A Workbook of

Practical Exercises in Coastal Zone Management for Tropical Islands

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Commonwealth Science Council

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PRACTICAL EXERCISES IN COASTAL ZONE MANAGEMENT FOR TROPICAL ISLANDS

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INTRODUCTION

The coastal zone - that region of a country where the marine and terrestrial environments are in direct contact - is of great significance to an island state. Islands have coastlines which are disproportionately large compared to their dry land area and human activities tend to be concentrated there because so much of the economy is based on, or related to, man's use of the sea. The great dependency on the coastal zone is exemplified by the tourism industry of many Caribbean or Pacific islands, where the favourable combination of sun, sand and sea forms the mainstay of the economy. In these tropical islands some of the most productive natural communities occur in the coastal zone, such as coral reefs, seagrass beds and mangrove swamps. Major fisheries production is supported also in nearshore environments, particularly in oceanic islands with narrow shelf areas dropping off rapidly into deep, often poorly productive, waters. Marine resource production is relatively high in coastal areas also because of the island mass effect (Sander & Steven, 1973); in which oligotrophic coastal water is enriched by nutrient input from island runoff and, in some cases, localised upwellings. This factor is much more apparent with high islands than with low, coral-based islands, cays and atolls. Many of the volcanic islands in the Caribbean have steep central highlands and narrow coastal plains so that the coastal zone is rapidly and directly influenced by surface runoff with its associated nutrients.

Most major cities in island states are located in the coastal zone where they developed from ports. Bays and lagoons, which provided safe anchorage, became centres of shipping activity, loading and warehousing, dry docking and repair. Supporting industry came to be concentrated in the coastal zone, with a continuing demand for more sea frontage through reclamation and landfill. Traditionally also, the sea coast has been a dumping site for sewage (Barnes, 1973), factory effluents and solid waste. With increasing industrialisation of many island states serious pollution problems have resulted, as the amount of these wastes increases and the composition becomes more complex. Marine pollution is essentially a coastal zone problem, in which toxic substances, oxygen depletion and eutrophication upset the natural balance and productivity of coastal communities, while recreation and shoreline residential areas suffer from unpleasant odours or unsightly garbage.

All these factors contribute to varied, and frequently intense, human impact on the coastal zone. Many governments are introducing measures to control the

resulting resource degradation, pollution and conflict between coastal resource users, but their efforts are hindered often by the special characteristics of this zone and the complexities of its management (Towle, 1971; McEachern & Towle, 1972).

Tropical island coastal zones are characterised by a great variety of physical and biological systems in close proximity and interaction. Frequently there are no obvious boundaries between adjacent systems, so that materials and organisms move freely from one to the other, as with the coral reef-seagrass-mangrove association (Ogden & Gladfelter, 1983). Processes in one area of the coast affect other areas rapidly, because of the presence of active transport systems in the form of tidal flows, sea breezes, river discharges and coastal currents. The coastal zone is essentially the interface between land, sea and air, and although we understand a great deal about the land on which we live, elemental interactions with the sea and air are relatively poorly researched. Furthermore, this zone receives the main effects of unpredictable, occasional events like hurricanes, storm surges and flooding and is the site of the continuous processes of erosion and redistribution of land-derived materials. For most islands the coastal zone is probably the most complex and dynamic area of the country.

Institutional responsibility for regulation of coastal activities, resource use and problem solving is characteristically diffuse. A variety of governmental agencies will be concerned with shipping, fishing, mineral extraction, tourism, real estate development, waste disposal, and conservation, even in small island states. Few countries will possess high level personnel trained specifically in coastal management or an infrastructure that permits integrated coastal resources planning and development. This problem has been recognised by several international agencies. For example, an Expert Group established by the Commonwealth Science Council under the chairmanship of Sir John Kendrew identified the need for training in Coastal Zone Management for island states of the Commonwealth (Commonwealth Science Council, 1984). Two programmes were initiated in 1985, a South Pacific Coastal Zone Programme and a project on Coastal Zone Management of the Lesser Antilles Region (Commonwealth Science Council, 1985). Both emphasised the need for education and training for coastal resource managers.

Although there is a large body of data and some clearly defined concepts available for understanding coastal zone problems, there is virtually no published material for **practical** training in relevant field and laboratory techniques. Computer searches conducted in libraries of the Coastal Management Unit, University of Michigan, and the University of the West Indies, Jamaica, failed to

locate any suitable materials of a purely practical nature. This is unfortunate, because the greatest problem appears to be the difficulty that scientists, planners and developers have communicating to one another their different perspectives of coastal resource management. Much of this difficulty stems from a lack of appreciation of the objectives and methodologies used by experts in other disciplines, and could be overcome to a great extent by exposure to each other's practical skills. The Commonwealth Science Council in sponsoring this workbook offers a series of exercises which illustrate a range of environmental, ecological and institutional aspects of the coastal zone management process for tropical islanders. The exercises are intended for use during advanced training courses and are designed to give practicing and prospective coastal managers "hands-on" experience of a range of essential techniques.

HOW TO USE THIS WORKBOOK

Outline of the Workbook

The workbook begins with an exercise concerned with defining the limits of coastal zone project areas, and continues by investigating the scope of such projects. These are essential first steps in defining the management unit and the identification of the issues involved.

It next addresses the critical issue of Development Impact Assessment. This is done by examining several aspects of Tourism Development; and later comparing these with problems in residential, port, industrial and fishery developments. These exercises concentrate largely on familiarisation with technical aspects of the coastal zone management process, framed within the context of development problem solving. The third chapter groups land use, institutional, legal and socioeconomic aspects under a general heading of Coastal Area Management Planning. Its purpose is to develop skills in planning and the use of technical data in decision making. This includes consideration of conflict resolution, criteria for assigning priority uses and for delineating areas of particular concern. The exercises which follow deal with coastal ecosystem management by illustrating techniques for evaluation, controlled exploitation of characteristic tropical island systems and their biota, and recovery of damaged ecosystems. The risk associated with some development projects, and planning for emergency events like oil spills form the basis of Chapter 5. The final exercise develops methods for project monitoring and endorsement, as an aid to planning and decision making in coastal zone management.

Format of the exercises

Each of the 20 exercises is a complete entity which can be used by itself. However, the exercises are arranged in a logical sequence so that several of them could be used together during a training course. Suggested group linkages are given for courses of varying duration in Appendix 1 which deals with **Training Course Construction.**

Exercises begin with a **Background** statement, which considers the problem area to be addressed, using case study examples where appropriate, and the basic concepts needed to address the problem. From these is derived the **Aim** of the exercise. To aid in selection and planning of appropriate exercises, the **Duration**, or time needed to complete the exercise, is stated, as is the **Suitable Location.** This is given as an indication of whether the practical work should be done in the field, laboratory or at both locations, but particularly of the type of field

site required. Choice of field site is critical, but can be suggested only in general terms because of the variability in natural conditions and degree of development in islands where the book will be used. The **Materials Required** are listed and **Instructions** given for field, drawing office or laboratory work, as for analysis of data and formats for presentations. From these, the **Product** or expected result is outlined, followed by its **Interpretation** and applications to the problem area. This aspect is illustrated at times by a worked example taken from an actual **Case Study**, and permits the reading and understanding of all the exercises even if they are not being used for actual practical work during a training programme.

The final section deals with **Alternative Exercises.** The intention here is to suggest other related exercises that could be used

(a) if the given exercise is not appropriate in a particular country.
(b) if longer or shorter exercises are required.
(c) if the tutor wishes to reinforce concepts by further work.
(d) if a particular training course can accommodate other related topics.

Further study of relevant concepts, case studies and alternative practical work is aided by suggestions for **Further Reading.** Literature citations contained in the exercise texts are listed in the References section at the end of the workbook. Those persons wishing to obtain copies of reports or publications mentioned in the text, or to obtain further information from agencies active in Coastal Zone Management, will find a list of **Useful Addresses** in Appendix 8. The literature citation is biased towards the islands of the Caribbean Region, as is much of the text. This reflects the working experience of the Authors. The general principles and suggested methodologies are of relevance, however, to island coastal zone management programmes throughout the tropics.

Using the Workbook

The Tutor

Selection of appropriate exercises must be done in accordance with the desired objectives, the type of persons being trained and the time available. Most of the early exercises are unidirectional and suitable for individual study and analysis in short periods. Later exercises are more suited to extended period group work. This is true particularly of the multidimensional tasks

involved with Coastal Area Management Planning, which incorporate exercises from several interrelated disciplines.

It is important that the tutor ensures adequate background study aid materials are available , such as maps, plans and data sheets, and also materials for producing the required reporting products. The latter means a range of stationery, markers, display charts and blank outline maps suitable not only for working on, but for displaying the product to other interested persons. All data need not be given out at the start of an exercise, as it can be constructive for participants to work out their own requirements for problem solving as part of the training.

The Trainee

This is essentially a **practical** workbook, so trainees should attempt to carry out the assigned exercises fully, not to be content just to read about them. This is particularly true where they concern work in disciplines other than your own. The scientist must understand as much as possible about the developer's objectives and aspirations, while planners or economists should appreciate what scientific data means or what environmental limits there might be to their projects. Important also for the trainee is presenting the findings in a clear and intelligible manner, especially to persons in other disciplines.

Every coastal area has its own characteristics and there can be no substitute for a thorough understanding of the situation that you are dealing with in your island. The case studies and other examples given to illustrate ideas in the text must be used only as a guide, or applied to the real life situation only after appropriate modification.

One of the greatest problems that coastal zone managers face in tropical islands is the shortage of good data concerning the physical and biological systems of the coastal environments. The tutor will see that you have as much background data as possible for tackling each exercise, but at some stage you will be called upon to make judgements. After seeking advice and consulting colleagues in the workgroup, "best available opinion" may be a valid tool in decision making and should be used with confidence. However, when information is available it should be sought avidly, assessed rigorously and applied appropriately !

* * *

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Many of the ideas presented in this Workbook have been tested already in training courses at the University of the West Indies, Mona, or have been reviewed critically by colleagues. However, the authors would welcome comments and suggestions for improvement from tutors and trainees who use this text. They are asked to write to the authors

directly or to the Commonwealth Science Council.

* * *

CHAPTER 1

PROGRAMME DEFINITION AND BASELINE DATA ACQUISITION

Introduction:

If coastal zone management is to be practicable and effective, the limits of the management unit must be defined clearly. The manager must know what he is concerned with in geographical terms, but appreciate also existing institutional responsibilities. Opinions differ regarding the seaward and landward **limits of the coastal zone** (United Nations, 1982) and these are a major concern of the United Nations Convention on the Law of the Sea (UNCLOS, 1982). However, some authors question the validity of the concept when applied to island situations (OTA, 1987). Most continental countries possess coastal areas which differ and are clearly separated from the hinterland, in so far as their geomorphology and socioeconomic activities are determined largely by marine influences. Many of the smaller, low islands, such as the Bahamas, are dominated throughout by the sea and for planning purposes "island management" is a more realistic concept. Where large islands or high islands are concerned, whether these are volcanic, raised limestone or continental in origin, lines of separation can be drawn between the terrestrial, coastal and oceanic zones under national jurisdiction. Once the coastal zone is defined, a programme for its management is required.

Knowledge of the **system to be managed** is of critical importance to formulation of an effective management programme. Information is available normally from published sources, maps and photographs, unpublished reports, expert and popular knowledge, although it must be interpreted and related to the situation under study. Where it is inadequate or needs updating, standard techniques can be used by the coastal manager to improve the **data base.** Once this is done the data must be accessible to the planner or manager, who will most likely want to involve government agency officials and resource users in the final formulation and execution of the coastal zone management programme. Various means of **mapping baseline data** are available and can make the task of baseline data acquisition and utilisation much easier. This chapter is concerned with some of these simple, but fundamental, aspects of management.

Exercise 1.1 DEFINING THE SCOPE OF A COASTAL ZONE MANAGEMENT PROGRAMME

Background:

Any programme of coastal zone management will be concerned with a specific zone of the island. It will differ in character or objectives from management programmes for other parts of the country and, ideally, it will require a coastal zone management authority or special committee to direct it. For planning purposes these distinctions are important, as they determine **what, where and who** will be involved in the programme.

Several choices are available in making these distinctions. One could, for example, include only the immediate intertidal area of the sea coast in the coastal zone. Then shipping, beaches and natural ecosystems extending up to the high tide level, such as mangrove swamps, would be managed by a special authority. Such a narrow definition would be unsatisfactory on the grounds that shipping uses the oceans also and receives cargo from the hinterland, beaches are nourished by land-derived sediment, and mangroves are influenced normally by riverine inputs and marine organisms. For effective management of natural intertidal systems, all associated coastal plain and drainage-catchment areas would need to be included in the coastal zone and watershed management would become an essential part of the coastal zone management process. Furthermore, this limit excludes characteristic, and important, coastal habitats like coral reefs, seagrass beds and the subtidal regions of bays, estuaries and lagoons, which would then need a separate marine authority to manage them.

One alternative would be to concentrate not on cartographic limits, but on the regulation of activities which are specific to the coastal zone. This approach would identify as coastal zone management concerns all shipping, the major part of an island's fishing, core activities in tourism and recreation, domestic and industrial waste disposal, and marine park development. A criticism would be that no one of these activities is confined 100% to the coastal zone, in either geographic or socioeconomic terms. Also, the relevant institutions may not for example administer marine parks separately from other aspects of conservation or sea-based tourism in isolation from inland activities.

Nonetheless, there is no doubt that certain activities are fundamentally **coastal**, like tropical island tourism, and, as such, merit special treatment. Several natural ecosystems are rarely found elsewhere. There are also

some problems which are characteristically coastal zone problems, such as beach erosion, oil pollution , marine fouling and fishery resource depletion, and these require a specialist approach to their solution. Coastal zone managers could restrict themselves to solving these problems, but even here it would be essential to define limits and institutional responsibilities. For example, loss of a valuable tourist beach through erosion may have been caused by human activities at a distant location (see Bacon & Head, 1985) or through-on site construction work which did not conform to controls placed on it by the central planning agency (St.Croix Avis, 1987). Its solution may lie in management of a whole stretch of coastline, or simply in attention to enforcement of regulations. Similarly, overexploitation of a reef fishery may have resulted from increase in the number of fishermen following decline in the agriculture sector; so its solution lies ultimately with the ministry responsible for employment, or in shifting effort to other areas such as tourism or mariculture. Overexploitation is seen then as a socioeconomic issue, rather than one needing fisheries biology or natural resource management skills; although these may be called upon at a later stage when attempting to resuscitate the damaged fishery.

It is important, therefore, when embarking on coastal zone management, both generally and in specific problem situations, to establish clearly the **scope** and **issues** involved, the **linkages** within and external to the situation, and the level of legal and **institutional responsibility.**

Aim:

To establish the scope of a Coastal Zone Management Programme.

Objectives:

To define the boundaries of a Coastal Zone Sector.
To identify the Coastal Zone management issues in this sector.
To rank the issues in order of importance.
To identify agency responsibility in the Coastal Zone sector.

Duration:

One day. Half day fieldwork; half day drawing office.

Suitable Location:

A natural area of island coast, preferably containing established industrial or tourism development; or the main

port area; or a large town based on a bay or lagoon; or an area of intensive natural resource utilization.

Materials Required:

Topographic map sheets (1:50,000 or larger scale depending on chosen site) - one per student, or per group.
Bathymetric charts.
Aerial photographs 1:12,500 or larger scale.
Data sources (as appropriate) for:

- Baseline geography and natural ecosystems
- Historic development changes
- Socioeconomic features (population, fishing, commerce, factory products etc.)
- Tourism sector (visitor numbers, linkages etc.)
- Government or other agency responsibility

Instructions:

Preliminary investigations.

1. Maps, charts and aerial photographs should be examined prior to the field visit, so that students are familiar with the geography of the area selected. (See also Exercise 1.2)

2. A series of sites should be pre-selected for field visitation. There should be about 10 of these to include all significant natural and man-made features of the area that can be examined during a half-day period.

Field methods

3. At each study site the following observations should be recorded:

   (a) The precise location (marked on the map).
   (b) Types of natural ecosystems, human activities or infrastructure (e.g. mangroves, fishing, loading cargo).
   (c) Area of coastline occupied by each feature or activity.
   (d) Reason why each activity, or piece of infrastructure, occurs there.
   (e) General statement on contribution of each activity to the economy (i.e. no. of jobs created, type of service provided).
   (f) Activities in adjacent areas.

(g) Any problems caused by each activity, or by adjacent activities.
(h) Any problems which hinder any of the above activities.
(i) Agency which regulates each activity, or controls infrastructure.

(When travelling between study sites, notes can be made on other types of activities observed.)

Analysis

4. On return to the drawing office/laboratory, field observations should be analysed as follows:

(a) Select broad usage categories for the area of coastal zone studied (e.g. Recreation; Fishing; Transport).
(b) List all activities observed under the appropriate usage category. Beside each activity indicate, in parentheses, how it is related to the coastal zone, e.g. Power station (seawater used for cooling).
(c) Estimate the percentage of the coastline occupied by each category. Rank these percentages in descending order.
(d) Rank the categories in order of their relative contribution to the island's economy. Compare this order with that given in (c).
(e) Link each identified activity with its responsible agency. List these concerned agencies under each category heading. (N.B. An agency may appear in more than one category).
(f) Identify areas of conflict between observed activities in the coastal zone.
(g) Identify the agencies responsible for reducing these conflicts.
(h) Suggest any activities external to the immediate coastal area studied that influence the activities listed in (b).
(i) List any agencies other than those listed in (e) and (g) with responsibility for items mentioned in (h).

Product

The analysis can be prepared in the form of maps, tables and linkage diagrams. These should be similar to those shown in Figure 1.1 and Tables 1.1-1.3, which are the results of a **Case Study** on the Kingston Harbour coastal zone, Jamaica, conducted in 1986.

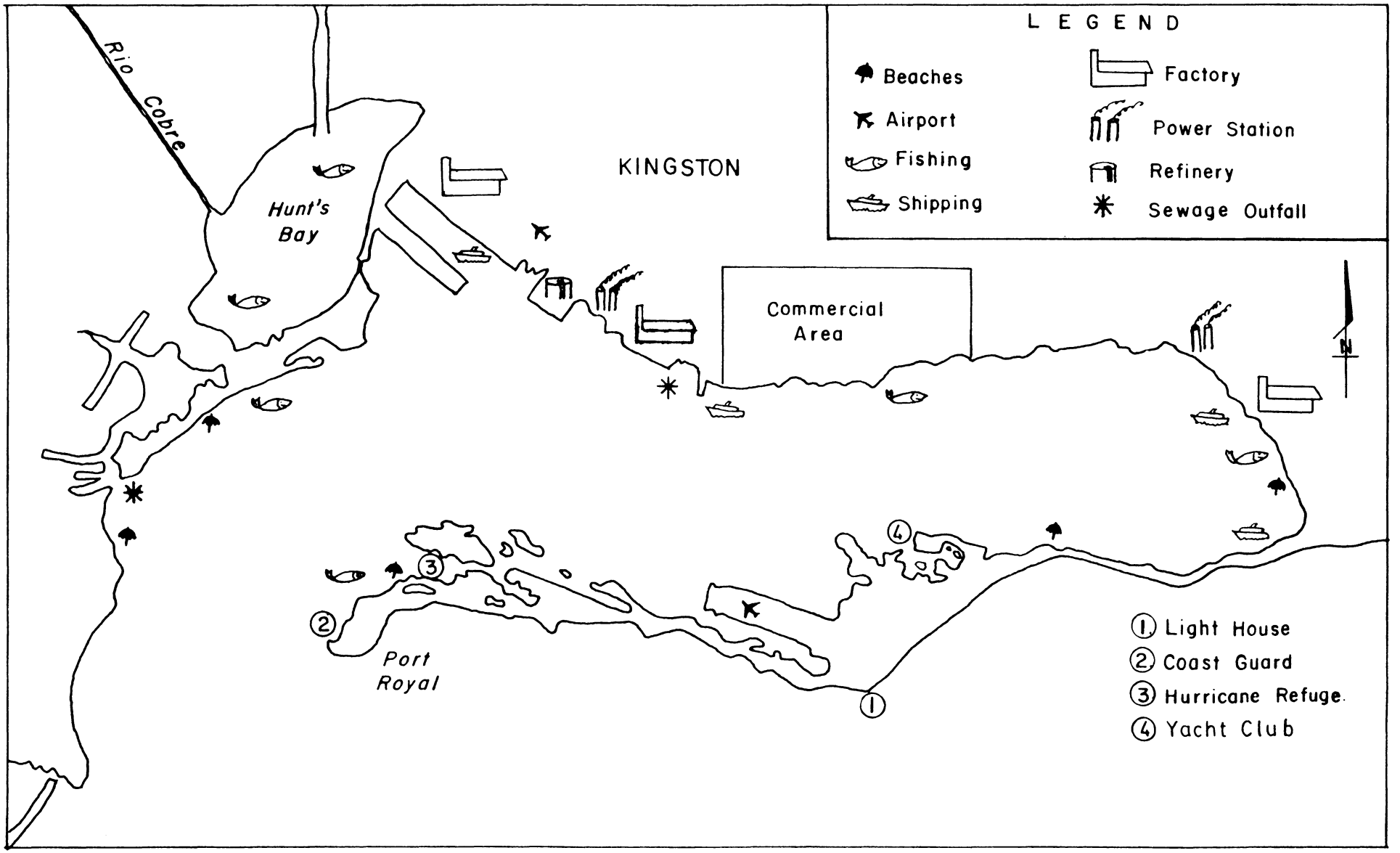


FIGURE 1.1 COASTAL LAND-USE: KINGSTON HARBOUR

Table 1.1 Percentage land use of the Kingston Harbour Coastal Area

Activity	% of Harbour coast
Shipping	20
Commerce	17
Recreation	15
Transport (roads, airports)	15
Forestry (timber, charcoal)	12
Manufacturing	10
Fishing	9
Waste disposal	2

.....

Table 1.2 Contribution to the National Economy of Activities in the Kingston Harbour Coastal Area

Activity	% contribution
Shipping	45
Manufacturing	20
Commerce	10
Transport	9
Waste disposal	7
Recreation	5
Fishing	3
Forestry	1

.....

Table 1.3 Some Institutions involved in the Management of the Kingston Harbour Coastal Zone (modified from Chow, 1987).

Institution	Area of Responsibility
1. Jamaica Defence Force/ Coast Guard	Control of oil spills
2. Jamaica Public Service Co.	Power generation (sea water cooled station)
3. Ministry of Agriculture	
Fisheries Division	Fisheries management
Forestry Division	Mangrove area management
Natural Resources Conservation Division	Natural areas management, environmental regulation
4. Ministry of Construction	
Office of Disaster Preparedness	Contingency planning for natural hazards
5. Ministry of Health	
Environmental Control Division	Water quality (health) management, pollution control and cleanup
6. Office of the Harbour Master	Maritime activity control
7. Petroleum Corporation of Jamaica	Petroleum shipments
8. Tourist Board	Recreational areas and cruise ship docking
9. Town & Country Planning Department	Kingston Metropolitan area planning control
10. Urban Development Corporation	Development & planning

.....

This should be followed by group discussion which attempts to define a practicable Coastal Zone Management Unit based on the study area. Key aspects for consideration are:

5. What activities are directly dependent on or influenced by resources or features of the coastal zone?

6. Are these activities located in a clearly defined zone?

7. How large an area to seaward or landward of this zone must be managed to support or safeguard activities within the zone?

8. What resources are critical to development within the zone ?

9. What are the major issues in this zone that require management:

   - to ensure continued resource use,
   - to reduce damage to resources and maintain quality of life in this zone,
   - to reduce conflict between users ?

.....

Alternative Exercises

(1) This assessment can be carried out on a <u>whole island basis</u>, given a small, little developed island, or a longer period of time with the larger island.

(2) In some cases a <u>specific development site</u> would be appropriate (see Ex. 2.2).

(3) An extension to any of the above exercises could be an investigation of <u>legal provisions for Coastal Zone Management</u> at a study site. This should be in the form of a critical survey of existing and required legislation enabling coastal management. This would include analysis of component clauses in environmental laws and agency involvement (see Ex. 3.6).

.....

Further Reading:

Armstrong, J., Bissell, H., Davenport, R. et al, 1974. Coastal Zone Management: the Process of Program Development. Coastal Zone Management Institute, Sandwich, Massachusetts, USA; 152 pages.

Brahtz, J.F.P. 1972. Coastal Zone Management; Multiple Use with Conservation. John Wiley, New York, 352 pages.

Cambers, G. 1985. An Overview of Coastal Zone Management in Six East Caribbean Islands. UNESCO Regional Office for Science & Technology for Latin America and the Caribbean, Montevideo, 69 pages.

Commonwealth Science Council 1987. Coastal Zone Management of the Caribbean Region: a Status Report. Commonwealth Science Council Technical Report, 227; 188 pages.

United Nations 1982. Coastal Area Management and Development, United Nations Department of International Economic and Social Affairs, Ocean Economics and Technology Branch, Pergamon Press, Oxford, 188 pages.

USDC 1987. Caribbean Marine Resources, Opportunities for Economic Development and Management. US Department of Commerce, Washington, D.C.; 91 pages.

***

Exercise 1.2 INTERPRETING COASTAL FEATURES FROM AERIAL PHOTOGRAPHS

Background:

Aerial photography is particularly useful when investigating areas which are poorly mapped or with difficult access, such as coral reefs and wetlands. Photographs can be used effectively to gain an impression of the general geography of an area prior to the commencement of field investigations. But, more importantly, many types of quantitative information not normally shown on maps can be read off photographs, e.g. dimensions of trees in a mangrove forest or density of plants in a seagrass bed. Aerial photographs frequently provide information about temporary natural phenomena, such as wave patterns and river flood outfall plumes, or about short term human activities such as numbers of fishing boats or holiday makers in a particular location and directions of waste-water effluent streams.

Most countries have aerial photographs taken at intervals over many years and these series provide some of the most useful information for coastal managers. Tropical island coastal zones are dynamic features and photographs of an area taken in different years can show beach erosion or accretion, development of mangrove swamps, structural changes of coral reefs, as well as the spread of industry, harbour facilities or resort real estate. Study of these changes can be used in the analysis of long-term trends in coastal zone development or environmental degradation, as well as being a reminder that the coastal ecosystems which we attempt to manage are evolving and being modified continuously by natural forces.

Aerial photography can be particularly useful, therefore, for aiding the description and inventory of coastal resources and for documenting changes in coastal ecosystems and human impacts. This exercise is concerned with **photo interpretation**, as a technique in coastal management. It is based on the use of standard vertical aerial photographs.

Aerial photographs are used extensively for modern cartography and the process of photogrammetry is discussed in relation to the preparation of Data Atlases in Ex 4.2.

Aerial photography is only one technique in the rapidly advancing field of remote sensing. Some types of satellite imagery are very sophisticated and can provide information about coastal zone phenomena on a regular basis. However, as Klemas (1984) points out, air photos are still preferable for certain components of the coastal zone, such as coastal geomorphology, erosion, vegetation and

land use (Table 1.4). They are also cost effective, easily obtainable and analysable without specialised training or equipment. Furthermore, there is a much longer historical record available for coastal zones in a national air photos archives than there is in any of the satellite imagery data centres.

Aim:

To identify images in a coastal zone aerial photograph.
To measure the sizes of selected objects identified on photographs.

Duration:

Half day drawing office/laboratory work, half day field work.

Suitable locations:

Determined by available aerial photographs

Materials Required:

Set of aerial photographs (stereoscopic pairs).

Availability of aerial photographs varies from island to island, according to government regulations. Photographs can be obtained in most countries from the Surveys Department or the Defence Forces. If photographs cannot be purchased, it is possible normally to get permission to examine them at the archives, even if this means holding the training session there by prior arrangement.

Stereoscope (loan from Surveys Department or college Geography Department).
Straight edge.
Overlay - transparent acetate sheets.
Drawing equipment.
Topographic maps sheets (same area, same scale).

Instructions:

Introduction to aerial photographs

1. Prepare a mosaic of the group of photographs by overlaying these roughly. Study this to get an overview of the whole area.

2. Select an individual photograph and study this with the naked eye.

Table 1.4. Performance of some aircraft and satellite remote sensing for coastal studies (modified from Klemas, 1984)

	Film Cameras		Multispectral Scanners		Thermal IR Scanners		Imaging Radar (SAR or SLAR)	
	AC	SC	AC	SC	AC	SC	AC	SC
Vegetation & Land Use	3	2	3	2	1	0	2	1
Biomass & Veg. Stress	1	1	2	1	1	0	1	0
Coastline Erosion	3	2	3	2	1	0	3	2
Coastal Geomorphology	3	2	3	2	0	0	3	2
Depth Profiles	2	1	2	2	0	0	1	1
Susp. Sediment Patterns	2	2	3	3	1	1	1	0
Susp. Sediment Concentration	1	1	2+	2	0	0	0	0
Chlorophyll Concentration	1	1	2+	2	0	0	0	0
Oil Slicks	2	1	3	2	3	1	3	2
Surface Temperature	0	0	0	0	3	3	1	0
Water Salinity	0	0	0	0	1	0	1	0
Current Circulation Patterns	2	2	2	2	2	2	2	1
Wave Spectra	2	2	2	2	0	0	3	2

Rating
3 = Reliable (Operational)
2 = Needs additional field testing
1 = Limited value (Future potential)
0 = Not applicable

Platform
AC = Aircraft (medium or low altitude)
SC = Spacecraft (satellite)

3. Locate on the map sheet the area covered by the photograph.

4. Locate on the photograph the main features shown on the map. Note their appearance (Figure 1.2).

5. Cover the photograph with a transparent overlay sheet. This should be attached on one side only to permit inspection of the photograph. The outlines of features of interest should be traced with pencil, ink or marker and labelled clearly.

6. Compare your tracing with the accompanying map sheet. What information have you recorded which was not represented on the map?

7. Select five or six objects clearly shown on the aerial photograph and mark their location on both your tracing sheet and the map sheet. These should be objects which are accessible in the field from roads, paths or along the sea front, are likely to be recognisable in the field and whose dimensions can be easily measured. Some suggested objects are

   (a) A sandspit across a river mouth
   (b) A low cliff
   (c) A stand of trees (thought to be mangroves)
   (d) A sea wall
   (e) A building

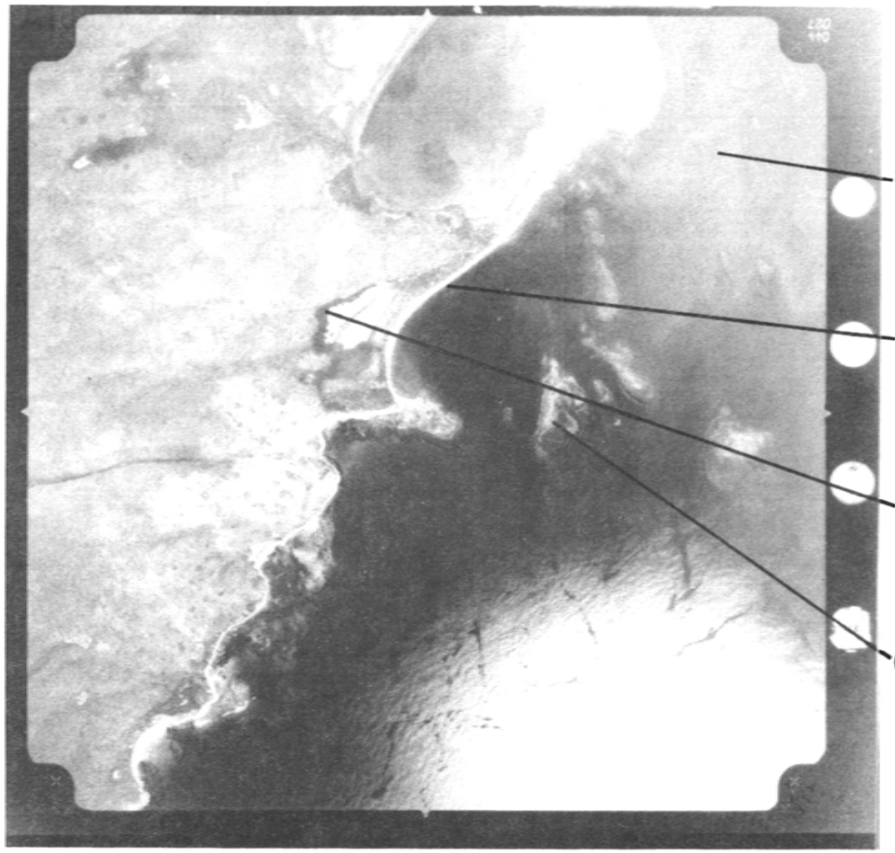
   Estimate the horizontal dimensions of the objects by reference to your photograph and map scales.

8. Visit the area shown on the photograph. Locate and examine the objects selected. Measure their horizontal dimension in order to "ground truth" your photo interpretation.

9. Measure or estimate the vertical height of as many of the selected objects as possible. Keep these measurements for use on return to the drawing office/laboratory.

Stereoscopic pairs

10. Examine each of a pair of aerial photographs in turn. Unless otherwise indicated, north is normally at the top of the photograph. Other information given includes the print identification number, date, time of day, altitude of the plane, and focal length of the camera, as shown in Figure 1.3. Locate these features.



Aids to Identification

TONE	TEXTURE	PATTERN	SITE
light	reflecting or rippled		
light	smooth	crescent or ribbon shaped	bay
dark	granular	rounded	fringing
grey	patchy	scalloped	inshore

FIGURE 1.2 APPEARANCE OF SOME COASTAL FEATURES ON AERIAL PHOTOGRAPHS

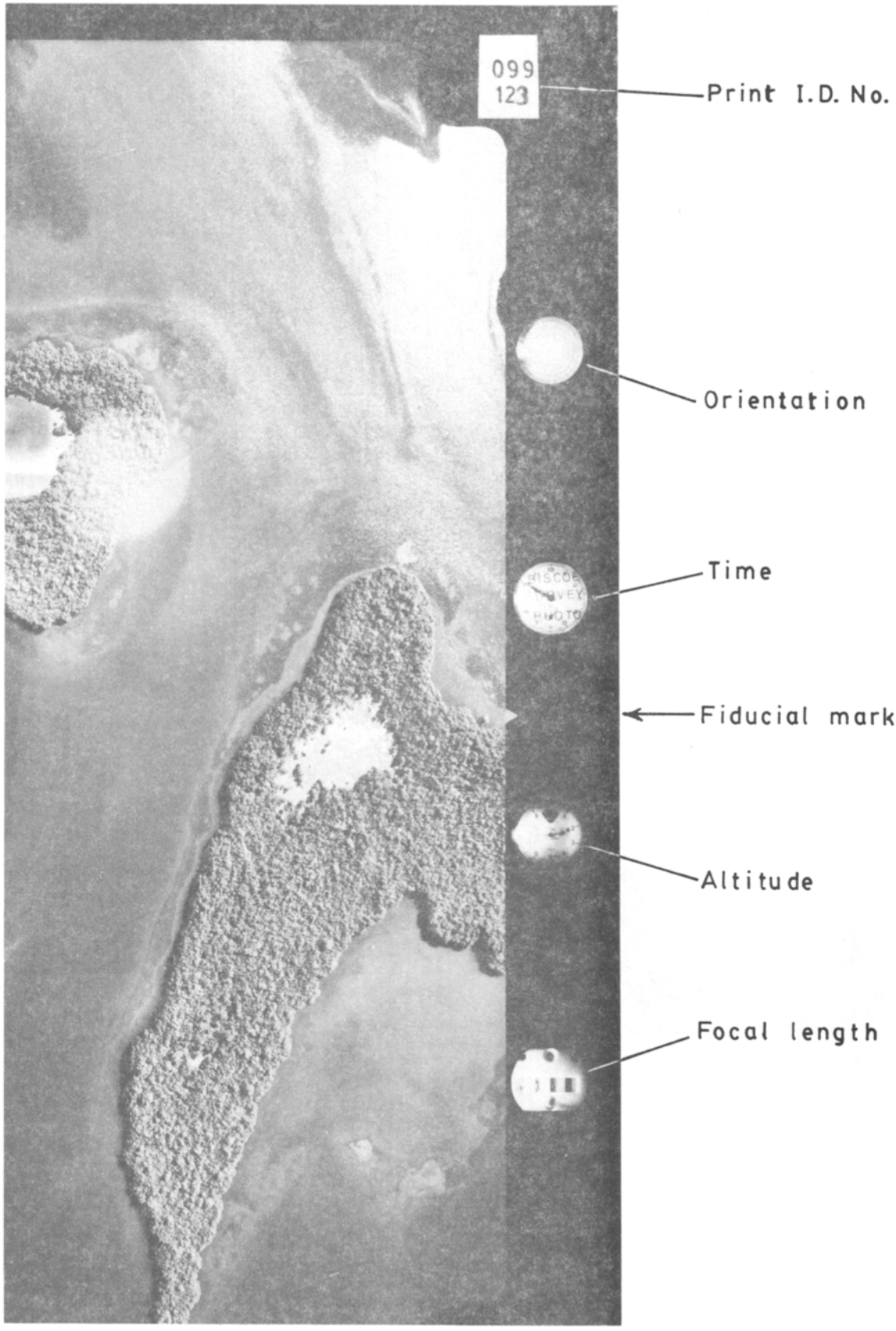


FIGURE I.3 COMPONENTS OF AERIAL PHOTOGRAPHS

11. Calculate the scale of the photograph, according to the following

$$\frac{\text{Camera focal length}}{\text{Altitude}} = \text{general scale}$$

Check this against the scale reported when the photographs were obtained. Note that this calculation is influenced by fluctuations in altitude of the plane during survey work, and is thus an approximation.

12. Locate the Principal Point on each photograph (Figure 1.4a). Mark the P.P. with ink or a pin hole.

13. Locate and mark on each photograph the image of the overlapping photograph's P.P. (Figure 1.4a). These secondary points are called Conjugate Principal Points.

14. Draw a line through the P.P. and C.P.P on each photograph. The line represents the flight path of the plane.

15. Overlap the photographs on a bench top so that the images match, flight lines superimpose, and the combined flight line lies from left to right (Figure 1.4b).

16. Slide the photographs laterally to separate them the distance of your eyes, about 5-6 cms. Place a stereoscope above the junction between the two photographs. Adjust the photographs and the stereoscope until a three-dimensional effect is achieved.

17. Examine the stereoscopic pair of photographs.

18. Refer to the field observations made under 9 above (vertical heights of selected objects). Locate these objects on the photograph and view them stereoscopically. Note their three-dimensional appearance and compare this with your records of size and elevation.

19. Use the stereoscope to measure the horizontal extent and vertical height of the selected objects. Check this against the field data.

Note: It is important to stress that the coastal manager need not restrict interpretive study to the standard government photographs. Aerial photographs taken

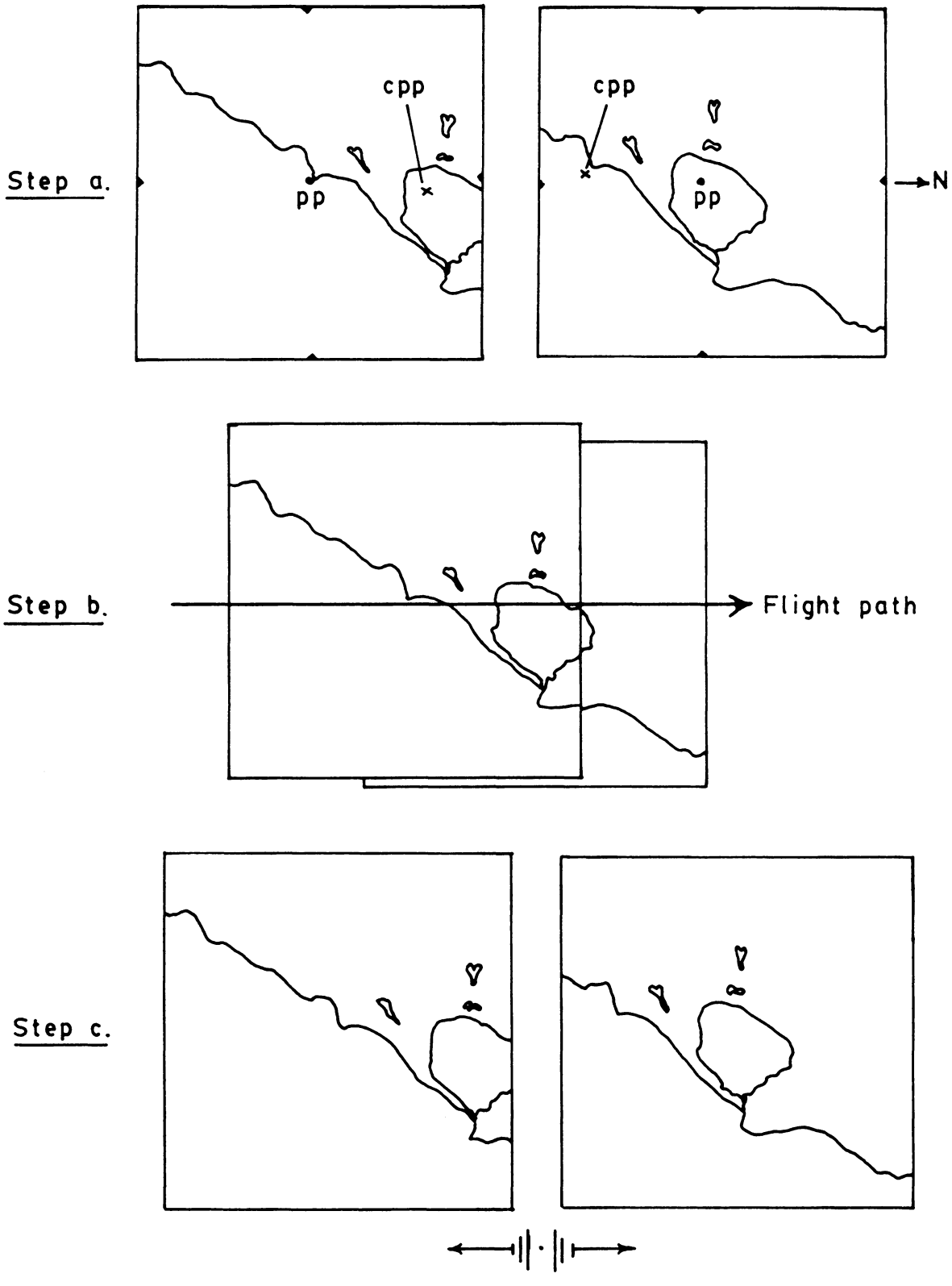


FIGURE 1.4 ORIENTATION OF AERIAL PHOTOGRAPHS FOR STEREOSCOPIC VIEWING

personally using a hand-held camera can be of tremendous value (Figure 1.5), particularly for short-lived events like flood run-off, or wave refraction patterns (see Exercise 2.2.). Aerial surveying from light aircraft is relatively cheap and yields abundant, high quality information once an observer gains some experience (see Appendix 2).

.....

Alternative Exercises:

1. Study the **changes** which have taken place in a selected coastal area over a period of five or ten years. Obtain and study two sets of photographs, taken at the start and end of the time period (and other sets taken in between, if available). Suitable subjects for study would be:

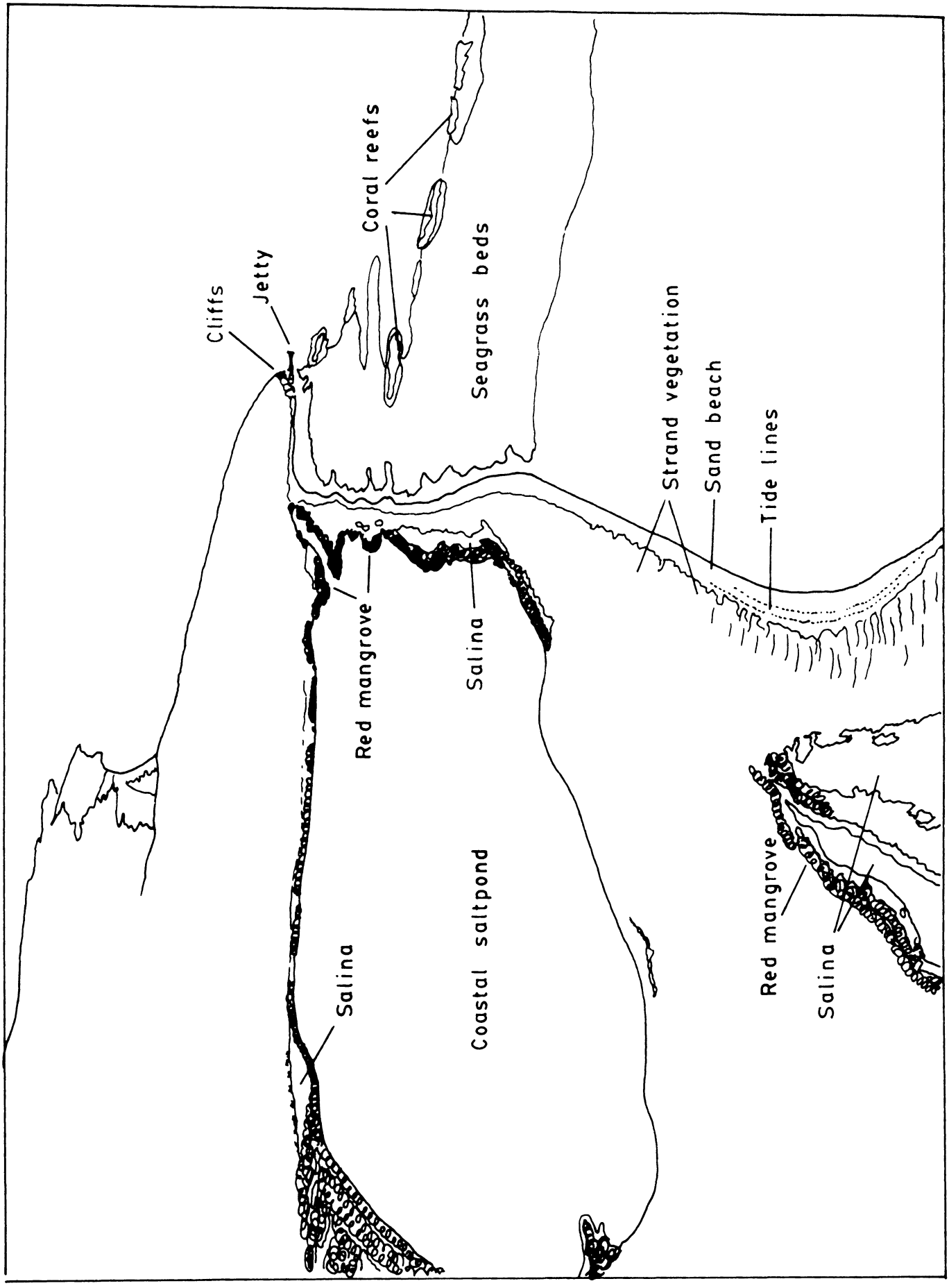
   a. the increase in coastal development
   b. vegetation changes resulting from reclamation in a coastal wetland
   c. extent of erosion of a beach
   d. growth or change in position of a lagoonal sandbar

2. Construction and interpretation of a photo-mosaic. This is an extension from the study of individual or stereoscopic pairs of photographs, to building a composite photo picture of a wider area. Obtain two identical sets of six to ten aerial photographs of a coastal area for which there is good map coverage. Use the following two methods of placing these together in a "mosaic":

   a. fit the edges of one set of photographs together by cutting around clear images (such as rivers, roads, forest margins).
   b. fit the other set of photographs together using fixed map points and measured distances, i.e. select two features on the accompanying map and measure the distance between them; locate these features on adjacent photographs and join the photographs so that the features are the equivalent distance apart; repeat this with features on all other pairs of adjacent photographs until the mosaic is complete.

      Compare the overall picture formed by the mosaic using the two methods. Because there will be some perspective displacement, compare the distances

FIGURE 1.5 OBLIQUE AERIAL PHOTOGRAPH (HAND HELD CAMERA) AND ITS INTERPRETATION (see opposite)



See photograph opposite

between fixed points on both mosaics with those given on the maps.

Further Reading

Sabins, F.F. 1978. Remote Sensing: Principles and nterpretation. W.H. Freeman & Co., San Francisco; 426 pages.

* * *

Exercise 1.3 MAPPING COASTAL FEATURES FOR MANAGEMENT PURPOSES

Background:

The accurate inventory and description of coastal features, such as natural ecosystems or human land-use, is essential before management decisions can be made or problems solved. The characteristics, areal extent and general distribution of features of interest can be recorded in a variety of ways, but visual presentation in the form of maps, charts or diagrams frequently makes interpretation easier. Although general maps, particularly topographic sheets, are likely to be available in most tropical island states, the coastal zone manager will be interested in specific information. To aid management decision making, it may be advantageous to produce new maps showing only certain types of information appropriate to the current problem situation. Furthermore, where maps of the study area are not available, or are not at a large enough scale, or the information is contained only in aerial photographs (see Exercise 1.2), a mapping project will be necessary.

Before mapping can commence, it is essential to decide on the **purpose** of the map or maps; i.e. what do you need to show in order to satisfy the project goals? There are several choices; for example, features and information can be distinguished on a map:

- simply by name, e.g. "beach", "seagrass bed", "hotel", (**Nominal System**).
- by being ranked to show differences between them, e.g. to distinguish a major recreational beach from a minor one (**Ordinal System**).
- by a scaling which shows the interval between ranks, as is done with contours and bathymetry, or by relating differences to a standard unit, e.g. number of hotels per square kilometer, (**Interval System**).

In all cases, appropriate **symbols** should be used to highlight the important characteristics of the information which the manager requires. Bearing these requirements in mind throughout the mapping exercise helps to avoid the temptation to include superfluous information, and produces clear, subject-oriented maps which are easy to use.

The following exercise, and accompanying case study, are concerned with coastal mapping of areas with inadequate cartographic representation of the ecosystems being studied. (Reference should be made to Exercise 3.3 which

includes mapping work associated with the production of Data Atlases; although that exercise is based on already existing maps and data sets). They relate to preliminary investigations of coastal ecosystems, such as those which might be required prior to permitting coastal development (see Chapter 2), establishing a protected area (see Chapter 3), or regulating resource exploitation (see Chapter 4). In each case it is necessary to record what systems are present, how these are distributed, and how they are structured. This information may need to be presented to a range of agency personnel with differing technical expertise and, thus, should be clear and readily decipherable.

Aim:

To produce maps characterising the ecosystems of part of the island coast.

Objectives:

a. To show the location and areal extent of the different ecosystems in the study area.
b. To rank the ecosystems in order of importance.

Suitable Location:

A coastal area, of not more than one square kilometer, which contains a variety of features, e.g. beach, lagoon & fringing reef.

Materials Required:

Transparent Acetate sheets
Blank maps
Stereoscope or desk magnifier
Drawing equipment
Transect lines - 30 to 50 m long, marked at 1 m intervals
Compass
Surveying poles

Instructions:

Preliminary Laboratory/Drawing Office Work

1. As a group, decide precisely what type of information is required.

2. Select main system categories which will be mapped, e.g. reef, wetland, littoral woodland.

3. Define each main category, and write this out so that

the group knows the characters and limits of each mapping category.

4. Select and define the sub-categories to be mapped, e.g.

Main Category	**Sub-Category**
Wetland	Rhizophora zone
	Avicennia zone
	Water channel
	etc.

N.B. If data is to be obtained from aerial photographs these sub-categories must be recognisable.

5. Select an appropriate scale for the maps. This should permit representation of the smallest areas of all sub-categories in relation to the required map sheet size.

6. Prepare base maps on which to enter survey data. The map sheets should show outlines of some landmark features, such as headlands, and the compass bearing. It may be useful to trace a grid onto the base maps as a guide to data entry, or to divide the area into sectors in relation to topographic, bathymetric or habitat features. Place a scale on the map; and leave a space for the Legend.

7. If aerial photographs are to be used, overlay these with acetate sheets on a light table and trace (a) topographic or bathymetric features, (b) outlines of the main systems, and then (c) outlines of the sub-systems. Ground-truth this information by a field survey of the study site (as described below).

Field Measurements

8. If aerial photographs are not available, conduct a field survey of the study site. Begin this by testing observer reliability, i.e. confirm that all members of the survey team agree on how to recognise all mapping categories and on what symbols to use on the field maps. To do this, all team members should survey a common area, and compare notes. The team leader should eradicate discrepancies, and estimate the percentage reliability of forthcoming observations.

9. Commence mapping using marked lines, or tape measures, to determine the boundaries between adjacent system categories. The lines should be placed along a regular grid oriented by using a compass. At

intervals on the shore, and frequently when using a boat in the bay or lagoon, determine the location of key data points. This is done most easily by the process of triangulation, i.e. by taking the compass bearings of two clearly visible landmarks and recording these; calculating the angle and drawing a line from each landmark; and fixing the position where the two lines intersect.

Analysis of Field Data

10. On return to the laboratory/drawing office, plot the fixed positions on the base maps and then plot horizontal and line transect data in relation to these points.

11. Having traced outlines which show the boundaries between adjacent system categories, place symbols within these boundaries to show clearly the location and relative distribution of the categories.

12. Once the map or maps are drawn, complete the mapping exercise and analysis as follows:

    (a) Assign an Importance Value.

    The coastal manager/decision-maker will need to be guided by some indication of "important" features in the study area. Depending on the specific issue being investigated, this can be indicated most easily by some form of ranking of the systems. This could be in order of areal coverage, frequency of occurrence, relative economic value or sensitivity to some stressor. As a group discuss the relative importance of the features mapped.

    (b) Summary Statement concerning the Study Area.

    From the field notes, prepared maps and suggested importance values, prepare a brief statement which summarises the general features of the study site.

Product

The mapping exercise should produce materials similar to those shown in Figures 1.6 & 1.7 and Table 1.5; which are taken from surveys conducted in the Virgin Islands (Anderson, et al, 1986; Beets, et al, 1986) and include vertical transect data intended to show the structure of

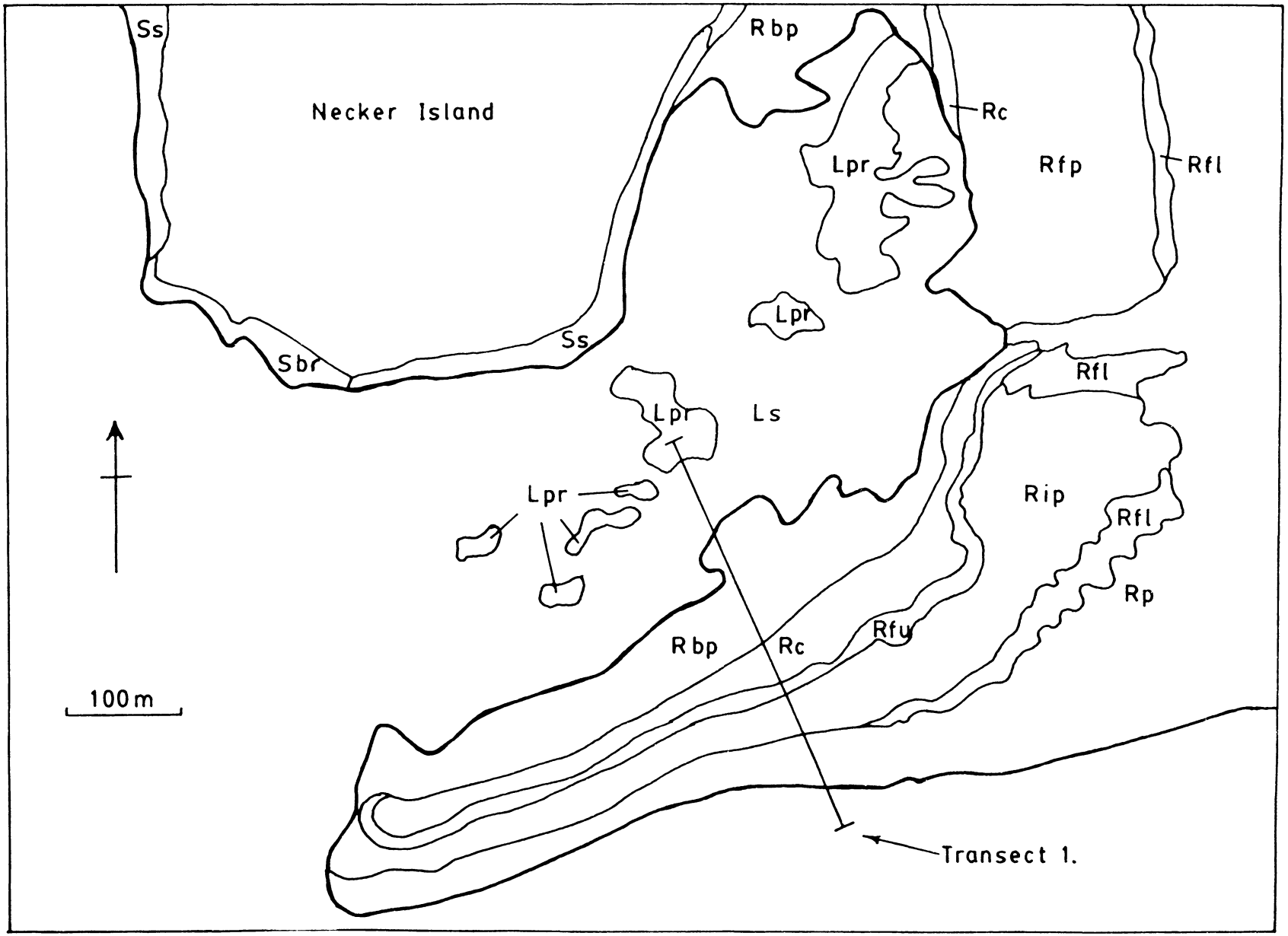


FIGURE 1.6 COMMUNITY DISTRIBUTION MAP - NECKER ISLAND
(for symbols and transect see Table 1.5 and Figure 1.7)

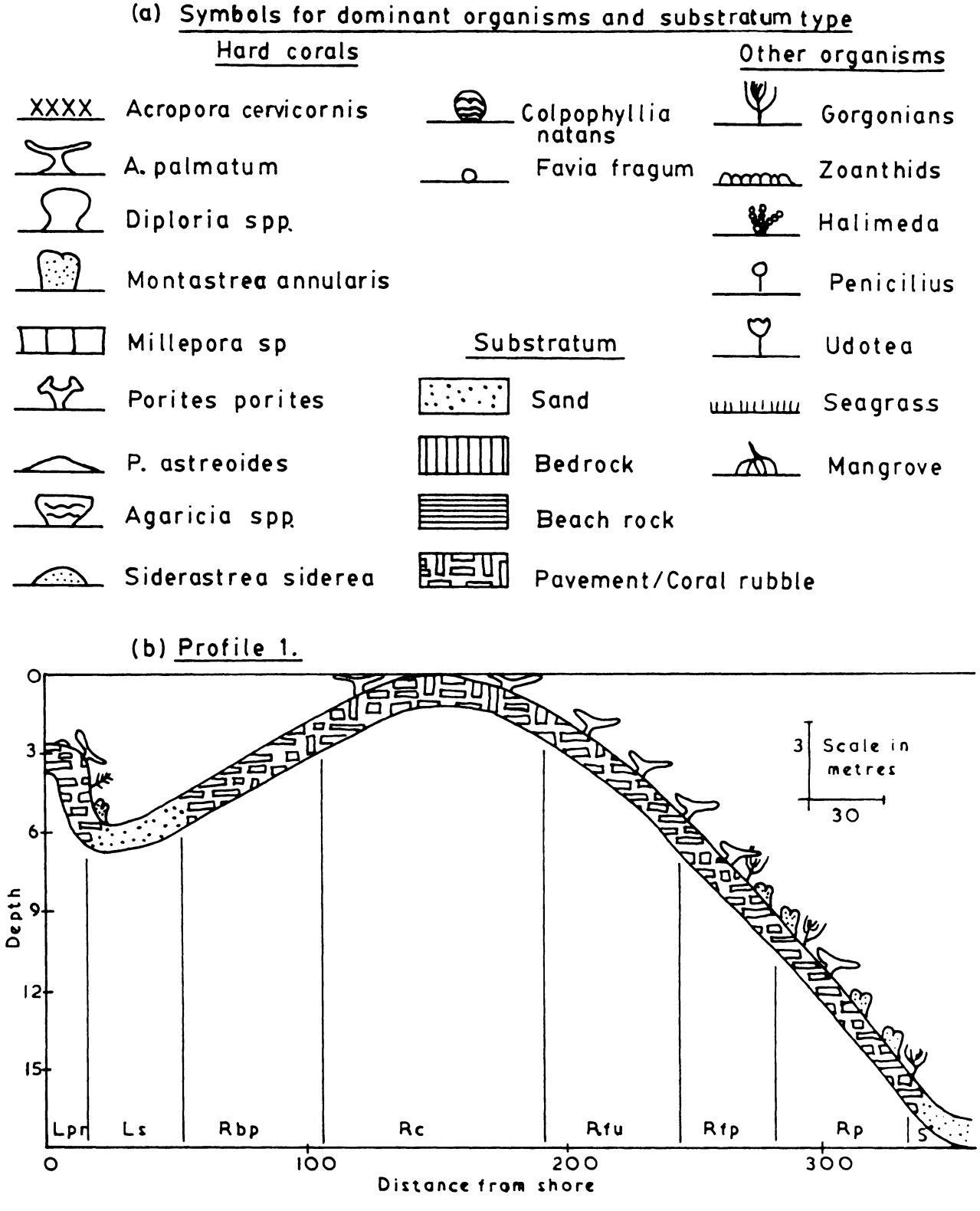


FIGURE 1.7 COMMUNITY MAPPING: (a)SYMBOLS, (b)TRANSECT PROFILE

Table 1.5 Example of Zone & Subzone Designations for Mapping of Coastal Ecosystem Features
(Source: Anderson et al, 1985)

Zone and Subzone	Designation
A. Shore Zone	S
1. Beach rock	Sb
2. Sand	Ss
3. Mangrove	Sm
4. Pavement	Sp
5. Gravel/cobble	Sg
6. Bedrock	Sbr
B. Subtidal Bedrock Zone	SR
C. Lagoon	L
1. Sand	Ls
2. Pavement	Lp
3. Seagrass bed	Lg
4. Patch reef	Lpr
(a)pavement	Lprp
5. Fringing reef	Lf
D. Shallow Bay Zone	SB
1. Sand	SBs
2. Pavement	SBp
3. Seagrass bed	SBg
4. Patch reef	SBpr
5. Mud	SBm
6. Algae	SBa
7. Fringing reef	SBf
E. Reef Zone (fringing & barrier)	R
1. Backreef	Rb
(a) head coral/grotto	Rbh/Rbg
(b) pavement	Rbp
2. Reef crest	Rc
3. Forereef	Rf
(a) upper (arborescent)	Rfu
(b) lower (massive)	Rfl
(c) pavement	Rfp
4. Sand	Rs
5. Gorgonian reef	Rgo
6. Pavement	Rp

Substrate Cover Type	Designation
Live hard coral	HC
Dead coral	DC
Gorgonian coral	Go
Zoanthids	Z
Macroalgae	A
Mangrove	Sm
Seagrass	G
Pavement/turf	T
Sand	S
Shore bedrock/cobble	Sbr
Beachrock	Sb

the coral reefs. Figure 1.7a shows examples of the types of symbols which can be used for dominant organism in the Caribbean; use of a few of which is demonstrated in profile 1 in Figure 1.7b.

