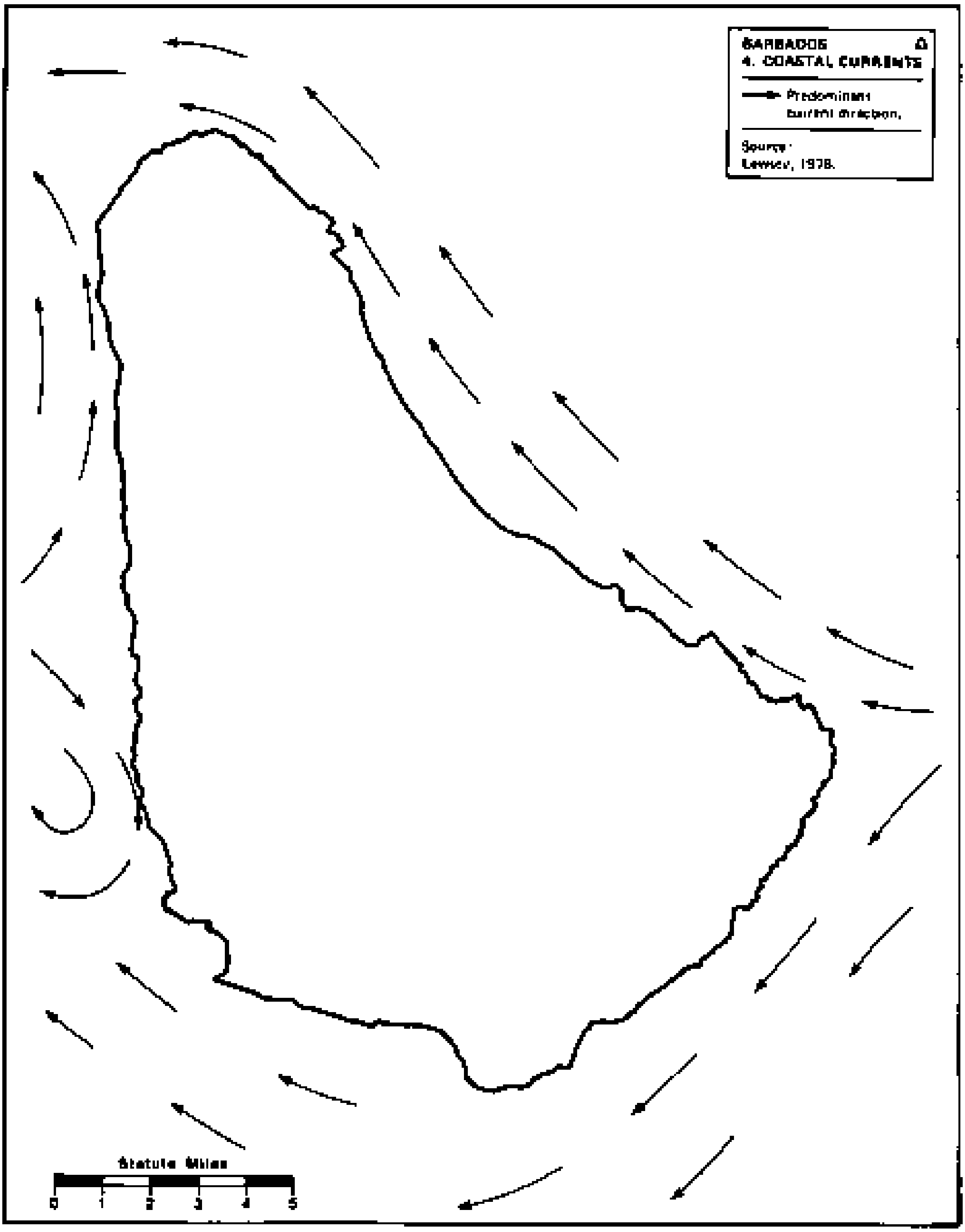
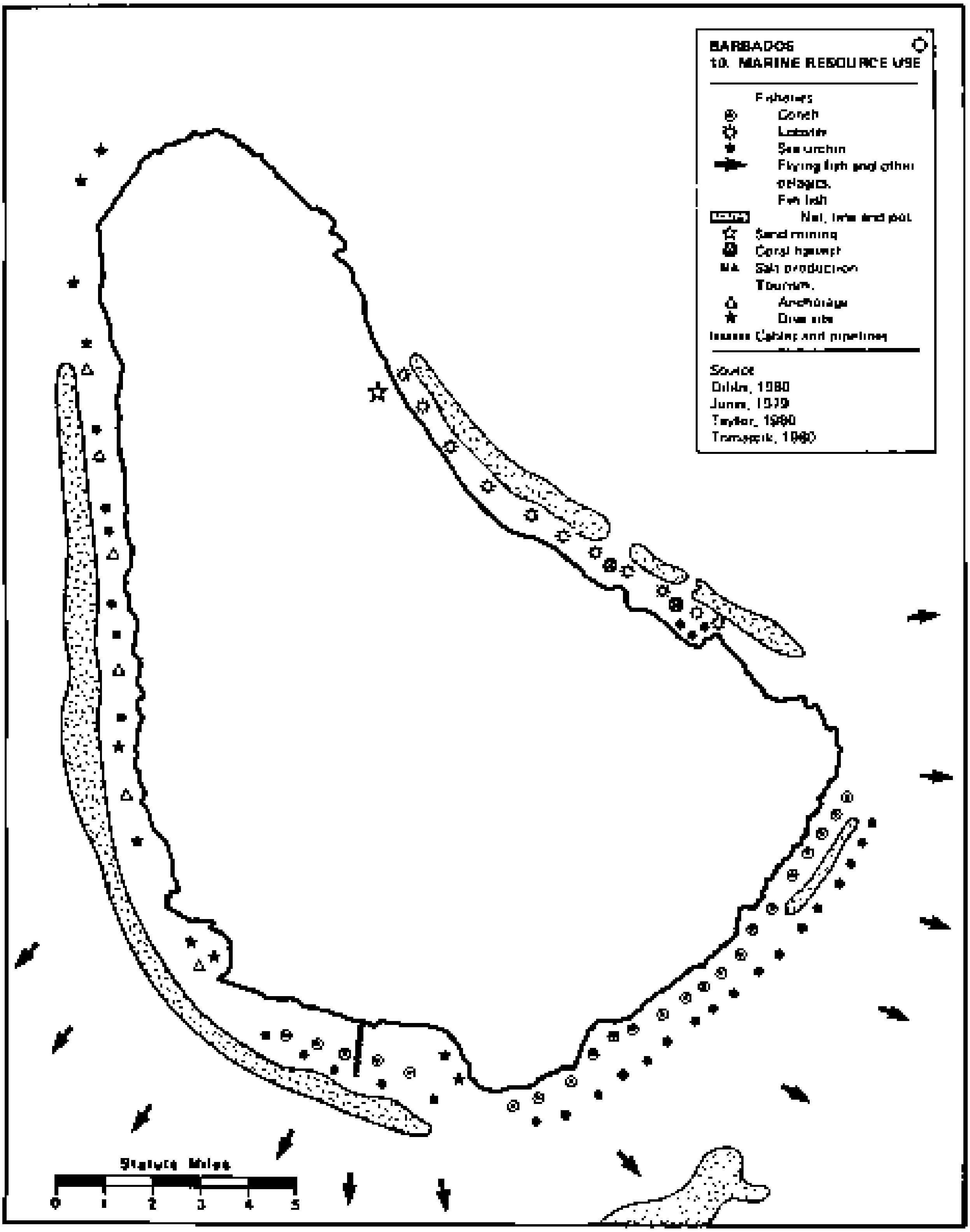


Figure 13.4

Eastern Caribbean Natural Area Management Program
Survey of Conservation Priorities in the Lesser Antilles

RESOURCE DATA MAPS • BARBADOS



13.6.3 Case study #3

Title: Bay of Fundy Resource Inventory

Produced by: Marine Resource Associates Ltd., Bocabec, New Brunswick, Canada.

Produced for: New Brunswick Department of Fisheries Fredericton, New Brunswick, Canada, 1979.

Scale: Various

Objective: This six volume inventory catalogued the shallow-water resources of the New Brunswick coast of the Bay of Fundy. The information was required to facilitate objective management decisions and resolve conflicts between resource-based and heavy industries.

Description: The graphic included demonstrates a simple marine survey technique of wide applicability (Figure 13.5). Scuba equipped specialists mapped a broad range of oceanographic, topographic and biological data. Simple, single colour report illustrations were adequate for this detailed and wide ranging survey. The illustrations were accompanied by an extensive presentation of data tables. The graphics were produced by basic pen and ink techniques.

Commentary: The effective land-water differentiation should be noted on Figure 13.6 "Sources of Seawater Passages". Graphic and tabular presentations are simple and effective (Figure 13.7). The standardized map base shown in Figure 13.8, however, is not suitable for all subjects. Still it remains a quick and economical production technique.

Figure 13.5

SUBTIDAL SURVEY TECHNIQUE. A 100 meter Transect line was laid across the bottom. Stations at 3 meter intervals were examined by a team of divers and depth, substrate and species abundance was recorded [The transect line is shortened for the purpose of illustration].

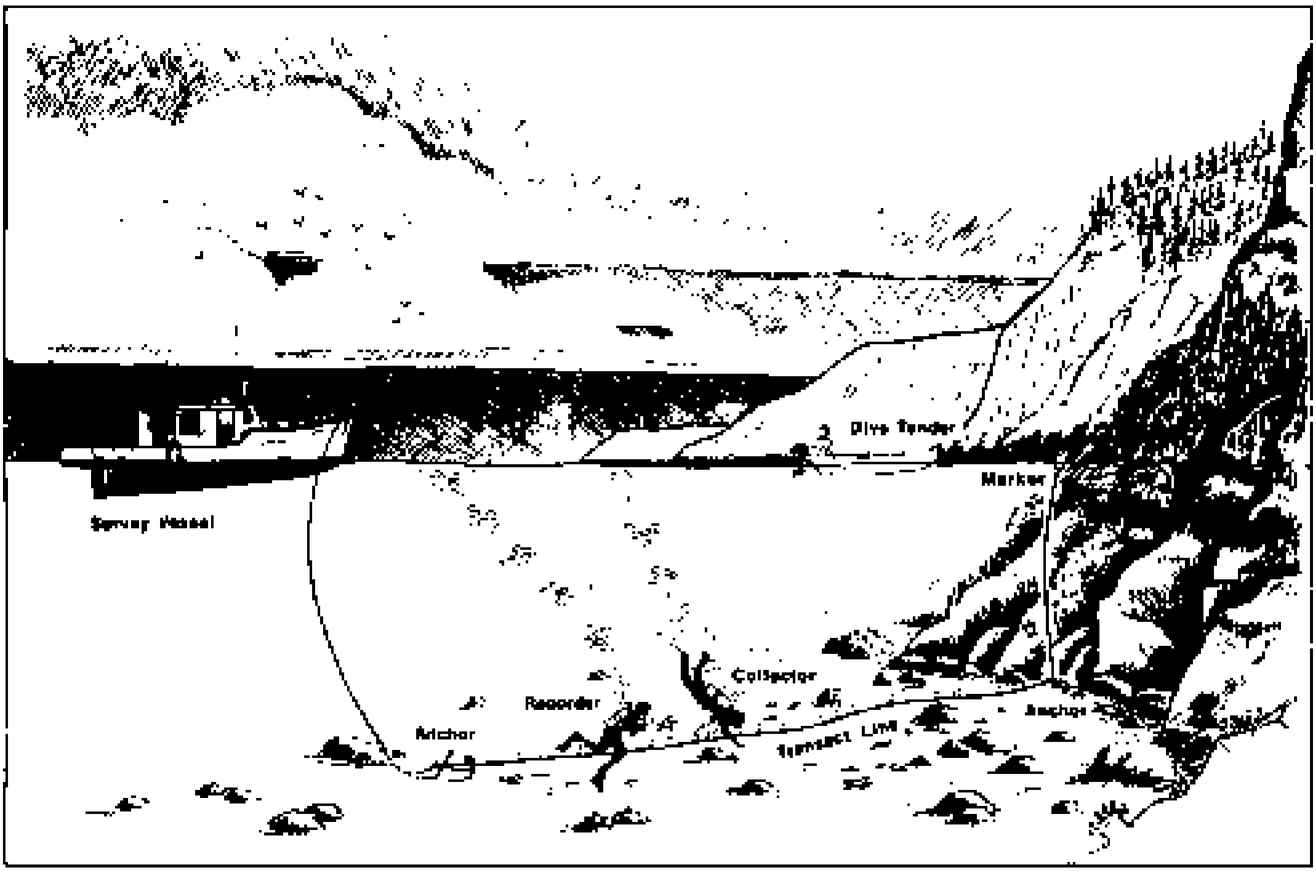


Figure 13.6

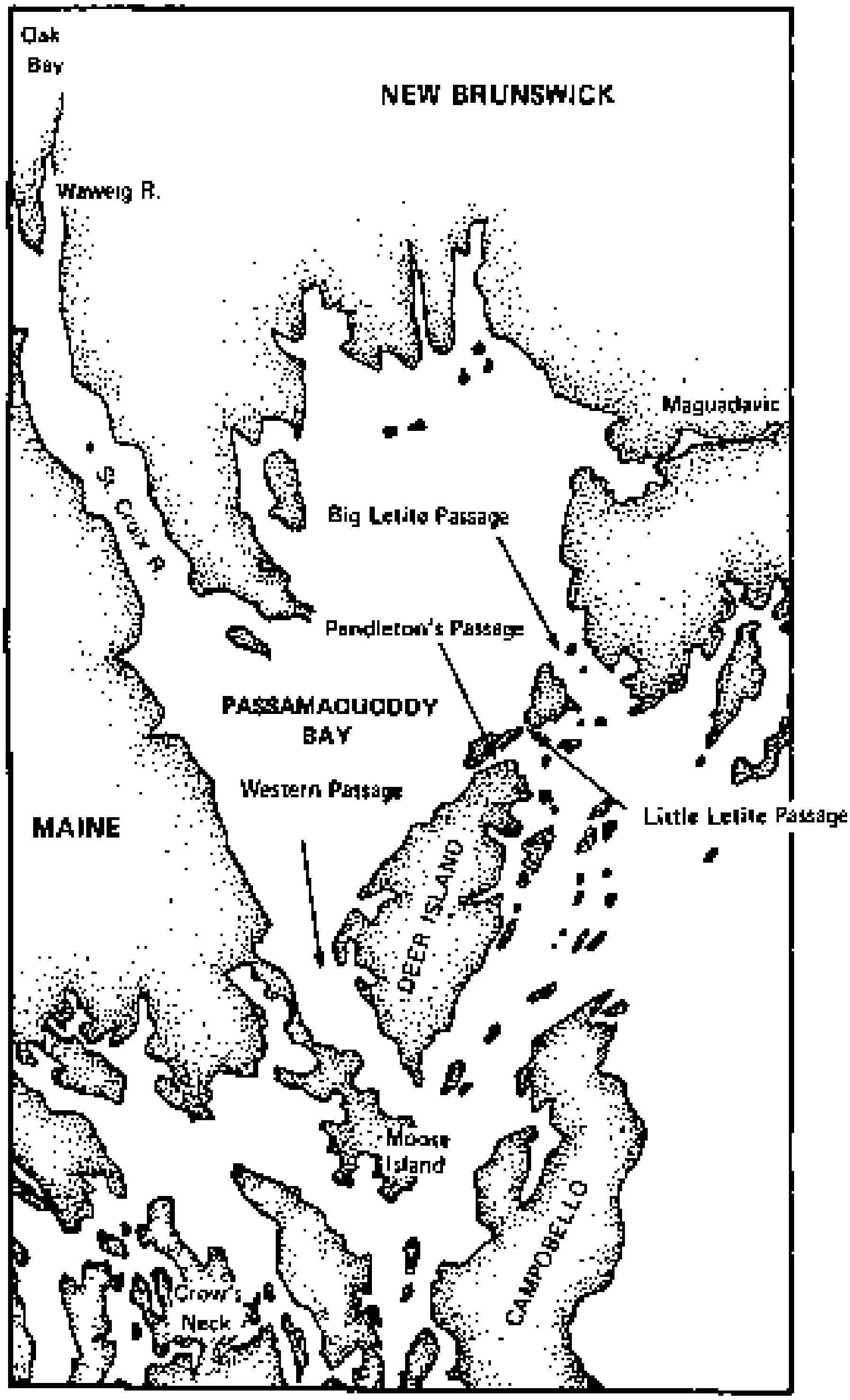

Oak
Bay
NEW BRUNSWICK
Waweig R.
Maguadavic
St. Croix R.
Big Letite Passage
Pendleton's Passage
PASSAMAQUODDY
BAY
Western Passage
MAINE
Little Letite Passage
DEER ISLAND
Moose
Island
CAMPOBELLO
Crow's
Neck

Figure 13.7

STATION NUMBER & SURFACE DISTANCE (Metres)

