DEVELOPMENT AND CHANGE ON THE BARBADOS LEEWARD COAST: A STUDY OF HUMAN IMPACT ON THE LITTORAL ENVIRONMENT

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For Marcia my wife,

and daughters Claire and Camille

ABSTRACT

The Barbados coast affords an excellent opportunity for studying man-environment relationships. Man's presence since settlement led to the elimination of indigenous flora and swamps, and the erection of various structures along the coast. By 1900 the pre-settlement littoral was replaced by a largely man-made landscape. Recently the leeward coast was subjected to further stress, particularly from tourism and recreation. The seasonal beach rhythm was disturbed to the extent that signs of 'permanent' erosion now exist. Increased effluent discharge has caused water quality to deteriorate and reef mortality to increase. There is presently no evidence of a reversal of these trends. Current coastal management policies are inadequate. A holistic approach to planning is therefore proposed. It seeks to reconcile competing interests, without exceeding the carrying capacity of the resource base. While the model is necessarily general to accommodate many coastal subsystems, it provides a framework within which operational decisions can be made.

RESUME

Le littoral de la Barbade offre une occasion excellente pour l'étude des rapports entre l'homme et son environnement. La présence de l'homme depuis la colonisation a entraîné l'elimination de flore indigène et de marécages. Elle a également entraîné la construction éventuelle de structures diverses le long des côtes. Par l'an 1900, un payasage largement conçu et aménagé par l'homme s'est substitué au littoral qui existait avant la colonisation. La côte à l'abri du vent a récemment subi un surcroît de demandes, surtout du tourisme et de la recréation. Le rythme saisonnier des plages fut disloqué à tel point qu'il existe à présent des signes d'une érosion 'permanente'. La qualité des eaux a dégéneré grâce à l'acroissement d'effleunts noicifs, ce qui a entraîné en même temps la mort progressive des récifs. Il n'y a actuellement aucun signe de redressement de ces tendances. La politique d'aménagement du littoral barbadien s'avère aujourd'hui insuffisante. On propose ici une approache globale a la planification des côtes: une approache qui cherche à concilier les intérêts qui entrent en concurrence, sans toutefois excéder la capacité des ressources à la base du système à les soutenir. Un tel modèle, de nécessité, reste générale pour permettre l'intégration de plusieurs sous-systèmes côtiers, tout en fournissant un cadre dans lequel on pourrait prendre des décisions opérationnelles.

CONTRIBUTION TO KNOWLEDGE

This research effort is intended to represent a meaningful contribution in the area of coastal resources management. Specifically the following can be regarded as important elements of that contribution:

1. This study which commenced in the fall of 1980, is the first of its kind to attempt so extensive an analysis of shoreline changes in Barbados.* It shows causal links and interrelationships between various socio-cultural, historical, ecological, physical and biological processes which have shaped the present littoral.
2. The work extends the data base on Barbados coastal changes, especially in the study of beach vegetation, erosion and accretion rates and beach-rock measurements.
3. The study makes a contribution to the field of environmental impact assessment by demonstrating how conventional approaches may be modified and made more relevant to small islands like Barbados.
4. The work proposes a comprehensive framework for coastal management, which is easily adaptable to the needs of other small oceanic islands.

* It predates the Coastal Conservation Project which started in March 1983.

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CHAPTER 1

INTRODUCTION

The analysis of man-environment relationships constitutes a major theme in geographic enquiry and dates back to the work of Marsh (1864), Barrows (1923) and Sauer (1938). The coast provides an excellent laboratory for examining such relationships. It is a complex and dynamic zone where marine and terrestrial forces interact, and is one of the most sensitive environments known to man (King 1972; Komar 1976; Krause 1978). The coastal zone has always held a special appeal to man, offering attractions ranging from the economic to the aesthetic. Consequently, man has congregated at the coast in transitory and permanent groups.

As with many other natural systems, man has significantly modified global littoral environments. The oceanic island of Barbados is a small developing country whose limited resources have undergone over three centuries of exploitation. The leeward coast has always played a pivotal role in the island's development. In the first decades of settlement, all ports and plantations were established on the west and south coast as indicated by Ligon's map (Figure 1). In addition forts, wharves, and bathing houses were erected in the nearshore zone (Schomburgk 1847). In the process coastal swamps disappeared and so too did their peculiar hydrophytic plant species. 'New' plants were introduced altering the

Figure 1. PHOTOCOPY OF LIGON's MAP (Circa 1657)

composition of the original coastal associations (Hughes 1750). Some beaches built up, others receded and a few disappeared altogether (Schomburgk, op. cit.)

DEVELOPMENT OF THE MAN-ENVIRONMENT THEME

Since the study focuses on development and change on the Barbados coast, it inevitably involves an examination of human impact on the environment. This subject lies at the core of the man-environment theme. The discussion which follows examines the evolution of the man-environment theme and in particular, those concepts which have direct relevance to resources and environmental management.

For nearly three decades following the initial efforts of Sauer (op. cit.) and others, much of the early interest in man-land relationships appeared to wane. The reason for the loss of interest is unclear, but it may be because of a perceived link with environmental determinism, which was a highly controversial subject at the time (Mitchell 1979). It was not until the 1960's that widespread interest was rekindled with the so-called 'environmental crusade' in the United States. This crusade peaked in the 1970's with the belief that 'doomsday' was imminent, resources were nearing exhaustion, levels of environmental degradation were dangerously high and man's very survival was threatened (Bell 1970; Eyre 1971;). Doubts were even raised as to whether restorative action could repair the damage (Meadows et al., 1972).

Such extreme views soon lost credibility as scientists became convinced that solutions or at least partial answers could be found. A new interest developed in 'pure research', as it was widely believed that effective solutions had to be based on a sound theoretical understanding of the various environmental subsytems (Blalock 1970; Taafe 1974; Gregory 1976;). Indeed Blalock (op. cit.) insisted that pure research should no longer be viewed as a 'scientific luxury', but should be regarded as a socially relevant exercise. Nelson et al. (1972) supported this view and demonstrated the futility of attempting to assess the effect of resources development without a clear understanding of the 'natural processes' at work.

Perhaps one of the most important concepts emerging from the application of 'pure research' findings to environmental problems was the notion of carrying capacity. As resource systems became better understood, it was realised that such systems could be substantially modified by development beyond certain thresholds. Carrying capacity was not an entirely new concept. However, Bates (1935) had earlier demonstrated from his research in Britain that different vegetation types exhibited varying levels of resistance to human trampling. Yet the concept was not systematically explored and only became popular again in the late 1960's and early 1970's. Much of the initial work focused on environmental planning in national parks and wilderness areas (Streeter 1971; Bayfield 1973;

Merriam and Smith 1974; Beardsley et al. 1974). However the idea was applied to other subsystems in order to provide guidelines for their rational use and development. The work of Trefethen (1972) on rivers, Martin (1973) and Manners (1974) on agricultural systems, Likens et al. (1970) on forests and Hills (1974) on savannas, represent important contributions in this field.

Initially carrying capacity was regarded more as a biophysical concept than as a behavioural one. Nevertheless early pleas from Davis (1963), Lapage (1963) and Lucas (1964) elicited some response and soon the concept became more widely applied, especially in recreation planning. Geographers have made a substantial contribution in this area, showing the applicability of carrying capacity to recreation demand and user satisfaction levels (O'Riordan 1969; Gilbert et al. 1972; Lewsey 1978; Lime and Stankey 1979). Lewsey's work is especially important as it assesses the effects of tourism on the carrying capacity of the Barbados resource base. Although the study does not focus specifically on the coastal zone, attention is drawn to the possible deterioration in the littoral. Moreover, concerns are raised over the additional pressures which tourism has placed on existing utilities such as water and electricity supplies.

A relevant and related aspect of the man-environment theme is the notion of perception. It is generally accepted that the manner in which man exploits and adapts to changes in the environment is largely conditioned by the way he perceives that environment. This thinking was evident from as early as 1850 in the work of Alexander von Humboldt. He recognised that the world environment was not simply a physical phenomenon but was also an entity variously 'reflected in the feelings of mankind' (Humboldt, op. cit.:62). The validity of this statment has been tested and demonstrated by Tuan (1968, 1971), Lowenthal (1967,1972),Saarinen (1969, 1970), Sewell (1971) and Sonnenfeld (1969, 1972). However, the theme of perception in natural hazards is of more direct interest to the present study. Many detailed reviews of natural hazards research have already been undertaken (J. Mitchell 1974; B. Mitchell 1979; Burton and Kates 1964; Burton and White 1978). According to J.K. Mitchell (op. cit: 312-313), geographers have been involved mainly with the following areas of enquiry: assessment of human occupance of hazard zones, adjustment to hazards, perception and estimation of hazards and estimation of the 'optimal' set of adjustments to various hazards. And it is in these areas that they have made their greatest contribution to natural hazards research.

The work of Burton et al (1968) represents a landmark study in the application of perception studies in coastal resources management. They demonstrated that measures adopted to combat coastal hazards (flooding and erosion) are consciously determined according to three criteria: perception of the hazard, knowledge and awareness of alternative adjustments and physical and economic costs of the adjustment. It is significant to note that similar criteria appear to condition public response to volcano and hurricane hazards in St. Vincent and Dominica (Marshall 1982). The validity of this model will be tested in the present work as these criteria appear to be serious considerations in the process of adjustment to erosion on the Barbados coast.

More recently, environmental impact assessment has become a major tool especially in applied research. In many ways impact assessment is not a new field of research; it represents a continuing interest in the man-environment theme, whose origin dates back to Marsh and Sauer. Yet it must be regarded as a significant stride forward as it seeks to provide more precise tools for identifying and predicting man-induced environmental changes. Environmental impact assessment has been variously defined (White 1972; Dee et al. 1973; Jain 1975; Leopold et al. 1971;). But one of the most complete definitions offered to date is proposed by Beanlands and Duinker (1983). They suggest that impact assessment

> "...refers to a process or set of activities designed to contribute pertinent environmental information to project or programme decision-making. In doing so it attempts to predict or measure the environmental effects of specific human activities...and to investigate and propose means of ameliorating those effects (Beanlands and Duinker, op. cit: 18).

There is an extensive literature which assesses current environmental impact assessment methodologies (McNeill 1973; Jain 1975; Holling 1978; Erickson 1979; Beanlands and Duinker 1983). Although it is unneccessary to attempt an exhaustive analysis here, the most widely applied methodologies will be briefly evaluated. The review establishes a basis for selection of an approach to be used in the present study, and identifies some of the problems encountered in assessing environmental impact in practice.

The methodologies most commonly used are the <u>checklist</u>, <u>overlay</u>, <u>matrix</u> and <u>network</u> approaches. The merits of the first two are that they can provide a base for preliminary evaluation. Their essential purpose is to develop an inventory of parameters which may be impacted upon by a proposed land use. Their greatest weakness is that on their own they cannot identify cause and effect relationships. Without any indications of possible causal links, conclusions drawn, impacts predicted and remedial planning would be highly speculative and tenuous.

Interaction matrices attempt to identify causal relationships between project activities and a wide range of environmental conditions. The technique also seeks to classify impacts acccording to 'magnitude' and 'importance', which are assigned numerical weightings. The method was developed by Leopold et al. (op. cit.). It has since been applied in a variety of studies by Schlesinger and Daetz (1973), Fischer and Davies (1973), Welch and Lewis (1976) and Rajotte (1978).

In its basic format the interaction matrix can only identify first-order impacts. It overlooks the possibility of successive impacts (from a single action) or even a combination of two or more actions resulting in one or more impacts. At varying stages in its application the methodology could become prone to subjectivity. For instance it lacks stringent guidelines for determining impact magnitude and importance in spite of the numerical weightings.

The network method defines a sequence of impacts which may be triggered by project activities. The technique attempts to link causes, conditions and effects and trace their interrelationships (Sorensen 1971; Ross 1974). Network analysis, unlike other methodologies, identifies <u>initial</u> as well as <u>consequent</u> impacts. It also seeks to identify combinations of interactions which could give rise to cumulative effects. These merits partly overcome the main limitations of interaction matrices. A major weakness of the network approach is the implication that causes and impacts can be clearly traced and linked to all subsequent impacts. Although this may seem reasonable from a theoretical point of view, in practice such imputed relationships may be non-existent or insignificant at best. In applying the method one must therefore avoid the temptation of developing an unmanageable number of networks which may be remote or difficult to 'operationalize'.

Nevertheless in spite of the above limitations, the matrix and network methods are still regarded as two useful tools in environmental impact assessment. Given the current 'state of the art', these approaches are among the most flexible and offer the necessary scope for modification to facilitate a wide range of resource management strategies. It will be shown in chapter 9 that these approaches can be adapted and reconciled to help form a basis for coastal resources management in small islands like Barbados.

MAN ON THE COAST

The literature abounds with examples of the way in which global coastal environments have been altered. Man has deliberately cleared forests to provide space for construction and settlement (Ketchum 1972; Lewis 1973; Hudson 1979) and unintentionally displaced species by trampling and habitat alteration at coastal sites (Olfield et al 1973; Owens and Drapeau 1973; Clark 1977; Jones 1978). New species have also been introduced (deliberately and accidentally) modifying the microenvironments of previously existing ones (Beach Erosion Board 1957; Watts 1963; Dolan et al. 1973). Globally coastal systems have been altered by the erection of groynes and jetties, the destruction of dunes, sediment mining, the filling of marshes and swamps and the dumping of effluent

(Wade 1972; Omholt 1974; Hughes 1974; Essink 1978; Hudson 1979).

The Florida coast is a well-studied example of a stressed environment, and illustrates the need for environmental impact assessment studies. The many marshes, submerged grasses and mangrove swamps provide habitats for thousands of marine organisms which are part of a complex web. Large quantities of fish are part of this chain, forming the basis of a fishing industry (commercial and sport) which earns the state over $100 million yearly (Lewis 1973:12). The Florida Coastal Coordinating Council (1971) has shown that nearly 75% of all tourists come to visit the beaches, enjoy 'unimpeded views' and participate in a variety of water sports. In addition industrial and commercial interests compete for Florida's coastal space because of its special locational advantages. The amenities offered have attracted a large resident labour force causing the population to increase from 3.5 million to over 8.0 million within two decades. In 1973 over 4500 new residents were settling in Florida weekly, with the overwhelming majority occuping coastal lands (Lewis 1973, op. cit.).

Unfortunately, the very attributes which lured developers to Florida's coast initially have now been drastically altered, and in some cases, the change is irreversible. Some of these effects are itemized in the following vivid description:

> "...the coastal zone suffered brutally at the hands of economic growth...High quality beaches and dunes were levelled for housing without regard for their natural beauty or storm protection qualities. Productive marshlands were filled and clean rivers and estuaries were polluted by industrial effluent, municipal sewage and runoff. The environmental degradation of Biscayne Bay, Marco Island, East Cambia Bay and the St. John's river is now well-documented history" (Lewis 1973:12).

The Florida experience illustrates the relevance to coastal management of various concepts central to the man-environment debate. The development process failed to recognise that there were certain limits of use beyond which resource quality would deteriorate. Hence the decline in organic productivity, fish populations and user satisfaction reflect a level of use beyond the capacity of the system.[1] In addition, the reef and dune systems, two important beach sediment reservoirs, have contracted considerably causing a marked imbalance in the annual sediment budget of many beaches. Over 75% of Florida's 782 miles of beach is presently classified as being in a 'critical state of erosion' and the above changes are part of the cause (Campbell and Spandoni 1982). Indeed it is clear that the notions of carrying capacity and thresholds have as much significance for coastal planning as they do for other types of resource development.

In the Florida case entrepreneurs perceived the coast

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1. According to Lewis (op.cit.) these problems are a direct result of the dumping of toxic effluent and overcrowding.

as having inexhaustible resources capable of yielding massive profits. Prospective residents and tourists regarded it as ideal for housing and recreation, while naturalists perceived the coast to be a sensitive environment which should be protected. In contrast, the main government agency, the Coastal Coordinating Council (established 1970) held the view that the littoral was ecologically sensitive but could sustain long term development with careful planning (Florida Coastal Coordinating Council, 1971). These various perceptions led to a variety of strategies and conflicts in resource use. What this situation demonstrates is that any attempt at coastal management must properly recognise the existence of different perceptions, attitudes and interests. For only then can areas of potential conflict be resolved and the widest possible range of alternatives considered.

Given the diverse components of the coastal subsystem and the many competing interests, the importance of the application of impact evaluation becomes manifestly clear. Environmental impact assessment seeks to rationalise resource development within an ecological framework, to achieve maximum productivity with the least environmental conflict. It is worth pointing out that a distinction ought to be made between impact assessment as a planning tool. Surely there are weaknesses associated with current methods. But as Sorensen (1971), Ketchum (1972) and Krause (1978) demonstrate, there can be little doubt that environmental impact assessment provides a sound conceptual framework for the management of coastal resources.

DEVELOPMENT OF THE BARBADOS LEEWARD COAST: PUTTING THE PROBLEM IN PERSPECTIVE

Settlement on the island's west coast increased slowly until the 1950's after which the exploitation of the littoral accelerated. The latter development was due partly to external stimuli; first increased wealth and leisure time in industrialised societies (particularly North America), and secondly the advent of jet aircraft and luxury liners, which made people in these countries more mobile. The improved economic status of locals and the stated policy of Government to allow unrestricted access to all coastal areas, caused the beaches to become focal recreational spots for Barbadians. A large number of luxury hotels, guest houses and private cottages were therefore built to accomodate this wave of development. Consequently, increased pressures were brought to bear on the coastal fringe by a largely transient population, both of foreign and local origin.

This recent expansion meant further transformation of the coastal environment. Remnants of the original flora including mangroves have been cleared. There are stretches of the west and south coasts where no vegetation now exists. Within the last three decades some beaches have narrowed considerably, a few have disappeared completely[1] and still a few others have been created as a direct result of human interference. In addition, an increase in marine pollution, contraction of the coral reefs and changes in the sediment budgets of beaches represent other overt manifestations of change.

AWARENESS OF RECENT COASTAL CHANGES IN BARBADOS

Of considerable concern at present is the threat, both perceived and real, of coastal deterioration in general and beach degradation in particular. Property owners have responded by erecting a variety of defences against sea encroachment. These structures, conspicuous along the west and south coasts, include coral rubble mounds, gabion revetments, sea walls and groynes. Observations in the field suggest that in a number of instances this type of response has proved to be ineffective. Other undesirable impacts have often been triggered and in extreme cases, the 'initial' problem aggravated. For example, the building of groynes at Dover in the active beach zone has resulted in beach starvation downdrift at St. Lawrence; while the erection of seawalls and revetments at Folkstone Beach led to rapid scourring and undercutting in front of the structures.

Government too has become aware of the deteriorating

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1. For example up to the mid-1950's a beach existed at Fontabelle, just north of Bridgetown. This beach has since disappeared.

situation on the island's coasts. Since the latter 1970's there has been some initial response fron Government. The Parks and Beaches Commission was established and additional powers were vested in other existing bodies (e.g. Town and Country Planning Office) to regulate land use in the littoral environment. Yet, for all this development remained largely uncontrolled, causing further deterioration during the last decade or so. Given the importance of the coastal zone to the island's development, the Government commissioned a coastal conservation study in 1983. The project was funded by the Inter-American Development Bank and the Government of Barbados, and was charged with investigating the causes of beach changes and making recommendations for coastal management. Pre-feasibility analyses have since been completed and are now being studies by Government consultants and various ministries. None of the specific measures have as yet been implemented but Government has indicated a willingness to do so in the near future.

AIMS AND FRAMEWORK OF THE PRESENT STUDY

Barbados affords an excellent opportunity for examining some aspects of the man-environment theme. This study seeks to chronicle the sequence of changes on the Barbados coast and identify ways in which man has contributed to such change. It is argued that many of the problems experienced in the coastal zone in historical as well as contemporary times, are largely man-induced. The island lacks a comprehensive coastal development policy and over the years the approach to management has been haphazard and uncoordinated. Given this background, the following primary research objectives have been conceived. There are:

(1) To document the extent of human influence on the island's littoral zone;

(11) To assess the consequences of such impacts in the recent past and examine their implications for the future development and stability of the coast;

(111) To develop a framework which can provide the basis for an effective coastal management plan for the island.

The study reflects the view that the assessment of human impact must necessarily involve the 're-creation' of past landscapes. If one is to determine with any confidence those changes which are man-induced, some understanding of the condition of the littoral in its 'original' state is necessary. An historical approach will therefore be adopted in seeking to establish the character of the Barbados littoral prior to settlement. This method dates back to Carl Sauer and has successfully employed by many workers including Dansereau (1957), Watts (1963), Harris (1965), Nelson et al.(1972), Vale (1977) and Byrne (1980).

Fortunately there is an impressive succession of studies providing a thorough coverage of the island's botanical history. These investigations span a period of over three centuries, beginning with the work of Colt (1631) and Ligon (1657) and continuing until as recently as

Watts (1963), Randall (1968) and Gooding (1974). What is significant about these studies is that there is little disagreement about the overall character of the coastal flora. The works are generally complementary, each adding to the mosaic mainly with regard to species diversity. The full extent of these sources will become apparent especially in chapters 3 and 4. The body of literature dealing with changes in the island's social, economic and cultural environment is even more substantial, both in quality and quantity. It is unnecessary to list the references here, but they are drawn from a wide archival base and include books, letters, newspapers, statutes, paintings and maps. They therefore represent excellent data sources for studying man's changing use and perception of the coast.