.....

Alternative Exercises:

Other than natural ecosystems, there is a wide range of subject areas suitable for preliminary mapping training in the coastal zone. This includes (a) coastal land-use, (b) distribution of economic activities, and (c) human settlement patterns.

If diving capability is available, aquatic communities can be surveyed (as in the Case Study above). Similarly, availability of boats with on-board sampling gear would permit a wider range of offshore survey and mapping work (see Agard, 1984).

.....

Further Reading:

Putney, A. D. 1982. Final Report. Survey of Conservation Priorities in the Lesser Antilles. Caribbean Conservation Association, Technical Report 1; 30 pages.

Robinson, A.H. & Sale, R.D. 1969. Elements of Cartography, 3rd Edit. Wiley International; 415 pages.

* * *

CHAPTER 2.

COASTAL DEVELOPMENT AND IMPACT ASSESSMENT

In most cases, the full use of coastal zone resources requires some form of infrastructural development. For example, the enjoyment of a bathing beach by tourists may be enhanced by construction of breakwaters or by provision of adjacent accommodation and refreshment outlets; a fishing village benefits from calm moorings and storage facilities; and commercial shipping depends on adequate docking space, dredged channels and navigation markers. Increasing development of the coast requires expansion of these structures by modification of coastal environments, as with the filling of mangrove wetlands for dock expansion and a race track in St. Thomas (Towle, 1985) or river diversion during industrial development in Point Lisas, Trinidad (McShine-Mutunhu, 1985).

Problems arise in many of these situations when the structure and dynamic features of poorly understood coastal systems are altered. Negative impacts of island coastal development projects have been reported by numerous authors, and include: coral reef damage through sand extraction for the construction industry in Moorea, French Polynesia (Salvat, 1980), with similar activities threatening reefs in Guam, Ponape, Yap and other Pacific islands (Wells, 1984); beach erosion and reduction in habitat diversity in Barbados (Cambers, 1985); and loss of a phosphorescent bay through wetland reclamation at Falmouth, Jamaica (Bacon, 1987a).

It must be remembered, however, that the natural environment is extremely resilient; the Caribbean islands, for example, have been subjected frequently to marked human impact for over 300 years but remain relatively healthy and productive (Bacon, 1985). For each island there are many examples of successful development projects, which suggest that island coastal areas can be modified without causing damage or deterioration of resource values. The coastal zone manager needs to be aware of the opportunities and limitations for manipulating coastal ecosystem components. It is possible then to understand the impacts of existing developments and to prevent negative impacts resulting from proposed projects (see Bryden, 1975 & Lewsey, 1987).

This section deals with development impact assessment by examining **tourism development**, which is of primary importance in the economy of many tropical island states. The principles and techniques developed in this context can be applied to coastal residential, industrial and

can be applied to coastal residential, industrial and fisheries developments.

In most tropical islands tourism is centered on the beaches. Stable deposits of clean sand and adjacent calm, clear seawater are favoured resources for this activity. It is important to maintain the quality of these resources in the face of natural changes and increasing development of coastal areas. Resort areas normally require infrastructure for marina and boating activities; and the necessary piers, breakwaters and groynes may be extensive where sailing is important or cruise ship stopovers frequent. Man-made structures in the marine environment must be constructed and located carefully to avoid problems of erosion, stagnation, wave damage, or interference with coastal current movements.

With increasing use of any coastal area by residents or visitors, waste disposal into the sea becomes a critical issue, as does disposal of effluents when recreational beaches are adjacent to industrial areas. There must be continued monitoring of water quality to ensure that the coastal seawater remains safe for human use.

Exercise 2.1 ASSESSING BEACH CHARACTER AND STABILITY

Background:

The liability of a coast to erosion and its response to varying inputs depend on a number of factors, the more important of which are listed below:

(a) **Exposure.** The exposure to wave attack, the protection by offshore reefs and headlands, and the form of the coastline in plan are all contributory factors.

(b) **Coastal type.** These are low coasts with or without dunes, rocky coasts, coasts with cliffs, all of which will behave differently.

(c) **Littoral drift.** The direction of littoral drift, and the amount of drift into and out of the stretch of beach are important.

(d) **Human interference.** The character of a beach can be completely changed by human interference with littoral processes. Among the worst forms of interference are beach sand mining, mining of coral reefs, and building in the active beach zone.

In addition to the character of a beach, it is important to determine its stability. Different kinds of stability may be recognized at any particular location. The major types are:

(a) **Long-term stability.** This is where major changes are brought about only by the largest infrequent storm waves.

(b) **Seasonal stability.** This is where the beach profile may vary cyclically through the year on account of seasonal changes in the wave climate.

(c) **Stability over a tidal cycle.** Appreciable variation over a lunar tidal cycle may be observed at many beaches.

Aims:

(a) To make an assessment of the character of a selected beach.
(b) To make an assessment of the long-term stability of the beach.
(c) To make an assessment of the seasonal and tidal stability of the beach.

Duration:

A minimum of one day in the field, and three days in the drawing office and laboratory.

Suitable Location:

Any beach that is accessible (i.e. not more than one to two hours drive away from the laboratory and drawing office). It is preferable that the beach has well-defined headlands, and that the phenomena to be studied are not too complicated. A beach located on the leeward side of the island is preferable, as the seasonal variations are better demonstrated.

Materials Required:

Topographic maps, hydrographic charts, geological maps, soil maps, aerial photographs of region under study. Where possible, maps and photographs made over several years should be examined, particularly the photographs.

Data sheets for wave direction and period and storm frequency.
Binocular microscope, oven, set of sieves (U.S. Standard 3/4 inch to No. 200; or British Standard 20 mm to 0.002 mm).
Surface floats and drogues.
Sample bags.
Level and levelling staves, 50 m tape.
A small boat with outboard motor at the site.

Instructions:

Drawing office methods

1. Review maps and materials provided on the beach site, and prepare a short note on the physical setting i.e. location, latitude, longitude, which coast, backbeach vegetation, headlands, orientation, degree of protection. (1 hour)

2. Use the optical equipment to convert maps to common scale (see Ex. 3.1). Then make comparisons of long-term erosion rate by plotting the extent of the beach in different years on a common map. If several aerial photographs are available for any one year, seasonal change in beach profile may be assessed, as well as long-term changes. (2 hours)

3. Prepare refraction diagrams from aerial photographs (Appendix 3). Estimate the wave periods from the wave

lengths shown on the photographs and depths taken from the hydrographic chart; or consult the data sheet. (1 hour)

4. Prepare refraction diagrams for extreme wave attack, using the hydrographic chart, and data sheet on hurricane waves and movement. (2 hours)

Field methods

5. Make two profiles on visit to the beach at low tide and high tide. Obtain estimates of breaker type, i.e. spilling, plunging or surging; height, and period at low and high tide (see Appendix 3).

6. Take samples of sand at mid-tide level at the same location as the profiles.

7. Measure longshore current by means of drogues and surface floats. This should be done just seaward of the breaker line. If the breakers are high, drogues should be used, while surface floats are adequate in areas of mild breakers.

8. Examine the headlands to determine the type of rock, and state of erosion, i.e. estimate whether sand is moving past the headlands, and if so, in what direction.

9. Take photographs at high and low tide of all salient features.

10. During the visit to the beach, interview users of the beach such as fishermen, bathers or surfers. Try and obtain data on the condition of the sea at various times of the year using the present state as the base, i.e. any severe storms, the extent of removal of sand by trucks, use of beach by turtles, etc..

Laboratory methods

11. On return to base, carry out sieve analysis and examine the samples under the binocular microscope to determine composition and roundness. Determine the Folk & Ward classifications, classify the sand as mineral, shell, coral or algal, and determine the likely source of the sand, (see the case study below). (2 hours)

12. Prepare the profiles. (1 hour)

13. Discuss the results. (1 hour)

14. Prepare a report on the results of the investigations. (3 hours)

Product:

The result expected from this exercise should be similar to the following **Case Study**. The information which follows is based on an actual example, although minor changes have been made in some of the details.

Physical Setting

Dickinson Bay is located on the north-west coast of Antigua (Figure 2.1) at approximately 17° 9′ N latitude and 61° 51′ W longitude. The beach, which is oriented in a north-east to south-west direction, is approximately 1,500 m long. The predominant geological formation along the northern part of this coast is the Antigua limestone which rises to elevations of between 60 m and 100 m above sea level. This formation outcrops at Wetherell Point, which is a prominent headland forming the northern extremity of the beach. The southern extremity of the beach is formed by the prominent headland called Corbizon Point, which is composed of an isolated outcrop of gravel cherts, locally known as the Corbizon chert beds.

The most prominent feature of the southern section of the coast is a large salina. The northern section of this wetland is separated from the sea by a strip of beach varying in width from 150 m to less than 30 m.

H.O. Chart 2064 (see Figure 2.1) shows that this section of coast is protected from the full force of the predominant waves by the outer reef (Salt Fish Tail). Further protection is afforded to Dickinson Bay by a line of reefs running from Wetherell Point due west and terminating in offshore islands (Little Sister and Great Sister) (see Figure 2.2).

Historic Erosion Pattern

Figure 2.3. shows comparisons of the 1942 and 1969 coastlines, as obtained from aerial photographs. The original scale of the aerial photography was approximately 1:20,000. This scale was too small for accurate measurement of erosion. However, it is estimated that the erosion in Dickinson Bay close to Corbizon Point between 1942 and 1968 was 30 m to 40 m.

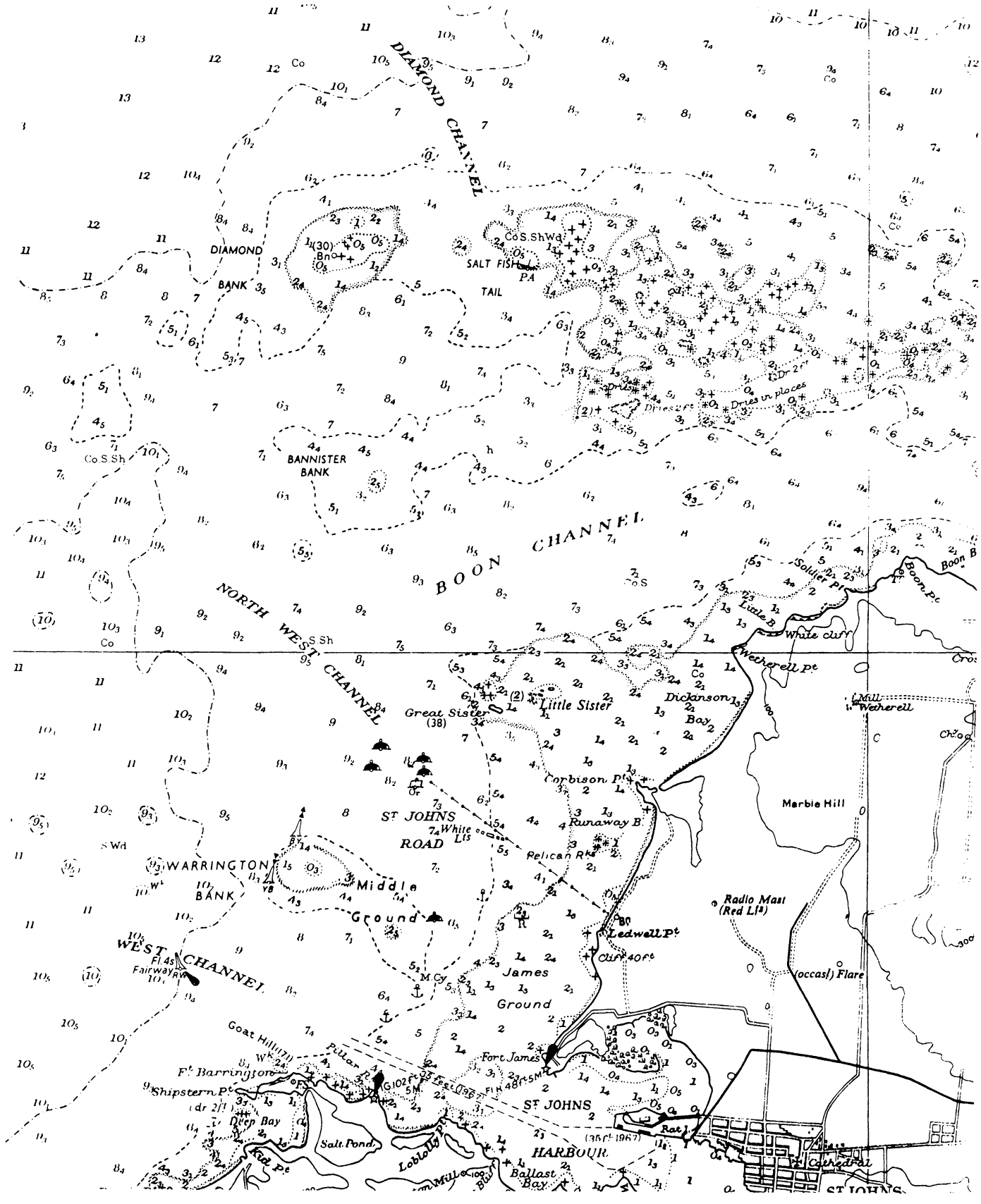


FIGURE 2.1 OFFSHORE CONDITIONS - N.W. ANTIGUA
(source: HO Chart 2064)

"Crown Copyright. Reproduced from Admiralty Chart 2064 with the permission of the Controller of Her Majesty's Stationary Office."

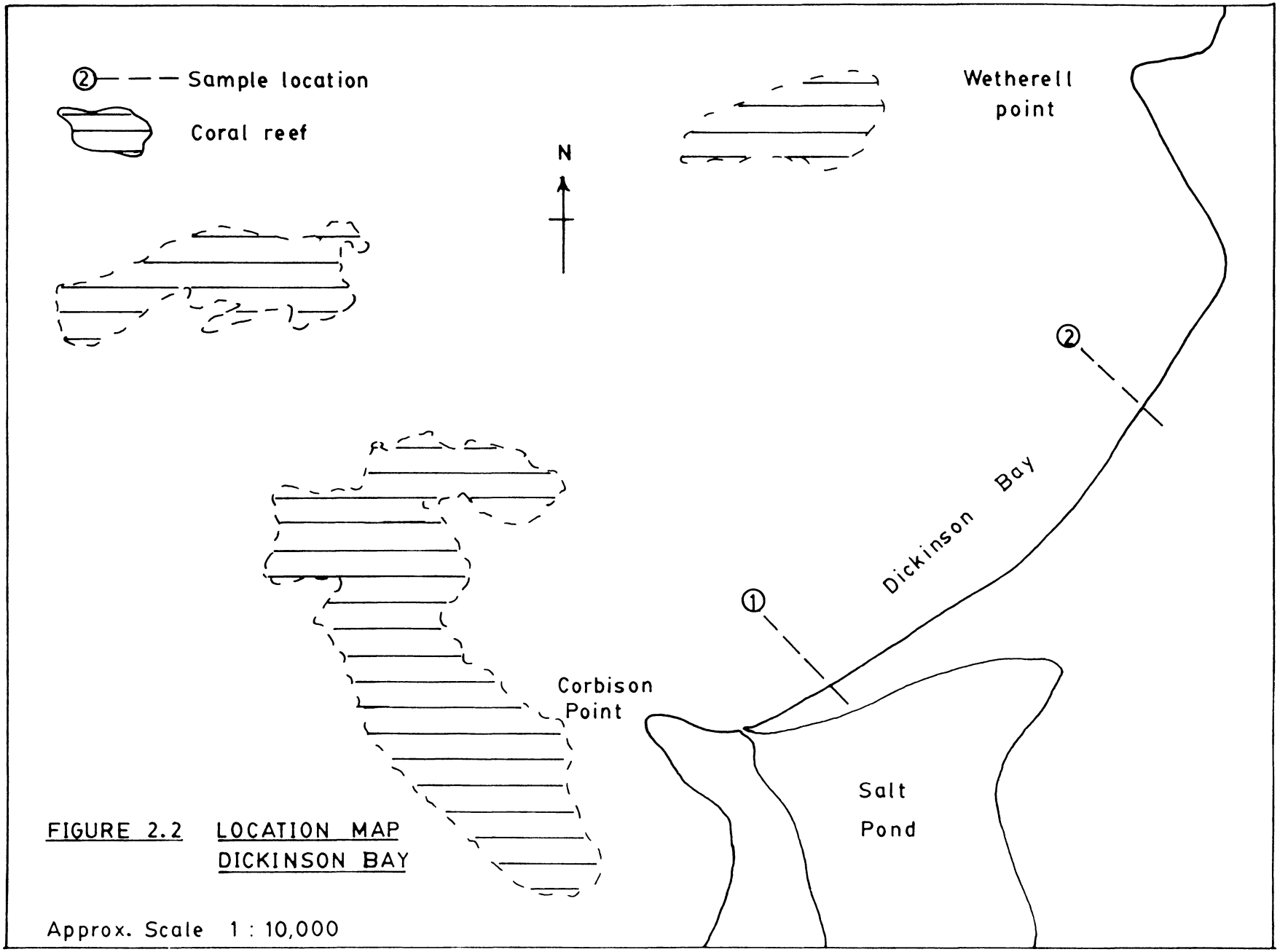


FIGURE 2.2 LOCATION MAP
DICKINSON BAY

Approx. Scale 1 : 10,000

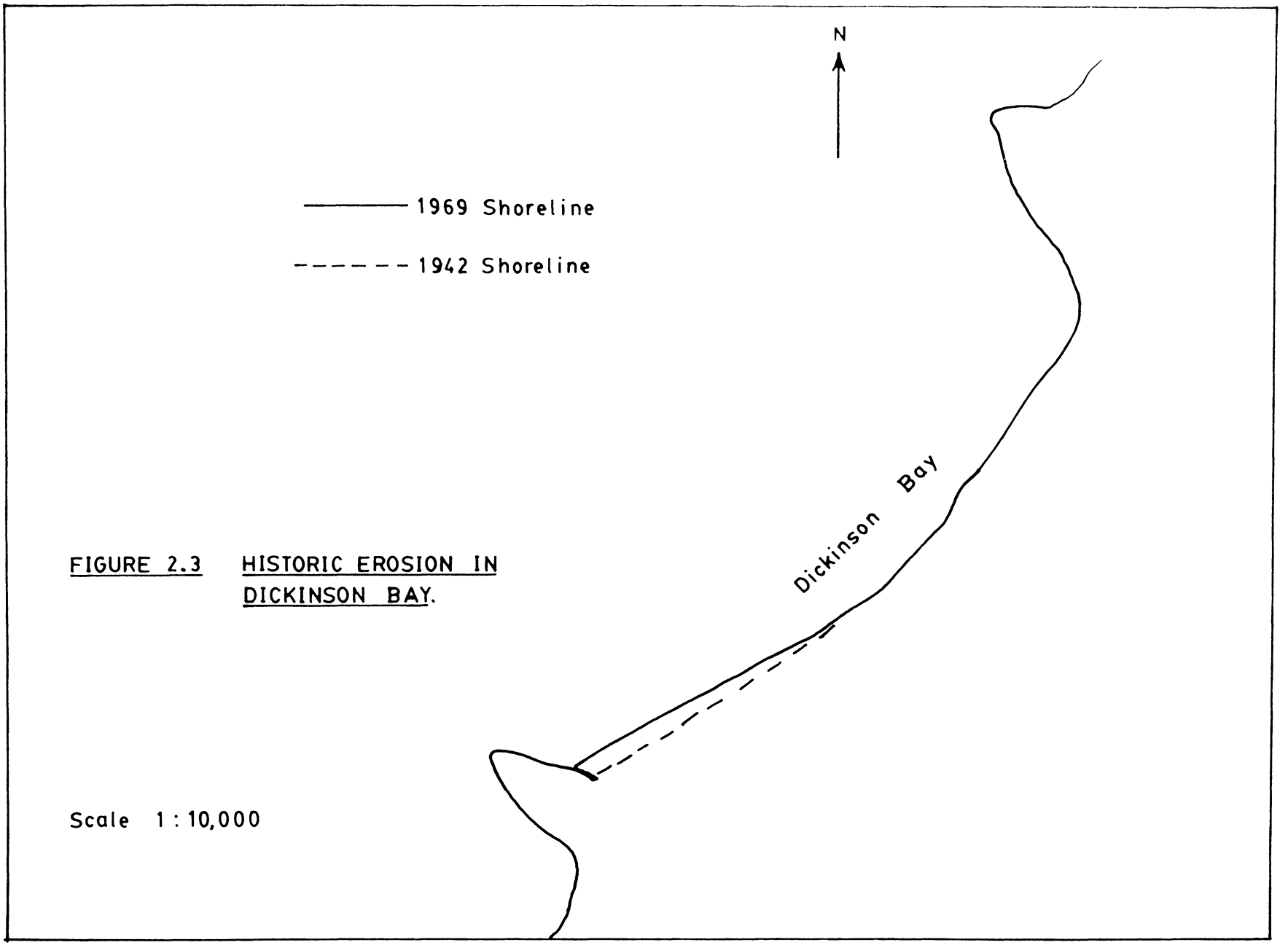


FIGURE 2.3 HISTORIC EROSION IN DICKINSON BAY.

Refraction Diagrams

Aerial photograph 99-AT.1-009, flown on 1st March 1968, shows very short-crested waves, with length 10m to 20m travelling from a north-easterly direction in Boon Channel opposite Dickinson Bay - the depth of water was 10 m to 15m. Longer waves of 60 m average length were measured approaching the coast from a north-westerly direction. The average depth of water in which these waves were observed, as given by Figure 2.1 was 3 m.

Long waves	Short waves
d = 10 m	d = 10 m to 15 m
L = 60 m	L = 10 m to 20 m
d/L = 0.166	d/L = > 0.5
From Appendix 3	Therefore L = Lo
d/Lo = 0.1293	And T = 2.5s to 3.5s

and Lo = 60/0.1293 = 464 m

But $Lo = gT^2/2\pi$ where g = gravity ($9.80665 ms^{-2}$)

And Therefore T = 17.2 s

The refraction diagram is shown in Figure 2.4.

Hurricane Wave Attack

Data on deepwater wave conditions, including hurricane attack is given in Table 2.1. Hurricanes pass Antigua, travelling in a westerly to north-westerly direction. Dickinson Bay is protected from waves travelling from all directions except between north-west and west; the direction of hurricane attack is from the west-north-west, therefore, production of a refraction diagram was not necessary.

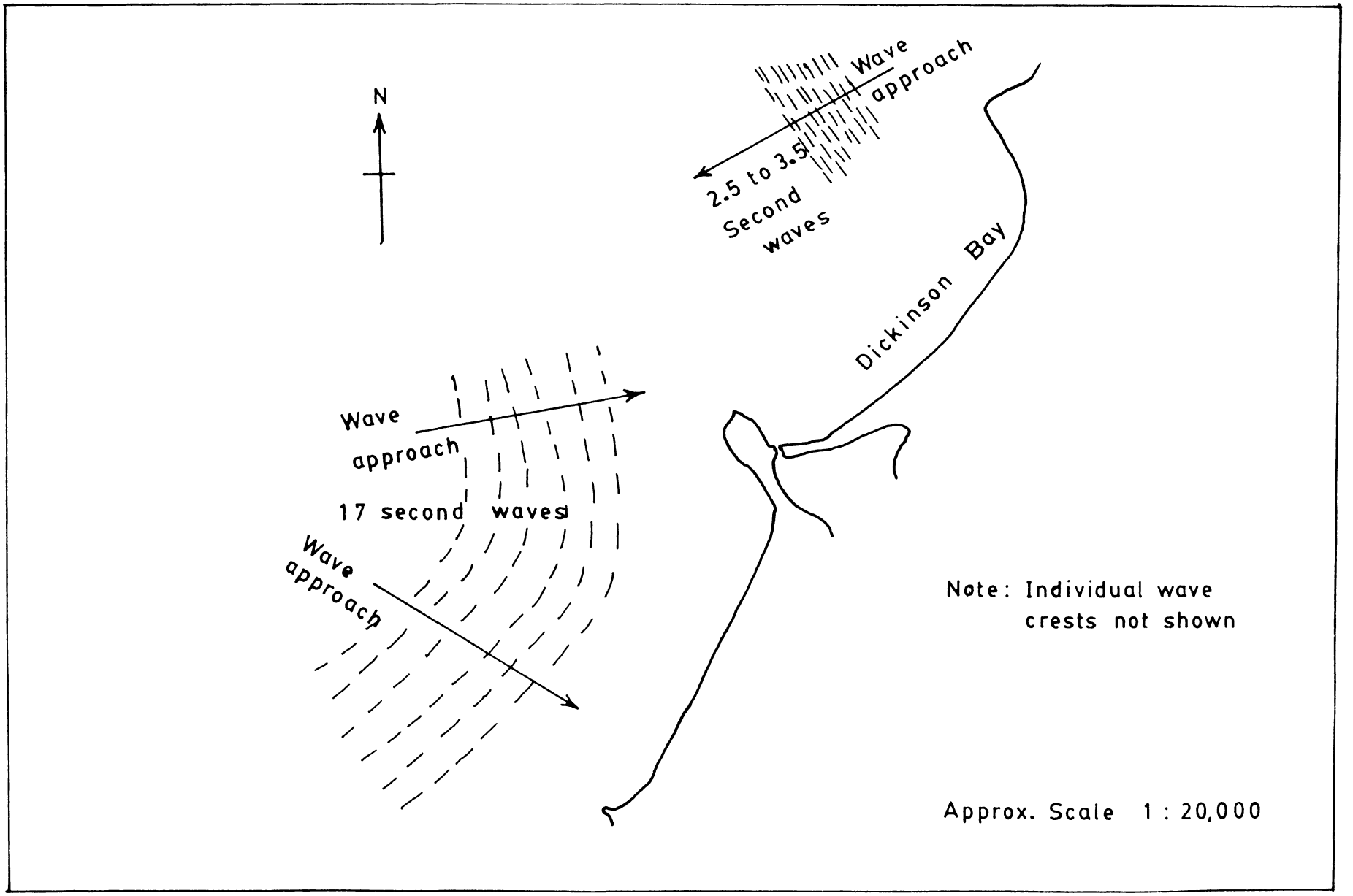


FIGURE 2.4 REFRACTION DIAGRAM FROM AERIAL PHOTOGRAPHY (1/3/68).

Table 2.1 Deepwater Wave Statistics

Frequency Occurrence Exceeded	Trade Wind waves		Northern swell		Hurricane waves	
	$H_{1/3}$(m)	T(sec)	$H_{1/3}$(m)	T(sec)	$H_{1/3}$(m)	T(sec)
50 %	3.3	7-10				
10 %	4.6	7-10				
1 %	7.0	7-10	1.5	14-16	1.5	6-8
Once/annum	8.5	7-10	3.6	16-20	3.0	6-8
Once/10 yrs	9.0	7-10	9.0	20-25	10.0	7-10
Direction of Approach	050^0 - 130^0		330^0 - 030^0		variable	

.....

Results of Field Visit and Laboratory Tests

Sections were taken at two locations, numbered 1 and 2 on Figure 2.2. These sections are shown on Figures 2.5 and 2.6. Samples of sand were taken at mid-tide level at the same locations as the profiles. These samples were washed and dried in an oven, and then sieved. The results of the particle analysis are given in Tables 2.2 and 2.3, while these results are plotted on semi-logarithmic paper on Figures 2.7 and 2.8. Small portions of the sand were examined under the binocular microscope and observations made of type of material present, and the shape of the particles.

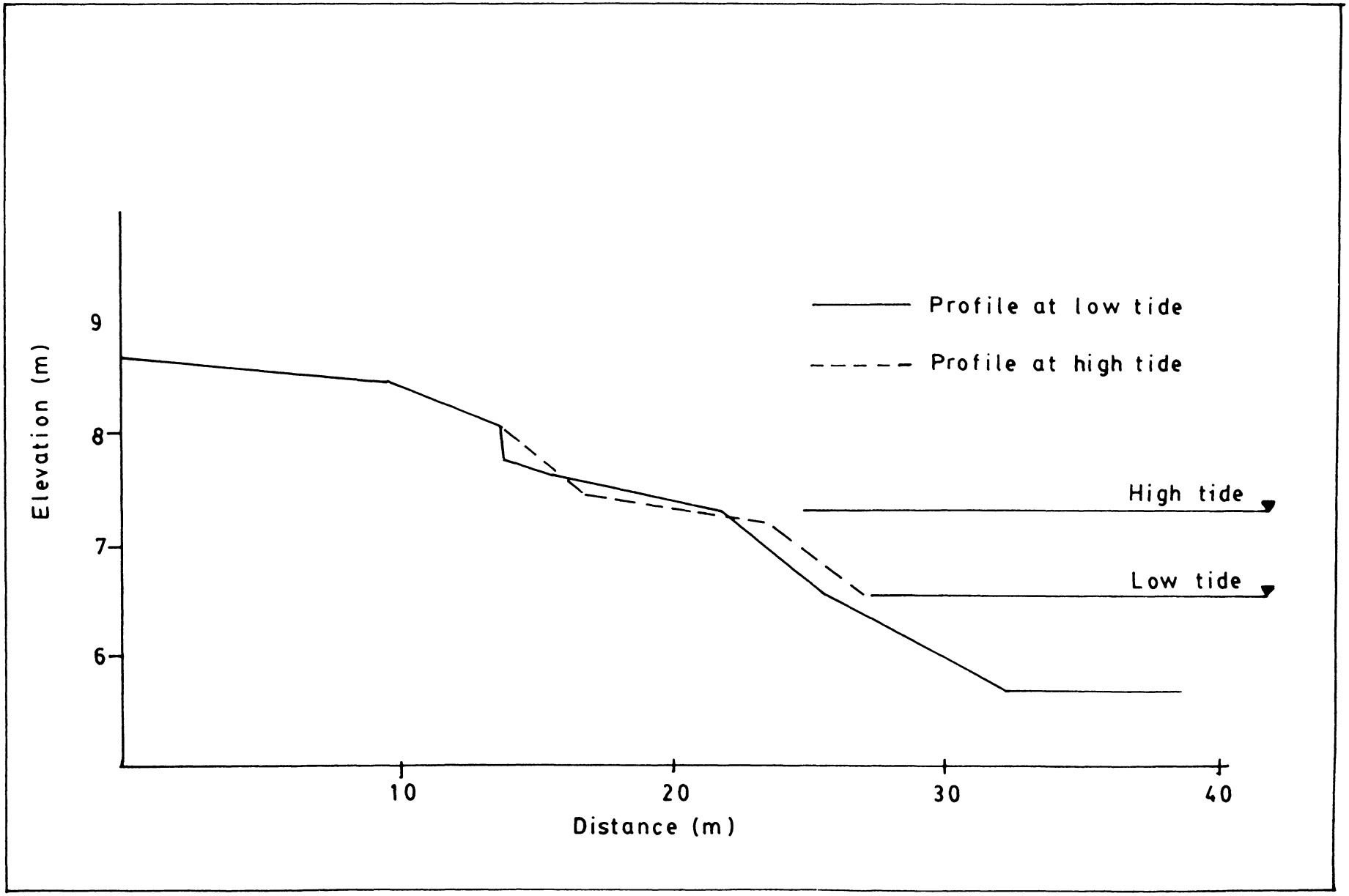


FIGURE 2.5 PROFILES AT SECTION 1 (see Fig 2.2 for location).

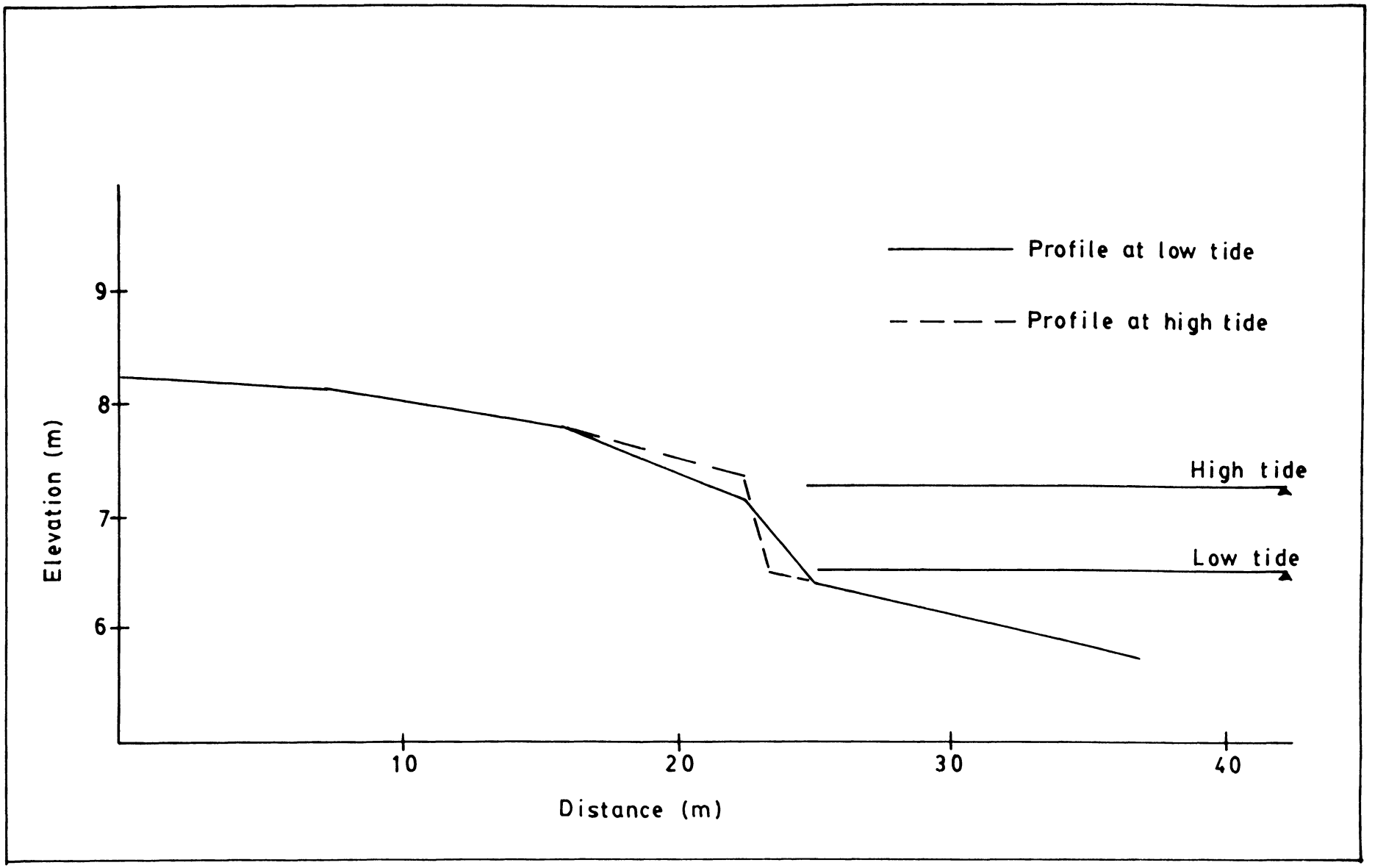


FIGURE 2.6 PROFILES AT SECTION 2. (see Figure 2 2 for location)

Table 2.2 Sieve Analysis - Data & Computation Sheet (Sample 1)

Date: 9/12/86
Sample No.2 Location of Beach: Dickinson Bay

Sample Location: Mid-tide Weight of Sample: 93.49 g

Prepared by:.....

Sieve openings Inches	mm	Sieve mesh	Weight of sand retained (g)	Percent retained	Cumulative percent finer
2.00					
1.50					
0.750					
0.375	9.530				
0.187	4.760				
0.094	2.400	7			
0.047	1.200	14	0	0	100.00
0.024	0.600	25	1.30	1.20	98.61
0.017	0.420	36	3.34	3.57	96.43
0.012	0.300	52	11.72	12.54	87.46
0.008	0.210	72	35.78	38.27	61.73
0.006	0.150	100	65.64	70.25	29.79
0.003	0.076	200	93.46	99.97	0.03

Table 2.3 Sieve Analysis - Data & Computation Sheet (Sample 2)

Date: 9/12/86
Sample No:1 Location of Beach: Dickinson Bay

Sample Location: Mid-tide Weight of Sample: 97.99 g

Prepared by: .....

Sieve openings Inches	mm	Sieve mesh	Weight of sand retained	Percent retained	Cumulative percent finer
2.00					
1.50					
0.750					
0.375	9.530				
0.187	4.760				
0.095	2.400	7	0	0	100.00
0.047	1.200	14	2.16	2.20	97.80
0.024	0.600	25	65.97	67.32	32.68
0.017	0.420	36	76.21	77.77	22.23
0.012	0.300	52	80.25	81.90	18.10
0.008	0.210	72	84.95	86.69	13.31
0.006	0.150	100	91.26	93.13	6.87
0.003	0.076	200	97.97	99.98	0.02

The type of breaker was observed and estimates of the breaker height were made. The breaker period was obtained by timing the passage of 10 breaker crests, using a watch. The results of the breaker observations are given in Table 2.4.

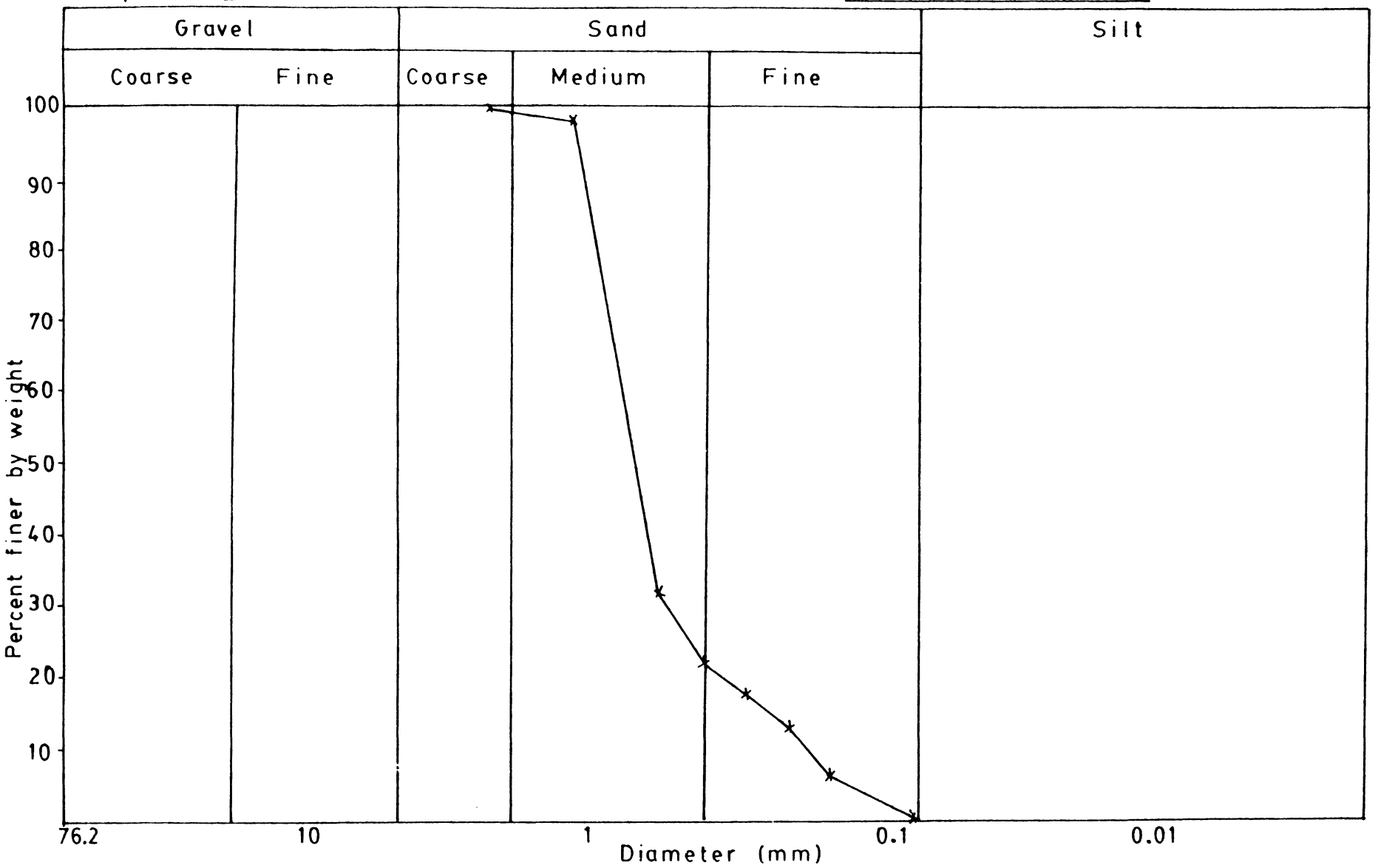


FIGURE 2.7 GRAIN SIZE DISTRIBUTION CURVE

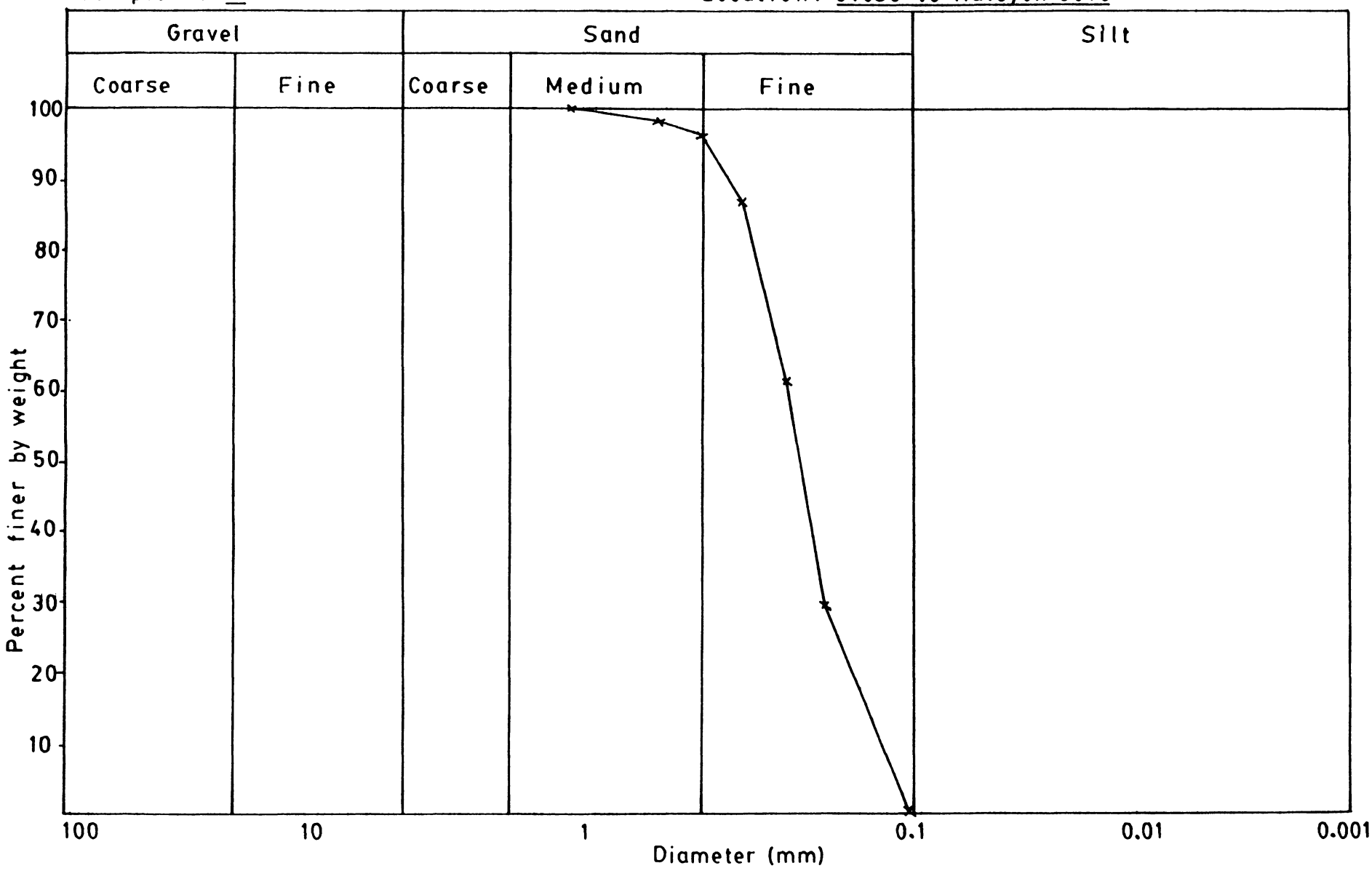


FIGURE 2.8 GRAIN SIZE DISTRIBUTION CURVE

Table 2.4 Breaker Observations

Date: 9/12/86
Beach: Dickinson Bay Observer:.....

Location	Time	Height (m)	Period (sec)	Type	Comments
Section 1	09.30	0.20	5.5	Spilling	High tide
Section 1	13.30	0.15	4.5	Spilling	Low tide
Section 2	09.45	0.10	2.0	Spilling	High tide
Section 2	13.45	0.10	2.5	Spilling	Low tide

.....

Surface currents were measured by releasing drift bottles just beyond the breaker line and measuring the time for the drift bottles to travel 10 m. The distance of 10 m was determined after making preliminary measurements to observe the speed and direction of the littoral current. The results of these measurements are given in Table 2.5.

Table 2.5 Littoral Current Observations

Location	Time	Current Speed (m/s)	Current direction	Comments
Section 1	10.30	0.01	190^0	High tide
Section 1	14.45	0.01	190^0	Low tide
Section 2	10.00	0.05	210^0	High tide
Section 2	14.15	0.03	210^0	Low tide

The headlands were examined; Wetherell Point showed very little sign of recent erosion; however, erosion was very evident at Corbizon Point. There was no evidence of recent littoral drift in either direction past Corbizon Point; but there were signs of sand entering Dickinson Bay past Wetherell Point.

Interviews with fishermen and others revealed the following:

(a) Around December or March the beach is affected by "groundswell". There were conflicting reports as to the time of occurrence of this "groundswell".

(b) Sometime in the past (the sixties ?) attempts were made to dredge an opening to the salina. Sand dredged from the opening was sold for construction purposes. The opening to the "salt pond" kept closing, and repeated attempts were made to open it, until eventually the scheme was abandoned.

(c) It was suggested that the beach close to Corbizon Point varied significantly in width, but no definitive information on the times of greatest or smallest width could be obtained.

The sea bed in Dickinson Bay, between the beach and the closer coral reefs, was covered with seagrasses and sea weeds. The dominant marine plants were the seagrasses Thalassia testudinum and Cymodocea filiforme, with upright and crustose algae, particularly Halimeda spp. growing among them.

Interpretation

Exposure: Dickinson Bay is a very protected beach, being located on the north-west coast, away from the full force of trade wind waves. The coast is protected further from the effects of northern swell and the occasional passing hurricane by the extensive reef system. For the majority of the time the coast is exposed only to very gentle locally-generated waves. During the rare periods of attack by hurricane waves or northern swell, waves approach the coast only near Corbizon Point from directions around west-north-west.

Coastal type: Dickinson Bay is a low coast without dunes.

Source of beach sand: Examination of the samples of beach sand revealed that they both originated from offshore sources, being comprised of algal, coral and shell fragments (see Table 2.6). The sample at Section 2 in the middle of the bay consisted of very well-sorted fine sand (G = 0.09 mm) with a median diameter of 0.19 mm; whereas the sample at Section 1 consisted of a less sorted medium sand with a median diameter of 0.71 mm. Section 1 was located close to the direction from which heavy wave action from hurricanes and northern swell approaches the bay.

Table 2.6 Sediment Characteristics - Dickinson Bay

Sample No.	Location	Colour	Folk & Ward Characteristics Md (mm)	Mz (mm)	E (mm)	St_1	Kg	Grain Shape & Composition
1	Close to Corbizon Point	White	0.71	0.66	0.35	2.61	0.94	Fresh, sharp fragments of marine shells & Halimeda platelets.
2	Near Halcyon Cove	White	0.19	0.19	0.09	2.74	1.14	Mainly fresh, irregular Halimeda fragments, with shell fragments.

It is concluded, therefore, that the major source of sand supply to the beach is onshore transport of products of the breakdown of the inshore reef - these materials are transported onshore close to Corbizon Point. Other sources of sand supply are littoral drift past Wetherell Point, and onshore transport of algal and shell fragments along the entire length of the beach.

Littoral drift: Figure 2.4 and the littoral current measurements (Table 2.5) suggest that littoral drift is southward for most of the time. However, the southern part of the beach can experience reversal of drift during periods of attack by hurricane waves or northern swell. The amount of littoral material moved northwards at such times may be very much greater than the normal transport rates experienced.

Long-term stability: The beach at Dickinson Bay is a barrier beach, which is an accumulation feature. The sand samples both show very high values of skewness (Table

2.7), which are typical of areas experiencing high rates of deposition. Three sources of sand supply have been identified, but no sinks for loss of sand have been found. Hence, over the long-term the beach is expected to accrete.

Table 2.7 Determination of Folk & Ward Characteristics

Location: Dickinson Bay Prepared by: .....

Characteristic		Sample 1	Sample 2
Ø 5	(mm)	0.130	0.085
Ø 16	(mm)	0.25	0.11
Ø 25	(mm)	0.49	0.14
Ø 50	(mm)	0.71	0.19
Ø 75	(mm)	0.94	0.25
Ø 84	(mm)	1.02	0.28
Ø 95	(mm)	1.16	0.39
$\text{Median}_{(md)}$	(mm)	0.71	0.19
$\text{Mean}_{(m^2)}$	(mm)	0.66	0.19
Std.deviation mm ϒ		0.35	0.09
Skewness SK_1		2.61	2.74
Kurtosis Kg^1		0.94	1.14

Median = Ø50

Mean = (Ø16+Ø50+Ø84)/3

Standard Deviation

= (Ø84-Ø16)/4+(Ø95-Ø5)/6.6

Skewness

$$= \frac{Ø84-Ø16+2Ø50}{2(Ø84-Ø16)} + \frac{Ø95-Ø5-2Ø50}{2(Ø95-Ø5)}$$

Kurtosis $= \frac{Ø95-Ø5}{2.44(Ø75-Ø25)}$

Seasonal stability: There are no measurements of beach profiles over different seasons. However, the northern part of the beach is very protected, and is not expected to experience much variation in wave climate during the year. On the other hand, the southern half will probably experience significant variation in wave climate during the year, and from year to year. Consequently, only the southern half of the beach is expected to experience seasonal variations in beach profile.

Tidal stability: The sections at Figures 2.5 and 2.6 suggest that significant tidal variation in beach profile

should not be expected at this beach.

Human interference: The erosion shown on Figure 2.3 at the southern section of the beach has been caused most likely by human interference. It is possible that the erosion was caused by efforts to dredge an opening to the salina.

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Further Reading

Bascom, W. 1980. Waves and Beaches. Anchor Books, New York; 366 pages.

Cintron, G. 1981. Environmental Impact of Sand Extraction Activities on the Insular Shelf. Department of Natural Resources, Puerto Rico; 27 pages.

Deane, C. 1987. Coastal erosion and accretion in the Caribbean Lesser Antilles. Commonwealthg Science Council Technical Publication, 227; 138 - 147.

Edmunds, H. A. 1987. Coastal proceses and erosion in St. Lucia. Commonwealth Science Council Technical Publication, 227; 22 - 30.

Folk, R.L. & Ward, W.C. 1957. Brazos River Bar, a study of the significance of grain size parameters. Journal of Sedimentary Petrology, 27; 3 - 27.

King, C.A.M. 1972. Beaches and Coasts, 2nd Edit. Edward Arnold, London; 570 pages.

* * *

Exercise 2.2 SITING COASTAL INFRASTRUCTURE

Background:

Developers frequently make alterations to coastlines without sufficient consideration of the physical processes being experienced at the site. One of the most frequent forms of change is brought about by the construction of solid breakwaters to provide calm conditions for the docking of boats.

The major factors to be considered in the design of a breakwater are its efficiency in providing sheltered conditions for docking, and the likelihood of the protected area being silted up by littoral drift. A preliminary diffraction analysis, combined with the type of information on coastal processes collected for Exercise 2.1, can provide guidelines on the probable effects of the construction of such structures, and on the suitability of the chosen site.

Other common alterations of the coastline are caused by the construction of groynes and causeways, and by small reclamations. Similar studies can provide guidelines for such constructions.

Aim:

(a) To study the effects of a rubble breakwater, constructed to provide a safe berthing area for pleasure boats, on wave action nearby.
(b) To use information from (a) above, along with information from Exercise 2.1, to predict the probable effects of the breakwater on sand movements in the coastal zone.

Duration:

Two to three hours.

Suitable Location:

Drawing office study, based on the same field site as Exercise 2.1.

Materials Required:

(a) Outputs from Exercise 2.1, i.e. hydrographic charts, refraction diagrams for normal and extreme wave action, and information on littoral drift and longshore currents.
(b) Drawing instruments.

Instructions:

1. Select a site for the breakwater, based on the depths of water and the draught of the vessels which are expected to use the facility.

2. Calculate the wave lengths for at least two conditions of attack.

3. Determine the polar coordinates of appropriate points, and use the diffraction diagram which corresponds to the directions of wave attack to determine the diffraction coefficient. Hence, obtain the reduced wave heights for the chosen points.

4. From the information obtained, make preliminary predictions of the effects of the structure on erosion and accretion of the beach.

Product:

The exercise should produce material similar to that which follows.

Nature of the alteration

It is proposed to construct a breakwater in Dickinson Bay (see Exercise 2.1) to provide safe berthing for yachts drawing up to 2.0 m of water. In order to satisfy navigation requirements, the breakwater should extend to 3.0 m of water. The location of the breakwater, shown on Figure 2.9, was determined from the underwater contours - it can be seen that any major change in its location will result in significant increase in the length of the structure. The direction of attack by trade wind waves, and by northern swell, is shown on the figure.

Calculation of wave lengths

Trade wind waves	Northern swell
H = 0.8 m T = 3.0 s	H = 0.5 m T = 15 s
Approach - 045^{O}	Approach - 290^{O}
$Lo = gT^2/2\pi = 14.1$ m	Lo = 351 m
d/Lo = 3/14.1 = 0.2128	d/Lo = 3/351 = 0.00855

From tables

d/Lo = 0.2359	d/Lo = 0.03722
and L = 12.7 m	L = 80.6 m

The templates

By measurement, the angle of approach for the trade wind waves (i.e. the angle between the direction of wave approach and the imaginary continuation of the impermeable breakwater) is 150^0 - see Figure 2.9. The appropriate template is Wave Diffraction Diagram - 150^0 Wave angle, as shown in CERC (1973) Figure 2-37 on page 2-93.

Similarly, the appropriate template for use with swell is Wave Diffraction Diagram - 45^0 Wave angle as shown on Figure 2-30 on page 2 -85 of the above reference.

It is required to determine the reduced wave height along the pier at 50 m, and 100 m from the shoreline for trade wind waves of 1 m height and 3 sec period.

Fifty metres along the pier corresponds to the polar coordinates:

60^0 , and 90 m or 90/12.7 = 7.1 L.

From Figure 2-37, diffraction Coefficient = 0.075

Therefore, reduced wave height = 0.075 m.

One hundred metres along the pier corresponds to the polar coordinates:

42^0 , and 50 m or 50/12.7 = 3.9 L.

From Figure 2-37, Diffraction Coefficient = 0.0095

Therefore, reduced wave height = 0.010 m

The use of the template is illustrated in Figure 2.10.

In order to determine:-

(a) the section along the coast north of the breakwater where the swell height is the same as before the construction.

(b) The swell height and direction in 1 m of water opposite a point on the beach 50 m north of the breakwater.

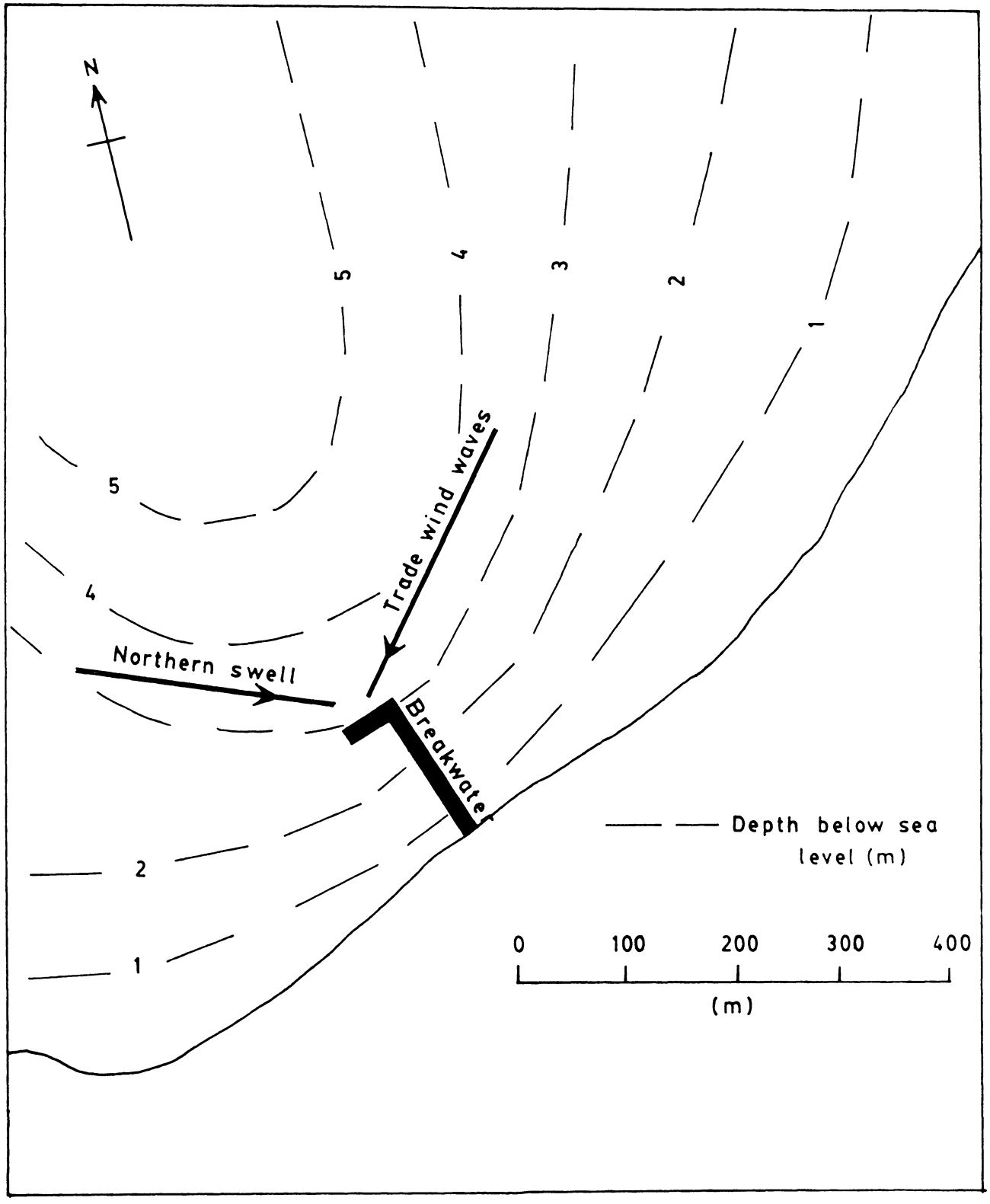

FIGURE 2.9 LOCATION OF BREAKWATER - DICKINSON BAY

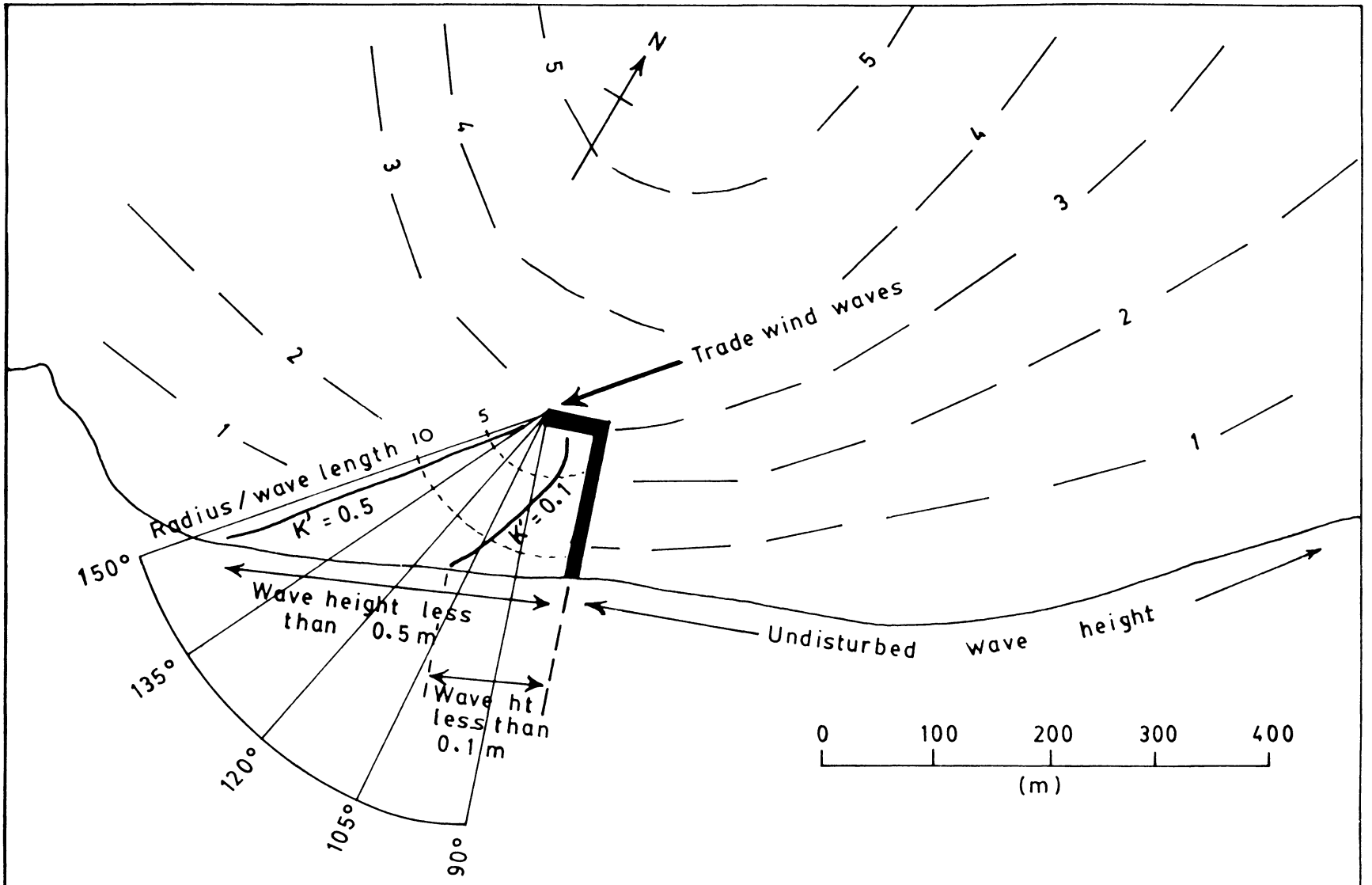

FIGURE 2.10 EFFECT OF TRADE WIND WAVES

Use the following swell conditions at the breakwater tip:

swell height = 0.5 m period = 15 s direction = 290^0

The area where swell heights are undisturbed relates to the area where the diffraction coefficient is 1.0. The area is shown on Figure 2.11.