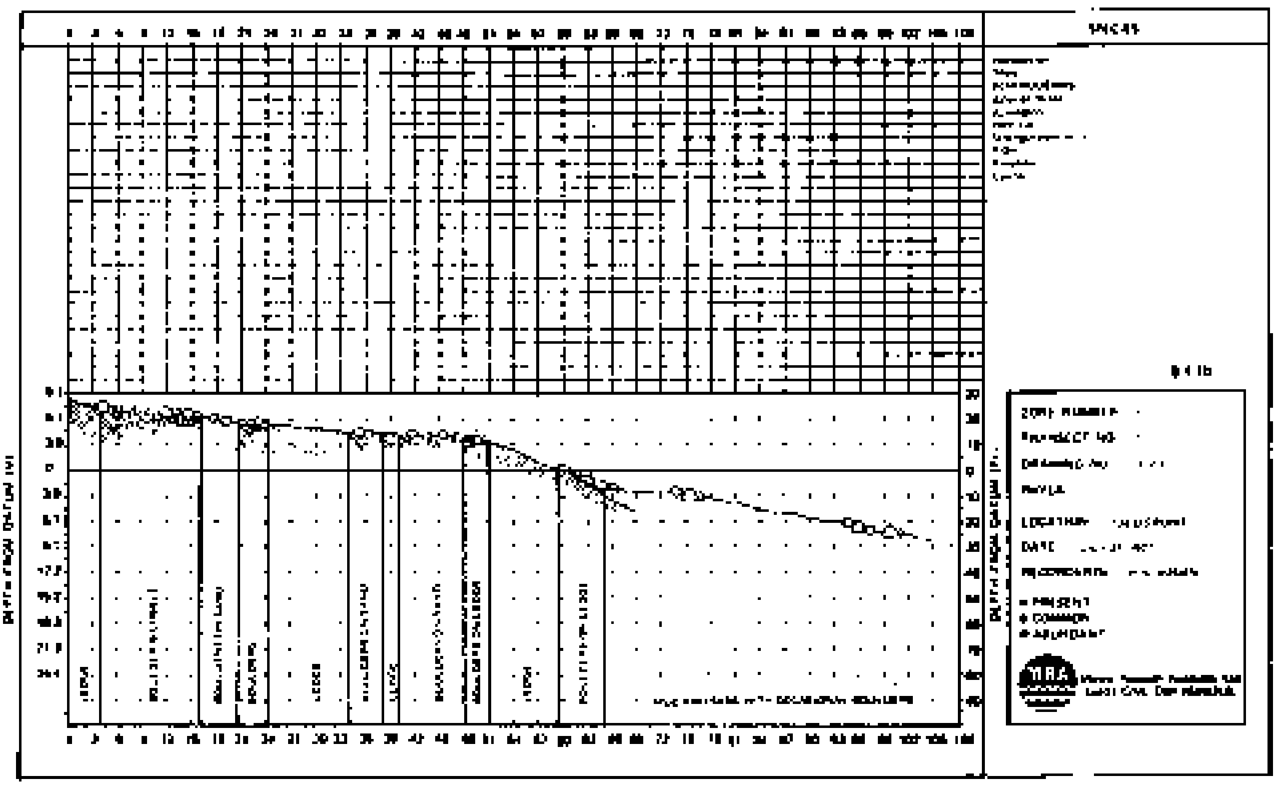
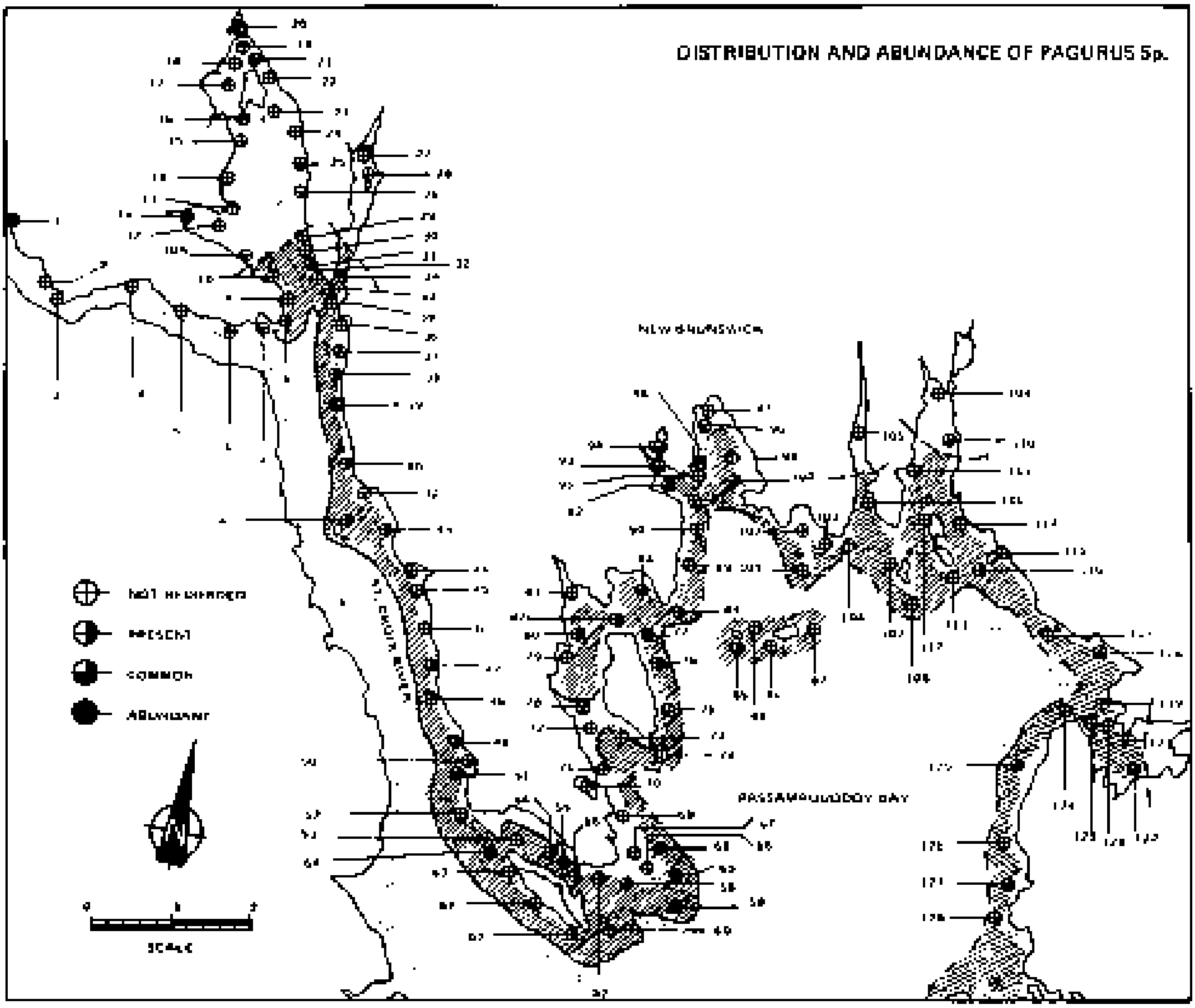


Figure 13.8


DISTRIBUTION AND ABUNDANCE OF PAGURUS Sp.
NEW BRUNSWICK
PASSAMAQUODDY BAY
ST. CROIX RIVER
SCALE

13.6.4 Case study #4

Title: Nova Scotia Fisheries Atlas

Produced by: Maritime Resource Management Service Inc., Amherst, Nova Scotia, Canada.

Produced for: Nova Scotia Department of Fisheries, Halifax, Nova Scotia, Canada, 1982.

Scale: 1:2,000,000

Objective: To provide a comprehensive compendium of information on the fishing industry of Nova Scotia. It was intended to be of value to fishermen, fish processors, administrators, educators, students and the general public.

Description: The detailed and well designed atlas contains 14 full-colour statistical thematic maps covering many aspects of Nova Scotia's fishing industry. It also features a variety of black and white maps, line drawings, photographs and explanatory text. The main subject areas are fish landings, the fishing fleet, employment, onshore facilities and infrastructure, and exports.

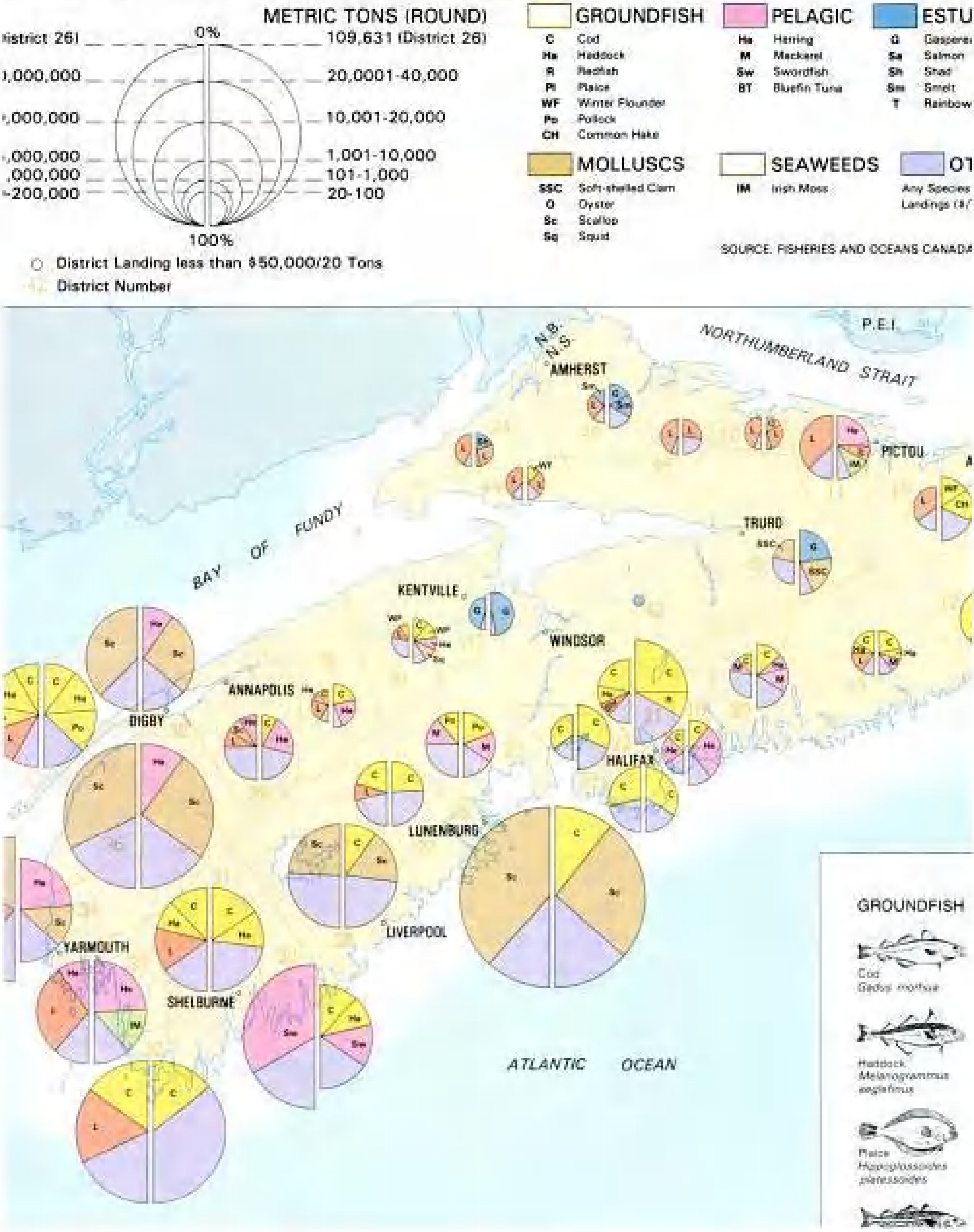
Commentary: This award-winning presentation contains excellent examples of the great volume of information which a properly designed multi-colour map can transmit clearly and easily. Each map was produced on a common base but used a different graphical and statistical method of presenting its thematic data, which lends variety to the overall design. An attractive combination of colours was enhanced by the use of vignetting to provide a white band around the coastline. This technique ensured that the area of greatest detail and interest was kept clear of interfering coloured background, and the "window" effect focuses the reader's attention. The atlas is also an example of the versatility of four process colour printing, with an additional colour. Open areas on most maps were usefully filled with related inserts, such as in the "Significant Species" map illustrated in Figure 13.9. This enhances the usefulness of the product to non-specialists. The significant 'key' names are all easily readable due to simple, sans serif, condensed type styles. Of note is the use of white paper for the explanation areas. The contrast with the adjacent pastel-coloured maps draws attention to the text. The use of an aesthetically pleasing buff-coloured background would not have achieved this result.

The atlas was relatively expensive to produce because of the number of multi-colour maps and their complexity.

Figure 13.9

ANT SPECIES

s Greater or Equal to 15% of Total Landed Value and Tonnage



13.6.5 Case study #5

Title: Geology of the Island of Newfoundland Preliminary Version

Produced by and for: Mineral Development Division, Newfoundland and Labrador Department of Mines and Energy, St. John's, Newfoundland, Canada, 1983.

Scale: 1:1,000,000

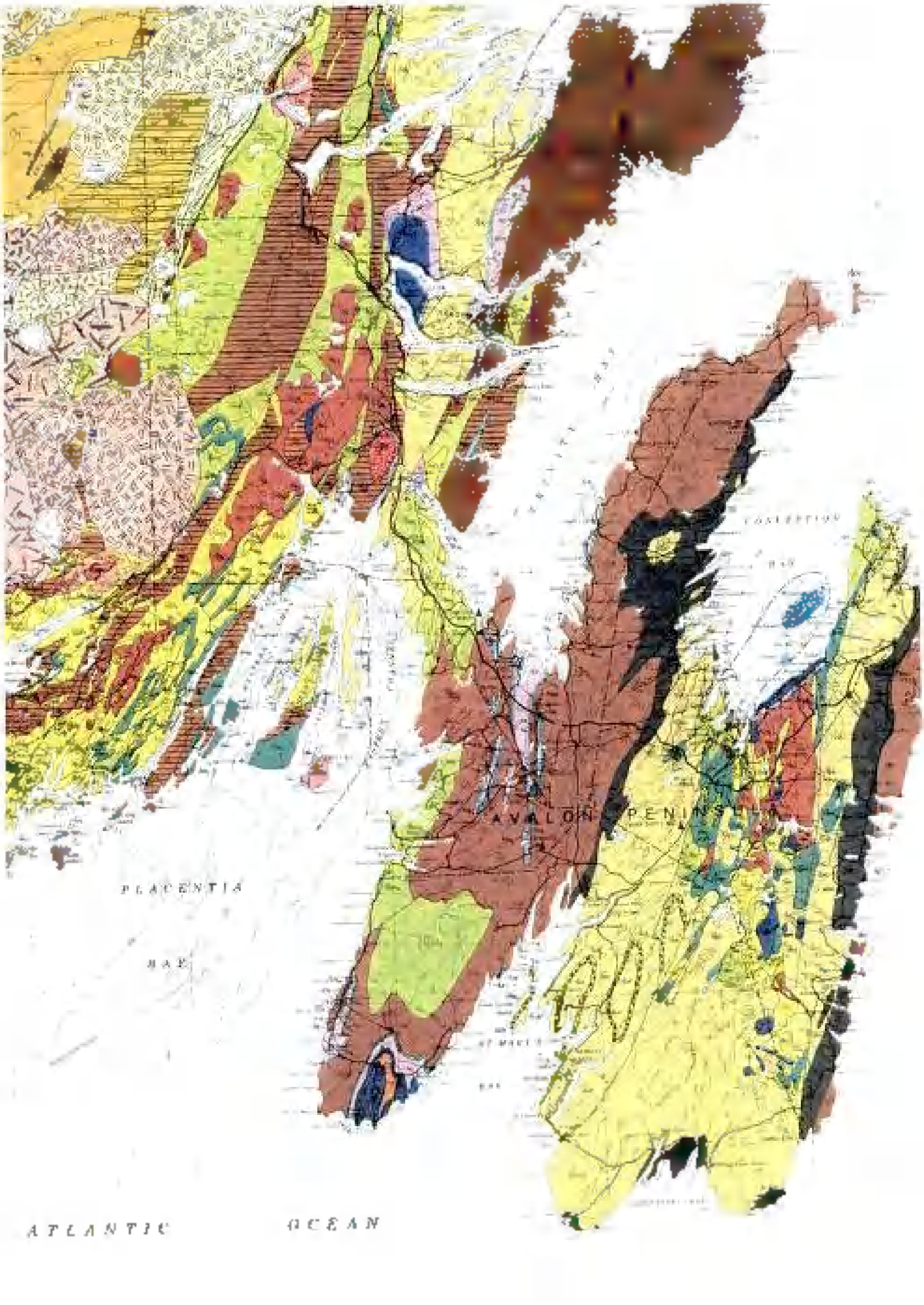
Objective: To produce an economical full colour geological map under time and cost constraints. It was intended as a vehicle for discussion and editing purposes prior to the production of a costly colour version by traditional methods. The map also served as a test for an alternative production technique.