The early historical records describing the physiographic characteristics of the island's coast are fewer and much less reliable. To this extent they can only yield a general picture of the coast. This aspect of the early shoreline is therefore not as well documented or understood as most other components of the littoral environment. Nevertheless the nature of the study makes it necessary to attempt some assessment of the state of the coast prior to, and soon after settlement.

In broad perspective the present work is intended to be a study in the assessment of human impact on the Barbados coast. A shortcoming of many impact assessment studies is that they seldom provide adequate guidelines for identifying 'critical' variables. The work of Leopold et al. (1971), Sorensen (1971) and Rajotte (1978) are cases in point. Although they suggest a wide range of variables for consideration, it is not clear which ones are really crucial. In small, developing countries where financial and technical resources are scarce, the identification of critical variables must be regarded as a priority. In the present case an attempt will therefore be made to identify some specific variables which historical and recent evidence suggest are highly sensitive to change. Procedures for mitigation planning and monitoring will also be outlined as essential components of the coastal management strategy. Mitigation is prescriptive; it involves the planning of remedial action to either lessen, or if possible, eliminate some or all of the undesirable impacts which a particular action or set of actions may cause. Monitoring refers to the repetitive assessment of an action at appropriately determined intervals of time. It is an important process because it provides a basis for distinguishing between project-related perturbations and changes inherent in the dynamics of the system being impacted. Only then can one properly assess the adequacy of mitigation and determine any additional measures which may need to be implemented.

The framework of the study is therefore designed to reflect the importance of these aspects of the management process. Initially an attempt will be made to achieve some understanding of the pre-settlement shoreline which will provide a datum line against which to assess subsequent change.

Changes in the littoral from settlement to the present will be described and explanations of these sought. The nature of, and reasons for these changes will demonstrate a need for management, a theme which will be examined in the final section of the study.

CHAPTER 2

PHYSICAL BACKGROUND TO THE ISLAND

Barbados the most easterly island of the Caribbean archipelago, is situated at latitude 13° 14'N and longitude 59° 37'W. It is about 33.5 km long, 22.5 km wide and has an area of approximately 430 sq. km . Unlike many of the neighbouring islands, Barbados is not volcanic, and exhibits a gently rolling topography. Its highest point, Mount Hillaby, barely exceeds 335 m (Figure 2). Barbados is a typical tropical coral limestone island with rainfall, humidity and temperature characteristics attributable primarily to its location in the path of the North-east Trade Winds.

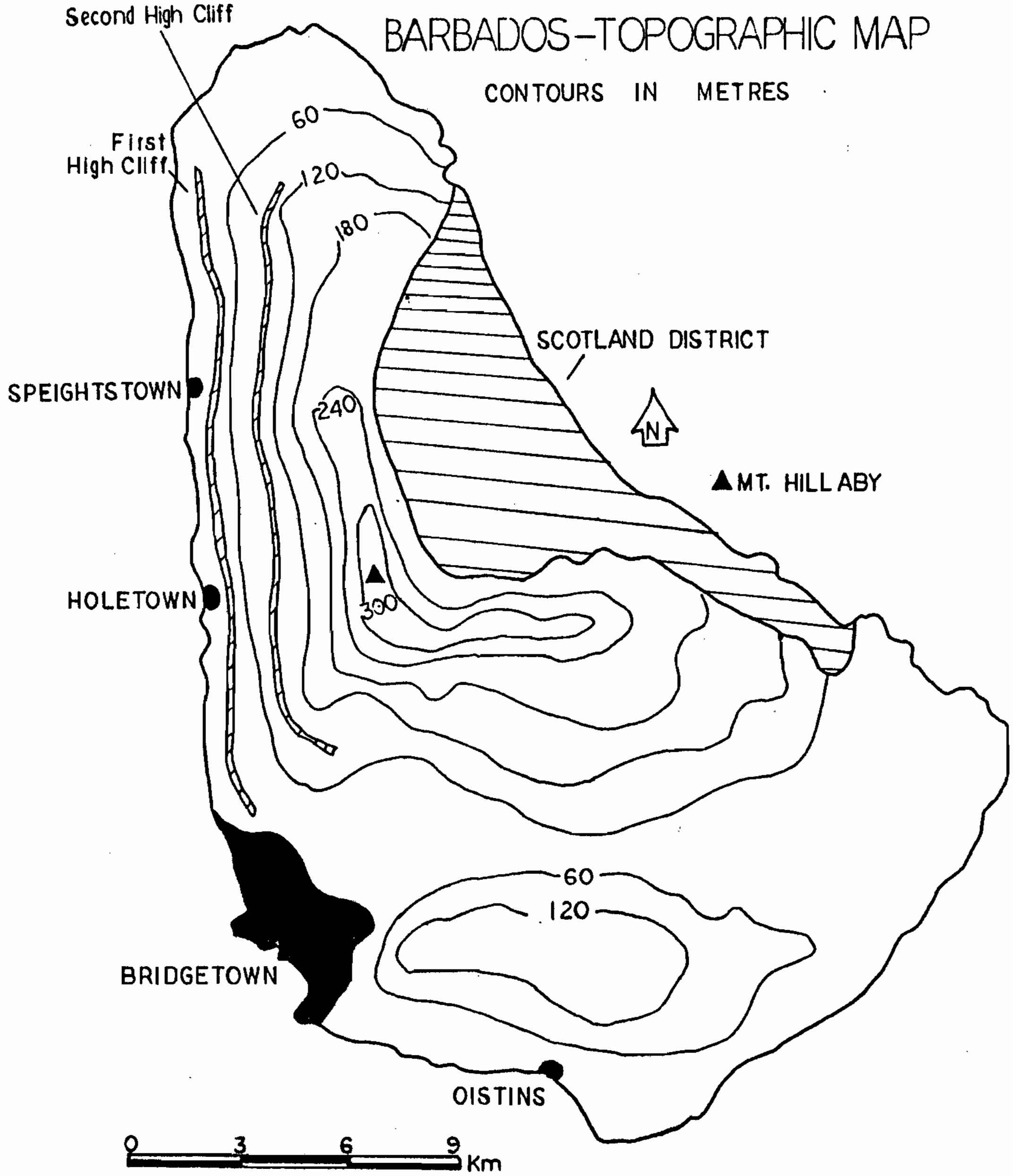
In the following sections, a review of the physical characteristics of the island's coast is undertaken, with the objective of isolating those factors which are relevant to an understanding of the processes of change in the littoral zone. At the same time, the review provides a brief background to some of those processes which determine the shape and structure of the coast itself.

Geology, Stratigraphy and Topography

The detailed geology of the island has been reviewed by many researchers, but the present level of understanding owes much to the work of Harrison and Jukes-Brown (1890), Trechmann (1933, 1937) and Senn (1940, 1946). The stratigraphic sequence is comprehensively described by Senn in his earlier publication. The oldest layer identified is

Figure 2

BARBADOS-TOPOGRAPHIC MAP



Barbados Topographic Survey 1974

the Scotland Formation. It consists of shales, sands and sandstones, is in excess of 100 m thick, and was deposited in the lower and middle Eocene. The Joe's River Formation (largely mudflows of the upper Eocene) is composed of silts, clays and tar sands and does not exceed 480 m in thickness. The 'Oceanics', a term first adopted by Harrison and Jukes-Brown (op. cit.), is a layer of upper Eocene and lower Oligocene age between 0-180 m thick, and largely composed of white chalk and radiolarian earth. This was later covered by the Bissex Hill Formation, which consists for the most part of siliceous marls and fine algal and foraminiferal limestone (Senn 1940, op. cit: 1590-1591). Overlying these is a capping of reef limestone, approximately 30-90 m thick, which was deposited mainly during the Pleistocene epoch.

Two distinct topographic regions may be delimited. In the north-east/central part of the island, there is a rugged, semi-circular zone, known as the Scotland District. It covers about one-seventh of the total land area and is heavily eroded. Its former coral cap has been removed and the older, underlying strata are exposed at the surface. This is an unstable area which frequently experiences landslides and mudflows.

In contrast, the region to the west and to a lesser extent the south, is characterised by a series of coral limestone terraces, which rise inland from the coast. Many of these terraces form bold topographic features running parallel to the west coast for long distances. Some others are broken and far less conspicuous. The two most prominent and easily identifiable of these are known locally as the first and second High Cliffs. They are approximately 30.5 m and 152.4 m above sea level respectively.

Formation of Coastal Terraces

The origin of the coral terraces has been a contentious area of study. Basically, two schools of thought evolved. On the one hand, the 'Erosionists' (represented by workers such as Trechmann op. cit; Senn op. cit.), suggested that the entire coral cap was formed just prior to uplift. They contended that as the island emerged, there was 'upward doming' of the coral layer and that subsequent faulting and abrasion by waves, produced terraces. The other school, the 'Depositionists' (e.g. Schomburgk 1848; Harrison and Jukes-Brown Op. cit.), argued that the terraces are the remnants of 'reef tracts' which formed at regular intervals during uplift. The theory further held that as emergence continued, these terraces became chronologically 'older' as succeeding reef tracts formed at lower elevations.

The controversy now appears to be resolved largely as a result of the findings of Broecker et al. (1968), and Mesolella et al. (1968, 1970). These workers independently discovered 'reef facies' embedded in the terraces (Mesolella et al., op. cit.). It was also discovered that the most recent reef tracts dated at 82000 yr. B.P. and 105000 yr. B.P. respectively, were superimposed on an older terrace formed about 125000 yr. B.P. (Broecker et al., op. cit.). The evidence would therefore suggest that each terrace represents an uplifted reef tract and a separate high sea level stand (Mesolella et al. 1968:271). It clearly supports the view even more recently espoused by Pittman (1974) and Speed (1979) that these terraces are essentially constructional features. According to Speed, the west coast developed during a high sea level stand from the deposition of carbonate sediments. These sediments produced an insular shelf with the recent deposits overlying older Holocene and Pleistocene reefs.

Sea Level Fluctuations

During the Wisconsin glaciation, a fall of global sea levels caused a westward displacement of the island's shoreline (James et al. 1971). Around 60000 yr. B.P. there was a brief sea level rise, producing a series of wave-cut benches and other beach features (James et al,. op. cit.: Bird 1970; Taylor 1974). Soon after the sea retreated, leaving a complex coral terrace which was subsequently drowned during the Flandrian transgression (Bird 1970:179). Around the time of the transgression, sea level was approximately the same as it was 60000 yr. B.P. (Bird et al. 1979). A barrier reef formed at the outer limits of the terrace, keeping pace with submergence for a time. Eventually the reef too became submerged, producing a discontinuous ridge which now restricts sediment loss to the offshore sink (Ibid). Between 10000 and 6000 yr. B.P. the sea continued to rise, but at a much reduced rate. Since then relative sea level has remained at roughly the same position. Although the island is believed to be rising at approximately 0.3 m/1000 yrs. (Bird et al. 1979), this slow rate of emergence is probably of negligible significance as an explanation of present beach changes.

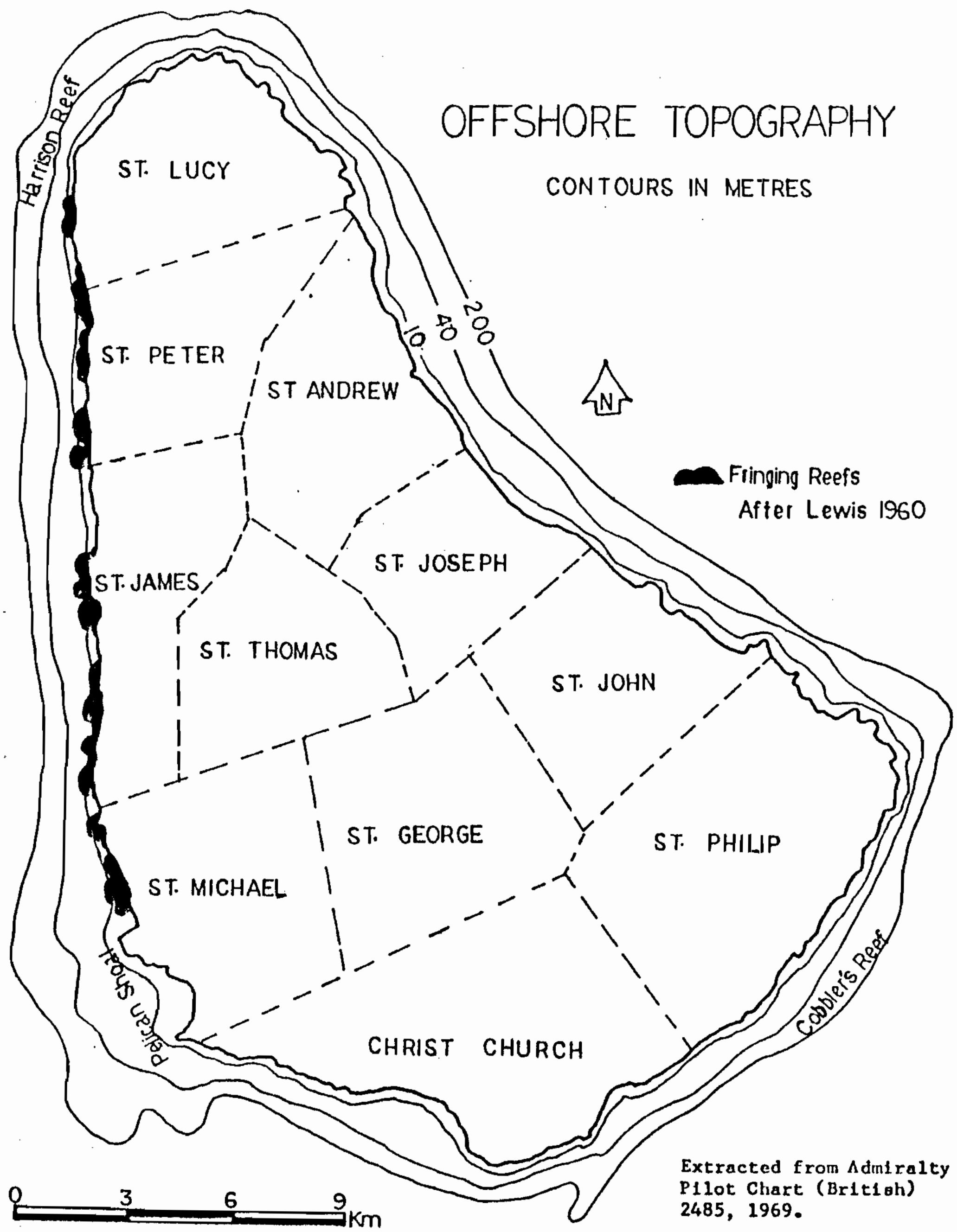
The above fluctuations led to episodes of retreat and advance of the shoreline. During the Flandrian (ca. 14000 yr. B.P.) sea level rose so rapidly that normal sediment accumulation could not keep pace. Shorelines retreated to such an extent that most beaches disappeared (Curray 1965; Cook and Polach 1973). Hence it is generally believed that present day beaches post-date the Flandrian, when sea level rose less rapidly (Ibid). These fluctuating sea levels placed global shoreline systems in disequilibrium (Godwin et al. 1958; Milliman and Emery 1968; Bloom et al. 1974). 'Natural' shoreline changes since the Flandrian (when sea levels remained relatively stable) are an attempt to re-establish a balance between marine processes and sediment supply (Komar 1976). Any serious disruption of this process could prevent the achievement of an equilibrium state (Ibid). This has particular significance for Barbados, where the coast has been subjected to continual human pressures ever since settlement. It is probable that such pressures could impact negatively on the maintenance of an equilibrium shoreline.

Offshore Reefs

The island's west coast is bordered by a discontinuous series of fringing coral reefs which occur in generally shallow water between 1.5 and 3.5 km from the shore (Figure 3). In addition there are extensive rubble banks off the south east and north west coasts, in particular Cobbler's and Harrison reefs respectively. A detailed study of coral reef development was undertaken by Lewis (1960). The west coast was found to be the only area where reef growth was active. The main area of growth stretched from Bridgetown north for a distance of about 16 km. In contrast the south coast was bordered by calcareous rubble banks with occasional patches of coral. The eastern and northern shores mainly comprised dead coral, supporting only secondary reef growth (Lewis op. cit.: 1133).

These fringing reefs were an important source of beach sediment (Bird 1979). Some sediment is also derived from the coastal cliffs which retreat mainly under the influence of sand abrasion. Lesser quantities are deposited by streams which cross the sand terrace. These silica sands were brought from the Scotland District by streams, probably during higher sea levels (Bird 1977). This latter supply is today not being replenished. To that extent it must be considered a finite source. Estimates suggest that the cliffs have been retreating by approximately 10.0 cm per century (Bird 1979). This slow rate of retreat, and

Figure 3



Extracted from Admiralty Pilot Chart (British) 2485, 1969.

the fact that the silica sands are not being replenished, demonstrate the importance of the reefs to the beach sediment budget. It must therefore be of some concern that pollution, at some locations, poses a threat to these reefs. For the very survival of the island's beaches is clearly linked to the survival of the reefs.

Beachrock Exposure Along the Barbados Coast

A notable feature of the Barbados coast is the occurrence of beachrock. The origin and composition of beachrock have been studied by a number of researchers, among them Ginsberg (1953), Russel (1962) Stoddart and Cann (1965). It constists of sand grains and rubble cemented by calcite and aragonite. The calcite is believed to result from the solution of carbonates which are deposited around the sand particles at or near the water table (Russel, op. cit.). Beachrock may form under a variety of conditions, but is almost invariably indicative of coastal erosion.

McLean (1964) was the first to study the occurrence of beachrock in Barbados. He found that it was generally confined to calcareous sand beaches backed by a limestone hinterland (p.44). This would explain the spatial pattern of outcrops in Barbados. Given the nature of the island's geology, it occurs along the west coast and to a much lesser degree along the south, southeastern and northern shores. Altogether, the length of outcrops totalled 3.0 km, covering an area of approximately 0.05 sq.km (McLean, op. cit.:43). Since these measurements were taken, there has been an increase in beachrock exposure on the island's west coast by some 46% (Bird 1977:39), between 1963 and 1975. This may be interpreted to mean that some erosion has taken place during that twelve year period, and most likely, significant sand loss. Field measurements during the summer of 1981 and 1982 reveal an increase in total length of exposures since 1975. Of even greater significance is the fact that beachrock is now exposed at locations where it was previously not observed. This must be disturbing for property owners in those areas for it indicates that those sections of the coast may be presently undergoing active retreat.

Meteorological Events - Storm Swells and Hurricanes

Research has shown that swell waves may occasionally modify the island's beaches. Donn and McGuinness (1959) have shown that such conditions may be generated by intense mid-latitude cyclones in the North Atlantic. Those systems which are responsible for swells in Barbados generally develop off the east coast of the United States.

For the most part these swells do not cause permanent beach modification (Deane et al. 1973); usually the beaches build back within a few days. However, under severe swell conditions, some sediment may be carried into the offshore zone and may become permanently lost to the beaches. Fortunately, these events with mean wave heights of 5.0m seem to be infrequent (Ibid).

Although no specific studies have been undertaken on the island, it is known that hurricanes can have serious effects on the beaches. Many coastal property owners and the Parks and Beaches Commission, have on occasion reported significant sand loss after the passage of these systems. The permanence of the damage is not known, but experience elsewhere suggests that severe, long-term damage can result (Stoddart 1963; Warnke 1966; Tanner, 1970).

A number of severe hurricanes struck the island during the late 17th and early 19th centuries. Historical accounts of the events indicate that there was considerable damage along the coasts. Waves in excess of 10.0 m were reported (Ligon 1657; Poyer 1808; Schomburgk 1847; Skeete 1963). It must be assumed that these events must have modified the beaches considerably. Since 1955 (hurricane Janet), few hurricanes have passed close enough to the island, to have much effect. Yet in spite of the low return period, they must be considered potential agents of beach modification. Many workers (including Brown 1939; Ball et al. 1967; and Adams 1980) have demonstrated that rare, catastrophic events of this nature, can cause more recession than 'normal' wave conditions, operating over many decades.

<u>Seasonal Distribution of Rainfall and its Impact on Beaches</u>

Mean annual rainfall varies between 1270 mm and 1524 mm. The year may be divided into a distinct dry and wet season. The former extends from December to late May or early June, and is characterised by periods of drought.

The wet season lasts from about June to November, during which time 65% of the total rainfall is usually recorded (Table 1). Most of the rainfall results from the development of easterly waves, tropical depressions and incipient storms, which pass over or close to the island (Nurse, 1979).

Table 1

Mean Monthly Total Rainfall (mm).

January	63.5
February	35.6
March	33.0
April	38.1
May	60.9
June	121.9
July	142.2
August	170.1
September	177.8
October	198.1
November	177.6
December	86.4

Source: Government Meteorological Office.

Heavy rainstorms in the wet season can have a noticeable effect on the island's beaches. The seasonal streams and artificial drainage outfalls often flood during this season. Those which reach the coast may erode large quantities of beach sand. Observations have shown that such sand loss is generally temporary, as most beaches recover naturally by the onset of the dry season. Nevertheless, in cases where the drainage lines have been canalised, and concrete conduits built across the beach, the rate of recovery is much reduced. In fact, at some locations (e.g. Paynes Bay, Fitts Village), the beach seaward of the outfalls no longer recovers as fully as it did, prior to the construction of the conduits in 1977. There is now an annual net loss of sand at these sites, by the end of the season.[1]

This is significant, in that it demonstrates how interference with coastal processes can impact on the stability of the beach system. The Government, through the Ministry of Works, is planning to canalise most of these streams, where they reach the coast. It would seem sensible to reconsider the implications of this plan, in the light of these observations.