Polar coordinates of the junction of the 1 m contour and the section 50 m north of the breakwater are:

15^0 , 120 m or 120/80 i.e. 1.5 L

Using Figure 2 -30 on page 2 -85 of the above reference, the diffraction coefficient is 0.37.

Interpretation

(a) The breakwater will provide very safe conditions for berthing for the majority of the year, when seas are dominated by mild trade-wind generated waves. Wave heights of less than 0.1 m in the protected area to the south can be expected at such times.

(b) The berths are subject to attack by the full force of northern swell and waves generated by the passing hurricane.

(c) The structure will stop the southward littoral transport of sand during periods of attack by trade wind waves.

(d) The cessation of southward transport of sand is likely to lead to the build up of sand on the northern side of the breakwater, and erosion on its southern portion.

(e) During periods of swell and hurricane attack, the northward transport of sand brought onshore will cease.

(f) The cessation of the sporadic transport of sand northward will lead to sand build up on the southern portion of the structure, and erosion on the northern portion. The erosion is likely to be most severe over 50 m closest to the breakwater.

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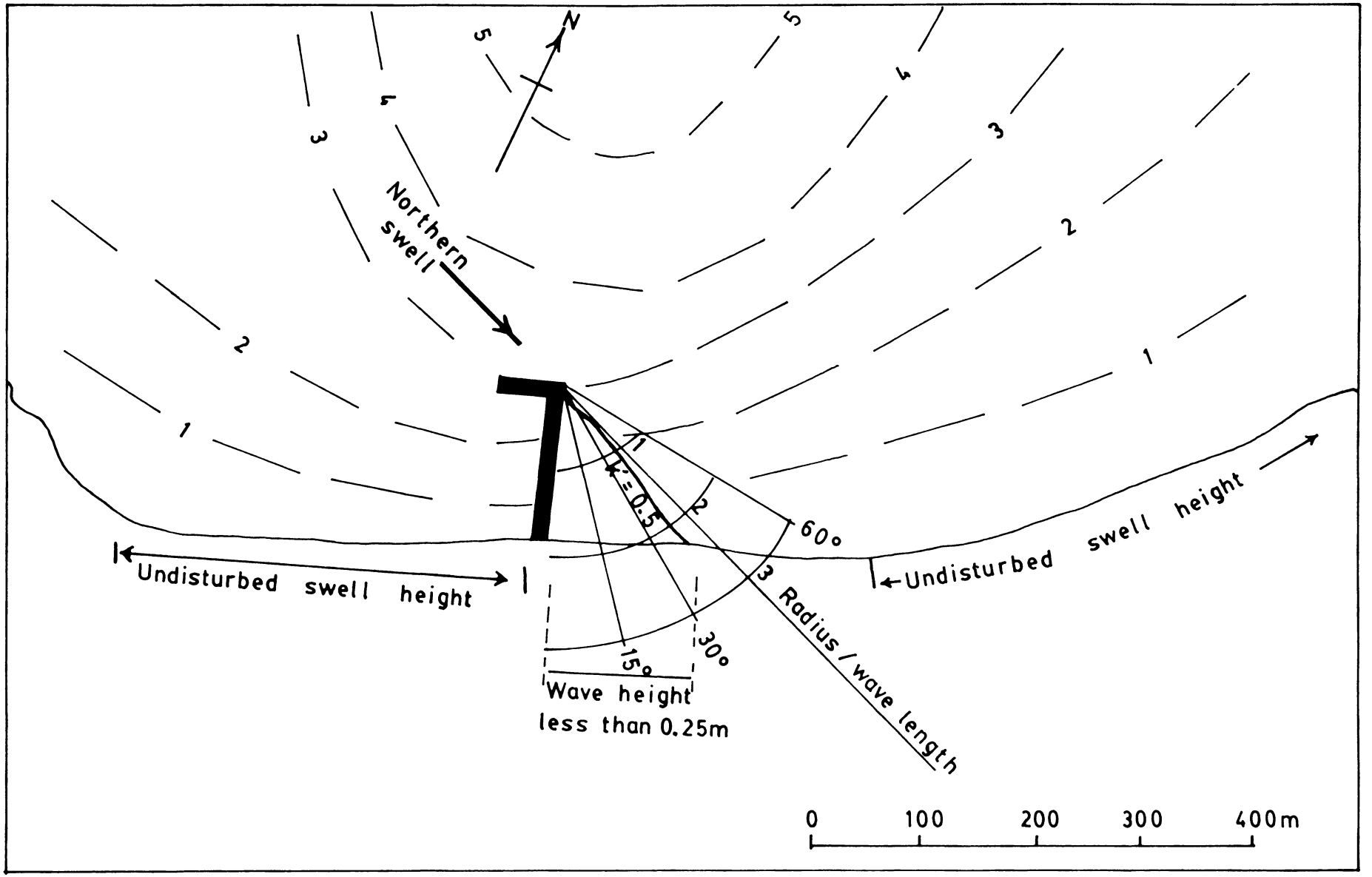

FIGURE 2.11 EFFECT OF NORTHERN SWELL

Further Reading:

CERC 1984. Shore Protection Manual. U.S. Army Coastal Engineering Research Center, Department of the Army, Corps of Engineers.

Geoghegan, T. 1985. Proceedings of the Caribbean Seminar on Environmental Impact Assesment, Barbados May/June 1985; 287 pages.

* * *

Exercise 2.3 DISPOSING OF WASTES IN THE SEA

Background:

Discharge of wastewater effluents into estuaries and seas is the most common method for the disposal of liquid wastes. The dilution of the effluent in the receiving water and the action of naturally occurring aquatic organisms can complete the treatment started on land in a wastewater treatment plant. Estuaries and coastal waters are used also to dissipate heat from once-through cooling systems such as large power stations, refineries, petrochemical plants, and liquefied natural gas (LNG) facilities.

Wastewater is subjected normally to one or more of the following processes:-

Primary treatment which removes coarse materials which may settle to form bottom deposits; and removes floating materials such as debris, grease and oil.

Secondary treatment which considerably reduces the concentration of substances imparting taste, odour, colour or turbidity to the water: and removes substances that are toxic or harmful to humans, or aquatic plant or animal life.

Tertiary treatment which considerably reduces the concentration of refractory organic materials, and nutrients - usually nitrogen (N) and phosphorus (P).

After treatment, the natural dispersion of wastewater effluents in coastal waters is achieved by dilution and chemical diffusion. The waste is less dense than seawater and consequently will float on the surface unless introduced at some depth.

Initial Mixing: If the waste is introduced as a high velocity jet, momentum entrainment will mix the volume containing the wastes with the receiving waters, rapidly diluting the wastes. If wastewaters are discharged directly from the shore, the degree of initial mixing is almost nil, and subsequent dilution and overall dispersion occur very slowly, since the polluted field stays in proximity to the shore. To achieve initial mixing it is advisable therefore to discharge effluents at some distance from the shore, and at some depth below the surface. The initial mixing terminates in the development of a more or less diluted, homogeneous field.

Dilution and Dispersion: The enlarged and diluted waste

volume is subjected to the complex physical processes of dispersion and movement. Pathogens in the water are subject to die-off (see Ex. 2.4).

The rate of dilution and dispersion is dependent on the velocity of the currents in the receiving water (see Sherwin & Deeming, 1980).

Aim:

To investigate possible alternative locations for outfalls from a central sewage treatment plant.

Duration:

Two days (one day field work; one day in the drawing office).

Suitable Location:

A suitable location is one where there are nearby recreational beaches and coral reefs. Preferably there should be changes in coastline orientation, so that different current velocities may be experienced.

Materials Required:

Topographic maps, hydrographic charts, and aerial photographs of region under study,

Fullest available information on currents in the seas around the island. (Sources of information are Sailing Directions, and Oceanographic Atlases)

Suitable dye (Rhodamine B, for example).
Cameras.
Fishing or other suitable small boat.
Light aeroplane (see Appendix 2).

Instructions:

1. Data on currents should be extracted from the information sources presented.

2. Flow patterns around the island should then be drawn, using the methods of Appendix 4.

3. Information on tidal currents should be extracted from the sources given.

4. The location of important natural features, such as reefs or seagrass beds, should be mapped from the

aerial photographs, (see Exercises 1.2 & 1.3).

5. Select three (3) alternative locations for the sewer outfall, and estimate the probable length of outfall needed for each case.

6. At each of the selected sites, anchor a boat and let out a steady stream of dye for fifteen (15) minutes. Dye should be released at each site on both falling and rising tide.

7. From the air, obtain photographs of the dye dispersal pattern within half an hour of release.

8. Prepare a report on the result of the investigations.

Product:

The information below is based on an actual example, although changes have been made in some details.

The Problem

A major resort complex is planned for the westernmost portion of the island of Tobago, as shown on Figure 2.12, in an attempt to boost the tourism industry. The major reefs and wetlands of Tobago are located in this area, and are advertised extensively for tourism promotion. It is necessary to provide maximum protection to these natural attractions, and, as a result, it was decided to construct a central sewage treatment plant with an outfall to the sea in an appropriate place. The sewage from the environs of the main town of Scarborough will be treated separately and discharged close to that town.

The Natural Features

The major natural features are shown on Figure 2.13, which was drawn from maps and aerial photographs. Three possible alternative locations for the sewer outfall are shown on that figure.

The Oceanic Currents

The following information on currents around Tobago was obtained:-

(a) H.O. Publication 22 (1963) reports that "between Tobago and Barbados the currents usually set north-

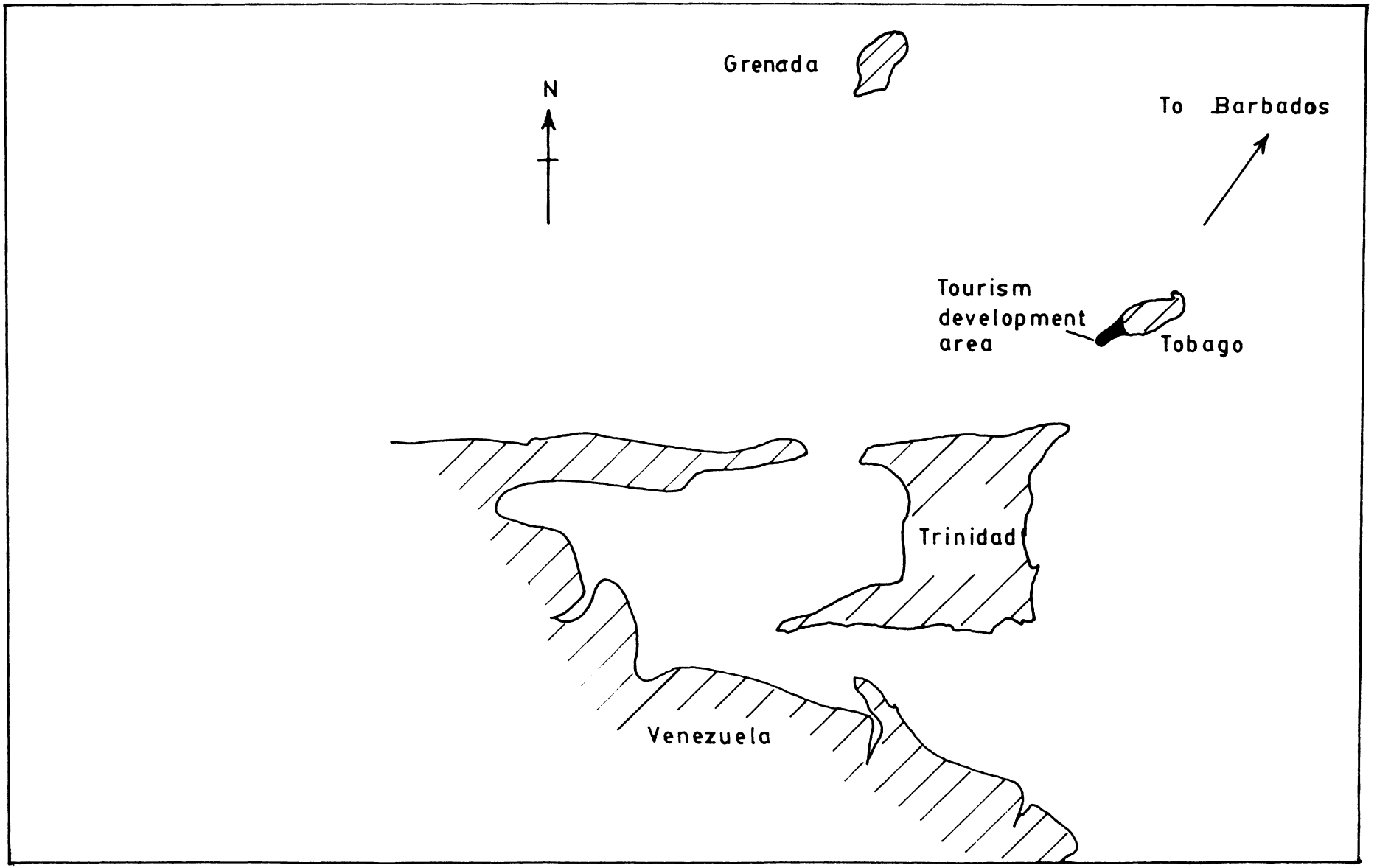

FIGURE 2.12 LOCATION MAP - TOBAGO.

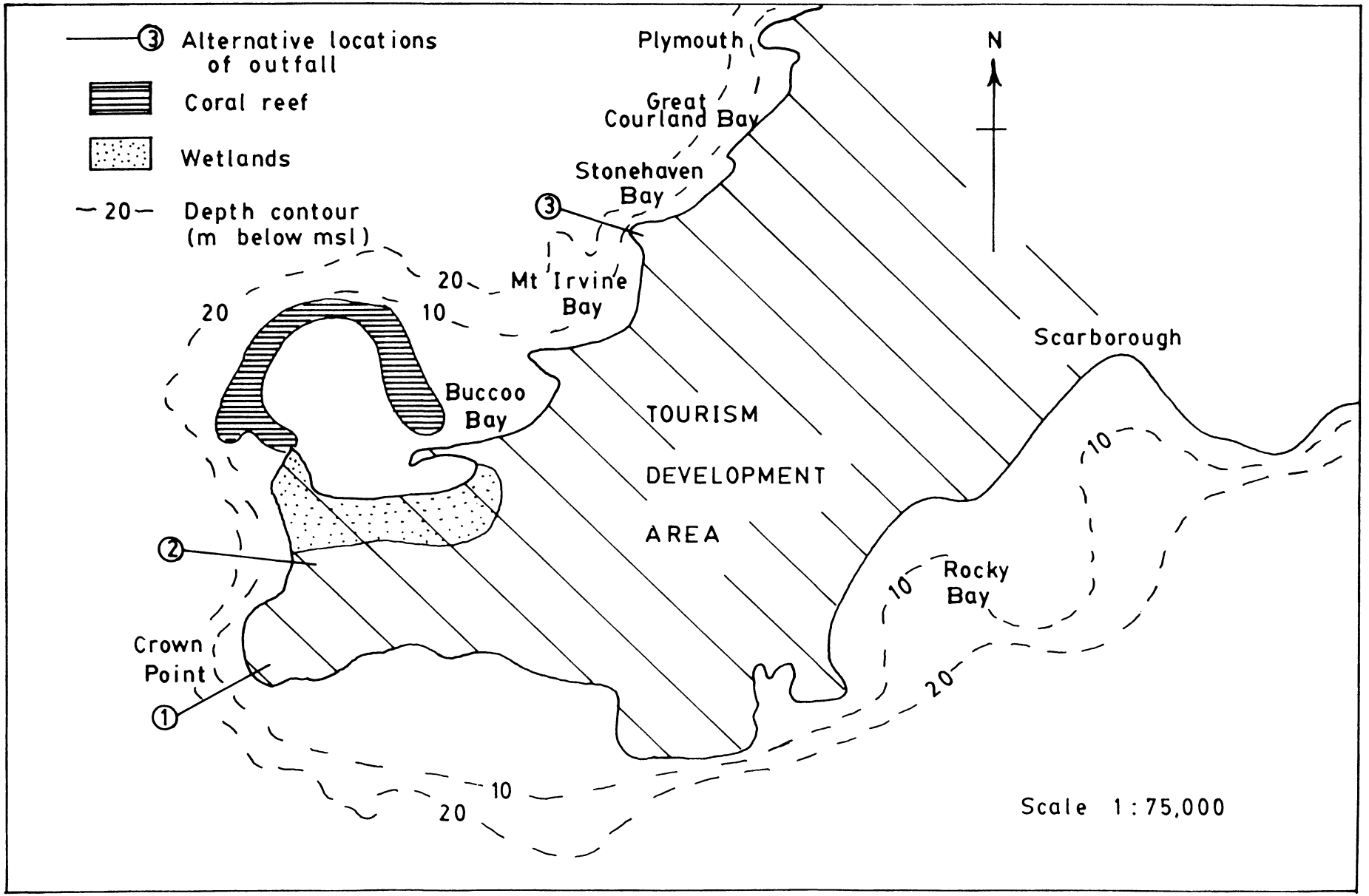

FIGURE 2.13 NATURAL FEATURES - NW TOBAGO

westward at rates of 1 to 2 knots, but in May to July rates of 2 to 3 knots have been recorded".

(b) The above publication reports also that "the velocity of the current between Tobago and Trinidad varies from 2 to 4 knots".

(c) Admiralty Hydrographic Chart 505 (1969) reports that "the South Equatorial Current flows in a predominantly north-westerly direction. Its rate is generally up to about 3 knots, but on striking Tobago it divides locally and passes the north-eastern extremity of the island at a rate of 3 to 4 knots".

The above information reveals that the currents around the island originate in the South Equatorial Current, and that because of the crowding of the streamlines as the current passes between Tobago and Trinidad high current velocities are experienced off the north-western tip of Tobago. Statistical data on the South Equatorial Current as, extracted from H.O. Publ. No. 700 (1965) is presented in Table 2.8.

Table 2.8 Ocean Currents off Tobago

Season	Direction	Occurrence %	Average Speed Knots
Winter (Jan-March)	N - W	50	1.3
	W	30	1.2
	other	20	0.8
Summer (July-Sept)	N - W	50	1.1
	W	20	0.9
	other	30	0.7

Source: U.S. Navy Hydrographic Office (1965) - Oceanographic Atlas of the North Atlantic Ocean, Section 1 - Tides and Currents. H.O. Publ. No. 700.

Flow Patterns

Patterns for westerly and north-westerly flow of the ocean current are shown on Figures 2.14 and 2.15 respectively. Figure 2.14 shows that when the current is flowing in a

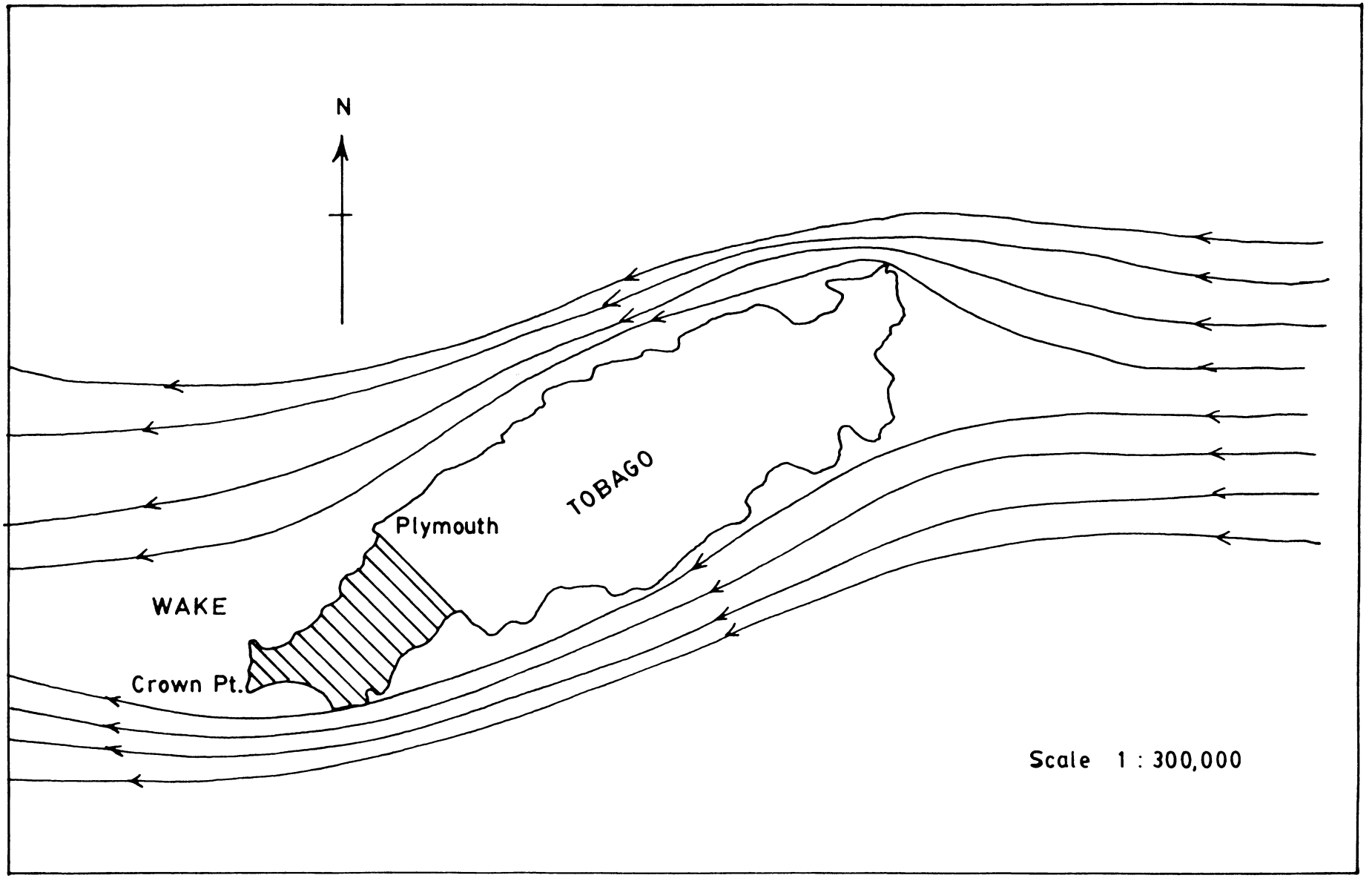

FIGURE 2.14 STREAMLINES: WESTERLY OCEANIC CURRENT

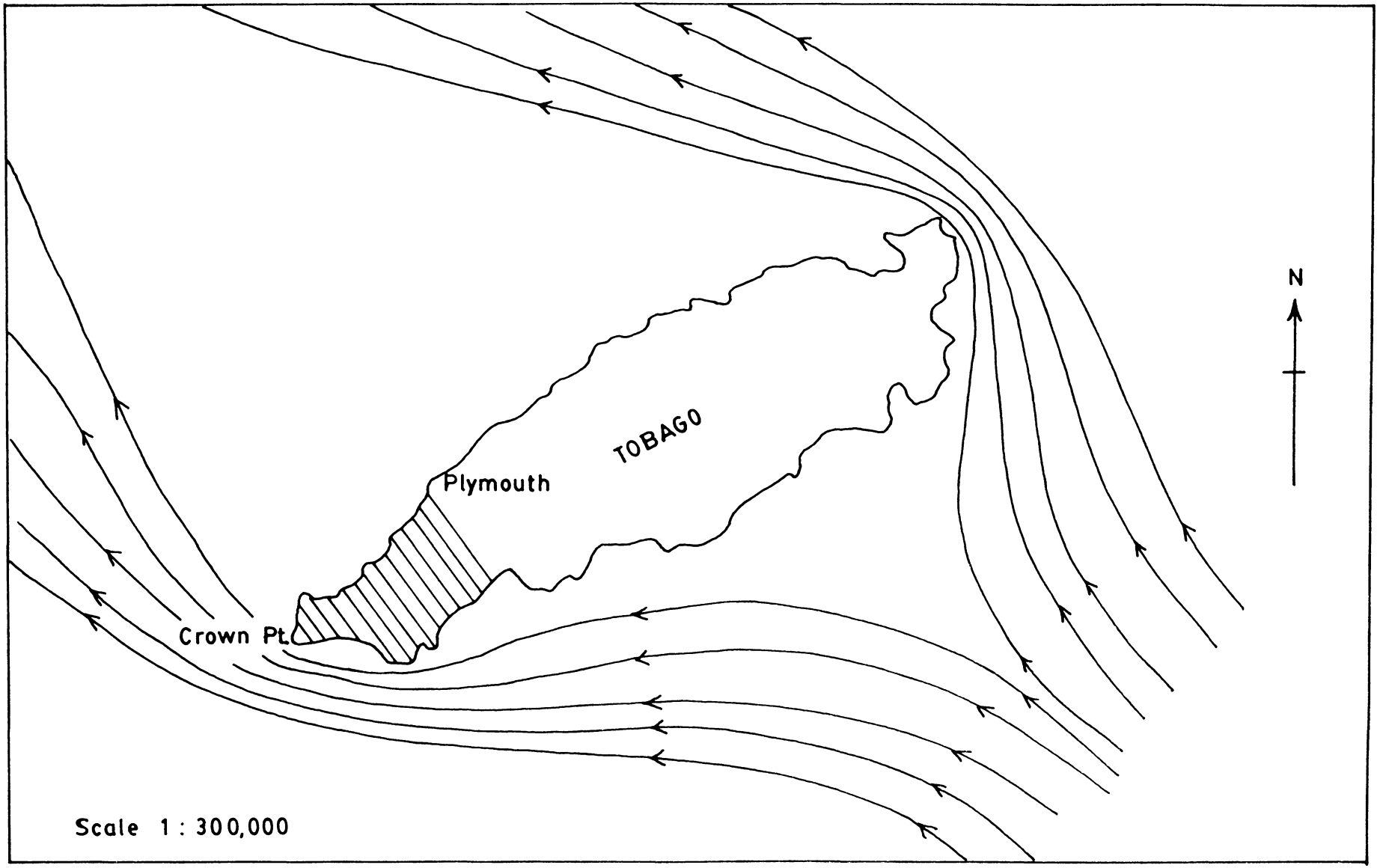

FIGURE 2.15 STREAMLINES: NORTH WESTERLY - OCEANIC CURRENT

westerly direction a small wake is formed off the north coast between Plymouth and Crown Point. No attempt has been made to categorize the wake, but it is expected that water movement in it will be very low. Small eddies are expected to break off the main wake and circulate in Little Courland, Stonehaven and Great Courland Bays. The net water movements in those bays due to the oceanic current is expected to be very low, therefore.

Figure 2.15 shows that when the oceanic current flows in a north-westerly direction, points of flow separation will form off Crown Point and the extreme north-western tip of Tobago. In this case the wake is larger. The net water movement due to the oceanic current in the bays of the north-western coast is again expected to be very low.

Tidal Currents

The following information has been extracted from H.O. Publication 22:

"The tidal currents in the vicinity of Tobago are variable and weak. The flood tidal currents accelerate the north-westerly sets and the ebb tidal currents slightly retard them,causing a cessation for a short time. The set is usually north-westward at a considerable rate, however."

"At the west end of Tobago, the south-east going tidal current, during its strength, sets close around Crown Point for about two hours just checking and diverting the north-west going current. Near the coast during the rising tide a slight eddy sets eastward into Great Courland bay, Stonehaven and Little Courland Bays. During the falling tide there is a set in the opposite direction which sometimes attains a rate of 1 knot near Buccoo Reef."

Results of the Field Tests

The dye was released on Monday 16th March, 1987. The predicted times and heights of the tide on that day were:-

Time	Height(m)
0428	0.91
1037	0.26
1639	0.98
2258	0.24

These values were representative of spring tide conditions, as new moon was on the 15th March.

The patterns of dye dispersal are shown on Figure 2.16, 2.17 and 2.18, for sites 1,2 and 3 as shown on Figure 2.13.

Interpretation

The theoretical streamlines, drawn on Figures 2.14 and 2.15, suggest that there is very little net water movement at sites 2 and 3. These were confirmed by the dye dispersal studies, as shown on Figures 2.17 and 2.18. At site 3, the dye dispersal studies suggest that there is current movement towards the shore at the rising tide.

This information suggests that the siting of an outfall at either sites 2 or 3 should be done with extreme caution, as there appears to be a possibility that the effluent will return to the shore and move towards the reef. On the other hand, both theoretical streamlines and the dye dispersal pattern shown on Figure 2.16 suggest that there will be significant dilution if the effluent is discharged around site 1. It appears also that the effluent will be swept away from the shore if discharged near this site.

.....

Further Reading

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UN/WHO 1982. Waste Discharge into the Marine Environment. Principles and Guidelines for the Mediterranean Action Plan, United Nations Environmental Programme/World Health Organisation, Pergamon Press, Oxford; 422 pages.

Ferguson-Wood, E.J. & Johannes, R.E. 1975 Tropical Marine ollution. Elsevier Publishing Co., Amsterdam; 188 pages.

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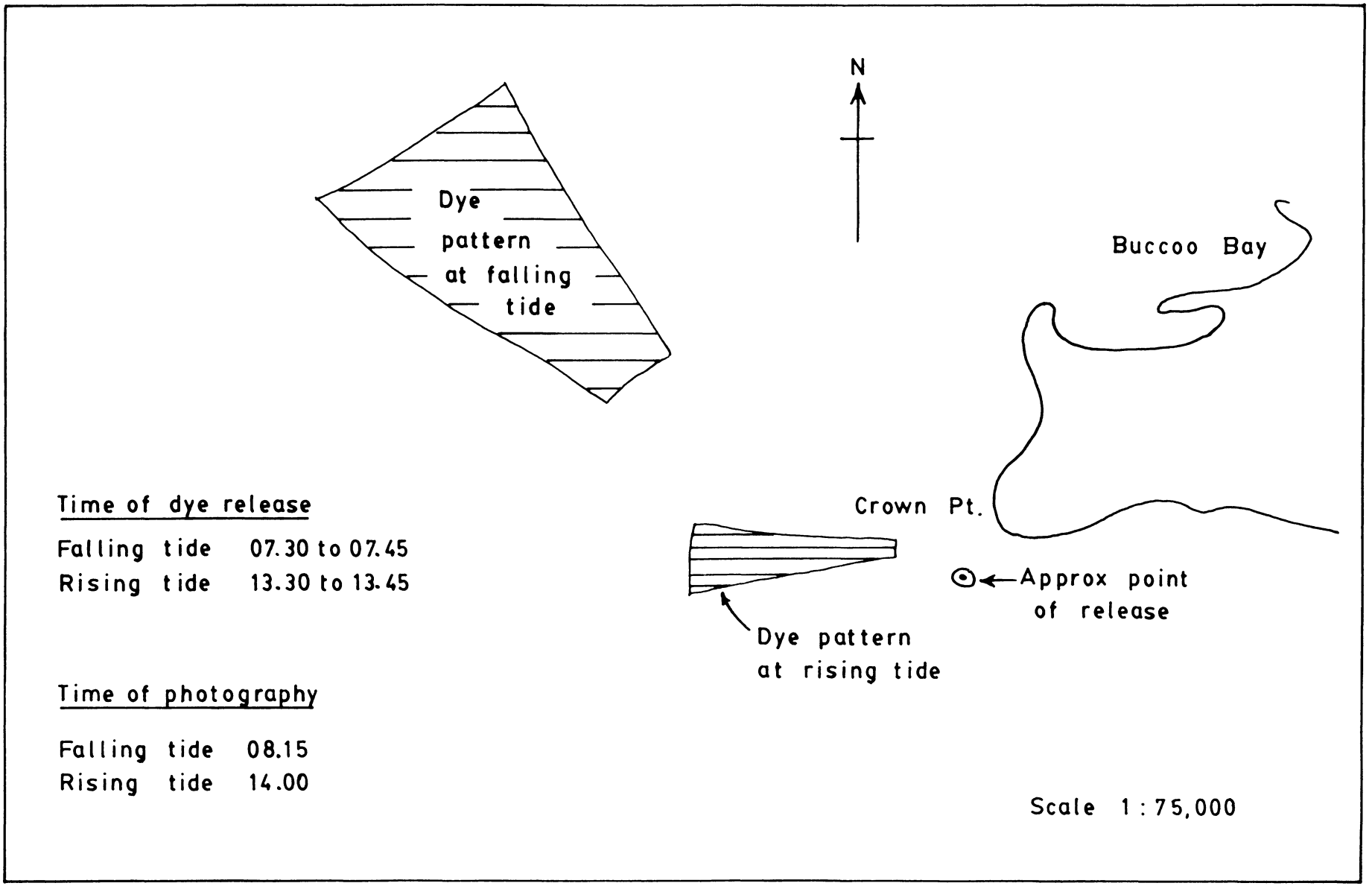

FIGURE 2.16 DYE PATTERN AT STATION 1

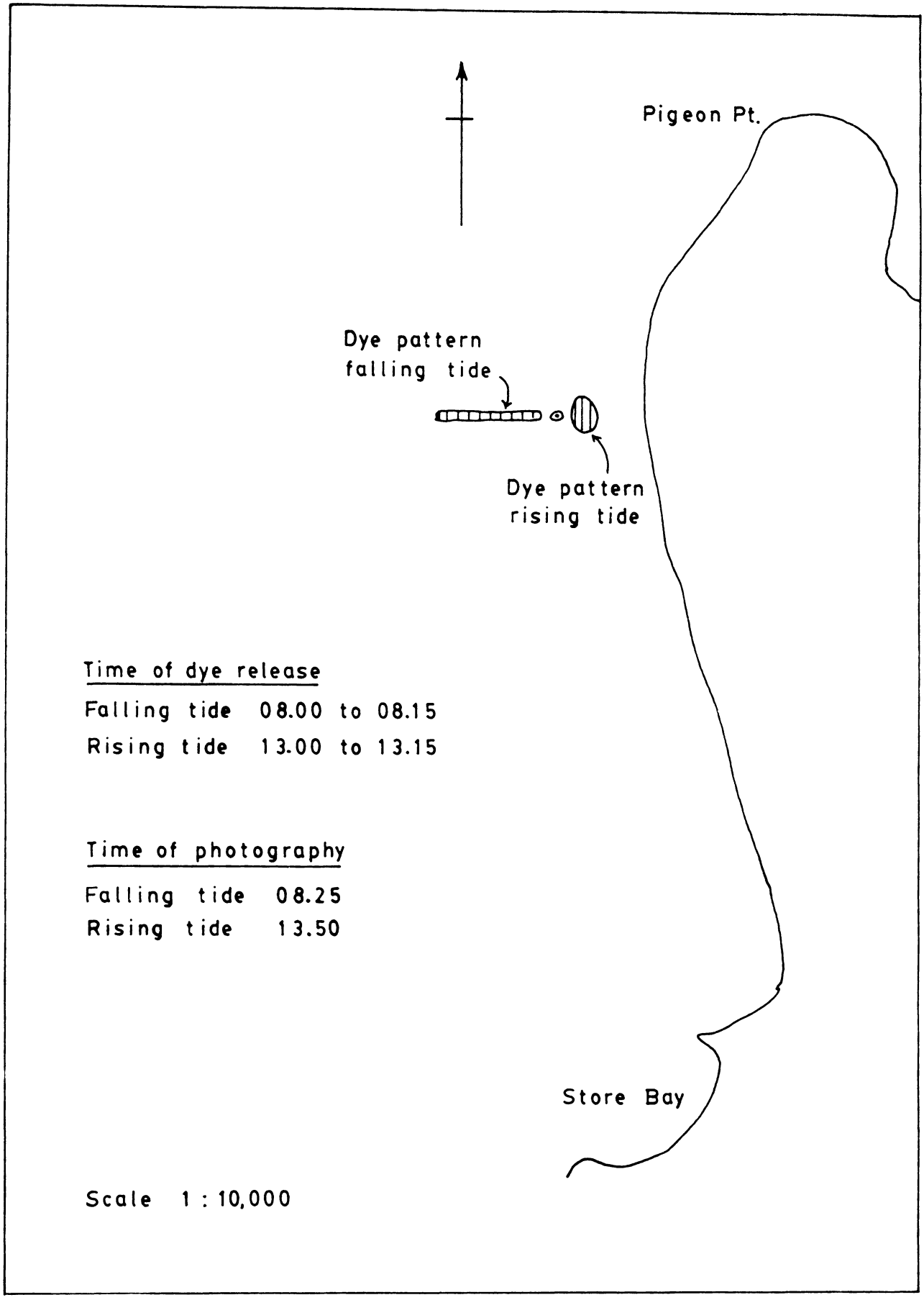

FIGURE 2.17 DYE PATTERN AT STATION 2

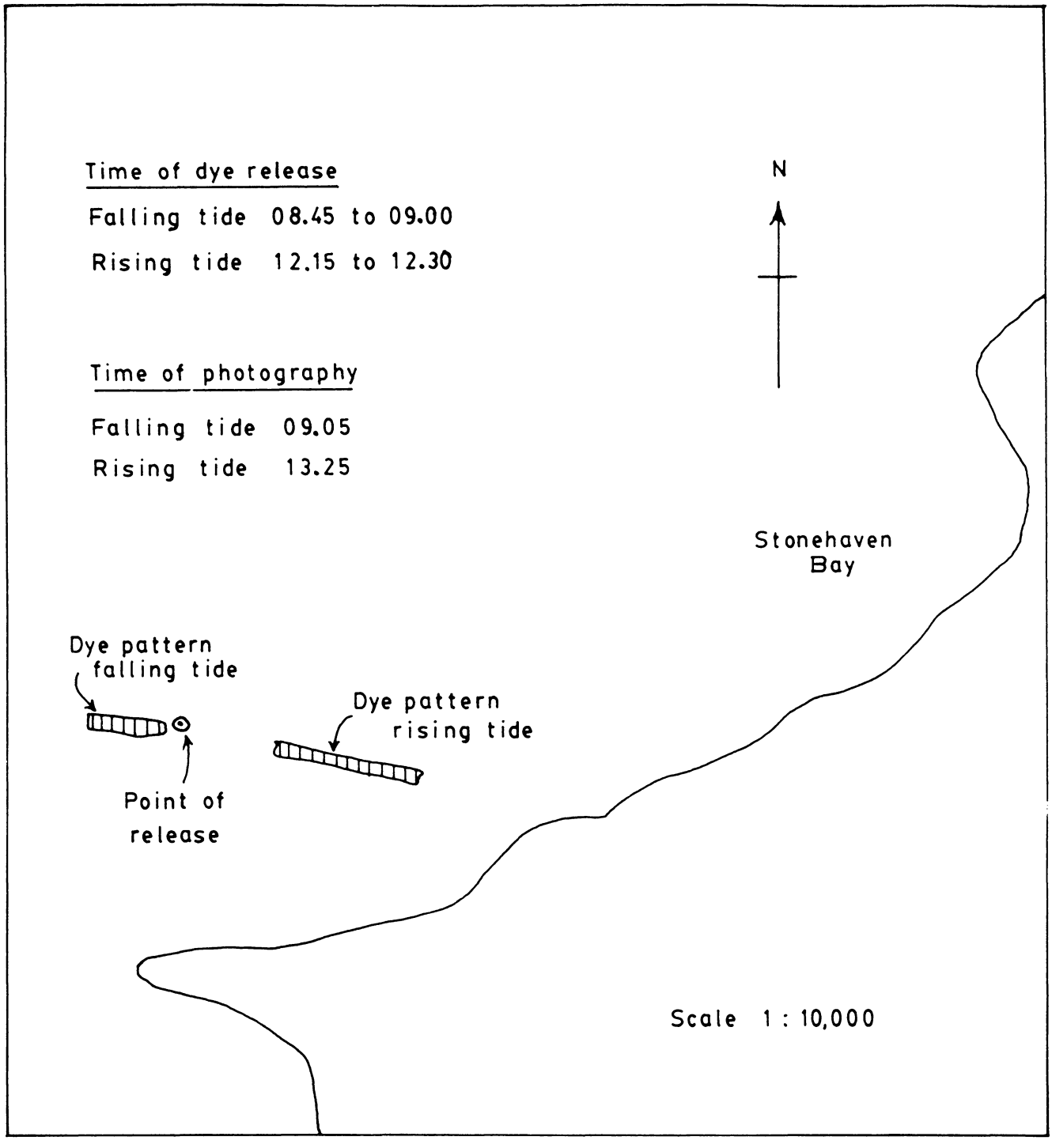

FIGURE 2.18 DYE PATTERN AT STATION 3

Exercise 2.4 MONITORING WATER QUALITY

Background:

As mentioned in Exercise 2.3, discharge of wastewater effluent into estuaries and seas is the most common method for the disposal of liquid wastes. The dilution of the effluent in the receiving water and the action of naturally occurring aquatic organisms can complete the treatment started on land in a wastewater treatment plant.

When domestic and similar pollutants are discharged into water, a succession of water quality changes take place. The water becomes turbid, sunlight is shut out of the depths, and marine plants, which by photosynthesis remove carbon dioxide from the water and release oxygen to it, die off. Scavenging organisms increase in number until they match the food supply. The intensity of their life activities is mirrored in the intensity of the biochemical oxygen demand (BOD).

Suspended matter is carried by the water or removed to the bottom by sedimentation. Bottom (benthic) deposits are laid down in thicknesses varying from a thin carpet to heavy sludge banks. Decomposition of the benthic deposits varies with the depth of deposit from aerobic to anaerobic. Pathogens are emitted to receiving bodies of water by municipal sewage discharge, discharge of sludges, discharge of some industrial wastes and in animal wastes. Runoff water, especially from animal husbandry and agricultural areas may also contain animal pathogens (Ward, 1984).

The hazards to human health from bathing waters arise from direct skin contact or from the swallowing of polluted waters. It is therefore important that coastal bathing waters be sufficiently free of pathogenic microbial life that water-borne infections do not pose a significant health risk to those who use them for recreation. There is agreement that the main indicator organisms for the contamination of recreational water by human pathogens are the faecal coliform group of bacteria.

Tests for **faecal coliforms** are also relatively simple, and the results readily understood. Their interpretation is aided by environmental health standards established by various agencies. For example, seawater is considered fit for **recreational use** when the faecal coliform count does not exceed 100 *E. coli* bacteria per 100 ml in 80 % of samples (E.E.C., 1976). *E. coli* is the commonly used faecal indicator bacterium *Escherichia coli*.

Faecal coliform counts can be conducted near beaches used for recreation or fisheries activities to gain insight into levels of contamination. Gradients of concentration along coastal transects can be used to locate sewage outfalls, so that appropriate steps can be taken to reduce health risks. This exercise is designed to demonstrate simple laboratory procedures for obtaining information on levels of contamination by sewage. Assistance should be sought from the Government Microbiology Unit, the Government Chemist, or biological laboratory of a local college for loan of apparatus or use of the laboratory for sample analysis. This should be arranged well in advance of the exercise session.

Aim:

To test seawater quality at selected sites.

Duration:

Two half-day periods; samples incubated overnight.

Suitable location:

To obtain a range of samples, water should be collected as follows:

(a) Near a known sewage outfall of a major town.
(b) In the same bay or lagoon far distant from the sewage outfall.
(c) From a recreational area near human habitation or hotels.
(d) From a recreational area away from human habitation.

Materials Required:

Sterile containers	-	preferably 100 ml glass bottles. Three replicate samples should be taken at each site.
Ice	-	sufficient to keep samples cool in the field.
Labels		
1 pipette (10 ml capacity), 1 pipette (1 ml capacity)		
Test tubes	-	9 per sample: 3 large (22 x 175 mm) 6 medium (15 x 150 mm)
Test tube rack		
Durham fermentation tubes	-	9 per sample. If not available these can be made by cutting and sealing sections of glass tubing 6 x 50 mm in size.
Cotton wool		

Cotton wool
Centrifuge
Incubator, or oven with thermostat.
Lactose broth - Two solutions are required, Single Strength Medium (SSM) prepared by adding 3.0 g beef extract, 5.0 g peptone, 5.0 g lactose to 1000 ml distilled water; stiring slowly in a water bath and adjusting pH to be between 6.8 - 7.0 after sterilization, according to methods of the American Public Health Association (1976); and Double Strength Medium (DSM). For each sample make up 30 ml SSM and 60 ml DSM.

Instructions:

Field methods

1. Water samples can be collected using a boat or from a jetty or pier.

2. Place the un-stoppered sterile container just below the surface of the water and fill completely.

3. Replace the stopper and store on ice in the dark until it can be transferred to the laboratory.

4. Observe the surroundings and note any visual or odour signs of pollution, and record human activities for possible correlation with the sample results.

Laboratory procedure

5. If the exercise is being carried out by a group, each member should take responsibility for one sample or sample site.

6. Bacteriological analysis must be carried out within 4-6 hours of collection.

7. For each sample site, set up the test tubes as follows:

   Place 10ml lactose broth in each of 9 test tubes, as shown in Figure 2.19.

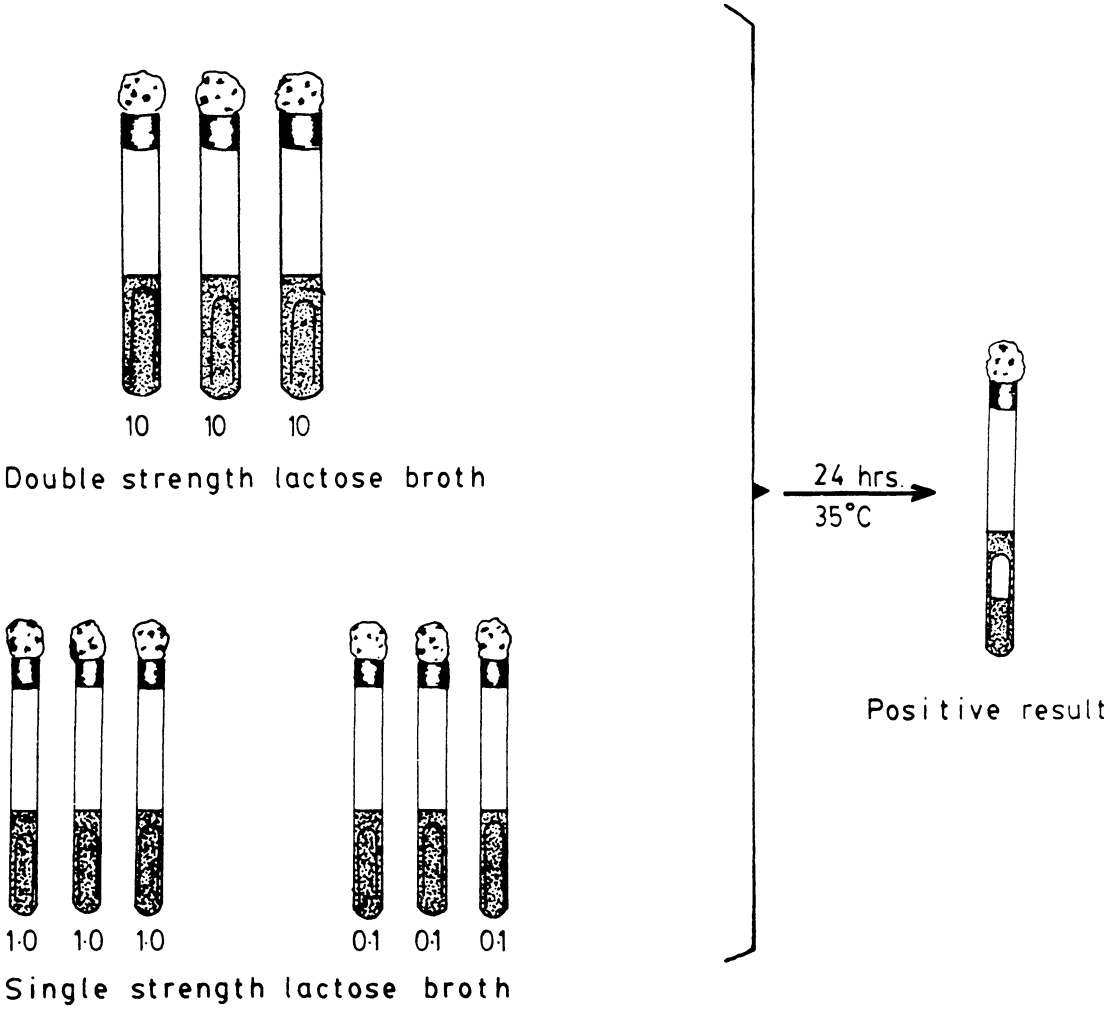

FIGURE 2.19 LABORATORY SET UP FOR BACTERIOLOGICAL ANALYSIS OF SEA WATER

Invert a Durham fermentation tube in each test tube. Place the batch of test tubes in a centrifuge and spin for 3-5 minutes to remove all air from the Durham fermentation tubes and fill them with medium.

8. Label the first three (large) test tubes 10ml, the middle three 1.0 ml, and the last three 0.1 ml, to indicate the amount of sample water that will be placed in each one.

9. Shake the water sample bottle thoroughly.

10. Use the 10 ml pipette to place 10ml of sample water into each of the first three tubes (DSM).

11. Use the 1 ml pipette to place 1 ml of sample water into each of the middle three tubes (SSM), and 0.1 ml into each of the last three tubes (SSM).

12. Shake the test tubes gently to mix.

13. Plug all test tubes with a cotton wool stopper.

14. Place sample tubes in an incubator for 24 hours at 35oC.

15. Examine the tubes for positive or negative evidence of the presence of coliform bacteria, as indicated in Figure 2.19.

Interpretation and presentation of results

Coliform bacteria ferment lactose to produce gas. If 10% or more gas is present in any one of the nine Durham fermentation tubes after incubation for 24 hours, this is presumptive evidence of the presence of coliforms. How many coliforms are present can be estimated from the total number of tubes showing positive results, using Table 2.9. This gives an estimate of the Most Probable Number (MPN) of coliforms in 100 ml of water, from which one can decide whether or not the water sample is polluted with sewage. In order to do this, present your results in tabular forms, as shown in Table 2.10 below.

Evidence of sewage pollution is so far "presumptive". In order to confirm that the gas is produced by coliform bacteria further tests should be carried out. If you are not satisfied with the presumptive evidence derived from your preliminary test consult with a microbiologist for further assistance or refer to the literature suggested below. Complete confirmatory tests will require a minimum of 48 hours further work.

Table 2.9 Coliform Bacteria MPN Determination from a Multiple Tube Test (Modified from Standard Methods of American Public Health Association).

Water Quality	No. of Tubes showing positive			MPN Index per 100 ml	95 % Confidence limits	
	3 of 10 ml each	3 of 1 ml each	3 of 0.1 ml each		lower	upper
Water satisfactory	0	0	0			
Water needs further testing	0	0	1	3	<0.5	9
	0	1	0	3	<0.5	13
	1	0	0	4	<0.5	20
	1	0	1	7	1	21
	1	1	0	7	1	23
Water unsatisfactory	1	1	1	11	3	36
	1	2	0	11	3	36
	2	0	0	9	1	36
	2	0	1	14	3	37
	2	1	0	15	3	44
	2	1	1	20	7	89
	2	2	0	21	4	47
	2	2	1	28	10	150
	3	0	0	23	4	120
	3	0	1	39	7	130
	3	0	2	64	15	380
	3	1	0	43	7	210
	3	1	1	75	14	230
	3	1	2	120	30	380
	3	2	0	93	15	380
	3	2	1	150	30	440
	3	2	2	210	35	470
	ETC.....					

Example: If gas is present in the first three tubes, and one each of the middle three and last three tubes, the test result is 3-1-1. This indicates a MPN of 75 bacteria per 100 ml, i.e. water quality is unsatisfactory. (The MPN is a statistical probability figure, with 95% probability of being between 14 - 230 bacteria).

.....

Table 2.10 Sample Data Table for Coastal Water Quality Analysis.

Date:..... Observers:.....
.....

Location No.	Observation colour	odour	flotsam	Sample No 1	2	3	Mean MPN	Comment * S	FT	U
ETC.										

* Refer to Table 2.9

S = satisfactory water quality
FT = further testing needed
U = unsatisfactory water quality

.....

Product Expected

1. The group's results should be pooled on Table 2.10, to indicate which coastal sites are thought to be contaminated with sewage.

2. Discuss the results and relate these to your field observations about possible sources of contamination.

3. Discuss and list possible future actions to improve water quality at the contaminated coastal sites.

Alternative Exercises:

1. Survey of Beach Tar Deposits

Petroleum hydrocarbon residues may be present in seawater, submarine sediments and organisms, and on beaches. Oil slicks or sheens reduce water quality for some forms of coastal recreation, whereas many aspects of oil pollution are less easily noticed. One serious nuisance factor is the presence of beach tar, which reaches island coasts from deliberate or accidental spillage of oil largely on the open ocean.

Beach tar deposits can be estimated in the following manner: A beach is visited and all lumps of tar scooped into a weighed container from a transect perpendicular to the sea. The collection area should be 2 m wide and stretch from the water's edge up to the beach vegetation. Replicate samples should be taken at 30 m intervals along a beach, preferably sampling at low tide. The samples are returned to the laboratory, weighed, and the weight for each transect recorded. A mean weight per beach should be calculated. Windward and leeward beaches should be compared.

The analysis should be concerned with (a) the magnitude of the beach tar pollution, and (b) its relative distribution in relation to the degree of beach use for recreation.

The exercise could be extended by calculating the costs of a clean-up operation (see also Knap et al., 1980).

2. Survey of Beach Litter

One common source of visual pollution in coastal environments is the accumulations of man-made waste materials as litter on beaches (Dixon & Dixon, 1981). These include materials with high persistence (more than three years) such as plastics, bottles, rubber, aluminium cans; those with moderate persistence (one to three years) such as cloth, iron, and steel cans; and low persistence materials (less than one year) such as paper, cardboard and food wastes. Beach litter originates from two main sources, that left on the beach by visitors and that stranded after being washed in from the sea.

The quantity and origins of litter can be investigated by the following method: At 20-30m intervals, depending on length of the beach, all litter is collected into labelled plastic bags from a transect perpendicular to the sea. The collection area should be 1-2 m wide and extend from the berm at the high water mark to the back beach vegetation. Siung-Chang & Deane (1984) sampled Trinidad beaches after the weekend when fresh supplies of visitor-deposited

litter were present. They considered that litter from the first two meters of the transect was stranded by the sea and that further back had been left by the visitors.In the laboratory, litter for each beach should be sorted into categories (either by type of object; type of substance; or degree of persistence; or all three if time allows) and a weight obtained for each category.

Relative amounts of litter on beaches can be compared in several ways:

(a) Windward and leeward shores, to assess relative importance of sea-borne items.
(b) Litter quantity in relation to visitor use.
(c) Beaches near town, from which garbage is derived via storm drains, compared with those at a distance.

Further investigations could identify products by trade label, e.g. drink cans, and suggest strategies for approaching the industries concerned. The costs of regular beach clean-up operations could be assessed also.

3. Measurement of BOD and Temperature

When domestic and related pollutants are discharged into coastal waters, a succession of changes in water quality takes place. The water becomes turbid, sunlight is shut out of the depths, and green plants, which by photosynthesis remove carbon dioxide from the water and release oxygen into it, die off. Decomposer organisms increase in number until they match the food supply. The intensity of their life activities is mirrored in the intensity of the biochemical oxygen demand (BOD).

BOD tests are widely used, as they give a very good indication of the condition of the receiving water, as well as the progress of decomposition of organic substances in that water. The BOD test is in itself a functional test, predicting the oxygen requirements of effluents. The tests are akso simple to perform.

Thermal pollution is of particular interest in tropical countries, as the water temperature is already close to the upper limit for sustained life. In addition, there is not much of a temperature gradient in coastal waters. Discharge of large amounts of cooling water can lead, therefore, to "dead" water over large areas, temperatures are easy to measure with standard thermometers, and can be combined with the measurement of BOD to indicate coastal water quality (see also Agard, 1984).

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Further Reading

A.P.H.A. 1976. Standard Methods for Examination of Water, Sewage and Industrial Wastes, (14th Edition) American Public Health Association, Anerican Waterworks Association and American Pollution Control Federation; 904 pages.

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Holdgate, M. W. 1980. A Perspective of Environmental Pollution. Cambridge University Press; 278 pages.

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Lewsey, C. D. 1987. The effects of tourism development on natural resources and infrastructural facilities - the case of Barbados. Commonwealth Science Council Technical Publication, 227; 148 - 180.

WHO 1981. Coastal Water quality Control in the Mediterranean. Final Report on the Joint WHO/UNEP Coordinated pilot Project [MED VII][1976 - 1980], World Health Organisation.

* * *

Exercise 2.5 PREPARING AN ENVIRONMENTAL IMPACT ASSESSMENT OF A COASTAL DEVELOPMENT PROJECT

Background:

Any development project in the coastal zone must, of necessity, alter associated environments. It will **impact** upon natural ecosystem structure and processes, social systems and economic conditions. The objective of most developments is to improve socioeconomic conditions in an area for a specific group of people; but the overall value of the project would be reduced if, simultaneously, it decreased living standards for any other local group or caused adverse environmental perturbation.

During the planning phase it is impossible to measure accurately all the consequences of a coastal development, but many of these can be **predicted.** If potentially adverse environmental impacts can be identified early enough, they can be avoided by appropriate modification to project design, One process by which impact of a project is determined is **Environmental Impact Assessment** (EIA). The assessment is made in the context of social values, existing legislation, economic and institutional constraints. It is based on an Environmental Impact **Analysis**, generally carried out by specialists using a variety of scientific and technical methods. The EIA resulting from the EI Analysis is formulated as an Environmental Impact **Statement** (EIS) and sent to the planners to aid in decision-making.

Ideally, EIA should be an integral part of project design, but frequently government agencies or regulatory authorities are called upon to conduct an EIA after the design has been completed by the developer. When this happens, EIA may appear to be a hindrance to development, rather than being seen as an aid to environmentally compatible utilisation of resources. Originally, the term "environmental" was used in the sense of adverse effects on natural ecosystems, plants or animals; the better usage includes the whole human environment with its economics and social aspects such as health and general welfare. In this sense, EIA must be seen as a valuable socioeconomic and aesthetic benefits to the nation. It is obvious, therefore, that EIA can be very complex as it attempts to predict a wide range of effects in the short- and long-term; it can also take a considerable period of time and require a range of expertise. However, the principles of Environmental Impact Assessment technique are very straightforward, and can be illustrated by a simple exercise and the case study below. Each of the stages of preparing an impact statement can be extended and refined

if the available database is adequate or expertise and time are available for further research. The nature of the EIA will depend on the complexity of the specific development project, but also its similarity to previous projects on which EIA's were conducted and from which information can be extrapolated.

Aim:

To plan the strategy for an Environmental Impact Assessment of a minor coastal tourism development.

Duration:

One to two days

Suitable Location:

Drawing Office/Laboratory

Materials Required:

Plans and drawings of a proposed development in the target island.
Maps and/or charts and aerial photographs of the development area as it is at present.
Background data files (or Data Atlas if available) on development area and associated areas, containing information on;

- natural ecosystem
- settlement patterns
- present activities and land-use
- economic conditions in area
- list and summary details of other planned developments for the area under study
- documents dealing with national development plans and objectives
- copies of laws or regulations concerning use of the area's resources.

Typing or word processing equipment.

Instructions:

1. Review available data on the development area. Identify key ecosystems and/or socioeconomic features which could be altered by development activities.

2. Review the development plans and drawings, and identify the key elements in the proposals, i.e. what aspects/actions in the development proposal need to be examined for possible effects on features identified above?

3. Refer to the outline for Environmental Impact Statements given in Table 2.11 and write out the EIS step by step. It is unlikely that all the information you require has been provided, so an important part of the strategy of preparing for an EIS is to identify data needs and appropriate methodologies for obtaining required data. List these requirements and indicate what information sources should be investigated or what field research should be conducted.

Table 2.11 Outline for Environmental Impact Assessments

1. Project Description:

   1.1 Purpose of porposed action/s.
   1.2 Description of proposed action/s (i.e. title, summary of activities).
   1.3 Environmental setting (i.e. nature and status of environment prior to action; related environmental aspects).

2. Land-use Relationships:

   2.1 Conformity or conflict with other land-use plans, policies and controls (national, regional, local; relevant legislation).
   2.2 Conflicts with other land-use plans; extent of possible reconciliation; reasons for proceeding with proposed action/s despite conflicts.

3. Probable Impact of the Proposed Action on the Environment:

   3.1 Direct (primary) negative and positive effects on

   - environmental factors.
   - national environments (and possibly international environment).

   3.2 Indirect (secondary) effects and consequences.
   3.3 General impact of proposed action.

4. Probable Adverse Environmental Impacts which Cannot be Avoided:

   4.1 Description of unavoidable impacts and their consequences.
   4.2 How unavoidable adverse impacts will be mitigated.

Table 2.11 continued..

5. Alternatives to the Proposed Action/s:

   5.1 Alternatives which might avoid some adverse effects.
   5.2 Alternatives which might avoid all adverse effects.
   5.3 Alternatives which might enhance environmental quality.
   5.4 Analysis of alternatives (Benefits, costs, risks).

6. Relationship between Local Short-term Uses of the Environment and the Maintenance and Enhancement of Long-term Productivity:

   6.1 Trade-of between short-term environmental gains at the expense of long-term losses.
   6.2 Trade-of between long-term environmental gains at the expense oif short-term losses.
   6.3 Extent to which proposed action forecloses future options.

7. Irreversible Commitments of Resources

   7.1 Unavoidable impacts irreversibly curtailing the range of potential uses of any part of the environment;

   - natural resources
   - materials
   - cultural resources
   - human resources.

8. Interests and Considerations of National Policy that Offset any Adverse Environmental Effects of the Proposed Plans:

   8.1 Countervailing benefits of proposed action/s.
   8.2 Countervailing benefits of any alternative action/s.

9. Statement of Conclusions:

   9.1 Approval of proposed action/s, with supporting rationale; or
   Approval, with recommended modification/s of proposal; or
   Disapproval of proposed action/s, with supporting rationale.
   9.2 Recommendations for action, or further investigation (e.g. by the developer, responsible agency or government).

.....