Description: The thematic information was produced on an overlay using commercially available colour pencils and the stomping technique (refer to Section 11.2.1). The hand coloured overlay was colour separated into negatives by an electronic scanner for each of the four process colours: magenta, cyan, yellow and black. A black composite negative was produced from the black overlay negative and a negative of the base map. This composite black negative and the magenta, yellow and cyan separation negatives were used by the printer to print the map.

Commentary: This map (Figure 13.10) illustrates the use of simple graphic techniques in combination with modern reproduction methods to produce an acceptable product more quickly and cheaply than by the use of traditional cartographic techniques. It is a technique which may be useful to small agencies which cannot afford an internal photomechanical operation. Manual colour separation techniques were not needed and only standard drafting tools and rub-down lettering were utilized.

The map could have been improved by the selection of colours with less contrast. Several other techniques utilizing water colours, felt pens, airbrushes could also have been used at little cost. These techniques are described in Section 11.

Figure 13.10



13.6.6 Case study #6

Title: 1983 Fishing Industry Synopsis - Gulf Region

Produced by: Maritime Resource Management Service Inc., Amherst, Nova Scotia, Canada.

Produced for: Canada Department of Fisheries and Oceans, Moncton, New Brunswick, Canada, 1985.

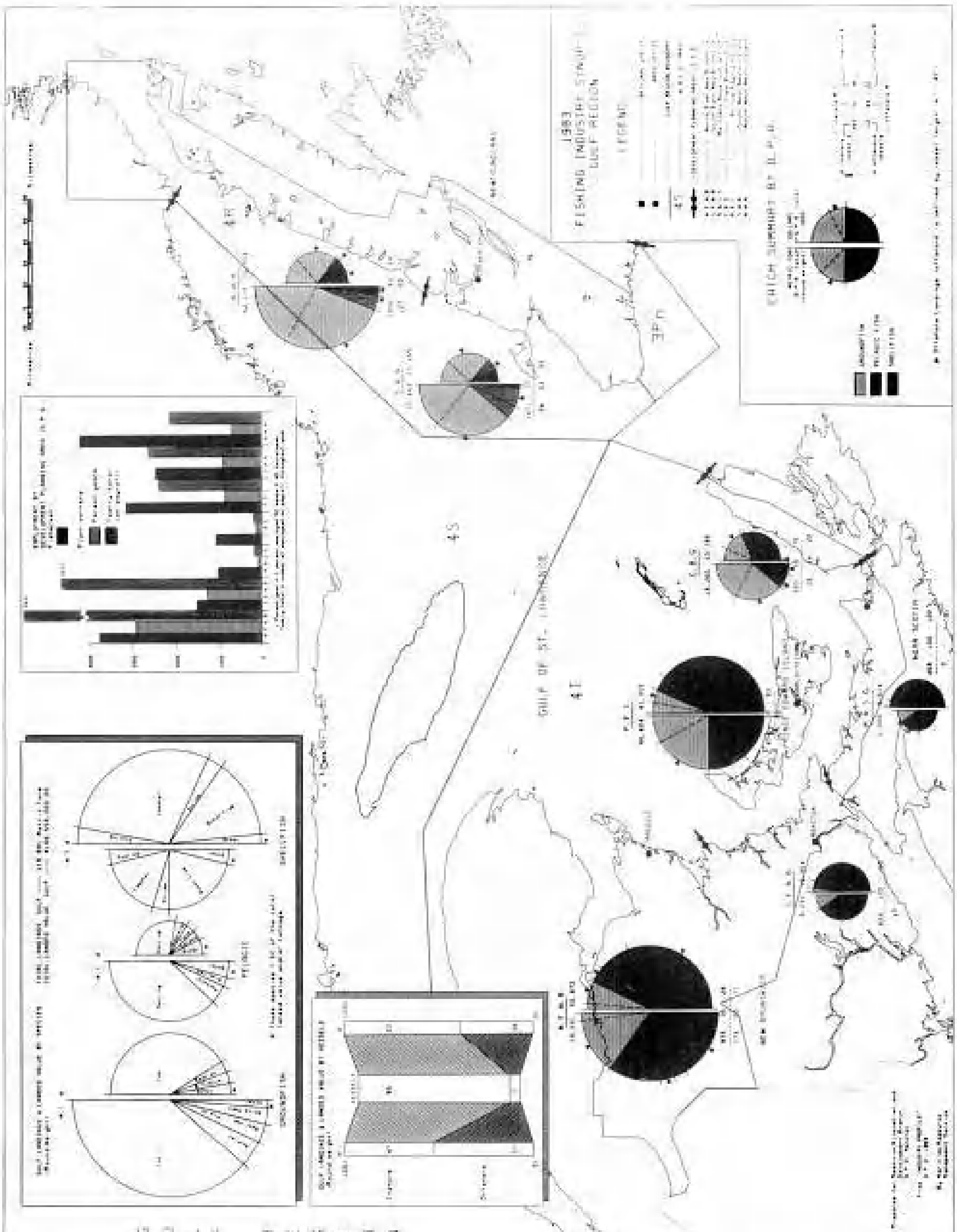
Scale: 1:2,000,000

Objective: A statistical display map was produced to depict data originally collected by fisheries personnel for planning purposes. It was designed and produced on a limited budget for internal departmental use.

Description: A hand drawn manuscript with pencilled statistical data was prepared and checked by the authors. The information was digitized and a plot was produced with a drum plotter onto drafting film. This was in turn used to create diazo prints for economical reproduction. No graphics terminal or other automated equipment was required.

Commentary: Although occasionally hard to read, this map displays most of the statistical information in a clearer and more easily understood format than a tabular presentation. The result is an acceptable display of a great deal of information (Figure 13.11).

Figure 13.11


1983
GULF REGION
LEGEND
GULF OF ST. LAWRENCE
4T
4S
4R
3Pn
NEW BRUNSWICK
NOVA SCOTIA
P.E.I.
G U L F   R E G I O N

13.6.7 Case study #7

Title: Nova Scotia Estuarine and Coastal Resource Inventory

Produced by: Maritime Resource Management Service Inc., Amherst, Nova Scotia, Canada.

Produced for: Nova Scotia Department of Fisheries and Canada Department of Fisheries and Oceans, Halifax, Nova Scotia, Canada, 1982.

Scale: 1:50,000 and 1:100,000

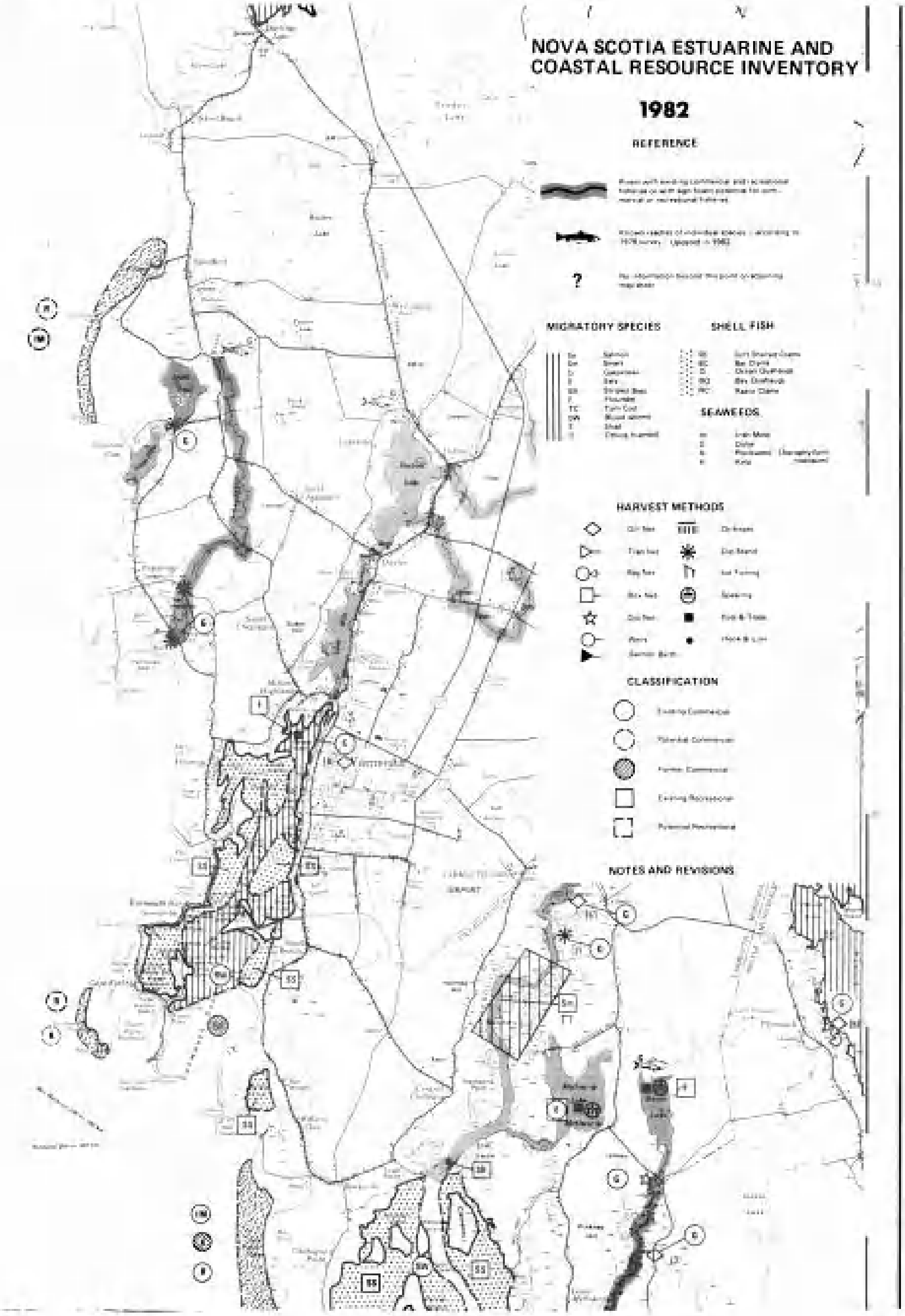
Objective: The inventory was designed as an aid to fisheries management in general, and in particular, the identification of fisheries opportunities and the impact assessment of industrial and municipal development activities on estuarine and adjacent inshore fisheries. In addition, it identified information gaps.

Description: The information included on the map was derived from a combination of published documents and interviews with government personnel and fisherman, and plotted onto standard 1:50,000 topographic base maps. The maps were drawn with pen and ink on translucent film and reproduced onto photographic film. Diazo prints were easily produced and distributed for correction and updating.

Commentary: This type of mapping can be produced relatively quickly and cheaply. The map shown indicates an excess of unrelated topographic information, resulting in a cluttered presentation (Figure 13.12). This problem could have been alleviated by screening the topographic map base to decrease its prominence.

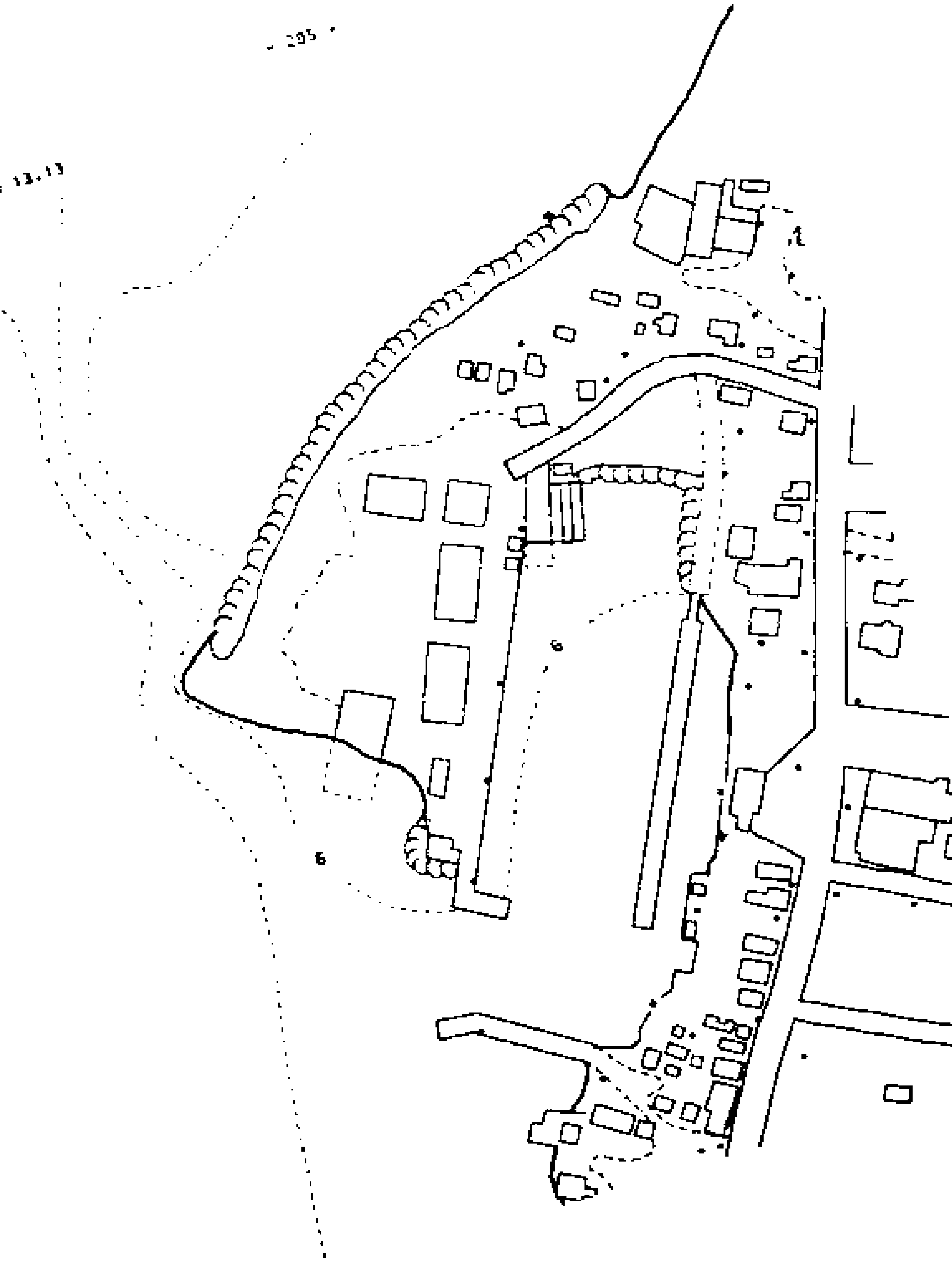
A variety of commercially available shading films and line symbols augmented by hand-drawn symbols are visible on this example. The widely dissimilar patterns are clearly distinguishable even when they overprint each other.

Figure 13.12


NOVA SCOTIA ESTUARINE AND
COASTAL RESOURCE INVENTORY
1982
REFERENCE
MIGRATORY SPECIES
SHELL FISH
SEAWEEDS
HARVEST METHODS
CLASSIFICATION
NOTES AND REVISIONS

13.6.8 Case study #8

Title:	Small Craft Harbours and Facilities Directorate
Produced by:	Maritime Resource Management Service Inc., Amherst, Nova Scotia, Canada.
Produced for:	Department of Fisheries and Oceans Small Craft Harbours Branch, Moncton, New Brunswick, Canada, 1985.
Scale:	Various
Objective:	To produce large-scale base maps of selected small craft harbours in Atlantic Canada through the use of aerial photograph interpretation, computer digitizing and photo-mechanical techniques.
Description:	These are large-scale engineering style maps (Figure 13.13). The maps are graphical representations of data derived from existing mapping and from aerial photography flown at low tide. The cartography was produced by a geographic information system (Geo Based) which references map data in relation to a recognized geographic coordinate system. The system produced overview, site and property plans for 250 harbours within the Gulf of St. Lawrence.
Commentary:	The main advantage of a GIS system is the ability to derive maps relatively quickly from any conceivable combination of the base and thematic data entered into the system. It is a flexible planning tool that solves a major cartographic problem - that of producing economically updated products. In this case study, a GIS system enables planners and engineers to make accurate assessments of the harbour infrastructure and environment.



205
13.13
6
6

13.6.9 Case study #9

Title:	Demersal Resources of the Gulf and the Gulf of Oman
Produced by and for:	Regional Fishery Survey and Development Project, United Nations Development Programme, Food and Agriculture Organization of the United Nations, Rome, Italy, 1981.
Scale:	Not indicated
Objective:	To estimate the potential yield of the stocks of commercial species of demersal fish in the project area, by means of exploratory trawling.
Description:	A series of simply produced, black and white maps were integrated into the body of a technical report. They illustrate the varying levels of catch per hour for the commercial and non-commercial species under study.
Commentary:	These maps are included as a case study primarily to show how easily graphical techniques can both clarify and hide essential information (Figures 13.14 and 13.15). The symbols in the explanation are the major problem. In some instances they are insufficiently distinct to clearly differentiate the various catch per hour zones. The lack of symbol/catch per hour uniformity between the 20 maps may also cause unnecessary confusion. In addition, the map surround is far "too busy" and detracts from the map content.