Coastal Vegetation Associations

Practically all the island's natural vegetation has been removed or transformed by human influence. It is believed that Turner's Hall Wood, an area of some 20.2 ha, represents the only surviving remnant of the 'original' vegetation. The original flora consisted of seasonal rain forest, with lower layers of scrub and surface plants. In the more arid parts of the island, open scrub woodland and xerophytic associations developed (Hardy 1934; Gooding 1942, 1966, 1974; Watts 1966). For the most part, the present vegetation cover is either of secondary or tertiary growth, or has been largely introduced.

Distinct coastal associations, which will be discussed in greater detail later in chapter 3, were identified all

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1. Personal communication with Mr. B. Seliah, U.N. Civil Engineering Consultant to the Barbados Government.

along the littoral. The most ubiquitous was the <u>Hippomane</u>-(Machineel) <u>Coccoloba</u> (seaside grape) association, which over centuries, became ecologically adjusted to coastal habitats (Hardy, 1934). The removal of this and other groups of species, has left the littoral more susceptible to scour by marine and terrestrial flooding. Dune sands, over the years, have become more mobile, and some dunes have migrated further inland (Gooding, 1974).

Although the early settlers had cleared most of the coast by the early 18th century, patches of the primeval coastal flora survived. As recently as 1968, Randall was able to identify fragments of these unique associations at 15 of the island's beaches, but continuing pressure for coastal space, has since led to the disappearance of some of these remnants. Today, sections of the coast are still being cleared for development, a process which will likely make the beaches even more prone to natural erosive forces.

THE WINDWARD AND LEEWARD COASTS - A COMPARISON

The Barbados coast may be described as regular, since there are only a few marked indentations. It is 92 km long, of which nearly 42 km is composed of sand beach, 11 km of sedimentary slopes, 32 km of coral limestone cliffs, and 6.4 km of artificial sea defences (McLean 1964). It should be pointed out however, that since McLean's work, coastal protection works have increased. Field observations suggest that the figure is now in the vicinity of 10.0 km.

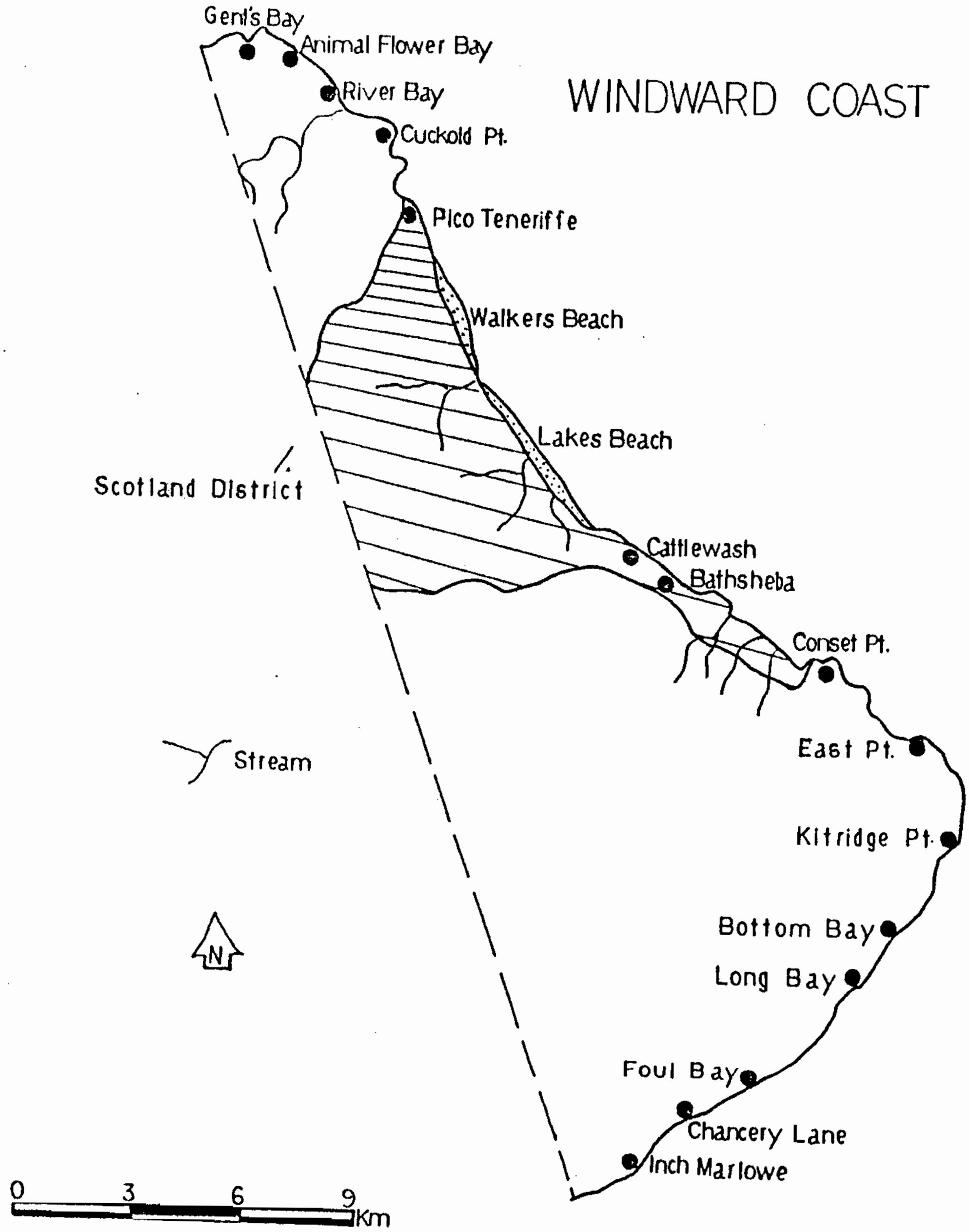
In terms of local detail, the coastline can be divided into a windward and leeward section. These exhibit some important contrasts, which will be dealt with below.

The Windward Coast

This section extends roughly from Gent's Bay to the north to Kitridge Point, and then south-west to South Point. It embraces much of the northern, eastern, and south-eastern sectors of the coast (Figure 4). It is an exposed coastline, facing the Atlantic Ocean, and the direct effects of the persistent north-east Trades. Wave energy is high, and a marked difference exists between wave amplitude here, and that observed on the west coast. At times of light wave action, wave amplitude on the east coast can be as much as 4 times greater than on the west coast. When there is moderate wave action, amplitude shows a sixfold difference; while with heavy waves, it may be 8 times greater on the east coast (Lewis 1960).

There are well developed cliffs, some of which are high with sheer drops to the sea. These are best illustrated at Animal Flower Bay, Little Bay and Pico Teneriffe, where the cliff line may reach 18.0 m above mean sea level. At other localities, such as East Point and Cobbler's Rock, the cliffs alternate with slopes of varying inclinations; but nowhere do they exceed 12.0 m elevation. Most of the indentations are on this coast and conspicuous headlands (e.g. Cuckold Point, Ragged Point, Inch Marlowe Point) are evident. A few streams reach the sea, but these

Figure 4



(Data extracted from Barbados Topographic Survey, 1974) are largely seasonal, except in the immediate vicinity of the Scotland District.

The composition of beach sands on this coast contrasts sharply with that of the west and south coasts. Apart from coral sands, silica and quartz grains form significant fractions of the sediment here. This is especially true of beaches bordering the Scotland District. In extreme cases, the beaches consist almost exclusively of these materials; for example at Walkers and Lakes Beaches (silica), and Cattlewash and Bathsheba (quartz). In contrast, leeward coast beaches are largely composed of coral sands (approximately 87-92%, Randall, 1968).

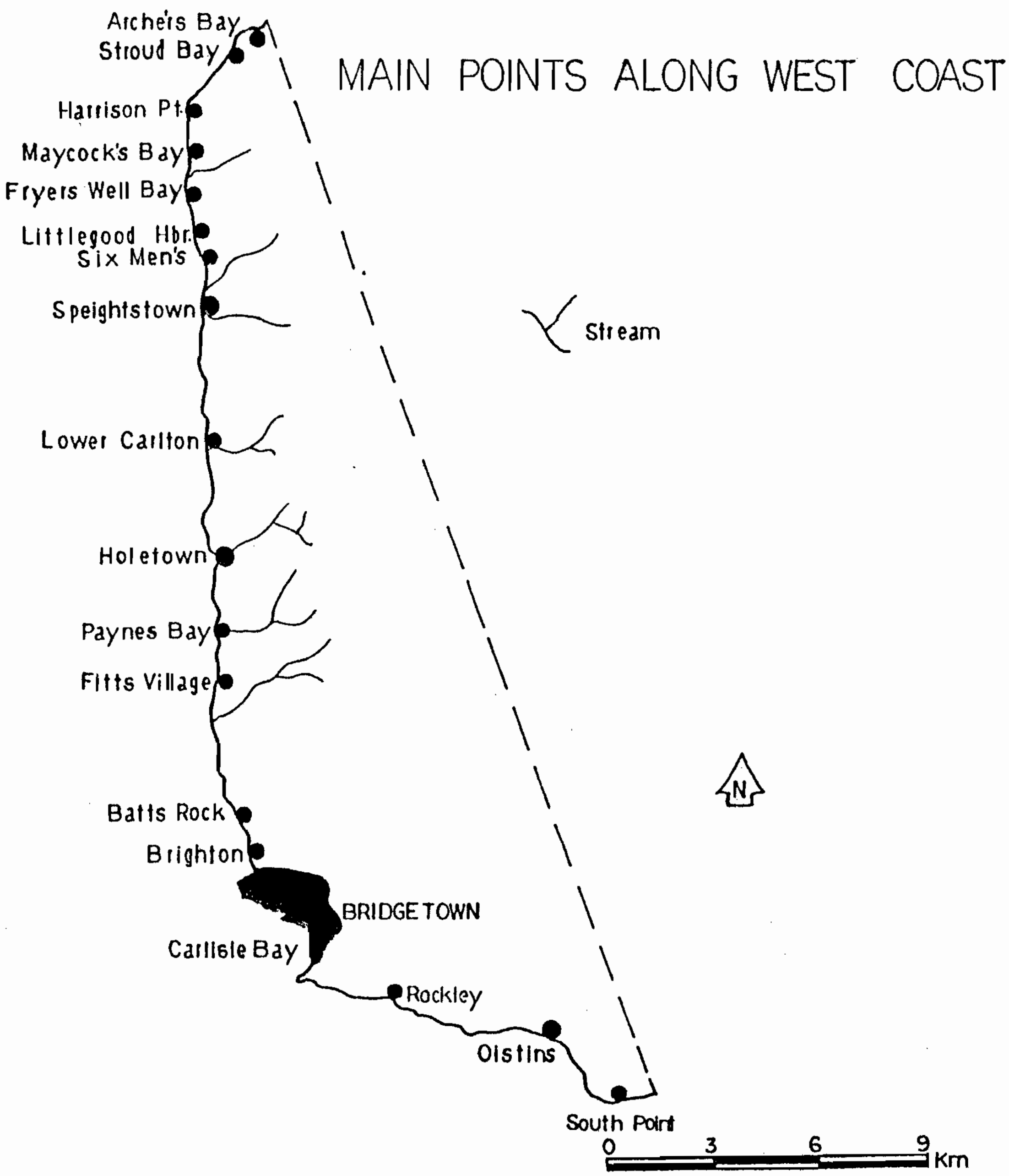
Unlike the leeward coast, dunes of varying age are present at many points. They have their best topographic expression in the Scotland District, near Belleplaine. Here, a series of old dunes, over 70 m high extends inland for a distance of about 1.6 km (Gooding 1974:14). At other locations, for example Bottom Bay and Long Bay, the dunes are of relatively recent origin. They stretch inland for more than 40-50 m, and range in height from 1.0 - 4.0 m.

The Leeward Coast

This sheltered coast, which forms the primary focus of the present study, is bounded for its entire length by the Caribbean Sea. It trends south-west from South Point to Needham's Point, after which it straightens out generally in a north to south direction (Figure 5).

Few prominent cliffs are to be found here, except to

Figure 5



(Data extracted from Barbados Topographic Survey, 1974) the north-west, at locations such as Halfmoon Fort and Harrison Point. However, though they drop vertically to the coast in places, they are not nearly as high as those on the windward side of the island. Measurements reveal that they vary in height from about 2.5 -10.0 m. Less conspicuous cliff forms occur at isolated localities along the west coast (e.g. just north of Batts Rock Bay and south of Littlegood Harbour), but their maximum elevation is no more than 3.5 m.

Dunes are virtually absent from this section of the littoral. However, it is believed the Rockley Beach to the south-west might be the remnant of a former dune series, the crest of which is now barely 1.0 m above the high tide line (Randall, op. cit:35).

A number of stream channels debouch on this coast. The rivers flow from interior highland sources, and function as important drainage arteries, especially during the summer rainy season. In their lower courses, just prior to reaching the sea, many have been canalised; in places these canals stretch across part of the beach. This is the case at Fitts Village, Paynes Bay and Lower Carlton, for example. At other points, for instance at Sandy Lane and Holetown, sand bars have formed across the estuaries. Often during heavy rains, these precipitate flooding of the sand terrace, as the runoff must breach the bars before reaching the sea.

As indicated earlier, wave energy conditions are low since the leeward coast is protected from the prevailing northeast Trades. Waves produced by this system only reach the leeward side indirectly, as energy refracted around the northern and southern headlands. Not unexpectedly, the waves are also much diminished in energy, as they approach from the northwest and southwest quarters of the island.

Research conducted on the west coast reveals that in any one year, there is a long 'winter' spell (moderate energy) during which waves approach from the northwest, and a shorter summer period (lower energy) with dominant waves arriving from the southeast. It is also demonstrated, that wave energy is at a maximum between Harrison Point and Fryer's Well Point in the north, but diminishes gradually towards the southern part of the leeward coast. In summer, the highest wave energy occurs at the southern end of the coast, though the concentration is not marked (Bird 1977: 35-36).

On the south coast proper i.e. between South Point and Needham's Point, highest wave energy is experienced between June and November (Deane et al. 1973). It is at this time of the year, that wind-generated waves reach the coast from directions varying between east-south-east, and south-south-east.

Generally, the beaches here are narrower than on the windward coast. However, the beaches on the south coast are markedly wider than those on the west coast proper. On the west coast, the average width is about 7-9 m, while those on the south coast vary between 10-12 m. There are two beaches located at Enterprise (former Coast Guard Station site) and Needham's Point which are markedly wider than average. In both cases the difference is a direct result of man's influence. Long groynes and breakwaters were built at these sites in the 1960's and early 1970's, causing large amounts of sediment to be trapped updrift of the structures. These beaches are now approximately 33.5 and 45.0 m wide respectively.

Dynamics of the Beach Cell

Research has shown that the west and south coasts comprise a number of distinct beach 'cells' (Deane et al. 1973; Bird 1979). These are relatively symmetrical arcs bounded at the extremities by convex headlands. The headlands which are fringed by coral reefs and coral flats, enclose a sandy bay, usually a few hundred metres wide (Bird op. cit.:230). In the case of the west coast, cell planform changes seasonally in response to variations in wave energy. The axis of each cell tends to shift to the northwest in winter, and to the southwest in summer, to face the dominant waves. Apparently, there is no significant change in the sand budget of the cells; but rather a backward and forward shift of sediment from one part of the cells to another (Bird, op. cit.:36-37). In their 'natural' undisturbed state, these littoral cells appear to be in a state of dynamic equilibrium.

CHAPTER 3

THE COASTAL ENVIRONMENT: 1627-1900

There is sufficient evidence to indicate that the island's shoreline underwent marked changes during the three centuries following settlement. Some of these alterations, particularly those relating to land use and vegetation, may be accurately traced from the historical records. The major problem however, is that the actual magnitude of the changes cannot be properly quantified, given the qualitative nature of the available data. However, it is still crucial to this study, that some understanding of the state of the shoreline prior to 1950 be achieved. After this date, an intensive and distinct form of land use became prominent in the littoral fringe, bringing greater pressures to bear on the active beach zone itself. In order to make a valid assessment of the impact of this new 'wave' of development, it would be necessary to have some clear knowledge of the state of the shoreline around and prior to 1950.

Equally important is the need to have some perception of the condition of the littoral before settlement. Again, on account of a lack of detailed information, assessment cannot be undertaken with the kind of precision that one would wish. Yet, even a generalised picture of the pre-settlement littoral would be necessary as a basis on which subsequent changes may be assessed. Since the central thrust of this study focuses on human impact on the coastal zone, it is essential to develop a profile of the littoral in its 'unexploited' state.

The Pre-settlement Shoreline

Very little is known about the coastal zone prior to colonization. However, the records of early settlers, historical maps and archaeological findings can be used to facilitate a partial construct of components of the environment, particularly vegetation.

The earliest records which Schomburgk could find merely alluded to "...long lines of sandy beaches...protected against the encroachment of the sea by coral reefs" (Schomburgk 1847, op. cit.:8). This reference to the leeward coast further suggests that the beaches were about 10-12 yds wide (approx. 9-11 m). Other information about the general physiography of the littoral is sketchy. One source points to the existence of stacks, which were believed to have formed just prior to settlement (Ligon, op. cit.). These small islands are shown off Harrison and Needham's Points in Ligon's original map (refer to Figure 1). In addition there were tinier rocks offshore and receding cliffs to the northwest (Ibid). These evidently were indicative of some earlier phase of erosion.

In 1631 the leeward coast was described as an area where the sea was encroaching on the land (Colt, op. cit.). Various locations including Holetown, Speightstown and Bridgetown were periodically threatened by marine flooding

(Ibid). Assuming Colt's claim to be reliable, and given Ligon's interpretation of the age of the stacks, it is probable that the leeward coast was experiencing general retreat at the time of settlement.

Coastal Swamps

It can be easily verified that swamps existed at many points on the west and south coasts. These formed mainly at river estuaries and other locations where sea water became trapped landward of the beach. They were confined to the low-lying regions of the littoral, and were no more than a few hundred metres from the shore (See Figure 6). The presence of these swamps was noted early in the island's history by Colt (1631), Ligon (1657), Hughes (1750) and Schomburgk (op. cit.). After careful observation, the following explanation was advanced for the formation of the Bridgetown swamp:

> "...for the ground, being somewhat lower within the land than the sea banks are, the spring tides flow over, and there remains, making a great part of that flat, a kind of bog or morass..." (Ligon op. cit.:25).

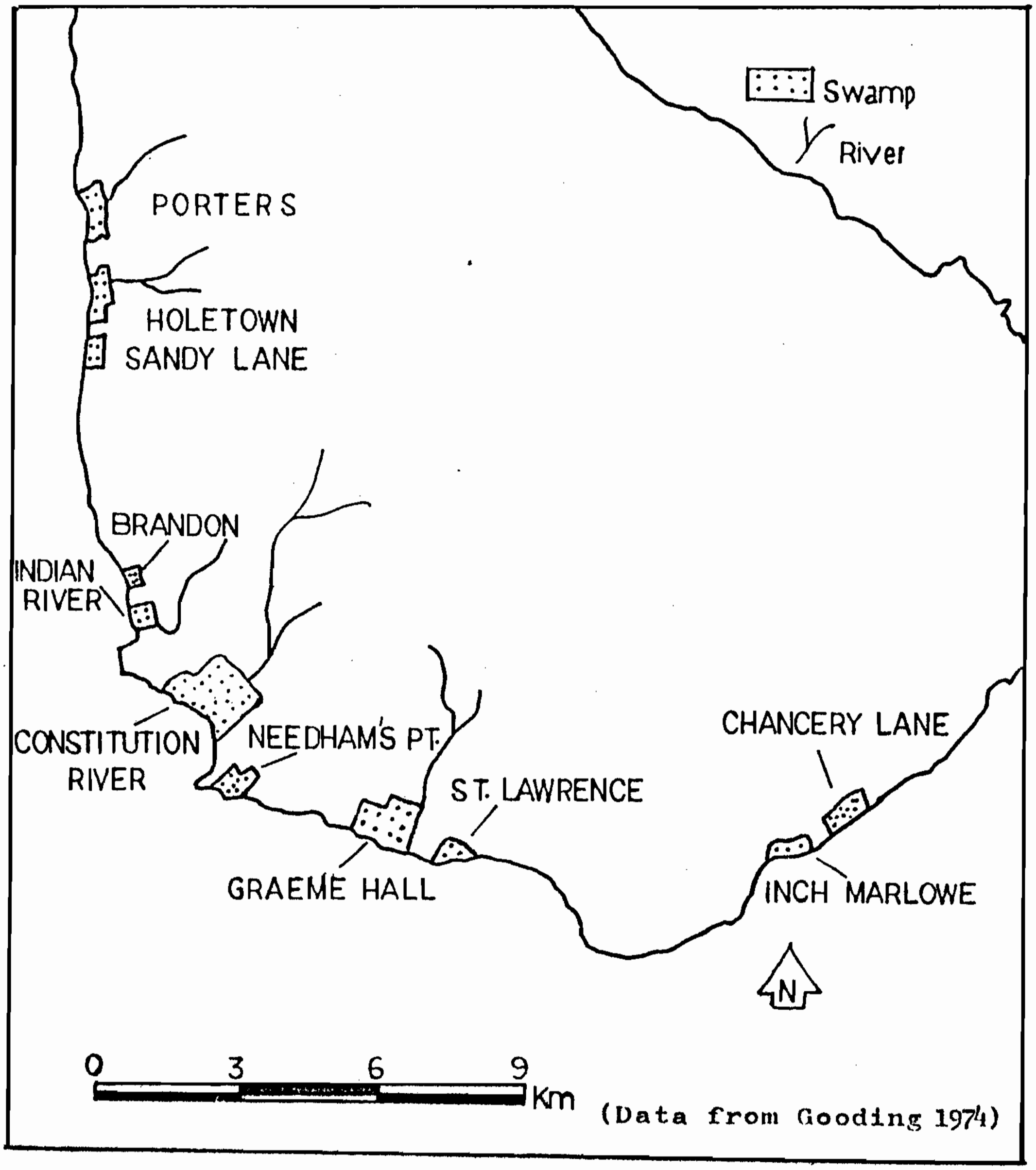
This was easily the most extensive swamp. Its area was estimated to be 5 acres, 28 perches (Alleyne 1978:31), or just over 2.0 ha.