4. The identification of probable impacts (step 3 on Table 2.11) is critical to the EIS. Where a project has many "actions" which might impact on a varied natural and man-made environment, their interactions at primary and secondary level can be clarified by presentation in the form of a matrix or similar format, as is done for the information from the case study (Figures 2.20 & 2.21) shown in Figure 2.22. Impacts have been identified, then assigned categories and values, to indicate negative or positive qualities and whether these are minor, moderate or major. This form of presentation draws attention to significant impacts, so that the whole range of impacts can be dealt with but in order of priority.

   Identify primary and secondary negative and positive impacts of the proposed development, and present these in tabular or graphic format.

5. Consider each potential impact in turn while referring to steps 4-6 in Table 2.11.

6. Move to the recommendations phase of the EIS by reference to steps 7 & 8 in Table 2.11. As with many of the other aspects of coastal zone management (previous exercises Chapter 2 and Chapter 3), the possible negative effects of the proposed development must be weighed against considerations of national development policy. For example, if the island government is desirous of expanding the tourism industry, some disturbance of coastal ecosystems and displacement of traditional activities may be justifiable. These, probably negative, impacts may be outweighed by the need to improve water quality in the target area or by new jobs created in the tourism service industries. Weigh up the implications of the proposed development and identify impacts which could be considered justifiable in relation to national policy guidelines and existing legislation. (N.B. Economic aspects are considered in greater detail in the following exercise, no. 2.6).

7. Write a brief concluding statement which does or does not recommend that the proposed development should be approved. This should be supported by clearly stated reasons, including instructions for further research or study where the development permit should be withheld because of inadequate information.

8. The final product should be an Environmetnal Impact Statement along the lines of Table 2.11, supported by appropriate maps and diagrams.

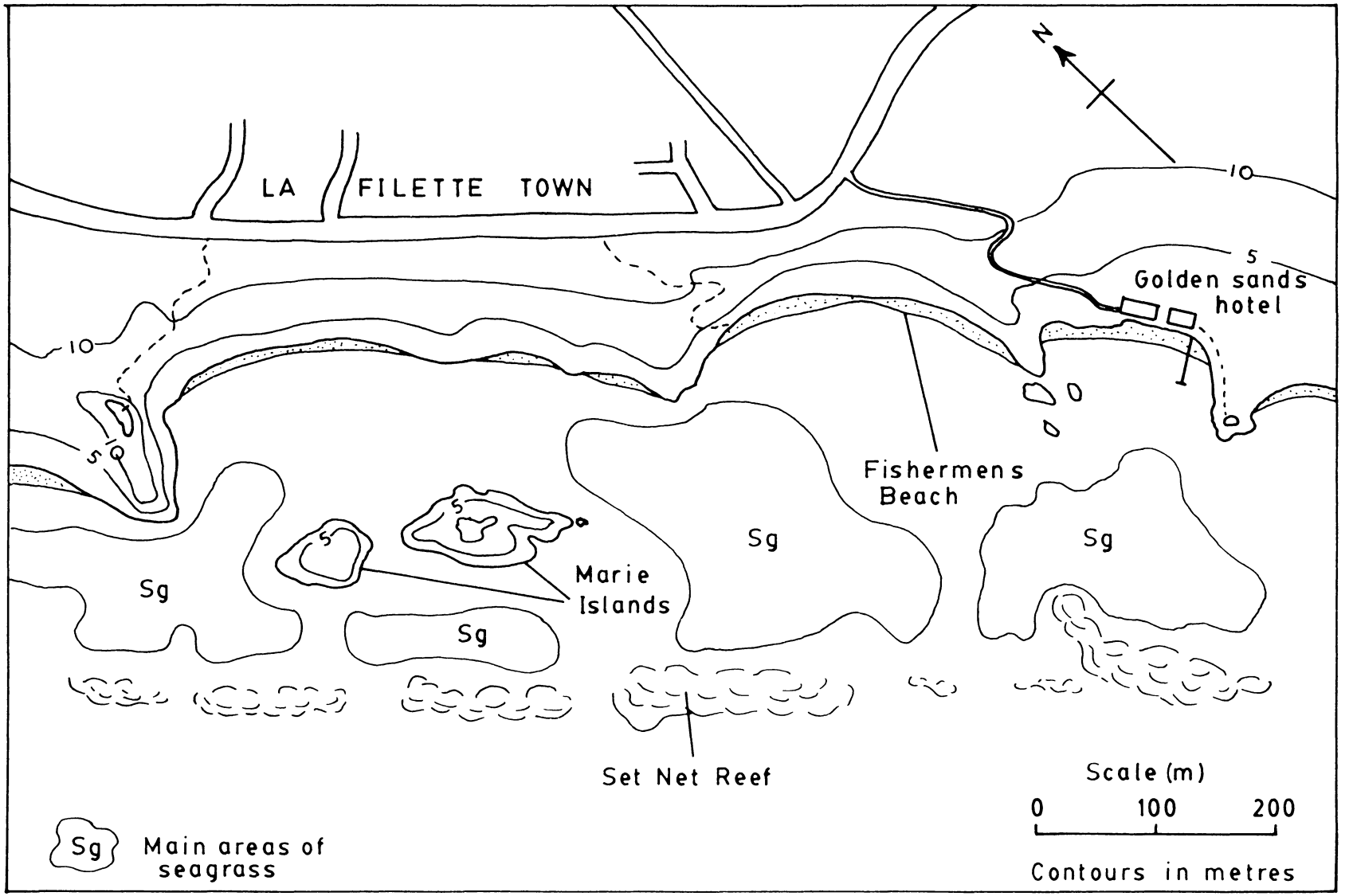

FIGURE 2.20 NATURAL FEATURES - LA FILETTE

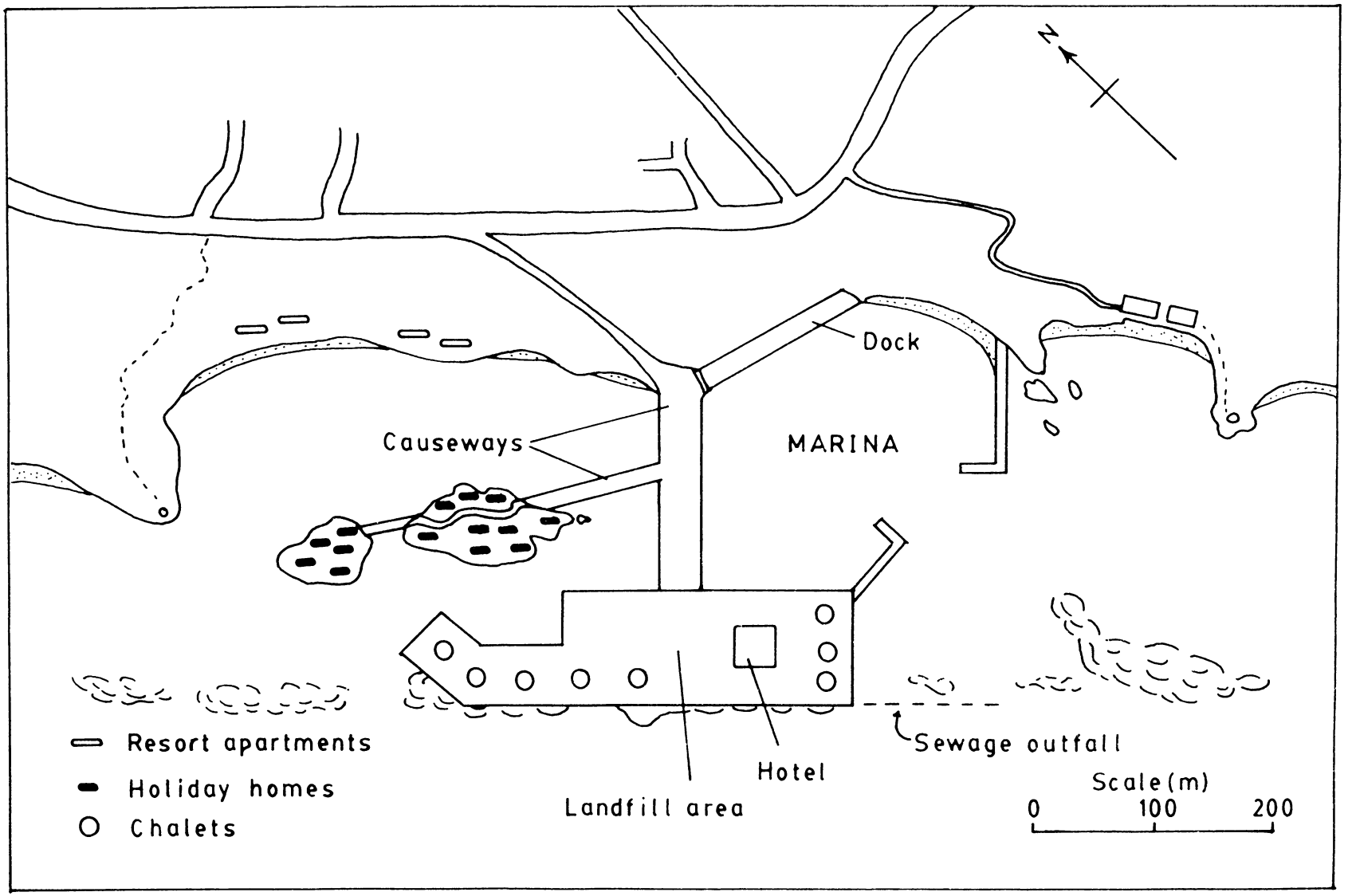

FIGURE 2.21 LA FILETTE DEVELOPMENT PROPOSAL (simplified)

PRIMARY IMPACTS 2 / 1 ACTIONS		Natural environment						Socioeconomic environment						
		Decrease water circulation	Increase turbidity	Decrease oxygenation	Decrease coral reef area	Disturb seagrass beds		Increase traffic	Increase local population	Displace traditional uses	Increase employment			
		2a	2b	2c	2d	2e	2f	2g	2h	2i	2j	2k	2l	2m
1a	Landfill-new island	2	3	1	3	1		0	1	2	3			
1b	Landfill-causeways	3	2	2	1	3		1	1	2	1			
1c	Dredging marina pool	0	3	3	0	3				3				
1d	Construction work							3		2	3			
1e														
1f	Small boat use	0	0	0	0	2				3	1			
1g	Sewage disposal		2		1									
3a	Primary production	-2	-3	-2	-1	-3								
3b	Fishery yield	-2	-2	-1	-3	-3				-2				
3c	Coastal protection	0	0	0	-3	-1								
3d	Property values							-1	+2	0	+3			
3e														

1 minor 2 moderate 3 major + positive - negative

FIGURE 2.22 EIA MATRIX FOR THE LA FILETTE DEVELOPMENT
(simplified and partially completed)

Case Study:

The National Physical Development Plan, vol.2 1986, identified several areas of the northeast coast for development, as part of the government's attempt to spread the benefits of a rapidly expanding tourism industry away from the overcrowded west coast resorts. One town which was in serious need for economic revival since the decline of its fruit export trade was La Filette, situated opposite the Marie Islands in the lee of Set Net Reef (Figure 2.20). A development company proposed the construction of a resort complex at La Filette, which would include an hotel and restaurant on landfill on the main reef, holiday flats on the Marie Islands and a marina/boating area at the site of the present fishermens' beach. The resort infrastructure was to be linked throughout by solid-fill causeways, and a series of groynes would ensure water quality and safety for recreationers (Figure 2.21).

During the preliminary phase of an EIA, the Department of Natural Resources identified and assessed possible impacts of the proposed development, and prepared this in the form of an EIA Matrix to be used during discussions with relevant government agencies. This matrix is shown in Figure 2.22.

The matrix can be interpreted by reading from Development Actions (1, top left) which impact on the components or processes of the environment (2, top centre), with a type and scale of impact shown in the body of the matrix. An identified Primary Impact at (2) can be expected to have any of the Secondary Impacts shown (3, bottom left). For example, Landfill for causeway construction (1b) is expected to reduce water circulation (2a) having a major impact on the environment (scale 3), and leading to negative secondary impacts such as a reduction in primary production of benthic plants (3a) and of fisheries production in the bay (3b).

In this Case Study, the matrix highlighted several major negative impacts on the natural environment and on the local fishing community. Even before the economic benefit-cost analysis was complete, these possible impacts were considered sufficiently serious for the developer to be asked by government to redesign the basic engineering in the proposal. (This Case Study is hypothetical)

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Alternative Exercises:

1. Environmental Impact Analysis is an extension of more conventional Cost-Benefit Analysis of the economics of development projects. EIA attempts to do the equivalent of a Cost-Benefit Analysis on less easily quantified aspects of the total environment, such as the costs of ecological disruption or loss of aesthetic resources. Translating some environmental or resource values into dollar equivalents is often difficult, but is essential for management of the total resource capital of island coastlines.

   Select a coastal development project, such as the Case Study presented above, and conduct analyses of two components, as follows:

   (a) compare the cost of one aspect of construction (e.g. building a new hotel) with the expected income (benefit). This ordinary Cost-Benefit Analysis will almost certainly show a net profit.
   (b) Compare the cost of construction above with the possible costs of damage caused by a storm, after the land-fill operation has destroyed the protective coral reef; i.e. attempt to put a dollar value on the protective functions of the healthy reef.

2. Assess the impacts of tourism development on adjacent areas and their infrastructure. The main exercise above concerned EIA at the <u>site</u> of development, but the introduction of tourism into a bay also affects the supporting town and neighbouring areas. Take into account likely effects on the system of roads, power supplies, water and sewage (treatment and disposal), displacement of people from the development area and migrations of people into the area (transport, housing, shifts in the economy).

3. Assess the impacts of a mariculture development project. The above exercises have been concerned largely with land-based activities, but the growing popularity of the culture of marine organisms in coastal waters is causing problems in many areas. Not only are there problems for the mariculturist trying to raise food organisms in polluted waters, but the presence of culture frames, rafts, submerged cages and other structures impacts on the natural environment and on economic activities in the coastal zone. Examine a functioning or proposed mariculture scheme and assess its impacts; including the used of local material in construction, effects on freedom of navigation on that part of the coast, on traditional uses of the area, on the local economy and water

quality.

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Further Reading

Devaux, R. J. 1987. The impact of the Rodney Bay Project on coastal processes. Commonwealth Science Council Technical Publication, 227; 117 - 131.

Kapetsky, J. M. 1981. Some considerations for the management of coastal lagoon and estuarine fisheries. FAO Fisheries Technical Paper, 218; 47 pages.

Lewsey, C. C. 1987. The effects of tourism development on natural resources and infrastructural facilities - the case of Barbados. Commonwealth Science Council Technical Publication, 227 148 - 180.

Marshall, B. V. 1975.Comprehensive Economics, pt. 2. Analytical and applied (2nd Edit.). Longman, London; 695 - 1163.

Odum, W. E. 1974. Potential effects of aquaculture on inshore coastal environments. Environmental Conservation, 1; 25 - 47.

Shopley, J. B. & Fuggle, R. F. 1984. A comprehensive review of current Environmental Impact Assessment methods and techniques. Journal of Environmental Management, 18; 25 - 47.

Williams, M. C. 1987. Environmental Impact Assessment in the physical planning process with special reference to the coastal zone. Commonwealth Science Council Technical Publication, 227; 59 - 83.

* * *

Exercise 2.6 ANALYSING THE ECONOMIC BENEFITS, COSTS AND RISKS OF COASTAL AREA DEVELOPMENTS

Background

Previous exercises in this Chapter have not dealt with the economic aspects of coastal development, although these have been implicit throughout. As examples, (a) construction of a breakwater (Ex. 2.2) will be of cost to the developer, but if erosion results this will reduce the value of the beach for residents and tourists; (b) a suitable location for a sewage outfall can be chosen (Ex. 2.3, but the best site on technical and environmental grounds could also be the most expensive in terms of pipe laying or distance from the treatment plant; (c) maintaining bathing waters free from coliform bacteria (Ex. 2.4) requires expenditure on monitoring services, and the higher the standard of coastal cleanliness required the higher the costs of waste disposal. However, if water quality standards are not maintained, financial losses might occur through increased medical bills or reduction in tourist numbers; (d) enviromental impacts of a resort development project were reviewed (Ex. 2.5), but there will be impacts on many sectors of the economy to be considered also. The developer will invest money and expect profits, and employees and service industries will receive and pass on money. But while this multiplier effect spreads the benefits through some parts of society, adverse impacts of the project might involve the government or small groups of citizens in a loss f revenue. On the other hand, if a different type of development had taken place in the area, such as La Filette Bay (Ex. 2.5), profits might have been smaller but the environmental damage and resulting costs to society negligible.

The outline for preparing Environmental Impact Statements for development projects requires consideration of alternatives to the proposed action (Table 2.11, Item 5). This includes an analysis of these alternative in terms of the **benefits, costs,** and **risks;** which helps the coastal zone manager to progress from what it is feasible to do on technical or environmental grounds, to what is advisable to do on economic grounds. In other words, over and above the environmental opportunities and constraints on coastal resource development, the manager must make an **economic choice**, in deciding between different uses of a resource, and must **allocate resources** between competing user groups in order to **maximise economic returns.** He must consider the effects of the development on both **private** and **public** sectors and take into account **short term** and **long term** benefits and costs (see Beckhuis, 1981).

The exercise which follows is an introduction to some of the economic aspects of coastal area development, designed for trainees with little previous knowledge of economics. It concentrates on some of the concepts involved in decision-making, and on developing a strategy for reviewing the economic implications of alternative proposals, rather than detailed monetary calculations. However, the instructor could replace the hypothetical case study presented with a local example for which financial predictions have been made, if the level of understanding of economics among the trainees merits this.

Aim:

To make a preliminary benefit/cost analysis of alternative uses of a coastal wetland area.

Duration:

One day (minimum).

Suitable Location:

Drawing office or laboratory, using the information provided.

Materials Required:

Report writing materials
Word processor or word processing facilities
Copies of the following reports (which are reproduced at the end of this exercise, below):

- "Summary of Bogue Swamp Development Plan"
- "Review of the Bogue Recreation Park Proposal"

A list of local financial information, (such as house prices, hotel rates, construction costs, transport fuel costs, labour costs, insurance and import charges), which should be provided by the instructor.
Pocket calculators

Instructions:

1. Review the documents provided. Discuss these with the instructor and ensure that you have a clear picture of the type and magnitude of the proposed developments.

2. Note the estimated costs of the proposed projects, and that the two competing investors are the Government (using public funds) and a private company (using share capital or loans). Make a list of the different ways the money will be spent (eg. materials, labour),

and from this a list of the groups of people who will benefit during the construction phase of each development. It is not necessary to estimate actual earnings or to calculate the cash flow, as you are concerned with where the benefits will be felt and the relative scale of benefits. However, if local financial data is available for comparison, advanced trainees may wish to do this.

3. Take each development in turn and list the types and likely number of persons who will benefit directly from it once it is operational. This should include (a) persons involved in operating the facilities, and (b) the visitors and others who will enjoy the facilities.

4. Compare the benefits to be derived from the two proposed developments (combined construction and operation phases). The comparison should examine numbers of persons who benefit or the likely cash flow paths through society. (It is not necessary to attempt monetary calculations for trainees to appreciate relative benefits of the competing proposals). Does it appear that the greatest benefits are likely to arise from the more costly development? If not, how do you account for this?

5. Before choosing to allocate the natural resources of the target area to the more competitive proposal, consider some of the indirect costs of either development. The area has a range of values at present, and "developing" it would mean some loss of value to current user groups. These include:

   (a) Fishermen
   - would incur loss of income from fishing in the swamp. Would also be displaced from fishing and mooring boats in this area.
   - might incur loss of income from fishing on the reef, if removal of mangroves upsets local marine food chains or reduces the supply of nutrients to the reef.

   (b) Recreationers - would no longer have free access to the swamp area for boating, swimming or other recreation and enjoyment.

   (c) Residents - amenity value would be reduced; loss of scenic qualities and increases in traffic, etc., are likely to affect house prices and use of guest houses on Jack's Hill.

Private costs, of investment by the developer, are more easily appreciated than **social costs**, such as loss of traditional employment by fishermen or loss of amenity value by residents and visitors. Discuss how important you consider these losses to be, and identify any other probable social costs of the proposed developments.

6. Calculate the **opportunity costs** of the existing uses of the Bogue Swamp area. An opportunity cost is a measure of what the user has given up in order to enjoy a resource. For example, an islander was prepared to give up buying other luxury items in order to buy fuel to drive his family to the Bogue Swamp for a picnic. Instead of buying a new stereo set, another person bought a second hand canoe in order to enjoy boating in the lagoon. The expenses of these two users can be considered as part of the value that people place on this natural area.

   Refer to the reports on the Bogue Swamp area and make a list of the types and numbers of persons who use or benefit from the area in its present condition.

   Calculate the opportunity costs for each group, as in the following example: Residents from different parts of the island visit the Bogue area for recreational purposes, and spend money on fuel, food, drink and photographic materials. If there were 9,500 visitor days last year and visitors spent on average $15, the opportunity cost for this user group was approximately $142,500 per year. If we had been considering a group of foreign tourists visiting the area by taxi and buying their food in the guest house, and spending on average $30, the opportunity costs would be doubled.

7. The total opportunity costs, calculated for the area without development, should be balanced against the proposed developments. Loss of opportunity should be considered a cost item; to what extent does it reduce the expectd benefits?

8. The two proposed developments modify the Bogue Swamp area to different degrees. Re-examine the proposals and assess which has the lower effect on present opportunity costs; for example, if residents value living above the Swamp because of its scenic character, which development disturbs scenic values less? Is the potentially lower profit from this "more acceptable" project justified by the scenic values which have been preserved?

9. Review the benefit/cost analysis conducted thus far and, in the light of the issues raised, draft a strategy for approaching a similar analysis with

another proposal. The strategy should list the actions to be taken in order of priority.

10. Conduct a **risk analysis** of the Bogue Freeport development. The benefit/cost analysis above has assumed, thus far, that certain benefits will accrue when the development takes place. Once cruise ships arrive and tourists spend money in the duty free shops, there will be benefits to the economy that repay investments and outweigh identified social costs. But what happens if tourists are <u>not</u> attracted to the area, or not in sufficient numbers?

    This question will have been faced by the investors at an early stage of preparing the development project proposal. They will have considered the risks involved and assessed the likelihood that their project will succeed (i.e. make a profit or improve conditions in the area).

    <u>Activity 1</u>: Students should list the types of information they would need for an economic risk analysis of the Bogue Swamp Development Project. This might include:

    - Outline of government policy on tourism sector expansion.
    - Predicted trends in tourist arrivals to the island.
    - The National (5 year) Development Plan, containing the projections on potential competing or supporting developments in or adjacent to the target area.
    - Data on the loans policy for tourism-type developments of the major local financial institutions.
    - other.....

    Students should refer to qualified resource persons for help with identifying needs for economic risk analysis.

    <u>Activity 2</u>: Students should also analyse the risk of economic losses resulting from (unexpected) environmental problems. For example, removal of mangroves and cutting of the navigation channel might result in deterioration of the fringing reef which protects popular bathing beaches and commercial waterfront property adjacent to the development site. Do the benefits to be derived from the proposed Bogue Development outweight the possible costs of increased wave and storm, damage to these neighbouring features? What is the risk and is it worth taking? (The <u>likelihood</u> of reef damage occurring would be assessed by standard of EIA procedures. These would provide a prediction, and stated degree of certainty. The

coastal zone manager should consider the chances, but assess the economic risks on the basis that damage can be expected).

List the types of information required to decide whether the private and social costs that can be expected following reef damage seriously detract from the potential value of the development. Is the economic risk high or low in this respect?

11. Prepare a written summary outlining the economic benefits, costs and risks involved in the proposed Bogue Swamp area developments. Give an overall assessment of the economic viability of both proposals.

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Alternative Exercises:

1. Students should make a study of opportunity costs during a field visit to a small recreational site, near the training centre. The numbers of persons using the site (preferably at peak time) should be estimated and the costs of running the site investigated. Students should conduct interviews, using a pre-prepared questionnaire, in order to find out how much visitors have spent to reach the site and how much they expect to spend in order to enjoy the site. Use these figures obtained from a small sample of the visitors to estimate the total opportunity cost.

   Follow the above study by drawing up a plan to attract twice as many visitors to the site. Estimate what it would cost to attract and cater for the increased visitor numbers (publicity, infrastructure and facilities, wardens, life guards or whatever is appropriate). Then compare the costs of running the improved recreational site with the estimated opportunity costs. Do you consider that the benefits of the proposed development would outweigh the investment and running costs?

Further Reading:

Dixon, J. A. & Hufschmidt, M. M. (Eds) 1986. Economic Valuation Techniques for the Environment. John Hopkins University Press, Baltimore, USA.

Gamman, J. K. & McCreary, S. T. 1988. Suggestions for integrating EIA and economic development in the Caribbean Region, Environmental Impact Assessment Review, 8; 43 - 60.

Koester, S. K. 1986. Socioeconomic and cultural role of fishing and shellfishing in the Virgin Islands Biosphere Reserve. Virgin Islands Resource Management Cooperative, Biosphere Reserve Research Report, 12; 24 pages.

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Exercise 2.6: **Supporting Document No. 1**

SUMMARY OF BOGUE SWAMP DEVELOPMENT PLAN

This summary is designed to help agency personnel obtain an overview of the proposed development of a tourism/freeport centre at the Bogue Lands, the details of which may be found in Ministry Document 42/87/216.

A. Existing Conditions

1. Bogue Swamp is the largest area of mangroves on the north coast, covering approximately 320 acres. The Swamp consists of seven mangrove-covered islands with shallow channels between, and two lagoons. The inner lagoon is also shallow, with a firm sandy bottom and patches of seagrass and is well known for its rich and varied fish life. The outer lagoon is deeper, falling to 12 ft in places, and separates the mangrove area from the coral reef. The reef is passable only by small canoes, except at the southern end where small yachts and motor craft can pass at high tide. The mangrove islands shelter the beach on the south (landward) side, giving very calm conditions much liked by families with children. Longshore currents keep seaweed and other debris off the beach and bathing area. Although less than one mile from the town, there have been no complaints of pollution of the beach or swamp area by oil, garbage or other offensive materials.

2. Ten fishermen reported regular fishing in the Bogue area, five on a full time basis, the others regularly in between other forms of employment. Trap fishing in the outer lagoon is practiced regularly by all fishermen interviewed. Some shrimp, used largely for bait, crabs of three species, lobster and some scalefish are also taken in the inner lagoon and among mangroves. About half the catch is sold to the quest houses on Jack's Hill, the balance is either sold on the beach at the eastern end where the fishermen moor their boats, or used for home consumption. The fishermens' families benefiting from use of the Bogue area number approximately 62 persons.

3. Recreational fishing is carried out throughout the area, but no estimate is available. The number of visitor days recorded during the last 12 months (by survey of persons entering he beach area from Hillside Lane) was 12,740. The largest number were islanders, totalling 9,500, while the balance were guided tour parties of foreign tourists staying in the main town.

4. Bogue Swamp is overlooked by Jack' Hill, probably the most exclusive housing area in the north. Property on the Hill fetches high prices, due to the spectacular views over the swamp and reef, the unspoiled nature of the local environment and general quietness (which is in contrast to the main town round the bay to the east). Jack's Hill has two guest houses, which boast 80 - 90 % occupancy throughout the year. "Hillcrest" caters to day trippers, especially foreign tour parties, and the view from the guest house verandah is probably one of the most photographed on the north coast. During the last 12 months this guest house recorded 8,320 day-trippers.

B. Features of the Development Plan

1. All mangrove will be cleared from the site; bottom material dredged from the outer lagoon and used to fill the Freeport site. An elongated landfill area of 120 acres will be levelled and joined to the base of Jack's Hill (present beach area). The following facilities will be constructed on the landfill site:

- Dock area with three berths (designed to receive cruise ships and freighters).
- Customs shed and warehouse.
- Six factory units (free zone manufacturing for export, expected to employ 300 workers).
- Enlarged access road, with guard post (there will be restricted entry to the Development Area) - Parking facilities.
- 12 chalets for duty free shopping; one restaurant with gardens, toilets and staff lounge.
- Navigation channel. A channel will be cut through the reef opposite the cruise ship dock (using mechanical means), large enough to permit entry by ocean-going vessels. Marker buoys and moorings will be provided.

2. Costs of construction are estimated at $40 million.
3. Construction time is estimated at 18 months to reception of the first party of cruise ship tourists, and 24 months to full operation of the facility.
4. Estimates show two cruise ships per week can be expected. There are no estimates of revenue from free zone operations which will be put out to tender.
5. The Ministry of Works will contract out construction work through normal tendering routes.
6. The Tourist Board will be mandated to manage the Feeport Development, probably through the establishment of a Bogue Freeport Development Authority.

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Exercise 2.6 **Supporting Document No. 2**

REVIEW OF THE BOGUE RECREATION PARK PROPOSAL

The alternative proposal submitted by "Leisure Investments Ltd." to the Department of Planning on 15th June 1988 concerns plans to build a recreation park on a site known as Bogue Swamp. The "Swamp" is Government land consisting of mangrove islands, lagoons and a beach fringing the northern side of Jack's Hill (a private residential area not included in the development area). The proposal has the following features:

1. Five of the mangrove islands will be graded and the major portion of the mangroves removed to make way for picnic and barbecue sites. These sites will include wooden shelters covered with palm leaves, with seating and wooden table.
2. Channels between and around all islands will be dredged to permit access by small pleasure craft. Landing stages will be constructed on each island.
3. An hotel will be constructed at the eastern side of the development area. This will be an exclusive 40 bed hotel in the form of separate cabinas/chalets, with tennis courts and freshwater swimming pool.
4. The hotel will be fronted by a marina, capable of berthing up to 50 pleasure craft, with full service facilities but not repair facilities. It is expected that the marina will be used largely by hotel guests (who will arrive by boat).
5. A channel will be dredged from the marina, through the inner lagoon to the western and of the swamp, where a passage to the sea already exists. A survey is being conducted at present to determine the necessity of deepening or widening the channel through the reef.
6. The beach area will be retained. Local residents will be permitted to use the beach, but an entrance fee will be charged. Licensed concessions will provide refreshments and watersports equipment; these will be controlled by the developer directly.
7. Construction costs are estimated at $20 million.
8. The first phase, continuing the hotel and marina facility, will be operational within 18 months. Navigation channel dredging will proceed simultaneously. The second phase which will begin once Phase 1 is completed will develop the picnic sites and other recreational facilites which will be used largely by islanders. Phase 2 should be completed within six months.
9. When fully operational, the Recreational Park is expected to employ 30 -40 persons full time. Extra part time staff will be required from time to time.

10. The report concludes with financial projections which suggest profits on the initial investments will be realised by the middle of year three.

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CHAPTER 3.

COASTAL AREA MANAGEMENT PLANNING

Introduction:

Effective management of the coastal zone of tropical islands requires that natural resource areas critical to development be identified, legally protected, and managed for sustainable use. These "critical areas" include economically or socially valuable area, or unique or representative natural environments as well as areas of historical or archaeological importance. "Protection" implies that the identified resource use for the area is given legal status which permits its management. In some cases, protection may mean isolating an area from human use to safeguard endangered wildlife or scenic features, but this is only one interpretation. Areas can be protected for fisheries purposes, so it becomes an offence for any activity to take place which detracts from fishermen's use of that area. Protection of an area can be also for tourism or recreation, which are important economic activities in many Caribbean and Pacific islands, or to ensure that multiple use of a coastal area can take place because it is possible to regulate where, when and how resources are utilized. Establishing a series of **Protected Areas** can be an effective method of managing the coastal zone, where resource ownership is less clearly defined than it is in the hinterland. An alternative terminology is in use in some Caribbean and other tropical islands of **Natural Area** management (see Putney, 1978). This has value in stressing that in any island it is possible to recognise certain areas which fall into distinct units geographically or ecologically, in which it is desirable to integrate all development activities. For example, river valleys with their catchments, floodplains and estuaries form "natural areas", as do wetland basins, peninsulas, and some lagoons or bays with their surrounding coastal zones. Natural Area Management Planning would attempt to regulate all activities within the demarcated area in relation to the specific characteristics of that area. It would seek to maximise social and economic development, but be constrained by the need to safeguard the ecosystem structure and viability on which that development was based. Because the area is an integrated natural system, all development activities must be integrated also.

There is another sense in which a "natural area" requires its own type of management. In a wetland or bay, for example, the economic uses are likely to be based on "nature", or a particular grouping of natural resources;

i.e. the economy of the area may depend on fish populations, mangrove productivity or the spectacular nature of reef dive sites. Natural Area Management Planning will be concerned, thus, with management of distinct areas of the island in which the natural resources are of paramount importance.

With this **System Plan** in place, studies of the management alternatives for each of the areas included in the system plan can be undertaken. Such studies aim to produce the information required to recommend the most appropriate management option. Following this a decree for the legal establishment and protection of the area and the approved resource uses can be drafted. This requires clear recommendations on boundaries, management category, and general management concept.

Once the individual area has been legally declared, a **management plan** is drafted to specify clearly (1) the present situation, (2) the desired situation, and (3) actions needed to achieve the desired situation. The management plan may be supplemented with **site plans** for specific development sites and/or construction drawings for particular facilities.

The exercises presented here are designed as an introduction to the skills and experiences necessary to plan the management of natural resource areas in the coastal zone. Students should be familiar with the overall planning sequence, by following through the process, as a team, from beginning to end. For small island nations, where the pool of human resources is likely to be limited, coastal managers will need to develop a comprehensive view of natural resource area management.

The training course/workshop or field course format is well adapted to the concept of learning by doing. Depending on the intensity, each training course (one for system plans, one for studies of management alternatives, and one for management plans) could be completed in about two weeks. The same material could be broken down into segments and presented as a course at an educational institution. This approach would work best if an easily accessible natural resource area and suitable background materials and management plans for existing protected areas were available for use during practical exercises.

Because the situation of each user of this Workbook will be different, all steps of the planning process from system plan to site and construction plans are outlined in Table 3.1. The user can concentrate on those steps of the process that best fit the training context at hand, without losing sight of the overall planning picture. However, less detail is given for the exercises suggested

Table 3.1 Steps in Planning the Management of Natural Areas

System Plan (as a plan by itself, or as part of a National Development Plan or Coastal Management Plan).

1. Define desired system characteristics and management categories.
2. Define selection criteria for individual areas.
3. Collect and map basic data on human and natural systems, at the national or regional level, based on the selection criteria. (see also Exercise 1.3)
4. Identify potential areas.
5. Rate each potential area in terms of selection criteria.
6. Select areas that will best match the desired system characteristics.
7. Draft plan, review widely, revise, and submit for approval at appropriate government level.

Study of Management Alternatives (for all areas recommended in system plan).

1. Define study area based on information provided in system plan. (see also Exercise 3.1)
2. Collect and map data on human and natural systems. (see also Exercises 1.3. & 3.1)
3. Analyse potentials, limitations, and constraints for management.
4. Define alternative management strategies and review with relevant government departments and resource users.
5. Verify appropriateness of management category temporarily assigned in system plan.
6. Synthesise preferred management concept and boundary recommendations.
7. Write up concise report, including a draft protected area declaration, and submit to relevant authorities.

Management Plan (Site Plans for legally protected areas)

1. Supplement data on natural and human systems contained in study of management alternatives.
2. Define specific objectives for management of area.
3. Divide area into management zones.
4. Design environmental, public use, and operations programmes.
5. Prepare integrated development programme including institutional measures, staff development, and physical development plans.
6. Estimate cost and define funding strategy.
7. Synthesise plan into concise document, review with

Table 3.1 continued..

relevant government departments and resource users, revise, and submit for official approval.

8. Evaluate and revise plan at regular intervals. (see also Chapter 6)

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under the Management Plans and Site Plan sections, because many of the operating principles are similar to those treated thoroughly under System Planning.

A. SYSTEM PLANNING

The goal of system planning is to propose the nature and content of a Natural Resource Area System for an entire island, a whole coastal zone, or a particular region of it. The nature of the system is defined by the management categories selected and the content by the physical areas included.

The plan which results from the exercises may either stand on its own or be incorporated into a national or regional development plan, or a coastal management plan. Ideally such a plan should include the elements indicated in the model table of contents presented in Table 3.2.

Table 3.2 Model Table of Contents, for a Protected Areas System Plan

1. Executive Summary
2. Introduction
3. Present Situation
    a. legislation
    b. government policy
    c. designated areas
    d. management infrastructure
    e. management activities

Table 3.2 continued..

4. Development of the System

   a. justification
   b. goals and objectives
   c. management categories
   d. site selection process and criteria
   e. areas recommended for inclusion in the proposed system

5. Management Requirements

   a. overview of the implementation process
   b. legislative requirements
   c. management infrastructure
   d. revenues and budget
   e. law enforcement
   f. cooperative agreements and concessions
   g. liability
   h. contributions from government ministries
   i. inclusion of private lands
   j. community participation

6. Management Programme

   a. research and planning
   b. information, awareness, and education
   c. institutional development

7. Conclusion
8. References
9. Appendices

   a. background on human and natural systems of the island
   b. summary of environmental legislation
   c. summary descriptions and maps of areas to be included in system
   d. budget requirements and revenue projections

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System planning requires familiarity with the following concepts and skills:

- the overall planning process
- conservation objectives
- management by objectives

- management categories
- selection criteria
- the use and analysis of maps, hydrographic charts, and aerial photographs
- field reconnaissance and interviewing techniques

The exercises which follow are concerned with each of these aspects. Ideally students should work through all the individual exercises in order to produce a complete System Plan. This will be most effective if done with the cooperation, support and participation of officials from relevant government agencies. A complete System Plan can be drafted in about 14 working days if well prepared in advance. To facilitate this the training site should be centrally located on the island, or within the target region, and there should be good access to information and transportation networks.

Exercise 3.1 PREPARING A DATA ATLAS

Background:

Effective development of a Natural Resource Areas System Plan requires considerable environmental and socio-economic data. This information is most usable when mapped at a common scale to facilitate analysis and synthesis through overlays, and published as a Data Atlas.

This exercise is designed to give students experience in collecting the required data and converting it into a common format. To carry out this task, students will need to know the kind of data that will be required, and the potential secondary sources for acquiring it.

Aim:

To familiarize students with the methods and techniques for developing a Data Atlas, a summary of relevant information on natural resources for a target island or region of an island.

Duration:

This exercise may need to be carried out over a period of several days. The exact time will depend on how much background information is supplied by the instructor, and the size and complexity of the island or region under study.

Suitable Location:

The training site should be near the major town or university of the island or region, where information networks are usually concentrated.

Materials Required:

1. Listing of information required for the Data Atlas (Table 3.3)
2. Model map format (Figure 3.1).
3. Listing of potential sources of information.
4. Simple drafting materials and equipment.
5. Overhead projector, artograph, enlarging and reducing photocopier, camera and slide projector, or other equipment capable of converting maps to a common scale by optical means.
6. Topographic maps, hydrographic charts, and aerial photographs of island or region under study.

Instructions:

1. Review list of information required (Table 3.3), note potential sources, and model map format (Figure 3.1).

Table 3.3 Information to be Included in a Data Atlas

- topographic map and bathymetric chart of coastal waters
- predominant currents
- rainfall
- relatively natural areas
- terrestrial life zones
- important marine habitats (mangroves, coral reefs, seagrass beds)
- endangered and locally important species (endangered species, game species, nesting seabirds, migratory species, nesting turtles, marine mammals etc.)
- natural, cultural and historic attractions (bathing beaches, waterfalls, unique or scenic features, reefs for snorkelling and diving, historical or archaeological sites, sites of religious importance, etc.)
- physical infrastructure (roads, airports, ports, towns and villages, industrial sites, waste disposal sites, sewerage outfalls, etc.)
- coastal resource use (fishing areas and landing sites; tourism and recreational facilities; good anchorages; watersheds supplying potable water, hydroelectric or irrigation systems; etc.)
- established and recommended parks and protected areas
- publicly owned land

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2. Review all topographic maps, hydrographic charts, aerial photographs, and reference materials which are available.

3. Assign each member of the group a subject category or map area that will be his/her responsibilty. Group members then carry out independent research to obtain data for their assigned map(s).

4. Use the optical equipment to convert maps to a common scale. This should be done as follows:

   (a) <u>Selecting the base map scale</u>:
   Since the final product of the exercise is a Data

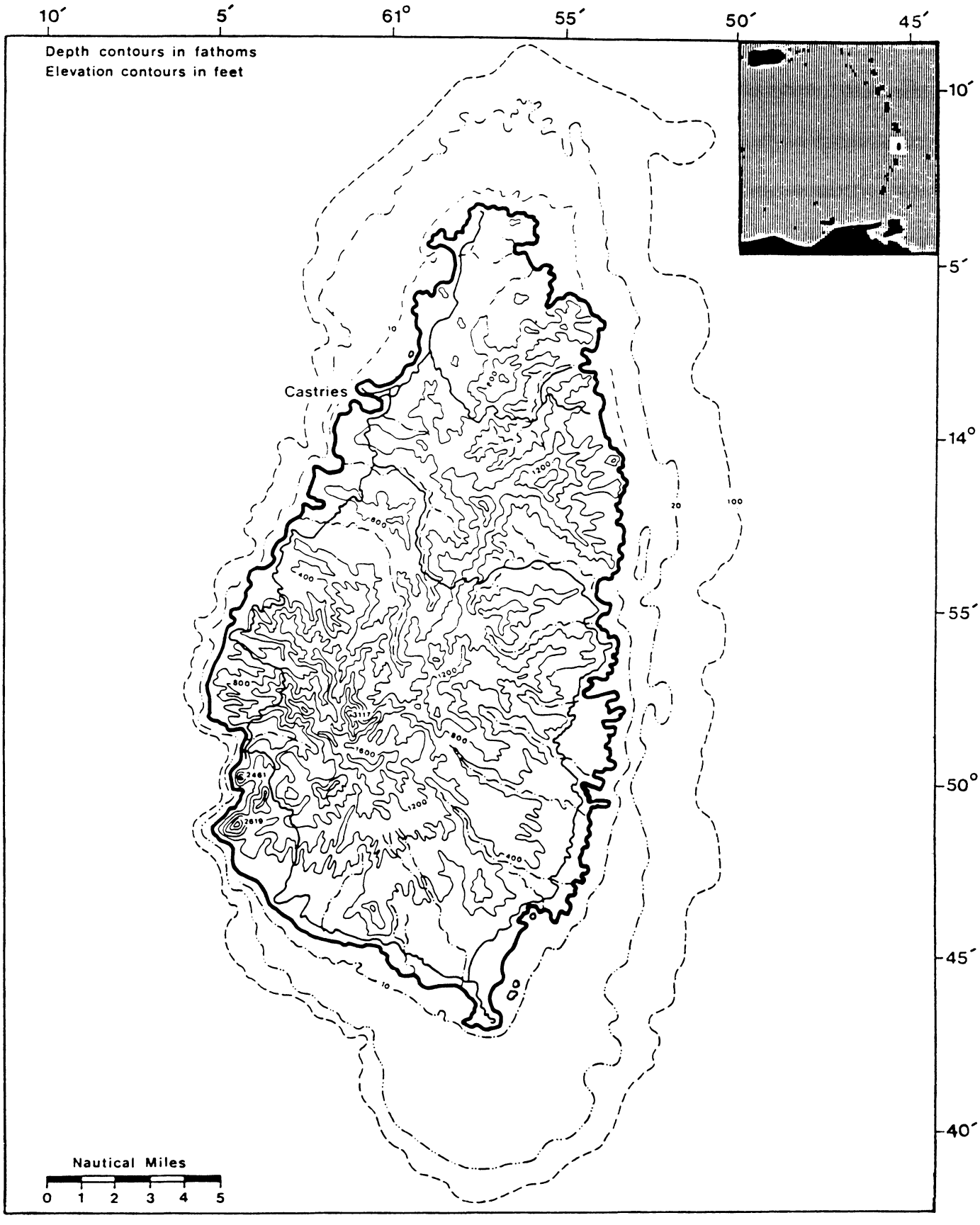

FIGURE 3.1 MODEL MAP FORMAT

Atlas that can be reproduced easily, the size of the maps will depend on the reproduction equipment that is available. For example, if a simple copy machine is to be used, the base map should fit the standard format (8.5 x 11 inches for machines produced for the U.S.A. market). If a model with more options is available, then its larger formats can be used (for example, 8.5 x 14 inches or 11 x 17 inches for models produced for the U.S.A. market).

(b) Producing the base map:
Once the size of the base map has been selected, a good topographic map of the island or region under study can be reduced by optical means to fit the available space. Sufficient space should be left so that the bathymetry of the island's marine shelf can later be filled in by reducing marine charts. Figure 3.1 is an example of a base map with both topography and bathymetry.

(c) Map reduction by optical means:
This is most easily accomplished by an opaque projector, which will project the image of a map. The projector can be moved, thereby adjusting the focal length so that the map is projected at the desired size. The map outlines are then traced onto drawing paper of the required format. This process is simplified by fashioning a rear screen projector, as follows - at night mount translucent drawing paper, with the appropriate map margins already drawn in heavy ink lines, on the outside of an easily accessible window. Project the appropriate size image onto the inside of the window where the paper is mounted, and trace the image on the paper on the outside. In most cases, the amount of detail will have to be decreased from the original map in order to fit the reduced size. For example, instead of showing 10 metre contours, it may be necessary to use only intervals of 100 metres.

If an opaque projector is not available, then the same results can be obtained by projecting photographic slides of the original map. Again, the slide projector can be moved to produce the image size required. A further alternative, usually requiring more patience and considerable trial and error, is the use of a reducing copy machine to reduce the image to the required size. If the map original is large, then it wil be necessary to reduce it in sections, fit and tape these together, and

further reduce them. With any means of optical reduction, it is critical to have a graphic scale showing on the map. so that the scale can be determined at the reduced size.

5. After conversion of all map data to a common scale, students should submit their contribution to the Data Atlas.

6. Maps should be checked and the results discussed by the group. A simple comparison of data will often show inconsistencies and errors. Correct any errors and eliminate inconsistencies; for example, endangered species will be found rarely in urban or agricultural areas; recreational beaches hopefully would not be found where sewage outfalls are located.

7. Assemble the separate contributions into a Data Atlas.

Product or Results Expected:

A Data Atlas containing a series of maps at uniform scale with environmental, resource use, and legal information relevant to the design of a Protected Areas System.

Interpretation and Application to the Problem Area:

The Data Atlas provides much of the background information needed for general decisions on resource management, and the design of a Protected Areas System in particular. The location and extent of key resources, and their uses, are displayed together with land ownership. Natural areas and resources critical to the development process can be pinpointed, potential protected areas identified, and conflicting uses noted.

Examples of completed Data Atlases for the 25 islands or island groups of the Lesser Antilles can be obtained from the Eastern Caribbean Natural Areas Management Programme (ECNAMP address in Appendix 8).

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Alternative Exercises:

The above exercise can be shortened considerably if all the information to be used in the Data Atlas is available to students at the start. The disadvantage of this

approach is the loss of practical research experience by the students.

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Further Reading:

Geoghegan, T. 1983. Guidelines for Integrated Marine Resource Management in the Eastern Caribbean; Repor on the Workshop, "Planning for Marine Resources Development". Eastern Caribbean Natural Area Management Programme, St. Croix; 52 pages.

IUCN (undated) Data Atlas: Planing a Marine Conservation Strategy for the Caribbean Region. International Union for the Conservation of Nature, Morges, Switzerland; 6 pages & 22 maps.

Putney, A.D. 1982. Final Report, Survey of Conservation Priorities in the Lesser Antilles. Eastern Caribbean Natural Area Management Programme, St. Croix; 30 pages.

Salm, R.V. & Clark, J.R. 1984. Marine and Coastal Protected Areas: a Guide for Planners and Managers. International Union for the Conservation of Nature, Morges, Switzerland; 302 pages.

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Exercise 3.2 DEFINING THE STRUCTURE OF A PROTECTED AREA SYSTEM

Background:

Management of a system of protected areas begins with basic policy decisions. What should the system include ? How many management categories are necessary to ensure that the major objectives of resource management and national development are attained and that conflicting uses are segregated ? What portion of the island's resources can or should be managed by a central authority? Which government agency, or non-governmental organisation, should administer each management category ?

To answer these questions, the resource manager must understand clearly the **objectives of resource management**, the different **groupings of objectives** for each management category and the **resource situation** of the island or target region.

Aim:

To establish the structure of the Protected Areas System through the definition of objectives for management, and their application to management categories.

Duration:

One day (8 hours)

Suitable Location:

Laboratory/drawing office

Materials Required:

1. Matrix of conservation objectives and management categories recommended by IUCN (Table 3.4).
2. Narrative description of protected area categories, e.g. for the British Virgin Islands (Appendix 5).

Table 3.4 Categories of Protected Areas and Corresponding Conservation Objectives

Categories used:

I	Strict Reserve	VI	Resource Reserve
II	National Park	VII	Anthropological reserve
III	Monument/Landmark	VIII	Multiple Use Area
IV	Managed reserve	IX	Biosphere Reserve
V	Protected Landscape/Seascape	X	World Heritage Site

Type of Objective:

1 = Primary objective for management of area and resources
2 = not necessarily primary, but always important objective
3 = included as an objective where applicable and whenever resources and other management objectives permit

Primary Conservation Objectives	Category I	II	III	IV	V	VI	VII	VIII	IX	X
Maintain sample ecosystems in natural state	1	1	1	1	2	3	1	2	1	1
Maintain ecological diversity and environmental regulation	3	1	1	2	2	2	1	2	1	1
Conserve genetic resources	1	1	1	1	2	3	1	3	1	1
Provide education, research, and environmental monitoring	1	2	1	1	2	3	2	2	1	1
Conserve watershed condition	3	3	3	3	2	3	3	3	3	3
Control erosion, sediment; protect downstream investments	3	3	3	3	3	3	3	3	3	3

Table 3.4 continued..

Primary Conservation Objectives	Category I	II	III	IV	V	VI	VII	VIII	IX	X
Produce protein and animal products from wildlife; permit sport hunting and fishing			2		3	3	3	1	3	
Provide recreation and tourism services		1	2	3	1		3	1	3	1
Produce timber, forage, or marine products on sustained yield basis				3	2		3	1	3	
Protect sites and object of cultural, historical and archaeological heritage		1	3		1	3	1	3	2	1
Protect scenic beauty and open space	3	1	2	2	1			3	2	1
Maintain open options; manage flexibly; permit multiple use					3			3	2	1
Simulate rational, sustainable use of marginal areas and rural development	2	1	2	2	1	3	2	1	2	2

Source: Salm, R.V. & Clark, J.R. 1984. Marine and Coastal Protected Areas: a Guide for Planners and Manager. International Union for the Conservation of Nature & Natural Resources, Morges, Switzerland; 302 pages.

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Instructions:

1. Review all materials provided (1 hour).
2. Set out the characteristics that the Protected Areas System should have (1 hour). These usually include as a minimum those areas considered to be:

   - areas with unique features
   - "national symbols"
   - areas critical to the survival of endangered or economically important species
   - areas of value for natural resource exploitation
   - areas of great value for recreation or tourism
   - areas representative of the island's or region's coastal and marine life zones
   - critical watershed areas
   - major historical or archaeological sites

3. As a group, discuss and design the protected area categories most appropriate to the study area; using Tables 3.4, Appendix 5 and the Data Atlas (see previous exercise), as reference (1.5 hours).
4. As a check on the group's decisions, go through the Data Atlas to see if samples of the most important resources of the island or region would be included in the protected area categories you have designed (0.5 hours).
5. Based on your decisions, draft a matrix of objectives and management categories, and describe each category in narrative form (1 hour).
6. Present the recommendations of the group to a review panel made up of local experts in the subject area (2 hours).
7. Incorporate the recommendations coming out of the review panel session into a final document on management objectives and categories for the Protected Areas System (1 hour).

Product or Results Expected:

1. Matrix showing the objectives and management categories for a Protected Areas System for the island or region.
2. A narrative description of each of the management categories selected.

Interpretation and Application to the Problem Area:

The results obtained by this exercise provide the conceptual underpinnings for the Protected Areas System. The matrix and narrative descriptions define the limits within which the central authorities should manage the most important natural areas of the island or region.

Table 3.5 and Appendix 5 provide actual examples from the British Virgin Islands.

Table 3.5 Criteria for Selecting Areas for Inclusion in a Protected Areas System : Sample List from the British Virgin Islands.

1. Biological Value:	Important to commercial species
	Important to endangered species/ wildlife
	Important to seabird nesting
	Diversity of habitats
	Uniqueness to the Islands
	Representativeness
	Naturalness (not subject to human interference)
2. Economic Value:	Fishery site
	Snorkel/dive site
	Charterboat anchorage
	Hurricane shelter
	Tourism attraction
	Watershed management
3. Social Value:	Cultural significance
	Recreation
	Aesthetics
	Education value
	Research value
4. Urgency:	Vulnerability
	Threat

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Further Reading:

ECNAMP 1986. A Parks and Protected Areas System for the British Virgin Islands. British Virgin Islands National Parks Trust and Eastern Caribbean Natural Areas Management Programme; 90 pages. (Unpublished report, available from ECNAMP).

IUCN 1978. Categories, Objectives and Criteria for Protected Areas. Commission on National Parks and Protected Areas, International Union for the Conservation of Nature and Natural Resources, Switzerland; 26 pages.

IUCN 1980. World Conservation Strategy. International Union for the Conservation of Nature and Natural Resources, United Nations Environment Programme & World Wildlife Fund; 24 pages, source books and maps.

Jacobs, P. & Munro, D.A. (Eds) 1986. Conservation with Equity: Strategies for Sustainable Development. International Union for the Conservation of Nature, Morges, Switzerland; 463 pages.

MacKinnon, J., Graham Child, K. & Thorsell, J. 1986. Managing Protected Areas in the Tropics. IUCN Conservation Monitoring Centre, Cambridge, UK; 295 pages.

Miller, K. 1980. Planning National Parks for Ecodevelopment: Methods and cases from Latin America; 500 pages. (Available in textbook form in Spanish or in xeroxed manuscript in English from the Author, International Union for the Conservation of Nature, Switzerland).

Putney, A.D., Honychurch, L., James, A. and White, D. 1984. Cabrits 2000: Development Concepts for the Proposed Cabrits National Park, Dominica. Eastern Caribbean Natural Area Management Programme and Government of Dominica; 24 pages.

Salm, R.V. & Clark, J.R. 1984. Marine and Coastal Protected Areas: a Guide for Planners and Managers. International Union for the Conservation of Nature, Switzerland; 302 pages.

Thelen, K.D. & Faizool, S. 1980. Policy for the Establishment and Management of a National Park System in Trinidad and Tobago. Forest Division, Government of Trinidad and Tobago; 26 pages.

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Exercise 3.3 IDENTIFYING AND VERIFYING POTENTIAL AREAS FOR INCLUSION IN A PROTECTED AREAS SYSTEM

Background:

In establishing a Protected Areas System, there are two basic questions that need to be answered. Which areas should be included in the system, and how will these be managed ? These questions are the subject of this exercise.

A Data Atlas provides an information overview that facilitates the identification of important natural resource areas to be included in the System. On the other hand, the management categories to be included in the Protected Areas System establish a policy framework, i.e. they define how areas of the System will be managed. However, before hard and fast decisions can be made, more detailed information is required to confirm the suitability of the selected areas and to identify potential conflicts that may arise from current resource use in these areas. This information can be obtained from published sources, unpublished documents, field reconnaissance, and interviews.

Aims:

To define the criteria that will be used to identify potential areas to be incorporated in the Protected Areas System, and to select areas to meet the established criteria.

To verify the suitability of areas preliminarily selected for inclusion in the Protected Areas System through documentation research, rapid field reconnaissance, and interviews.

Duration:

10 - 12 hours, depending on the complexity of the target island or region of the island, will be required for defining the criteria.

Verification will require approximately two weeks; depending on the size of the study area, availability of transport and availability of relevant documentation.

Suitable Location:

Laboratory/Drawing office, and field work using a base facility central to transportation and information networks.

Materials Required:

1. List of criteria for rating potential protected areas, e.g. as simplified from the System Plan for the British Virgin Islands (Table 3.5).
2. Data Atlas, as developed in Exercise 3.1, or similar information.
3. Matrix of management objectives and categories (as from Exercise 3.2 or Table 3.4).
4. Narrative description of the management categories (as from Exercise 3.2 or Appendix 5).
5. Equipment for optical reduction and copying of maps.

Instructions:

Identification of Potential Areas

1. Using Table 3.5 as a reference, define the criteria that should be used to rate potential areas for inclusion in the Protected Areas System of the target island or region (1 hour).

2. Analyse the environmental, socioeconomic, and legal data provided on the natural resources of the study area, to identify potential areas to be included in the System. This can be expedited by the development of a series of transparent map overlays to identify key areas that can achieve the largest number of management objectives. For example, the most obviously important natural areas can be identified by overlaying the following information from a Data Atlas:

   - the larger "relatively natural" areas
   - concentrations of "important marine habitats", "endangered and locally important species", and "natural, cultural, and historical attractions"
   - key watersheds from the "coastal resource use" map
   - large blocks of "publically owned lands"

   Note the boundaries where these various resource values overlap. Areas with the greatest concentration of resource values are assumed to be the ones with greatest value for resource protection. Once these areas have been identified, they should be rated using the criteria that were specified earlier. The areas should be listed in order of priority (2-3 hours).

3. Other areas, which may not have multiple resource values but which have one or two very important

values, should be identified also for inclusion in the System. Examples of such areas include the habitat of endangered species with high symbolic value, or areas of particular aesthetic appeal. The Data Atlas will be of little help at this stage, because the identification of these areas depends on value judgements. In these instances, the opinions of those knowledgeable about local resources may be more important, and can be gained from interviews (4 hours).

4. Present the preliminary list of areas identified to a review panel made up of relevant government officers, scientists, and representatives of non-governmental interest groups such as local conservation organisations, fishermen, the tourism industry, wood-using industries, or other major resource users (1-2 hours).

5. Taking into account the results of the review panel meeting, draft a final map of the areas identified (1 hour).

Product or Results Expected:

Map delineating areas that should be investigated for inclusion in the Protected Areas System.

Interpretation and Application to the Problem Area:

The map of the potential protected areas is used as the basis for narrowing the search for elements to be included in the Protected Areas System. It is one of a series of steps in the planning process from very broad, general information, such as that presented in a Data Atlas, to more detailed levels of information on areas of particular interest. Increasing detail is needed as more precise decisions are made.

An example of a map of potential areas for inclusion in a System Plan from the British Virgin Islands is presented in Figure 3.2.

Verification of Potential Areas

6. Assign an area, outlined on the map of protected areas for potential inclusion in the Protected areas System, to each student or group of students. Discuss data needs as a group, starting with the items indicated in Table 3.3, and come to agreement on a definitive list that is practicable in terms of the criteria being used (Table 3.5, or similar list) and the time available (1 hour).

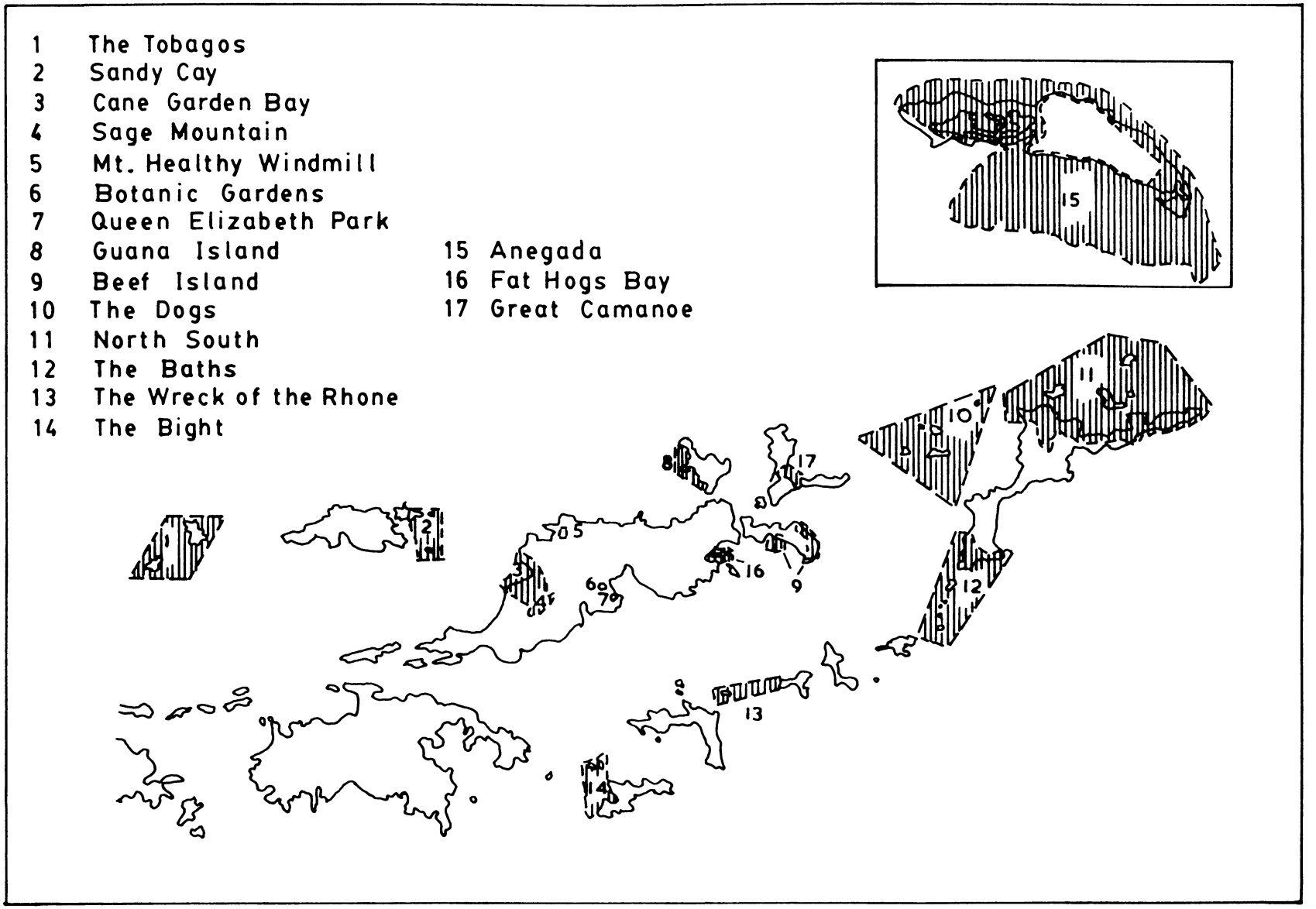

FIGURE 3.2 PROPOSED PROTECTED AREAS SYSTEM - BRITISH VIRGIN ISLANDS

7. Each student or group of students should develop a base map for their assigned area (see Exercise 3.1). Thematic information provided by a Data Atlas or by the instructor should be transfered onto copies of the base map. This information will be checked and supplemented during the exercise (2 hours).