Figure 13.14

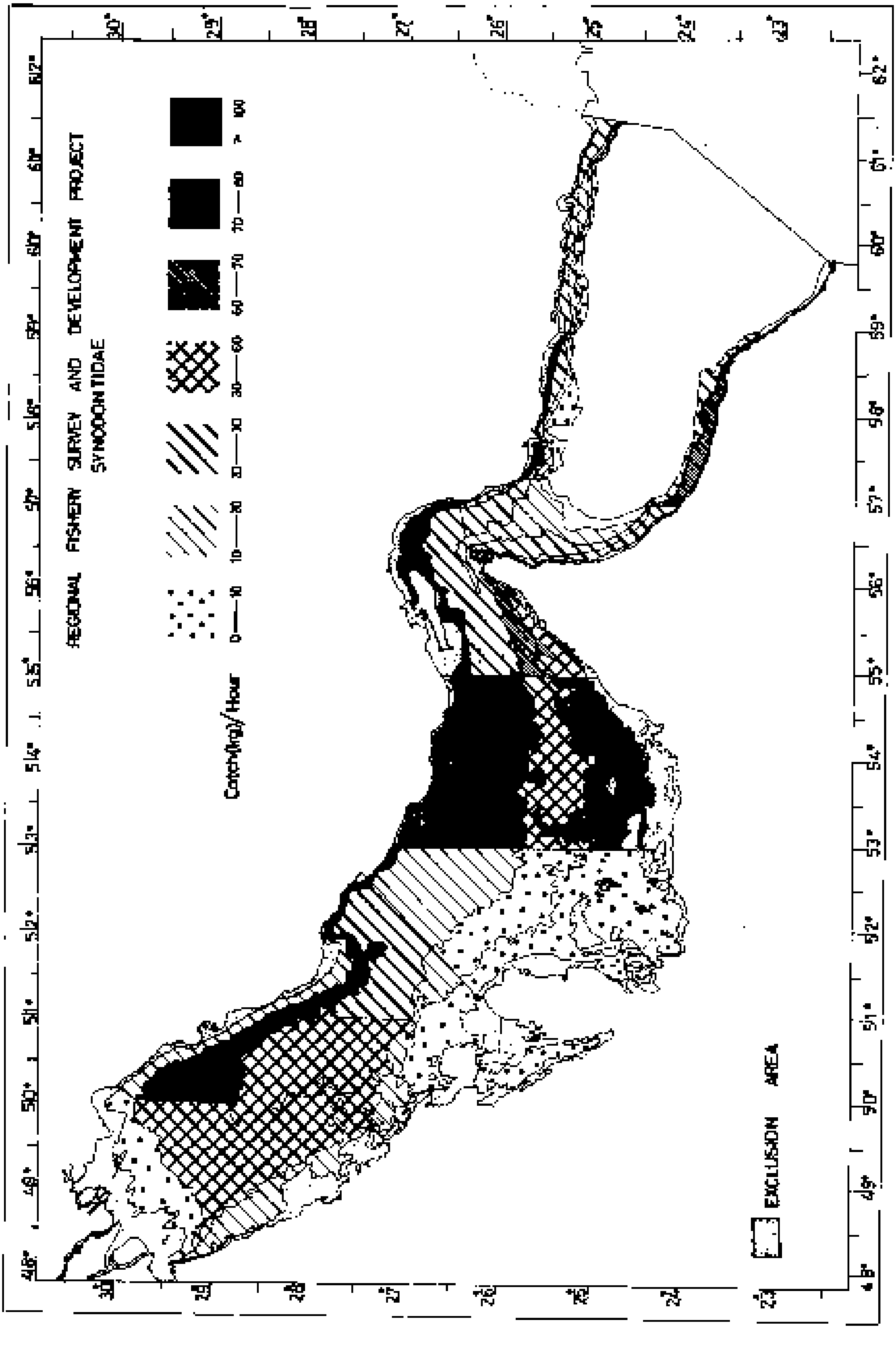
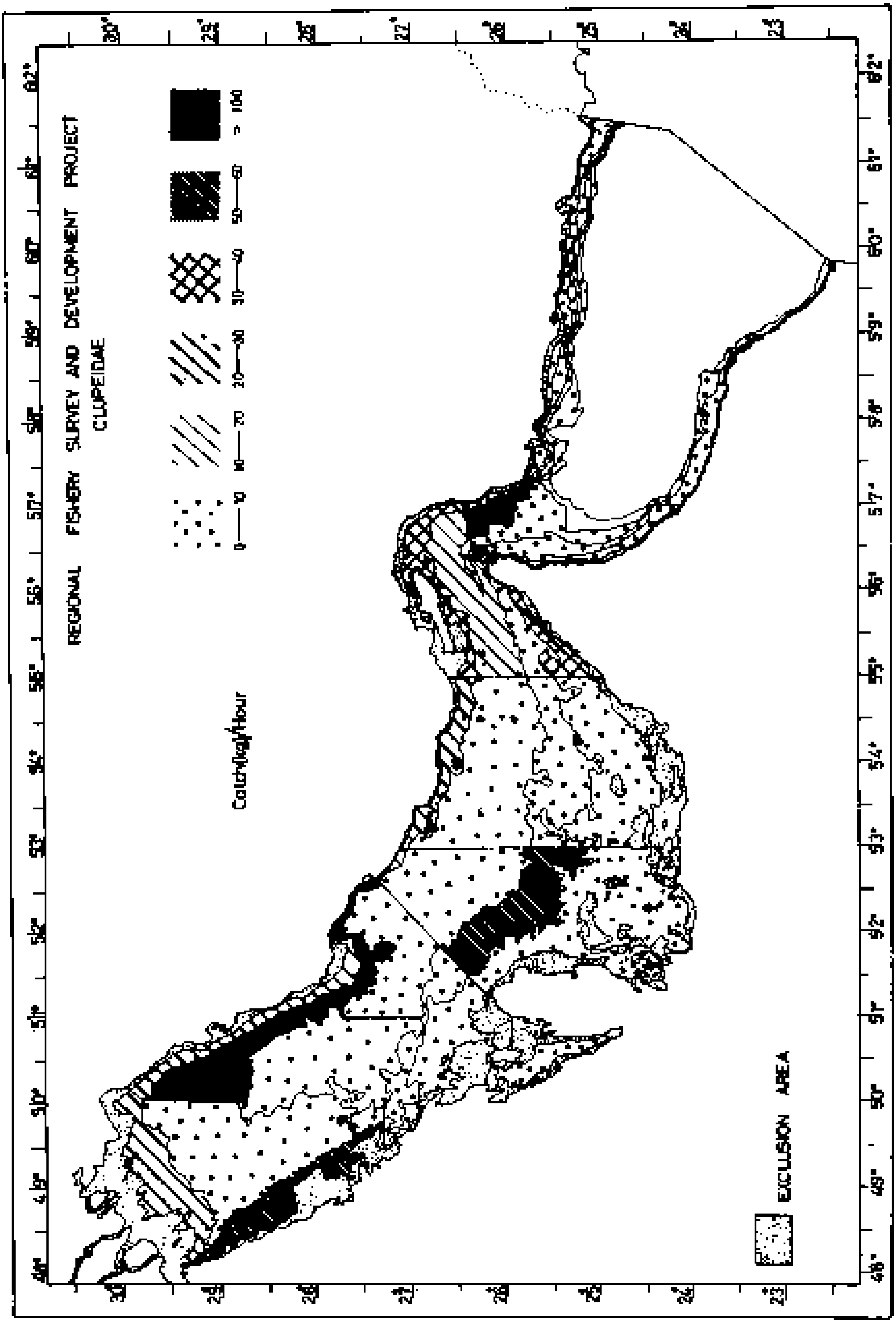

REGIONAL FISHERY SURVEY AND DEVELOPMENT PROJECT
SYNODONTIDAE
Catch(kg)/Hour
EXCLUSION AREA

Figure 13.15


REGIONAL FISHERY SURVEY AND DEVELOPMENT PROJECT
CLUPEIDAE
Catch(kg)/Hour
EXCLUSION AREA

13.6.10 Case study #10

Title:	Coastal Resources Inventory and Mapping Program (C.R.I.M.P.) St. Georges Bay Pilot Study
Produced by:	Maritime Resource Management Service Inc., Amherst, Nova Scotia, Canada.
Produced for:	Newfoundland Department of Forestry and Agriculture Lands Branch, and Environment Canada Lands Directorate Environmental Management Service, St. John's, Newfoundland, Canada, 1975.
Scale:	1:125,000
Objective:	This map is part of two pilot studies carried out in Newfoundland for the proposed Coastal Resources Inventory and Mapping Program. The two maps produced (St. Georges Bay and Conception Bay) were designed to provide detailed resource information for managers in both private and public organizations. The study identified physical, biological and economic characteristics of the coastal zone for such purposes as contingency planning, industrial site selection and the preservation of biologically sensitive areas.
Description:	Four maps were produced from the same topographic base and positioned on a single sheet together with related descriptive material. Each component map is a multi-colour thematic study. A comprehensive report detailing the study methodology accompanied the map sheet.
Commentary:	This product is an example of a complex, scribed and mechanically colour separated map, produced by traditional techniques (Figure 13.16). Each map consists of a full-colour, standardized presentation using solid colours, tints and overprint colours with additional black and red patterns and symbols. It demonstrates the range of colours derived from the four colour process, aided by commercially available shading patterns and individually scribed patterns applied as overprints. The format of four component maps on a common base and on one map sheet facilitates comparisons and makes scale and layout considerations relatively simple. The colours and patterns were chosen to reflect the topic as nearly as possible, giving a varied presentation to each of the four map elements. The related information in the legend was presented in a clear and open type style (Figure 13.17). The map face information, however, should have a bolder style to improve the legibility of some areas.

Figure 13.16

Figure 13.17

LEGEND

VEGETATION COVER

PRODUCTIVE FOREST LAND

- Softwood Stand
- Hardwood Stand
- Mixed Stand

NON–PRODUCTIVE FOREST LAND

- Non–Productive Forest Land
- Swamps and Bogs
- Rock Barrens
- Non–Forested Land

WOOD HARVESTING LIMITATION

- Slope (greater than 25 %)

WILDLIFE HABITATS

- Wildlife Habitat Boundaries
- M Moose
- C Chipmunk
- G Grouse
- W Waterfowl
- AH Arctic Hare

FISHERY ACTIVITIES

- Salmon
- Smelts
- Herring (spawning area)
- Scallop
- Groundfish
- Lobster
- c Clams
- e Eel
- Capelin
- Major Scheduled Salmon Streams

SOURCES OF INFORMATION

Forestry Branch, Newfoundland Department of Forestry and Agriculture.
Wildlife Division, Newfoundland Department of Tourism.
Fisheries and Marine Service, Environment Canada.
Surveys and Mapping Branch, Canada Department of Energy, Mines and Resources.
Canadian Hydrographic Service, Environment Canada.

13.6.11 Case study #11

Title: A Remote Sensing Technique for Quantifying Lobster Fishing Effort 1983. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1217

Produced by and for: Canada Department of Fisheries and Oceans, Scotia Fundy Region, Halifax, Nova Scotia, Canada, 1983.

Scale: Various

Objective: To assess the geographic distribution and the fishing effort expended in the lobster fishery of St. Margaret's Bay, Nova Scotia.

Description: Colour transparencies were taken with a standard aerial survey camera at a scale of 1:6,000 from a small aircraft. A mosaic was prepared from these images (refer to Section 8.9). Using an illuminated digitizing table the locations of the lobster buoys were entered into a Geographic Information System and plotted onto a base map of the coastal features and bathymetry.

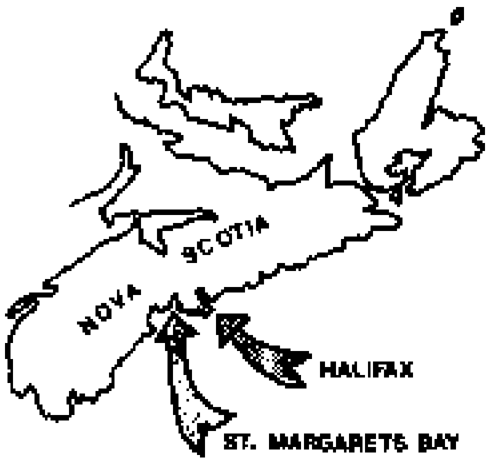
Commentary: This is an example of a publication in which the application of basic cartographic skills could have provided distinct improvements in graphic presentation at little or no extra effort and cost.

Figure 13.18 - The key maps are open (i.e. lacking a margin) and hence appear to be unfinished. The lower one may pose problems with land/water differentiation for readers unfamiliar with the geographic area. A commercially available tint, similar to that used in the arrows, should have been introduced to create a window effect on the land/water interface.

Figure 13.19 - This map could have been drawn at a smaller scale and a less dominant north arrow should have been used.

Figure 13.20 - A simple heavy dot would have been a more appropriate symbol to represent the buoys rather than the complex symbol used. Only the location is significant, and a dot can be photographically reduced more effectively. The title is not specific and the geographic location of the information cannot be easily identified. The graphic presentation appears unfinished which may influence the user's opinion of the survey.

Figure 13.18 Locations of test sites.



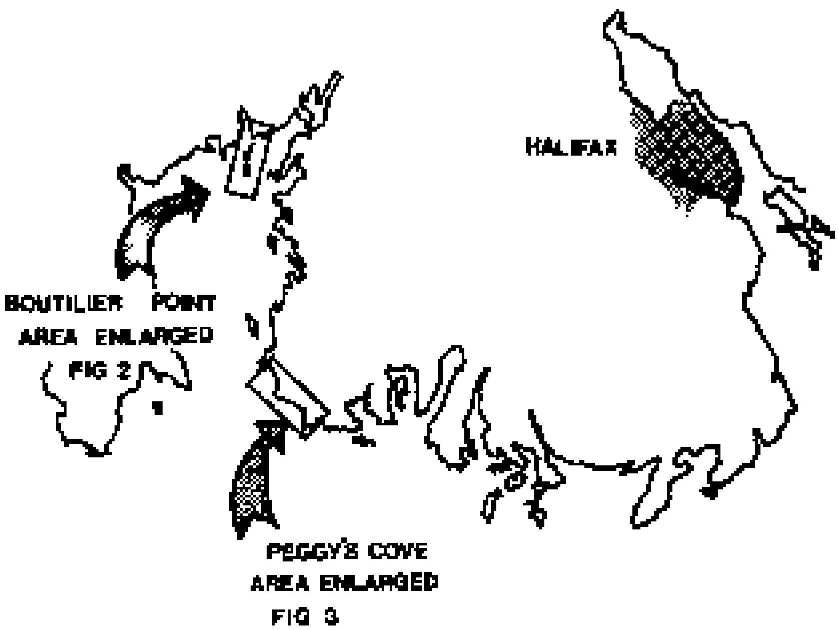


Figure 13.19   Map of buoy locations - simulation.