PLANT INTRODUCTION TO THE ISLAND

All available geological evidence supports the view that Barbados has always been an oceanic island. Hence the flora which became endemic must have crossed the ocean by some means. There is an extensive literature dealing

Figure 6

COASTAL SWAMPS



with the origin and global dispersal of plants (e.g. Guppy 1917; Wulff 1943; Beard 1949; Sauer 1952), some of which deal specifically with Barbados (Guppy, op. cit; Hardy 1934; Beard op. cit; Gooding et al. 1965; Watts 1963). The shores of Barbados are washed mainly by the South Equatorial Current flowing from Africa across the Atlantic and along the South American coast. It was first established by Guppy (op. cit.) and later substantiated by Hardy (op. cit.) and Beard (op. cit.) that much of the island's vegetation came originally from the west coast of Africa via this means. Analysis by Guppy (op. cit.) suggested that about 90% of all the forest species of west and east Africa produced seeds which were capable of surviving a journey of that length. It has also been suggested that the Trade winds were an important medium of dispersal. Gooding et al (op. cit.), Allan (1957), Hardy (op. cit.) and Watts (1966) have shown that many of the seeds present in Barbados produce fruit and seeds which are easily wind-borne and have originated from all over the Tropics. Birds too have been identified as dispersal agents with respect to Barbados. It is established that "...seeds could be carried by birds in their crop...and dropped as excreta or could be carried in mud caked to their feet" (Barton 1953:9). Field studies conducted by Gooding et al. (op. cit.), Beard (op. cit.), and Hardy (op. cit.) have independently confirmed this view.

Man has been an important agent for the introduction of plants to the island. Some species were brought in as crops. Some were used as ornamentals and others were accidentally introduced (Watts 1966). Some woody species, for example _Terminalia catappa_, _Swietenia mahogoni_ and _Cordia obliqua_ were deliberate introductions which became naturalised on the coast (Ibid). In contrast, many grasses including _Jasminium fluminense_, _Emilia coccinea_ and _Catharanthus roseus_ apparently arrived accidentally, but found suitable coastal sites in which they became well established (Hardy, op. cit; Watts, op. cit.).

It is suggested that initially the rate of colonisation would have been slow since there were only a few individuals producing seed. With increasing numbers through competition and adapation, a greater quantity of seed would be produced and colonisation would become more rapid (Ibid). It is out of this process of adaptation that unique associations emerged.

Hippomane - Coccoloba Association

According to Gooding (1974), the Barbados littoral was originally covered by dense forest and a thick ground cover. The most common species were _Hippomane mancinella_ (manchineel) and _Coccoloba uvifera_ (seaside grape). These dominated the vegetation of all coasts and formed a unique association, described as 'coastal forest' (Ibid). They are xerophytic in character and in a mature state can survive long periods of drought. Also in this association were _Ficus citrifolia_ (bearded fig) and _Tabebuia pallida_ (whitewood), which were also xerophytic. Their presence in the Hippomane - Coccoloba association is substantiated by Hughes (1750, op. cit.:124)

Enterpe globosa - Manilkara bidentata

Another association, dominated by Enterpe globosa, (palmito) and Manilkara bidentata (bully tree) was also prominent along the coast (Colt, 1631; Ligon, 1657). It occured on the red, sandy soils of the littoral, and was generally found inland of the beach zone itself (Hardy 1934). Other species present in this zone were Chlorophora tinctoria (fustic), Lignum vitae[1], Sapium hippomane (poison tree), and various species of acacia. There is not enough evidence to determine whether the latter group were essentially coastal species, or whether they were individuals which occasionally found their way into this association. Watts (1963:144) speculates that acacia would have been well suited to this group, since it could exist under similar ecological conditions.

Acacia farnesiana - Cordia curassavica

Acacia farnesiana (sweet briar) and Cordia curassavica (black sage) appeared to thrive well in sandy entrenchments on the coast (Watts, op.cit.). They are salt-tolerant and could also be found in dry, rocky sections of the west coast (Hughes, 1750). Lantana involucrata (a variety of white sage) and Croton balsamifer (seaside sage) were frequently found in this group (Gooding et al. 1965;

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1. No common name.

Hughes, op. cit.). These were prevalent along the northern, north-western and southern coastal cliffs.

Mangrove Vegetation

Mangroves were present at most swamps on the west and south coasts. They represent an association unique to tropical tidal zones, and were widespread in the Caribbean (Gleason and Cook, 1926; Stehle, 1935; Chapman, 1944). Although the term 'mangrove' was not used in the earliest literature describing these plants, there is no doubt about their presence in the pre-settlement littoral. References to "swamp trees' and "tangled roots" by Colt (op. cit.) support this contention. While it is highly likely that many more species existed, evidence for only four types can be found. These are *Rhizophora mangle* (red mangrove), *Conocarpus erectus* (button mangrove), *Avicennia nitida* (dwarf mangrove) and *Laguncularia racemosa* (white mangrove). Of these, the red and white varieties were the most common (Gooding 1974).

Research has shown that mangroves seldom grow in isolation; but are the dominants in an association which often includes submerged marine angiosperms (e.g. *Thalassia testudinum*), grasses (e.g. *Spartina alterniflora*), succulent shrubs, ferns and epiphytes (Watson 1928; Davis 1940; Richards 1952: 301-302). Nowhere in the literature on Barbadian flora, is there any mention of any such associated species. However, it would be reasonable to speculate that some such plants were present, as was the case in Jamaica (Chapman, op. cit.; Stehle, op. cit.), Trinidad and Guyana (Richards, op. cit.), and Puerto Rico (Gleason and Cook, 1926).

Riparian Species

There appears to be some evidence of a riparian association (Watts, 1963), which would probably have been confined to the infrequent stream courses, especially those which maintained perennial flow. Watts (op. cit.) identified three locations: Long Pond, Green Pond and the Bridgetown Constitution River. Only the last location falls within the present study area. Practically all the streams which reached the leeward coast were seasonal, which meant there was insufficient moisture to support a distinctive riparian association on a permanent basis.

The full composition of this association is not clear, but it seems that Chenopodium ambrosoides (wormseed weed) was present (Hughes, 1750 :170). There are numerous hydrophytes and mesophytes which were well suited to muddy stream banks and estuaries. Many of these, including Commelina diffusa (pond grass), Eichornia grassipes (water hyacinth) and Cyperus ligularis[1], are present in the estuary at Graeme Hall.

Littoral Ground Cover

Many grasses and weeds found favourable habitats along the coast. Some were localised in occurrence, being

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1. The reader is referred to Gooding (1974: 90-95) for a full catalogue of these plants.

strongly influenced by soil depth, moisture availability and salinity; others were ubiquitous, colonising a wide range of habitats (Hughes, 1750). The most widespread were Sporobolus virginicus and Paspalum distichum (two varieties of crab grass) which occurred in all sandy zones, especially in the "pioneer" fringe on the beach. They are halophytic, though they have also been found in areas virtually free of salt. They are useful for anchoring mobile sand, and to that extent may have been present on the dune sites of the south coast. Also important was Ipomoea pes-caprae (seaside yam) which is salt-tolerant, and in many cases grew right down to the water's edge (Hardy 1934).

Frequently found in close association with these, was Pectus humifusa (duckweed), a plant adapted to seashores and waste places (Gooding et al. 1965). In addition, Portulaca oleracea (purslane) and Stachytarpheta jamaicensis (vervain) were present. These however were confined to the more arid sections of the coast, such as the north west (St Lucy), and south (Christ Church). They were not species of the pioneer beach zone, but were more prevalent in the inner zones of the coast (Gooding et al. 1965). Generally, they prefer more compact sands than pioneer species, and are less tolerant of saline conditions. A list of the dominant primeval coastal species is given in table 2.

Table 2

Pre-settlement Coastal Vegetation

Trees and Shrubs	Brief Description of Habitat
Hippomane mancinella	Xerophytic; loose or compact sands; saline conditions.
Coccoloba uvifera	Xerophytic; loose or compact sands; high salinity.
Tabebuia pallida	Xerophytic; compact soil; moderate salinity.
Ficus citrifolia	Xerophytic; compact soils; moderate to low salinity.
Enterpe globosa	Sandy soils; low salinity moderate moisture.
Manilkara bidentata	Compact sandy soils of moderate to low moisture.
Chlorophora tinctoria	Sandy soils of low moisture content.
Lignum vitae	Low salt tolerance; compact, sandy soils; low moisture
Sapium hippomane	Low salt tolerance; medium to low moisture; sandy soils.
Acacia farnesiana	Sandy entrenchments; low moisture; halophytic.
Cordia curassavica	Sandy entrenchments; low moisture; halophytic.
Lantana involucrata	Coastal cliffs; halophytic; little moisture.
Croton balsamifer	Coastal cliffs; halophytic; little moisture.
Grasses and Herbs	
Sporobolus virginicus	Pioneer zone; loose or compact sands; halophytic.
Paspalum distichum	Pioneer zone; loose or compact sands; halophytic.
Ipomoea pes-caprae	Moderately deep sands; salt-tolerant; pioneer zone.
Pectis humifusa	Seashores and waste places; low moisture; sandy soils.
Portulaca oleracea	Xerophytic; sandy soils; low tolerance to salt.
Stachytarpheta jamaicensis	Low moisture; compact soils; low salinity.

Sources: Hughes 1750; Hardy 1934; Watts 1963; Gooding et al.1965; Gooding 1974.

Many of these species were present in other parts of the Caribbean and in other regions of the Tropics. In Antigua, Barbuda and Aguilla there was a distinct *Hippomane mancinella* association, similar mangrove species and a strand vegetation dominated by *Ipomoea sp.* and *Sporobolus sp.* (Harris 1965). Most of these species were also found in similar associations in Trinidad (Beard 1946), Bahamas (Byrne 1980), Puerto Rico (Cook and Gleason 1928), Mauritius and the Seychelles (J.D. Sauer 1960, 1967) and Kenya (Isaac 1968). The early vegetation of the Barbados littoral could therefore be considered typical of many tropical coralline coasts.

THE COAST AFTER SETTLEMENT

Impact of Permanent Settlement - Deforestation

Perhaps the most lasting impact of settlement, was the extent of land clearance on the leeward coast. The first settlers landed at Holetown, and soon extended their range beyond Speightstown, and south beyond Oistin (Poyer 1808:20-21). The leeward coast therefore became the main locus of developement, and consequently was the area where the brunt of the initial forest removal took place.

Many requirements had to be met: suitable arable land, building materials and domestic needs. In addition fuel needs were extensive and wood was the only readily available source (Ligon. Op. cit.; Schomburgk 1847). There is evidence that some wood was exported too; for it was pointed out that the forests "...afforded lignun vitae and fustic, which became articles of immediate export to England" (Poyer, op. cit.:17). This brought even greater pressure to bear on the coastal forests. So extensive was the land clearance, that by the end of the 17th century, timber had to be imported to supplement local supplies (Hughes, 1750; Davy, 1854). Extensive stretches of the coast previously covered in forests, were now almost bare of vegetation within the first few decades of settlement.

Reduction and Disappearance of Species

Many species found earlier became less common or absent. Ficus citrifolia almost disappeared from the southern and western shores, though it could still be found inland, especially near cliffs (Gooding, 1974). This was also true of Enterpe globosa (palmito) and Manilkara bidentata (bully tree), which disappeared from the littoral by the year 1700 (Gooding et al. op. cit).

The rarity of some species by this time, must be attributed not just simply to slow regeneration (e.g.Manilkara), but also to deliberate selection by man. Manilkara was excellent for timber, durable and easily workable (Ligon, op. cit.:14). Mention has already been made of the exportation of Lignum vitae and Chlorophora to the metropole. Like mangrove, these were considered excellent for timber and fuel (Schomburgk 1847).

The impact of man on the mangrove communities can be well documented from the historical literature. Most of the swamps were systematically cleared of mangroves and filled (Harlow, 1926; Alleyne, 1978). The 2.0 ha of swamp at Bridgetown was reduced to a few individual trees, and the reclaimed land was used for the construction of commercial buildings and the extension of Bridgetown (Alleyne, op. cit:31). This particular location became permanently altered, and was replaced by a landscape entirely man-made. By the middle of the 18th century, two varieties of mangrove, Conocarpus erectus and Avecennia nitida had become extinct (Gooding et al., 1965).

Again, the Barbados case is by no means unique. Man is known to have reduced the vegetation stock and eliminated swamp environments on numerous other tropical coasts, including the Caribbean, Central America and the Pacific (Harris op. cit.; McBryde 1947; Fosberg 1963). As in Barbados, deforestation and swamp reclamation in these regions resulted from rapid population increases and increasing demands for food, housing and fuel.

Appearance of 'New' Species - 1627-1700

Trees and Shrubs

New species appeared, some of which eventually became dominant on the west and south coasts. Cocos nucifera (Coconut palm), is one species which certainly was absent at the settlement. It grew so tall[1] and was of such importance to the inhabitants, that it could hardly have escaped notice if it were present. Well adapted to sandy coastal environments, it was first introduced in 1647. By 1700, it had become a member of the Hippomane-Cocoloba association (Hardy, op. cit.). Cocos nucifera regenerates

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1. This tree sometimes reaches heights greater than 30m.

quickly from its own nuts which fall to the surface when ripe, germinate and take root. The nuts are encased in a thick, hard husk, allowing them adequate protection. This accounts for its great abundance so soon after introduction.

Cassia glandulosa (Tamarind) and Poinciana pulcherrima (Barbados pride) became known to the Barbados littoral sometime between 1647 and 1650 (Hughes, op. cit.). The former could have reached the leeward shore purely by accident, but its fruit is known to have been a source of food in the New World (Polunin, op. cit.:259). To this extent, Cassia might also have been a deliberate introduction. The woody shrub Mallotonia gnaphalodes (Seaside lavender) became prominent especially in the vicinity of sand dunes. Never previously seen on the littoral, it was first noticed by Hughes in 1647. It spread rapidly, and lived in close proximity to such dominants as Hippomane mancinella and Tabebuia pallida.

Two additional xerophytes became naturalised on the coast: Aloe barbadensis (Barbados aloe) and Opuntia dillenii (prickly pear). These were introduced around 1650 and were particularly suited to the drier parts of the coast, especially 'Coralline sea rocks' (Gooding 1974:172). These added a measure of diversity to the thorny, xerophytic scrubland, previously dominated by Agave barbadensis (maypole) and various forms of cactus.

The Period 1700 - 1900

There is a surprising lack of literature detailing the island's flora between 1700 and 1900. During this time only Walduck's letters of 1710 and 1711, and the work of Hughes (1750) give any reliable insight about vegetation changes. Of the woody species introduced, none are recorded as having reached the littoral.

However some grasses and a few sedges were introduced, some deliberately (Hardy 1934). The catalogue containing these plants is given in Hughes (1750). It lists Egragrostis ciliaris (dog's grass), Chloris radiata (plush grass) and Eleocharis mutata (bulrush)[1]. The first two lived in habitats ranging from dry to moist, sandy to rocky and could tolerate relatively high salinity (Hughes, op. cit.). Chloris is xerophytic and colonised the cliffs to the north and south. Elecharis is a sedge, which grows best in water or wet soil (Gooding 1974:145). Given this habitat preference, it may be assumed that it grew in coastal swamps and probably on the banks of streams which reached the coast.

One of the first plants to become established after 1800 was Swietenia mahogani (mahogany), which was introduced in 1806 as a windbreak and timber species (Schomburgk 1847). Though not peculiar to the coast, it

1. Randall (1968:87) suggests that bulrush and plush grass might have been accidentlly introduced, since they were Caribbean natives. He however believes that dutch grass, being ideal for pasture was a deliberate introduction.

became adjusted to conditions there, and soon spread rapidly. _Casuarina equisetifolia_ (casuarina) was imported from Australia around 1870 as a windbreak, hedge plant and source of fuel (Watts 1963). Its rapid spread is largely due to its ability to compete successfully with other well-established species (Gooding 1974:126). _Delonix regia_ (flamboyant) and _Terminalia catappa_ (almond) were deliberately planted as ornamentals on the coast.

Table 3

Plants Introduced on the Littoral Between 1627 and 1900

Species	Habitat Requirements
1627-1700	
Cocos nucifera	Sandy, saline soils; moderate moisture.
Cassia glandulosa	Moist, compact soils; tolerant of moderate levels of salinity.
Poinciana pulcherrima	Moist, compact soils of relatively low salinity.
Mallotonia gnaphalode	Sand dunes; fine sands; moderate salinity.
Aloe barbadensis	Rocks and sea cliffs; xerophytic conditions.
Opuntia dillenii	Rocks and sea cliffs; xerophytic conditions.
1700-1800	
Egragrostos Ciliaris	Varying moisture ; drought-resistant; high salinity.
Eleusine indica	Moderate moisture; drought-resistant; saline soils.
Chloris raidata	Rocky shores; low moisture.
Elocharis mutata	Hydrophytic conditions.
1800 - 1900	
Swietenia mahogani	Variety of habitats; low salt tolerance; compact sands.
Casuarina equisetifolia	Variety of habitats; halophytic.
Delonix regia	Variety of habitats; low salt tolerance. Compact sands.

Table 3 (Cont'd)

Species	Habitat Requirements
Terminalia catappa	Halophytic; moderate moisture; sandy soils.
Jasminium fluminense	Disturbed sites; variety of soil and moisture conditions.
Emilia coccinea	Disturbed sites; no particular soil or moisture preference.
Conyza canadensis	Disturbed sites; moderate moisture; sandy soils.
Catharanthus roseus	Disturbed sites; no particular soil or moisture preference.

Sources : Hughes 1750; Schomburgk 1847; Hardy 1934; Watts 1963; Gooding 1974.

Additional grasses were identified on the littoral after 1848. They included *Jasminium fluminense* (wild jasmine), *Emilia coccinea* (red thistle), *Conyza canadensis*[1] and *Catharanthus roseus* (periwinkle). Their introduction was probably accidental, given the amount of global traffic at the time of their arrival. Their origins range from Madagascar to India, to North America. They appear to have simply sprung up along the coast at heavily disturbed sites (Hardy, op. cit.). The more aggressive species such as *Jasminium* and *Emilia* eventually became naturalised. Table 3 is a list of the more common species introduced after 1627.

LAND USE ON THE LITTORAL

Plantations

Accompanying these plant introductions were a number of other changes which further modified the coast. Population grew from a few persons at settlement to 23,000

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1. No common name.

by 1650 (Watts, 1963:182-183). Most of the inhabitants lived in close proximity to the coast, a trend which continued until the late 1600's, when the interior became more accessible. Ligon's map (Figure 1), illustrates the pattern of coastal settlement around 1650.

By 1655 there were 745 sugar plantations, nearly all of the forest had been removed and the small leaseholds of the first two decades of settlement eliminated (Tree, 1972:22). By 1650 sugar cultivation had been undertaken commercially (Ligon, Op. cit.) dominating the arable land of the west and south coasts. The original character of the coast was increasingly being replaced by a man-made landscape, a trend which was to continue in the years ahead.