8. Each student or group should carry out documentation research on their area, as follows:

   - sources of information cited in the Data Atlas, or those provided by the instructor, should be noted, and the original documents consulted to get more detailed information on the target area (2 hours).
   - libraries should be consulted for detailed information on the target area (minimum 4 hours).
   - further unpublished documentation should be sought from local management agencies and interest groups, e.g. forestry and fisheries departments; the central planning, tourism and water authorities; local wildlife and conservation societies (minimum 2 days).
   - new information should be added to the thematic maps, and corrections made where necessary. Corrections should be listed for future reference (1 hour).

9. Interviews should be conducted with key resource persons located near the training facility. This should be carried out in conjunction with documentation research. New information and corrections should be noted and added to the thematic maps.

10. Each student or group of students should plan a rapid field reconnaissance (2 hours), as follows:

    - relevant maps should be assembled and appropriately sized base maps prepared (see Exercise 3.1).
    - routes to be followed on land, by water, or even by air, should be planned and sketched on a copy of the base map.
    - particular sites or features to be visited and photographed should be noted and located on the base maps.
    - persons to be interviewed (e.g. resource users, land owners, senior residents), if already known, should be noted and the locations where they can be contacted indicated on the base maps.
    - documents, maps, historic photographs, or other pieces of graphic information to be sought should be listed.
    - data to be collected should be listed. This may

include the presence and range of key species; past and present resource use; histories of important local residents; noteworthy natural, historical, or archaeological features; access routes; dangerous elements; seasonal events, such as weather, wind or current changes, animal migrations or resource uses; pollution sources and dispersion routes; key resource persons; present human population numbers and distribution; etc..

- since time for the reconnaissance will be limited, data needs should be listed in order of priority; and data that can be obtained by other methods (aerial photographs, maps, available documentation) should be deleted from the list.
- data needs should be checked against the list developed during step 2. What data is essential for decision-making at the System Plan level? Are these needs given sufficient priority in the reconnaissance plan ? If difficulty is experienced in defining realistic data requirements, guidance should be sought from the tutor.

11. The rapid field reconnaissance should be carried out by each student or group (approximately 1 week, depending on size of the study area, and availability of transportation). Students should be impressed with the time constraints involved, and not given opportunity for additional field study. In this way they will be encouraged to identify priorities and plan realistically.

12. Interviews are an important part of any rapid field reconnaissance. Students should be sensitive to the differences between urban and rural people, and the ways these differences influence interview procedure. The following general guidelines are suggested:

    - before asking any questions interviewers should identify themselves and state clearly the purpose of the visit. This should be stated in terms that can be understood easily in the local context. For example, stating that the interview concerns "establishment of a protected area system" may not communicate effectively.
    - People are naturally suspicious of strangers asking questions. Considerable sensitivity and tact are required on the part of the interviewer. A certain level of confidence must be reached before important questions can be discussed. The information gathering process will be helped enormously if already known individuals or relatives can be contacted first.
    - While rural people are usually very knowledgeable about the resources that sustain their livelihood,

they may use a vocabulary quite different from a student's. Care must be taken not to talk down to an informant or show any contempt for the vocabulary or expressions used.
- Many people are put off by formal interviews, especially when answers are recorded or written down. Questions are better woven into an apparently informal conversation and answers recorded after concluding the discussion.
- The best informants are often those who receive, or perceive, some benefit from the presence of an interviewer; for example, employees where food or lodgings are taken, guides, or those providing transport services.

13. Information gathered during the field reconnaissance should be noted and added to the thematic maps. Corrections should be made where necessary.

14. Each student or group should make a presentation to a review panel made up of the wider group, or, preferably, local experts from relevant government ministries, interest and user groups. Relevant new data should be presented, and corrections noted. An updating of the resource values assigned, using the criteria presented in Table 3.5, should be made for comparison with other areas (2 hours, depending on the number of groups making presentations).

15. At the end of the presentations, the review panel and students should discuss the individual recommendations, and develop a concensus on the areas recommended for final inclusion in the Protected Areas System (2 hours).

Product or Results Expected:

A map of the target island or region indicating the areas recommended for final inclusion in the Protected Areas System.

Interpretation and Application to the Problem Area

After verifying the suitability of the areas recommended for inclusion in the Protected Areas System, sufficient information will be available for writing a Protected Areas System Plan. Such a plan can be submitted, knowing that enough research has been done to indicate with relative confidence the value of the resources of the recommended areas, their current uses, and what potential opposition can be expected if these areas are included in the System.

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Alternative Exercises:

An alternative to this exercise, which targets a particular island or region, would be to carry out the same steps for an hypothetical case.

This could be accomplished by starting with the Data Atlases already available from ECNAMP for the British Virgin Islands. The results of the exercise could then be compared with the System Plan cited above.

The advantage of this approach would be the reduced time required for preparation of the exercise, and the comparison which could be drawn between the work of the student group and the professionals who carried out this exercise in the British Virgin Islands. On the negative side, this approach would be artificial. Informed value judgements, which play a large part in decision-making for any protected area system, would be impossible since neither the students nor local resource experts would have sufficient knowledge of the resources of the target areas.

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Further Reading:

See reports listed under the preceeding exercise.

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Exercise 3.4 DRAFTING A SYSTEM PLAN

Background:

A System Plan is a document that guides the development of a Protected Area System. It documents the system's **current status**, sets appropriate **goals** and **objectives** for further development, and indicates the **policies, legislation, programmes, personnel** and **budgets** required to achieve the stated goals.

Aim:

To draft a plan for the development of a System of Protected Areas for a given island or region of an island.

Duration:

Approximately 6 days

Suitable Location:

Working from a Drawing Office, the training site should be located near the major town or university of the island.

Materials Required:

1. Model table of contents for a System Plan (as in Table 3.2).
2. Matrix showing the management categories and corresponding objectives for the study area (as from Exercise 3.2 or Table 3.4).
3. A narrative decription of the management categories for the study area (as from Exercise 3.2 or Appendix 5).
4. A list of criteria for selection of potential areas for the Protected Areas System (as from Exercise 3.3 or Table 3.5).
5. Map showing areas identified for inclusion in the Protected Areas System (as from Exercise 3.3 or similar).
6. Base maps and basic data for each of the areas identified for inclusion in the system (as from Exercise 3.3 or similar information).
7. Drafting, copying, and word processing equipment.
8. Current legislation and policy statements regarding parks and protected areas.
9. Information on current budget and personnel levels for management of the Protected Areas System (including government votes, donations from non-governmental organisations, and grants from technical assistance organisations).

Instructions:

1. Review all available information (unless this has been done in relation to previous exercises) (1 hour).

2. Invite relevant government officers to a discussion of the requirements for implementing the Plan (3-4 hours), with specific attention being given to:

   - legislative changes
   - institutional changes, cooperative agreements and concessions
   - management programmes, in areas of research and planning, information, education and awareness, resource management, and institutional development
   - budgetary and personnel implications
   - liability
   - fund raising and land aquisition

3. Provide a standard report format and assign each student or group of students a section of the Plan to be written (8 hours).

4. Produce a first draft of the Plan, using an editorial committee made up of the instructor, a student group leader, and if possible a government representative. The remaining students should prepare the graphics (8 hours).

5. The draft Plan should be copied and reviewed by relevant government officials (e.g. parks officer, district officer, planning officer), representatives of resource users (e.g. Chamber of Commerce, Hotel Association, Fishermens' Cooperative), and a representative of a local environmental organization. The participation of these persons at this critical stage must be arranged well in advance of the training session (1 day).

6. Proposed revisions of the Plan should be discussed by the group as a whole and decisions taken on necessary amendments (2 hours).

7. The Final Plan is drafted and submitted to government by the editing committee (8 hours, assuming word processing equipment or typing facilities are available).

8. The students should present the Plan at a seminar to which key government officials, resource users, and members of environmental organisations have been invited. An overhead projector could be used to project graphics (8 hours, including preparation time, organisation, and delivery).

Product or Results Expected:

1. A formal document outlining a plan for development of a Protected Areas System for the target island or region.
2. An oral presentation on the contents of the System Plan to concerned parties.

Interpretation and Application to the Problem Area:

Once the System Plan is developed, attention can be turned to the further study and legal establishment of each area contemplated in the plan, and to the development of the required institutional base.

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Alternative Exercises:

1. In those cases where a System Plan for the target island or region exists already, that plan can be reviewed and updated as necessary following the steps outlined in the exercise above.

2. The preparation of a System Plan can form the basis of a training exercise without the participation of such a wide range of external participants. The instructor must then brief the students more fully or provide further backgound information. This will detract from the value of the exercise as given, but reduce the required time considerably.

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Further Reading:

The same sources as for Exercise 3.2.

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B. STUDIES OF MANAGEMENT ALTERNATIVES

Introduction:

The study of management alternatives is a tool for making sound recommendations for legal declaration of a specific protected area. It is often difficult to decide how much information is required for this step in the planning process, but, as a minimum, the study should provide sufficient information to make recommendations on the appropriate management category, boundaries, and management concept for the area. A draft decree for establishment and legal protection should be included in the study. It should be borne in mind, however, that it may be unwise to invest human and financial resources in a detailed study until the area has been declared part of the island's Protected Areas System.

Before a protected area can be brought into the system, it must be justified and the various alternatives for management considered (Diamond, 1975). This justification must then be approved by the competent authority and enabling legislation or decree emitted.

The following exercises are designed to provide students with the concepts and experiences needed to carry out a study of management alternatives for a proposed protected area of a tropical island. The exercises can be carried out in their totality only if a relatively small area is selected for this study.

To carry out all the exercises, the students will need to be familiar with the following concepts or skills:

- the place of the study of management alternatives in the overall planning process
- management by objectives
- management categories and their differences
- information gathering and analysis through documents, maps, charts, and aerial photographs, interviews, and field reconnaissance
- requirements for the legal declaration of parks and protected areas

The complete study of management alternatives can be carried out in about a week (more or less 5 working days) if properly prepared in advance and conducted as a team project and if a relatively small area is selected. The students will need to be accommodated near to the study site and have access to transportation.

Materials Required:

1. Matrix showing categories of protected areas and conservation objectives (Table 3.4)
2. Summary of current legislation applicable to parks and protected areas in the island under study.
3. Reference library of relevant documents, maps, charts, and aerial photographs.
4. Island or regional System Plan for Protected Areas (if available; or if prepared under Chapter 3A).
5. Simple drafting and mapping materials and equipment.
6. Typing or word processing services, or equipment.

If it is not possible to complete the entire set of exercises as outlined, portions of it can be undertaken separately. The instructor can fill in the information that the students would have generated from the omitted activities. While leaving out the field reconnaissance portion of the exercises will condense them considerably, this portion is perhaps the most important. It exposes the student to real situations and provides experience in dealing with natural resource issues within the context of rural societies.

Exercise 3.5 SELECTING A PREFERRED MANAGEMENT ALTERNATIVE FOR A PROPOSED PROTECTED AREA

Background:

The study of Management Alternatives for a specific Protected Area is conducted at an intermediate level of detail; more detailed than the System Plan, but less detailed than the Management Plan. The detail is found not so much in the quantity of background information provided, as in the quality of analysis. Thus, the analysis of the potentials, limitations, and constraints for management of a natural area is the central feature of the study of management alternatives.

The overall aim is to provide information needed for drafting legislation for legal protection of an area identified in the Protected Areas System Plan. This requires analysis of the resources and their use within the particular Protected Area, evaluation of **alternative strategies** for management, recommendations for a **preferred management alternative,** definition of **boundaries** of the management unit/s, and elaboration of a general **management concept.**

Stage 1

Aim:

To conduct an analysis of the main potentials, limitations and constraints for management of a proposed Protected Area.
To produce a well documented analysis of the characteristics of a proposed Protected Area and their implications for management.

Duration:

Two days, if the required information is available.

Suitable Location:

The exercise can be conducted at a base facility central to information and transportation networks.

Materials Required:

1. Model outline of a study of management alternatives (Table 3.6).
2. Information summaries developed as part of Exercise 3.3, or similar information.

Table 3.6 Outline of Management Alternatives, Cabrits Development Area, Dominica (Source Putney,1983)

SUBJECT	OBJECTIVE	ALTERNATIVES	PROS	CONS
1. Development Control, Area Adjacent to Peninsula	Maintain environmental quality especially with respect to sediments, sewage, maintenance of present coastal current patterns, and aesthetic considerations in all of control area including slopes adjacent to the peninsula and Douglas Bay.	a. Utilize presently existing mechanisms of development control exercised by the Physical Planning Department.	a. Requires no new legislation.	a. Department does not have sufficient personnel and infrastructure to enforce standards at present.
		b. Seek new legislation giving broad oversight powers to a new statutory body such as a Cabrits Development Authority which would coordinate development activity of the whole area.	b. Would enhance integration of development control function with management of the National Park, and increase on-site enforcement.	b. Would require new legislation; higher cost.
2. Establishment of a National Park or other protected area	Manage the complex of marine, historical, recreational, and biological resources as a unit under government administration for social and economic development while maintaining the quality of the resource base.	a. Include in a National Park the historical area, the marine areas adjacent to the peninsula and Douglas Bay, and the public lands of the swamps.	a. Would integrate management of all critical historical, natural, and recreational resources of the area and strenghten development control of approved projects in the swamp.	a. Would limit new developments of the swamp area to projects compatible with a park environment.
		b. Include in a National Park the historical area, the marine areas adjacent to the peninsula and Douglas Bay.	b. Would integrate management of the historical & recreational resources of the area.	b. Would lessen control of development in the swamp area.
		c. Include in a Historical Monument the historic area of the peninsula.	c. Would provide management for the historical resources.	c. Would leave areas adjacent to historical area open to inappropriate development possible damage to

MANAGEMENT ALTERNATIVES, CABRITS TABLE 3.6 (Continued)

SUBJECT	OBJECTIVE	ALTERNATIVES	PROS	CONS
				recreational and fisheries resources.
3. Development concept	Provide a coherent overall vision of the kinds of development that would be sought.	a. Encourage appropriate cultural and educational activities within the National Park or Historical Monument, but limit all visitor accommodations to areas adjacent to the Park.	a. Gives priority use of historical and recreational resources to educational and cultural development of Dominicans.	a. May lessen incentives to commercial enterprises and sacrifice revenues that could be used for development of the educational infrastructure
		b. Balance appropriate cultural and educational activities within the National Park or Historical Monument together with visitor accommodations and other commercial ventures which properly fit into the historical and natural environment.	b. Provides for balanced use of the histotorical, and recreational, and natural resources and and management of the natural and recreational resources.	b. Can tend to domination of the area by expatriots and foreign visitors, with many benefits accruing to non-Dominicans.
		c. Encourage appropriate commercial activities within the National Park or Historical Monument together with visitor accommodations and other commercial ventures which properly fit into the historical and natural environment.	c. Stimulates a rush of commercial activity that will create jobs over the the short run.	c.-Probably would lead to expatriot domination. -Would probably lead to a degradation of the historical, recreational and natural resources and a reduction in employment over the long run. -Educational and cultural uses by Dominicans would be sacrificed. -Would require investments in major infrastructure development.
4. Institutional Responsibi-	Provide a practical framework for the	a. Managing the area within existing legal framework:	a.-Would not require new	a.-May unnecessarily constrain

MANAGEMENT ALTERNATIVES, CABRITS TABLE 3.6 (Continued)

SUBJECT	OBJECTIVE	ALTERNATIVES	PROS	CONS
lities	development, administration, and conservation of the area.	Physical Planning for development control of the wider development area and National Parks to manage the National Park area, and an inter-institutional Advisory and Coordinating Committee.	legislation. -Could utilize presently employed personnel but also technical and financial assistance from international organizations.	commercial activities and local participation. -May not create dynamic for private investinvestment or attract private grants.
		b. Manage area under existing legislation, but create private foundation and delegate considerable authority for commercial, educational, and cultural activities.	b.-Would only necessitate creation of new foundation or use of existing foundation. -Foundation would be able to maintain independence necessary to facilitate rapid development of commercial, educational, and cultural activities. -Would maintain Government control over general policy, but facilitate development activities.	b. Would require technical and financial assistance for rapid development of foundation.
		c. Establish a semi-autonomous Cabrits Development Authority with overall responsibility for development and conservation of the area.	c.-Authority could potentially generate its own funds after initial development period -Would concen-	c.-Would require new legislation and a period of technical and financial assistance. -Would sidestep and weaken existing government

MANAGEMENT ALTERNATIVES, CABRITS TABLE 3.6 (Continued)

SUBJECT	OBJECTIVE	ALTERNATIVES	PROS	CONS
			trate authority and thereby encourage a rapid and coherent development of the area.	departments. -May cause Government to eventually lose control over policy to commercial interests.

3. System Plan developed in Exercise 3.4, or similar information.
4. Simple drafting and mapping materials and equipment.
5. Typing or word processing services, or word processing equipment.

Instructions:

1. Review the information summary maps on one of the target areas developed during Exercise 3.3, or similar information (1 hour). If available, students who studied the target area during Exercise 3.3. should present the information to the class.

2. A field trip to the target area should be organised, so that all class members get a feel for its resources, their uses, and current and potential conflicts (1 day, or more depending on the area involved). As above, the students who studied the area as part of the earlier exercise should take a lead role in organising this trip.

3. Each student, or group of students, should be assigned a section of the "background information" from the Data Atlas or other materials produced during the study. Each student or group should analyse the information and determine the implications for management (2 hours). Students should list the facts and assumptions which are thought to represent potentials, limitations or constraints for management of the area. Students should go through the list and ask: "What is the significance of this fact or that assumption for management ?", "How does it influence our decisions or alter our perceptions ?". The answers to these questions give the planner what is needed for making decisions.

4. Each student should then write up his/her subsection of a "background" chapter (1 hour). Information pertinent to decision-making should be highlighted. For each topic discussed, the implications for planning and management should be noted. If no implication is obvious, then the information should be left out; for example, an indication that three sand types are found in the study area is of no value unless we know how the specific characteristics of these sands have implications for management. Which sands form the best beaches, or which are probably breeding habitat for biting sandflies, and what does this imply for their potential uses? These are the types of questions that need to be covered in this part of the exercise. Experience indicates that analysis is the most difficult aspect of planning for students. It

requires a rather broad spectrum of knowledge, and logical reasoning. Students may require considerable assistance during this phase of the study, and should be encouraged to consult with resource persons.

5. Each student, or group, should present his/her subsection to the class for critique (3 hours). Is the paper concise ? Has extraneous or unimportant information been presented without its associated management implications ? Have the most important facts and assumptions been selected over the trivial or less important ?

Product or Results Expected:

A document analysing the characteristics of the proposed Protected Area and their implications for management should be produced which will provide the information needed to determine the alternatives available for management.

Stage 2

Aim:

To identify and define the various alternative management strategies for a potential Protected Area.

Duration:

4 - 6 hours of classwork.

Suitable Location and Materials Required:

As in Stage 1.

Instructions:

1. Review the general management categories, and their characteristics, presented in the System Plan (Exercise 3.4) and the preceding analysis of potentials, limitations and constraints for management of the area.

2. Review the sample outline of management alternatives for the Cabrits area of the island of Dominica (Table 3.6) and the alternative management structures for the Baths area of the British Virgin Islands (Table 3.7). Note how the most urgent issues and options are systematically defined.

3. Groups of students should independently define the

issues and options for the target area being studied. These will vary considerably from one part of the area to another, but generally will fall under the headings of objectives, management authority, development control in buffer areas, boundaries, zoning, access, facilities, activities, management programmes, and revenues.

4. The instructor should then group the issues and options identified by the students and present them in outline form to the class. Through discussion the class should arrive at a consensus on the most relevant issues and options, and put them into a single outline similar to the examples shown in Tables 3.6 & 3.7.

5. Each student should be assigned the task of reviewing the outline of issues and options with a relevant resource person (e.g. government officer, representative of major user group, land owner, local politician).

6. Later in the day, or at a later class session, students should report on the reaction of the individuals interviewed. They should decide if the outline needs to be changed in the light of the resource persons' inputs and, if so, draft a new outline document.

Product or Results Expected:

An outline of the major issues and options for management of the proposed Protected Area.

Interpretation and Application to the Problem Area:

The outline statement provides a stimulus for defining the various alternatives for management of the target area. It is only a stimulus, however, because the definition of alternatives requires a clear understanding of the possibilities. In the context of small developing island nations, these are not usually clear, and there is often no base of experience to guide planners. The question for discussion is how far one should go in making assumptions about the capabilities of institutions, the ability to bring on trained staff, the feasibility of aquiring key pieces of land, or of taking control over areas of coastal waters.

Table 3.7 Alternative Management Structures for the Baths Protected Area, BVI (Source ECNAMP, 1986)

ISSUE	DESCRIPTION	OPTIONS	PROS	CONS
Management Authority	Who is responsible for management of the area? Related issues: -law enforcement -development control -land management	1. Have management regulated by planning controls and existing laws.	No new legisla- required. No new management structure required.	Existing enforcement capability inadequate. Interest groups (NPT, land owners, commercial users) have no input. No coherent management of overall area. Use conflicts.
		2. Have management regulated by NPT.	Simplifies management of whole area under one set of criteria.	Existing NPT resources, including law enforcement capability and budget, inadequate. Requires new legislation. May create conflict with local interest groups and landowners.
		3. Establish joint management authority for area comprised of representatives of NPT, Planning, private landowners, commercial users and local residents.	The needs of all interest groups can be discussed and solutions arrived at by consensus. Cooperative service facilities, such as as garbage collection, allow more effective operation.	Decision-making can be unwieldy and time consuming. May be impossible to enforce decisions of management authority. Requires new legislation.
Development control	How will land use by regulated? By whom?	1. Have land use regulated by planning controls and existing laws.	No new management structure required.	Requires improved coordination between government bodies, increased law enforcement capability and greater political will.

Table 3.7 continued...

ISSUE	DESCRIPTION	OPTIONS	PROS	CONS
		2. Landowners to develop covenants for land use.	Would control development with minimum government involvement.	Would not provide coordination for overall management of area and limits involvement of NPT and Planning. Would not regulate location, kind, or quality of developments.
		3. Develop a common set of controls for low density development and use for entire area.	Would provide one set of criteria for development. Standards for environmental quality would be set and regulated for the entire area.	Would limit option of landowners for development of their property. Requires increased political will to withstand pressures from landowners.
Boundaries of Protected Areas	Assuming a park or protected area will be created, what areas should be included in it?	1. Maintain existing boundaries of national parks within study area and create additional parks at the Baths and the Copper Mine.	Would require minimal new legislation.	Would make overall management of area difficult. Would not allow control of marine activities.
		2. Create a Baths National Park that includes present park areas, that Baths proper, Copper Mine Point, a coastal strip from Fort Point to Devils Bay, and a marine area including all cays south to Round Rock.	Would permit integrated management of critical coastal areas.	Would require purchase of easement along coastal strip on private lands or other commitment from landowners. Would not allow for adequate control of development in watersheds behind coastal strip.
		3. Create a Baths National Park that includes all land area from Fort Point south to Devils Bay and east to Copper Mine Point, as well	Would control development in the most environmentally sensitive	Would require purchase of privately owned lands or other commitment from landowners.

Table 3.7 continued...

ISSUE	DESCRIPTION	OPTIONS	PROS	CONS
		as an offshore marine area that includes all cays south to Round Rock.	marine, cosatal and terrestrial areas.	
Trail Access	Along the coast, to attractions.	1. Improve present arrangement of trails leading off road.	Least additional cost.	Limited access and continued concentration of use.
		2. Build loop trail to connect the Crawl, Spring Bay, and the Baths; improve trail to Devils Bay; and build a trail connecting the Baths road to the Copper Mine.	Would cost less while improving access to major attractions.	Access would only be partly improved. May require purchase of easement.
		3. Create a coastal trail for public use.	Would improve access to areas now difficult to reach, such as Fort Point, and from beach to beach. Would improve aesthetic experience of users. Would spread usage of beaches more evenly.	Would reduce privacy and increase litter problem by spreading it over a wider area. Would necessitate expense of building and maintaining trail over very difficult terrain. May require purchase of easement.
Facilities	Includes restrooms, garbage collection, concessions.	1. Simple, basic facilities provided on public lands by NPT.	Would provide visitors with basic facilities. Would not require collaboration with landowners.	Would require initial expense and constant maintenance Would not provide easy access to facilities for the majority of visitors to the area.
		2. Issue a controlled number of private concessions at specific points, and control kind, location, and quality.	Would increase facilities available to visitors while solving sanitation problems. Would make pos-	Would limit flexibility of commercial ventures.

Table 3.7 continued...

ISSUE	DESCRIPTION	OPTIONS	PROS	CONS
			sible overall management of area. Would not require outlay of scarce NPT resources.	
		3. Permit unregulated businesses on private land.	Would provide facilities for visitors. Would not require outlay of scarce NPT resources.	Might not solve sanitation problems or overcrowding. Would make overall management of area impossible.
Revenues	Required to assure proper management and maintenance.	1. Collect commercial user fees from charter boat, dive tour, and land-based operations.	Those using the the natural resources would contribute to their maintenance.	Would place burden of fees on commercial users. Would require fee collection system.
		2. Lease concessions while seeking cooperative solutions to management and maintenance.	Would probably provide very cost-effective management while assuring that those using resources would contribute accordingly.	Would require constant dialogue among concessioners, management authority commercial users, and other cooperators.
		3. Make agreements with commercial users to voluntarily provide all desired services.	Would not necessitate structures for fee collection or concession leasing.	Would require constant dialogue and full cooperation of commercial users.

Stage 3

Background:

Selection of a preferred management alternative follows once the issues and options have been defined clearly. A planner may agonize over the options and feel a responsibility to come up with the "correct" answer. However, in management, there are no "correct" answers, only a range of options. Once the planner sees his role as being to clearly identify those options, and their probable consequences, and to structure the decision-making process so that all relevant parties make knowledgeable inputs, then he will make more progress. The planner's responsibility is not to make the decision, but rather to make sure that relevant information, and the interests of all elements of the management community (resource users, interest groups, managers, researchers, administrators, politicians) are presented accurately and taken into account in the decision-making process.

Aim:

To gain familiarity with the process of selecting from a variety of alternatives a preferred management strategy for a potential Protected Area.

Duration:

4 - 6 hours of classwork, plus preparatory work by groups.

Suitable Location and Materials Required:

As in previous stages of the exercise.

Instructions:

1. The class should divide into teams representing resource users (e.g. fishermen, hoteliers), interest groups (e.g. the local conservation society, or mayor of a neighbouring community), resource managers (e.g. a local fisheries or forestry officer), administrators (e.g. the Permanent Secretary or Commissioner of a ministry or department of government), researchers, and politicians. Each team should take the role of the group it represents and defend its interests against the others.

2. Each team should define the preferred management strategy (based on the interests of the group it represents) in terms of objectives, zoning,

management programmes, development cost projections, expected revenues, cooperation with other agencies, and relations with adjacent land use.

3. With the instructor using his skills as moderator, the class should reach a consensus on a preferred management strategy that all groups can accept (2 hours).

4. After consensus is reached, the students should reflect on the exercise, pinpoint which groups had the greatest differences, and analyse why the differing positions were held. They should also try to determine how compromises were reached and how consensus was built (at least 1 hour).

5. The class should then appoint an editing team to write up the details of the preferred management strategy (as agreed by all groups) (2 hours).

6. While the editing team is doing their write-up, the balance of the class should form a legal team to note the elements that should be included in the legislation declaring the protected area. As a minimum, this should include a description of the boundaries of the area, the defined management category for the area, and a brief summary of the management strategy for the area (1 hour).

Product or Results Expected:

A description of the preferred management alternative for a potential Protected Area and a preliminary listing of the elements that should be included in the legislation to declare the area.

Interpretation and Application to the Problem Area:

The study of management alternatives provides the minimum information required to officially declare a Protected Area. Once the study has been completed, it can be reviewed at the technical levels of government and, once approved, promulgated by the legislative arm of government and passed into law.

Alternative Exercises:

As an alternative approach, a public hearing could be staged, in cooperation with the competent authority for Protected Areas. At the training course hearing, interested parties could be asked to give their views on the preferred management option for the area in question, and a consensus position sought. Students could act as facilitators and observers by clarifying and tracking positions of the various interest groups, and by analysing

how consensus is built. After the hearing, the instructor could guide the students in analysing the dynamics of the process, and in writing up the consensus that emerges.

Further Reading:

ECNAMP 1986. The Baths - a Management Strategy for the Proposed Protected Area. Eastern Caribbean Natural Area Management Programme; 17 pages.

McEachern, J. & Towle, E.L. 1972. Resource Management Programs for Oceanic Islands. Transactions of the 37th North American Wildlife and Natural Resources Conference, March 1972, Washington; 145 - 159.

Putney, A.D., Honychurch, L., James, A. & White, D. 1984. Cabrits 2000 - Development Concepts for the Proposed Cabrits National Park, Dominica. Eastern Caribbean Natural Areas Management Programme & Government of Dominica, ECNAMP Report No. 2; 24 pages.

Other sources as in previous exercises in Chapter 3.

* * *

Exercise 3.6 DRAFTING A DECREE FOR ESTABLISHMENT AND LEGAL PROTECTION OF A MULTIPLE-USE AREA.

Background:

Recommendations on boundaries, management category and preferred management strategy can be used to synthesise a draft decree for legal declaration of a protected area. The final drafting of legal documents will be done in the equivalent of an Attorney General's Office, but it is important for coastal zone planners and managers to be involved at the drafting stage. This ensures that the draft reflects the management objectives and contains accurate technical details, but it must be remembered also that the manager may later be responsible for administering the regulations which he is drafting.

Legal provisions for protection of a natural area can be in the form of (a) **International Conventions**, administered in conjunction with other neighbouring or interested countries and agencies, (b) **Laws**, administered within the state by the central government, or (c) **Bye-laws**, formulated and administered by local government or corporations. All three categories of regulations may be appropriate in the management of a protected area. In general terms, all three categories contain similar clauses in a similar order of priority. The following exercise examines the components of regulations which help achieve some of the objectives of coastal area management. These will be at the level of a national law for establishment and protection of the resources of a Multiple-use Area.

Aim:

To analyse and draft essential components of Natural Resource Area legislation.

Duration:

One day.

Suitable Location:

Drawing Office/Laboratory.

Materials Required:

Data Atlas for a selected Multiple-use Area (see Exercise 3.1).
List of conservation objectives for a Multiple-use Area in order of priority (Table 3.4).

Summary of management objectives.
Summary of chosen management strategy (see Exercise 3.5).
Copies of already existing, similar laws (to study suitable wording).
Writing materials and equipment.

Instructions:

1. As a group, or by assigning tasks to individuals, prepare statements/clauses appropriate to the following components of a proposed law:

   a. **Title** - a brief statement declaring the subject of the law. (A date will be added when the law is gazetted).
   b. Statement concerning the **relationship to previous laws** on the same or similar subjects, e.g. "These Regulations replace those of Act No. .... of 1941".
   c. **Definitions** - A statement, or listing, of precise boundaries of the Multiple-use Area; of technical terms, such as "Fisheries Zone" or "wildlife"; and of species which are given special status. If the number of species referred to is large, they can be listed in "Schedules" at the end of the document, e.g. "1st Schedule: Animals which may not be hunted".
   d. **Regulatory Clauses** - A series of clear, unambiguous statements explaining what <u>can</u> and <u>cannot</u> be done in the area. Great care must be taken in formulating these clauses so that loopholes are not left in the law. A Statement such as "No person may hunt a protected animal" can be strengthened by changing it to "No person may catch, kill, or cause to be caught or killed, or have in their possession or offer for sale, any protected animal or part of a protected animal", for example.
   e. **Punishment Clauses** - the punishment for offences against these regulations must be stated. This is usually in the form of a monetary fine or period of imprisonment, but in both cases a <u>maximum</u> must be stated. It is important that the size of the fine is realistic; for example, if it is in punishment for trading a female lobster bearing eggs, it must be related to the market price for a lobster of that size.
   f. **Identification of Enforcement Officials** - The officers designated to enforce the law must be listed and their powers of arrest clarified.
   g. **Exemptions** - In some cases it may be necessary to grant exemptions to the regulations. For example, to give rights of entry to a protected

area by inspectors or by scientists engaged on valid research projects. The latter might include rights to collect specimens of protected species for research. In stating exemptions, the procedure for obtaining the necessary permit must be explained.

h. **Amendments** - The minister responsible for administering the regulations should be empowered to modify clauses or make additional regulations from time to time, provided this does not alter the 'spirit' of the law.

i. **Supporting Documents** - It may be appropriate with a proposed coastal protected area to append a navigational chart or map, which can accompany the schedules of special species or other appendix-like material.

2. As a group, coordinate individual clauses into a main document, review it, and finalise for presentation to local agency personnel for their comments.

* * *

C. MANAGEMENT PLANS

Introduction:

Management plans are documents which guide the development and management of a park or protected area in accordance with the decree or legislation which mandated its establishment. They should not be a compendium of information, but rather concentrate on the analysis of **resource values** and **potentials**, and prescribe the measures that will be taken to protect and develop these resources.

A model table of contents for a management plan is presented in Table 3.8. This is a simplified model and needs adaptation to the situation of each park or protected area.

Parks and protected areas are not "set aside" from use, but rather are actively managed to protect their resources and produce specific goods and services. The particular mix of goods and services that is expected should follow from the management category of the area (National Park, Wildlife Sanctuary, etc.) and the text of the legal instrument designating the area. How the mix of goods and services is to be obtained from the areas is prescribed in the managment plan.

The exercises which follow are designed to familiarise the students with the concepts and tasks required to manage a park or protected area, and teach the student how to set them down in an orderly fashion in a management plan. The exercise is only practicable if is carried out in a relatively small park or protected area. Since many of the skills required to develop a management plan have been covered earlier in this chapter, the exercises which follow focus on two key aspects not yet addressed - zoning and the design of management programmes.

To be able to develop a management plan, students will need to be familiar with the following concepts:

- the overall planning process (Table 3.1) and steps in the development of a plan (Table 3.9)
- management by objectives
- the different management categories and their objectives
- the park and protected areas system plan for island or region (if available)
- use of maps, hydrographic charts, and aerial photographs
- mapping and overlaying of technical data
- field reconnaissance and interviewing techniques

Table 3.8 Management Plan Outline

I. Introduction

- A. Location
- B. Legislative mandate
- C. Previous planning work
- D. Importance of the area

II. Synthesis of Background Information

- A. Biophysical features
- B. Cultural features
- C. Resource use
- D. Limitations and constraints

III. Management and Development

- A. Objectives
- B. Boundaries
- C. Zoning
- D. Management programmes
  1. interpretation and education
  2. research and monitoring
  3. recreation and tourism
  4. resource protection
- E. Administration and maintenance
  1. enforcement
  2. concessions and permits
  3. maintenance
  4. institutional arrangements
- F. Integrated development
  1. development areas
  2. personnel
  3. institutional relations
  4. general development map
- G. Development schedule

Literature Cited

Appendices

- A. Site plans for development areas
- B. List of key references

Table 3.9 Steps in the Development of a Management Plan

1. Review work already undertaken

   - Background information
   - Study of management alternatives
   - Management strategy
   - Preliminary implementation plan
   - Other research

2. Identify for whom planning is being done (user group).

3. Compare the stated goals and objectives of management with the present situation and identify issues, needs, and activities that relate to each objective.

4. Field reconnaissance.

5. Map location of existing stresses and activities by objective.

6. Public review of information, objectives, and expression of needs.

7. Incorporate public input into objectives, issues, and activities.

8. Define management requirements

   - areas of conflict
   - issues to be addressed through area management and regulation
   - use zones
   - development areas
   - infrastructure required outside of development areas
   - personnel requirements
   - synthesis of management programmes

9. Prepare site plans for development areas.

10. Draw up composite development sequence and cost.

11. Draft and distribute preliminary plan.

12. Interdepartmental and public review of plan.

13. Synthesis of final plan.

.....

- basic administrative organisation

Materials Required:

- model management plan outline (Table 3.8) and description of steps in the development of a management plan (Table 3.9).
- matrix showing categories of protected areas and conservation objectives (Table 3.4).
- narrative description of protected area categories (e.g. Appendix 5).
- summary of current legislation applicable to parks and protected areas in the island.
- reference materials on area to be planned (maps, charts, aerial photographs, previous studies of the area, documentation including data on area, etc.).
- multiple copies of a standard base map for the study area.
- simple drafting and mapping materials and equipment.
- typing or word processing services, or equipment.

Exercise 3.7 ZONING A NATURAL AREA FOR MANAGEMENT PURPOSES

Background:

Many types of managed natural areas will be designed for multiple uses, in which a range of activities can be expected to take place simultaneously or periodically. As Table 3.4 indicates, there may be primary and secondary objectives to be achieved, with the possibility of some conflict resulting. Consequently, activities must be conducted in an ordered manner, to reduce management problems and to avoid deterioration of the resources under protection. The usual way of accomplishing this is to divide the park or reserve into a number of clearly demarcated **zones**, in which only certain activities can take place.

The terms used to describe the zones vary from one country to another, but are based on the same general principles. The nomenclature used by Thalen and Faizool (1980) in their plan for protected areas in the islands of Trinidad and Tobago can be taken as a model. An area is set aside as the **Scientific Zone**, from which the public are excluded totally. This ensures that natural systems and processes continue without interference; this zone would be an important part of Strict Reserves or Biosphere Reserves, and is likely to be located distant from centres of human disturbance. Related to this might be a **Wilderness Zone** in which visitors would be permitted access, but the area would not be developed, i.e. visitors would have the opportunity to experience ecosystems in their natural state. Other parts of the protected area would be included in an **Extensive Use Zone**, in which visitors would be able to spread out and enjoy the resources with the help of special facilities. Provision of guides, tour boats, marked nature trails, board walks and explanatory notices would ensure extensive access throughout this zone. The point or points at which visitors to the park were received would need to provide other facilities, such as parking space, toilets, refreshment outlets or souvenir stalls. These would be **Intensive Use Zones**, with concentrated infrastructure and visitor use. Depending on the status of the resources of the park (see Exercise 4.4), it might be necessary to close off some areas in order that they, or component species, recuperate from previous impacts. **A Recuperative Zone** was used for a portion of the Caroni Swamp National Park, Trinidad, which had been damaged by attempted reclamation, as shown in Figure 4.2.

As an example, in designing a zoning plan for a recreational area, it is necessary (a) to decide what is needed to protect the resources, (b) what visitors are

hoping to see or experience in the protected area, (c) what activities can take place in particular regions, and (d) to establish boundaries that can be clearly distinguished in the field. The following exercise examines some of these aspects, with reference to a coastal park.

Aim:

To produce a zoning scheme for a protected area, in accordance with the designated management objectives.

Duration:

One day.

Suitable Location:

Drawing Office/Laboratory, supported by field visits as necessary.

Materials Required:

All materials used in the previous exercise.

Instructions:

1. Review all materials from the relevant Protected Areas System Plan (see Chapter 3A) and the study of management alternatives (see Chapter 3B), or equivalent information derived from other sources.

2. Develop a plan for supplemental data gathering where necessary (documentation, interviews, and field reconnaissance).

3. Review the specific objectives for management of the area, which have been selected from alternatives discussed in Exercise 3.5.

4. List the management implications of the stated objectives, e.g. if wildlife protection is an objective, it will be necessary to establish a Scientific Zone or equivalent.

5. Identify and map the area or areas where each objective can be realised. Select key areas for activities under each objective, i.e. there may be three or four sites around a mangrove swamp or lagoon where visitors could watch waterfowl. Isolate those sites where visitor activity might disturb the birds for some reason, such as during the nesting season, and choose where it would be easiest to

build observation platforms; place all suitable areas within an Extensive Use Zone, or equivalent.

6. Note (a) opportunities for resource development (see Ex. 3.3.) in the various zones. (b) constraints (see Ex. 3.5), e.g presence of inhabitants or present land-use, or previous resource depletion. (c) any external influences which impact on a zone or its resources. These might be pollution inputs, navigation lanes, rights of way.

7. In the light of 3 to 6 above, define major management zones and zone boundaries. Indicate these on a study area base map.

8. Outline management specifications for each zone.

9. Within each zone where physical facilities will be required, e.g. mooring buoys or board walks, areas which lend themselves to physical development should be noted and mapped as potential "development areas". To these should be added those sites which will be needed for administrative facilities.

10. The physical developments that will be required in each development area should be indicated, and, based on expected levels of resource use, the required capacities should be estimated.

11. Summarize the management requirements for each of the zones suggested.

* * *

Exercise 3.8 DESIGNING DEVELOPMENT AND OPERATIONS PROGRAMMES FOR PROTECTED AREAS

Background:

In order to outline a full development programme it is necessary to integrate the implementation of the management programmes into a **development sequence** (Table 3.8). Physical, institutional and personnel development must all be addressed. Diagrams or flow-charts giving an overview of all planned development can then be drafted. These would include a chronogram and budget estimate.

Aim:

To identify the logistic requirements for operation of a Protected Area.

Duration:

Two Days (minimum).

Suitable Location:

Drawing Office/Laboratory exercise.

If possible, a field visit should be made to the site of a proposed Protected Area in the host island.

Materials Required:

Either all materials prepared for preceding exercises, or the plans for a proposed Protected Area (including a statement of the management objectives and the zoning scheme).

Instructions:

1. Review the management plan prepared for the selected Protected Area.

2. Define the nature and extent of the (a) Environmental, and (b) Public Use Programmes. Estimate, and list, all infrastructure and facilities which will be needed to run these programmes. If structures like notice boards, viewing towers or tour-boat docks are to be constructed, identify the materials which will be used and estimate quantities as accurately as possible (using information provided by the instructor, or through enquiries at local

businesses).

Make a list of the inputs that will be needed if structures are to be provided for the Park's programmes; e.g. architects, building contractors, surveyors.

3. The day-to-day running of the Park facilities should be reviewed, to decide on personnel, equipment and financial implications. There may be a need for a vehicle, secretarial assistance, water and electricity supplies, for example.

4. A development programme should be designed, i.e. a chronogram showing the dates when activities are expected to commence, or to be completed. This could be in two parts, to deal with developments within the first year of operation and with long-term development of both conservation , public use and research. The activities of the development programme should be translated into cost estimates for each phase of development.

5. A funding strategy, based on cost and revenue estimates, should be defined, drawing on all possible sources.

6. Personnel requirements should be defined for all aspects of Park management. Staffing should be phased into the development scheme, and should include provision for training.

7. Development controls should be outlined, so that implementation relates to the original plan, and impacts on the natural and cultural resources are avoided.

8. All sections of the plan should be assembled into one document by a drafting committee. The steps in the development of this plan are summarized in Table 3.9, and an example of a management presented in Table 3.10.

9. The draft plan can be presented to interested governmental officers, land owners, representatives of interest or user groups, and researchers for review, provided this has been organised well in advance of the exercise. The drafting committee can then revise the draft and produce a final version of the plan for distribution. Alternatively, the draft can be reviewed and finalised by the trainees, directed by the instructor.

Table 3.10 Example of Selected Management Programmes for a Small Marine Park in the British Virgin Islands

1. Research and monitoring

Research carried out within the Park will be of two types: that carried out by or on behalf of the National Parks Trust with the aim of improved management, and that carried out by outside investigators. The Trust's applied research programme will consist of research on existing management problems (first priority), and subjects relevant to management that may be related to existing problems or may lead to later problems. Research programs that require immediate implementation are:

1. Investigation of existence and damage caused by introduced species on Dead Chest Island.
2. Inventory of wreck artifacts.
3. Assessment of potential impact of a trail at Dead Chest on seabird nesting.

All research carried out by outside investigators is subject to approval and supervision by the Trust. The Trust will assist and facilitate research that is directly relevant to management of the Park. Other requests to carry out research will be reviewed on a case by case basis, and approved or denied based on their potential impact both to the natural environment and the human activities being carried out in the Park.

Monitoring of heavily used marine environments is critical to their protection. A long term monitoring programme will be established using two research sites: one in the most heavily used area around the Wreck of the Rhone and a control site in the research zone on the north tip of Dead Chest. Baseline data for both sites are provided in Anderson et al. (1985). Monitoring techniques are described in Appendix B.

2. Resource management

a. Fishing: All but subsistence level fishing by native BVI fishermen with special permit will be permitted in the Park, and this only in the General Use Zone. This stipulation will permit the very small and dwindling number of Salt Island fishermen to continue a traditional subsistence activity. The Park has in recent years been little used for fishing. A few fishermen from Tortola and Salt Island have set traps within the park, but this is not a

Table 3.10 continued...

commercially important activity. There are indications that the area has been overfished in the past and has not yet recovered. The limitation of fishing to a negligible amount will reduce the safety hazards caused by fishing boats and recreational boats using the area. It will also provide an opportunity for fishery stocks to recover.

b. Dead Chest Island: Dead Chest currently receives very little visitation. The islet does not currently appear to be used for seabird nesting, which may be because rats are present. The policy of the Trust will be to eliminate exotic predators whenever possible in order to restore the natural flora and fauna. If research indicates that rats are present on Dead Chest, measures should be taken to eliminate them. In order to protect the natural vegetation and fauna of the islet, visitation will not be encouraged, though it will not be actively prohibited unless it increases substantially from existing levels, thereby creating unacceptabe impact.

c. Moorings and anchoring: Anchoring at Lee Bay has damaged seagrass beds, and anchoring around the Wreck has destroyed living corals. Therefore, all anchoring will be prohibited except in the General Use Zone, and visitors by boat will be required to use the moorings at Lee Bay and the Wreck. Moorings should also be provided at Blonde Rock. Descriptions of the types of mooring to be used at each site and other details of the mooring system are shown in Appendix C.

3. Interpretation

Most interpretation of the Park's natural and cultural features is being done to acceptable standards by the dive operators who bring the bulk of visitors to the Park. The dive operators should be assisted and accommodated in continuing to carry out this function for the Trust.

Interpretative materials available on the park include the book, "The Royal Mail Steamer Rhone," by George and Luana Marler, and the brochure prepared by the Trust. The brochure provides interpretative material and also describes used of the mooring system. Copies should be distributed regularly to all dive and charterboat operators, and each charterboat should have a copy on board.

Table 3.10 continued..

The group most difficult to reach is that which visits the park on private yachts. Arrangements should be made to distribute the brochure and other interpretative materials that might be developed in the future through Customs and Immigration Service at each point of entry to all private yachts entering the Territory.

4. Interpretation

The policy of the Trust will be to encourage the use of the Park for marine sports, particularly SCUBA diving and yachting. In order to assure the protection of the resource and the safety of visitors regulations, surveillance, and provisions for accidents and emergencies will be required.

A brochure has been prepared showing the park boundaries, listing regulations, and describing the use of the Park mooring system. Adequate numbers of these should be distributed regularly to dive and charterboat companies and ports of entry to assure that everyone using the Park gets a copy. The brochure should also be updated periodically as needed.

In order to provide surveillance in the absence of NPT staff, formal arrangements should be made between the Trust and the Dive Operators' Association to certify dive operators as auxiliary officers of the Trust. They should not be given law enforcement powers, but would be expected to contact visitors, explain regulations, and assist in emrgencies. Dive and charterboat operators working in the Park will also be required to carry adequate accident and liability insurance. Captains will be required to have Red Cross Advanced First Aid certification, and a PADI or NAUI certified Dive Instructor must accompany all boats from which visitors will be diving. These requirements will be spelled out in concession contracts (see Section 6. below). Should serious law enforcement situations occur in the Park, the assistance of the Customs Officers will be requested. Eventually, the Trust will employ three rangers - for Tortola and surroundings, Virgin Gorda and surroundings, and Anegada. The Tortola ranger will have responsibility for the Wreck of the Rhone.

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Alternative Exercises:

1. Segments of the overall exercise can be cut out and tailored to medium length or shorter training sessions. As with the other exercises, the instructor can shorten the exercise by providing the information that would have been produced by the students themselves in the longer version.

2. Another approach that could be taken would be to update an existing management plan, following each of the steps outlined. This would reduce the amount of time required for each step, and yet familiarise students with all aspects of the process. The major limitation is, of course, that few coastal area management plans have been prepared, and thus may not be available for training course use in most tropical island states.

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Further Reading:

ECNAMP 1979. Draft Team Plan for the Management and Development of the Proposed Buccoo Reef National Park. Eastern Caribbean Natural Area Management Program Workshop on Natural Area Management, Tobago, April-May 1979; 37 pages.

Thelen, K. D. & Faizool, S. 1980. Site Plans and Design Analysis: Caroni Swamp National Park. Forest Division, Trinidad and Tobago; 36 pages.

* * *

Chapter 4.

COASTAL ECOSYSTEM MANAGEMENT

Introduction:

Coral reefs, seagrass beds and mangals are the characteristic ecosystems of tropical island coastlines. They are associated with rocky headlands, bays, beaches, lagoons, and sometimes estuaries and deltas on the larger islands. Each has its characteristic plant and animal components, and the structure and productivity are regulated by a range of physico-chemical and biotic processes. In most coastal ecosystems, both terrestrial and marine influences are important, and variations in local conditions of climate, geomorphology and oceanography can affect the way the systems develop and function.

The plants and animals forming, and contained in, the major ecosystem types are of considerable value to the economy of most tropical islands. It is important, therefore, to sustain these ecosystems and their resources by appropriate management. Biological resources are generally "renewable", and management will seek to ensure the wise use of these resources by as many people as possible over the longest possible time period (managers may wish to plan for a 25-30 year period). In other words, management should aim at " the conservation of coastal ecosystems at the highest achievable carrying capacity" (Clark 1977).

As with any type of resource management, the first step is to identify the resource and assess the nature of resource use. Its location, composition and condition are investigated and documented. Condition or **status** is assessed relative either to its condition in the past or to the desired condition according to national coastal zone management goals. If the status differs from what is expected or desired appropriate management strategies can be formulated to alter the status; these may require manipulation of the ecosystem or regulation of human impacts, or both.

One of the greatest problems encountered in coastal ecosystem management is the natural variability in ecosystem structure and processes in different parts of most island states. This means that management interventions may work better in some habitats than others, or that development impacts might be more severe on an ecosystem at one site than on an apparently similar

ecosystem at another. Over and above the preliminary inventory and status assessment, individual natural habitats must be **evaluated** for their ecological and economic roles with regard to conservation and development of the coastal zone. To do this the coastal manager must understand the methods and data assembled by ecologists, if these are to be used in ecosystem management decision making. Of critical importance is data which will be used to calculate the **yield** of products from reefs, mangrove swamps, and other coastal ecosystems, because this will influence regulatory policies to control resource exploitation.

In many islands, where natural resource utilization has not been based on wise traditional or scientific principles, overexploitation of resources has resulted, with consequent ecosystem damage and loss of income. Before the damage can be reduced or further prevented the manager must determine why it occurred, by investigating the way in which ecosystem function has been perturbed. Further ecological research may be required to determine what the carrying capacity for the system under exploitation should be, so that renewed resource use can be encouraged on a sustainable basis. Where depletion or ecosystem damage are severe, a determined effort may be needed to **resuscitate** the resource. This will require, again, an understanding of the way the particular species population or ecosystem responds to manipulation, and of the techniques available for natural resource recovery.

This Chapter guides the student through a series of exercises designed to give experience in coastal ecosystem management and exposure to some of the problem areas in tropical island situations. The emphasis is on biological aspects, but it must be remembered that resource use has socio-cultural, economic and institutional aspects also. All these aspects must be understood to some degree if good management decisions are to be made that have a chance of being implemented. Exercises 4.3 and 4.4 introduce these non-biological aspects of resource management in a general way, and trainees should refer to concepts developed in Chapter 3 above.

Exercise 4.1 ASSESSING THE STATUS OF COASTAL ECOSYSTEMS

Background:

Natural coastal communities are an important part of the economic **resource base** of most islands. Coral reefs, mangroves, and seagrass-algal beds make a significant contribution to food and materials production, tourism, employment, and coastal protection. The majority of these systems have been exploited for long periods and are subjected to pollution and development stress. As a consequence, sustainable exploitation is a priority concern for many environmentally aware governments.

Prior to taking any management decision with respect to natural communities, it is essential to evaluate their **status**. This evaluation builds on the baseline ecological description of the system, by considering how much the system deviates from pristine natural conditions as a result of human impact. General categories that can be used to describe an ecosystem are listed in Table 4.1.

Table 4.1 Categories for describing status of coastal ecosystems.

1. Pristine
2. Impacted
   - slightly modified
   - moderately modified
   - greatly modified, but apparently healthy
   - greatly modified, and showing sign of damage
   - severely damaged
3. Destroyed

.....

In most cases, the status designation will determine the available management options. For example, if the ecosystem is "severely damaged", the best option would be either total protection to permit natural recovery or a programme of active resuscitation (see also Ex. 4.4). If an ecosystem has been "destroyed", as through land reclamation or timber removal in a mangrove swamp, a

decision must be made as to whether or not it is desirable ecologically, feasible technically, or advisable economically to attempt to rebuild it.

Options would be selected also in terms of the island's coastal management goals (see also Ex. 3.1). For example, if a Nature Reserve for scientific or educational purposes is required, it would be best to select a "pristine" or "slightly modified" ecosystem. Alternatively, if the ecosystem selected as a Reserve for some special attribute is found to be "greatly modified, and showing signs of damage" the proposed management strategy would have to include removal of the factors causing damage or siting the reserve elsewhere. A status assessment is of great socioeconomic importance where large numbers of people derive livelihood from a system's resources, as it might indicate that present impact is threatening future utilization, with potential economic losses.

Data concerning the nature of the particular ecosystem in the past is required as the baseline for assessing present status. Where published scientific data is not available the manager may have to rely on popular knowledge. Good knowledge and experience of the structure and functioning of that type of ecosystem is essential also, because of the natural variability of coastal ecosystems. For example, not only do coral reefs and mangrove swamps show a spatial zonation of the species as a reflection of localised environmental differences, but also temporal successional changes, responses to episodic events like hurricanes, differences on windward and leeward shores of islands and latitudinal variations between islands (Milliman, 1973; Bacon, 1987b). Furthermore, there are likely to be a variety of types of human impact, both presently and in the past, and variations in the intensity of those impacts. Damage may not become apparent until a particular threshold of impact has been reached; or only as a synergistic effect of two or more human activities, or human activities and unusual natural events, in combination.

An illustrative **case study** is the management plan developed for the Caroni Swamp by the Forest Division, Government of Trinidad & Tobago, which had regulatory responsibilty for this coastal mangrove area (Thalen & Faizool, 1979). Figure 4.1 shows the within-system variability in vegetation, and effects of attempted reclamation in the 1920's (Bacon, 1975); and Figure 4.2 shows the zoned management plan for the swamp which was based on status assessments of its sub-regions in 1974. The least impacted area with most diverse fauna was designated as the "Scientific Zone", to be used for research and monitoring purposes only. Whereas the area to the north and west of the swamp was considered to be badly degraded and designated as "Recuperative Zone - not

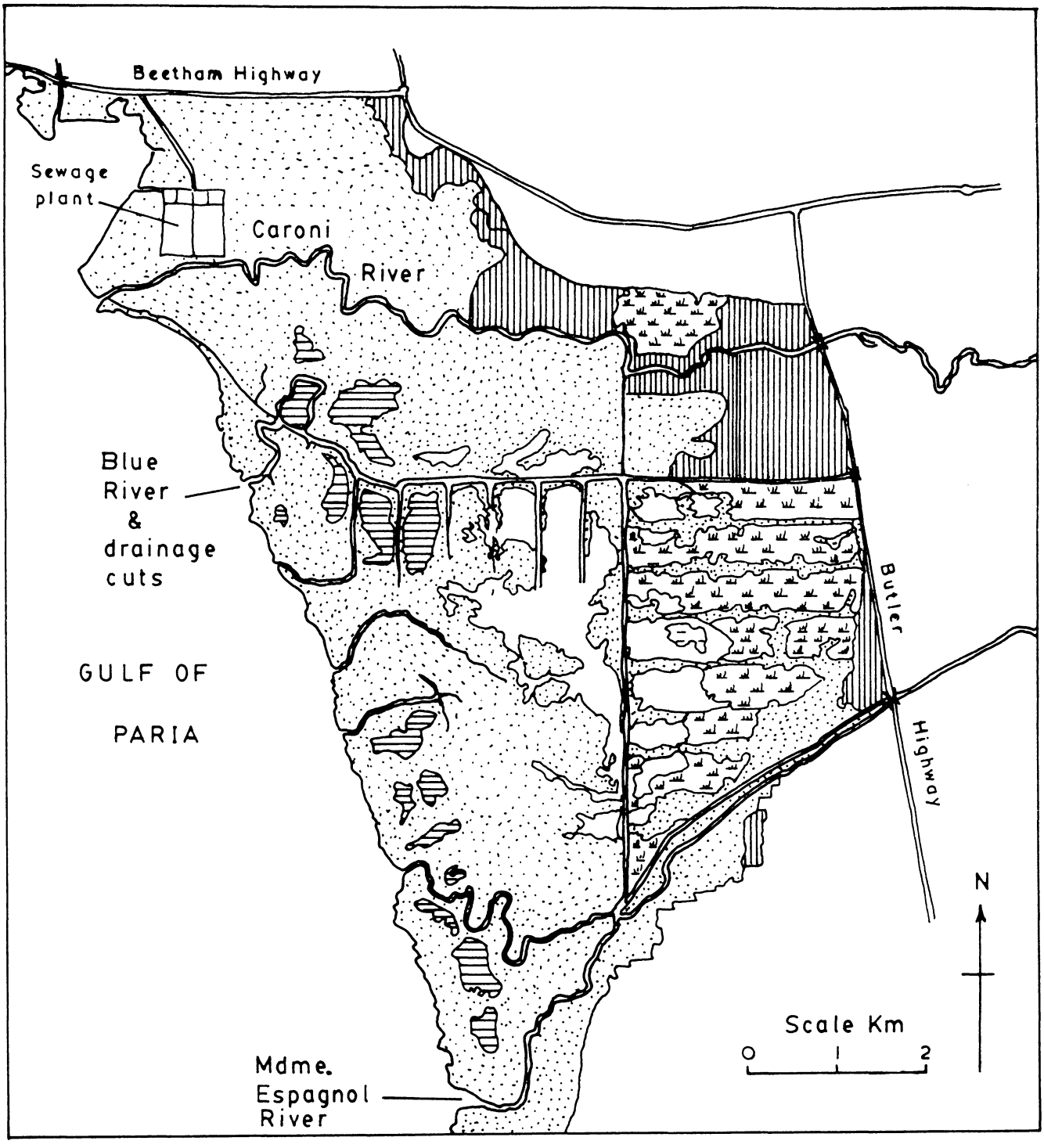

FIGURE 4.1 EXISTING CONDITIONS - CARONI SWAMP, TRINIDAD

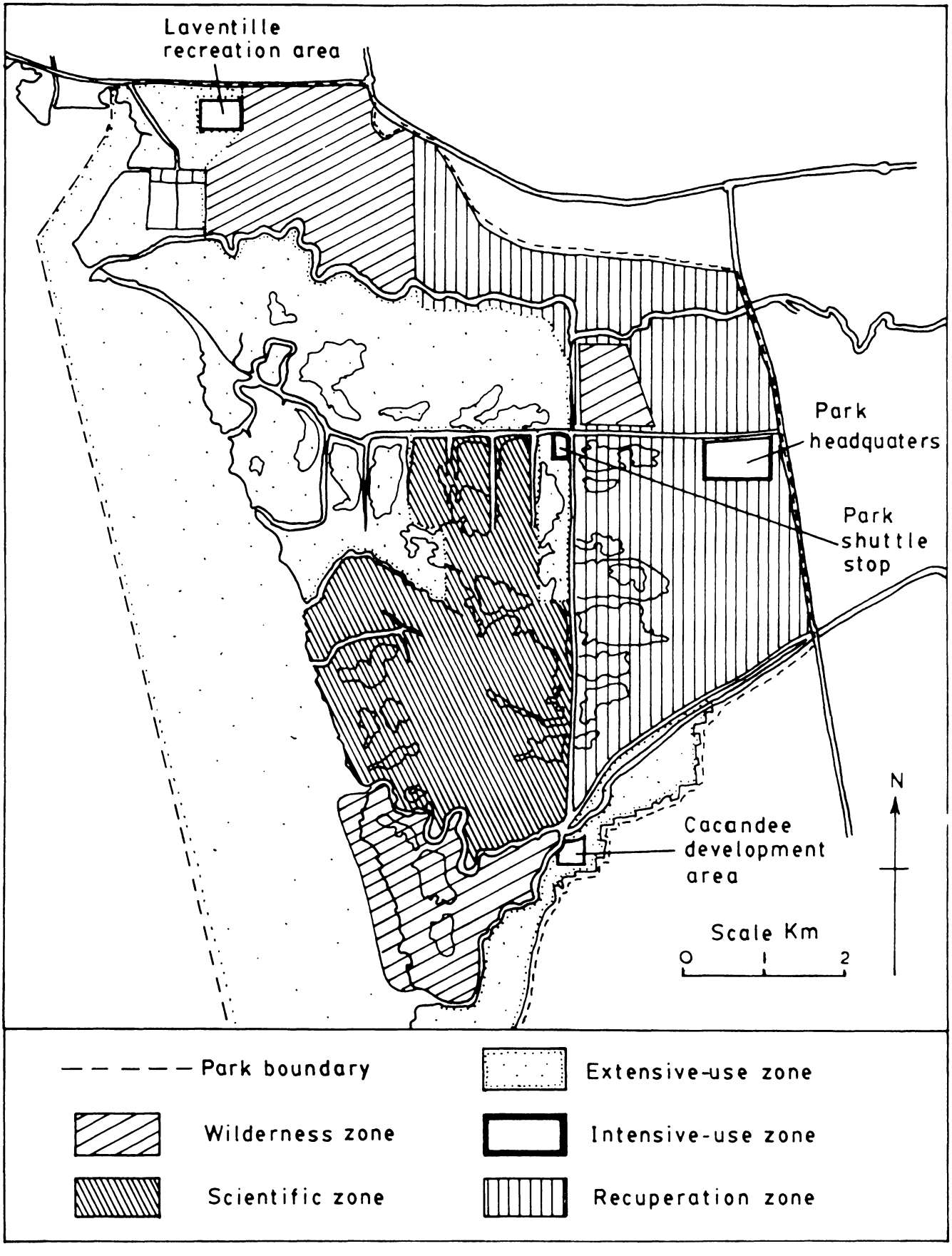

FIGURE 4.2 ZONING PLAN - CARONI SWAMP NATIONAL PARK

to be utilized until its natural biota had re-established".

Status assessments for selecting management options are appropriate for small areas of island coasts, as well as large complex areas like Caroni Swamp. Status assessments can be used to compare all patches of one ecosystem type throughout an entire island, for example when developing a National Coral Reef Management Plan. In all these cases, the management process depends on the accuracy of the status assessment.

This exercise is concerned with a common, and economically significant coastal ecosystem, the coral reef. Suggestions follow for alternative exercises which concentrate on other tropical island ecosystems.