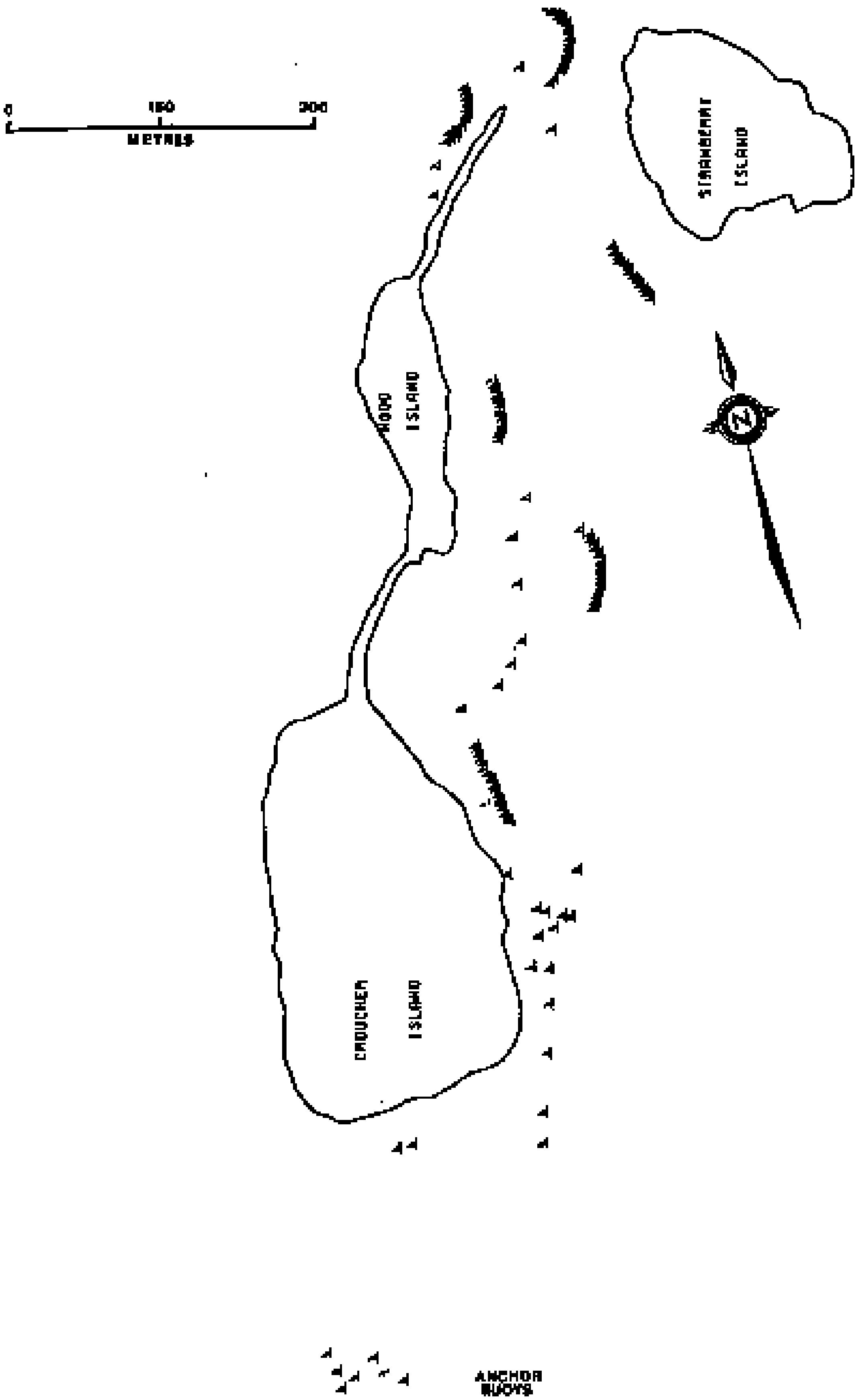
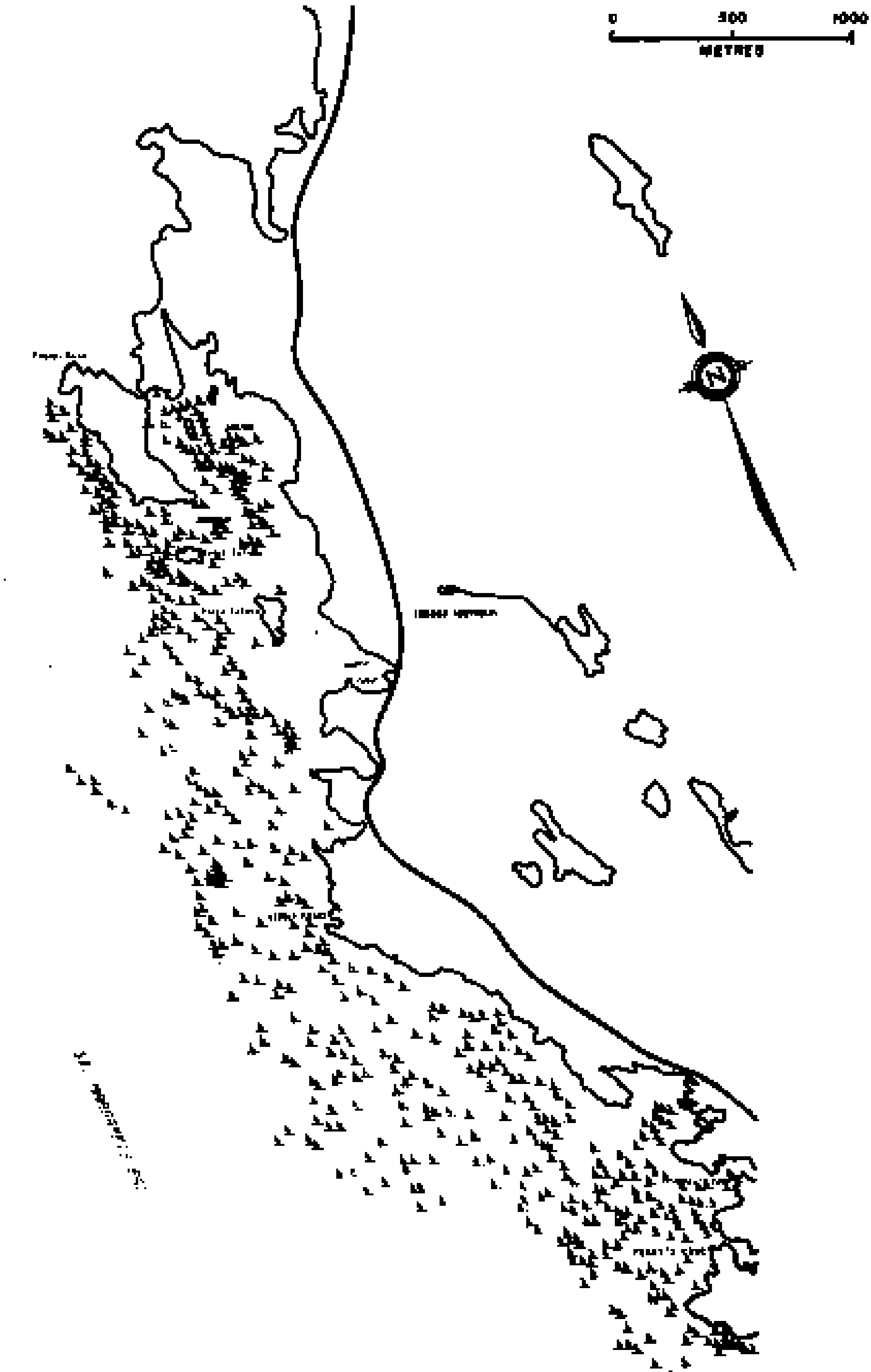


Figure 13.20 Map of buoy locations - actual fishery.



13.6.12 Case study #12

Title:	Barbados Coastal Conservation Study (unpublished)
Produced by:	Hunter and Associates, Mississauga, Ontario, Canada Proctor and Redfern International Limited, Canada David Lashley and Partners, Barbados.
Produced for:	Ministry of Housing and Lands Government of Barbados, 1984
Scale:	1:5,000
Objective:	The study was designed to evaluate the condition of the beaches on the south and west coasts of Barbados.
Description:	The intensity of development in the coastal zone has caused marked beach erosion due to the degradation and destruction of beach vegetation and inshore fringing coral reefs. Because the beaches are a major tourist attraction in Barbados, their erosion is of significant importance to the Barbados economy. In addition to detailed field surveys, historic and current ground and air photography was analyzed to determine erosion rates and patterns. The results of the study were presented in the form of a Map Atlas, a Diagnostic Survey Report and seven Technical Background Reports. The latter covered a comprehensive range of topics including the meteorology, geo-morphology, coastal oceanography, ecology, and fisheries and fisheries management issues associated with the south and west coasts of Barbados. The 1:5,000 scale Map Atlas (72 X 98 cm) consists of 14 geographically contiguous photo-base maps (Figure 13.21). Each photo-base map is accompanied by four separate thematic line maps which portray respectively substrate (Figure 13.22), land use/vegetation (Figure 13.23), beach changes (Figure 13.24) and coastal defence (Figure 13.25).
Commentary:	The maps are a good example of the use of air photographs for the production of base maps, but in contrast to Case Study #1, the mosaic process was not required because of the relatively large scale of the maps. The selected air photographs were enlarged to the appropriate scale and overlaid with drafting film on which the shoreline and key features were traced by hand (pen and ink) to produce base line maps. These base line maps were then reproduced using the diazo technique. The thematic information was added to the diazo copies by hand (pen and ink) and the resulting manuscripts reproduced, also with the diazo technique. This type of product can be quickly and economically produced and reproduced with limited materials and facilities. The exclusion of colour

further simplified the task. The letter codes drawn with the aid of templates and the other symbology are appropriate for the levels of thematic complexity presented.

A few points of criticism: the lack of land/water differentiation may be confusing to those map users unfamiliar with the Barbados coastline. The level of detail does not warrant the large scale of the maps and consequent size of the Atlas which tends to be cumbersome. Finally, the lack of consistency in the choice of road symbols is particularly confusing in Figure 13-24. This is compounded by the fact that the geographic relationship of the road and the coastline is only presented for two of the six shoreline and beach configurations.

Figure 13.21

Figure 13.22

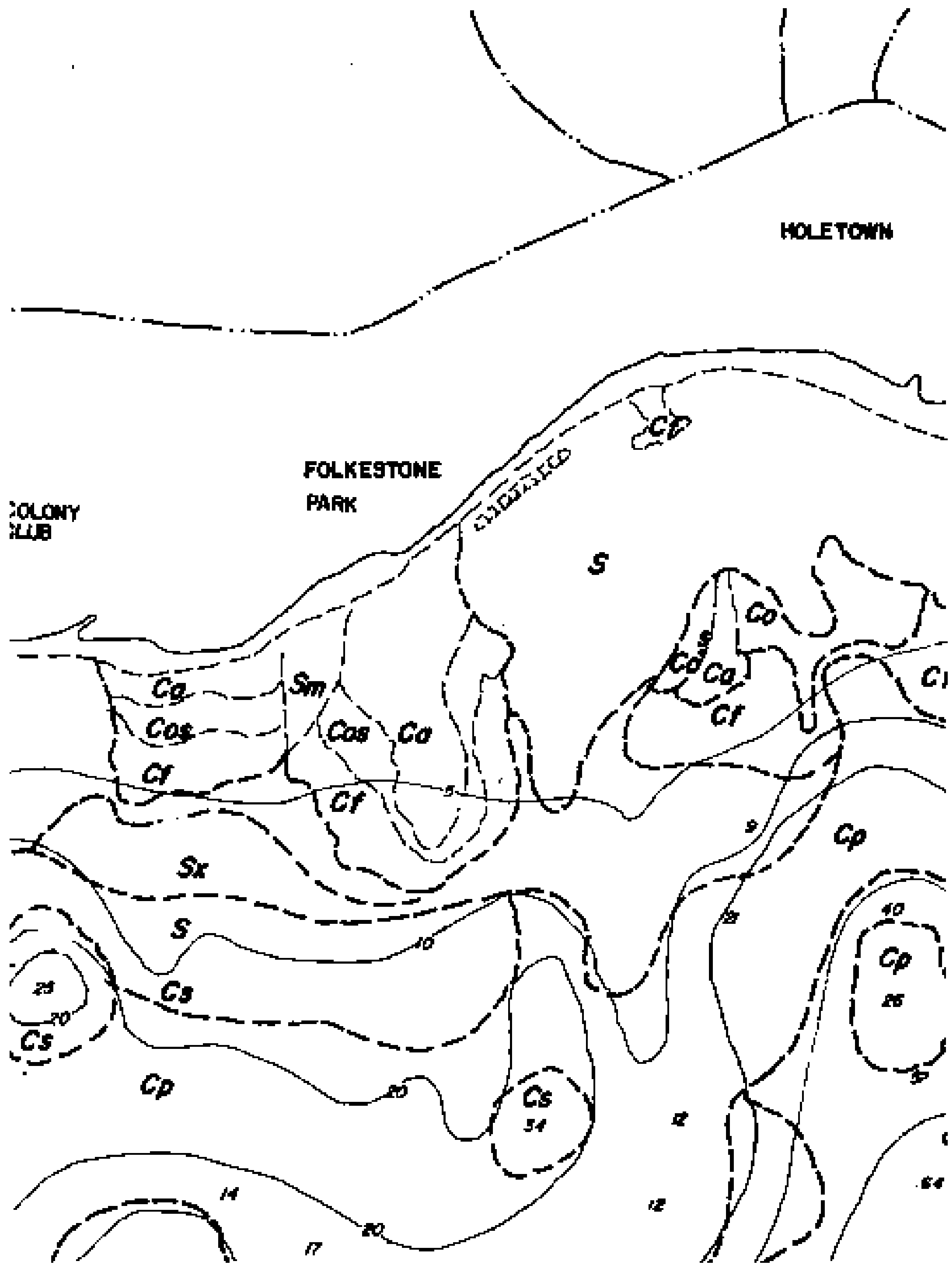

HOLETOWN
FOLKESTONE
PARK
COLONY
CLUB
S
Co
Cg
Sm
Cos
Co
Cf
Cf
Sx
S
Cs
Cp
Cs
Cp
Cs
Cp

Figure 13.23

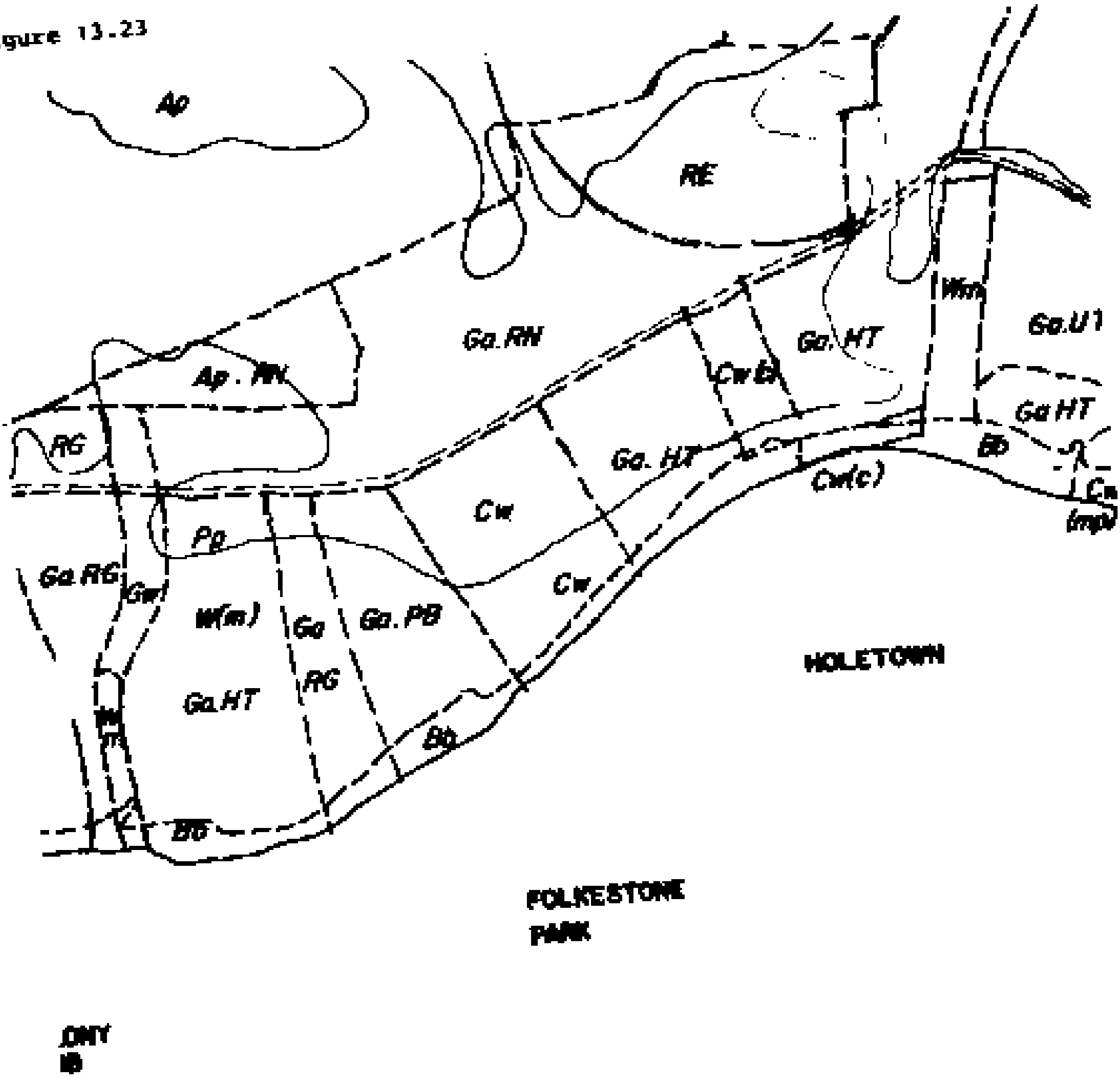

Ap
RE
Ga.RN
Ap.RN
Wm
Ga.U1
Ga.HT
Cw
Ga HT
RG
Bb
Cw(c)
Pp
Ga.RG
Gw
W(m)
Ga
Ga.PB
HOLETOWN
Ga.HT
RG
Bb
FOLKESTONE
PARK