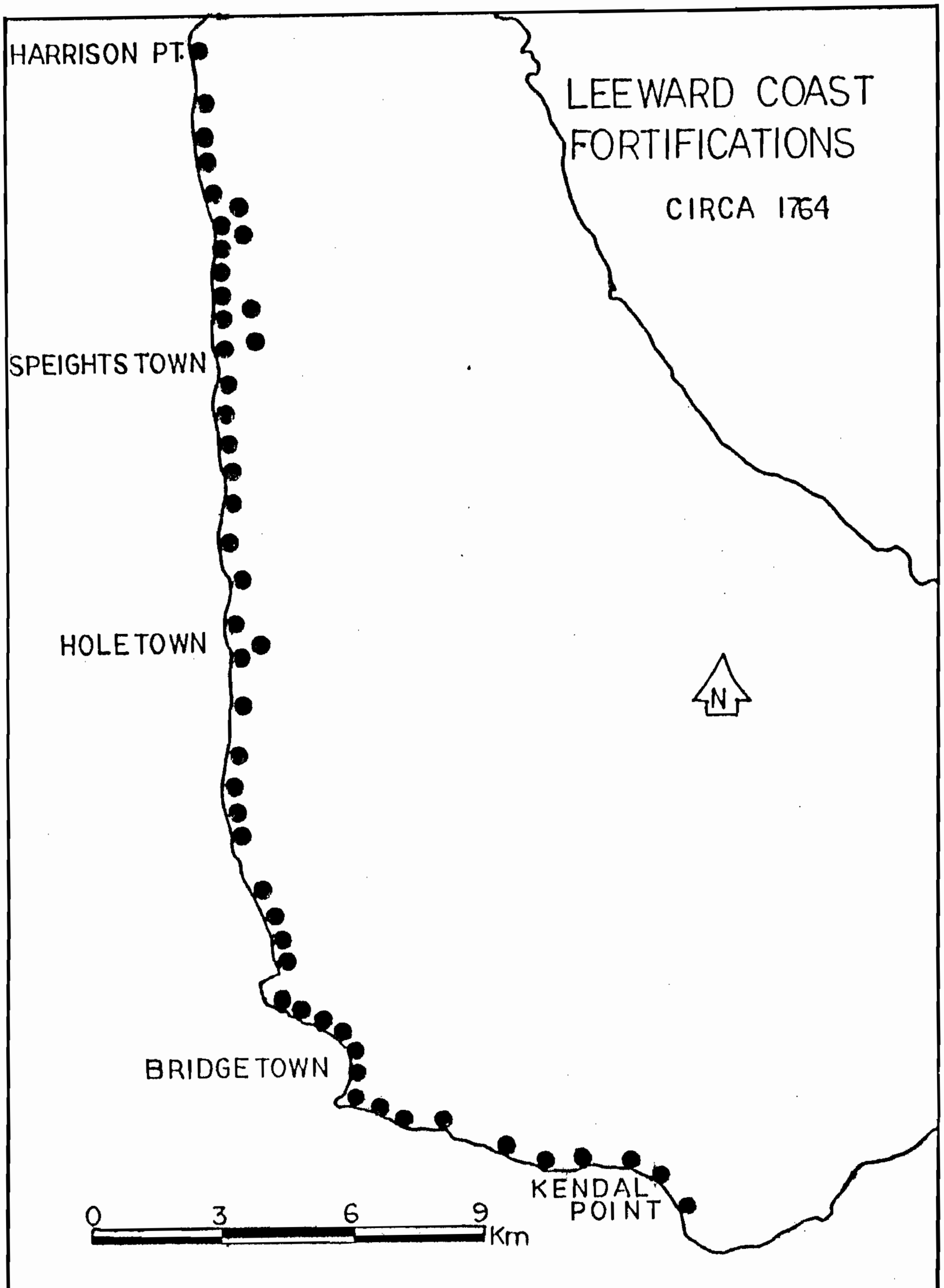
Housing

It should be noted that at this stage of the island's development, and even into the early 20th century, there had been little housing construction in the beach zone itself. Most residences were set back on the sand terraces some distance from the high water mark (Hunte 1974:117).

Leeward Fortifications

From as early as 1647, acts were passed in Parliament authorizing the fortification of the leeward coast. First hand observation by Schomburgk (1847), revealed that there was a line of forts along the beach from Harrison Point to Oistin. There were some 51 forts by 1764, most of which were built on the beach itself (Poyer, 1808). Figure 7

Figure 7



(Data after Poyer, 1808)

gives the location of these forts.

Port Facilities

Wooden and concrete jetties were built at the main port sites of Bridgetown, Oistin, Speightstown and Holetown. These were constructed during the 17th and 18th centuries to facilitate shipping of cargo. The exact dates that the Speightstown, Holetown and Oistin wharves were built are not easy to ascertain; but they were certainly completed by the late 1700's.

The Bridgetown docking facilities started as early as 1630, expanding into a fully-fledged system of wharves by 1791 (Alleyne 1978). The construction of the Bridgetown facilities is known to have had disastrous effects on the coast. Scour increased to the north of Bridgetown, as far as Indian River. Eventually the coastal road became prone to flooding by the sea (Oldmixon, 1708). By 1800, the wharves had trapped so much sand and mud, that the port area itself became unnavigable even by flat-bottomed boats (Alleyne 1978:35).

Other Structures

From the late 1800's to as recently as the 1940's a number of bathing houses (with adjoining jetties) were also erected.[1] They were mainly concentrated on the south coast, but a few were located on the west coast as well.

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1. Laws of Barbados vols.1 (1912) and 2 (1918). Advocate Printing Co. Ltd., Bridgetown , and Sweet & Maxwell Ltd., London.

Figure 8 shows the location of bathing houses and jetties up to 1900.

NATURAL CATASTROPHES : IMPACT OF HURRICANES ON COAST

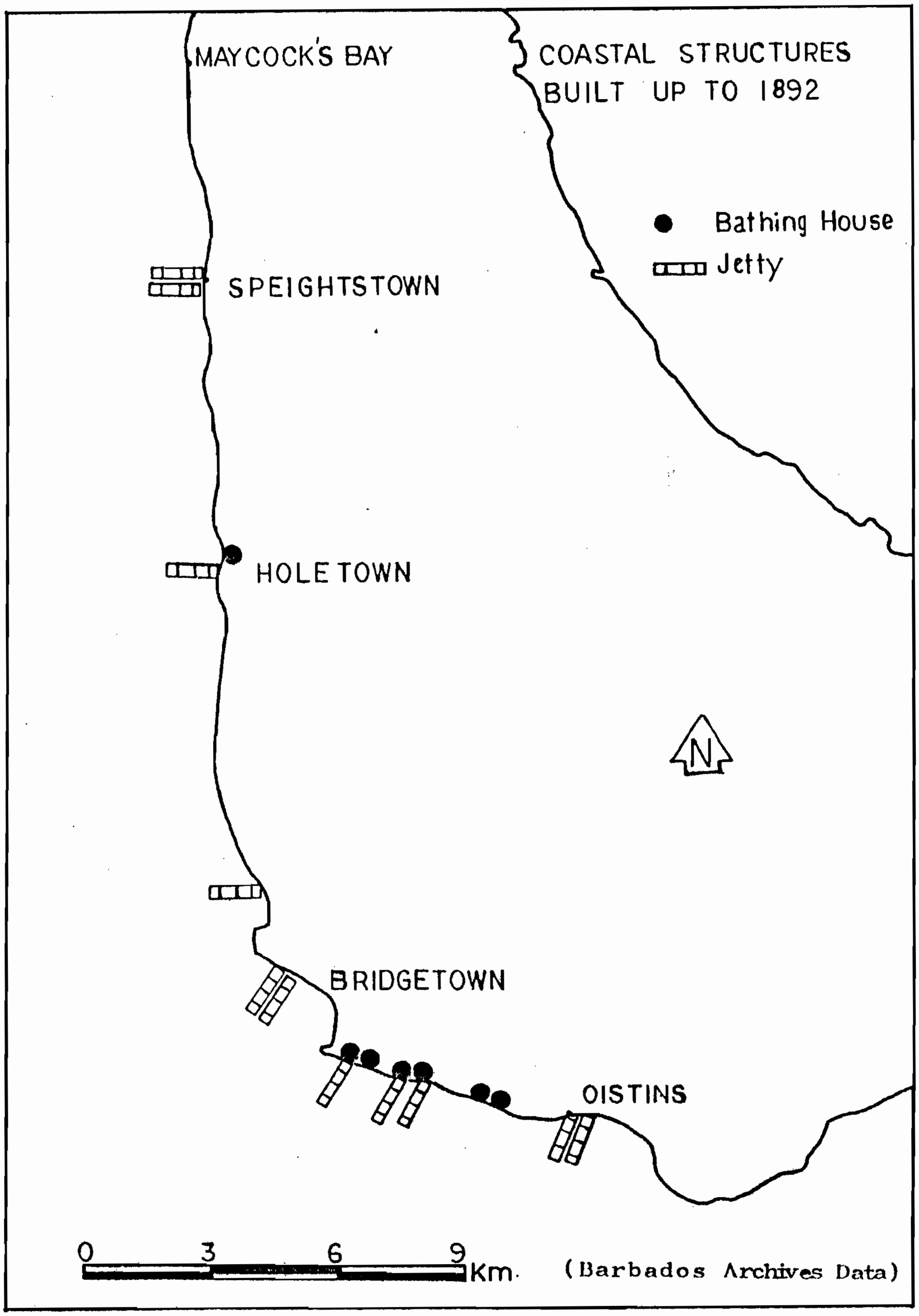
Historical evidence indicates that some severe storms and hurricanes passed over the island between 1667 and 1950 (Figure 9). By all accounts, many of these hurricanes especially those which struck in 1675, 1780, 1795, 1831, and 1898, were very intense. In some cases, waves in excess of 10.0 m were reported (Ligon 1657; Poyer 1808; Schomburgk 1847). There was much damage to vegetation, and in exposed parts of the leeward coast, trees were completely uprooted (Hughes 1750; Schomburgk 1847).

It is known that hurricanes can inflict severe damage to beaches. Experience in the Caribbean and elsewhere suggest that such effects may be permanent (Stoddart 1963; Warnke 1967; Tanner 1970). It has also been shown that catastrophic events of this nature, can cause more erosion than 'normal' wave energy operating over many decades (Brown 1939; Warnke et al. 1966). It is therefore probable that these events modified the beaches quite considerably.

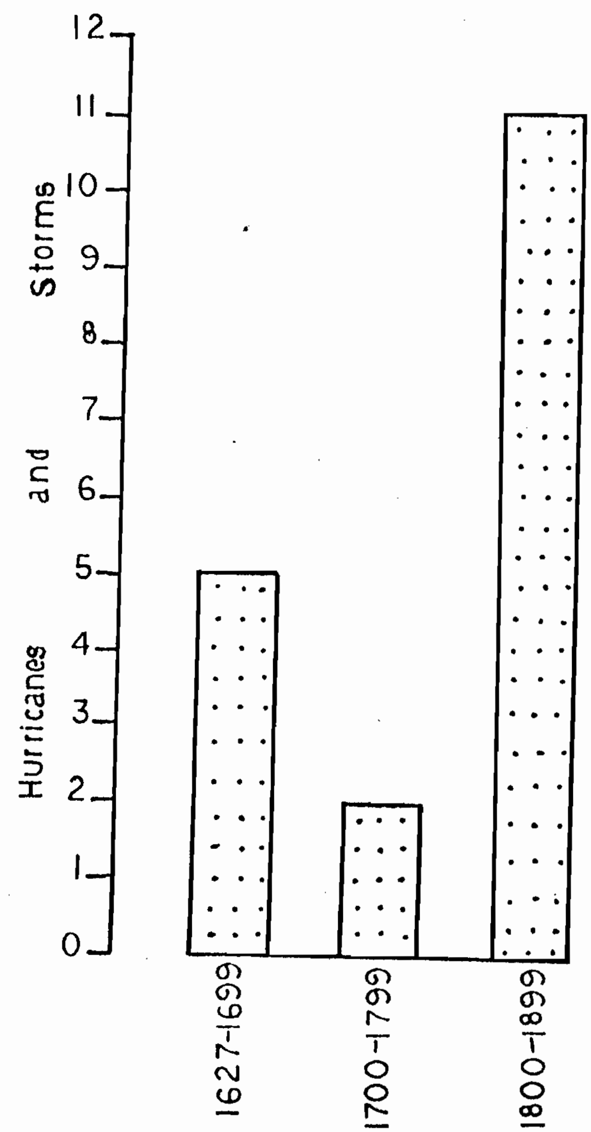
THE BEACH ZONE

Unfortunately it is impossible to record the precise pattern of beach morphological changes in either a temporal or spatial context. The kind of data base required to do this does not exist. The only data available are sketchy and qualitative. Nevertheless, the information is invaluable since it indicates noticeable differences

Figure 8


MAYCOCK'S BAY
COASTAL STRUCTURES
BUILT UP TO 1892
Bathing House
Jetty
SPEIGHTSTOWN
HOLETOWN
N
BRIDGETOWN
OISTINS
0
3
6
9
Km.
(Barbados Archives Data)

HURRICANES AND SEVERE STORMS, 1627–1899



Data Sources: Schomburgk (1848), Poyer (1808), Skeete (1963).

Figure 9

between conditions then and those of the present.

South Coast

A sketch map dated 1820 and held by the Barbados Museum, depicts a section of the Worthing coast with a beach about 20.0 m wide. There is no information before this date which one may use to trace the history of this beach. However, around 1850 the Worthing coast was being encroached upon by the sea (Davy 1854). Today, the section of the beach shown in the sketch does not exceed 10.0 m at its widest point. Another diagram also in the Museum, shows a moderately wide beach south-east of Needham's Point, near the Military Hospital, in 1831. This beach suffered considerable erosion and by 1895 had been reduced to a narrow tract of sand (Hardy 1934. Op. cit.). At present it is a mere 2.0 m wide.

During the middle and late 1800's Oistin too was experiencing recession. An old fort was destroyed by the encroaching sea, and the cannon were reported to be constantly under water (Davy 1854:39) It is not certain how much erosion this would have represented in quantitative terms, but since coastal forts were set back from the water (Schomburgk op. cit.) it certainly indicates that Oistin was an actively retrograding coast at the time.

Around 1887 a beach of "considerable width" existed at Hastings but became "inconspicuous" by 1900 (Hardy 1917:16). Although the width of the beach was not explicity stated, some idea of the extent to which the shoreline was receding is given in the following observation:

> "The sea now washes up to the cliff which once backed this beach at a distance of some 20 yards from high water mark" (Hardy, op. cit.:16).

Further to the east another wide beach completely disappeared between the 1890's and the early 1900's (Ibid), for it seems that the entire Hastings coast was retrograding towards the end of the 19th century.

Carlisle Bay

A map[1] of Bridgetown now in the Barbados Archives, shows an extensive sand beach between the wharf and Molehead during the 1860's (Figure 10). The beach was approximately 457 m long and 12.0 m wide. Today the beach has almost disappeared. A patch of sand now only becomes visible at low tide, and even then does not exceed 2.0 m in width.

The Bridgetown Reef Area (now Carlisle Bay) was also showing signs of recession at this time. A map affixed to a letter to the Colonial Secretary, showed that the mean high water mark shifted by some 90 feet (27m) between 1869 and 1876. The letter expressed concern about the fate of the warehouse and fort if the sea continued to encroach (Figure 11). It is difficult to explain this rapid rate of recession; but it might be recalled that Barbados was

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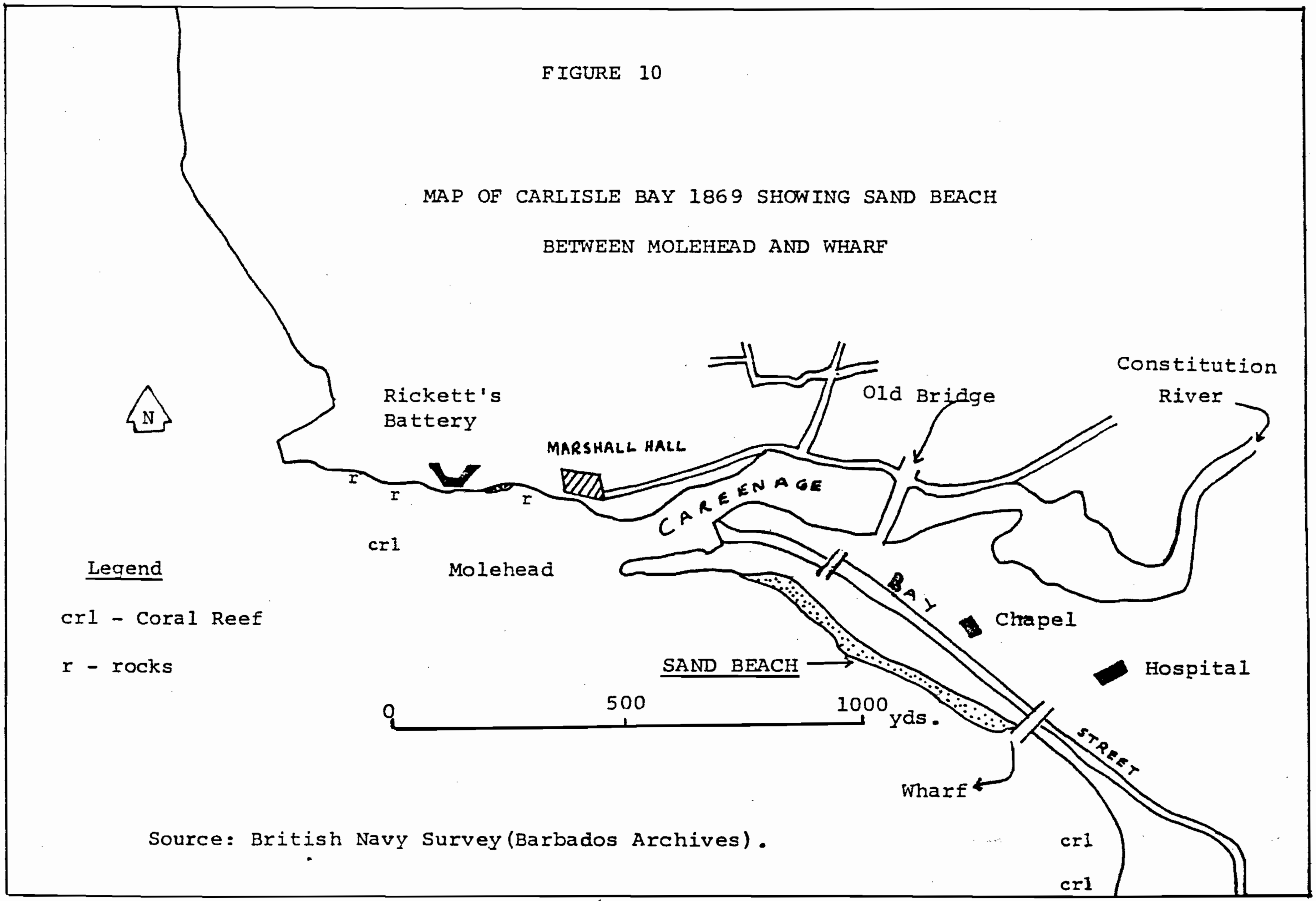
1. Barbados Archives Repository.

FIGURE 10

MAP OF CARLISLE BAY 1869 SHOWING SAND BEACH

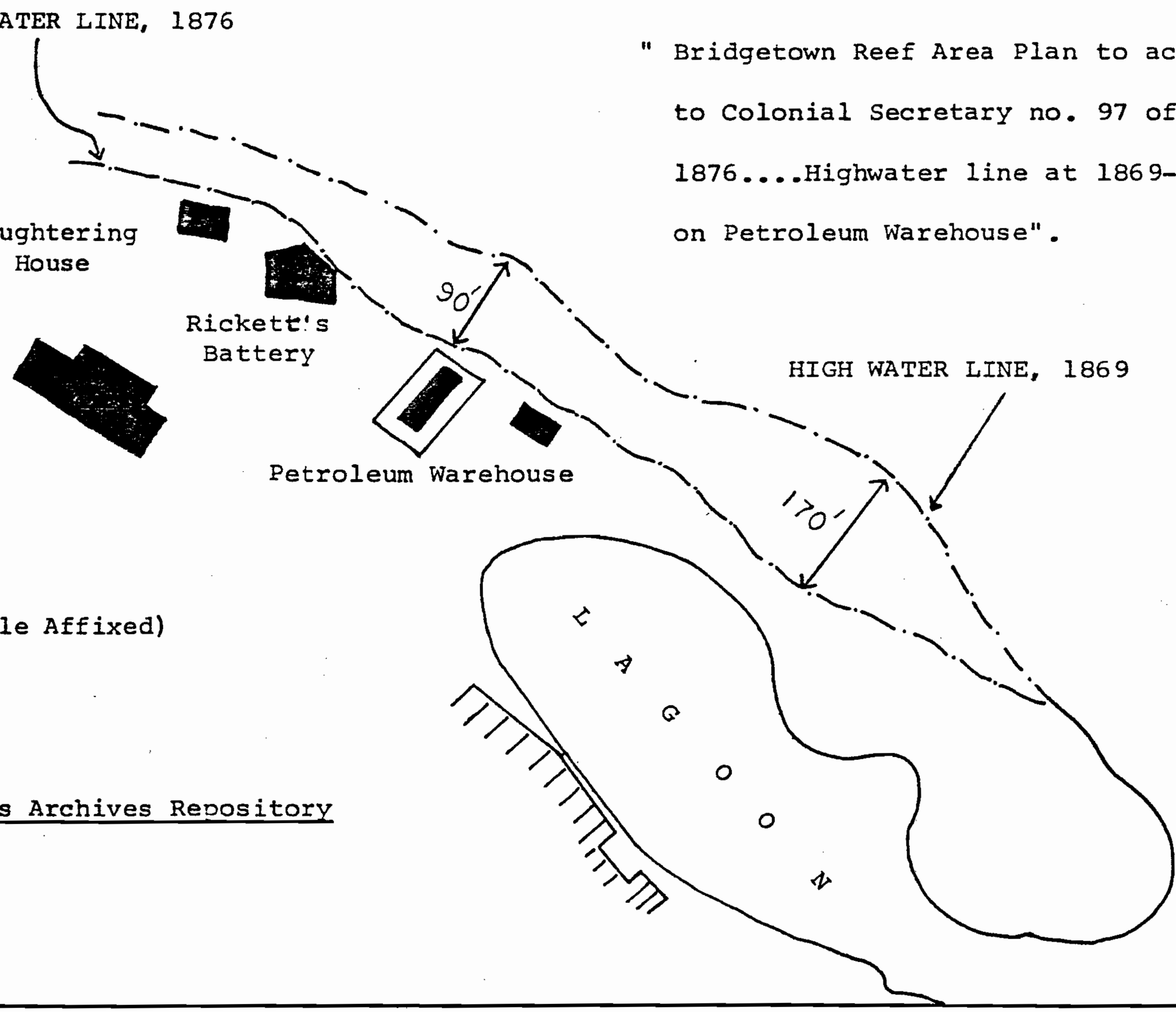
BETWEEN MOLEHEAD AND WHARF



Source: British Navy Survey(Barbados Archives).