The ability of a reef to provide goods and services is related directly to the presence or absence of certain organisms, most of which are readily recognisable by the non-specialist. A fisherman wants to catch fish, and knows that a healthy, productive reef shows a certain balance between living corals and seaweed cover; a tourist wants to see a variety of live animals, so his or her satisfaction during a tour relates largely to reef species diversity; while a hotelier wants the beach protected by the reef and replenished with particles from the reef, so also needs to be assured that the neighbouring reef is a living, actively growing, coral-animal dominated structure. Each of these user groups, and others, may be responsible for reducing the value of the reef resources by perturbation of the ecological balance, through overfishing, through walking on and breaking off coral heads, or discharging sewage. The effects of such impacts are recognisable in changes of biota over time, i.e. the reef does not contain the normal range of organisms; or the relative abundance of organisms differs from what is expected (see Porter, 1972; Dahl, 1981). Even where prior data are not available, present community gross composition gives a useful <u>preliminary</u> indication of reef status; Archer (1985), for example, reported that live coral cover in Barbados ranged between 20 - 37 % whereas it had normally been greater than 50 - 60% in the Western Caribbean. Even when it is remembered that reef species diversity and abundance vary with depth, aspect and locations, such departures from the expected norm can help to focus the natural resource manager's attention.

Aim:

To make a preliminary assessment of the status of a coral reef.

Duration:

One day (depending on the availability of historical or other baseline data).

Suitable Location:

An area of fringing reefs, small patch reefs, or coral cays, preferably within the main barrier on the island shelf. Selection should be made (a) bearing in mind the swimming/diving competence of the trainees, and (b) in order to examine a gradient of conditions, from areas known to be heavily impacted by human activities to those thought not to be. An area used by tourists, where trampling and/or intensive spear fishing have taken place, makes a suitable "impacted" site. Sites should be at least 1 km apart, but preferably on the same side of the island (so that results are not biased by windward/leeward coastal variations in reef structure). Choosing areas that have been described at an earlier date can assist interpretation of the data collected.

Materials Required:

Per group (3 - 4 persons)

Transect line, that should not float, marked at 1 m intervals.
A weighted line marked at 0.5 m intervals to be used for depth measurements.
Underwater writing slate (three to four clipboard or smaller size sheets of white formica tied loosely together).
Waterproof Identification Guides, if available.
Compass

Personal

Face mask, snorkel, fins
(life support vest; SCUBA gear, as appropriate)

Instructions

Field Methods

Measurements can be made in the more accessible, shallow reef flat area by inexpert swimmers; or on the reef slope if SCUBA is to be used. The instructor must ensure that measurements are made in similar depths in all comparative sites. A plotless line transect method will be employed,

as follows:

1. Place the transect line parallel to the shore (Figure 4.3) and anchor it so it is relatively taut.

2. Record the site and depth on the underwater slate which has been prepared in advance as shown in Table 4.2.

3. Investigate the line over a distance of 10 m and record -

   (a) any organism which intercepts the line, and
   (b) the proportion of the line intercepted by each organism.

   For example, a brain coral, Diploria, is located and intercepts the line between 1.25 and 1.48 cm from the start, i.e. it intercepts along 23 cm of the transect.

   For this introductory exercise, algae can be recorded as colonies, rather than trying to count individual plants; and where layered organisms occur or one organism is seen below another, only the surface in contact with or directly below the line should be measured.

   As far as possible, identify and record all sessile macroalgae and macro invertebrates intercepting the transect.

4. Move the transect line to a new location 1 m deeper than the first, but still parallel to the shore, and repeat the measurements and record keeping.

5. Repeat with further transects at 1 m deeper intervals, to a total of at least five transects.

6. Each sub-group should record a replicate set of transects nearby, but at least 10 m away from the first set (Figure 4.3).

   If more than one group of trainees is running transects, these could be treated as replicate samples and analysed for intra-site variability. As there may be differences in the field competence of the sub-groups, this might introduce a source of error. Sub-group compatibility can be tested by all sub-groups working over the same transect and comparing results at the start of the exercise.

7. Repeat the transect measurements at the other location/s being used in this comparative study.

Table 4.2 Sample Data Recording Format for Coral Reef Survey

Species	Total linear cover (cm)	% cover	No. of colonies	% colonies
Corals				
species A				
species B				
species C				
etc				
Total corals				
Algae				
species A				
species B				
species C				
etc				
Total algae				
Seagrass				
Bare sand				
Other biota				
species a				
species b				
etc.				
Total non-coral/algal				

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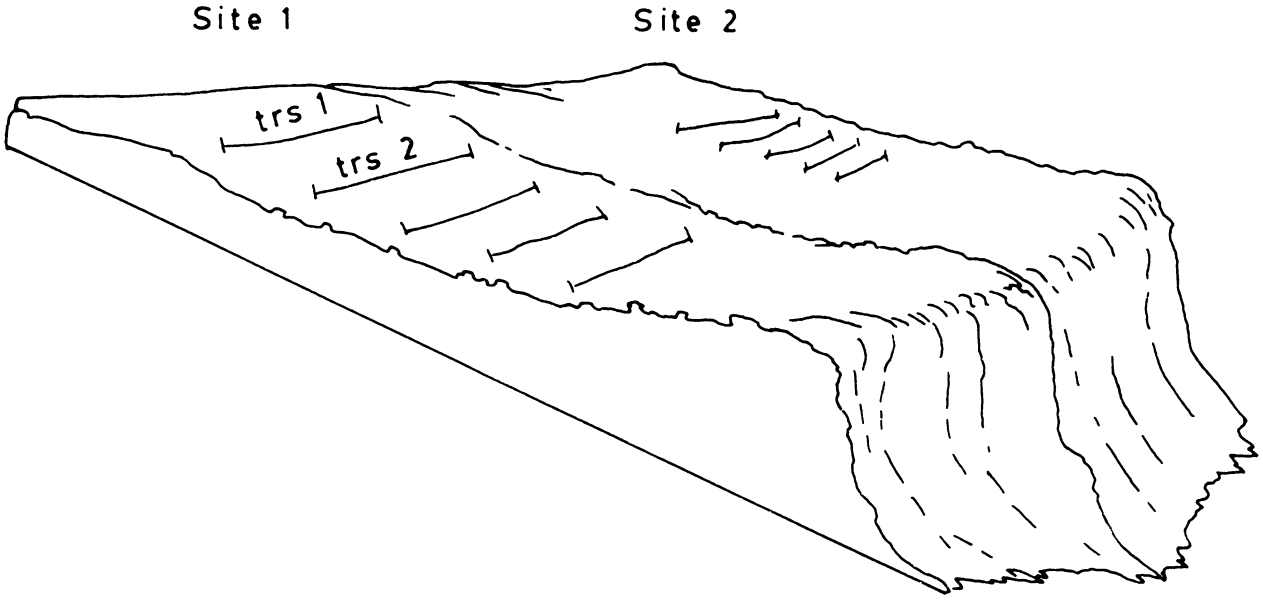

FIGURE 4.3 LINE TRANSECT POSITIONS

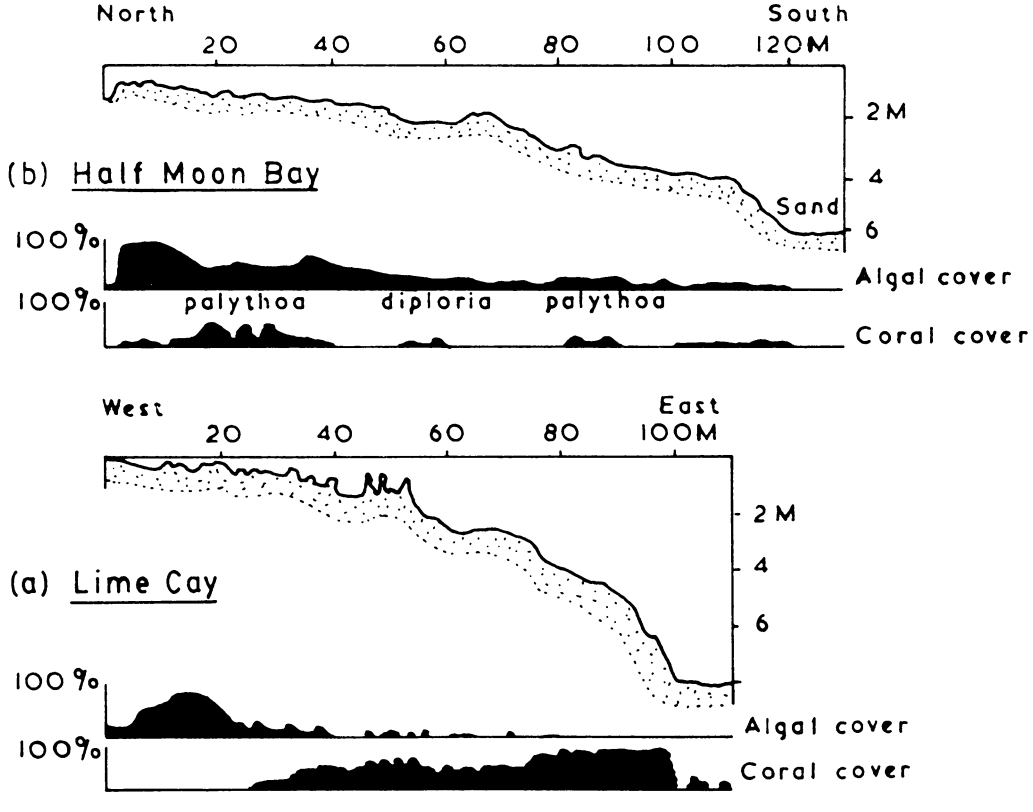

FIGURE 4.4 PROFILES COMPARING TWO JAMAICAN REEFS

Laboratory Methods

8. Transfer all data to data sheets, using a format similar to that shown in Table 4.2.

9. Draw profile diagrams of the transects using depth measurements (see Figure 1.7). This will allow visual comparison of replicate sites and different locations.

10. For each transect calculate and record -

    (a) % cover for each species, and
    (b) % of total number of colonies occupied by colonies of each species.

11. Using data from all replicate samples at each site, calculate means and standard deviations for all data.

Analytical procedures

12. Status at the single location can be assessed by listing in order of importance dominant organism groups, from % cover estimates. This list is compared with historical data or expert opinion on what a healthy reef in the island should be like. For example, J. Woodley (personal communication 1987) suggested that most Caribbean reefs had 60% or more living coral, with good development of staghorn coral, Acropora cervicornis, and coralline algae widespread with fleshy algae occupying less than 10% cover. The occurrence of dead coral showing white skeletons without algae growing on them was evidence of recent death of the coral. Recent events in the Caribbean, such as coral diseases, have altered these cover estimates. In any island where this analysis is attempted up to date information should be consulted. Does the survey data suggest deviation from the norm at this location ?

13. As there is likely to be considerable localised variation in complex coral reef communities, you should test your series of transect data for within system and between system variability by ANOVA or other appropriate statistical test.

14. Plot the relationship between total coral cover (hard corals and soft corals) and total algal cover at each location.

15. Draw a histogram which shows number of species and % cover at each site, under different categories of

organisms, such as "corals", "algae", "other biota".

16. Compare the mean % cover of corals and algae at the different sites.

17. Give a brief narrative description of any marked differences between study locations. Note which location appears to have the highest coral cover and the greatest coral species diversity (for purposes of this exercise these features are taken to indicate healthy reef environments, as suggested in the literature referred to above).

18. Assuming that significant differences between reef locations are demonstrated, arrange your reef locations in order of deteriorating status.

19. Discuss the results of your preliminary status assessment. Remember that alteration of the natural balance of a reef community could be the result of pollution, overfishing or natural phenomena like hurricanes.

Product:

Data can be presented in tabular form, as indicated, or as figures and species list as shown in the following **Case Study:**

Two reef areas studied by Head and Hendry (1985) are illustrated by the profile, Figure 4. 4. The more pristine site at Lime Cay showed initially high algal cover which declined as nearly 80% coral cover was found on the reef crest and forereef. Half Moon Bay showed coral cover much lower with heavy mats of macro-algae throughout the transects. Lime Cay showed a much more diverse coral fauna and greater numbers of sea fan species (Table 4.3). The suggestion was made that the Half Moon Bay reefs showed evidence of disturbance, due possibly to sewage pollution.

Assessment of status does not necessarily answer many questions, but is more likely to point to the need for further research. It does help to focus attention on potential problem areas, by indicating that something is not as expected (see Table 4.1). A status assessment can indicate the nature of a problem; for example, increased seaweed growth on a coral reef suggests some degree of nutrient enrichment (eutrophication) which, if not explainable by natural causes, might be related to nearby sewage discharge. On the other hand, an assessment which showed low levels of commonly expected reef fishes would suggest that the problem is more likely related to the fishing pressure than to pollution, and the manager would

Table 4.3 Anthozoan and hydrozoan 'coral' species present on the Lime Cay and Half Moon Bay traverses.
For abundance, 1 = single specimen, 2 = uncommon, 3 = common, 4 = abundant, 5 = locally dominant.

	LIME CAY	HELLSHIRE
Stephanocoenia michelinii	1	
Acropora palmata	5	1
A. cervicornis	3	
Siderastrea radians	4	3
S. siderea	2	3
Agaricia agaricites	2	
Porites porites	5	
P. astreoides	4	3
P. branneri		3
Montastrea annularis	4	2
M. cavernosa	3	1
Diploria clivosa	5	3
D. strigosa	5	3
Colpophyllia natans	1	
Isophyllia sinuosa	2	3
Isophyllastrea rigida	2	
Rhodactis sanctithomae	2	
Ricordea florida	2	
Zoanthus sociatus	4	4
Zoanthus sp.	2	
Palythoa caribbea	5	5
Erythropodium caribaeorum	2	
Plexaura flexuosa	3	
Pseudoplexaura porosa	3	
P. flagellosa	3	
Eunicea tourneforti	3	
Muricea atlantica	3	
M. pinnata	3	
Pseudopterogorgia acerosa	4	1
P. americana	5	
Gorgonia flabellum		2
G. ventalina	4	
Millepora alcicornis	4	2
M. complanata	2	3
TOTAL SPECIES NUMBER	32	16
TOTAL ABUNDANCE SCORES	100	39

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be aided in deploying scarce resources in an appropriate direction. Although the coastal manager might be more concerned with pressing and vocal demands from the resource users, his primary task is to maintain in a viable form the resources on which those user groups depend. Although the problem might be seen as reduced incomes by fishermen, the cause probably lies in the condition (status) of the reef which they are working; and the resource users' problem is unlikely to be solved while the resource is in a less than optimally productive state. Continued economic development of natural resources in the coastal zone is dependent on regular checks on the "environmental bank balance".

Alternative Exercises:

1. Reef status assessment by fish counts

   Considerable information is available on the composition and abundance of coral reef fish populations in tropical islands (Munroe & Williams, 1985). Perturbation of reef condition will be reflected in changes in the fish community, particularly lowering of diversity.

   One simple technique for estimating the diversity is the Stationery Visual Census Technique described by Bohnsack and Bannerot (1986). This is best done using SCUBA, but can be adapted for snorkel surveys from the surface.

   At randomly selected points, all species of fish are recorded which are observed within an imaginary cylinder extending from the surface to the seabed, with a radius of 24 ft (7.5 m) during a five minute interval. Further points are selected, based on a number of swimming kicks determined from random number tables. Additional information on fish fork-lengths, size of schools, or other parameters, can be recorded as appropriate.

2. Assessment of the legal status of coral reefs.

   For management purposes, the legal status of a natural resource is as important as its ecological status. As a desk exercise, or through visits to relevant government agencies, legislation can be examined.

   It is important to decide what type of legal protection is required (a) for the reef itself, (b) to control use of reef resources, (c) to buffer the reef from adverse external impacts, such as water-borne pollutants or excessive land run-off, or (d) to remove

already existing adverse human impacts.

The adequacy of existing legislation can be assessed and preliminary drafts can be prepared of any new legislation which may be required (see Chapter 3). Emphasis should be placed on provision for enforcement of legislation, bearing in mind the particular difficulties of managing coral reef environments.

3. Reliability of sampling procedures in highly variable natural environments.

As mentioned, differences between sample sites are frequently obscured by ecosystem variation along transects or between neighbouring plots. A coral reef is an ideal place for demonstrating the importance of an appropriate sampling method, including replication and inter-investigator compatibility.

Coral species diversity and cover estimates can be compared using 2 - 3 methods described in the UNESCO Coral Reef Research Methods handbook. A comparison should be made of the results obtained using different methods and by different groups of trainees using the same method. The accuracy of a sampling method should be related to the number of replicate samples taken. Standard statistical or biological methods texts should be consulted.

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Further Reading:

Banner, A. H. 1974. Kaneohe Bay, Hawaii: urban pollution and a coral reef ecosystem. Proceedings of the 2nd International Symposium on Coral Reefs, 2; 685 - 702.

Beller, W.S. (Ed). 1979. Transactions at the Conference on Environmental Management and Economic Growth in the Smaller Caribbean Islands, St. Michael, Barbados, Sept. 1979; 103 pages.

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* * *

Exercise 4.2 CONDUCTING HABITAT EVALUATION

Background:

Coastal ecosystems are complex, and understanding how they function or what organisms they support requires specialist knowledge and long periods of research. The coastal manager is concerned rarely with biological intricacies, such as taxonomic composition, diversity indices, food webs or productivity estimates, and is more likely to want to know why and how ecosystems should be managed. A further problem faces the manager where island coasts contain several, apparently diverse, areas of any ecosystem type, e.g. lagoons of different shapes and sizes or swamps dominated by different mangrove species. In these cases, should there be a common management strategy for each ecosystem type or should there be a ranking in order of their ecological importance? If the latter, how should the several areas of an ecosystem type be ranked to show priority order for exploitation ?

Exercise 3.3 considered criteria for selecting natural areas, in terms of their general value to society. This included criteria for "biological value" (Table 3.5), although no attempt was made to quantify that value. The exercise selected for areas "important" to commercial species or wildlife, but did not discuss how to decide whether one habitat was more important than another on economic or aesthetic grounds. Every coastal ecosystem, be it seagrass bed or salina, has **ecological value**, and, ideally, these values should be sustained. But the development situation in most islands dictates that only some coastal areas can be retained in their natural state. Areas with **commercial** species or those considered **unique** or **representative** (Table 3.5) are identified readily and their preservation easily justified during coastal zone management planning. When the management objective is conservation of a particular wildlife species, selecting its most important habitat is problematic, but critical to the survival of that species.

The evaluation of wildlife habitats is important for several reasons;

(a) It assists the manager to concentrate scarce resources on protecting the areas of greatest importance to the target wildlife species.
(b) It helps locate development activities, particularly those likely to impact on commercially or aesthetically important species, in the less valuable areas of habitat.
(c) It permits the manipulation of habitats to produce

optimal conditions for the target wildlife, as when previously impacted sites are being returned to productive status.

Many techniques have been devised for habitat evaluation. One evaluation model, reviewed by Golet (1978), used maximum wildlife diversity and production as the standard against which a series of wetland habitats could be evaluated. Criteria used under the Ramsar Convention to select wetlands of international importance (Table 4.4) stress the numbers of waterfowl supported by particular sites.

Table 4.4. Criteria for Identifying Wetlands of International Importance. (Source: The Ramsar Convention 1971)

1. Quantitative criteria for identifying wetlands of importance to waterfowl

   (a) Regularly supports either 10,000 ducks, geese or swans; or 10,000 coots; or 20,000 waders; or
   (b) Regularly supports one percent of the individuals in a population of one species or subspecies of waterfowl; or
   (c) Regularly supports one percent of the breeding pairs in a population of one species or subspecies of waterfowl.

2. General criteria for identifying wetlands of importance to plants or animals

   (a) Supports an appreciable number of rare, vulnerable or endangered species or subspecies of plant or animal.
   (b) Is of special value for maintaining the genetic and ecological diversity of a region because of the quality or peculiarities of its flora and fauna.
   (c) Is of special value as the habitat of plants or animals at a critical stage of their biological cycles.
   (d) Is of special value for its endemic plant or animal species or communities.

3. Criteria for assessing the value of representative or unique wetlands.

   (a) Is a particularly good example of a specific type of wetland characteristic of its region.

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However, wildlife diversity and abundance of individuals are rarely characteristic of small island habitats, so a suitable technique would evaluate habitat in terms of one or a few target species. The following exercise is based on Habitat Suitability Index models (Schamberger & Far (HEP) formulated by the US Fish and Wildlife Service (see Schamberger & Kumpf, 1980; USFWS, 1985).

Aim:

To evaluate the quantity and quality of habitat available to a selected species in an island or region of an island.

To rank the areas of available habitat in order of importance for the conservation of the target species.

Duration:

Minimum 1 day (depending on the quality of ecological data available and the location of sites used by the target animals).

Suitable Location:

Laboratory or drawing office work, supported by field work in two or three local sites. Preferably the study sites should be of different sizes and one should either be impacted by human activity or scheduled for development.

Materials Required:

Topographic maps of island or region.
Aerial photographs of the study sites.
Narrative summary of biology of the selected animal species, including information on food requirements, reproductive habitat requirements, migratory movements or territorial behaviour, as appropriate.
Drawing materials.

Instructions:

Preliminary Study

1. Select a species of animal for study. Preferably, this should be a resident species with some recognised commercial or aesthetic value, e.g. a national symbol, a game or food species, or an endangered species. Choice of a bird might be advisible, particularly one of the coastal waterfowl, because the biological data base is often better in tropical islands than for other animal groups.

2. Study the literature and summary report provided, and list key biological requirements of the target species, e.g.

   - food type
   - foraging habitat type
   - cover, e.g. preferred roosting site
     preferred nesting site
     means of protection from predators
   - special factors, e.g. site tenacity (e.g. use of traditional nesting sites) or response to human disturbance
   - interspersion, i.e. distances travelled between roosting sites and foraging areas

3. On the maps provided, locate areas of apparently suitable habitat. Take into account portions of habitat used for all life history requirements, e.g. feeding areas, roosting areas, migratory routes. Use aerial photographs to supplement this activity.

4. Estimate the size of all areas of apparently suitable habitat in the island or region. Sum these and record the total. This gives an indication of the <u>quantity of available habitat</u>.

Field Study

5. Select at least three sites from the above list (preferably sites which can be visited on the same day) and confirm their use by the target species.

6. Make field measurements which permit comparison of the suitability of these sites for the target species. This measure of the <u>quality of the available habitat</u> should be made as follows:

   - select some of the more easily measured habitat variables, such as distance between roosting and foraging areas, distance between cover and sources of human disturbance, area of vegetation stands used for nesting.
   - Quantify these values, and compare between sites. If three sites are being assessed, assign values on a relative scale from 1 - 3 for each variable; sum these and record the totals for each site.
   - If the optimum habitat conditions are known (from available literature or from a local expert), establish a Habitat Suitability model format. This model should be in index format, i.e. a ratio between the value under investigation and a

standard of comparison, as follows:

$$HSI = \frac{\text{Site habitat condition}}{\text{Optimum condition}}$$

As shown in Figure 4.5, assign habitat variables to a scale of (unsuitable)0 - 1(optimum). Sum these values and record them.

7. Calculate Habitat Units for each site, as the product of the HSI (quality) and total site area available (quantity), from the above estimates. The Habitat Units can be used for inter-site comparisons, as indicated below.

Habitat Assessment

8. Existing conditions in the study sites should be compared. Identify the site with greatest capability for supporting the target wildlife species, and rank others in order of decreasing capability. Discuss the implications of this rank order for conservation of the target species.

9. Assuming that one of the study sites is being impacted by human activity, and that this impact is likely to continue, calculate Habitat Units at fixed periods in the future for that site, i.e. estimate remaining area and/or habitat condition after one year, two years or 5 years. Compare the future condition of all sites and discuss the implications.

10. Assuming that one site is earmarked for development, predict Habitat Units on completion of the development. Discuss how the development might be modified to maintain Habitat Units as close to existing conditions as possible.

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Alternative Exercises:

1. Habitat assessment can be made using a range of species. In this case, habitat suitability indices must be calculated for all species and then combined to produce HU's. This can be complex and will require considerably more information on the

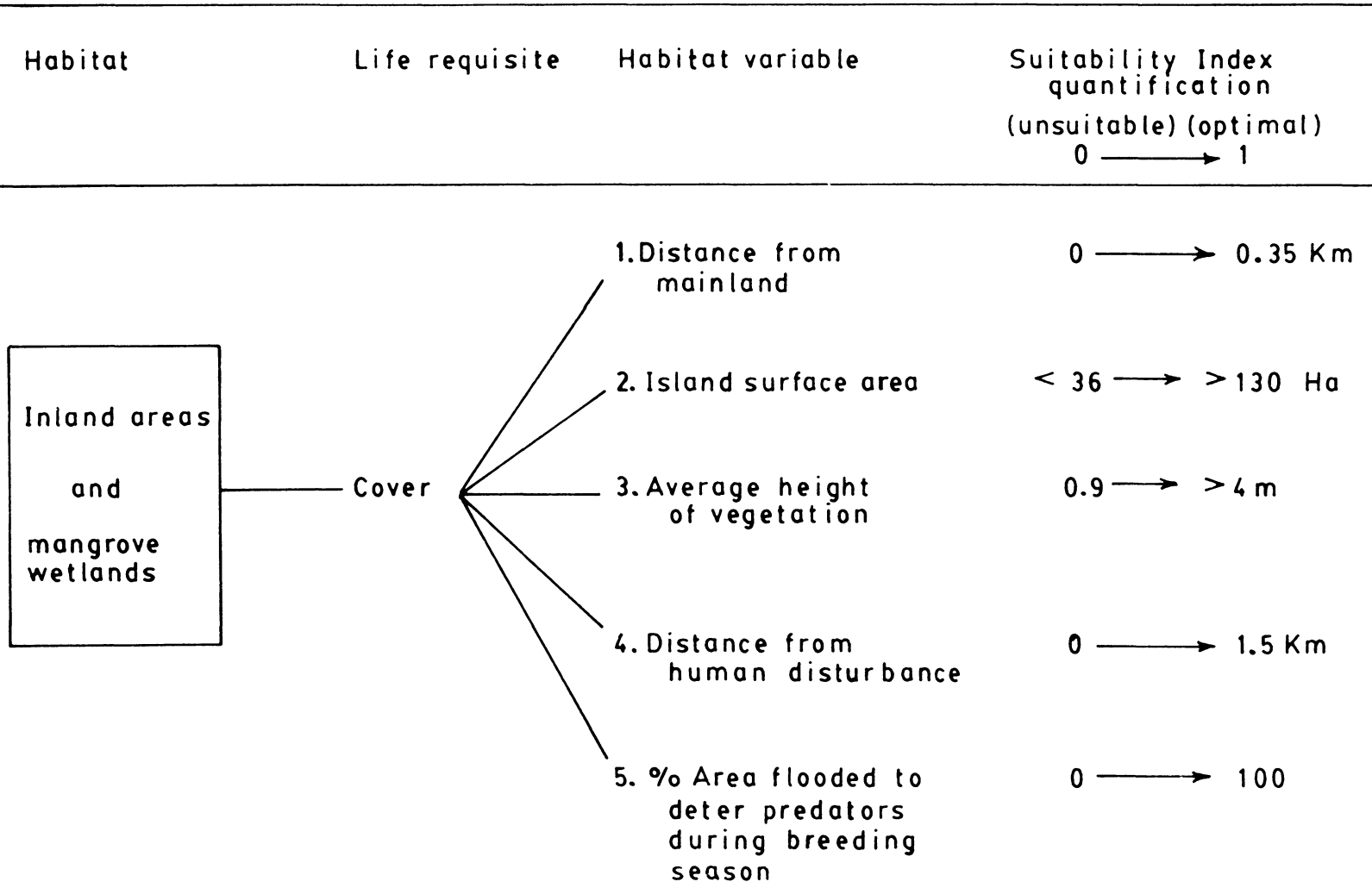

FIGURE 4.5 SAMPLE HABITAT SUITABILITY INDEX CHART: BASED ON A SINGLE LIFE REQUISITE COVER FOR WHITE IBIS (Data after USFWS, 1985)

ecology of the sites. A broader treatment of this nature will produce a more accurate assessment of habitat value, however.

2. One of the sites studied in the main exercise which had a low habitat value could be reinvestigated with a view to improving its value. This extension of the main exercise could be used to suggest how the site or ecosystem could be manipulated in order to remove negative features. For example, the removal of sources of human disturbance or the planting of more trees might make the site a more suitable breeding area for the target species.

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Exercise 4.3 CALCULATING OPTIMUM SUSTAINABLE YIELDS FOR COASTAL RESOURCES

Background:

There is a wide range of directly harvestable natural resources in the coastal zones of tropical islands. Primarily these are fin-fish, but other edible species such as sea-mosses, conch, shrimp, lobsters and sea turtles are of economic importance in many areas. Stony corals, sea fans, black coral and sea shells have minor, but widespread use in the tourism and handicraft sectors, both locally and in international trade; while renewable non-biological resources include beach sand and salt.

Theoretically, the supply of sea salt is unlimited. Beach sand in tropical islands can be mined rarely in large quantity or for long periods without causing environmental disturbance (Cintron, 1981). Some very slow growing organisms, like black coral (Antipatharians), can be eradicated easily by over-enthusiastic harvesting (Mailer, 1982); sea turtle populations decline rapidly if too many nesting females are killed on beaches or too many eggs are taken (Carr & Schroeder, 1967; Carr, 1980); and overexploitation of mangrove timber may lead to habitat alteration that prevents natural regrowth of the forest (Hamilton & Snedaker, 1984). The removal of coastal resources at levels beyond the capacity of the population or ecosystem to restore them, not only reduces the size of available resources, but has serious socioeconomic consequences (Snedaker & Getter, 1985). In small tropical islands resources are characteristically limited and ecosystems fragile (Towle, 1971; McEachern & Towle, 1972), so that the effects of careless utilization or overexploitation may be extreme.

In order that loss of resources (and income and jobs) and consequent environmental deterioration in the coastal zone be prevented, exploitation rates must be regulated. There are several approaches to this very important aspect of coastal zone management, some of which stress the technical aspects of establishing permitted **yields**, while others concentrate on legal or institutional measures for regulating user-group activity. Both are important, but the second approach depends also on an understanding of the **potential yield** or **carrying capacity** of the resource being studied. Methods of predicting yield are summarized in Appendix 6. One of these, Optimum Sustainable Yield (OSY), forms the subject of this exercise and, as its name suggests, is a measure that has direct management implications. Theoretically it can be applied to any coastal or marine resource which is renewable. It

accommodates within the calculations effects on the user-groups of managing the resources which they are exploiting.

The most advanced work on predicting yields has been concerned with marine fish populations (Cushing, 1975; Gulland, 1977). Data requirements and statistical treatments are necessarily complex because of serious restraints on obtaining accurate estimates of fish stocks. It is virtually impossible to study an entire population of a fish species in any area of the coast, because most catch methods are 'blind', fish move in and out of the area, and fishing gear is selective for particular size/age classes of fish. Long periods of research producing long series of fisheries statistics are necessary for yield prediction. This is because fluctuations in marine environmental conditions, sometimes due to events in far distant parts of the oceans, affect rates of recruitment, growth and mortality in fish populations. Coral reef fisheries, which are typical of so many tropical islands, are based on multi-species stocks (Munro & Williams, 1985), the analysis of which requires specialist knowledge outside the scope of this Workbook.

To simplify the OSY calculation, this exercise deals with an easily accessible, fixed-size coastal resource which can be sampled in its entirety, namely mangrove trees for use as timber or charcoal. The principles of yield prediction can be illustrated through hands-on experience in most tropical islands without the need for costly or complex equipment. Furthermore, no capture or destruction of resources is actually required for this training activity. The exercise assumes that the study area is pristine and not presently used by anybody. This is probably unrealistic for most mangrove areas, so some of the socioeconomic aspects of management are raised at the end of the section.

Aim:

To calculate the Optimum Sustainable Yield of timber from a mangrove stand.

Duration:

One day (depending on location and data availability).

Suitable Location:

A small (about 4-5 ha) mangrove area, preferably accessible from the land or by a small boat, close to the laboratory or training centre.

Materials Required:

50 m long rope, marked in 1 m, intervals.
Tape measure, marked in cms.
Compass.
Map of site (or aerial photograph).
A simple field key to local mangrove species.
Data sheet giving local market prices of mangrove timber and/or charcoal.

Instructions:

Field methods

1. Select an area of mangrove forest using the map or aerial photograph. This should be a clearly defined area, or part of a larger area, of mangrove which can be studied in the available time frame.

2. Estimate the gross areal coverage of this 'stand' of mangroves in hectares, and record this.

3. In the field, set out a quadrat 10 x 10 m (0.1 ha) in size using the marked rope. Tie the rope to suitably placed trees or use stakes to mark the boundary. Set the boundary marker line at a fixed orientation using the compass to ensure regular quadrat placing. Mark the quadrat position on the map.

4. Systematically study each tree and record the species and the diameter of the trunk, as follows:

   - Mangrove species are identified using a simple key provided by the instructor.
   - Diameter of the trunk is most easily calculated by measuring circumference (c) with a flexible tape measure. This is done at breast height or above prop roots as appropriate. Diameter at breast height equivalent is dbh = c/π , recorded in cm.

5. Count the number of established (growing) seedlings in the quadrat.

6. Measure trees in a second quadrat, and repeat this until about 25% of the total area has been sampled. With small areas, use quadrat sampling to measure all trees.

7. Parameters for mangrove growth rates and biomass (timber) production rates will vary with different species and different geographic locations. If rates for mangroves in the island being studied are known these should be utilised, otherwise, for purposes of this exercise, general conversion factors modified from Lugo and Snedaker (1975) can be applied (Table 4.5, Figure 4.6). (These make several assumptions and generalisations, which could be refined if time permits to give more accurate estimates, by reference to the mangrove literature).

Table 4.5 Conversion factors and measurements - mangroves

1. Mean increase in dbh = 0.33 cm yr^{-1}
2. Mean weight increase per tree (above 10 cm dbh) = 1 kg yr^{-1}
3. Seedling initial mean weight = 6.3 g
4. Mean weight increase per seedling = 0.4 g yr^{-1}

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Enter your data for the measured area on the Table provided. A separate table could be completed for each species of mangrove in the stand (cf. the example Table 4.6).

8. Calculate the standing crop of timber (kg) for each dbh class of trees;

   crop = no. of trees x dbh to weight conversion factor

Table 4.6 Sample Field Data Format - Mangrove yield survey

Location name: Observers:

Date: Time: from to

Quadrat No:	1	2	3	4	5	6	7	8	9	10
Species No. 1. Rhizophora										
Tree No.	circumference or dbh									
1	.	.	.	.	.	.				
2	.	.	.	.						
3	.	.								
4	.	.								
etc..										
Mean No.seedlings	.	.	.	.						
Species No. 2 Avicennia										
Tree No.	Circumference or dbh									
1	.	.	.	.	.	.	.	.		
2	.	.								
Mean No. seedlings	.	.	.							
etc.										

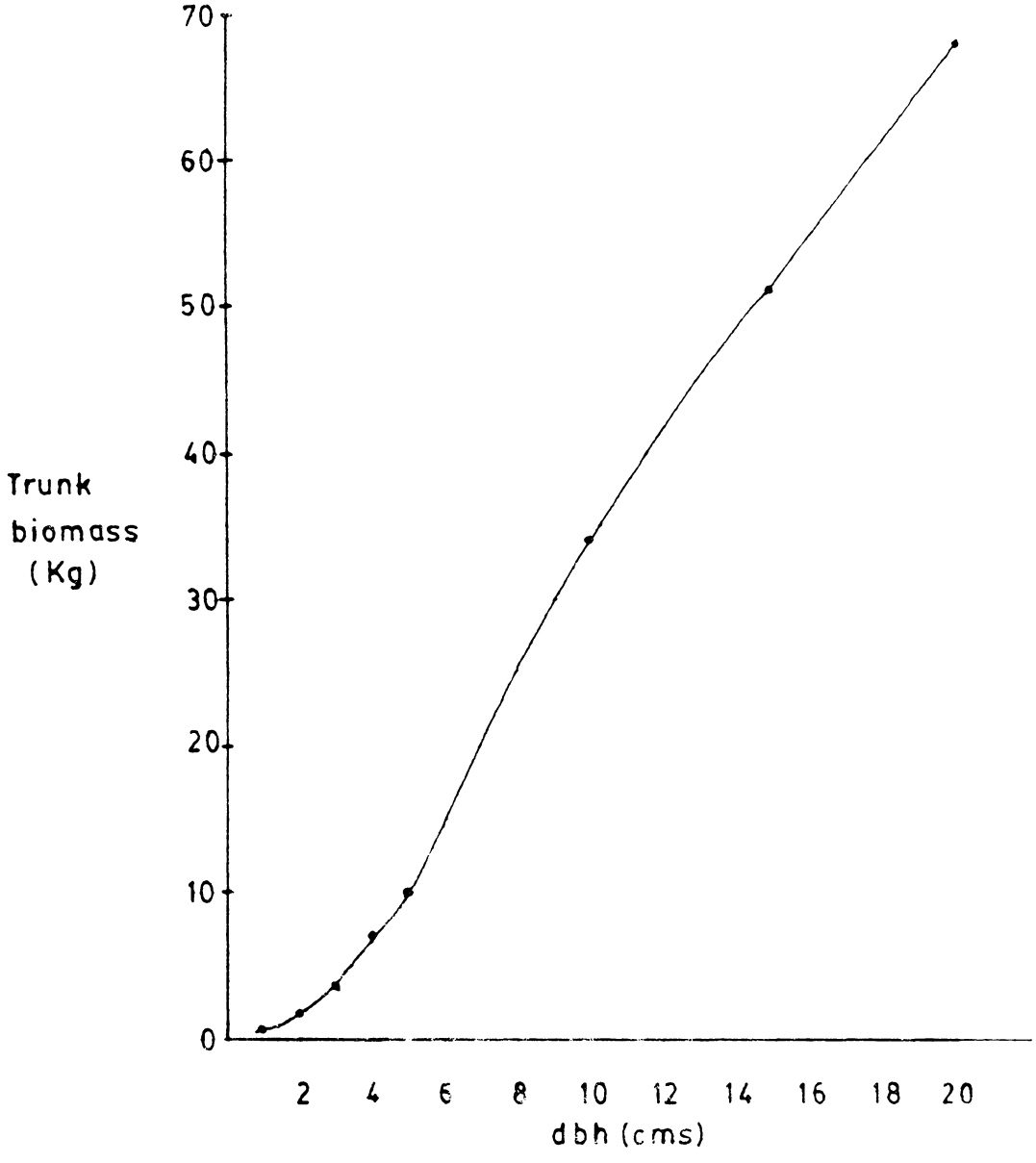

FIGURE 4.6 GENERAL RELATIONSHIP BETWEEN dbh AND BIOMASS OF RED MANGROVE TREES (modified from Golley et al, 1962 and various other authors)

9. Calculate the mean weight of the timber stocks for each dbh class in the measured mangrove sample plots (see example, Table 4.7).

10. Calculate the total timber stock for the whole mangrove stand:

    = mean for sample plots (kg m^{-2}) x no. of m^2 in stand.

Management options

11. The total timber stock (10 above) is available for exploitation, management decisions must be made concerning method of harvesting. The main options (see also Ex. 3.1) are as follows:-

    a. Clear fell the mangrove forest to remove all timber; the harvest will be equivalent to the total timber stock/standing crop (as estimated in 10 above).

    Note: With mangroves growing at a mean rate of 0.33 cm yr^{-1}, it will be necessary to wait approximately 35 years before any further crop is ready for harvesting. This has economic implications for resource users.

    b. Selective harvesting is an option if large sized timber or wood for charcoal is required. One could harvest only trees with greater than 10 cm dbh, for example. Calculate what proportion of the total stock is available under this restriction. The yield is smaller, of course.

    Note: Trees in dbh class 7-9 cm will reach harvest size in about three year's time. It will be necessary to wait several years for other size classes to reach harvestable size. This method forces resource users into an irregular exploitation cycle.

    c. Continuous or regular harvesting

    The two previous options give sustainable yields of timber/charcoal over long periods of time but at irregular intervals, so are not optimal for the user group. It should be possible to calculate a smaller, but continuous mangrove crop which would support permanent industries; for example a small regular amount of timber cut and prepared as charcoal for the the weekly market.

Table 4.7 Survey of Mangrove Timber Stocks - L'Anse Paletuvier, September, 1987.

(a) Trees		A		B	C
dbh class (cm)	No. trees in sample plot(500m)	Timber in sample plot (kg)	Timber wgt per m^2 (kg)	Total timber in stand (5.6ha) (kg)	Expected total timber in stand after 1 year (kg)
> 15	1	60	0.12	6,720	6,832
15	5	255	0.51	28,560	29,120
14	2	96	0.19	10,752	10,976
13	0	-	-	-	-
12	12	492	0.98	55,104	56,448
11	10	380	0.76	42,560	43,680
10	22	748	1.49	83,776	86,240
6 - 9	24	528	1.06	59,136	60,480
1 - 5	57	262	0.52	29,344	30,940

Total A = 2,821 kg

Mean = 0.63 kg m^{-2}

Total B = 315,952 kg

Total C = 324,716 kg

Increment C - B = 8,764 kg

(b) Seedlings	D		E	F
No. in sample plot	Biomass in sample plot (kg)	Seedling biomass (g m^{-2})	Total biomass in stand (kg)	Expected total biomass after 1 year (kg)
4,500	28.35	56.7	3,175	3,377

Total B + E = 319,127 kg

Total C + F = 328,093 kg

Stand Increment (C + F) - (B + E) = 8,966 kg

Further calculations

12 . Continue to fill in the data table as follows:

- Assume the annual weight increase per tree over 10 cm dbh is 1 kg. For smaller trees read weight increases from Fig 4.6. Calculate the increase in timber weight (G - for growth) for the whole stand for the next year.
- Assuming the mean weight of established seedlings to be 3.6 g, calculate the total weight of seedlings per m^2. Calculate the total weight of seedlings in the stand (R - for recruitment).
- Assume a weight increase per seedling of 0.4 g yr^{-1}. Calculate the biomass of seedlings (recruitment) in the whole stand at the end of Year 1.
- Sum the total timber weight and seedling weight at end of Year 1 (G + R).
- Assuming a 30% mortality (M) for seedlings and trees, calculate the annual increment in timber weight as;

Annual increment (yr 1) = R + G - M

Management decisions and further calculations

13. Theoretically, an amount equivalent to the annual increment of mangrove biomass could be removed without altering stand integrity. This is essentially the Surplus Yield Model (Appendix 6). The question is, how should this yield be removed ?

- Compare the 'surplus yield' figure with that for the total timber weight of trees over 10 cm dbh. How similar are these figures ? Could the yield be taken by removing only the larger trees ?
- Compare the expected yields for trees over 10 cm dbh for each species of mangrove. Could any one species supply the surplus yield ?
- In order to sustain seedling recruitment, it would be advisable to leave occasional mature trees in the stand. Reduce the yield of mature trees by 10% to take this into account.
- Make a final calculation for the (much reduced) amount of 'surplus yield' available for annual harvesting from the stand.
- Calculate the amount of timber which could be harvested;

(a) monthly
(b) weekly

- Calculate the area of the stand that must be cleared to supply the timber;

(a) each month
(b) each week.

14. Refer to the data sheet giving local market prices for mangrove timber. Calculate the market value of the following:-

(a) total stand timber crop
(b) annual (surplus yield) crop
(c) monthly harvest quota
(d) weekly harvest quota

15. Discuss the socioeconomic implications of these different yields. What number of persons would be required to cut timber in these various ways and what income could each expect ? Pay special attention to manpower requirements and income for cutting the most restricted amount on a weekly basis.

Note: Your calculation has probably shown that regulation of mangrove cutting to 'surplus yield' amounts severely limits its direct economic value, and employment generation prospects. There are those who would argue that, with such low economic returns, it would be better not to cut, but preserve mangrove stands for their wildlife and fisheries values. This is probably true for clear felling as this causes reduction in forest cover, frequently leading to adverse alteration of swamp sediments and production rates. These changes can be avoided to a large extent if mature trees are left at regular intervals (the shelterwood system in forestry practice); which as mentioned above also aids seedling recruitment and juvenile growth.

Selective removal of large trees can be beneficial to stand productivity, as it gives opportunity for increased growth by young trees. It can improve the economic value of the stand also, if the less desirable species are removed to encourage growth of the better timber or charcoal species (e.g. Rhizophora in the Caribbean islands).

Planning for OSY

16. Finally, plan the harvesting strategy for this mangrove stand.

mangrove stand.

- Formulate a scheme for regular cutting of trees of a particular dbh that will ensure sustainable timber yield.
- Determine manpower needs for

  (a) cutting timber
  (b) marketing timber
  (c) replanting seedlings
  (d) husbanding young trees and cleaning the stand

17. Prepare draft regulations for management of the stand.

This exercise was designed to expose trainees to the principles and implications of yield estimation, and for simplicity used a "natural" mangrove stand. However, there are few cases in tropical islands where mangroves are in their natural state and are not used by somebody. If management options are to be determined in the real-life situation, there must first be an assessment of current resource use and its rationale. Socio-cultural, economic, and institutional components of this rationale must be understood before realistic options can be considered. Determining OSY (for mangrove timber for example) may be a theoretical starting point, but just as important are overall questions, such as who uses the mangrove and for what? What are the current rates of each type of use and how do they relate to one another ? Are there compatible or competative uses ? Which uses or combination of uses produce the greatest net benefit, and is timber harvest one of them? If so, are the current harvest rates above or below the theoretical OSY (for timber)? If above, what alternatives are there to continuing harvesting at current levels and what incentives might be used? Which user groups can best afford to reduce harvest rates? Given the institutional set-up and user groups involved, what management measures might be most effective in achieving the target harvest levels? Students should keep in mind the management planning concepts generated in Chapter 3 while considering the implications of OSY assessments.

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Alternative Exercises

Yield estimation may be conducted on virtually any coastal resource, provided either that catch data are available or it is accessible for research purposes. Basically one

wishes to know:

- How much of the resource is there, per unit area ?
- How much can be taken annually ?
- What harvest technique should be used ?
- How can requirements of the user groups be accommodated ?
- What regulatory and enforcement measures are needed to ensure sustainable yield ?

Suitable field oriented study examples are as follows:

(a) Yield of oysters from mangrove roots.
Estimate stock by counting numbers of oysters per linear metre of channel margin, or per root and number of roots per linear metre. Obtain growth rate to market size for the species. Assume year-round spawning in most tropical oyster species, giving continuous recruitment.

Yield calculated for whole mangrove area, assuming harvest method is removal of individual oysters. If harvest involves cutting of whole roots, recruitment rate calculations must involve growth rates of mangrove roots (see for example, Gill & Tomlinson, 1977). Continuous spawning means that closed seasons for regulation of stocks have little meaning. A better regulatory mechanism might be rotational harvesting from the margins of different channels of the swamp in successive years.

(b) Yield of brackish water crabs
Several species of large crabs are collected in swamps and estuarine environments, particularly on the drier marginal areas, such as Cardisoma guanhumi and Ucides cordatus in many Caribbean islands. Crabs are caught in or at their burrows using hooks or traps.

Stock assessment is made by counting burrows per unit area, catching crabs and calculating % burrows occupied by market-sized crabs. Growth rates are obtained from the literature; recruitment is assumed to be continuous.

(c) Yields of marine conch
Several species of large marine gastropods are harvested for food (e.g. Strombus gigas) or the shell trade (e.g. Charonia variegata). In coastal areas of the Caribbean conch are found in seagrass beds and shallow lagoonal environments.

Stock assessment is made by snorkel or SCUBA surveys, estimating number seen either per unit area or per time period. Growth rates, spawning season and recruitment rates are obtained from the literature,

Most conch are easily tagged, so that stock size observational estimates can be cross- checked by mark - release - recapture techniques.

For a - c above, an estimate of current fishing pressure (fishing mortality) should be obtained before calculating potential yield.

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Pauly, D. 1980. A selection of simple methods for the assessment of tropical fish stocks. FAO Fisheries Circular. No. 729; 54 pages.

USDC 1987. Caribbean Marine Resources, Opportunities for Economic Development and Management. US Department of Commerce, Washington, D.C.; 91 pages.

Walsh, G.E. 1977. Exploitation of mangal, pages 347 - 362 in Chapman, V.J. (Ed) Wet Coastal Ecosystems, Elsevier Publishing Co., Amsterdam; 428 pages.

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Exercise 4.4 PLANNING THE RECOVERY OF DAMAGED COASTAL ECOSYSTEM RESOURCES

Background:

Tropical coastal ecosystems are subjected to varied and often severe human impacts. **Overexploitation** of extractable products can lead to damage or even loss of resources, as has happened with many populations of sea turtles (Hopkins & Richardson, 1984), and manatees (Bertram, 1974). Intense fishing pressure on reef fishes can upset the ecological balance leading to deterioration of reef building coral populations (Munro & Williams, 1985) and loss of protective reef structures. Although their importance to coastal stability and productivity is widely acknowledged (Hamilton & Snedaker, 1984), mangroves have been cleared extensively to make room for coastal development and agriculture (Hudson, 1983). Dredging activity in the coast zone is implicated in the loss of coral reefs (Grigg, 1970) , while coastal pollution and eutrophication have done considerable damage to seagrass beds (Thorhaug et al, 1985), with their attendant fish nursery and sediment stabilising properties.

As mentioned in the discussion on status assessments (see Ex. 4.1), coastal managers in almost every tropical island will be faced with stressed, damaged or severely diminished natural resources. A very important management option, therefore, is the **recovery** of such resources to the condition where controlled utilization could take place once more. Clear decisions must be made concerning the rationale for attempting resource recovery and the objective of a recovery plan. After this several key factors must be investigated before deciding how recovery will be achieved, and the time period involved. The recovery plan must be placed in an appropriate economic and social context in all phases of the planning. A recent, ongoing recovery plan can be used to illustrate these points:

Case study: The U.S. Sea Turtle Recovery Plan (After Hopkins & Richardson, 1984)

a. Rationale

The following six species of sea turtle occur in coastal regions of the southern U.S.A. and associated states and, under the Endangered Species Act 1973, are listed and

considered to have the following status:

1.	Loggerhead	- Caretta caretta	T
2.	Green turtle	- Chelonia midas	T
3.	Kemp's Ridley	- Lepidochelys kempi	E
4.	Olive Ridley	- L. olivacea	T
5.	Hawksbill	- Eretmochelys imbricata	E
6.	Leatherback	- Dermochelys coriacea	E

E = Endangered species - a species in danger of extinction throughout all or a significant portion of its range.

T = Threatened species - a species likely to become endangered in the forseeable future.

b. Objectives

i - The survival and eventual recovery of listed species or populations, so that they may be removed from the endangered or threatened list.
ii - The conservation of sea turtle habitat as an aid to recovery of the species.
iii - The protection of the species after delisting.

c. The recovery procedure (for each species)

c.1 Collection of baseline data on population status.
c.2 Identification of the causes of decline in the stocks.

Five factors identified:

i. Destruction and modification of habitat
- Pollutants from industrial and residential development
- Exploratory oil and gas drilling
- Disposal of garbage at sea
- Dredge and fill operators
- Power boats

ii. Overutilization for commercial purposes
iii. Inadequate regulatory mechanisms
iv. Disease and/or predation
v. Incidental catch

c.3 Designing appropriate research for describing desired population numbers and habitat characteristics.

c.4 Developing management recommendations.

i. Reduction of turtle mortality on land
- Protection of nests in situ

- Predator reduction
- Increased law enforcement

ii. Reduction of turtle mortality at sea
- Prevention of incidental catch (e.g. by shrimp trawlers)
- Increased law enforcement

iii. Enhancement of production from nesting beaches
- Rearing eggs in hatcheries
- Headstarting (keeping young turtles in captivity until large enough to have a better chance of survival when released)

c.5 Monitoring populations.

c.6 Assessing success or failure of management techniques applied.

c.7 Recommending changes in management strategy.

c.8 Updating the plan as new information becomes available.

The U.S. Sea Turtle Recovery Plan is based on the biology of the target species, but one obvious weakness is its lack of attention to the socioeconomic aspects of sea turtle utilization, other than recommending improved enforcement of regulations banning such use. In small tropical islands where dependency on coastal resources is likely to be greater at subsistence level, a recovery plan would need to take cognisance of these aspects.

The exercise which follows considers the **basic biology** of another damaged resource, but stresses **cost factors** and suggests opportunities for **community participation** in the recovery process.

Aim:

To prepare a plan for the recovery of damaged seagrass beds.

Duration:

1 day (6 hours)

Suitable Location:

Laboratory/drawing office exercise using an hypothetical case-study. This should be supported by field observations in similar environments where students are not familiar with seagrass beds.

Materials Provided:

(a) An Executive Summary from a consultant's report (page 220).
(b) The following accompanying maps and data tables:

Fig. 4.7	Physical features of Green Turtle Bay.
Fig. 4.8	a. Mooring sites (Nov. 1986) b. Extent of seagrass beds 1985-1987
Table 4.8	Fishery Catch Statistics, Green Turtle Bay 1983 -1987
Table 4.9	Visitor boat moorings 1983 -1987

(c) Summary of seagrass replanting methodology (Appendix 7).

Instructions:

1. Study the Executive Summary taken from a report by a consultant ecologist under Government Contract BWI - 19A/1987.

2. Study the accompanying maps and data tables; Figures 4.7 - 4.8 and Tables 4.8 - 4.9.

3. Discuss the issue and decide on the following:-

   - What is the nature of the problem ?
   - What is the extent of the problem ?
   - What is the cause (or causes) of the problem ?

4. You are faced with two options, as manager of this coastal area, either ignore the problem or attempt to correct it.

   - What are the likely economic and social costs of ignoring the problem ? Attempt to express these at today's currency value and identify who will bear these costs.
   - Make a list of all actions necessary to correct the problem.
     This should be subdivided as follows:-

     (a) Reduction of impacts by fishing industry.
     (b) Reduction of impacts by yachting interests.
     (c) Reduction of impacts from other sources.
     (Remember that fishing and yachting make significant contributions to the economy, so you wish to sustain these activities in Green Turtle Bay while controlling adverse impacts.)

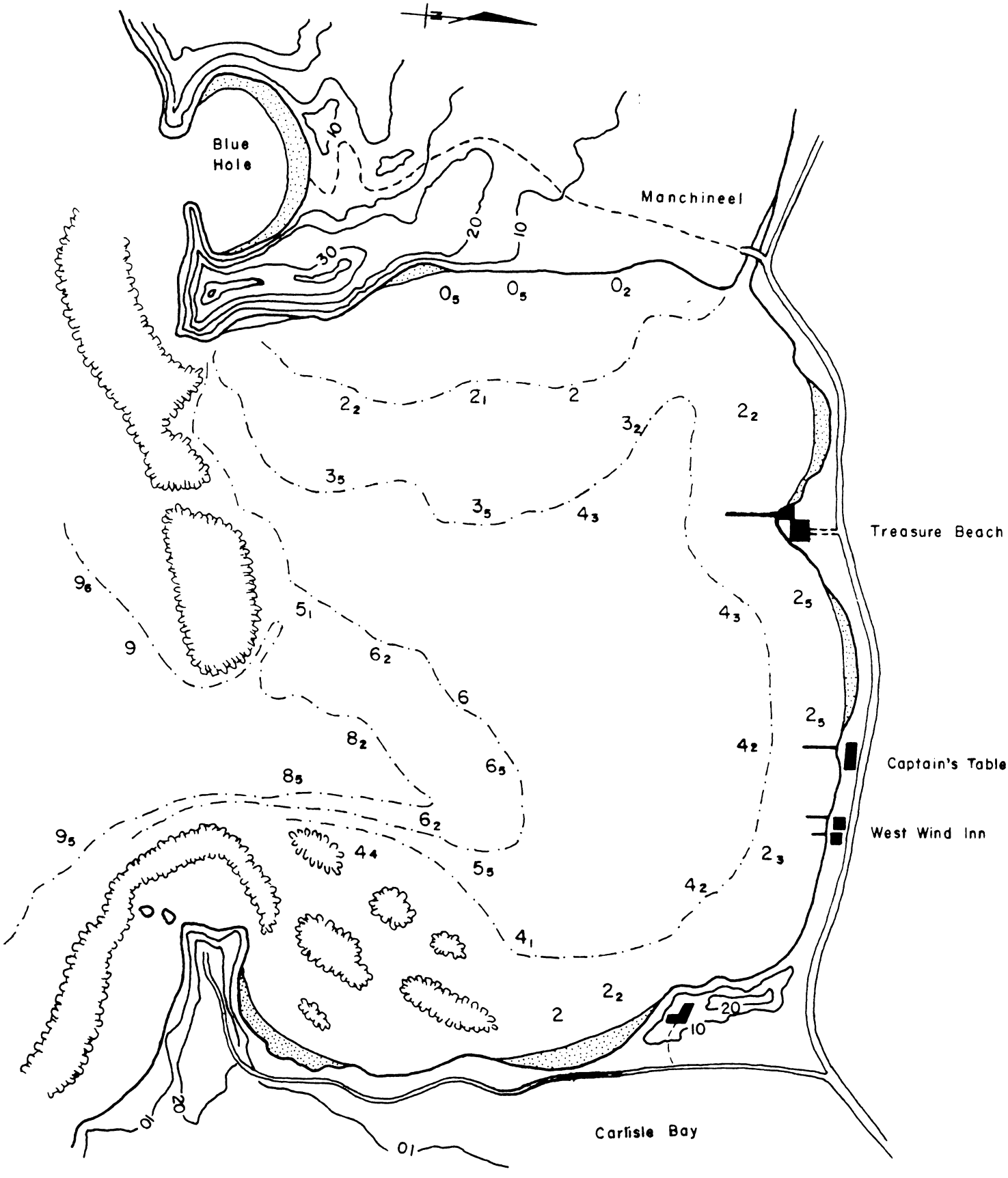

FIGURE 4.7 PHYSICAL FEATURES - GREEN TURTLE BAY

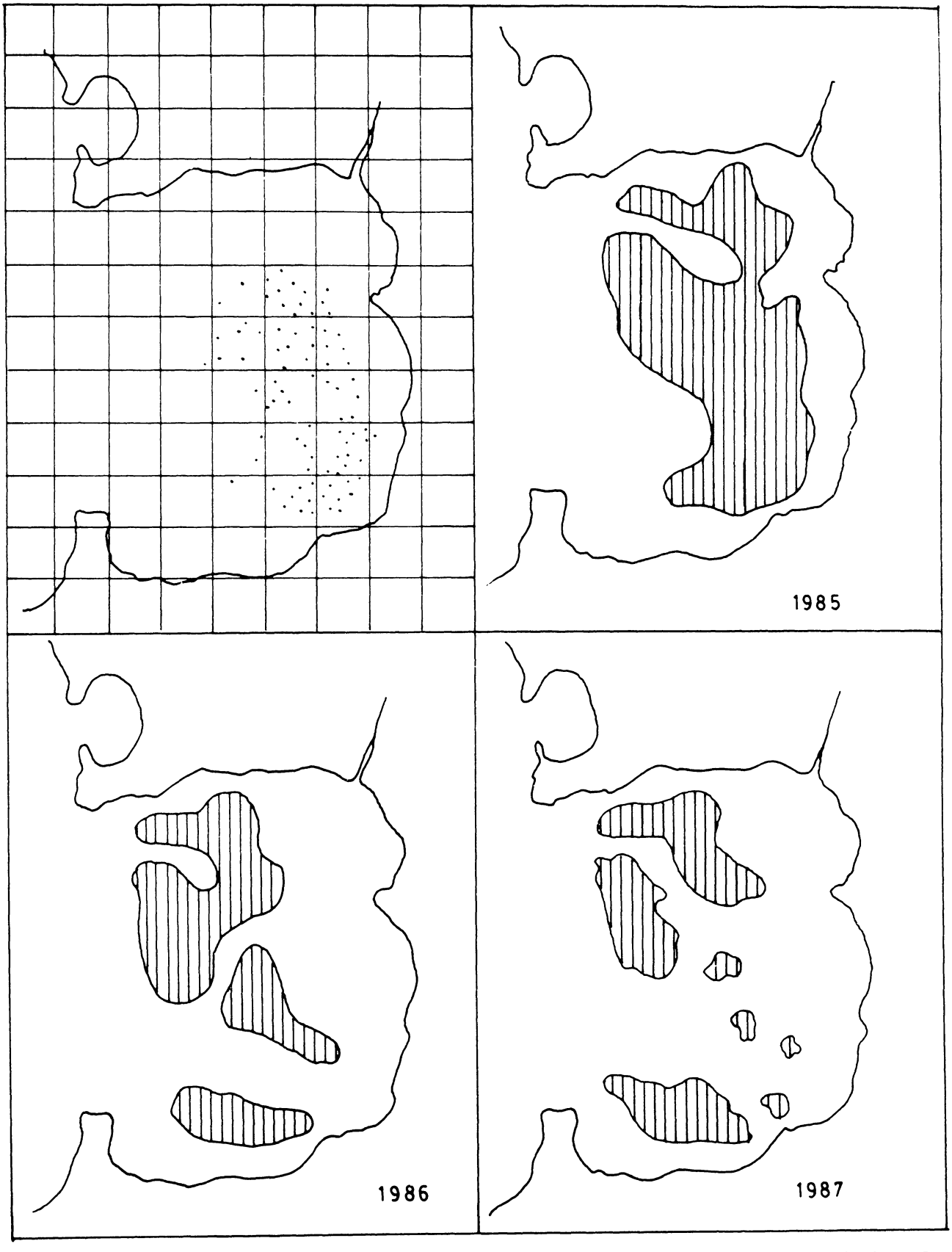

FIGURE 4.8 GREEN TURTLE BAY - BOATS MOORED DURING TWO DAYS AIR SURVEY (top left), AND SEAGRASS DISTRIBUTION 1985 TO 1987

Table 4.8 Catch statistics: Green Turtle Bay, 1983 -1987

Year	No. Active fishermen by method of catch				Annual catch kg				Approx Total income US$
	Seine	Trawl	Line	Spear gun	Fish	Shrimp	Conch	Total	
1983	15	0	8	4	86,000	5,660	8,424	100,088	128,34
1984	12	0	9	5	92,050	6,480	7,860	106,390	137,99
1985	6	12	6	6	104,500	84,600	8,800	197,900	419,20
1986	4	17	4	3	72,224	12,026	6,320	90,570	131,97
1987	5	10	15	2	8,160	2,320	162	10,642	17,79

Source: Western Region Fisheries Center, Annual Report 1987.

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Table 4.9 Visitor boat moorings: Green Turtle Bay, 1983 - 1987.

Year	Annual boat moorings (all foreign craft)				Mooring fees US$
	Treasure	Captain's Table	West Wind Inn	Total	
1983	82	21	6	109	216
1984	78	22	82	182	364
1985	410	141	185	736	3,680
1986	482	152	322	956	9,560
1987	960	740	820	2,520	70,600

Source: National Yachting Association, Annual Report, December 1987.