Figure 13.24

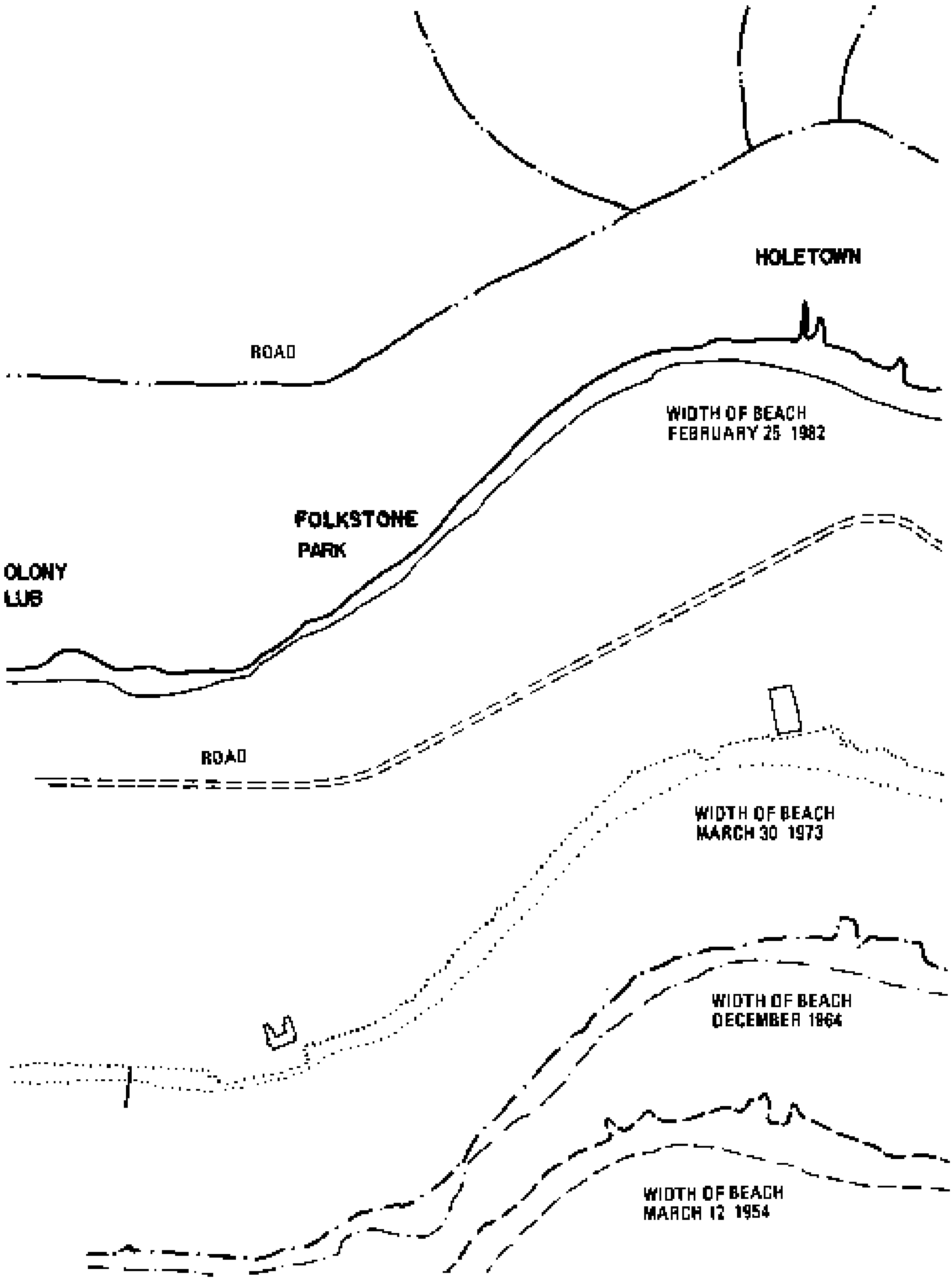
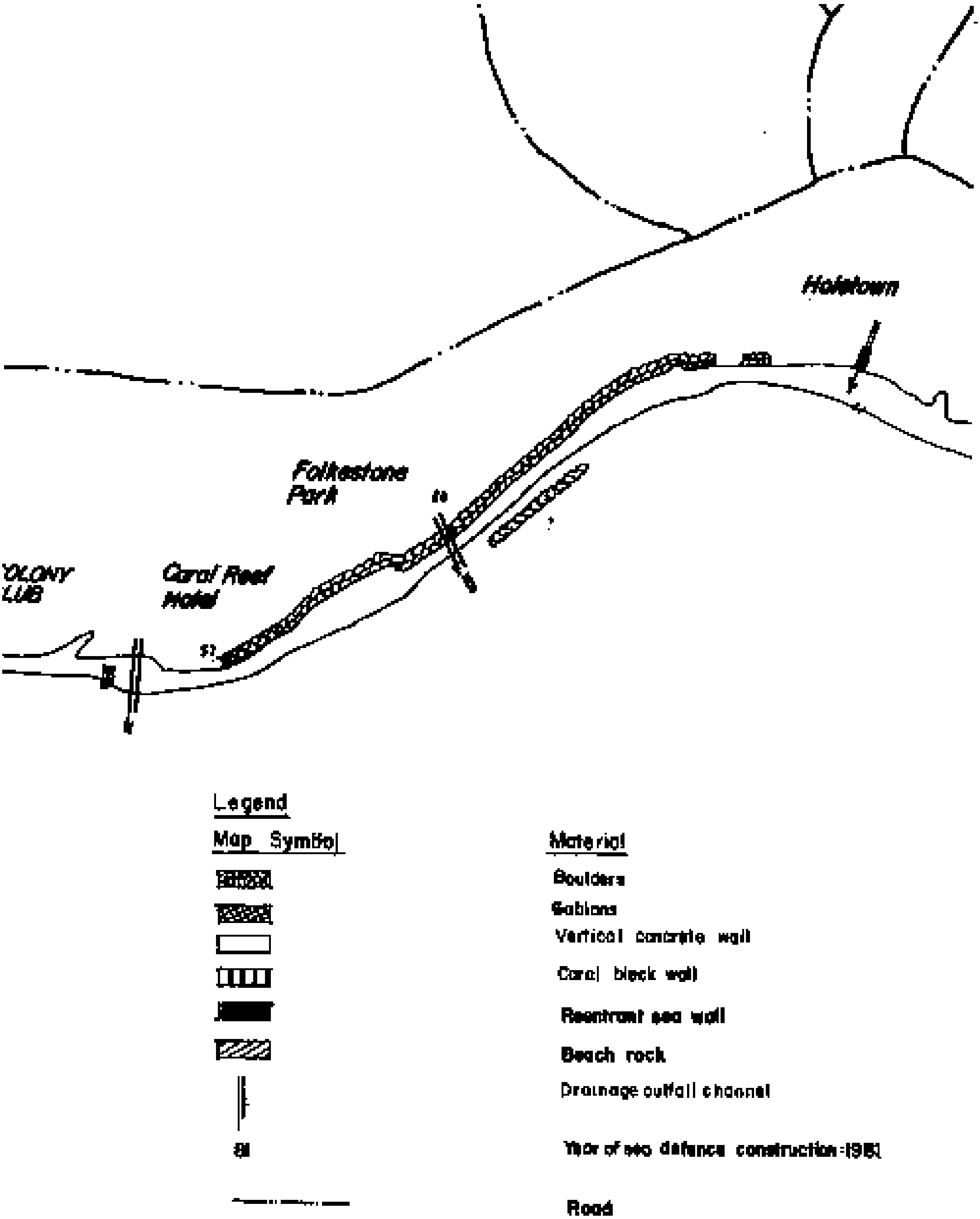

HOLETOWN
ROAD
WIDTH OF BEACH
FEBRUARY 25 1982
FOLKSTONE
PARK
OLONY
LUB
ROAD
WIDTH OF BEACH
MARCH 30 1973
WIDTH OF BEACH
DECEMBER 1964
WIDTH OF BEACH
MARCH 12 1954

Figure 13.25


Holetown
Folkestone Park
Coral Reef Hotel
Legend
Map Symbol
Material
Boulders
Gabions
Vertical concrete wall
Coral block wall
Reentrant sea wall
Beach rock
Drainage outfall channel
81
Road

SECTION 14

14. ADVANCED TECHNOLOGY

From the previous sections it will be apparent that the form and methods of data collection are of great importance to a marine resource mapping program. The collection phase may include a variety of techniques from relatively simple and inexpensive data gathering exercises, such as the deployment of field personnel equipped with felt markers and base maps, to the complex operations associated with data collection from remote sensing platforms (satellites, fixed wing aircraft and helicopters). The information collected can be stored in the conventional manner on hard-copy maps, or it can be entered into the computer of a geographic information system (GIS) and stored in a digital form.

Utilization of these more sophisticated techniques is certainly not essential for the development of a marine resource management plan. They should be considered, however, since the more elaborate data collection, storage, analysis and presentation procedures are now becoming readily available.

The automated production of topographical maps and hydrographic charts was briefly referred to in Section 5. The rapidity of research and development in this field can be appreciated by reviewing the proceedings of recent automated cartography symposia. Limited investment mapping systems, which consider the automated production of thematic maps, are currently available with modestly priced hardware (computer, terminals, plotters, etc.) and software (computer programs).

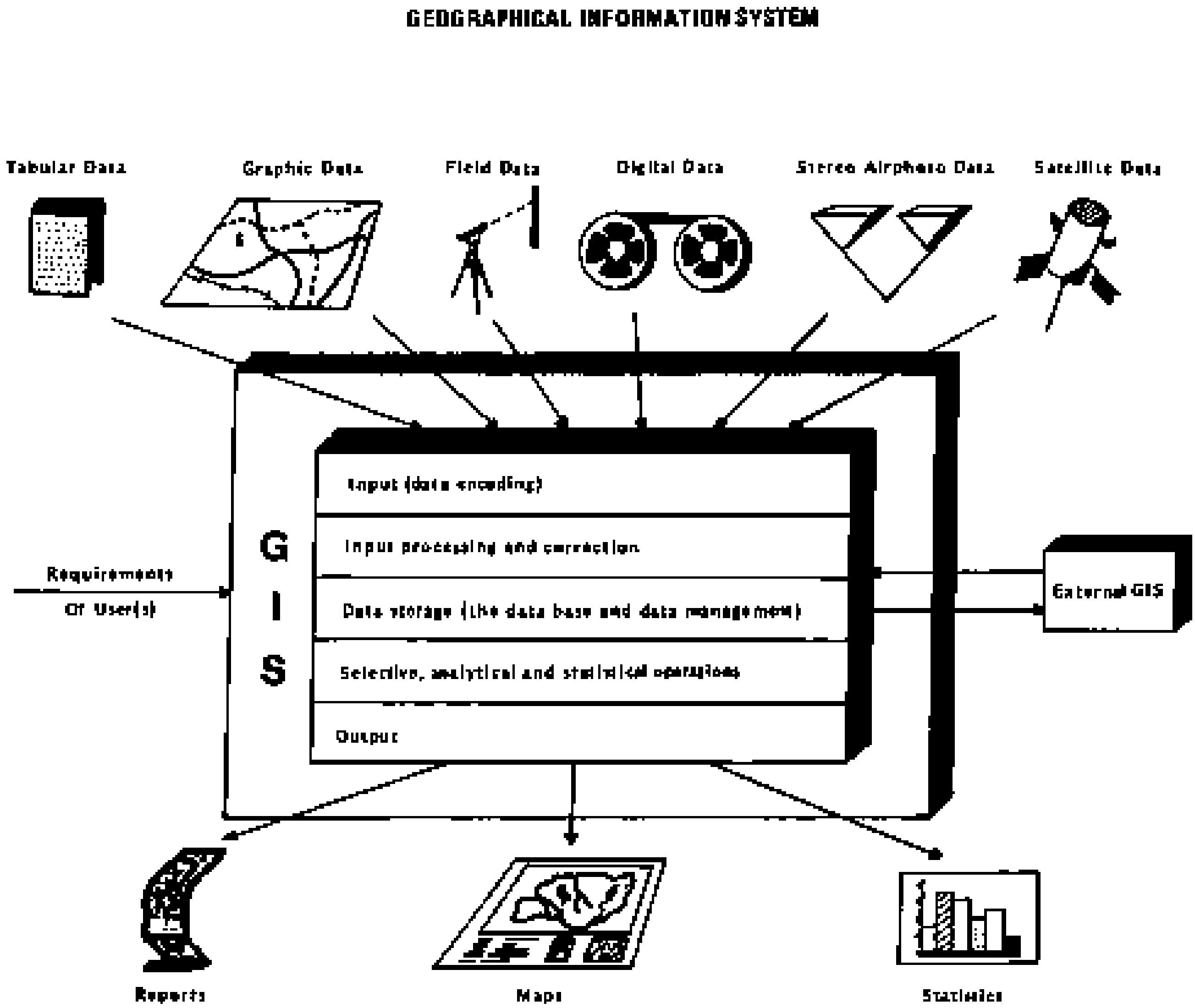
Because of their complexity, earth resource analysis (e.g., fisheries) and land use planning require the investigation of the relationship of large volumes of detailed information, hence the demand for Geographical Information Systems (GIS). The essential elements of an automated GIS are indicated in Figure 14.1.

A Geographic Information System permits automated inventory and management of geographic (spatially related) data such as that contained on maps, charts and other graphical representations. A GIS uses a combination of hardware and software to input, store, analyze, manipulate and output graphic and text data in a variety of formats. There are four main activities involved in this process:

i) Input: User documents such as maps, charts, aerial photographs, tabular or text data are entered into the system via a digitizing table, through keyboard terminals or from existing digital media using a number of specially developed interfaces. Alternatively, a map may be scanned, rather than manually digitized, with a laser or optical scanner;

ii) Processing: Once data is entered into the system it can be processed, stored, analyzed, synthesized or queried to create an unlimited range of products and to answer questions regarding the data;

Figure 14.1 The essential elements of an automated Geographic Information System (GIS). (After H.J.G.L. Alders, 1980)



iii) Output: Output can be generated from the system for temporary viewing on a terminal (colour or black and white), or as hard copy for distribution or publication using a printer, plotter or other hard copy devices;

iv) Communication: With the aid of recently developed protocols, both alphanumeric and graphic data can now be transmitted over dedicated telephone lines with relative speed, accuracy and economy.

Special software and hardware are required components of a GIS. The software can be purchased and used on the following hardware:

i) digitizing table;
ii) colour graphics display terminal(s);
iii) video display terminal(s);
iv) micro, mini or main frame computer(s);
v) plotter;
vi) line printer;
vii) disk drive(s);
viii) tape drive(s);
ix) hard copy unit(s).

Figure 14.2 indicates a typical hardware configuration. A GIS is especially suited for processing and handling dynamic (i.e. frequently changing) data, the subject of thematic resource maps. Most GIS systems are similar in configuration but subtle software differences make some systems more versatile than others.

Interfaces have been developed which permit a GIS system to receive and transmit data from/to other systems. In addition to its mapping function, the computer of a GIS can be used in a "number crunching" capacity for stock assessment and other statistical needs of marine resource management.

When the concept of a GIS has been accepted as an integral component of marine resource mapping and management, the development of a fully integrated marine resource management system becomes a possibility. The components of such an interfaced system, in addition to the GIS, might include (Figure 14.3):

i) Database management system, which can track and index data or information within the system components;

ii) Image analysis system, which can provide timely new or updated data collected from remotely sensed imagery;

iii) A storage system, which can store, access and display graphic documents such as marine charts which do not require constant updating. Microfilm or laser videodisc systems can fulfill this role.

The task of interfacing such diverse systems is currently in progress and although many of them cannot yet be described as "user friendly", the trend towards automated marine resource mapping and management is inexorable.