FIGURE 11

" Bridgetown Reef Area Plan to accompany letter to Colonial Secretary no. 97 of 16 October 1876....Highwater line at 1869-1876 advancing on Petroleum Warehouse".



(No Scale Affixed)

Barbados Archives Repository

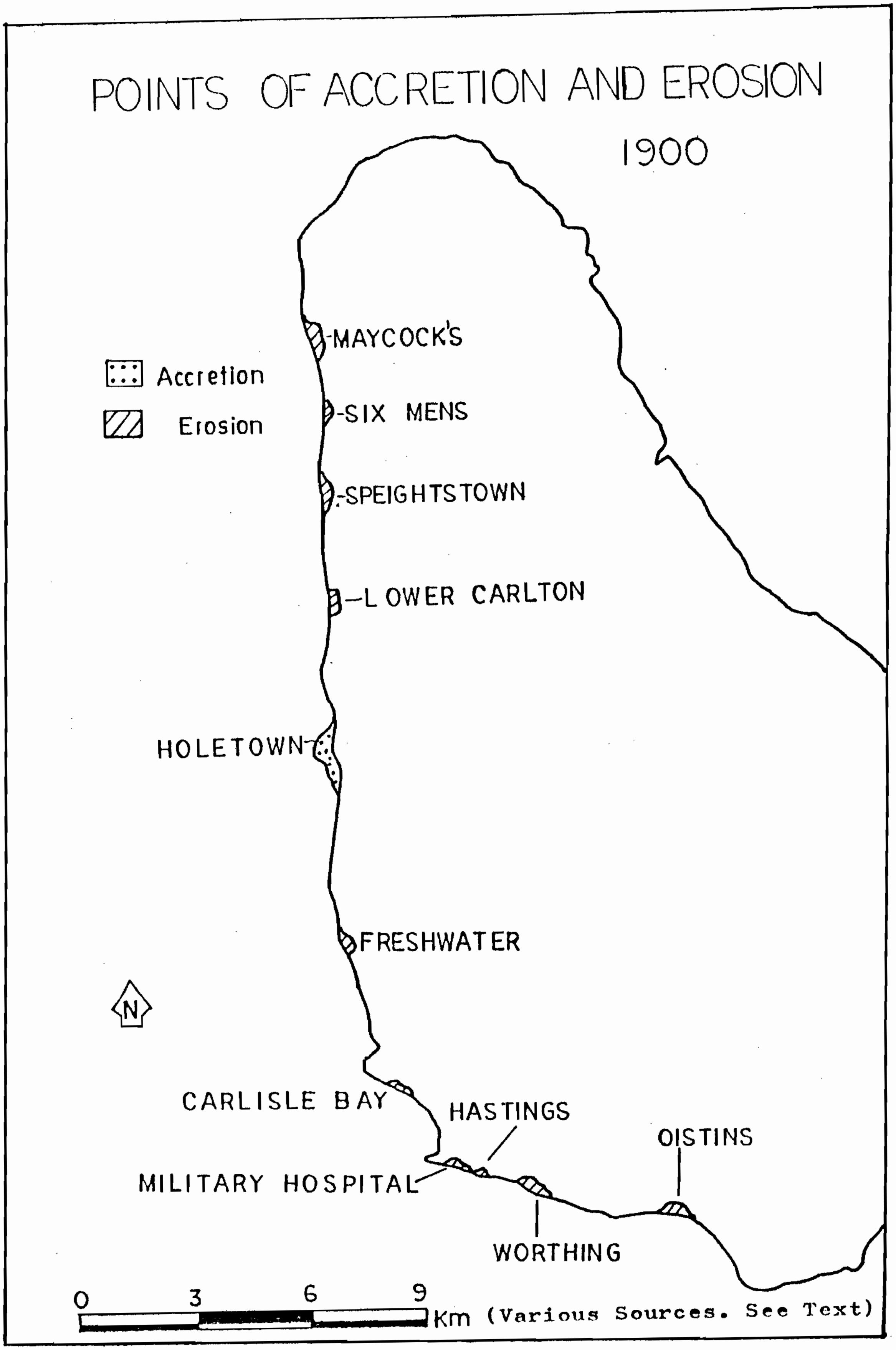

POINTS OF ACCRETION AND EROSION
1900
Accretion
Erosion
MAYCOCK'S
SIX MENS
SPEIGHTSTOWN
LOWER CARLTON
HOLETOWN
FRESHWATER
N
CARLISLE BAY
HASTINGS
MILITARY HOSPITAL
OISTINS
WORTHING
0
3
6
9
Km (Various Sources. See Text)

Figure 12

struck by 5 major hurricanes between 1860 and 1875 (Sinckler 1913). In nearly all cases, the Bridgetown area was the worst affected (Ibid). It is likely that this spate of events, coupled with the impact of the wharves to the east (earlier described), accentuated the rate of scour along this section of the coast.

West Coast

There is much less information about the state of the beaches on the west coast. However, Davy (1854, op. cit.) leaves no doubt that accretion was taking place at Holetown. He referred to 'silting' and 'shoals' which were causing difficulties for small craft loading and discharging supplies; but this did not appear to be the general pattern along this coast. It is reported that fortifications at Maycock's, Speightstown and Freshwater (Valiant Royalist fort) were being threatened by the sea around 1845 (Schomburgk. op. cit.) Later in the 1890's tree roots at Six Men's, Speightstown and Lower Carlton were being undermined, and the highway frequently flooded.[1] This is clear evidence that these locations were experiencing coastal erosion.

Figure 12 shows points of accretion and erosion on the coast around 1900.

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1. This informtion was contained in a report on the state of the highways, sent to the Colonial Secretary in 1896.

CHAPTER 4

THE COASTLINE: 1900 - 1950

At the start of the 20th century, the island was experiencing difficult economic times; it had not yet recovered from the crises of the last half of the previous century. There was a cholera outbreak in 1884, productivity on the estates declined, and some began to sell out or subdivide into peasant lots (Starkey 1939 :210). Between 1888 and 1896, 159 estates were either sold or went out of production (Colonial Reports :Barbados, 1920-21:6). In addition, there was a period of instability between 1884 and 1891, caused by irregular weather and a sharp drop in sugar prices (Starkey, op. cit.). Drought and fungoid disease destroyed the cane crops, and by 1900 there was little sign of recovery.

New solutions had to be sought to revive the economy. Intensive agriculture was practised, crop rotation was introduced and new breeds of cane were imported (Starkey, op. cit., 1939). Eventually the economy recovered, and by the end of the 1930's, sugar was cultivated almost to the exclusion of other crops.

LAND - USE CHANGE : RELOCATION OF PLANTATIONS AND INTRODUCTION OF TOURISM

A noticeable trend accompanied these changes. The leeward coast plantations were gradually being abandoned in preference to better soils of the interior, mainly in the St. George Valley, St. John and St. Thomas. By the early 1900's, only a few plantations of any significance survived on the leeward coast. The land had been overworked, and production costs on the sandy coastal soils were much higher than in the fertile interior (Report to the West Indian Royal Commission, 1897:198).

The pattern of land use changed considerably. The plantations which had lined the coast soon after settlement, vanished (See Figure 1). Smaller plots were now being cultivated to support the population that settled in villages, near the main highway. The main centres at Holetown, Speightstown, Oistin and Bridgetown continued to expand in size and range of functions. They were linked by a well developed artery, stretching from Oistin to Speightstown, via Bridgetown and Holetown.

Soon after the abandonment of the coastal plantation lands, members of the planter and merchant class built residences near the sea. Essentially these were private cottages, but were used to accommodate a small number of visitors, who came annually to the island. The steady trickle of visitors increased to such an extent, that by 1910 there was a small tourist industry. This was especially important in the winter months, as a destination for visitors from Britain (Colonial Reports, 1910-11:20).

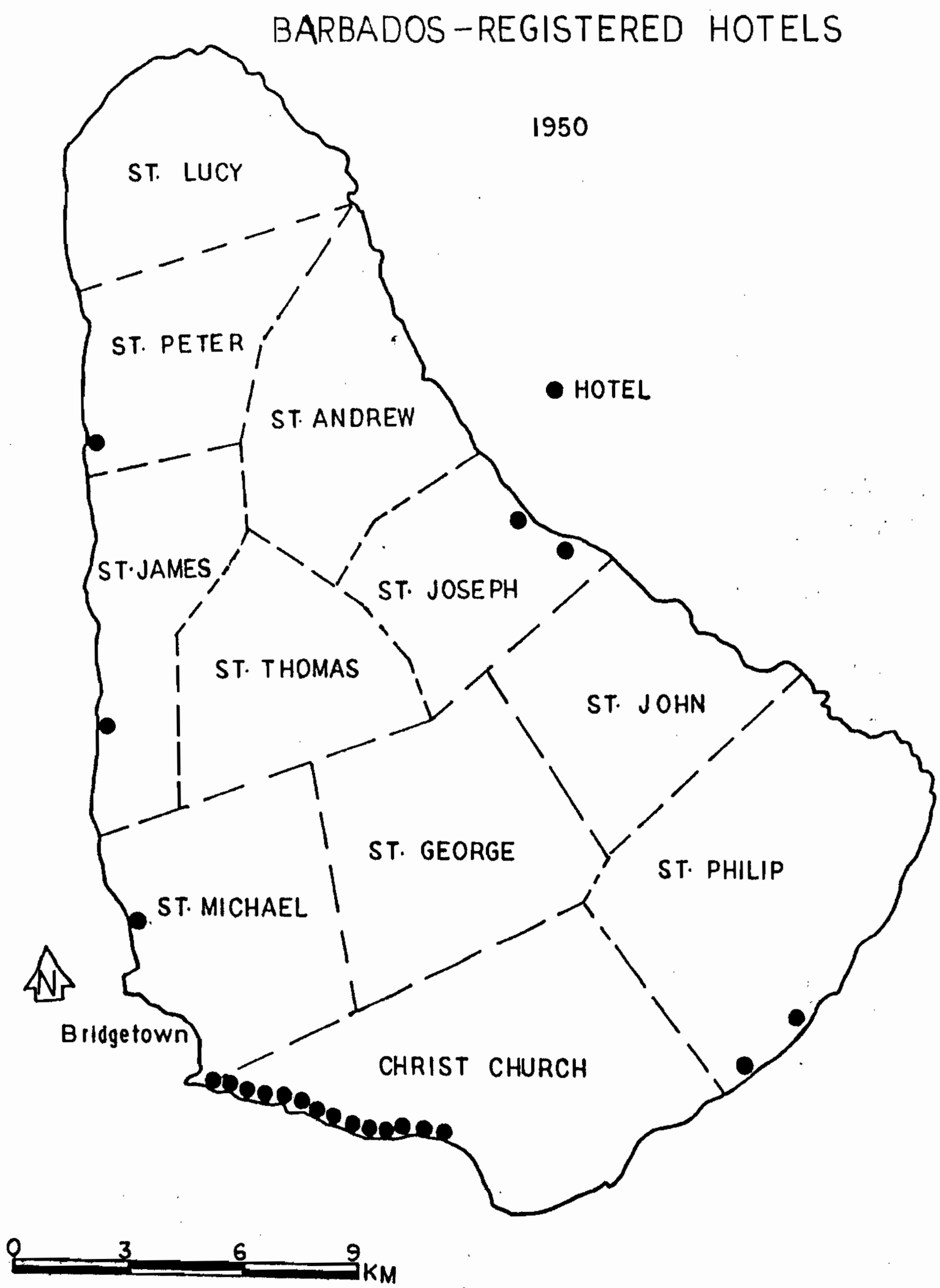
At first the emphasis was on the south coast. The reasons for this are not entirely clear, but there are two factors which certainly contributed. First, there was a high incidence of malaria which affected the west coast most, up until the 1920's. Secondly, the west coast was low-lying and was therefore prone to marine and fluvial flooding (Savage 1937). As recently as 1937, not a single hotel was located on this coast. The main hotels and guest houses were located on the Hastings, Worthing and St. Lawrence coasts. Even up to the end of 1950, tourist accommodation was still largely confined to the south coast (Figure 13).

THE STATUS OF COASTAL VEGETATION

Declining profitability of leeward coast plantations meant a de-emphasis on further expansion of the coast in this zone. In many cases the land was practically ignored. Thereafter, the vegetation started to regenerate, and parts of the coast previously cleared became forested. Thick strands of *Hippomane* and *Tabebuia* lined the coast (Sinckler 1913:2; Hunte 1974:116). *Coccoloba* flourished along the northwest, lower west and southwest coasts (Hardy 1934; Hunte Op. cit.). Around 1935, there was dense coastal forest at Freshwater Bay (Hunte, Op. cit.). The situation described here certaintly creates a picture far different from what had earlier existed. The dense primeval vegetation which Colt (1631) described, had been cleared within the first three decades of settlement (Ligon, 1657; Hughes 1750; Schomburgk 1847).

It is significant that this apparent regeneration of flora occurred at a time when the littoral was not heavily exploited by man. As the coast was now subjected to far less human pressure, the conditions favouring regeneration

Figure 13



(Data from Barbados Museum Records)

at many sites appeared to improve. Hence, there is reason to believe that there was a causal link between this vegetation response, and a reduced human presence.

Examination of the botanical literature for the period, reveals that only 3 new shrubs were reported along the coast. These were Phyllanthus epiphyllantus (herringbone), Calotropis procera (French cotton) and Euphorbia mesembryanthenifolia (Seaside spurge). These colonised the compact, coarser sands behind the beach, where salinity was reduced (Beard 1949; Hardy 1934). They are hardy species, capable of surviving long periods of drought (Ibid).

Similarly, not many additional grasses appeared on the coast between 1900 and 1950. Only Wadelia trilobata, Egletes prostrata[1] and Sesuvium portulacastrum (Seaside samphire) are known to have colonised the littoral during this period. They were sufficiently tolerant of the saline, sandy conditions to become well established. The first two grew as prostrate herbs, sometimes putting out roots from their tiny branches. They therefore became useful in the stabilization of mobile sand, as was the case on the dunes of the south coast (Gooding 1974:144, 197). Sesuvium is a halophyte which thrives well in rocky coastal areas, though it may also be found less frequently on the beach sand.

One of the most noticeable vegetation changes was the

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1. No common name

near disappearance of mangroves. It was earlier shown that these communities had dwindled ever since settlement. However, during the 1930's and up until the early 1940's, remnants could still be found at the Constitution River estuary, Porters, Holetown, Brandon and Needham's Point (Gooding et al., 1965). These survived in spite of the systematic clearance carried out during the previous period. By 1950 the swamps at Porters, Brandon and Needham's Point were completely drained and the trees eliminated. The Constitution River estuary was canalised and Rhizopora mangle removed from the river's banks. The only surviving trees are presently to be found at Graeme Hall and Holetown. Field research during the summer of 1982, revealed that only a few dozen individuals are present at the latter two locations.

It is likely that the deliberate elimination of these swamps came as a result of yellow fever and malaria outbreaks during the early 20th century (Starkey 1939:210; Fonaroff, 1966). Both epidemics are spread by mosquitoes and swamps are breeding grounds for these insects. Consequently there may have been a deliberate policy to eliminate swampy environments in general.

Beginning in 1940, there was an effort by the Colonial Government to replant the island's coasts. The programme was carried out on Crown as well as privately-owned land. The Casuarina, Coconut and Mahogany were the main species planted. In the year 1941 alone, 119 Mahogany, 254

Coconuts and 1343 Casuarina trees were planted at Needham's Point and Gravesend (Annual Report, Dept. of Agriculture 1941-42:6). The programme was continued in subsequent years, and between 1942 and 1944, 10,712 additional trees were planted at Needham's Point, Gravesend and Rockley. Smaller quantities were planted on the west coast at Holetown, Speightstown and Heywoods. The scheme was significant not for its extensiveness, but because it was a response to threats of erosion. An 'encroaching sea' was causing flooding on the sand terrace, and in severe cases, the main coastal highway[1]. In a sense, it acknowledged the importance of vegetation as an element in coastal conservation. Initiation of the scheme also suggests that the Government perceived the threat of erosion to be serious at the time.

Oddly enough, a Government-sponsored programme of land clearance occurred in phase with the afforestation scheme. The felling was species-selective, as its stated objective was the elimination of the manchineel from the island's shores. During a single year 1941-42, "300 manchineel trees of various sizes were felled and sold for firewood (Anunal Report, Dept. of Agriculture 1941-42:6). The programme continued until 1948, by which time it is estimated that well over 2,000 trees were removed.

The manchineel was cleared because its sap and berries are poisonous, and was thus considered a 'nuisance species.

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1. Report to the Colonial Office from the Director of Agriculture, 1944.

It is a member of the original coastal flora and over the centuries played a crucial role in anchoring coastal sands (Gooding 1974). Its indiscriminate removal is likely to have had disastrous consequences for the stability of the beaches. The full implication of the removal of this and other species will be examined in Chapter 5.

BEACH EROSION AND ACCRETION

South Coast

The section of the coast stretching from Oistin to Welches was experiencing what appears to be severe erosion up to 1950. The area is described as one in which "sea encroachment" was making "considerable inroads" on the beaches (Barton 1958:8). This fact is confirmed by a local naturalist who recalls that the highway was often flooded at high tide during the late 1940's and early 1950's.[1]

There is also evidence that the coast from Dover to Rockley, was prograding noticeably. The width of Maxwell beach, for example,

> "...measured from the high water mark, to the zone of artificially planted trees, bordering its landward side, was about 150 yards" (Hardy, 1934:36).

Further it was described as "comparatively newly formed," since it did not exist up to the early 1920's (Ibid). Gooding (1977) substantiates this claim and points out that accretion was occurring along the entire coast, as far as Rockley. The Dover-St. Lawrence-Worthing coast changed

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1. Personal communication with Mr. Edward Stoute, July 1982.

from practically no beach at the start of the century to a wide beach with sand dunes in the 1930's (Gooding 1977:181). The mean width of beaches along this coast was about 11.0 m. The trend apparently continued into the 1950's, by which time Rockley beach had also advanced by a few metres (Ibid).

Similarly, from about 1930 the Hastings coast accreted as the sea was constantly

> "...depositing stones and sand on the beach, causing it to be enlarged and extended" (Hardy, op. cit.:16).

In particular the beach at Gravesend was said to be advancing rapidly, and was approximately the same width as that behind Pavillion Court (8-10 yds: Hardy, op. cit.). This accretion phase lasted for about another three decades into the 1960's, as is indicated by aerial photographs for 1950 and 1964.

<u>Leeward (West) Coast</u>

It appears that beaches at the northern end of this coast continued to recede. Savage (1937) reported that the foundations of Harrison, Maycock and Denmark Forts were heavily undermined by the sea. In addition the road between Speightstown and Six Men's was often flooded by seawater. He estimated that the sea had encroached the land by almost 10 ft (3.0 m) since the early 1900's. Further south, Heron Bay beach was also retreating. Erosion was first noticed here around 1925 when properties in the bay became threatened (Tree 1972). By 1950 the wall fronting one of the properties was so heavily undermined, that it was on the verge of collapsing.

The shoaling which started at Holetown prior to 1900[1], was still evident. A beach about 15.0 m wide had formed by 1945 in the vicinity of the river estuary. The beach continued to build up to such an extent that the river mouth became permanently blocked by sand. It is believed that accretion was occurring along this entire stretch of coast, as far as Sandy Lane. The presence of small sand bars across the estuary there (though less permanent than at Holetown), support this belief.

The beaches at the extreme south of the west coast appeared to be receding around 1950. The beaches at Land's End and Indian River 'narrowed considerably' since the 1890's (Barton 1953). Hence there was no effective buffer between the sea and the road on that section of the coast. In fact, that part of the coastal road was completely washed away by 1950 (Barton, op. cit.:8).

There is reason to believe that beaches at Brighton were beginning to build up towards the middle of this century. Sand was reported to be piling up around the jetty near the rum refinery. The jetty facilitated loading of rum and molasses onto lighters, for transport to the Bridgetown harbour. The area became so shallow that in

1. Personal communication with Mr. Edward Stoute, July 1982.

1948 an act of parliament was passed permitting the pier to be extended.[1] Another source recalls a large accumulaton of sand in front of the guest house 'Brighton-on-sea, in the mid 1940's.[2] Based on the owner's recollections, it is estimated that the beach must have widened by at least 2.0 m between 1920 and 1945. The general pattern of beach change is illustrated in Figure 14.

SAND MINING

Archival records reveal that sand mining became widespread on the Barbados coast in the early 1900's. Beach sand was easily accessible and became the main source of fine aggregate used in construction of the dense road network, which developed after 1900. It was also used extensively in public and private construction in the main urban centres, particularly in Bridgetown (Savage 1937; Barton 1953). It should be noted that the extensive use of beach sand during this period only became common after the Beach Protection Act of 1694 was repealed in 1898.[3] In other words there was no legal restriction governing beach sediment removal at this time.