- Put a dollar cost on the actions suggested, and compare this with possible losses estimated above. Your calculations should include costs of materials and labour, as appropriate.
- Plan a chronogram for mitigation activity, i.e. a timetable for the corrective actions listed above.

5. Once plans are finalised for removing adverse impacts on the seagrass beds, prepare a plan for recovery of damaged areas of seagrass. You have two options, viz., (a) rely on natural recovery and spread of seagrass which may take several years, or (b) assist recovery by replanting.

   - Examine figure 4.8 and assess the technical feasibility of replanting all damaged areas in Green Turtle Bay. Study some of the scientific literature relating to seagrass replanting in your region and note that some authors, such as Fonseca 1987, consider that replanting schemes have a low chance of success.
   - Estimate how many transplants you will need and the cost of obtaining these (refer to Appendix 7).

     Transplants can be removed from areas of healthy seagrass, taking care not to uproot or denude too much of these areas. Select areas likely to be a source of plants for transplanting.

     Estimate the cost of other materials used in replanting.

     Estimate manpower needs and labour costs to complete replanting in 2 - 3 months.

6. Draw up a budget for the total costs of adverse impact mitigation and seagrass bed recovery.

   Compare with socioeconomic costs of ignoring the problem, noting who will bear these costs, and decide on the most appropriate management options.

7. If you decide on the option of taking corrective action, plan a resource recovery strategy for Green Turtle Bay.

8. The success of your recovery strategy will depend heavily on cooperation from the fishing community and yachting interests; hopefully, it will be seen as a benefit to both, plus local recreationers in the long-term. There are advantages, therefore, in "community participation" in the seagrass restoration project.

- List ways in which the community can assist, e.g. collecting transplants; preparing sprigs for planting out.
- Calculate cost savings at all levels of the project through the use of voluntary labour or other forms of local assistance.
- Budget funding and time for creating community awareness of the restoration project.

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Supporting Document

Executive Summary: Report on the Destruction of Seagrass Beds in Green Turtle Bay.

1. Factors leading to deterioration of water clarity, increased accumulation of weed on beaches, and reduced fishing yields in Green Turtle Bay, were investigated over the three month period March through May, 1987.

2. All human activities dependent on the bay were documented. Three main categories of activity were observed: fishing, yachting and recreational beach use.

3. Fishing was conducted from the fishing depot at Manchineel (Figure 4.7). There were 32 fishermen in full-time employment, showing preferences for different gear. Fishermen all confirmed serious reduction in catch rates since 1985, especially for fin fish with turtles (Chelonia mydas) and conch (Strombus spp.) rarely obtained nowadays (Table 4.7).

4. Previous productive fishing areas had been largely in the eastern and south eastern sections of the bay.

5. Three bayside hotels had become popular with foreign yachtsmen in recent years. Sail and motorised craft anchor in the bay near to Treasure Beach, Captains Table and West Wind Inn while patrons enjoy the facilities (Figures 4.7 & 4.8). Records of the National Yachting Association show an over 2,000% increase in small craft stopovers in the last five years; and collection of mooring fees now exceeds US$70,000 per annum (Table 4.8).

6. Green Turtle Bay is rarely used by local boats.

7. The Carlisle Bay beach is used by local families for

recreation, largely at weekends. The maximum number of persons on the beach at any one time during the survey was 106.

8. Residents and recreationers confirm that Carlisle Bay has been fouled by weed much more than usual during late 1986 and early 1987. Collections of weed made at weekly intervals throughout the survey were 86% Thalassia, 10% algae and 4% Syringodium.

9. Deterioration in water quality was confirmed using a Secchi disc. The disc was visible only to the depth of 1.0 m at any point in the south eastern half of the bay, and only during calm weather. At most times visibility was less than 0.5 m. Visibility for divers underwater in this sector was rarely greater than 1.0 m. - Pilkington & Haynes mapped seagrass distribution in 1985 along transects while snorkelling at the surface, indicating that visibility was much greater at that time.

   - One hotelier reported decreasing use of the sea by guests for bathing, and frequent complaints of poor water quality.

10. The floor of the entire bay was surveyed by a team of biologists and experienced SCUBA divers, using a grid of parallel transects marked at 2 m intervals. Bottom substrate type and plant community composition was mapped for the area 1 m wide on each side of the line.

11. The seagrass, Thalassia testudinum, was the dominant marine plant. Fleshy algae were the next most abundant group.

12. The distribution of seagrass was compared with maps produced in a previous study in 1985 by Pilkington & Haynes (Figure 4.8). It was found that a 48% reduction had occurred in the area covered by seagrasses since 1985.

13. Detailed observations over a three month period indicate that seagrass beds are being damaged by two principal activities:

    (a) use of otter trawls by fishermen damages seagrass blades and disturbs sediment.
    (b) boats pulling up anchors, and occasionally dragging anchors, uproot seagrasses.

14. These causes of damage are quantified and (b) is shown to cause greatest mortality to the plants.

15. It is recommended that the use of otter trawls be

banned with immediate effect.

It is recommended that adequate mooring facilities be provided for small craft and that yachting regulations be formulated to discourage bottom anchoring in Green Turtle Bay.

(Note: Figure and Table numbers refer to the preceeding exercise, not to those used in the original consultant's report)

End of Summary

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Alternative Exercises

Actual recovery of damaged biological resources or ecosystems is normally a lengthy process, so that for training course purposes it may not be possible. However, with prior planning and laboratory support the feasibility and some of the problems associated with recovery can be demonstrated, as follows:

1. Survival of Seagrass Transplants

   Three to four permanent plots 5 x 5 m can be established and marked with lines or blocks. Seagrass plugs, sprigs or seeds can be planted, using techniques of Appendix 7. This will require at least one day's work. The plots should be inspected at intervals of one week to monitor replanting success, for as many weeks as possible. The following can be measured (1) Amount of growth, (2) relative growth of plugs, sprigs and seeds, (3) % mortality or loss of transplants.

2. Effects on a donor bed of removing seagrass transplants

   Transplant plugs should be removed from a donor bed according to a regular grid pattern. The site can be revisited at intervals to study (1) if removal has led to erosion of the bed, or (2) the rate of filling up of patches from which seagrasses were removed.

3. Reseeding an overexploited conch population

Juvenile conch can be reared in the laboratory in advance, or collected from areas of high population density. They can be released into a marked section of the depleted area (provided that suitable habitat conditions are present, according to the literature). For this exercise, the site should be revisited at intervals of two to three days to study (1) dispersal of the released stock and (2) % loss (assumed natural mortality).

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Further Reading:

Bacon, P.R., Berry, F.D., Bjorndal, K. et al. (Eds). 1984. Proceedings of the Western Atlantic Turtle Symposium, San Jose, Costa Rica, July 1983, Center for Environmental Education, Washington, D.C.;1138 pages.

FIU 1984. Seagrass Restoration in Caribbean Nearshore Areas. Florida International University and the United States Agency for International Development; 70 pages.

Lewis, R.R. 1982. Creation and Restoration of Coastal Plant Communities. CRC Press, Inc., Florida; 219 pages.

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CHAPTER 5

RISK ASSESSMENT AND CONTINGENCY PLANNING

Introduction:

Island coasts are exposed frequently to extreme forces generated by tropical storms. The damage caused by hurricanes (typhoons or cyclones) may be from direct effects of the strong winds or indirect effects such as flooding. Direct and indirect damage to coastal areas occurs also from the tsunamis which may be generated by other events such as earthquakes.

While they cannot be prevented, these events can be predicted with increasing accuracy, so that steps can be taken to remove people from danger areas and secure property against possible damage. However, **Disaster Preparedness** should not be solely an emergency procedure in response to immediate perceived danger, but part of long-term national planning (Schnabel, 1972). It should include the following:

(a) **Risk Assessment** - in which the coastal areas most likely to be subjected to hurricane, storm surge or flooding are identified; or alternatively, the areas likely to suffer the greatest economic losses should a natural disaster occur.

(b) **Contingency Planning** - in which a strategy is devised for dealing with the disaster should it occur, or, preferably, when it is forecast. To be most effective, the Contingency Plan should be prepared well in advance and, if possible, rehearsed.

Both aspects of Disaster Preparedness carry the implication that human settlement and economic activity should be reduced in, or removed from, the areas of greatest risk from natural disasters. This concept is important in coastal development planning; it raises the whole question of set-back lines, and the location of industries and tourism infrastructure at the land-sea interface (United Nations, 1982; Deane, 1987).

In addition to the possible impacts of the sea on human activities, there are potential ecological and economic disasters associated with man's impact on coastal areas. Chief among these are accidental spillages of oil and toxic substances in ports and harbours. The agency responsible for Disaster Preparedness would need to assess the risks involved in the transport and use of these

substances, locate critical areas, strengthen preventative measures and prepare Contingency Plans. Each aspect would require detailed and accurate knowledge of coastal structure and processes, of socioeconomic conditions and development activities in the coastal zone. There would also need to be coordination of responsible agencies and their enabling legislation, as there would be for dealing with natural disasters. Risk Assessment and Contingency Planning thus form an important component of the coastal zone management process; and the exercises which follow are designed to illustrate some practical approaches to this complex topic.

Exercise 5.1 PREDICTING COASTAL FLOOD HAZARD

Background:

Among the many effects of tropical storms on island coasts, the greatest damage is probably caused by the **storm surge.** This is "an abnormal rise in water generated by a tropical storm along coastal regions. A storm in a sea or ocean creates a circulating mound of water, of small surface elevation, which follows the storm's core. On its approach to shallow waters, the mound of water feels the bottom and begins to elevate; on striking the coast it is further amplified by coastal barriers before receding seaward. The length of the coast affected by a surge averages about 100 miles and the surge may last for a period of several hours" (WMO, 1981).

It is possible to **predict** which sections of an island's coast are most likely to experience storm surges. This is being done by studying coastal geomorphology and prevailing wind patterns (Deane, 1987) supported by analysis of historical records (Naughton, 1984) (see also Exercise 2.2. & Appendix 3). However, the actual location of maximum storm surge is dependent on the track of the hurricane itself, which is less easily predicted.

For Risk assessment purposes, the degree of **vulnerability** of the coast may be a more practical criterion, i.e. if a storm surge should occur there, which parts of the coast are likely to suffer the greatest damage? This will depend on observable, and measureable, characteristics of the coastal zone, including natural features and human settlement patterns (Table 5.1), rather than predictions. An analysis of these characteristics, and planned changes to sections of the coastal zone, can be prepared in the form of maps or tables which highlight the most vulnerable areas. This exercise deals with one likely effect of storm surge, **flooding of low-lying areas** of the coast as a result of abnormal rise in sea level. (Flooding could occur also as a result of rainfall associated with the hurricane storm, and the effects are likely to be most severe in the same areas identified as being vulnerable to flooding with seawater). **Flood Hazard Prediction** can be carried out rapidly and with reasonable accuracy in most tropical islands because it relies almost entirely on the fixed locations of land-based features on available topographic map sheets.

Aim:

To prepare a map showing coastal areas most likely to be flooded by hurricane storm surge.

Duration:

One Day (minimum).

Table 5.1. Characteristics of a coast which might contribute to damaging effects of hurricane storm surge.

a. Physical characters:

- topography (sea level to 10 m contour)
- bathymetry
- nature of the island shelf
- presence of reefs, and other inshore features
- presence of mangrove swamps, or lagoons
- natural drainage pattern
- reclamation works
- extent of fill
- modification of drainage channels

b. Settlement characters:

- location of settlements
- number of settlement units
- size/extent of settlements
- types of structures used
- range of activities in the settlement (residential, commercial, industries & specialised sites, recreation, farming)
- nature of connecting infrastructure

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Suitable Locations:

Drawing Office/Laboratory exercise.

Materials Required:

Topographic map sheets of island, or portion of island coast. These will need to be large scale maps, showing fine contour detail.
Descriptive information or data on the nature of settlements in the target coastal area (population density, types of housing, types of industries).
Summary of scheduled developments for the target coastal area.
Drawing materials.

Map making materials (see Chapter 3).

Instructions:

Map Work and Preliminary Analysis

1. On the topographic maps provided, distinguish low-lying coastal areas. Assume that a storm surge causes a rise in sea level of one metre; mark or shade all areas up to one metre above sea level. Trace this onto a clear acetate sheet.

2. Repeat the above step for storm surges up to 5 m and 10 m.

3. Overlay the acetate sheets, and trace onto a fourth sheet to show the vulnerability of the target coastal area to flooding by storm surge waves of different heights.

4. On a further overlay sheet, trace the locations of settlements and their supporting infrastructure. Distinguish, by means of symbols, between residential, commercial, agricultural and industrial features.

5. Overlay the settlement pattern map with the flood level maps and produce a summary narrative description of the extent of damage that could be expected with storm surge waves of different height.

6. Return to the settlement map (stage 4 above), and distinguish as far as possible between different types of developments, i.e. use symbols to distinguish between villages dominated by wooden houses as opposed to concrete/brick houses; or industries and activities that might create special problems if flooded, such as sewage treatment plants or solid waste dumps. Modify the narrative description if any of these features might lead to increase in economic losses or environmental problems.

7. Continue the analysis of the possible effects of flooding by considering whether it would be advisible to relocate any part of existing settlements or their infrastructure. (Bear in mind that "risk" is being considered, and willingness to risk damage must be weighed against costs of relocation. In some cases the benefits of being sited close to the coast, for certain industries and tourism facilities, become part of the equation for

risk assessment).

8. Examine the summary of development plans for the target coastal area. In the light of the mapping and analysis conducted above, recommend any changes or relocations that might avoid losses due to flood damage in the future.

Final Analysis

9. Represent the information and concepts generated above in the following way:

   (a) **Risk Intensity Maps** - as drawn above to show risk in terms of relative height above sea level and degree of socioeconomic losses.

   (b) **Best Use Maps** - which show recommended categories of land-use in the relative risk zones; i.e. land below 1 m a.s.l. which has a high risk of storm surge flooding could be earmarked for wildlife conservation or wilderness type recreation; housing could be restricted to land with relatively low risk, and certain sensitive industries removed to sites with extremely low risk.

   Support this final analysis with a narrative summary of the relative area available for each designated activity.

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Alternative Exercises:

1. Factors which modify effects of hurricane storm surge on coastal areas can be examined, provided good topographic maps and bathymetric charts of the island are available. Inshore features are known to affect storm waves; barrier beaches, coral reefs and mangrove swamps can dampen their height and energy, whereas certain patterns of sea bottom contour (Bathymetry) can increase them (see also Exercise 2.2). Maps of an island can be examined and coastal features of this type identified.

2. Analysis of historical records of storm surge damage can be carried out and an attempt made to explain why the intensity of damage varied in different parts of

the affected coastal area. This depends on the availability and accuracy of the historical records. Damage data should be compared with risk intensity maps based on elevation and settlement patterns, as prepared above.

3. Human activity in the coastal zone is imperilled by global changes in sea level. Some two thirds of the population of most tropical islands and the major part of their economic activity is centred at, or very close to, sea level; including capital cities, ports, mariculture facilities and tourism infrastructure. In recent years, good evidence has accumulated of a slow but continuous rise in mean sea level of from 10 - 20 mm annually. Initially this does not appear to be of great significance for coastal zone management, but if students calculate the posible change in water level after 10 or 15 years a different picture emerges. Students could discuss the long-term implications of sea level rise on (a) subtidal systems, such as coral reefs (b) intertidal systems, such as mangrove swamps, (c) rates of erosion and sedimentation, (d) the horizontal displacement of the shoreline, (e) human settlement in supratidal situations, and (f) economic activities in the coastal zone. If detailed contour maps of one economically significant coastal area are available, a prediction could be made of the extent of coastal flooding and resulting economic losses after several years, presuming that the rate of sea level rise remains constant. A further calculation could be of the cost of improving coastal defences to prevent flooding or erosion.

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Further Reading:

Pirazzoli, P.A. 1985. Sea level change. Nature and Resources, 21 (4); 2 - 9.

Schnabel, R.E. 1972. Disaster Preparedness. Office of Emergency Preparedness, Washington, D.C.; 364 pages.

United Nations 1982. Coastal Area Management and Development. United Nations Department of International Economic & Social Affairs, Ocean Economics & Technology Branch, Pergamon Press; 188 pages.

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Exercise 5.2 OIL SPILL CONTINGENCY PLANNING

Background

Oil spilt into the marine environment is known to cause serious ecological damage and economic losses. Technology is available for containment and clean-up of spilt oil, but its effectiveness depends on rapid deployment of appropriate gear or dispersants by trained personnel. Successful deployment depends also on accessibility to the site of the spill and the sea conditions following the spill.

Because of the serious damage that might result from a spill, no country can afford to wait for an accident and then start to work out what to do about it. A more sensible approach is to prepare a "Contingency Plan" in advance, so the responsible authorities are ready should a spill occur. For this, the planners try to predict:

(a) where a spill might occur,
(b) what is likely to happen when the spilt oil spreads in the sea, and
(c) how to protect those coastal areas which are likely to be affected.

Even on a small island it would be difficult and costly to protect the whole coastline, so a decision must be made concerning which coastal ecosystems or economic activities get priority for protection. Other aspects that must be planned are:

(a) who will take responsibility for organising the clean-up operation,
(b) who will actually do the work,
(c) what equipment will they use,
(d) where will that equipment be stored,
(e) how will the equipment and personnel be transported to the site of the spill,
(f) how will orders and instructions be communicated and the clean-up operation coordinated.

Aim:

To produce the outline for an Oil Spill Contingency Plan for the island.

Duration:

3 - 4 hrs

Suitable location:

Drawing Office/Laboratory

Materials required:

a. Topographic map (large scale) of the whole island and surrounding seas.
b. Topographic maps (1:50,000 or smaller scale) of sub-regions of the whole island.
c. Bathymetric charts of inshore areas and harbours.
d. Wind rose diagrams, January through December (obtained from the main airport or other meteorological station)
e. Sea surface current diagrams, for all coasts, January through December.
f. Data sheets and/or diagrams showing distribution of major fishing grounds and fishing communities; hotels and major tourist beaches; important coastal ecosystems (eg. mangrove areas) or marine species (eg. sea turtle nesting beaches); ports and petroleum product handling sites; air fields; mooring locations of marine police launches or coastguard boats.

Instructions:

1. Locate high-risk oil spill areas around the island

   - for tanker accidents at sea
   - for tanker accidents when entering or leaving port
   - for spills during loading or off-loading.

2. Chart the likely directions of movement of spilt oil in the sea in order to identify areas of possible impact on the coastline. These are predicted from wind and surface current data. Take note of any seasonal changes in these factors. For example, reference to streamline flow patterns around the island of Tobago resulting from wind-driven currents (Figures 2.14 & 2.15) show a likely impact on eastern but not western coasts. Prevailing winds around Jamaica (Figure 5.1c) suggest likely movement of spilled oil alongshore from east to west, with marine currents showing a strong onshore component on both northern and southern coasts. Inshore eddy currents and tidal effects will further modify the actual path of an oil spill, and the likelihood of a tanker accident is increased during storm or other "abnormal" weather conditions.

   Although the main movement of oil will be due to movements of the water mass (i.e. currents), the major part of a spill will be floating at the surface and therefore affected by wind direction. Seasonal

changes in strength and direction of winds and currents (Figure 2.14 & 2.15) will affect the general pattern of drift.

The accuracy of prediction depends on the accuracy of available wind and current data, both recorded and forecast, particularly for inshore areas. Current speed, and therefore likely travel time of spilled oil, is an important consideration in planning the response time of clean-up crews.

3. Map the distribution of the different coastal ecosystems and identify priority areas for protection. Coastal ecosystems will be affected by spilled oil in different ways. Some will be more **vulnerable** than others; for example floating oil is more likely to strand on intertidal rocky shores than on submerged seagrass beds, or alternatively, is more likely to persist on sheltered mangrove roots than on exposed wave-washed rocky cliffs. (Use of a Vulnerability Index is discussed in Alternative Exercise 2 below). Some ecosystems will be more **sensitive** to petroleum hydrocarbon residues than others; for example, oil might destroy a population of rocky shore biota but recolonisation will be rapid once the oil disperses, whereas if oil kills red mangroves the resulting habitat damage will reduce the likelihood of population re-establishment. In the case study presented below, coral reefs and mangrove swamps are identified as "key ecosystems" because of their vulnerability and sensitivity (Figure 5.2a). These common tropical island ecosystems are priority areas for protection also in terms of their **importance** for coastal protection, marine foodchain support and commercially exploitable resources.

   The group should identify the types of ecosystem present in the coastal zone of the study island and discuss their priority ranking, using the above criteria.

   In some cases, in addition to ecosystems, there might be resource organisms under threat from an oil spill; for example, nesting sea turtles, migratory or resident wading birds or marine mammals. Habitat used by these organisms might need to be included in any maps showing priority areas for protection.

4. Map the distribution of economic activities in coastal areas and identify priority areas for protection.

5. Use a table or diagram to show clearly areas of highest priority for protection (combine 3 & 4 above).

6. Map areas of the coastline which might be inaccessible

to the clean-up crew, from both/either land or sea.

7. Prepare a diagram showing a suggested "command structure" and lines of communication for operation of the plan.

8. Map the main routes for transporting clean-up equipment from its storage site to priority areas of the coast. Consider land, sea or air routes.

The plan should be presented in the form of annotated maps and/or diagrams, so that a reader can grasp quickly the objectives of the plan and the suggested logistics of the clean-up operation.

You may assume that a set of clean-up equipment is stored at the Harbour Master's office in the main port. The equipment is ready on the dock side and consists of a boom, barrels of chemical dispersants, a work boat, a hand-operated pump and a small winch.

Product expected

The Contingency Plan will be a series of "visual aids" suitable for notice board display at a training course. Examples of maps and diagrams which form part of a similar plan for the coast of Jamaica are shown in Tables 5.2 & 5.3 and Figures 5.1 & 5.2; and interpreted as follows: Oil tanker routes (Figure 5.1a) show that accidental spillage is most likely off the east or southeast coasts, while six areas are identified with off-loading ports (Figure 5.1b & Table 5.3). Likely directions of movement of spilled oil are, on average, from east to west (Figure 5.1c). The distribution of coastal ecosystem types (Figure 5.2a) and economic activities (Figure 5.2b & Table 5.2) indicates that five areas of the coast should be considered priority for protection (Figure 5.2c). The chain of command for plan operation would include the Jamaica Office of Disaster Preparedness and the Office of the Prime Minister making the decision to launch clean-up operations, under coordination by the Defence Force/Coast Guard using funds and labour provided by the Parish or District Councils. The Natural Resources Conservation Department would advise on environmental protection and monitor the operation (see also Table 1.3).

Table 5.2. Annual catch and landings on Jamaican fishing grounds

	FISHING GROUND				
	NORTH SHELF	SOUTH SHELF	PEDRO BANK	OTHER BANK	TOTAL/ AVERAGE
Annual catch	1107.85	3610.19	1590.70	896.63	7205.37
No. of landings	119.64	173.15	7.53	27.71	328.63
Catch per landing	20	46	466	71	4

(Various sources)

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Table 5.3. Petroleum and petroleum products - outports 1981.

	Petroleum products in tons (1 ton = 1016 kg)					
Port	Total	Fuel	Gas oil	Bunker C	Marine diesel	Auto diesel
Montego Bay	120,045	120,045	-	-	-	-
Ocho rios	13,609	13,568	-	41	-	-
Port Esquivel	631,246	547,347	-	83,899	-	-
Port Kaiser	635,650	619,381	16,269	-	-	-
Port Rhodes	30,611	6,440	-	16,042	3,543	4,586
Rocky Point	162,749	162,749	-	-	-	-
Total	1,593,910	1,469,530	16,269	99,982	3,543	4,586

(Various sources)

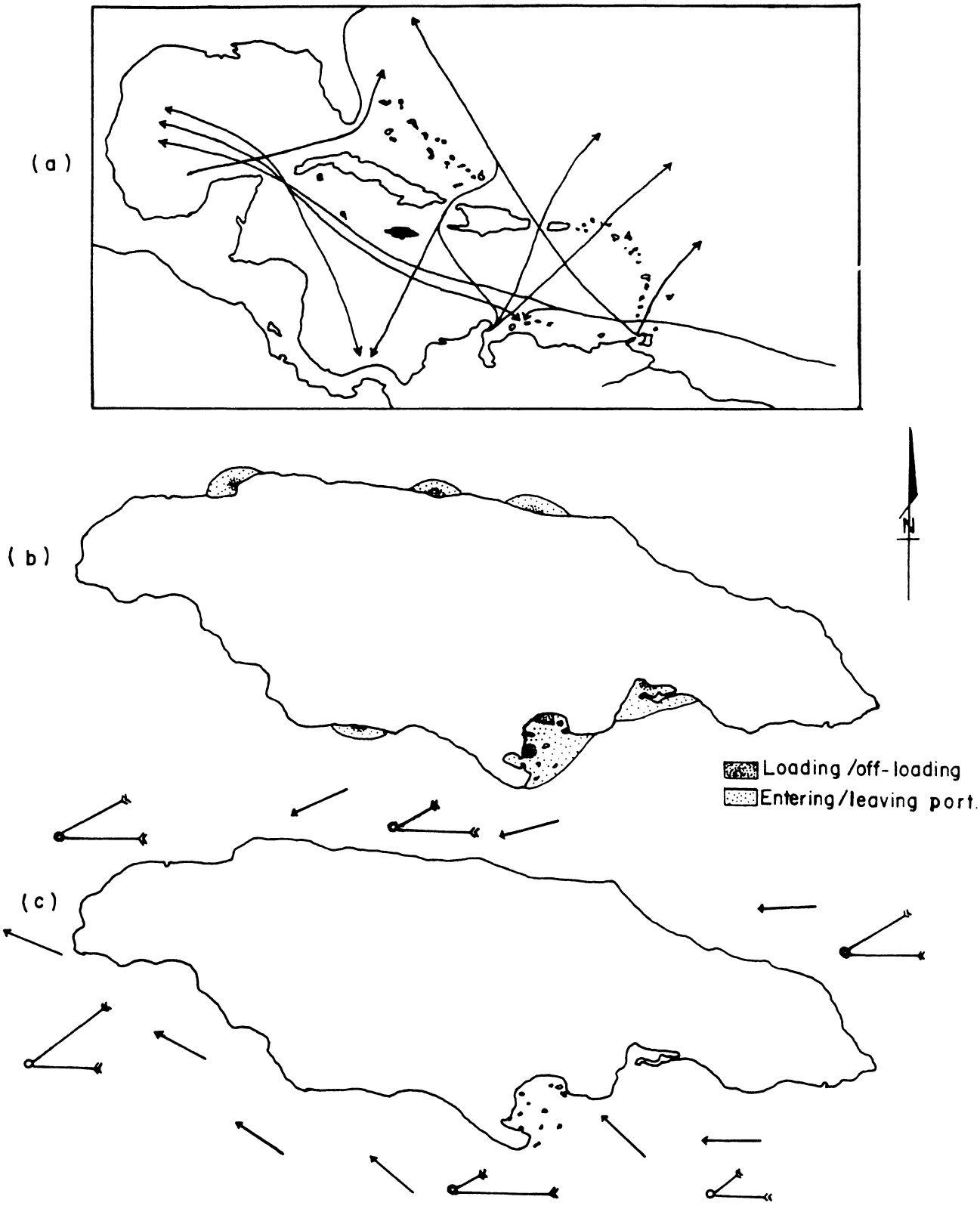

FIGURE 5.1 (a) MAJOR OIL TANKER ROUTES, (b) INSHORE HIGH RISK SPILL AREAS, (c) WINDS AND CURRENTS

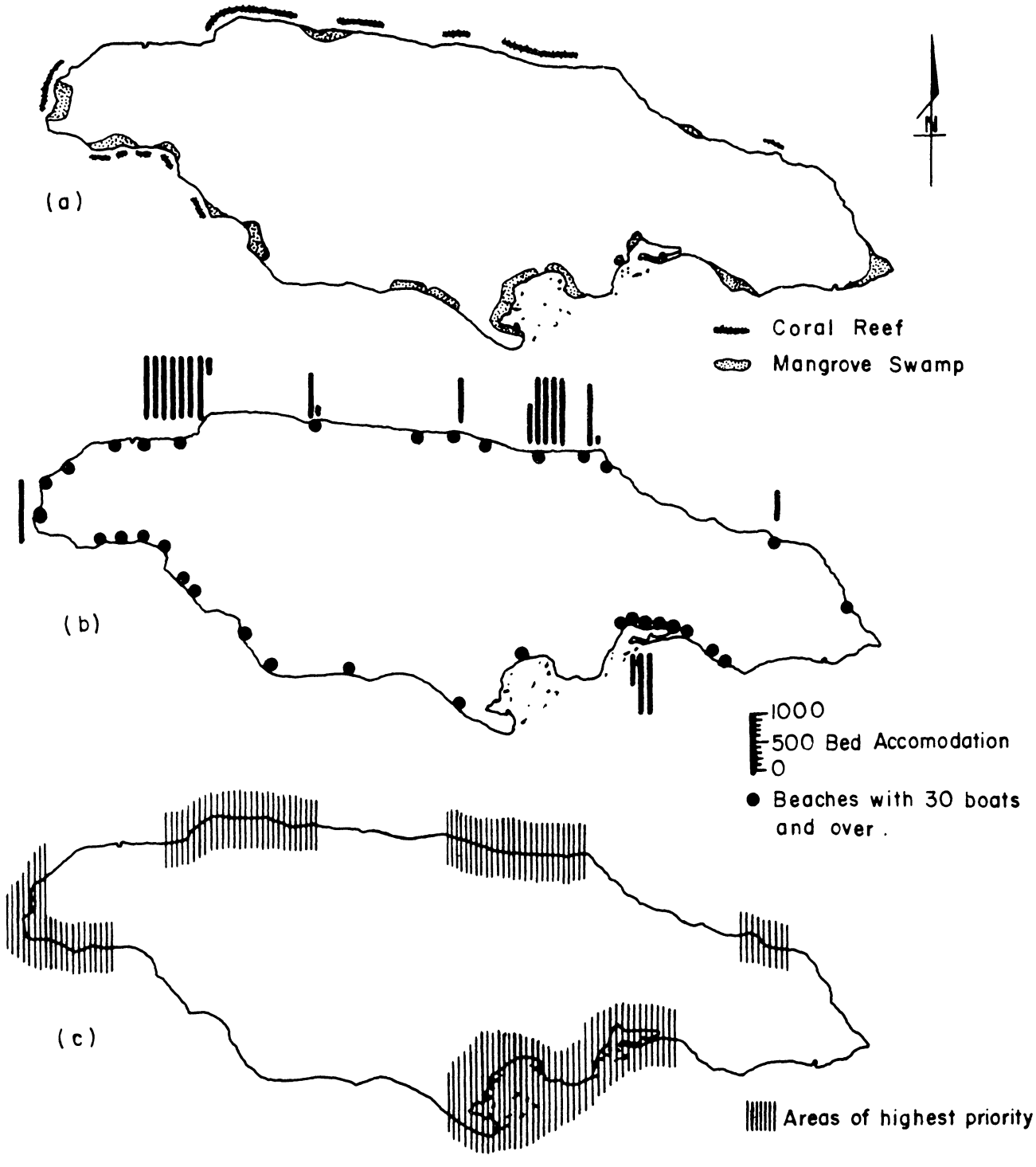

FIGURE 5.2 (a) KEY ECOSYSTEMS, (b) CENTRES OF ECONOMIC ACTIVITY - TOURISM AND FISHING, (c) AREAS OF HIGHEST PRIORITY FOR PROTECTION

Alternative Exercises:

1. Oil spill control in a harbour.

   Oil Spill Contingency Plan could be prepared for a smaller section of island coast, such as the main harbour. The principles will be the same, but finer detail will be required and more precise data handouts supplied.

   Oil may be spilled from loading and offloading at storage tanks or a refinery, or from shipping, or from a land-based source. Likely wind or current-driven movements of the oil can be estimated by techniques given in Chapter 2, or can be measured in the field.

2. Preparation of an Oil Spill Vulnerability Index.

   As an extension of the main exercise above, or as a preliminary to it, an Oil spill Vulnerability Index can be prepared for the whole island coast. This is based on the physical longevity of oil in each type of coastal environment in the absence of clean-up attempts. It produces a classification similar to that shown in Table 5.4. The use of vulnerability indices is described by Gundlach and Hayes (1978) and Owens and Robilliard (1980). (see also Exercise 5.1)

3. Identification of sources of spilled oil.

   Samples of existing petroleum hydrocarbon residues can be collected and the possible sources identified (see also Exercise 2.4). If suitable laboratory apparatus is available, such as a spectroflourometer or a gas chromatograph, the type of oil (actual source) can be identified with considerable accuracy. This is important not only for providing opportunities to control oil pollution at source, but also in obtaining compensation from the polluter.

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* * *

Table 5.4 A Suggested Coastal Classification For Trinidad Based On Its Vulnerability to Potential Oil Spill Damage (Source: Georges, 1982)

	Vulnerability Index	Coastal Environment	Comments	Examples
LOW ↑	1	Exposed, steeply dipping, cliffed rocky headland.	High energy little oil would strand, little clean up needed.	N & N.E coasts.
	2	Eroding wave cut platform.	Most oil removed by natural processes in a few weeks.	La Fillette Point Radix, S. coast.
	3	Flat, fine-medium grained sand beach (0.0625-0.25mm).	Close packed sediment resists penetration, oil may persist for many months.	Cocos Bay, Irois Bay.
	4	Steeper, medium-coarse sand beach (0.25-2.0mm).	Oil may sink 20mm into sand, clean up difficult	Maracas, Cumana, Icacos, Cedros.
↓	5	Exposed compacted sandy mudflats.	Oil does not penetrate can persist for one year.	Erin, Moruga, off Roussillac.
	6	Mixed sand & gravel beach.	Oil penetration rapid, clean up difficult.	Chaguaramas.
	7	Gravel-boulder beach.	Similar to above.	Cyrils' & Damien Bays.
	8	Sheltered rocky coasts.	Oil may persist for may years.	S. shores of offshore islands.
HIGH	9	Wetland.	Oil may persist for more than 10 years impact severe.	Caroni Swamp.

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Appendix 1.

TRAINING COURSE CONSTRUCTION

To work through all the exercises in this text would require about six weeks of field and drawing office/laboratory time, preceded by considerable preparatory effort from the tutors. When only shorter training periods are available, it will be necessary to select the most appropriate exercises for demonstrating the required concepts or skills. This selection can be made by the training course organiser, but the following comments are intended as guidelines.

1. One to two day courses:

The majority of exercises, apart from those in Chapter 3, can be completed in one or two days. If taken in isolation for this type of use, the tutor may need to provide additional introductory background materials.

2. One week courses:

Two approaches can be made to use of the Workbook over five to seven days.

(a) Using the first exercise in each chapter. This will expose students to the major concepts in coastal zone management. The lead exercises can be linked together by enlarging upon the introductory section of the chapter and the exercise background materials through a lecture or tutorial-type presentation.

(b) Using all exercises in any one chapter. Four or more exercises are presented in most chapters, and these deal with different aspects of major topics, e.g. Chapter 4 treats four aspects of Coastal Ecosystem Management, viz. status, habitat evaluation, resource yields and recovery of damaged resources. These four exercises can be extended by use of suggested alternative (i.e. additional) exercises. Chapter 5, with only two exercises presented, has alternative exercises which would take one or two additional days to complete.

3. Two weeks, or longer courses

Two week courses could be formulated by linking two or more chapters and carrying out the major exercises. Chapter 3, Natural Area Management, is designed for a minimum two weeks work, and is best taken as a whole as

the exercises follow one another closely.

In all cases, the length of time to be devoted to any exercise depends on the sophistication of the students and the amount of prior preparation by the tutor. It should be emphasised, however, that the collection of data by field work, laboratory experimentation, library search and questionnaire is an important part of training experience; and that the essentially practical nature of the exercises should be retained as far as possible.

Figure Ap1.1 shows how selection of exercises can be made in order to construct an extended training course. From this diagram, it will be apparent that most exercises have "pre-requisites", i.e. for concepts and skills to be developed logically the exercises should be carried out in order. For example, a resource assessment cannot be made effectively before a resource inventory has been completed; and, similarly, advanced planning for a marine park must be preceded by agreement on the management objectives for the park. If single exercises are to be used, during short courses, the tutor must ensure that this pre-requisite information has been supplied and understood.

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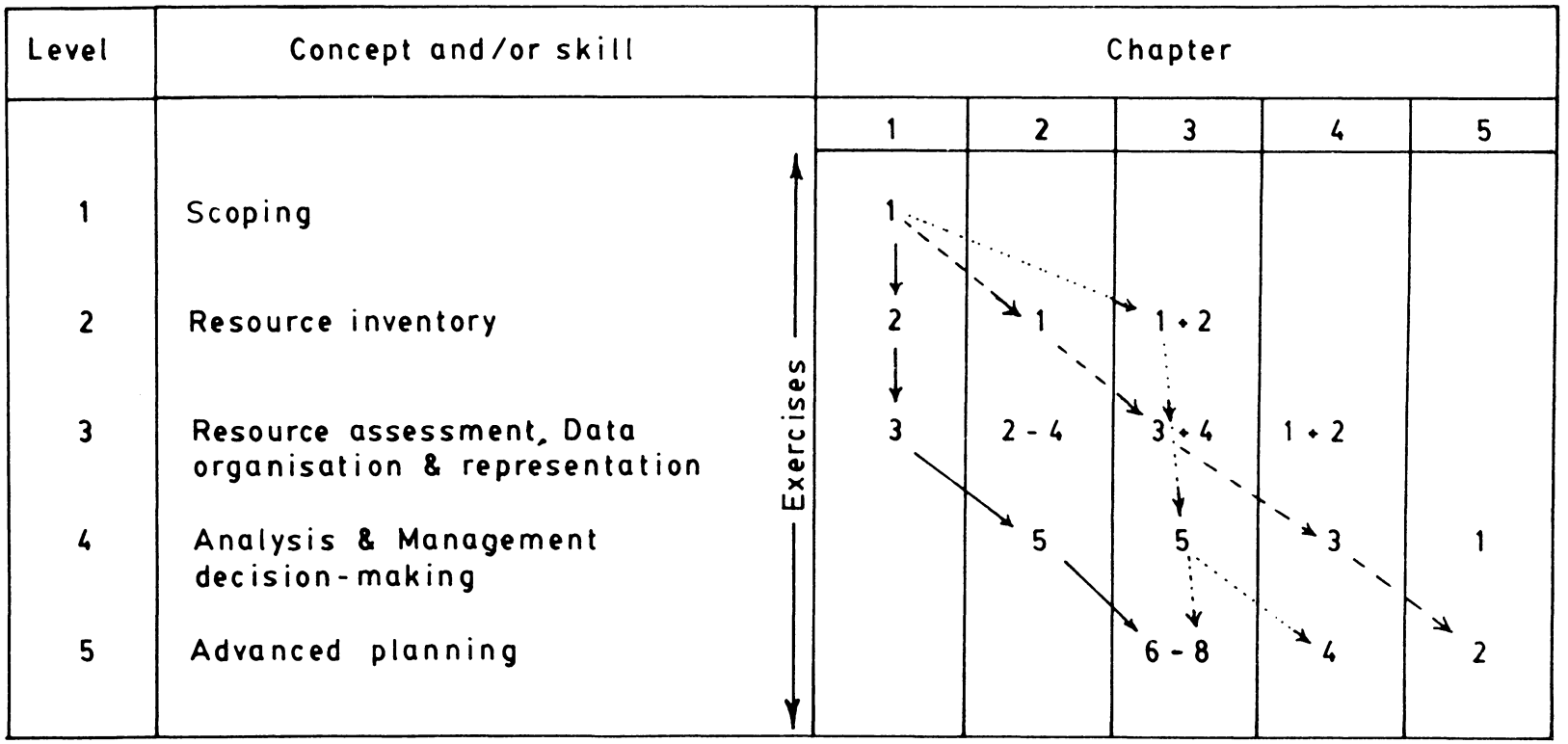

FIGURE Ap1.1 GUIDE TO EXERCISE SELECTION FOR TRAINING COURSES
(arrows show some possible pathways)

Appendix 2.

GUIDELINES FOR CONDUCTING AERIAL SURVEYS OF COASTAL FEATURES

Aerial surveying is particularly valuable for observation of short-term coastal phenomena or occasional events. It has been used successfully to examine wave and current patterns in the nearshore environment, in the latter case going aloft to track the spread of dyes like fluorescein or rhodamine B which had been released some hours earlier. Aerial survey is an accepted method of inventorying many animal populations, such as resident and migratory shorebirds, manatees, dolphins, some of the larger pelagic fish and sharks, and also sea turtle nests. In a similar way, it can be used to count visitors on recreational beaches or concentrations of fishermen. Where recent aerial photographs are not available or maps have insufficient detail, the coastal manager can upgrade baseline data in a rapid and cost-effective way from the air.

Detailed guidelines for conducting aerial surveys of beaches were contained in the Manual of Sea Turtle Research and Conservation Techniques (Pritchard, Bacon, Berry et. al. 1983), prepared for the Western Atlantic Turtle Symposium. The guidelines which follow are a simplified version based on that manual, and are reproduced by kind permission of the publishers (Center for Environmental Education, Washington).

1. Decide on your **objectives**, i.e. what precisely do you want to observe, study or record.

2. Choose the type of **light aircraft** that you need .

   (a) The size is determined by the numbers of observers i.e. pilot plus one, two or three passengers.
   (b) A single engine, four seat, wing above cockpit aircraft is highly recommended.
   (c) If there is to be extensive flying over water twin-engine aircraft provide a greater degree of safety.
   (d) Helicopters permit hovering for longer-period observation, but are expensive.
   (e) It is recommended that the military or coast guard be approached for use of helicopters, as their pilots are frequently expert at observational flying and have good knowledge of island coastlines.

3. **Before the flight,**

(a) ensure that the pilot is familiar with your objectives. Plan your route in consultation with the pilot
(b) Ask the pilot to keep you informed continuously of your location relative to the charts, the plane's altitude, flight path and speed. Check the plane's fuel capacity in relation to the desired survey time.
(c) Check the local weather conditions
(d) Ensure that safety equipment has been provided and that you are familiar with safety procedures

4. **Survey personnel**

(a) A team of three observers is most versatile, as there can be one each on the left and right sides plus one recording information.
(b) Alternatively, there can be one observer, with the second person checking observations and keeping the records.
(c) If you are conducting a solo survey, it is advisable to have a tape recorder for keeping records, which can be transposed later on or to use a camera. Check this when on board to ensure it is recording clearly above the aircraft noise. A hand- held digital counter may be useful also for certain types of data collection.
(d) If aerial survey is to be conducted frequently, observers should check each other's reliability, especially with inexperienced observers, and factor this into the results,

5. **Time of survey**

The best time to survey the coastline from the air is early morning, from full sunrise to about 1000 hours. After this, reflection from the sea surface, beaches and vegetation obscures details. There may be a haze developed by late morning, continuing through the afternoon, especially during the wet season. For certain observation beach, the optimum time for observations should be ascertained in advance from ground survey.

6. **Speed, altitude and distance offshore**

These parameters are determined by the objectives of the survey. Most observers will want to fly as slowly as possible, and the safe speed/stalling speed must be ascertained from the pilot.

(a) For most observations of animal populations, ecosystems, coastal oceanographic and human

activities, the plane should fly at about 80 knots, at an altitude of 1,000 ft, at a distance offshore that forms a 45 angle to the feature being observed,i.e. about 250-500 ft to the side of the feature.

(b) Visibility is normally best if the pilot flies with the sun behind the plane or with the plane between the sun and the feature being observed, i.e. the east coasts of islands give best results from morningtime surveys.

(c) When surveying greater distances, fly at a greater altitude.

7. Data recording

Observing from a fast moving aircraft and keeping notes simultaneously is difficult. It is advisable to have data recording forms prepared in advance, and these should be designed to suit the survey requirements. An example, used during sea turtle aerial beach survey to describe shoreline characteristics, is given as Table Ap2.1.

Table Ap2.1. Sample Aerial Survey Data Recording Form

Sea Turtle Aerial Beach Survey

Form 1: ZONE RECORDS Page___of_____

Country_____ State_____ Date(s)_____

Chart(s) Used_____

Observers(s)_____

Recorder(s)_____

Zone Name or Number	Zone Landmarks Start	End	Distance KM-NM	Lat	Long	Shoreline Characters

etc.....

Table Ap2.1 continued...

Form 1 Explanations

a. Country and State. Write these in. They will be computer-coded in subsequent analysis of the entire area.
b. Date(s). Of form preparation or when the flight(s) was made.
c. Chart(s) Used. Give source, number, scale.
d. Observer(s). List names of all involved in formulating this form.
e. Recorder(s). List names of people filling out form.
f. Headings(s). Give from start to end in approximate degrees or positions. In circling an island, headings will be inclusive.
g. Zone Name or Number. Before starting an aerial survey, the coastal zone should be divided into zones. Zones should be numbered serially and may be of different lengths. Zone borders should be based on permanent, easily recognised landmarks, which are shown on the charts.
h. Zone Landmarks. The name of a permanent physical feature (either natural or man-made) easily seen from the air is written in the "start column." When zones are continuous, the landmark at the "end" of one zone will be the "starting" landmark for the next zone. When areas are discontinuous, the new landmark is written in the next row and the zone name or number is repeated.
i. Distance KM-NM. This is the shoreline distance of the zone in kilometers or nautical miles. The time taken to travel this distance should be measured also.
j. Lat. Long. The latitude and longitude in degrees and minutes (to the nearest tenth minute) are calculated from a chart and recorded for the start of the zone.
k. Shoreline Characteristics. This is a synopsis of the characteristics of the shoreline that occur in each zone. Where more than one type of shoreline occurs along a zone, either record the dominant type or give the different types in estimated percentages.

---

8. As many as possible of the aerial survey observations should be ground-truthed immediately after returning to base, as a check on observer reliability. Alternatively, a second team could be ground-truthing concurrently.

Appendix 3

SIMPLE WAVE THEORY

Introduction:

The effects of water waves are of the greatest importance to several coastal processes. However, when one examines waves in the ocean they often appear confused and constantly changing. This is particularly true while the waves are under influence of the wind, because of the presence of several wave fields. Actual water wave phenomena are complex. i.e. they are difficult to describe mathematically.

In order to deal with these phenomena a "simple wave", i.e. one which can be described in simple mathematical terms, is assumed. Several "simple" wave theories have been developed. The most elementary theory, referred to as linear wave theory, was developed by Airy. This wave theory assumes a sinusoidal wave form, and is applicable over a wide range of conditions. For shallow water conditions, sinusoidal wave theory predicts the waveform and associated conditions rather well, although there are difficulties in making the computations. At the limit of cnoidal theory, certain aspects of wave behaviour may be described satisfactorily by solitary wave theory. The solitary wave theory is particularly useful for describing conditions in the breaking zone, and is easy to use.

Some Definitions and Classifications

Definitions

Complex waves	- waves which cannot be described in simple mathematical terms.
Simple wave	- a wave which can be described in simple mathematical terms.
Periodic wave	- a wave whose motion and surface profile recur in equal periods of time.
Progressive wave	- a wave form which moves relative to the fluid.
Direction of propagation	- the direction in which the wave form moves.
Complete standing wave	- a wave form which merely moves up or down (clapotis) at a fixed position.

Classifications

Many types of action create disturbance, and hence wave action in the sea, viz.:

Attraction of sun and moon	- Tides
Deep sea earthquakes	- Tsunamis
Wind blowing over water	- Wind Waves

Tides have periods of the order of 12 hours; tsunamis have periods of the order of 15 minutes; while wind waves generally have a period of less than 0.1 second to greater than 5 minutes. There are several restoring forces which attempt to bring the sea surface back to its equilibrium postion after it has been disturbed. The wind waves are classified by these restoring forces, which are :-

(a) Coriolis force - This acts on the longer wind waves.
(b) Surface tension - This acts on the very short wind waves.
(c) Gravity force - This acts on the high energy portion of the wind waves i.e. waves of period 1 to 30 seconds.

Gravity waves can be further separated into two states:

(a) Seas - when the waves are under the influence of wind in a generating area.
(b) Swell - when the waves move out of the generating area, and are no longer subject to significant wind action.

When dealing with coastal processes or determining wave forces on structures, we are usually interested in gravity waves i.e. waves of period 1 to 30 seconds. In particular, waves of period 5 to 15 seconds occur with great regularity. These are either :-

(a) Simple, periodic, progressive gravity waves.
(b) Simple, periodic, standing gravity waves.

Linear Wave Theory

Descriptions and Definitions - Figure Ap3.1 shows

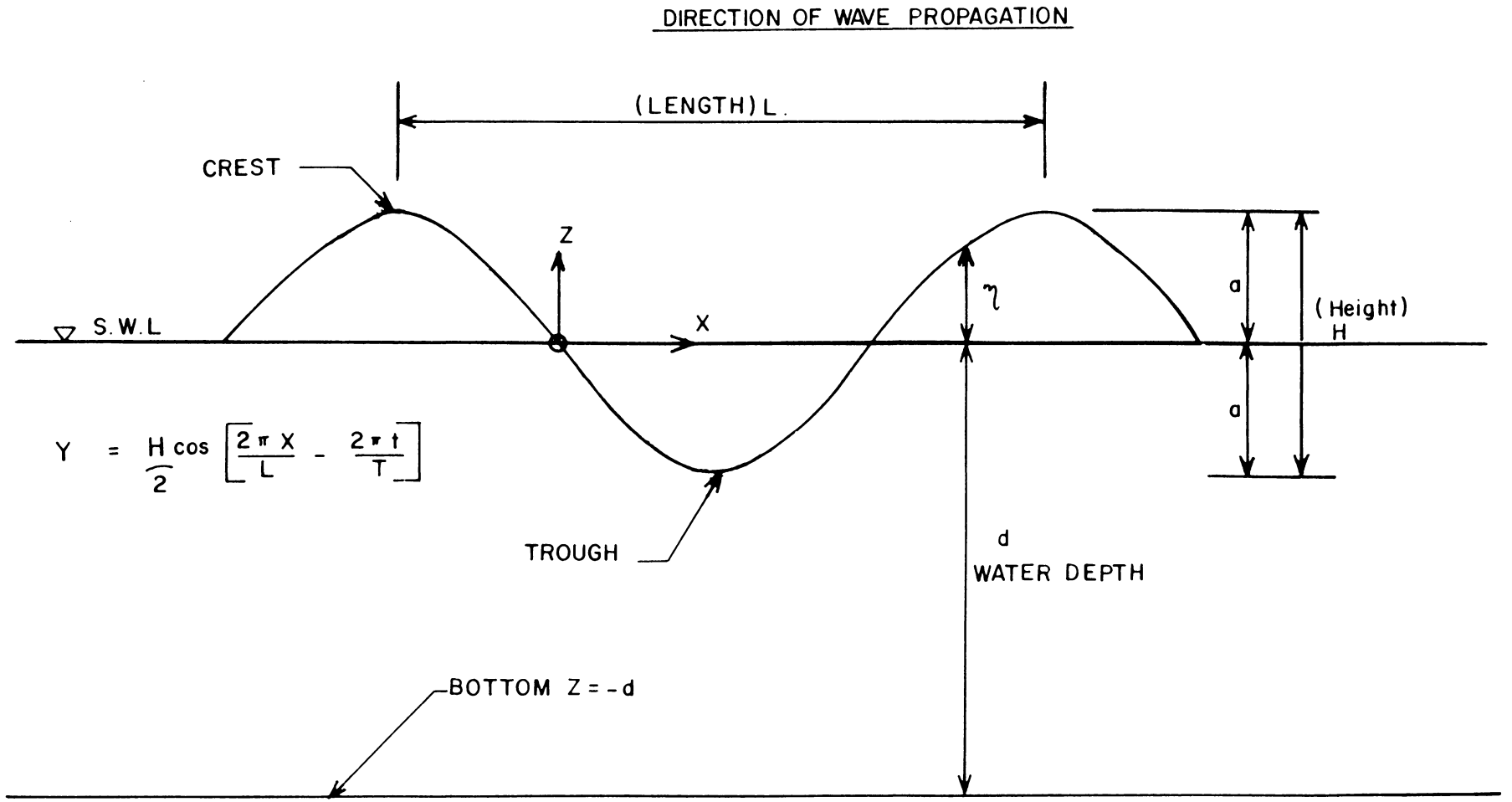

FIGURE Ap 3.1 DEFINITION OF TERMS
LINEAR WAVE THEORY

the simple progressive wave propagating in the x - direction. The equation of the wave profile is :-

$$y = \frac{H}{2} \cos\left[\frac{2\pi x}{L} - \frac{2\pi t}{T}\right] \qquad (3.1)$$

where y = displacement of water surface relative to still water level (S.W.L.)
H = wave height (vertical distance from crest to trough)
L = wave length (horizontal distance between corresponding points on two successive waves)
T = wave period (time for two successive crests to pass a given point)
d = depth (distance from bed to still water level)

Wave Celerity, Length and Period

The speed at which a wave form propagates is termed the wave celerity, C.

$$C = \frac{L}{T} \qquad (3.2)$$

The general equation for the celerity of gravity waves is:-

$$C = \left[\frac{gL}{2\pi} \tanh\left(\frac{2\pi d}{L}\right)\right]^{1/2} \qquad (3.3)$$

where $g = 9.80665 \text{ m s}^{-2}$

when $d/L \geqslant 0.5$ $\quad \tanh\left(\frac{2\pi d}{L}\right) \longrightarrow 1.0$

and $C_o = \left(\frac{gL_o}{2\pi}\right)^{1/2}$ DEEP WATER WAVES (3.4)

The subscript is used to represent deep water conditions.

When $d/L \leqslant 0.04$ $\quad \tanh\left(\frac{2\pi d}{L}\right) \longrightarrow \frac{2\pi d}{L}$

and $C = (gd)^{1/2}$ SHALLOW WATER WAVES (3.5)

Equation 3.3 is used for TRANSITIONAL WAVES, i.e.

$$0.04 < d/L < 0.5$$

From Equation 3.3. we obtain:-

$$L = \frac{gT^2}{2\pi} \tanh\left(\frac{2\pi d}{L}\right) \tag{3.6}$$

And from Equations 3.2 and 3.4 we get:-

$$L_o = \frac{gT^2}{2\pi} \tag{3.7}$$

Now, T remains constant throughout the travel of a wave form; moreover T is easily measured. Hence L_o, the wave length in deep water, can be determined easily. The following relationship is used to determine the wave length at any depth, once the wave period is known:

$$d/L_o = d/L \tanh\left(\frac{2\pi d}{L}\right) \tag{3.8}$$

The term d/L has been tabulated as a function of d/L_o by Weigel (1948), and is presented as Appendix C in Volume 111 of the Shore Protection Manual (CERC, 1984).

Breaking Wave - The maximum height of a wave travelling in deep water is limited by a maximum wave steepness for which the wave form can remain stable. Waves reaching the limiting steepness will begin to break.

In <u>deep water</u> the limiting steepness is given by:-

$$\frac{H_o}{L_o} \simeq 0.142 \tag{3.9}$$

When the wave moves into shoaling water, the limiting steepness which it can attain decreases. The limiting steepness then becomes a function of the relative depth, d/L, and the beach slope perpendicular to the direction of wave advance. Several investigators have presented empirical equations and curves relating breaker height to wave steepness and beach slope. However, as a first approximation, the following equations are recommended:-

$$H_b/H'_o = \frac{1}{3.3(H'_o/L_o)^{1/3}} \tag{3.10}$$

and $$d_b/H_b = 1.28 \tag{3.11}$$

where d_b = depth of water at point of breaking

H_b = breaker height above S.W.L.

H'_o=unrefracted deep water wave height

There are three types of breakers: Spilling, plunging and surging. Spilling breakers break gradually, and are characterized frequently by "white water" at the crest. Plunging breakers are characterised by a curling over of the top of the crest and a plunging down of this mass of water. Surging breakers peak up as if to break in the manner of a plunging breaker; but then the base of the wave surges up the beach face with the disappearance of the collapsing wave crest.

Wave Refraction

Theoretical Considerations - Equation 3.3 shows that wave celerity depends on the depth of water in which the wave propagates. If the wave celerity decreases with depth, wave length must decrease proportionally. Variation in wave celerity occurs along the crest of a wave moving at an angle to underwater contours, because part of the wave in deeper water is moving faster than the part in shallower water.

In addition to refraction caused by variations in bathymetry, waves may be refracted by current or any other phenomenon which causes one part of a wave to travel faster than another. However, quantitative evaluation of the effects of refraction by currents is difficult.

The decrease in wave celerity with decreasing water depth is analogous to the decrease in the speed of light with an increase in the refractive index of the transmitting medium. This analogy has allowed the use of Snell's Law for the preparation of refraction diagrams. Several graphical and numerical procedures are available, but fundamentally all methods of refraction analysis are based on Snell's Law with some simplifying assumptions.

The assumptions usually made are:

(1) Wave energy between wave rays or orthogonals remains constant. (Orthogonals are lines drawn perpendicular to the wave crests, and extend in the direction of wave advance.)
(2) Direction of wave advance is perpendicular to the wave crest, that is, in the direction of the orthogonals.
(3) Speed of a wave of given period at a particular location depends only on the depth at that location.
(4) Changes in bottom topography are gradual.
(5) Waves are long-crested, constant period, small-

amplitude and monochromatic.

(6) Effects of currents, winds, and reflections from beaches and underwater topographic variations are considered negligible.

The change of direction of an orthogonal as it passes over relatively simple hydrography may be approximated by Snell's Law:

$$\text{i.e } \sin \alpha_2 = \frac{C_2}{C_1} \sin \alpha_1 \qquad (3.12)$$

where α_1 = the angle a wave crest makes with the bottom contour over which the wave is passing

α_2 = a similar angle measured as the wave crest passes over the next bottom contour

C_1 = wave celerity at the first bottom contour

C_2 = wave celerity at the second bottom contour

From equation 3.12, a template may be constructed which will show the angular change in that occurs as an orthogonal passes over a particular contour interval, and permits the construction of a changed-direction orthogonal. Such a template is shown in Figure Ap3.2.

Procedure for construction of a refraction diagram by the orthogonal method - Charts showing the bottom topography of the study area are obtained. Underwater contours are drawn on a tracing paper overlay, on which the shoreline has been placed. In tracing the contours small irregularities are smoothed out.

The range of wave periods, wave heights and wave direction is obtained from previous studies or by hindcasting. C_2/C_1 values for each interval are calculated - see Table Ap3.1. A different table and refraction diagram is required for each separate wave period and/or direction.

To construct orthogonals from deep to shallow water, the deep water direction of wave approach is first determined. A deep water wave front (crest) is drawn as a straight line perpendicular to this wave direction, and suitably spaced orthogonals are drawn perpendicular to this wave front and parallel to the chosen direction of wave approach. These lines are extended to the first depth contour shallower than $L_o/2$ where $L_o = gT^2/2$

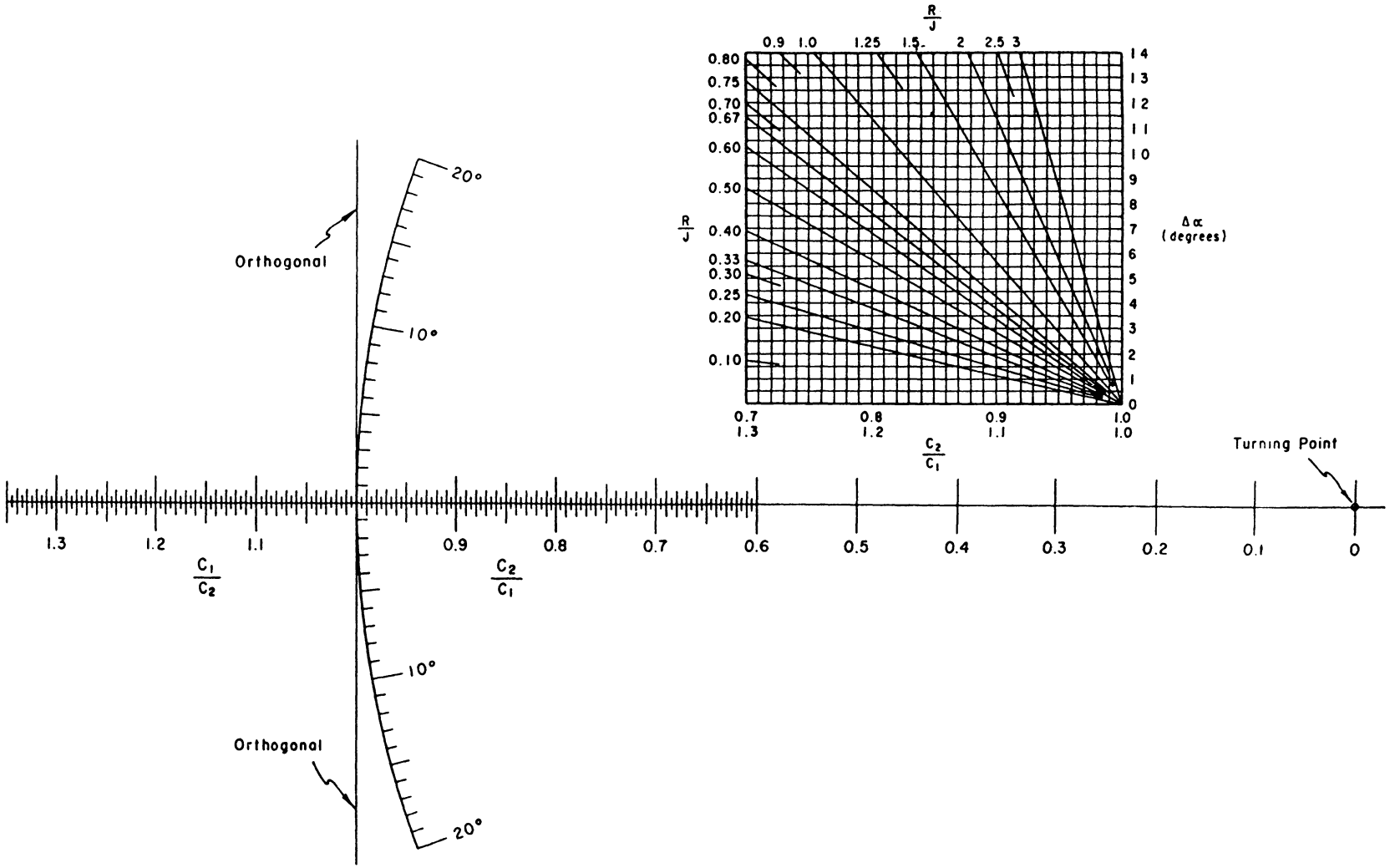

FIGURE Ap 3.2 Refraction Template

Table Ap3.1 Sample Data Table for Wave Refraction Studies.

DATE:_____ COUNTRY_____

LOCATION_____

Wave Period (T) = 10 sec.