Figure 14.2 Typical hardware configuration for an automated GIS

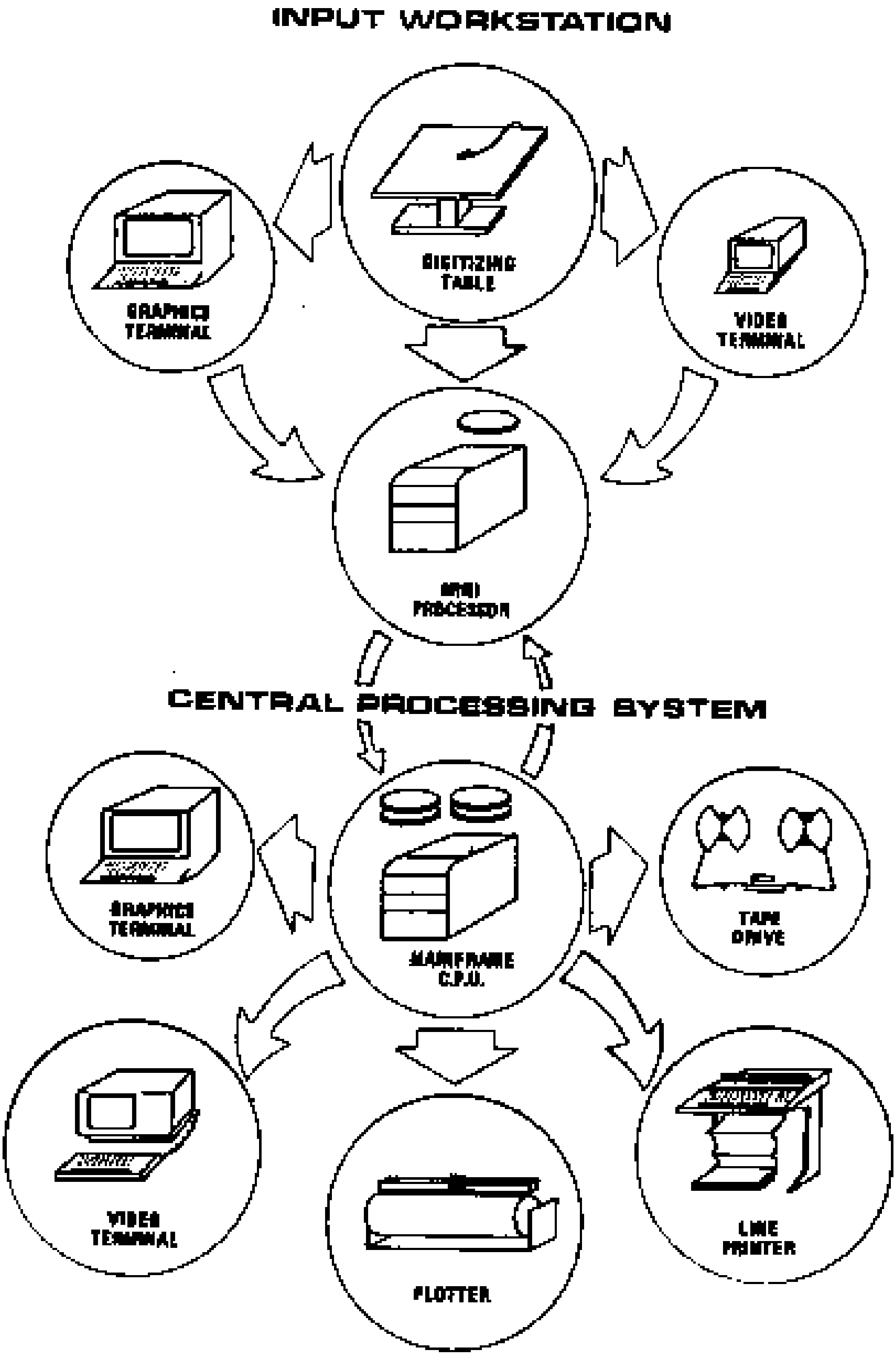
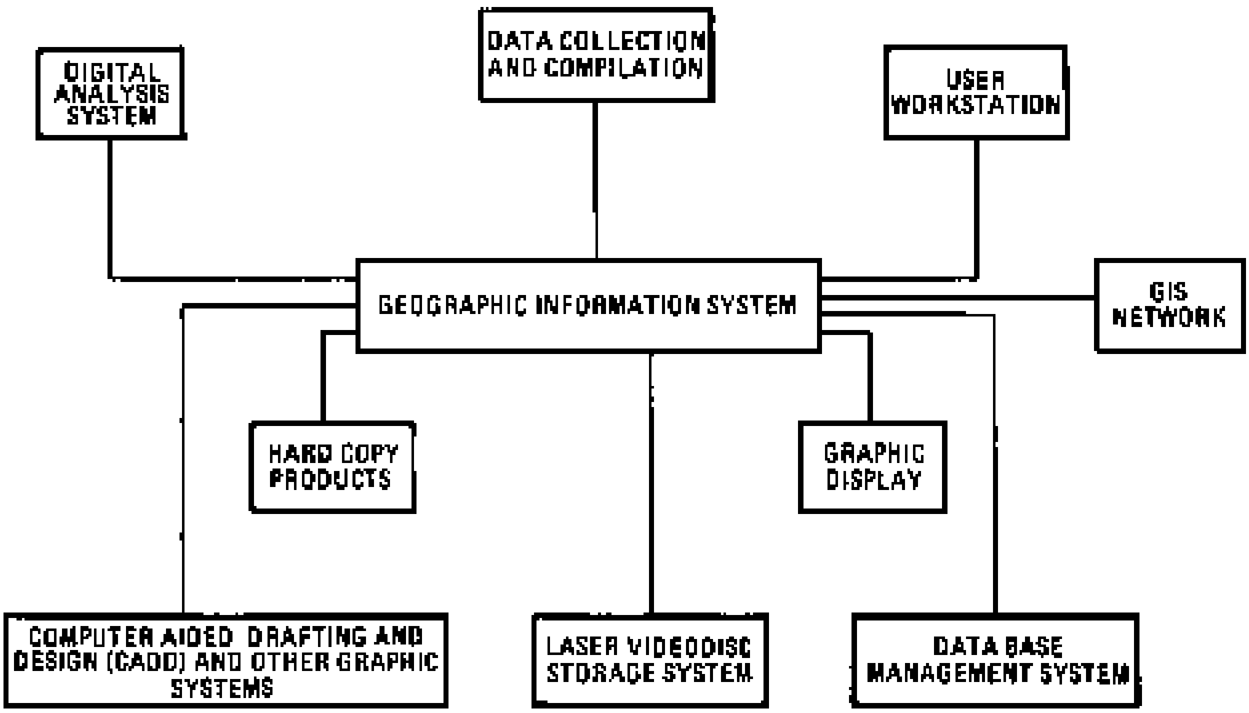


Figure 14.3 Components of an integrated resource management system.



SECTION 15

15. TRAINING INSTITUTIONS

To the knowledge of the authors, a comprehensive list of training institutions which offer courses in cartography is not available. In particular it is difficult to identify resource mapping programs specifically designed for the needs of developing nations. Interest in adapting or setting up programs for foreign students, however, is increasing rapidly in Canada, the United Kingdom and the U.S.A. The following selection of training establishments has been derived from several sources and is offered as a guide to the various types of training programs available.

15.1 International Training Institutes

15.1.1 International Institute for Aerial Survey and Earth Sciences (I.T.C.)

The most well known training institute and the only one specifically created to offer training to students from developing countries is the I.T.C. in Enschede, Holland. It offers a wide variety of courses at several levels, from introductory to graduate, which are most often taught in English. The I.T.C. recently (1985) announced a new course in nautical cartography in two formats. A five month course beginning in November of each year is available to graduates, technologists and technicians who have had formal training in cartography at a recognized institution and have considerable experience. A longer term course of fifteen months which begins in February of each year is available for those without prior training and experience.

15.1.1.1 Affiliated training institutes:

The I.T.C. also supports the establishment of affiliated institutes in developing countries. Some of those already operational are the following:

i) Centro Inter-Americano de Fotointerpretacion (C.I.A.F.) Apartado Aéro 53754, Bogotà, D.E., Colombia;
ii) Indian Photo-Interpretation Institute (I.P.I.) P.O. Box 135, Dehra Dun (U.P.), India;
iii) School for Photogrammetric and Cartographic Operators, 10 Jalan Ganesha, Bandung, Indonesia;
iv) Regional Centre for Training in Aerial Surveys, P.M.B. 545, Ile-Ife, Nigeria.

15.1.2 Other international training institutes

Other well known institutions historically attended by foreign students include the following:

i) Directorate of Overseas Surveys (D.O.S.), Southampton, England;
ii) École Nationale de Science Géographique, Paris, France;

iii) Swiss School for Photogrammetric Operators, St. Gallen, Switzerland;
iv) International Advanced Training Centre for Photogrammetry Operators, Stuttgart, Germany.

15.2 National Training Institutes

15.2.1 Training institutes in Canada

Many universities, colleges and post-secondary institutes offer cartographic and related courses. Unlike the United States, most of the emphasis has been on practically oriented, technician and technologist training at the technical school level. It was not until 1981 that Memorial University of Newfoundland initiated a specialized cartography major at the undergraduate level. Several universities offer graduate courses which are usually part of the geography or engineering programs. The number of foreign students training in Canada is rapidly increasing.

15.2.1.1 Training and technological institutes:

i) The College of Geographic Sciences in Lawrencetown, Nova Scotia is the only technical institute in North America specializing in mapping, surveying and geographic related training. Programs are intensive and relatively short. The following are available: Surveying, Surveying Assistant, Surveying Office Technician, Cartography, Remote Sensing, Planning Technologist, Scientific Computer Programming, Computer Graphics and Geographic Information Systems. The College also maintains modern photogrammetric facilities. The cartography program is a 50 week, total emersion program of 2400 hours in a single training year;

ii) Sir Sanford Fleming College, Lindsay, Ontario offers a three year technologist program in Thematic Cartography, the longest program of its kind in Canada. Located at the School of Natural Resources, the College also offers the following programs: Forestry Technician, Fish and Wildlife, Earth Sciences, Geographic Information Systems, Geological Technician and Farm Management;

iii) Algonquin college, Ottawa, Ontario offers cartographic training. The six semester, two year program in surveying and mapping enables the student to specialize in either cartography, surveying or photogrammetry;

iv) Seneca College, Toronto, Ontario, specializes in municipal and resource aspects of cartography in its four semester, two year program. It offers a work-study program and a block laboratory time approach so that individual subjects are covered in relatively short, intensive study periods. The College also offers optional courses in a number of marine resource subject areas;

v) CEGEP (Collège d'Enseignement Général et Professionel) Limoilou, Québec, Québec and CEGEP de l'Outaouais, Hull, Québec, both offer extensive cartographic training.

15.2.1.2 Universities: Only Memorial University of Newfoundland in St. John's, Newfoundland offers a degree course in cartography as part of its Geography program.

Other universities with extensive course offerings in cartographic subjects are:

i) Brock University, St. Catherines, Ontario;
ii) Carleton University, Ottawa, Ontario;
iii) Ottawa University, Ottawa, Ontario;
iv) Queen's University, Kingston, Ontario;
v) Waterloo University, Waterloo, Ontario;
vi) University of Alberta, Edmonton, Alberta;
vii) University of Calgary, Calgary, Alberta;
viii) University of New Brunswick, Fredericton, New Brunswick;
ix) University of Sherbrooke, Sherbrooke, Québec;
x) Université Laval, Québec, Québec.

15.2.2 Training institutes in the United Kingdom

i) Diploma courses:

a) de Havilland College, Boreham Wood, Hertfordshire - Land Survey and Cartography;
b) Kingston College, Kingston-upon-Thames, Surrey - Surveying and Cartography;
c) Somerset College, Taunton, Somerset - Surveying and Cartography;
d) Vauxhall College, London - Surveying and Cartography;

ii) Undergraduate courses:

a) University of Glasgow, Glasgow - Topographic Sciences;
b) University of Newcastle, Newcastle-upon-Tyne - Surveying Sciences;
c) North East London Polytechnic, Dagenham, Essex - Surveying and Mapping Sciences;
d) Oxford Polytechnic, Headington, Oxford - Cartography;
e) Portsmouth Polytechnic, Portsmouth, Hampshire - Geography with cartographic options;
f) University College of Swansea, Singleton Park, Swansea - Topographic Science;

iii) Graduate courses:

a) University of Glasgow, Glasgow - Survey, Photogrammetry or Cartography;
b) University of London, London - Cartographic Communication (London School of Economics);
c) University College of Swansea, Swansea - Cartography;

iv) Other organizations:

a) Directorate of Overseas Surveys, Maybush, Southampton - Photogrammetry, Cartography and Photomechanics;
b) School of Military Survey, Feltham, Middlesex - Army Survey course;

v) Hydrographic surveying:

a) Plymouth Polytechnic, Plymouth, Devonshire - Graduate diploma in Hydrographic Surveying;
b) North East London Polytechnic, Dagenham, Essex - Short course in Sea Surveying.

A more detailed review of cartographic related training in the U.K. may be found in the following publication: Report on full-time training in the United Kingdom in land survey, photogrammetry, remote sensing, cartography and map reproduction (including printing), cadastre, land resource and management studies and hydrographic surveying which are available to overseas students (refer to Kenworthy, E.V., 1983 in bibliography).

15.2.3 Training institutes in the United States

Many universities offer courses in cartography and sometimes remote sensing as part of their Geography programs which are mostly concerned with thematic, small-scale mapping. The following universities specialize in this area:

i) Certificate programs:

a) California State University at Long Beach, California;
b) George Mason University, Wisconsin;
c) State University of New York at Buffalo, New York;

ii) Bachelors level:

a) Akron University, Akron, Ohio;
b) George Washington University, Washington, D.C.;
c) Idaho University, Idaho;
d) Salem State University, Massachusetts;
e) University of Wisconsin, Madison, Wisconsin;
f) East Central Oklahoma State University, Oklahoma;

iii) Masters level:

a) George Mason University, Wisconsin;

iv) Doctoral level:

a) University of Kansas, Lawrence, Kansas;
b) George Washington University, Washington, D.C.;
c) University of Wisconsin, Madison, Wisconsin.

In addition to those listed above, most universities in both developed and developing nations which offer geography programs also have one or more courses in cartography and often in other related areas such as remote sensing. Cartography is included frequently in the curriculum of universities and technical schools which offer surveying and other engineering subjects.

The following publication, although dated, may be of assistance in identifying training institutes and programs world wide: Orbis Geographicus (refer to Meynen, E., 1968/72, in bibliography).

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APPENDIX

GLOSSARY OF TERMS

ACTINIC LIGHT RAYS	The invisible, chemically active light rays which act on photographic emulsions.
AERIAL PHOTOGRAPH	A photograph of a portion of the earth's surface, taken from an aircraft. There are two principal types of photographs; vertical (the camera lens is parallel to the ground below) and oblique (lens is purposely titled from the vertical, generally 30-60 degrees).
AERONAUTICAL CHART	A map of the earth's surface, designed for aviation use. Depicts necessary topographic information, aids to navigation and obstructions.
ALGORITHM	A set of well-defined rules for the solution of a problem in a finite number of steps.
ALPHANUMERIC CHARACTERS	Computer coded characters which represent numerals or letters of the alphabet.
ARTWORK	Drawings, overlays, etc., prepared for reproduction of maps or graphics.
AUTOPOSITIVE	A class of photographic material which yields a positive image from a positive original without an intermediate negative stage.
AZIMUTH	The angular distance in a horizontal plane measured clockwise from true north to a given course or celestial object.
BACKLIGHT	Light passed through a clear or translucent copy from behind the image in photographic reproduction.
BAND	A selected range of wavelengths of the electromagnetic spectrum.
BAR SCALE	A line or parallel lines divided at specific intervals indicating map distances in relation to earth distances.
BASE MAP	A map containing geographic information for purposes of referencing study data and displaying its distribution and inter-relationships.

BATHYMETRIC CHART	A map showing water depths and underwater topography, often in various shades or colours.
BEARING	Direction of a line with reference to the cardinal points of the compass.
BENCH MARK	An accurately established elevation point in relation to chart datum.
BUOY	A floating object, moored or anchored to the sea bottom, used as an aid to navigation or as a floatation device.
CADASTRAL MAP	Large-scale maps indicating subdivisions, townships, and exact positions and dimensions of properties.
CARTOGRAPHY	The art, science and technology of making maps and charts and their study as scientific documents and works of art.
CHANNEL	(1) The part of a body of water deep enough for navigation; (2) The deepest part of a stream, bay or strait through which the main current flows; (3) A band of radio frequencies within which a radio station must remain to prevent interference.
CHROMA	The range from neutral grey to full saturation of a single colour hue.
COLOUR SEPARATION	(1) The mechanical and hand process of separating artwork destined to be coloured into negative overlays or components for each of the printing colours; (2) The optical process of separating coloured artwork by means of colour filters into separate single-colour negatives for each of the subtractive primary colours.
COMPILATION	The assembly of source material such as aerial photographs, photogrammetric information, surveys and data taken from existing maps.
COMPOSITE PRINT	Reproduction of two or more images on a single base.
CONJUGATE PRINCIPAL POINT	The photographic position on an aerial photograph of the principal point of the adjoining photograph.

CONTACT PRINT — A photographic reproduction made from a negative or positive in contact with sensitized paper, film or printing plates in a vacuum frame and therefore produced at an identical size.

CONTINUOUS-TONE — A photographic image which contains a smooth and continuous transition of tones from black to white.

CONTOUR — An imaginary line connecting points on the land surface or sea floor of the same elevation or depth respectively.

CONTOUR INTERVAL — The difference in elevation between adjacent contours.

CONTRAST (Photography) — The difference in value or tone between highlight and shadow (background) on an image.

CONTROL — System of accurate measurement used to obtain distances and directions. The specific controls are classified as follows:

(1) Horizontal, relating to parallels and meridians;
(2) Vertical, relating to elevations;
(3) Astronomic, relating to the solar system;
(4) Ground, relating to photogrammetry;
(5) Recovered, identified from other sources.

COORDINATES (Grid) — System for locating points on the earth's surface by means of a rectangular grid superimposed and keyed to a map projection.

COPY — Term used in the printing industry to refer to any material such as photographs or artwork which will be reproduced.

CRT — Cathode Ray Tube - a video display.