Although available sources do not identify specific areas where sand mining occurred, there is little doubt

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1. Barbados Distilleries (Jetty) Act, 28th October, 1948.

2. Personal communication with the proprietor Mr. James A. Tudor, August 1981.

3. See _A List of Acts Passed in the Island from 1643 to 1762 Inclusive_. Barbados Museum and Historical Society, p.57.

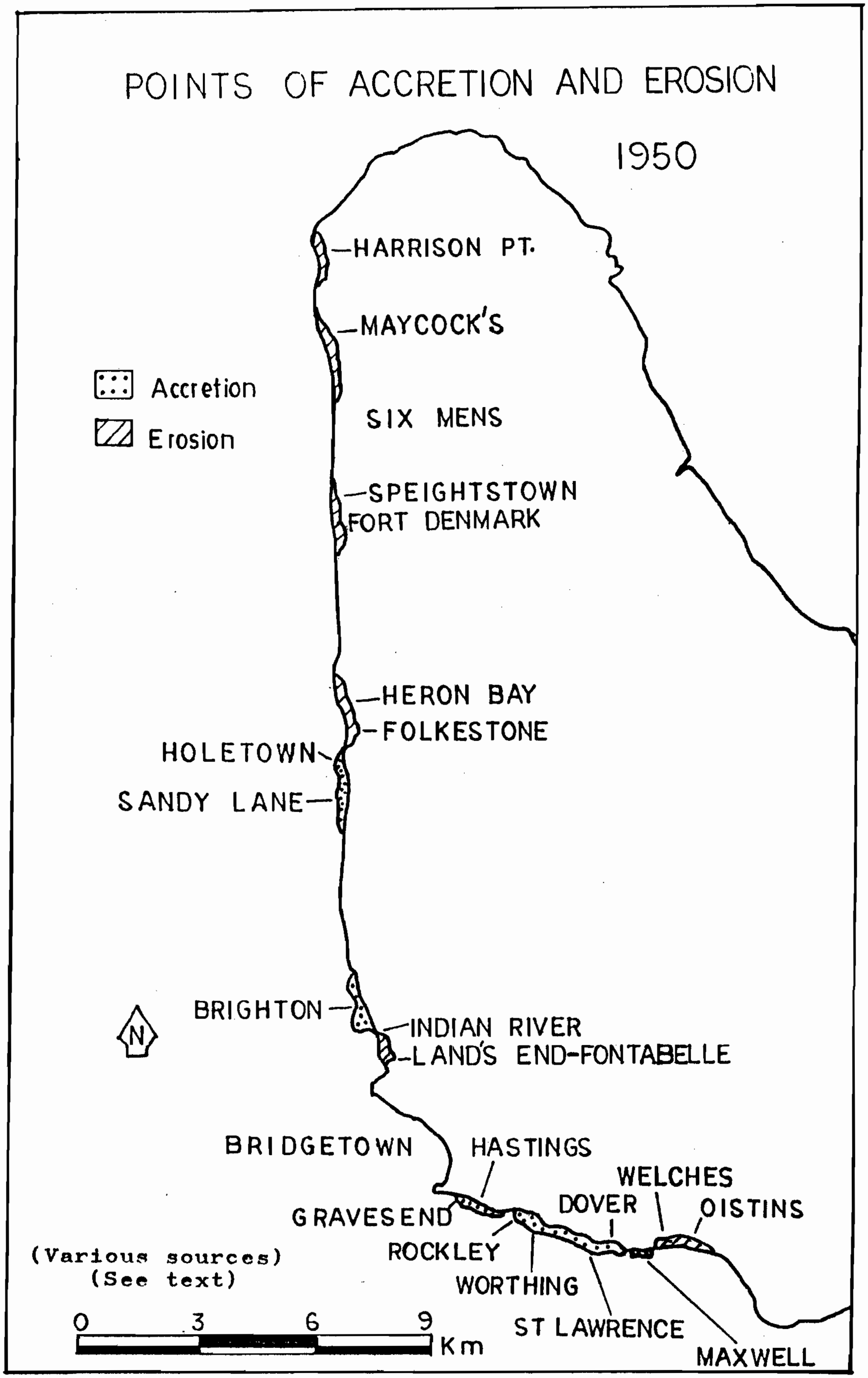
POINTS OF ACCRETION AND EROSION
1950
Accretion
Erosion
HARRISON PT.
MAYCOCK'S
SIX MENS
SPEIGHTSTOWN
FORT DENMARK
HERON BAY
FOLKESTONE
HOLETOWN
SANDY LANE
BRIGHTON
INDIAN RIVER
LAND'S END-FONTABELLE
N
BRIDGETOWN
HASTINGS
WELCHES
DOVER
OISTINS
GRAVESEND
ROCKLEY
WORTHING
ST LAWRENCE
MAXWELL
(Various sources)
(See text)
0 3 6 9 Km

Figure 14

that this activity was concentrated on the west and south coast beaches. Even up to the late 1920's accessibility to the windward side of the island was restricted, and the east coast was largely undeveloped. In addition, most of the projects for which this sediment was required were located in the developing sections of the island, stretching from Oistin to Speightstown (Sinckler 1913; Savage op. cit.). It is therefore unlikely that sand would have been brought from the windward coast, when there were readily available sources in close proximity.

Concerns about the exploitation of beach sand were raised in the local legislature during the 1940's and stricter control was recommended.[1] However there is no record of additional measures being approved to halt the practice until 1958, when the present beach protection regulations were instituted. One can only speculate on the impact which sand mining would have had on the Barbados coast during this period. However, it is known that the buffering effect of the beach rapidly diminishes unless the sediment is being adequately replaced from another source, such as onshore transport by waves (Ketchum, 1972; Komar, 1976). In such cases, depending on the amount of sand mined, the littoral sediment budget will show a negative balance, which manifests itself as scour in the given beach cell.

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1. House of Assembly Debates, for the 1941-42 session of Parliament.

STRUCTURES IN THE NEARSHORE ZONE

The construction of jetties and bathing houses which had begun during the late 19th century, continued. During the period 1919 to 1948, the legislature granted permission for the erection of 8 additional bathing houses and 7 jetties[1]. As in the earlier period, few were located on the west coast (Figure 15).

The period after 1900 is the first time since settlement, that any reference to the erection of groynes can be found. The first such reference was contained in a legislative order of 1919, permitting such construction at Maxwell beach. The solid concrete groyne was intended to protect the existing beach near Maxwell Inn. The groyne was 200 ft. long ($\approx$ 61 m) and extended in a south-westerly direction out to sea. Four more groynes of roughly similar dimensions were later built on the south coast : one each at Rockley (1923) and St. Lawrence (1940) and two at Hastings (Oceanview and Palm Beach Hotels 1930 and 1932 respectively)[2]. See Figure 14.

It is evident that all these groynes were built illegally. In each case the acts legalising their existence were made retroactive to the actual dates of construction. In order to discourage the widespread

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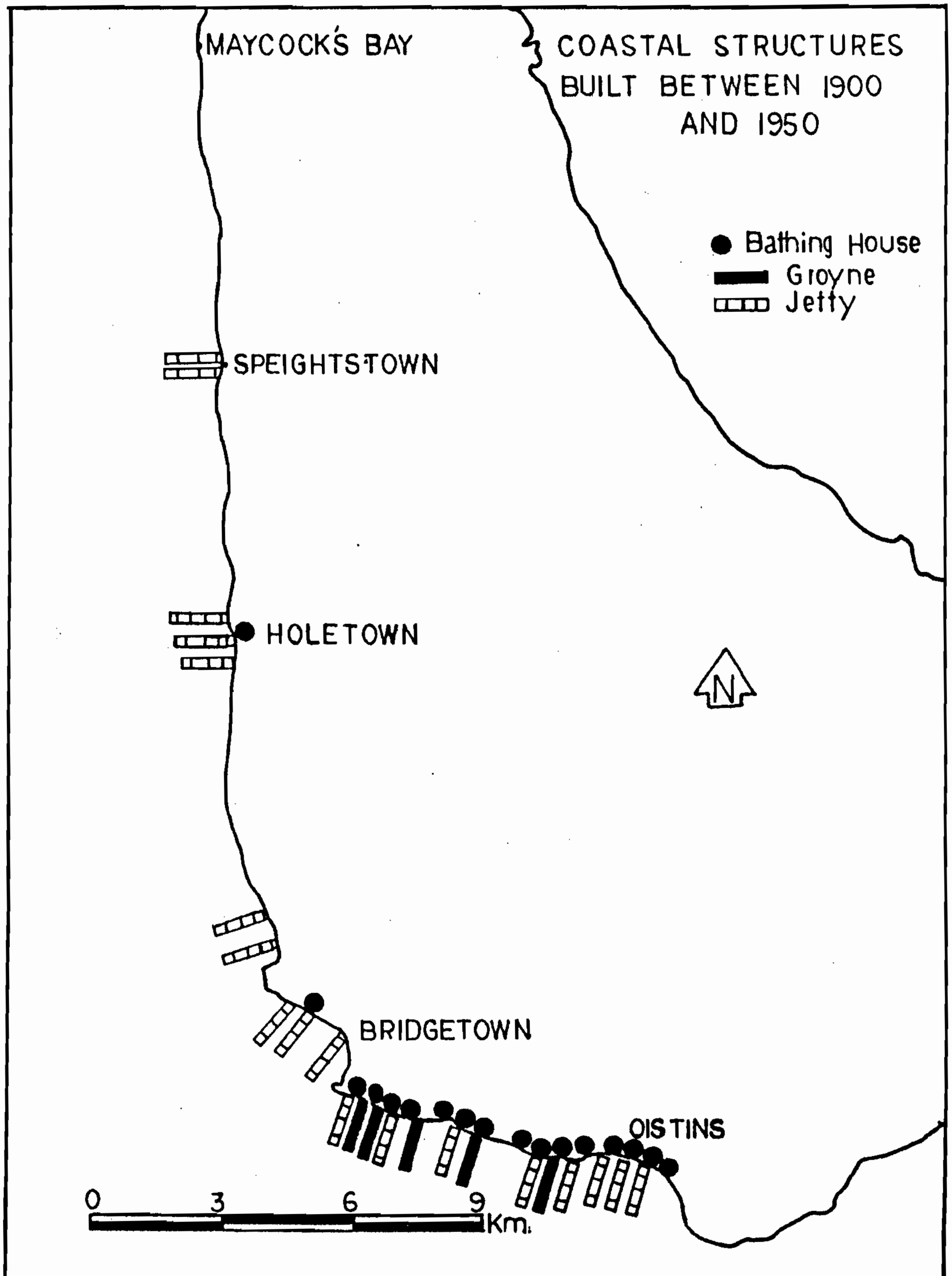
1. Various sections of Laws of Barbados, vol.3, parts 1 & 2 1956. Sweet & Maxwell, London.

2. Laws of Barbados, vol.3, part 3, 1956. Sweet & Maxwell, London.

Figure 15



(Barbados Archives Data)

erection of such structures, the Legislature made it clear in 1944 that permission was required before construction. Given these considerations, it is probable that many other such structures may have been present on the coast around this time.

Significantly, the points of accretion on the south coast around 1950 (Refer to Figure 14) closely approximate the location of the groynes. Although the beaches may have been building up prior to the groynes, it is likely that their presence accelerated the process. Given that net littoral drift is from south-east to north-west (Deane et al. 1973), this pattern of sediment accumulation would be a likely result.

From the middle of this century there was a renewned economic interest in the coastal zone. Land use became predominantly residential and recreation on the west and south coasts were further altered to accommodate this new emphasis. The decades following 1950 represent a period of intensive development, characterized by increasing human pressure on the littoral. An examination of the nature of these pressures, as well as the changes which took place post - 1950, will be undertaken in the ensuing chapter.

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1. See the Hansard Report for June 1944.

CHAPTER 5

COASTAL CHANGES 1950 - PRESENT

THE GROWTH OF TOURISM

After 1950 the character of the island's west and south coasts was rapidly transformed. The coastal landscape changed from one in which there were a few hotels and residences, separated by numerous wide open spaces, to a virtually continuous ribbon of development. Although there is some evidence of this trend prior to 1950, the period of most intense development was between 1960 and 1980. The lack of governmental planning and of a general conservation ethic, are partly responsible for the negative environmental effects which this development caused. The problem has been placed in clear perspective by Tree (1972).

> "With the extension of the runway and the advent of jets in 1962, the pace of tourism accelerated...creating a boom in hotel and apartment building. Sadly, the government, through its Town Planning Agency, was not sufficiently geared to deal with such an emergency. Unplanned horrors have been allowed to spoil great hunks of what was once lovely countryside, while the south coast has been given over to one ugly development after another" (Tree, Op. cit.:7)

Before examining the spatial structure of this land use change, it is necessary to give the background against which the whole process occurred. It must be made clear that the Island Government was the chief architect of this rapidly expanding tourism sector. Faced with a high population and massive unemployment during the 1950's, the government became convinced that tourism was the panacea for these problems. In 1956, the Hotel Aids Act was passed (Laws of Barbados vol 3; p.3. 1956: 986). A number of incentives were given to entrepreneurs, including income tax rebates and licences to import materials and equipment free of duty. Further concessions were granted in 1967, when the act was revised and amended. Under the new provisions, some hotels became eligible for 10-year tax exemptions, while others obtained government financing at interest rates as low as 5%. The response to these concessions is indicated by the fact that a total of 102 hotels applied for aid between 1959 and 1970 (Table 4 (a)). In addition, 205 applications to build hotels[1] were submitted to the Town Planning Office during the same period (Table 4 (b)). In each case, more than 92% of these applications were successful.

Table 4(a)

Applicants Receiving Aid (1959-70) Under Hotel Aids Act

Yr	No of Applicants	No. Receiving Aid
1959	6	6
1960	6	6
1961	8	8
1962	3	3
1963	5	5
1964	8	8
1965	6	6
1966	10	9
1967	7	7
1968	11	10
1969	20	18
1970	12	12

Source : Ministry of Tourism, Barbados.

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1. Includes guest houses and condominiums.

Table 4 (b)

Applicants Seeking Permission To Build Hotels, 1950-70

Yr.	No. of Applicants	No. Granted Permission
1959	4	4
1960	6	6
1961	7	7
1962	11	10
1963	15	13
1964	8	8
1965	8	8
1966	10	10
1967	30	27
1968	61	54
1969	20	20
1970	25	23

Source : Town and Country Planning Office, Barbados.

The number of recognised tourist units rose from 17 in 1950 to 820 in 1980. Since the coastal fringe[1] (as defined below and excluding Bridgetown) contains some 65 sq. km, this represents a density of 12.6 units per sq. km of land. An even better perspective on density is achieved if one excludes the section of the west coast north of Heywoods, where there is little resort development. This accounts for roughly 11 sq. km of land; hence a figure of 15 establishments per sq. km would provide a more accurate picture of density.

The extent to which tourism dominated coastal land use can be further gauged from the land occupancy table below. The amount of land occupied by tourist/recreation facilities, increased from approximately 46.5 ha in 1950 to about 607 ha in 1982. During the decade 1960-70 alone,

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1. The coastal fringe is here defined as all land extending from the beach zone inland for approximately 0.5 km.

over 470 ha of land were brought into this sector. At the present time, tourist and ancillary services occupy nearly 50% of all land along the western and southern coastal fringe.

Table 5

Estimated Amount of Land Occupied by Tourism, 1950-70

Yr.	Land (Ha)	% Increase Over Previous 5 Years	% Available Land
1950	46.5	-	10
1955	64.7	28	13
1960	174.0	63	19
1965	424.9	61	25
1970	647.5	37	37
1975	789.1	18	43
1980	833.6	6	58

Sources : Town and Country Planning Office; Lands and surveys Department ; Aerial photographs.

Spatial Impact of Tourism

It may be recalled that up to 1950 virtually all resort development was concentrated on the island's south coast. This situation changed dramatically during the decades that followed. A combination of factors may be cited as the reason for this change. In the first place, previous fears of malaria and yellow fever were eliminated soon after the end of the Second World War. This was partly accomplished by the filling in of the last remnants of swamps.[1] Secondly, as the need for prime beach-front lots increased Government invested heavily in infrastructural improvements on the west coast, such as road construction and utilities. In addition, a number of

1. Unfortunately some of these swamps contained various species of mangroves, which were also eliminated.

wells were sunk and roadside ditches constructed to ease the problem of flooding after heavy rains. Finally, land costs on the south coast were higher than elsewhere, as a result of the early concentration of resort development there. Table 6 gives estimated land costs for selected west and south coast locations (ca. 1960).

Table 6

Comparative Land Cost Estimates, South and West Coast Locations, 1960

South Coast	$Bds./sq.ft.	West Coast	$Bds./sq.ft
Oistin	0.75-1.00	Prospect	0.25-0.50
Maxwell	0.90-1.25	Lower Carlton	0.25-0.50
St. Lawrence	1.00-1.10	Appleby	0.50-0.75
Dover	1.00-1.30	Paynes Bay	0.45-0.80
Worthing	1.00-1.50	Porters	0.50-1.00
Marine Gdns.	1.50-1.75	Mullins	0.50-0.75
Navy Gdns.	1.50-1.75	Holetown	0.50-1.25
Rockley	1.75-2.25	Sandy Lane	1.00-1.50

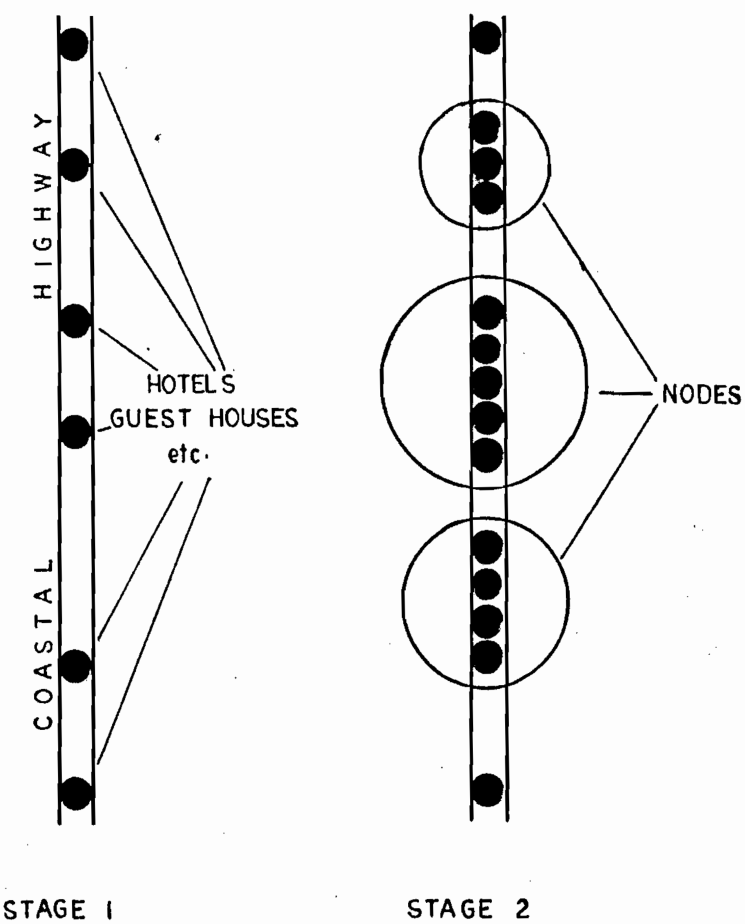
Sources : Various Real Estate Records and Land Valuation Division Estimates.

Process of Development on West Coast

The development of tourism on this coast can better be explained by reference to the diagram presented in figure 16. The process may be traced through two distinct stages. Initially, hotels appeared to be simply randomly sited along the main coastal highway between Freshwater and Godings Bays. This is evident from Ministry of Tourism records which give dates of construction and location of accommodation, since 1965. After the 1960's however, various nodes or concentrations developed and became superimposed on the already established linear pattern. Such points occurred at Paynes Bay, Sandy lane and Holetown

Figure 16

SCHEMATIC DIAGRAM ILLUSTRATING SPREAD OF TOURIST CENTRES ONTO WEST COAST



Explanatory note: In stage 1, tourist accomodations are haphazardly dispersed along the main coastal highway. In stage 2, the ribbon pattern is maintained, but specific sections of the coast become focal points or nodes on account of certain locational advantages. (See text).

- Sunset Crest. Presently, 77% of all west coast accommodations are located in these areas. When the data are broken down by category of accommodation (Table 7), each accounts for at least 10% (and as much as 55%), in each category. The fastest growing centre is Holetown, where no less than 35% of each class of accommodation is located.

Table 7

Registered Tourist Accommodation (Establishments) in Three Selected Areas as a Percentage of Total West Coast Accommodation, by Category

Category	Sandy Lane	Holetown - Sunset Crest	Paynes Bay
Luxury	18	45	18
'A' Class	10	52	15
'B' Class	10	35	20
Apartments	10	55	20
Apart./Hotel	10	50	15
Guest House	15	40	25

Source : Ministry of Tourism Statistics

The reasons for the dominance of these centres has never been documented. Nevertheless an examination of previous land use inventories, as well as information volunteered by hoteliers, suggest three major considerations. First, the beaches here have long been considered among the most scenic and accessible of all west coast locations. Secondly, there was adequate available land on both sides

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1. These inventories were made available by the Town and Country Planning Office and the Lands and Surveys Department.

of the coastal highway for providing service facilities. Thirdly, particularly in the case of the more northerly centres, the 'pull' effect of an already existing town (Holetown) was important. Here basic services were already available.