Wave Length (L_o) = $gT^2/2\pi$ = 156.1m

d (m)	d/L_o	tanh $2\pi d/L$	C_1/C_2	C_2/C_1
60	0.384	0.9852	0.984	1.017
50	0.320	0.9690	0.967	1.034
40	0.256	0.9374	0.938	1.066
30	0.192	0.8791	0.883	1.132
20	0.128	0.7763	0.762	1.313
10	0.064	0.5914		

NOTES : (1) Refraction calculations should begin at d=L/2
(2) Col. 3 obtained from Table D-1 in Appendix 1.

Prepared by_____

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Starting with any one orthogonal, and using the template in Figure Ap3.2, the following steps are performed in extending the orthogonal to shore:

(a) Sketch a contour midway between the first two contours to be crossed, extend the orthogonal to the midcontour, and construct a tangent to the midcontour at this point.
(b) Lay the line on the template labelled <u>orthogonal</u> along the incoming orthogonal with the point marked 1.0 at

the intersection of the orthogonal and midcontour. (See also text Figures 2.10 and 2.11)

(c) Rotate the template about the turning point until the C_2/C_1 value corresponding to the contour interval being crossed intersects the tangent to the midcontour. The orthogonal line on the chart now lies in the direction of the turned orthogonal on the template.

(d) Place a set square along the base of the template and construct a perpendicular to it so that the intersection is midway between the two contours when the distances are measured along the incoming orthogonal and the perpendicular. Note that this point is not necessarily on the midcontour line. This line is the turned orthogonal.

(e) Repeat the above steps for successive contour intervals.

Interpretation of Results - Refraction diagrams can provide a measure of changes in waves approaching a shore. However, the accuracy of refraction diagrams is limited by the validity of the theory of construction, the accuracy of depth contours, and the care taken in the preparation of the diagrams. The direction of the nearshore waves can be determined from the refraction diagram, while the wave height can be estimated from the following formula:

$$H = KH_o = \sqrt{(b_o/b).H_o} \qquad (3.13)$$

Where H = refracted wave height
b = distance between orthogonals

Wave Diffraction

Introduction - This is the phenomenon by which energy is transmitted laterally along a wave crest. It is most noticeable on the leeward sides of islands, and where an otherwise regular train of waves is interrupted by a barrier such as a breakwater. Calculation of diffraction effects is important for several reasons. Wave height distribution in a harbour or sheltered bay is determined to some degree by the diffraction effects of the natural or man-made structures which provide protection.

The process is similar for other types of waves, such as light or sound waves. The problem has been studied by several researchers, who used the following assumptions:

(a) Water is an ideal fluid.
(b) Waves are of small-amplitude and can be described by linear theory.
(c) Depth shoreward of the breakwater is constant.

Diffraction Calculations - Wiegel(1962) used a theoretical approach to study wave diffraction around a single breakwater. From his presentation, diffraction diagrams have been prepared which, for a uniform depth adjacent to an impervious structure, show lines of equal wave height reduction. These diagrams are shown in Figures 2-28 to 2-58 of Volume 1 of the Shore Protection Manual.

The graph coordinates are in units of wavelength (L). The diffraction coefficient (K') is defined as:

$$H = K'H_i \qquad (3.14)$$

where H = Wave height in the area protected by the breakwater

and H_i = Incident wave height in the area unaffected by the breakwater

When applying the diffraction diagrams to actual problems, the wave-length must first be determined using Equation 3.7 and the table in Appendix 1. It is then useful to construct a scaled diffraction overlay template on tracing paper to correspond to the hydrographic chart being used. One radius wavelength on the template must be identical to one radius wavelength on the hydrographic chart. The lines of equal K' can be sketched in.

Charts have also been prepared for waves passing a gap comprising two breakwaters. They are available in the Shore Protection Manual.

Wave Reflection - Water waves may be either partially or totally reflected from natural or man-made barriers. The phenomenon is very important in the design of harbours, as the reflection may be very uncomfortable for the vessels using the facility.

A reflection coefficient is usually denoted:

$$r = H_r/H_i \qquad (3.15)$$

where H_r = reflected wave height

and H_i = incident wave height

Table Ap3.2. lists reflection coefficients frequently used.

Table Ap3.2 REFLECTION COEFFICIENTS

Covering	Reflection Coefficient (r)
Smooth, impermeable wall	1.0
Concrete blocks	0.9
Turf	0.85 - 0.90
1 layer of rubble	0.8
2 or more layer of rubble	0.50 - 0.55
Tetrapods	0.5
Natural beaches	0.001 - 0.40

Using Linear wave theory (Equation 3.1),

$$y_i = \frac{H_i}{2} \cos \left[\frac{2\pi x}{L} - \frac{2\pi t}{T} \right] \qquad (3.16)$$

Where r = 1.0, i.e. full reflection:

$$y_r = \frac{H_i}{2} \cos \left[\frac{2\pi x}{L} + \frac{2\pi t}{T} \right] \qquad (3.17)$$

The water surface of the combined wave is:

$$y = y_i + y_r$$

$$\text{Therefore, } y = H_i \cos \frac{2\pi x}{L} \cdot \cos \frac{2\pi t}{T} \qquad (3.18)$$

Equation 3.18 represents the water surface for a STANDING WAVE or CLAPOTIS, which is periodic in time and in x, and has a maximum height of 2H.

Wind Waves - The earlier discussion was concerned with idealized, monochromatic waves. The pattern of waves on any body of water exposed to wind action is unlike this ideal picture. Waves of different heights and periods are usually present, as are various directions of wave propagation. At present, there are several methods of presenting measured wave data in terms of wave spectra. However, before the development of those methods, waves were measured by visual methods, and the concept of Significant Wave Height was developed. Most of the formulae for shore processes use the significant wave height, H . It has been found that waves measured in nature are statistically distributed, and that the Rayleigh probability distribution fits the data. It has also been found that $H_s = H_{1/3}$

where $H_{1/3}$= average height of one-third highest waves

and $H_{1/3}$= 1.6 H

where H_{av}= average height of all waves.

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Further Reading:

U.S. Army Coastal Engineering Research Center 1984. Shore Protection Manual. Department of the Army, Corps of Engineers.

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Appendix 4.

BASIC FLUID MECHANICS

Introduction - Fluids differ substantially from solids in their behaviour. In simple terms, unlike a solid, a fluid is a substance which cannot resist a shear force without moving. Fluids are usually classified as liquids or gases. A liquid has intermolecular forces which hold it together so that it possesses volume but no definite shape. A gas, on the other hand, consists of molecules in motion which collide with each other tending to disperse it so that a gas has no set volume or shape.

Hence, a liquid poured into a container will fill the container up to the volume of the liquid regardless of container's shape; on the other hand, a gas will fill any container into which it is placed.

Some Definitions - the following terms and definitions will be used throughout:-

Pressure - The pressure in a fluid at rest is defined as the normal compressive force per unit area acting on a surface immersed in the fluid. The pressure at a point in a fluid at rest is the same in all directions. Such an isotropic pressure is called hydrostatic pressure. In addition, there exist not only normal pressure, but shear forces or stresses when the fluid is in motion.

Viscosity, Friction, and Ideal Flow - All fluids have viscosity which causes friction. The importance of this friction in physical situations depends on the type of fluid and the physical configuration or turbulence. If the friction is negligible the flow is classified as ideal.

Figure Ap4.1 shows different relationships between shear stress and shear strain rate in fluids. A wide range of fluids show a simple relationship between shear stress and shear strain rate - these are classified as Newtonian fluids. The relation between shear stress and strain may be written

$$\tau = \mu \frac{du}{dy} \qquad (4.1)$$

where μ is called the coefficient of dynamic viscosity. The coefficient of kinematic viscosity ν is denoted by:-

$$\nu = \mu / \rho \qquad (4.2)$$

where ρ is the mass density.

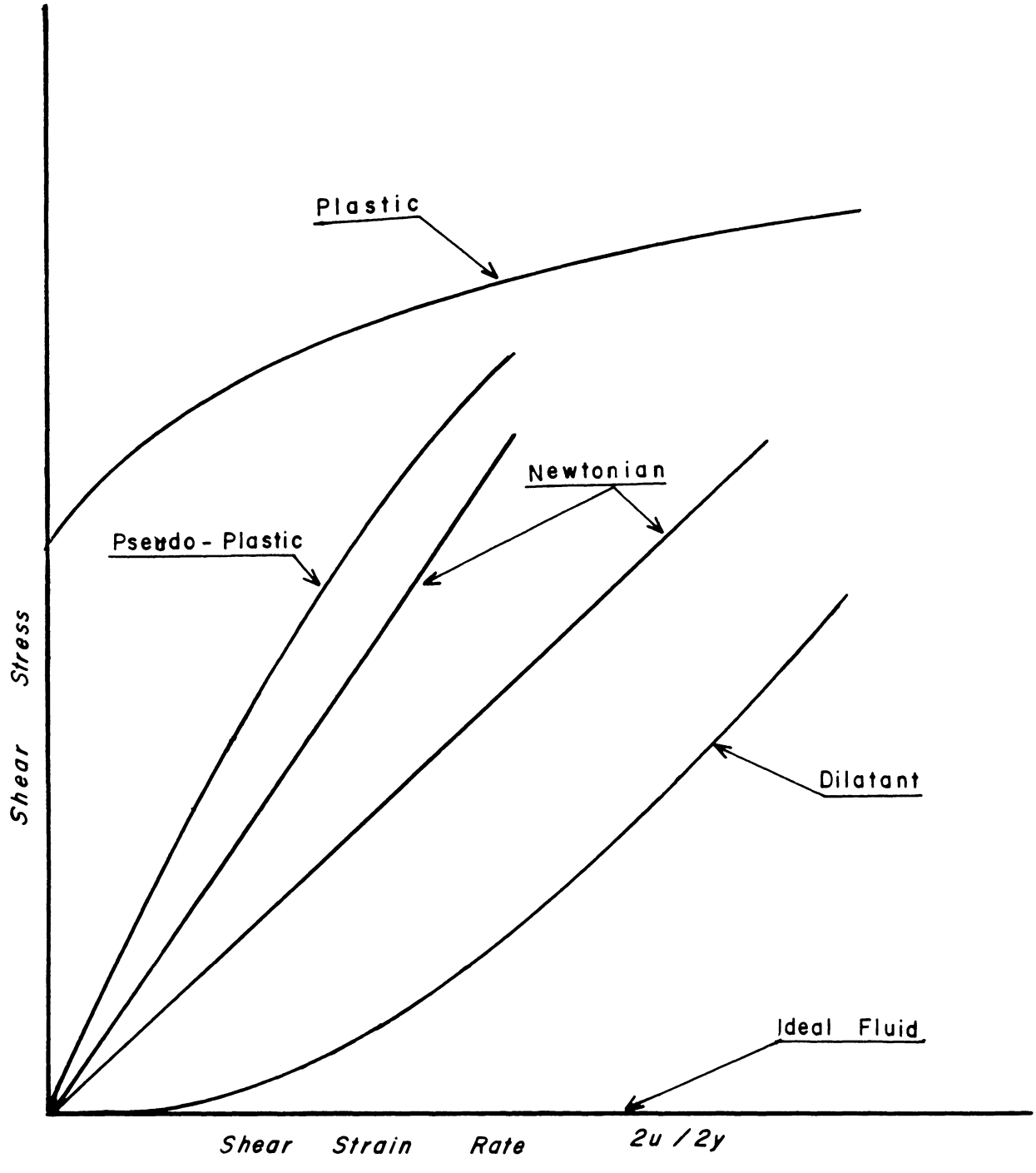


FIGURE Ap4.1 TYPES OF VISCOUS AND PLASTIC FLUIDS

Water, air and gasses are essentially Newtonian: while grease and muds show non-Newtonian behaviour.

If a fluid has no viscosity and does not flow in a turbulent manner, the flow is said to be ideal. An ideal flow then has no internal friction and hence no internal dissipation or losses. Actually, of course no fluid is ever really ideal, but some fluids, at least in certain regions of flow, approach ideal conditions very closely and are considered such for analysis.

Laminar and Turbulent Flow - the term laminar flow is used to describe a flow in which the fluid flows in laminae or layers, as opposed to turbulent flow in which the velocity components have random fluctuations imposed on their mean values (Figure Ap4.2). A stream of dye inserted in a laminar flow will streak out in a thin line and always be composed of the same fluid particles. However, in turbulent flow the dye line will quickly become tangled up and mixed in with the fluid as it flows along.

Reynolds Number, R_x - for any fluid the velocity and channel configuration determines whether flow is laminar or turbulent. As the velocity increases the flow changes from laminar to turbulent, passing through a transition regime. Both laminar and turbulent regimes occur in nature, but turbulent flow seems to be the more natural state of affairs. A dimensionless number, the Reynolds Number, R_x ,is used to characterize the flow regime.

$$R_x = \frac{u.x}{\nu} \qquad (4.3)$$

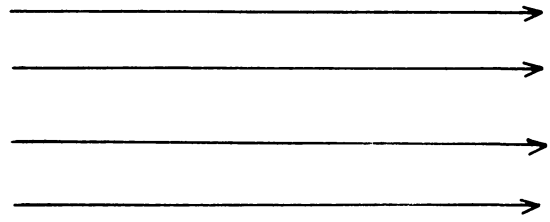
where u = velocity of flow

ν = kinematic viscosity of fluid

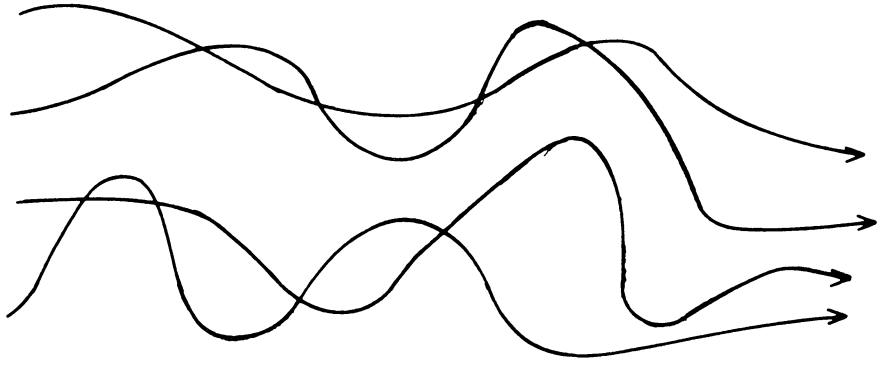
and x = characteristic dimension (length, diameter, depth)

Streamlines and Patterns of Flow - It is often desirable to have a complete diagram of the direction of motion at a number of points in a fluid stream. This can be done by drawing streamlines on a plan of the flow. These lines are drawn so that they are tangential to the direction of flow at every point. Streamlines are therefore often curved, and an infinite number of them can be drawn in any particular part of a flow. Frequently, it is desired to consider a finite portion of a flow - in such cases a streamtube is often postulated. This is a prism of fluid bounded by streamlines. Therefore, by definition, no flow can occur across the walls of a streamtube.

When fluid flows over a solid surface or shape, it is sometimes found that a streamline which is touching the surface at one place is not touching somewhere else. The



Laminar Flow



Turbulent Flow

The lines are pathlines which indicate the flow paths of particles.

FIGURE Ap 4.2 LAMINAR AND TURBULENT FLOW.

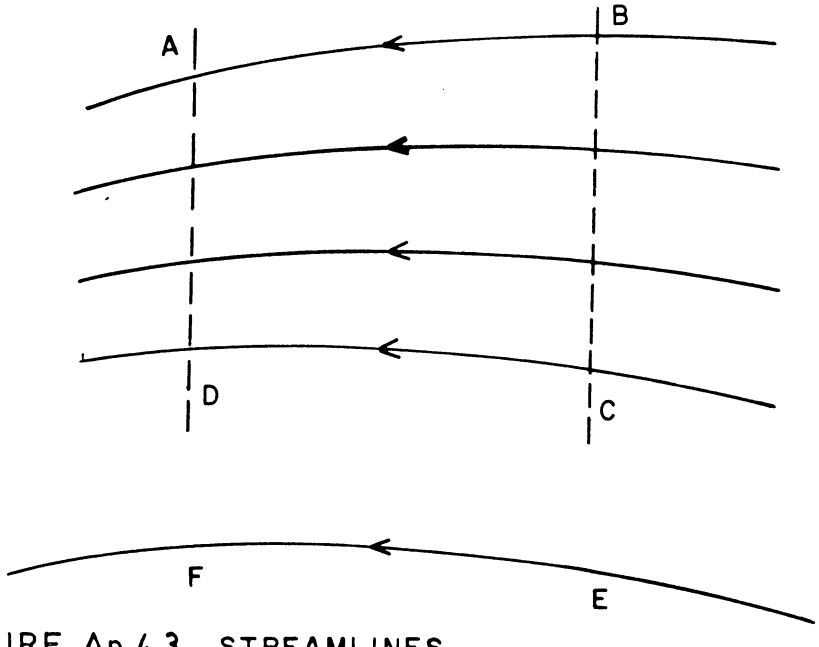


FIGURE Ap 4.3 STREAMLINES

flow is now said to breakaway or separate from the surface. At low velocities of flow (laminar flow) a mass of fluid called the wake remains between the separated streamline and the surface: this mass does not take part in the main flow and may rotate slowly forming an eddy. At higher velocities of flow (turbulent flow), there are rotary irregular motions, with non-permanent eddies being shed from the surface.

Some shapes, notably aircraft wings and well-designed ships hulls, have no breakaway on them at all in their normal operating condition, so that their shape is that of a streamline. Their shapes are therefore called streamlined.

Theoretical plotting of Streamlines - There are several experimental methods for obtaining the patterns of flow around objects. However, it is frequently desirable or necessary to predict a flow pattern at the planning stage. By using the essential property of streamlines, that they do not cross, it is possible to produce methods of plotting flow patterns.

Consider any two streamlines, AB and CD, not necessarily parallel, of a fluid in motion (Figure Ap4.3). The fluid is of constant depth and there are other streamlines between AB and CD. Since there is no flow across streamlines, the same quantity of fluid per unit time passes AD as passes BC.

$$\text{That is} \quad \int_A^D udn = \int_B^C udn = \text{constant} = \psi \qquad (4.4.)$$

where u is the velocity at any point on the lines AD or BC and dn is a small length at right angles to the streamline at that point. The quantity is expressed as a volume per unit time, or, in other words, streamline CD is always a 'discharge' of ψ distant from AB even if the length it is distant from AB changes. Consequently CD can be labelled by its discharge from AB, and it can be called streamline

$$\left(\psi = \int_A^D udn \right) \text{ relative to AB.}$$

Another streamline such as EF, further from AB than CD, will clearly have a larger value of ψ than CD. ψ is called the stream function and is only a method of labelling streamlines, to give them a quantitative meaning, depending on their position within the stream.

A different method of marking a flow is by the plotting of "potential" lines on it. Along any streamline values of a quantity $\phi = \int u\,ds$, called the potential, can be marked off, where s is the distance measured along the streamline. The potential, though having this precise meaning is a fictitious quantity and it cannot be measured directly with instruments. Referring to Figure Ap4.3, if A is taken as the zero point for potential on AB, then

$$\phi \text{ at } B = \int_A^B u\,ds \qquad (4.5)$$

Points on other streamlines can also be marked off with their values of ϕ, and those with the same value on different streamlines linked to give contours of the same ϕ, called equipotential lines. By their definitions:-

equipotential lines are always at right angles to streamlines.

The two properties are used to draw streamline maps by a method of successive approximations. Although the method of successive approximations produces the correct streamline pattern for any boundary, a correct way is to combine two or more simple patterns until one of the streamlines coincides with the boundaries concerned. The method of conformal transformation has also been used to obtain flow patterns for a large number of cases.

For incompressible flow situations in which the boundary layer remains thin, ideal-fluid results may be applied to flow of a real fluid to a satisfactory degree of approximation. Converging or accelerating flow situations generally have thin boundary layers, but decelerating flow may have separation of the boundary layer and development of a large wake that is difficult to predict analytically.

Boundary Layer Concepts - The methods described above are applicable to cases of ideal fluid flow (these are approximated by cases of low velocity.). In 1904 Prandtl developed the concept of the boundary layer, which provides an important link between ideal-fluid flow and real-fluid flow. The boundary layer concept states:-

For fluids having relatively small viscosity, the effect of internal friction in a fluid is appreciable only in a narrow region surrounding the fluid boundaries.

From this hypothesis, the flow outside of the narrow region

near the solid boundaries may be considered as ideal flow and treated theoretically.

A boundary layer on a plane surface parallel to the direction of flow is the simplest case to study. Since the fluid at the boundaries has a zero velocity relative to the boundaries, there is a steep velocity gradient from the boundary in to the flow. This layer moves along the body, the continual action of shear stress tends to slow down additional fluid particles, causing the thickness of the boundary layer to increase with distance from the upstream point. (See Figure Ap.4.4).

For smooth upstream boundaries, the boundary layer starts out as a laminar boundary layer in which the fluid moves in smooth layers. As the thickness of the boundary increases, it becomes unstable and finally transforms into a turbulent boundary layer in which the fluid particles move in haphazard paths, although their velocity has been reduced by the action of viscosity at the boundary.

The thickness of the laminar boundary layer, δ , at a distance x from the leading edge is given by:-

$$\frac{\delta}{x} = \frac{4.65}{\sqrt{R_x}} \qquad (4.6)$$

in which $R_x = \frac{u.x}{\nu}$ (4.7)

and u = velocity beyond the boundary layer.

When the Reynolds number for the plate, R_l , reaches a value between 500,000 and 2,000,000, the boundary layer becomes turbulent, and :-

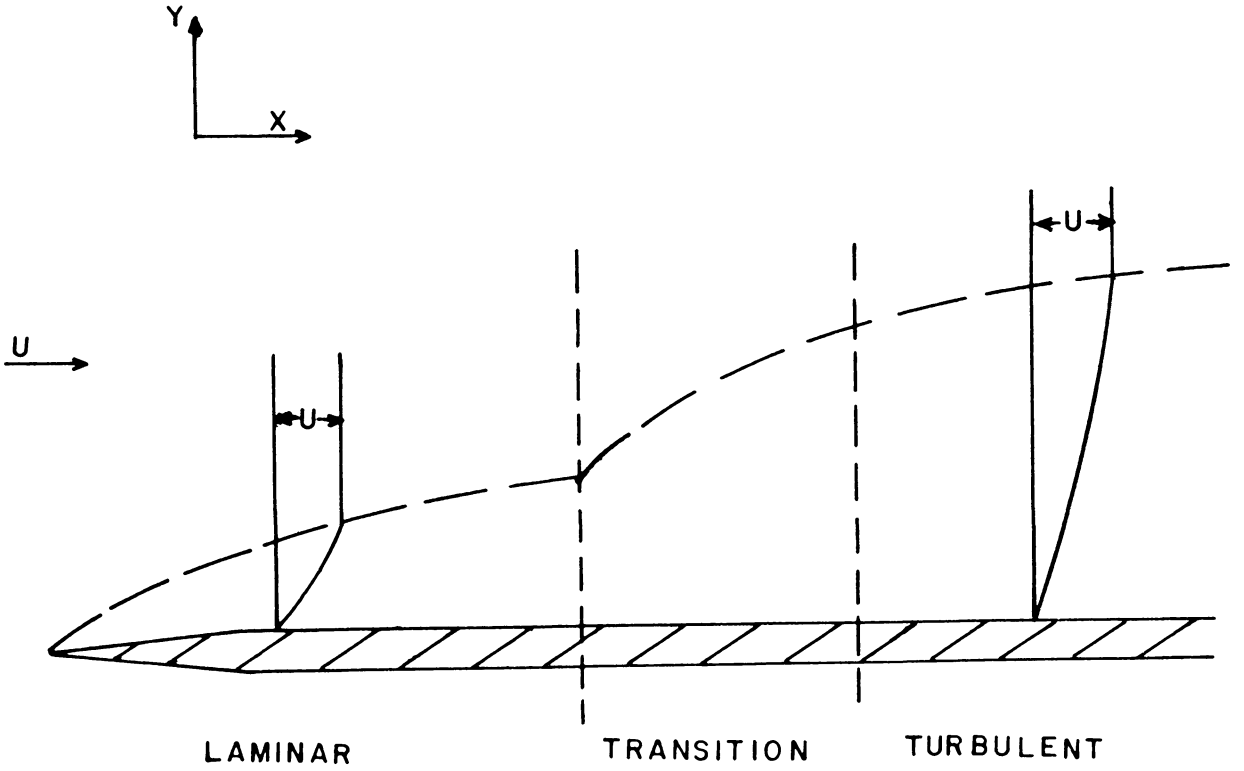
$$R_l = \frac{u.l}{\nu} \qquad (4.8)$$

Where l = the distance from the leading edge.

The thickness of the turbulent boundary layer, δ , at a distance x from the leading edge is given by:-

$$\delta = 0.37 \; x \; / R_x^{1/5} \qquad (4.9)$$

Along a flat plate the boundary layer continues to grow in the downstream direction, regardless of the length of the plate, when the pressure gradient remains zero. With the pressure reducing in the downstream direction, as in a conical reducing section, the boundary layer tends to be reduced in thickness.



Dotted Line shows outer Limit of Boundary Layer

Scale in Y direction greatly exaggerated.

FIGURE Ap4.4 BOUNDARY LAYER GROWTH ON A FLAT SURFACE.

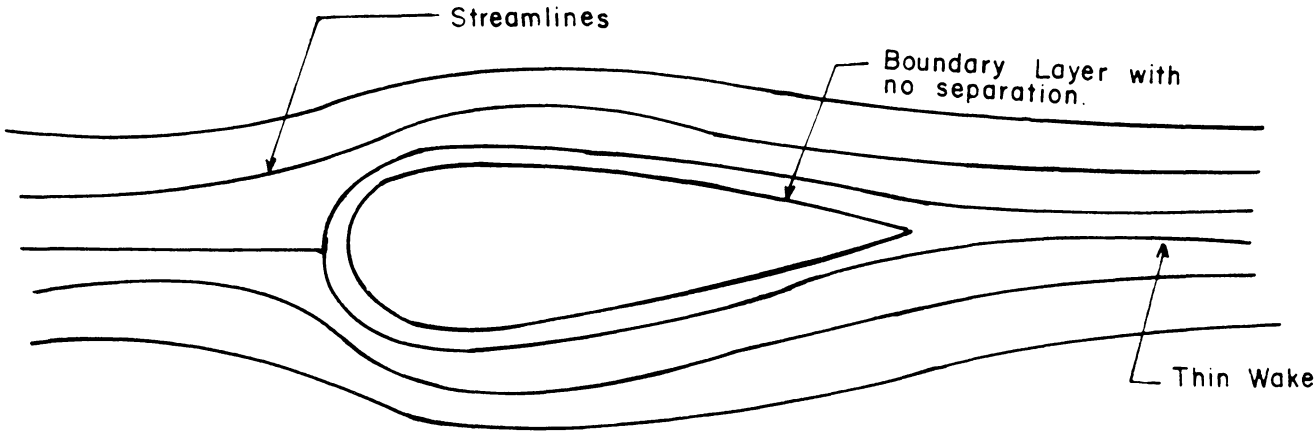
For adverse pressure gradients, i.e. with pressure increasing in the downstream direction, the boundary layer thickens rapidly. The adverse gradient plus the boundary shear decrease the momentum in the boundary layer, and if they both act over a sufficient distance, they cause the boundary layer to come to rest. This phenomenon is called separation. The boundary streamline must leave the boundary at the separation point, and downstream from this point the adverse pressure causes backflow near the wall. The region downstream from the streamline that separates from the boundary is known as the wake.

Streamlined bodies are designed so that separation occurs as far downstream along the body as possible, and as a result the wake is small. For a bluff body, on the other hand the flow is separated over much of the surface, and the wake is large. Examples of streamlined and bluff bodies are shown in Figure Ap4.5.

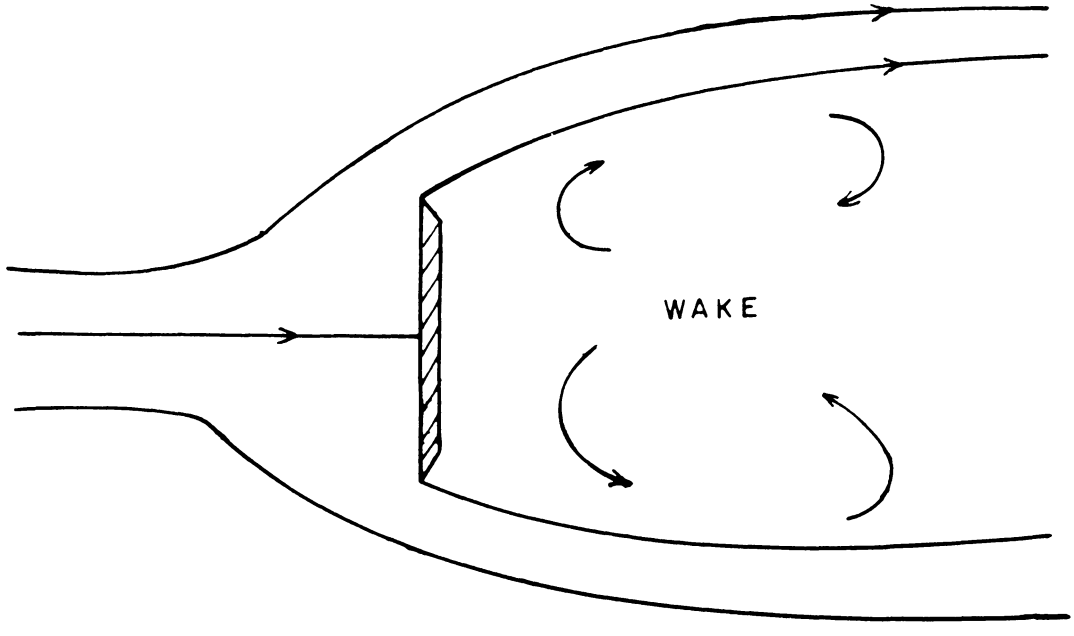
The flow pattern in the wake depends on the Reynolds number of the flow. We may consider as an example the flow past a circular cylinder of diameter d, with its axis perpendicular to the flow. For very low values of $Re = ud/v$ ($Re < 0.5$) the streamlines come together as shown in Figure Ap4.6(a). If Re is increased to range 2-30, the boundary layer separates symmetrically from the two sides at the positions S,S (Figure Ap4.6(b)) and two eddies are formed which rotate in opposite directions. At these Reynolds numbers they remain unchanged in position. Behind the eddies, however, the main streamlines come together, and the length of the wake is limited. With the increase of Re the eddies elongate as shown in 4.6(c) but the arrangement is unstable and at Re approximately equal 40-70 (for a circular cylinder) a periodic oscillation of the wake is observed. Then at a limiting value of Re (about 90 for a circular cylinder), the eddies break off from each side of the cylinder alternately and are washed downstream. In a certain range of Re above the limiting value, the eddies are continuously shed alternately from the two sides of the cylinder and, as a result, they form two rows of vortices in its wake, the centre of a vortex in one row being opposite the point midway between the centres of consecutive vortices in the other row. This arrangement of vortices is known as a vortex street or vortex trail. The energy of the vortices is ultimately consumed by viscosity and beyond a certain distance from the cylinder the regular pattern disappears.

Similar behaviour is observed when fluid flows past different bluff shapes.

Turbulence occurs not only when fluid flows past a solid boundary, but also when two fluids flow past each other with different velocities. Turbulent mixing then takes place between the streams so as to equalize their velocities. This free turbulence - that is turbulence not bounded by solid

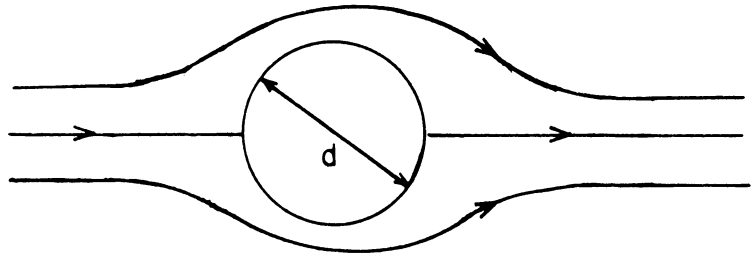


(a) Streamlined body

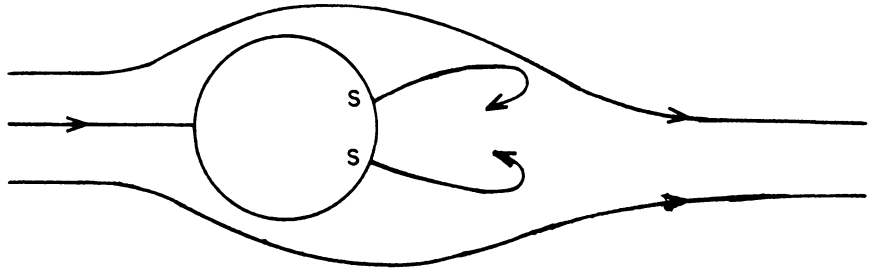


(b) Bluff body

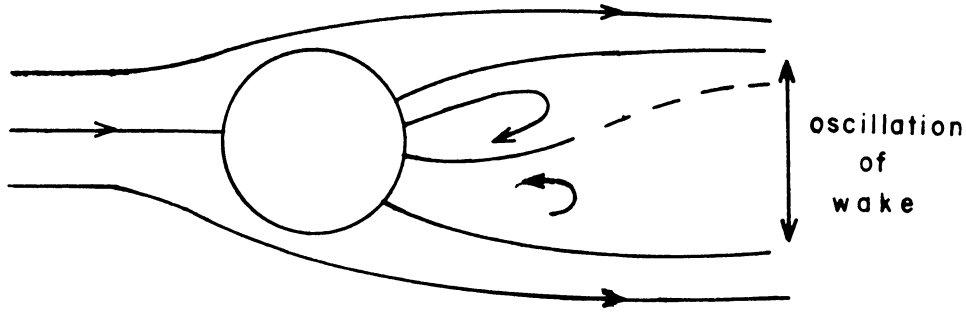
FIGURE Ap 4.5 FLOW AROUND STREAMLINED AND BLUFF OBJECTS.



(a) Re < 0·5



(b) Re = 2 to 10



(c) Re 40 to 70

FIGURE Ap 4.6 DEVELOPMENT OF WAKE BEHIND A CYLINDER

walls - occurs, for example, when an oceanic current flows into a large expanse of nearly stationary fluid enclosed in a gulf or bay.

Drawing streamlines by successive approximations - the property of streamlines and potential lines being at right angles to each other is made use of in this method of drawing streamlines. If streamlines and potential lines are drawn at equal intervals, then the shapes between them are squares.

The boundaries of the flow are drawn to scale, and a guessed set of streamlines put in, using the boundaries as streamlines. At one part of this guessed pattern, preferably where the velocity is uniform, commence drawing smooth curved lines at right angles to the guessed streamlines, spacing these lines so that at one area they produce squares. It will soon be found that if squares are drawn in the space between two streamlines then the continuation of the lines at right angles will not result in squares between other pairs of streamlines. This is due to errors in the original guessed streamlines.

Revisions can therefore be made to the streamlines at the places where the squares are most in error, but this process will be found to make the original equipotential lines incorrect, so that revisions are necessary to them. In this way, successive adjustments to the guessed streamlines and equipotentials are made until a correct pattern is obtained. In places where there are rapid changes of streamline spacing, additional streamlines and equipotential lines can be drawn between the original set of both.

The patterns obtained by this method give a good representation of flow of oceanic currents past islands only in the area before the formation of a wake. The type of wake can be estimated from the information given in paragraph 4.5 above.

Further Reading:

Massey, B. S. 1970. Mechanics of Fluids. Van Norstrand Reinhold, New York; 508 pages.

Streeter, V. L. 1966. Fluid Mechanics. McGraw Hill, New York; 705 pages.

* * *

Appendix 5.

AN EXAMPLE OF PROTECTED AREA CATEGORIES FOR SMALL ISLANDS

A Case Study from the British Virgin Islands.

Because of the proliferation of names for protected areas worldwide, the International Union for the Conservation of Nature and Natural Resources (IUCN) has adopted a standardised series of categories (IUCN, 1978). These have been designated with continental countries in mind, in which national parks are often many times larger than the entire British Virgin Islands. However, many of these categories can be altered slightly for application to the BVI. The following categories (with their IUCN number) are especially applicable to the BVI.

- National categories

  II National Park
  III Natural Monument
  IV Nature Conservation Reserve
  V Protected Landscape
  VIII Multiple Use Management Area

- International categories

  IX Biosphere Reserve
  X World Heritage Site

Using the IUCN recommendations as a guideline, and taking into account the particular local circumstances, the following categories are recommended for the Parks and Protected Areas System for the British Virgin Islands:

Category 1:

These are established to protect relatively large natural and scenic areas of national significance for recreational, educational, and scientific use. They contain large areas and entire ecosystems that are less altered by human exploitation and occupation. Category 1 areas are managed to prevent adverse human impacts on the area and to enforce effectively respect for the ecological, geomorphological, or aesthetic features which have led to their establishment. The park is managed and developed so as to permit human use for research, education, recreation, and tourism on a controlled basis while maintaining the area in a natural or near-natural state. Portions of the area should be devoted to preserving in an unaltered state representative samples of physiographic regions, biotic communities and genetic

resources, and species in danger of extinction. This category has been adapted from the IUCN "National Park" category.

Category II:

These are created to protect and preserve nationally significant natural and historic features because of their special interest or unique characteristics and, to the extent consistent with this, provide opportunities for public appreciation, tourism, education, and research. This category normally contains one or more discrete features such as a geological formation, a unique natural site, or an historic property. Natural features to be protected ideally show little or no evidence of man's impact. These areas may be of any size and generally do not contain a diversity of features or representative ecosystems to justify their inclusion in Category 1, but they have particular importance for public education and appreciation. Although they have recreational and touristic value, these areas should be managed in such a way that they remain relatively free from human disturbance, and retain their inherent features unimpaired for the long term. This category has been adapted from the IUCN's "Natural Monument" category.

Category III:

These are established to assure the natural conditions necessary to protect nationally significant species or biotic communities. The size of the area will depend on the habitat requirements or specific characteristics of the species or community to be protected. Relatively small areas, such as nesting sites, mangrove stands, or other communities of special interest may be included in this category. Human intervention or habitat manipulation may be required to provide optimum conditions for the species or community, according to individual circumstances. Limited portions of the area may be developed for public education. Non-exploitative recreational activities may be permitted in some areas. This category combines elements of IUCN's "Scientific Reserve" and "Nature Conservation Reserve" categories, but permits more flexibility concerning human activity.

Category IV:

This category has been established for small parks and gardens in developed countries. Category IV includes National Parks Trust areas that have been altered significantly from their natural state and that are managed for local recreation and education. There is no corresponding IUCN category.

Category V:

These are established to maintain areas which retain nationally important natural and scenic values for public enjoyment and economic development through recreation and tourism. The normal lifestyle and economic activity of the area is maintained, but the preservation and development of natural and scenic resources, traditional landscapes and resource uses, and historic and archaeological features are promoted for cultural, educational, and scientific purposes, as well as tourism development. Given the importance of these areas to local communities, management policy is developed by a committee made up of local residents, resource users, relevant government departments, and the National Parks Trust. The area should be large enough to maintain its special natural, cultural, and scenic qualities. Category V areas will be established often in association with more stringently protected areas with which they will comprise single legal entities. The category includes some of the objectives of IUCN's "Protected Landscape" and "Multiple Use Management Area" categories, but essentially is a new category adapted to the special management needs of small islands like the BVI.

Two **International Categories** of protected area may be used also, or be superimposed on National Categories. These are:

Biosphere Reserve:

This category is established to create a worldwide network of areas representative of the World's natural diversity. It includes representative samples of a major biome in both its natural state and as altered by human use. The area is managed to conserve ecosystems and ecological diversity, and to link conservation and development. Research, education, and training opportunities are provided to develop and promote conservation and ecologically sound development. The area should be sufficiently large to accommodate its several uses without conflict and have adequate long-term legal protection. Each area must be approved by the Man and the Biosphere International Coordinating Council before it can receive designation as a Biosphere Reserve. In the BVI, management policy for each reserve would be established by a local committee consisting of representatives of the local community, resource users, relevant government departments, and the National Parks Trust. A core natural area would be established on Crown Lands, but areas under various forms of use on private lands may be included also. This international category may overlap with some of the national categories.

World Heritage Site:

This category is established through the International Convention concerning the Protection of the World's Cultural

and Natural Heritage, and designates areas of "outstanding universal value". The primary objective is to protect the features for which the area was considered of World Heritage quality. Research and education may be secondary objectives. Areas to be considered under the Convention are restricted to those which are truly of international significance. Natural sites must meet one or more of the following criteria:

- be outstanding examples representing the major stages of the Earth's evolutionary history
- be outstanding examples representing significant ongoing geological processes, biological evolution and man's interaction with his natural environment
- contain unique, rare or superlative natural phenomena, formations or features or areas of exceptional natural beauty
- be habitats where populations of rare or endangered species of plants and animals still survive

Also World Heritage Sites must fulfill conditions relative to the integrity of the site. Management stresses the maintenance of the heritage values, continuation of legal protection, and promotion as to its significance to the country, its people, and the World. All sites must have strict legal protection and be owned by government or a non-profit trust. While recreation and on-site interpretation will generally be developed, some sites may be of such significance and fragility that public use will either be strictly controlled or prohibited. These exceptional areas must be recommended by the nation responsible for the site for declaration by the International World Heritage Committee. This international category may overlap with national categories.

Source: British Virgin Islands National Parks Trust and Eastern Caribbean Natural Area Management Programme, 1986. A Parks and Protected Areas System for the British Virgin Islands. Unpublished Report, 90 pages.

* * *

Appendix 6

INTRODUCTION TO THE METHODOLOGY FOR BIOLOGICAL RESOURCE YIELD PREDICTION

Estimation of the potential yield from any type of coastal plant or animal resource must be based on an understanding of the population structure, and how this changes naturally and as a result of exploitation. The same factors govern natural changes in plant and animal populations as those which affect human population size, i.e. the rate of change in the population number N can be expressed as:

$$\Delta N = B - D + I - E$$

Where B = number of births per year
D = number of deaths per year
I = number of immigrants
E = number of emigrants

This equation can be adapted for commercially important populations, such as fisheries, using the equation of Russell:

$$P_2 = P_1 + (R' + G') - (M + F)$$

where P_1 = the stock in the first year (or start of sampling period)

P_2 = the stock in the second year (or end of sampling period)

R' = annual increment through recruitment

G' = annual increment through growth

M = annual sum of deaths due to natural causes

F = annual sum of deaths due to exploitation (e.g. fishing)

Each of these parameters can be measured (with varying degrees of difficulty) for any population of resource organisms. Some basic biological information is required, such as breeding seasons and numbers of juveniles normally recruited, and other aspects will need to be measured over a valid time period. Once a basic understanding of the dynamics of the population has been obtained, models can be

prepared for optimising the harvest. Several production models are used by fisheries scientists and can be studied in the texts suggested for Further Reading in Exercise 4.3. The general principles behind three of these are discussed below.

a. Surplus Yield Production Model:

A population of resource organisms is maintained by the balance between recruitment to the population and loss from it. Part of the loss through natural causes can be transferred to man through harvesting. However, the population will increase in size (weight) by entry of young to the stock and growth of all individuals, until limited by the carrying capacity of the environment. If the amount of recruitment can be estimated, it is possible, theoretically, to remove an equivalent amount while the population size remains stable; and the population will have the capacity to increase again until its carrying capacity is reached:

$$dN / dt = a' N (1 - N / K^*)$$

Where N = number in the population
a' = instantaneous rate of increase
K* = carrying capacity of the environment.

The model is concerned with utilising the fraction of the stock (a'), and the equation has been modified to the standard descriptive model of Schaefer, as follows:

$$dP / dt = a' P (Pm - P) - FP$$

Where P = stock (weight)
Pm = maximum stock (weight) at carrying capacity of the environment
a' = instantaneous rate of natural increase
F = fishing mortality (i.e. F at which maximum sustainable yield is maintained)

The Surplus Yield Model is useful only where accurate estimates of the stock density are available. Although the amount of the production "surplus" which is available for harvest can be estimated, the timing of its availability is less easily forecast, because the increment results mainly from recruitment rather than growth. The recruitment of juveniles to any population can fluctuate widely depending on previous conditions during reproduction and existing conditions for juvenile survival; thus, it may not be regular or instantaneous.

b. Yield Curves

A more accurate estimate of stock size at any one time would be obtained by following the growth/weight increase of different year classes. Any population of organisms will contain groups of individuals that recruited into the population following successive breeding periods. The available yield will be determined, thus, by the different rates of weight increase by year classes at different stages of their life cycle. Wide fluctuations in the timing and size of recruitment will lead to variation in the available stocks. Although referred to commonly as "year classes", recruitment in tropical marine populations seldom occurs only once per year, so the term "cohort analysis" is to be preferred.

Yield curves can be prepared, as in Figure Ap.6.1, which separate the stock and its recruitment from catch and fishing effort/intensity. This models the relationship between catch and effort. For example, for Species 1, the yield per recruit rises rapidly to the asymptote (A) giving maximum harvest; an increase in fishing effort (B) may give slight increase in catch as population size fluctuates around this level. With Species 2, there will be a peak in yield at F = 0.5 (A), but, because of a rapid decline in average weight as the population ages, there will be a decline in yield with any increase in effort (B).

Yield Curves are particularly useful for single species resource stocks. However, many currently harvested tropical resources contain mixed stocks, sometimes including large numbers of species, as in fish-pot fisheries common in coral reef areas. The Schaefer-type model can be adapted by calculating catchability coefficients for all components of the stock, and assuming these are constant because of the relatively uniform seasonal conditions experienced by tropical species. This would include use of a cohort analysis to follow individual species throughout their growth cycles.

c. Morphoedaphic Index of Yield

The yield analyses described assume that morphometric factors are the only ones affecting population size. However, production (yield) by tropical marine populations is influenced be edaphic and climatic conditions, and also by other factors of the biological environment in which the resource stock lives. For populations of fish, sea turtles, conch or lobsters important environmental influences include (a) physical characteristics - area of suitable habitat, depth, current and tidal movements, and extent of shoreline development; (b) physicochemical characteristics - mean temperature, dissolved oxygen levels, presence of pollutants; and (c) biological characteristics - number of trophic levels in their food chains, levels of predation,

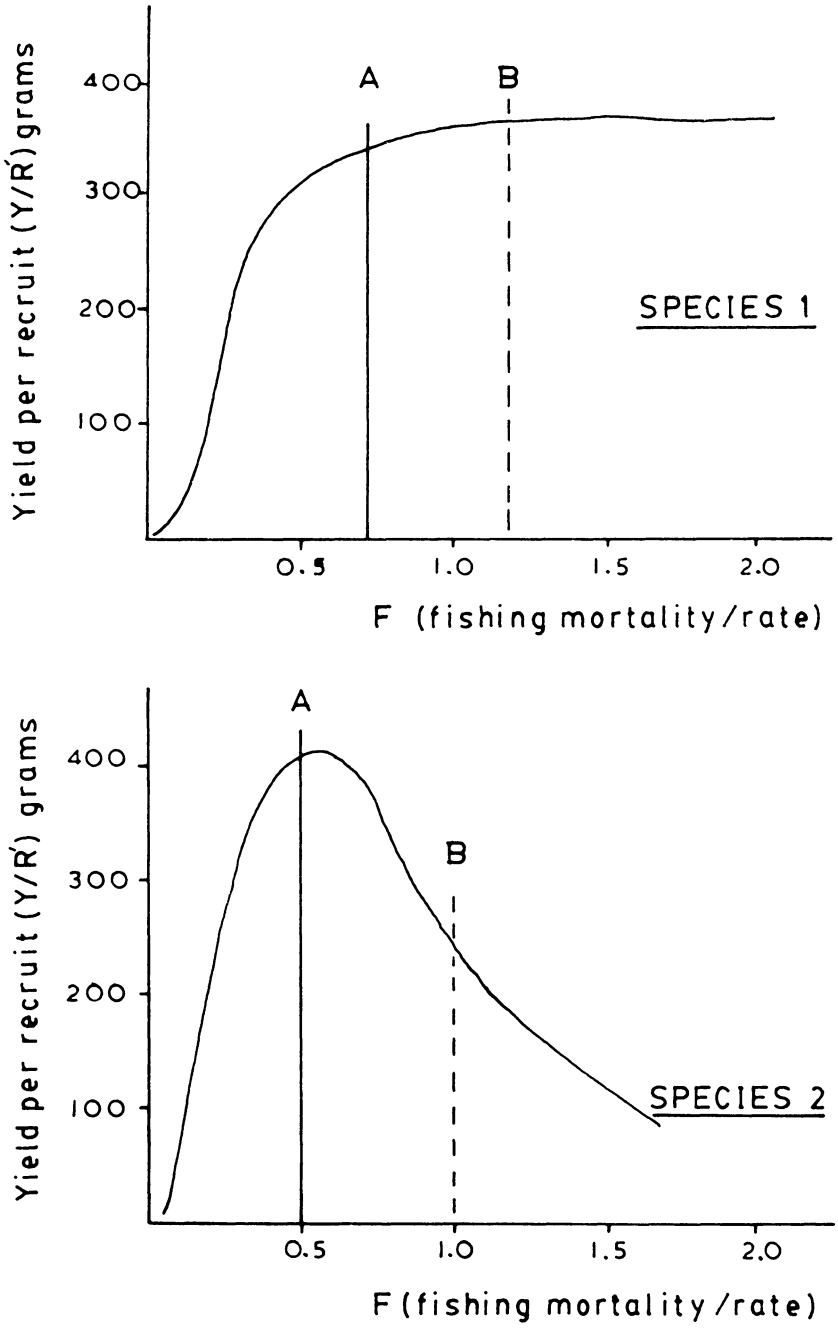


FIGURE Ap6.1 SAMPLE YIELD CURVES

parasites and disease.

These factors influence the general levels of attainable production, and can be assessed by use of a Morphoedaphic Index. For example, one could use a regression of resource production on morphometric and edaphic factors, such as the production of a conch population as a function of mean water depth and area of available food materials. In its simplest form, suitable available habitat is a key factor in production of a resource organism; for example, if 150 km^2 of mangrove root habitat occur around the coast with an estimated potential oyster productivity of 2.5 mt km^{-2} yr^{-1}, it can be expected that the sustainable yield for the whole island will be below 375 mt yr^{-1}. If poor water circulation gives lower growth rates in one area, pollution restricts use of oysters from another area, and predation by pufferfish leads to 15 % mortality throughout the island during the dry season months, the oyster fishery must plan for much lower annual yields.

Resulting Management Methods:

From the above, it is apparent that a relationship exists between the attainable harvest and the ability of the resource population to sustain that harvest. Yield assessment leads logically towards yield restriction at levels or in ways that will sustain the desired yields. Restrictions can be applied by resource managers in several ways:

a. Capture of certain species - to preserve lower trophic level food organisms used by commercially important species.
b. Capture of certain age classes - to reduce harvest of juveniles or immatures that have not yet reproduced. This can be accomplished by gear restrictions, such as banning of small mesh fishing nets, or size restrictions, such as minimum catch sizes for sea turtles or lobsters.
c. Harvest rotation - by prohibiting capture of the resource in different areas of the coast on a rotational basis. This is a standard technique with forestry resources, for example, where timber is cut from an area which is then left for long periods, such as 30-50 years, while stands of new trees mature. The annual timber quota is taken in rotation from further forest plots, with the industry's planners ensuring that sufficient timber is available, or is being replanted, to maintain output during the intervening years while the harvested plots are re-growing. The rotation period must be related to the time required for growth to maturity of the target organism, or to re-establishment of the community composition that gives the best economic returns when harvested. Closing an area for fixed periods is beneficial if it permits recovery from

damage caused by harvesting procedures, such as trawl disturbance to seagrass beds or root loss through cutting of mangrove oysters. It may also permit re-establishment of valuable climax species which, under conditions of continuous exploitation, have little chance to grow.

The size of plot and amount of resources in a plot currently being exploited in a rotation cycle must be large enough to support the total number of fishermen, or other resource users, that will be concentrated there due to exclusion from closed areas. Resource management schemes which include rotational harvesting depend upon an accurate understanding of the population dynamics of the resource organism in the target area; but they must be devised in consultation with the resource users, as they have important social and economic implications.

One of the major factors contributing to resource over-exploitation in tropical island coastal environments is the open nature of the use of resource below the high tide line. Generally speaking, marine resources are available on a free-for-all basis, in the absence of controls similar to private land ownership or forest reserve type restrictions for terrestrial resources. Although detailed treatment of the legal aspects of coastal resource utilization is beyond the scope of this text, it can be appreciated that rational management can only be applied if restrictions are introduced in order to ensure sustainable yields. One important task for coastal managers is to assist resource users in making agreements on which resources will be exploited, in which areas, at which times and at what rates; and how resource replenishment will be accomplished.

d. Maintenance of traditional harvest methods - by restriction of advanced technologies or gear, and supporting local village or community efforts.
e. Restricting entry - reducing the numbers of persons utilizing the resource by licensing. Numbers can be restricted also by use of incentives which encourage persons into alternative activities.

Support can be applied to resource populations in several ways:

a. Establishment of sanctuaries - to permit growth and reproduction of parts of the population of organisms without interference, with the intention of their spreading out to restock the utilization areas. For example, the juveniles of many commercially important tropical fish species use mangrove areas as "nursery habitat". By designating mangrove areas as "Fish Sanctuaries", critical life history stages can be protected and fish populations sustained.

Where continuous breeding takes place, as it does in many tropical species, permanent sanctuaries may be required. On the other hand, seabird and sea turtle populations could be sustained by giving sanctuary status to nesting areas only during the breeding season; although it would be advisible for some parts of the adult populations to be protected at all times as resource reservoirs.

Exploitation of the stocks of all tropical island coastal resource organisms should be supported by a strictly enforced sanctuaries programme. As indicated in Chapter 3, one of the major functions of a Protected Areas System is to help sustain an island's resource capital.

b. Removal of physical or ecological limits to population increase - in order that an increased number of juveniles will recruit into the population; as with provision of cultch surfaces for spat and removal of predators in oyster culture schemes.

c. Juvenile rearing and release - maintaining eggs and early juveniles under laboratory conditions can significantly decrease mortality. Release of late juveniles into the natural environment should lead to increased recruitment in wild stocks. This is the principle behind headstarting of sea turtle hatchlings. This process, which is still at the experimental stage, attempts to reduce the very heavy natural mortality of freshly emerged hatchlings by rearing them until they are larger, stronger and better able to feed for themselves.

Biological resource yield prediction should be based on analysis of past and present catch statistics, on the description of suitable habitat conditions, and on the likely effects of intensive management on the size of the resource stocks.

* * *

Appendix 7.

SUMMARY OF SEAGRASS REPLANTING METHODOLOGY

1. Survey the area, identify and map regions covered with seagrass (Figure Ap.7.1) (label as areas A), and areas requiring replanting (label as areas B). Areas thought to require replanting must be chosen with care. It is not sufficient to assume that a bare patch within or close to a seagrass bed should be revegetated, as the sediment type or prevailing current strength might make this patch unsuitable. It is essential to refer to published descriptions or seek expert local opinion of the previous extent of seagrass cover. Alternatively, air photos at an appropriate scale can be studied, in order to ascertain the previous extent and distribution of seagrass cover in an area.

   Seagrass beds are rarely uniform over large areas, but field survey should quickly distinguish the healthy patches. Generally, these will be dense, with long leaf blades, relatively sparse epiphytic growth, and a diverse associated benthic invertebrate and fish fauna. Patches deviating widely from this general form may benefit from replanting. However, it must be remembered that latitudinal variation, sediment composition, water depth and clarity all influence seagrass bed development.

2. Identify and note on the map any areas (B) with strong currents, or strong sediment scour; designate as (BB).

3. Collect seagrass transplants from donor beds (A). These should be "Sprigs", which are apical meristems with about 150 mm of rhizome and several leaf blade shoots; "Plugs" which are 150 mm lengths of rhizome, roots and soil; and seeds, collected from beds where fruiting is taking place, according to season. Sprigs and plugs should be collected in a ratio of 3:2, and they should be stored in net bags underwater or in trays dampened with seawater.

4. In the laboratory, or in the boat if replanting is to be done immediately, prepare the sprigs for transplanting (see Figure Ap. 7.1). Two to three sprigs should be attached to a section of 10 mm diameter construction rod 10 cm long, using twine or plastic bag-ties. Plugs will be planted as they are. Three seeds should be placed in holes in a concrete disk, 5 cms in diameter (Figure Ap.7.1) and the holes plugged with a mixture of clay and a phosphate-based fertilizer.

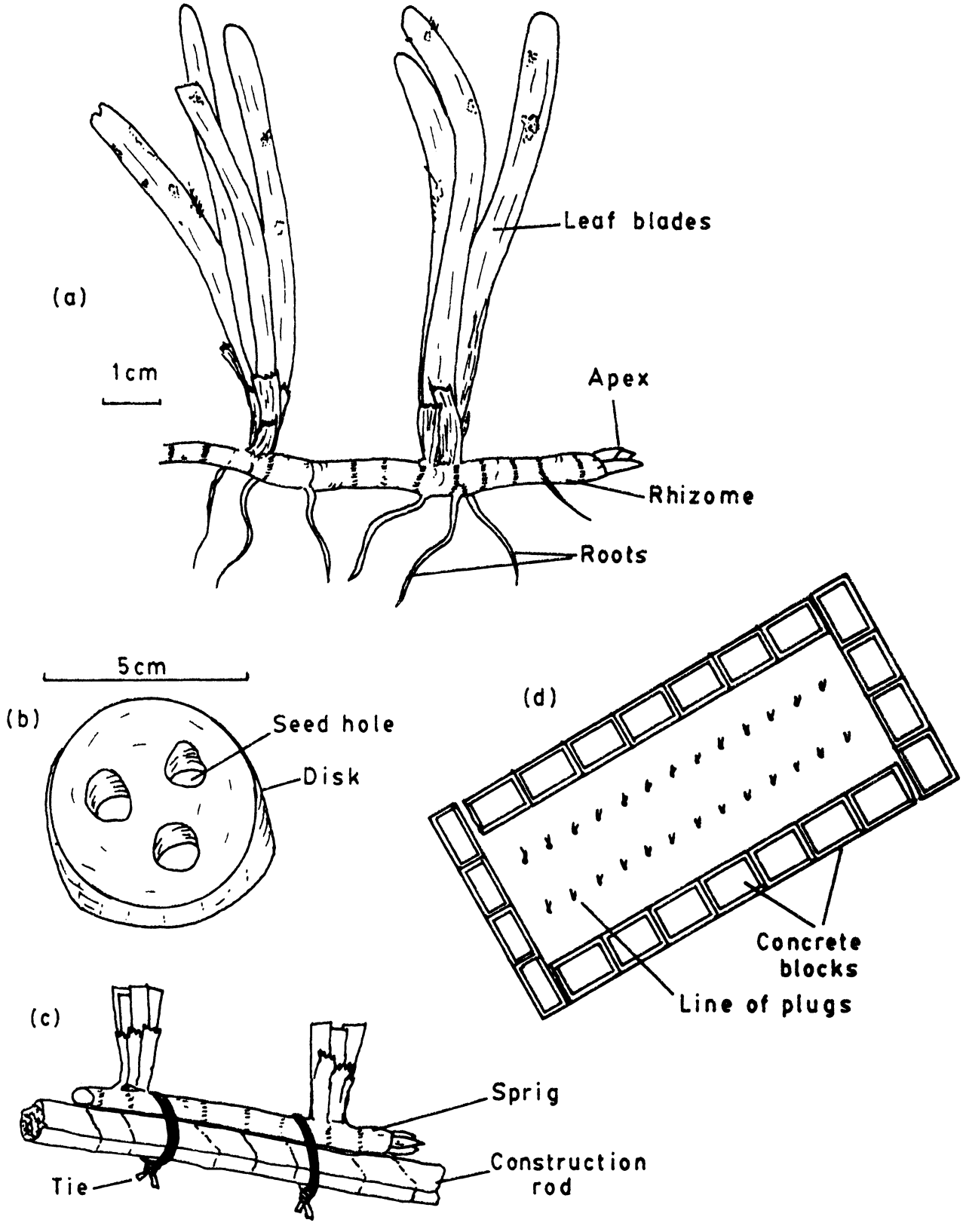


FIGURE Ap7.1 (a) SEAGRASS PLANT, (b) CEMENT SEED RING, (c) SPRIG PREPARED FOR PLANTING, AND (d) WALL OF BLOCKS ACTING AS A BAFFLE.

5. For large replanting areas, distribute the transplants along transects 3 m apart, running perpendicular to the main current direction. Sprigs and plugs or seed rings should be planted alongside a measuring tape at 0.5 m intervals, and also 0.5 and 1.0 m apart on either side of the tape.

6. For small replanting areas, distribute the transplants from centres so they are 0.5 m apart.

7. Sprigs and plugs should be pushed into the sediment, after making a hole by hand or with a suitable instrument, and tamped into place. Seed rings should be placed firmly on the sediment surface.

8. For best results, a sequence of 3 sprigs - 2 plugs - 1 seed ring - 3 sprigs should be used along the transects.

9. For areas designated (BB), a wall of blocks should be built to act as a baffle protecting the transplants from current scour. This should be constructed along the upstream side of the planting area, as shown in Figure Ap.7.1. For large areas or serious current scour, lines of blocks should be placed 1 m apart. Where strong wave action occurs in shallow water, blocks may need to be anchored securely with sections of construction rod.

10. Transplants and seed can be collected from shallow areas by wading or snorkelling. Planting in deeper areas is best done by using SCUBA. Planting teams should consist of (minimum) a pair of divers, supported by a boatman and two assistants (loaders, transplant suppliers).

11. The planting team should be able to complete a 10 x 20 m plot in 1 to 2 hours, and to work 4 similar plots per day; provided that there is a steady supply of previously prepared sprigs, plugs and seed rings.

12. Replanted seagrass beds should be monitored for at least 18 months. There should be an inspection after the first and second months, and subsequently at two-month intervals, to assess replanting success. Subsequent replanting may be needed where patches of transplants have not taken or have been uprooted.

(**Sources:** Kelly et al, 1971; Thorhaug et al, 1985; van Breedveld, 1975, and personal communication P. Gayle).

* * *

Appendix 8.

USEFUL ADDRESSES, including those of agencies mentioned in the text

American Public Health Association (APHA)
1015 18th St. N.W., Washington, D.C., 20036, U.S.A

Association of Island Marine Laboratories of the Caribbean (AIMLC)
c/o Department of Marina Sciences, University of Puerto Rico, Mayaguez, Puerto Rico.

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Practical Exercises in Coastal Zone Management for Tropical Islands

This workbook contains a series of exercises which illustrate environmental, ecological and institutional aspects of the coastal zone management process in tropical islands. The exercises are intended for use during advanced training courses or higher education, and are designed to give practising and prospective coastal managers "hands-on" experience of a range of techniques.

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