CULTURAL FEATURES — Map features that have been built or established by man. These include: roads, dams, canals, bridges, boundaries, etc.

CYAN — One of the subtractive primary colours which is used in the four colour printing process. It reflects blue and green light and absorbs red light.

DATA BASE — A store of information, usually in digital form, organized so that retrieval can be done on a selective basis.

DATUM	A reference, such as a line, or plane, in relation to which the position of other elements is determined.
DENSITOMETER	An instrument for measuring the amount of transmitted or reflected light.
DENSITY	The degree of darkness (light absorption or opacity) of a photographic image.
DEVELOPER	The chemical agent and process used to render photographic images visible after exposure to light.
DIAPOSITIVE	A transparent positive on a stable base.
DIAZO	A process normally used for reproduction in contact printing techniques or to provide a light sensitive coating for proofs and plates.
DIFFUSION TRANSFER	A system which consists of a photographic emulsion on which a temporary negative is produced. A chemical or activator softens the unexposed image parts and a positive image is transferred to a receiver sheet during processing.
DIMENSIONAL STABILITY	The ability to maintain size; the resistance of paper or film to dimensional change due to variations in temperature or humidity.
DISPLACEMENT	A shift in the position of an image on an aerial photograph due to tilt, local variations in relief or scale changes.
DRYING HEIGHTS	The height above the sounding datum of rocks and banks that cover and uncover with tidal fluctuations.
DUPLICATING FILM	A film for making positives from positives, and negatives from negatives.
ECHO SOUNDER	A device which measures the time it takes a sound signal to travel from a ship to the ocean floor and back. This is converted into a depth reading.
EDITING	Checking a map in its various stages of production to insure correct interpretation of the data sources used and final appearance before reproduction.

ELECTROMAGNETIC SPECTRUM	The range of electromagnetic radiation from the shortest cosmic rays, through gamma rays, x rays, ultraviolet radiation, visible light, infrared radiation, microwaves and all longer radio wavelengths.
ELECTROPHOTOGRAPHY	Image transfer systems used in copiers to produce images using electrostatic forces.
ELEVATION	Vertical distance above sea level.
ELEVATION TINT	The layer of colour between selected and general contours, according to altitude.
ELEVATION TONES	A method of accentuating the elevation expressed by the contours through the use of different tones of the same colour.
ELLIPTICAL DOT	In halftone reproduction, elongated dots which give improved gradation of tones, particularly in middle tones and vignettes.
EM	A square measurement in type composition which equals the width and height of the point size being set. So named because the letter "M" in early fonts was usually cast on a square body.
EMULSION	A suspension of light sensitive materials such as silver halides, in a colloidal substance (usually gelatin), which is used to coat photographic films, plates and papers.
EN	One half the width of "em".
EQUAL AREA	Applied to maps showing areas correctly throughout the map.
EQUIDISTANT	Applied to maps which have selected lines along which distances, or scale, can be measured correctly.
EXPOSURE	The step in photographic processing during which light produces the image on the light-sensitive emulsion.
"F" STOPS	In photography, fixed stops for setting lens apertures and controlling the light entering a lens and shutter system.
FALSE COLOUR FILM	Film that does not record the blue light reflected from a subject but instead registers the green, red and infrared radiation it reflects. This produces an abnormal coloured image.

FEATURE SEPARATION	The process of preparing a separate piece of artwork or negative for only selected portions of the data on a complex map.
FILTER	A transparent medium that absorbs specific regions of the spectrum and transmits other portions.
FIXING	Chemical action following development to remove unexposed light sensitive materials from a film. This makes the image stable and insensitive to further exposure.
FLASH EXPOSURE	In halftone photography, the supplementary exposure given to strengthen dots in the shadow areas of negatives.
FLAT	In printing, the assembled composite of negatives or positives ready for platemaking.
FLATBED PLOTTER	A digital plotter in which the output material is mounted on a flat surface.
FLIGHT LINE	The path that an aircraft or other airborne sensor follows when collecting data.
FOCAL LENGTH	In photography, the distance measured along the optical axis from the optical centre of the lens to the film plane, measured when the lens is focused at infinity.
FONT	In type composition, a complete assortment of letters, numbers, punctuation marks, etc., of a given size and design.
FORESHORE	The intertidal zone of a beach.
FORM LINES	Lines that represent contours that are sketched to show the shape of the terrain rather than elevation.
GEODESY	The science which considers the size and shape of the earth on a mathematical basis.
GEODETIC	Basic relationship of the earth to the curvature of its sea level surface.
GRADIENT	The rate of change of a variable quantity.
GREY SCALE	A strip of standard grey tones, ranging from white to black, placed at the side of original artwork during photography to measure tonal range and contrast obtained on the copy.

GRID	Network of lines on a plane surface upon which coordinates are based and to which the map features are referenced.
GUIDE IMAGE	Image obtained on scribing film by a photo-chemical method. The image is used as a guide for scribing.
GUTTER	The blank space or inner margin, from printing area to binding on a page.
HACHURE	Line symbol used to indicate land formations on maps.
HALATION	The spreading of light beyond its proper boundaries in a developed photographic image.
HALFTONE	A continuous-tone image such as a photograph, reproduced through a crossline or contact screen, which converts the image into dots of various sizes.
HICKEYS	In printing (offset), spots or imperfections caused by dirt or other particles on the printing plate.
HISTOGRAM	A graphic display of information which shows the frequency of occurrence along the vertical axis and the individual values along the horizontal axis.
HOMOLOGRAPHIC	Applied to maps showing the same graphic representation.
HUE	The characteristic of a colour associated with a wavelength of light which distinguishes it from other colours.
HYDROGRAPHIC CHART	A chart showing water features such as depths, channels, islands and other aids to navigation.
HYDROGRAPHY	Science which deals with the measurement and description of physical features of the oceans, lakes and rivers and their adjoining coastal areas.
HYPO	An abbreviation for sodium thiosulfate or sodium hyposulphite, a chemical used to fix the image on a photographic film after it has been developed.
HYPSOMETRY	Vertical control in map making with reference to elevation relative to an established datum.

INFRARED RADIATION	Energy in the 0.7-100 micrometres (microns) area of the electromagnetic spectrum. "Invisible light", longer than visible light, is known as the near infrared. This can be recorded on photosensitive materials. Far infrared radiation is often termed "thermal infrared" and must be recorded by electronic means.
INTENSITY	The richness or brilliance of a colour.
ISOTHERM	A line connecting points of equal temperature.
ITALIC	The style of letters that slant, in contrast to the normal upright or Roman form. Used for emphasis in text and commonly to refer to water features on maps.
JUSTIFY	In type composition, to space out lines uniformly to a predetermined length.
KERNING	In type composition, the subtraction of space between letters or characters so that they appear closer together and form a visual unit.
KEYLINE	An outline drawing of finished artwork to indicate the exact shape, position and size for each of the basic elements in the design.
LANDMARK	A conspicuous man-made or natural feature that may be of assistance to a mariner for determining position.
LARGE-SCALE	Scale of 1:25,000 or larger (1:10,000, 1:5,000, etc.). The smaller the number, the larger the scale.
LASER	Acronym for Light Amplification by Stimulated Emission of Radiation. An intense light beam with very narrow band widths.
LAYOUT	The drawing or sketch of a proposed piece of artwork.
LEADING	In type composition, the distance between lines of type, measured in points.
LETTERSPACING	The placing of additional space between each letter of a word.
LINE MAP	Map composed of point, line and area symbols as contrasted to continuous-tone images.

LITH FILM	A high contrast, orthochromatic film used traditionally for photomechanical work.
LORAN	Acronym for Long Range Navigation. A system using pulsed, low frequency radio waves.
LOWER CASE	The small letters in type, as distinguished from capital letters.
MAGENTA	One of the subtractive primary colours which is used in four colour process printing.
MAGENTA SCREEN	A dyed contact screen, used for making half-tones.
MANUSCRIPT	Original drawing of a map as compiled from various data sources.
MAP	A graphic representation of the earth's surface drawn to an established scale on a plane surface.
MARGIN	That area of a map or chart lying outside the border, also known as "surround".
MARGINAL INFORMATION	The explanatory notes, diagrams and scales shown in the map margin.
MASKING	In photomechanical processing, the blocking out of an area by means of actinically opaque material to prevent exposure in the blocked out area.
MEAN	A statistical term meaning the average value of a data set.
MERIDIAN	A north-south line connecting the poles.
MOIRE	The undesirable screen pattern of light and dark patches caused by overlapping screens printed at incorrect angles.
MOSAIC	Two or more overlapping aerial photographs assembled together.
NADIR	In aerial photography, the point vertically beneath the perspective centre of the camera lens.
NANOMETER	A unit of length, one billionth of a metre or 1 X 10^{-9} m. Also known as a millimicron.
NAUTICAL CHART	Hydrographic or marine map.

NAVSTAR-GPS	Acronym for Navigational Satellite Timing And Ranging - Global Positioning System; a system of 18 satellites offering precision navigation.
NEATLINE	The inner border of a map.
NEGATIVE	An image formed of lines and symbols which allow the passage of light on a background which is opaque to light.
OPAQUE	Impervious to the rays of light. Opaque also refers to a variety of substances that prevent transmission of light.
OPEN WINDOW NEGATIVE	A negative having open areas in which solids, screens, rulings and tints of a colour may be printed.
ORTHOCHROMATIC	Photographic materials insensitive to red light but recording ultraviolet, blue, green and yellow light.
ORTHOPHOTO	Image derived from aerial photographs by differential rectification so that all scale errors have been removed.
OVERLAY	A transparent or translucent material which is fitted or registered over the base map in use for the purpose of adding information.
OVERPRINT	New information printed on an existing map or chart to show data of importance or additions to those originally printed.
PANCHROMATIC FILM	Photographic film sensitive to all visible colours of light.
PARALLAX	The apparent change in the position of one object relative to another when seen from a different location.
PASS POINTS	Points determined from photographs by photogrammetric methods for use in orientation of other aerial photographs.
PHOTO ENGRAVING	Photomechanical process for converting any object that can be photographed into a relief plate for letterpress printing.
PHOTO MAP	An unrectified reproduction of an aerial photograph or a mosaic made from several aerial photographs for the purpose of depicting geographic and/or thematic information.

PHOTOGRAMMETRY	Method of obtaining accurate measurements from aerial photographs.
PHOTOGRAPH	General term for a positive or negative print on various support materials produced by several reproductive methods.
PHOTOMECHANICAL TRANSFER (PMT)	A diffusion transfer copying process which produces high contrast images on film or paper in line or halftone.
PICA	A unit of type measurement used in type-setting. One pica is approximately 1/6 inch.
PIN REGISTRATION	The use of accurately positioned holes and special pins on artwork, films and plates to ensure proper registration and fit of components and overlays.
PLANIMETRIC MAP	Map indicating only the horizontal positions of features without regard to elevation.
POINT	A unit of type measurement. There are 12 points to a pica and approximately 72 points to one inch.
POSITIVE	An image formed of lines and symbols which are opaque to light on a background which either allows all light to pass through (transparency) or reflects all light (a white background).
PRESS PROOF	A map proved on a printing press or taken from the first printed copies for editing purposes.
PROCESS COLOURS	The subtractive primaries, yellow, magenta and cyan plus black used in four colour process printing.
PROGRESSIVE PROOFS (Progs)	Proofs made from the separate plates in colour process printing, showing the sequence of printing and the result after each additional colour has been applied.
PROJECTION	A system of lines on a map representing a series of imaginary lines on the earth's surface.
PROOF	A preliminary single or multi-colour copy of a map, chart or graphic produced by photo-mechanical processes for the purpose of editing and correction, and to show final appearance before printing.

PROVISIONAL MAP	A rapidly produced map that sacrifices accuracy for speed of production.
RADAR	Acronym for Radio Detection and Ranging; an instrument using beamed and timed electromagnetic radiation to detect or track objects, measure height or obtain an image of the surface.
RAGGED LEFT	In typesetting, text that is aligned on the right and ragged on the left edge.
RAGGED RIGHT	In typesetting, text that is aligned on the left and ragged on the right edge.
REFLECTION COPY	A copy of artwork produced on opaque materials which must be photographed by light reflected from its surface.
REGISTER	The correct position of one component of a composite image in relation to the other components.
REPROGRAPHY	Copying and duplicating.
REVERSE LETTERING	Light lettering on a dark background.
REVERSE READING OR WRONG READING	An image readable in a normal way (left to right) when viewed from the non-emulsion side of a film copy.
RIGHT READING	An image readable in a normal way (left to right) when viewed from the emulsion side of a film copy, plate or paper print.
SAFELIGHT	A special darkroom lamp used for illumination without fogging sensitized materials.
SANS SERIF	A typeface without serifs.
SCALE	The ratio of distance measured on a map to the corresponding distance on the ground.
SCREEN	Sheet of transparent film or glass carrying a regularly repeated pattern which may be used in conjunction with an area negative to photomechanically reproduce areas of the pattern.
SCREEN ANGLE	Angle at which halftone screens or screen tints for each colour are printed in relation to one another to avoid moire patterns. Angles normally used are black 45°, magenta 75°, yellow 90°, cyan 105°.

SCREEN, HALFTONE	A variable opacity screen used to convert continuous-tone to varying size dots.
SCREEN RULING	The number of lines or dots per inch on a halftone screen or screen tint.
SCREEN TINT	A screen of closely and evenly spaced dots or lines used on open window negatives to produce tones.
SCRIBING FILM	A transparent base which carries an actinically opaque coating that can be removed by scribing to produce open images. The finished scribesheet can be used as a photographic negative in the photomechanical processes.
SEISMOMETER	A device for recording data on the structure of the earth's crust by recording small sounds, obtained from distant earthquakes or man-made sources. An Ocean Bottom Seismometer (OBS) records data from the ocean bottom.
SENSOR	A generic name for a device that senses either the absolute value or a change in a physical quantity such as temperature or salinity and converts that change into an input signal for an information gathering system.
SERIF	The short cross-lines at the ends of the main strokes of many letters in some type faces.
SHORELINE	On charts this represents the line of contact between the land and a selected water elevation.
SIDELOOKING RADAR	An all-weather, day or night remote sensor. It is defined as an active sensor; it generates its own energy, which is transmitted and reflected from the ground target area in the form of a photo-like picture. Also known as Side-Looking Airborne Radar or SLAR.
SIDE-SCAN SONAR	An acoustic device which sends out a beam of sound waves laterally from a ship's course to map the seabed topography in broad swaths.
SPECTRAL SIGNATURE	Quantitative measurement of the detected properties of an object at several wavelengths.
SPECTRUM (Light)	The complete range of colours in the rainbow, from short wavelengths (blue) to long wavelengths (red).

SPECTRUM (Radiation)	A series of radiation wavelengths sequentially arranged.
STABILIZATION PROCESS	A rapid-access photographic process which uses special paper in which a developing agent is incorporated into the emulsion layer, allowing fast development.
STANDARD DEVIATION	The square root of the arithmetic mean of the squares of the deviations from the mean. A measure of the dispersion from the mean in a frequency distribution.
STEREOGRAPHIC	Having a visual three-dimensional appearance.
STEREOSCOPIC FUSION	The mental process which combines the two perspective images on the retinas of the eyes in such a manner as to give a mental impression of a three-dimensional model.
STEREOSCOPIC MODEL	An optical three-dimensional reconstitution of an object by means of superimposed projected images of a stereoscopic pair, or the viewing of the pair of photographs with the aid of a stereoscope.
STEREOSCOPIC PAIR	Two aerial photographs of the same area taken from different camera stations. A portion of the same area appears on both photographs.
STRIPPING FILM	Thin photographic film which, after exposure, may be removed from its base support and transferred to any suitable medium, using a thin layer of wax as an adhesive.
TELEMETRY	The science involved with measuring a quantity, and transmitting this value to a station for interpretation or recording of the quantity.
THEMATIC MAPPER	A multispectral scanning system with seven channels of operation.
TILT	The angle between the optical axis of a camera and a plumb line.
TINTS	Even-toned area of a colour.
TOOTH	The slightly rough finish of paper or plastics which permits ink to adhere to the surface.
TOPOGRAPHY	The features of the surface of the earth, including relief, vegetation and water.

TRANSPARENT COPY	A copy such as a colour transparency or positive film which allows the passage of light, permitting a clear view of objects beyond.
ULTRAVIOLET RADIATION	Electromagnetic radiation of shorter wavelengths than visible radiation but longer than x-rays; in the wavelength interval between 10 and 4000 Angstroms (one Angstrom equals 10^{-10} of a metre).
VACUUM FRAME	A contact frame, the upper surface consisting of glass, from which air is extracted to ensure close contact between photographic materials during exposure.
VALUE (Colour)	The sensation of relative darkness (low) or lightness (high) of a colour or tone compared to another or as measured in relation to a grey scale.
VIGNETTING	The gradual fading of a colour.
XEROGRAPHY	A copying process that utilizes a selenium surface and electrostatic focus to form an image.
ZENITH	The "point" in the sky directly above a given place.

M-43
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