The first wave of movement toward the west coast started around 1960. In this year alone 10 new hotels were built, compared to 5 on the south coast. By 1970 there were over 100 units on the west coast. It might also be pointed out that of the 17 luxury hotels on the island, 11 are located on the west coast compared with 4 on the south coast.[1,2]

Table 8

Percentage Increase in Land Occupancy by Hotel Sector, West and South Coasts, 1950 -80

Yr.	West Coast(ha)	% Increase
1950	6.0	
1955	16.2	62.5
1960	60.7	73.3
1965	202.3	70.0
1970	343.9	41.2
1975	424.9	19.0
1980	449.2	5.4

Yr.	South Coast (ha)	% Increase
1950	40.5	
1955	48.6	16.7
1960	113.3	57.1
1965	222.6	49.0
1970	303.5	26.6
1975	364.2	16.6
1980	384.4	5.3

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1. The other two are on the Windward south-eastern coast.

2. Although the the linear extent of the west coast is about one-third greater than the south coast, available accessible beach space for construction, is approximately the same.

Growth on this coast is further reflected in the land occupancy data. West coast units occupied only 6.0 ha in 1950, but by 1970 had increased to 344 ha. Table 8 indicates that for every successive 5-year period after 1950, the percentage increase in land occupancy was substantially greater than on the south coast.

BEACH CHANGES

Data Sources and Method of Analysis

Assessment of beach change must include some consideration of accretion and erosion. Variation in beach width over time provides a good index of this change. This information was extracted from aerial photographs for 1950, 1964 and 1973, (1:5,000) and British Ordnance Survey maps, based on the photography and surveyed ground information. In addition, field measurements were taken in the summer of 1981 and 1982 to complement these sources.

The photographs were examined with a mirror stereoscope and clearly identifiable sections of the beach were noted. However, not all such areas were equally identifiable on each separate sequence. Hence, only segments which could be identified on all three sets of photographs were selected. The desired point[1] along the beach was chosen, and the width determined as the distance between the water's edge and the rear of the beach.

Many researchers studying beaches from aerial photographs, often use the vegetation line to measure

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1. This point was located close to the centre of the photograph, as scale distortion is least here.

changes in width. It is argued that where beaches accrete over the long term, vegetation tends to advance; where they recede, so too does vegetation (Davis 1957; Hwang 1980; Campbell and Hwang 1982). Any shift in the vegetation line is therefore seen to be a measure of shoreline advance or retreat. Along the Barbados coast the vegetation has been altered considerably by human action. Over the years large areas have been cleared for construction and other purposes. In many cases, ornamentals have been planted in front of properties. A shifting vegetation line is therefore not automatically indicative of accretion or erosion, on this coast. Thus it was decided that the edge of buildings (reproduced in all sets of photographs), would provide a more satisfactory way of 'fixing' the rear of the beach.

Limitations of Method

There are two major sources of error. The first is associated with differences in beach width, caused by seasonal variation in quantity of sediment present (Richards and Bird, 1970). This would be important to the present study as 1981-82 field measurements were obtained during the summer, while all the aerial photographs were taken during the 'winter'. However, careful examination of ground level photographs[1] indicates that such variation has a greater impact on the height of the berm, than on the

1. These were examined in association with J.B.Bird, who possesses a series of photographs dating from the mid-1960's. These ground level sequences cover many locations over different seasons.

overall beach width. Hence, it can be assumed that errors from this source, are of an insufficient magnitude to invalidate the pattern described below.

The second relates to scale distortion inherent in the photography itself. To estimate the error, the distance between fixed points was measured on the ground, and compared with corresponding distances on the photographs. This discrepancy was small, and did not exceed 0.3 m (1.0 ft.). Therefore for all measurements, the probable maximum error is estimated to be 0.3 m or about 2.0%. All photographs were taken at a time when tides were approximately similar (Table 9). Since the differences in elevation and slope are not great along the coast, scale discrepancies from these sources are assumed to be negligible.

Table 9

Tide Data for Carlisle Bay - Heights Above Datum (metres)

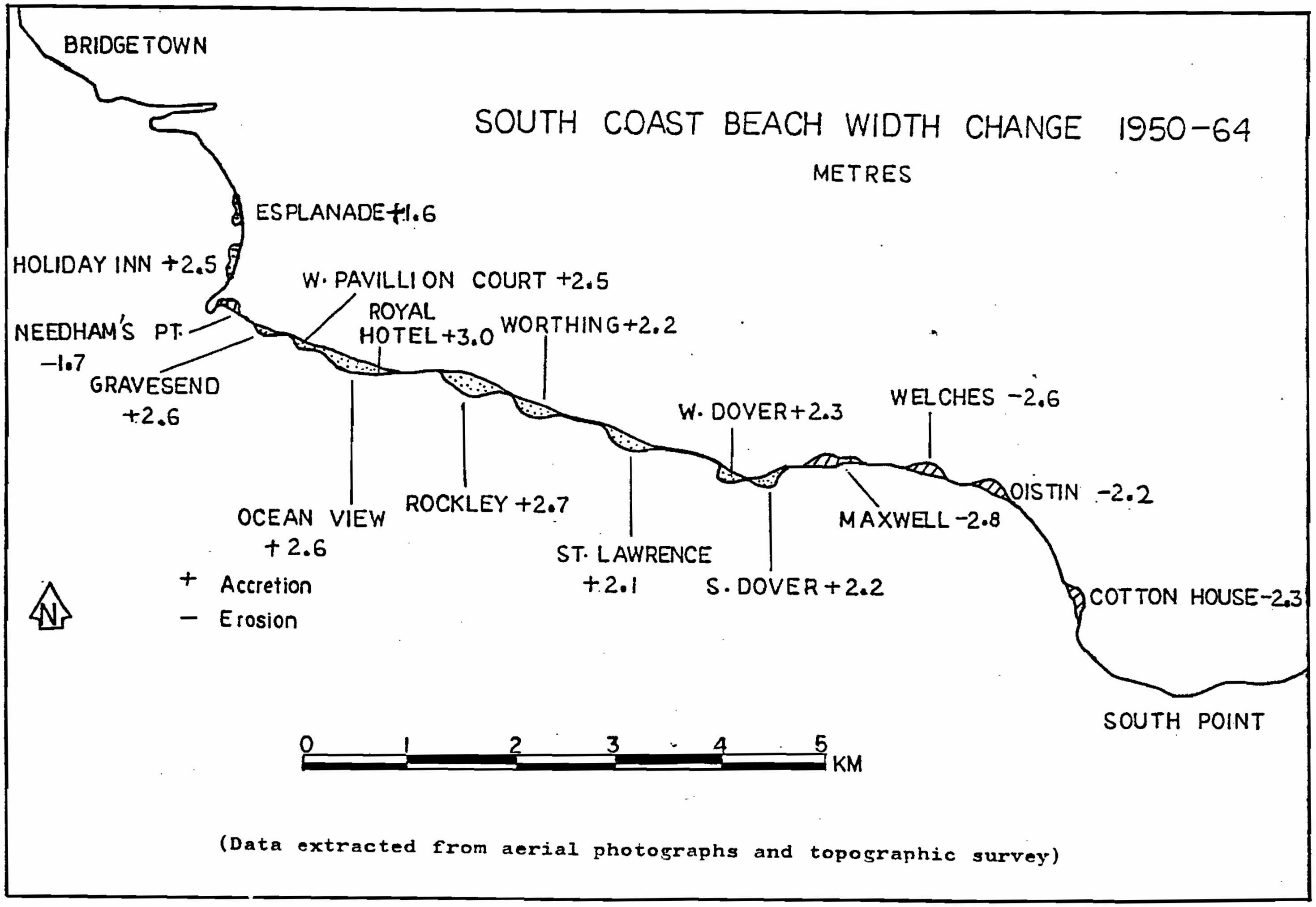
	Dec. 1-8, 1950	Nov. 1-10, 1964	Dec. 1-10, 1973
Minimum	0.63	0.68	0.72
Maximum	0.75	0.77	0.79
Mean	0.69	0.72	0.75

South Coast

1950 - 64

A clear picture of erosion and accretion emerges when the data for this period are examined. The areas adjacent to Oistin Bay suffered noticeable erosion, as is evidenced by the Maxwell and Cotton House coasts which retreated by an average of 2.2 m. Maximum retreat occurred at the western extremity of Oistin Bay, where Welches and Maxwell receded by more than 2.5 m. The reason for the erosion experienced during this period is not clear. It has been suggested that the change may have resulted partly from the impact of hurricane Janet in 1955 which approached the island from the south. Patches of coral were torn from the substrate and some marine communities destroyed (Coastal Conservation Project, 1984: Section 17- 54). Empirical evidence has shown that reef damage by hurricanes upsets the sediment balance and often causes permanent beach erosion. Hurricane Betsy inflicted severe damage to the reefs off Aligator Spit, Florida in 1965, causing the shoreline to retreat for several years after (Warnke 1966: 2015). In 1960 hurricane Donna destroyed patch reefs off southern Florida, killing coral communities and precipitating widespread beach erosion for nearly a decade (Tanner 1961). Similar effects have been reported from British Honduras (Stoddart 1969), Rhode Island (Richardson 1978) and the Mississippi - Louisiana coast (Tanner 1970).

The other section of the coast stretching from Dover to Gravesend, experienced an accretion phase. The beaches prograded by more than 2.0 m at all locations. Maximum accretion occurred along the Hastings - Rockley coast, where there was an average of 2.7 m. Beaches within Carlisle Bay (Holiday Inn and Esplanade) also widened though at a considerably slower rate than those in the Hastings - Rockley zone. The pattern only becomes disrupted at the westernmost tip of the coast (Needham's Point), where the beach contracted by approximately 1.7 m.



BRIDGETOWN
SOUTH COAST BEACH WIDTH CHANGE 1950-64
METRES
ESPLANADE +1.6
HOLIDAY INN +2.5
W. PAVILLION COURT +2.5
ROYAL HOTEL +3.0
WORTHING +2.2
NEEDHAM'S PT. -1.7
GRAVESEND +2.6
W. DOVER +2.3
WELCHES -2.6
OISTIN -2.2
MAXWELL -2.8
OCEAN VIEW +2.6
ROCKLEY +2.7
ST. LAWRENCE +2.1
S. DOVER +2.2
COTTON HOUSE -2.3
+ Accretion
— Erosion
N
SOUTH POINT
0 1 2 3 4 5 KM
(Data extracted from aerial photographs and topographic survey)

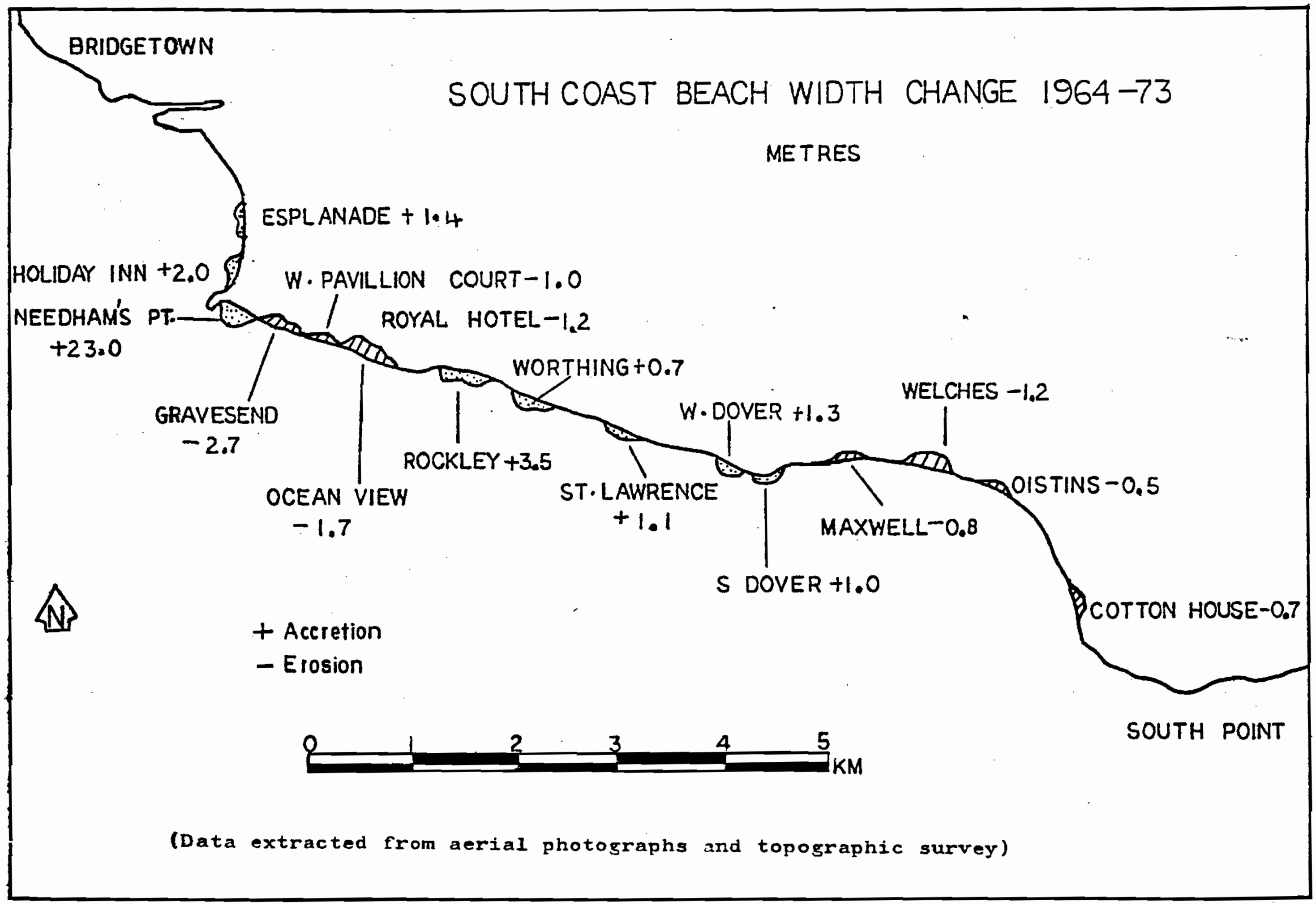
Figure 17

(Figure 17). Net change for all south coast locations is given in Appendix 1 (a).

1964 -73

The period 1964 - 73 exhibited a broadly similar pattern to that described previously. There were however a few significant changes. The beaches along the Hastings coast which had widened between 1950-64 experienced sediment loss. In one case, Ocean View, the loss was greater than 1.5 m. This depletion is probably related to the rapid accumulation in the adjacent Rockley Bay area. Previous research has shown that a large volume of sand moves into the Hastings cell from Rockley Bay cell (Deane et al., 1973) The build up at Rockley would therefore have meant a reduction in the volume of sediment moving westward. In the absence of compensation from another source, the result would be a negative sediment balance downcoast at Hastings (Figure 18).

It is interesting to note that in the three cases where beaches widened significantly, there is documented evidence of direct human interference. At Rockley the 3.5m of new beach resulted from the extensive replanting of vegetation and groyne construction. During the late 1950's and early 1960's flooding along Highway 7 became a common occurrence in the vicinity of Rockley Beach. The government planted *Terminalia catappa*, *casuarina equistifolia*, *Thespesia populnea* and *Cocos nucifera* from the edge of the highway seaward to beyond the 'normal' high



(Data extracted from aerial photographs and topographic survey)

Figure 18

water mark.[1] In addition two groynes roughly 30 m long were erected. The width of the beach increased and became stabilised to the extent that flooding eventually ceased.[2]

At Needham's point, two groynes each about 45 m long and an offshore breakwater were built in 1965. The aim was to create a beach in front of the Hilton Hotel. The structure proved so effective that between 1964 and 1973 an additional 23 m of sediment had accumulated. The wide beach behind the Holiday Inn was also in part artificially created. Though not intentionally designed to form a beach, a previously dilapidated pier was realigned and restored, extending some 75.0 m out to sea. The beach gained 2.0 m between 1964 and 1973 as a result of the piling up of sediment on the south side of the pier. The Dover - Rockley area continued to accrete. Average increase was approximately 1.0 m, except at Rockley where the beach built up at a far greater rate (Appendix 1(b)). This was the continuation of a trend which started sometime prior to 1950. The beaches at Cotton House and Oistin Bays showed only small quantitative changes, receding by an average of 0.5 m. Those to the west, Welches and Maxwell, experienced slightly greater losses, approximately 1.0 m.

1973 - 1982

Since 1973 rapid sediment accumulation has been occurring at the site of the former Coast Guard Station.

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1. Information supplied by Mr. D. Grant, former manager, Parks and Beaches Commission.

2. Ibid

Accretion has been more rapid here than at any other location on the island, post 1950. In 1974 the Government built the station here in an area where no beach existed. A pier and breakwater were erected to provide mooring faciltities in a zone where the littoral current moves an appreciable quantity of sediment alongshore (more than 800 m^3/day; Deane et al. 1973). The extent of sediment accumulation at this location is graphically demonstrated by the coastal conservation Project (1984). Figure 19 gives a comparison of beach width 1954 and 1982, along that segment of the coast, and is reproduced from the Coastal Conservation Atlas. Much of this sand became trapped and by 1976 a beach 15.0 m wide had already formed. By 1982 the beach was 35.5 m wide, representing an average accumulation rate of 4.4 m per annum. In the meantime, shoaling has extended south along the Enterprise coast as far as Cotton House beach. The latter, which had been receding up to 1973 has since extended by 2.3 m. Accretion is continuing on the Maxwell - Dover coast. Maximum net accumulation has occurred at Maxwell where 1.5m of sediment were added since 1973. Another area of accretion is Needham's Point, which had been advancing rapidly since the late 1960's. A further 12.8 m of fine sediment were trapped between 1973 and 1982. The Holiday Inn and Esplanade beaches continue to widen as they have done without interruption since 1950. Indeed the entire Bay Street segment has stabilised as

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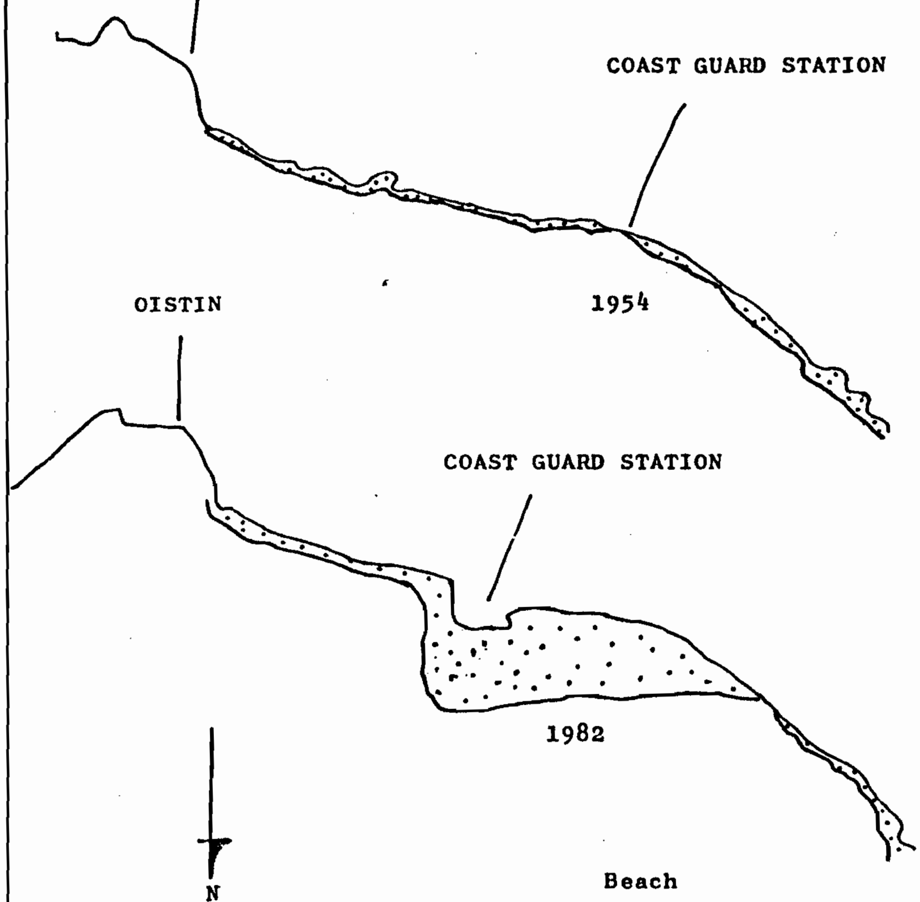
1. Parks and Beaches Commission estimates.

COMPARISON OF BEACH WIDTH - COAST GUARD STATION SITE, 1954 and 1982

Figure 19



(From Coastal Conservation Project Atlas, 1984)

0 50 100 150 200 250 metres

adequate amounts of sediment from offshore sources are moving along the coast (Coastal Conservation Project 1984).

At present erosion on the south coast is concentrated along the St. Lawrence - Gravesend and Oistin - Welches coasts. (Figure 20). In the latter case, excessive sand loss has partly resulted from a coastal reclamation project at Oistin. The scheme, initiated in August 1980, reclaimed an area of 1.8 ha. It effectively enclosed most of Oistin beach and a portion of the immediate foreshore. It is only since March 1981 that sediment began to accumulate in front of the works. Welches to the west also suffered a disruption of sediment supply, retreating by an estimated 2.0 m since the project.[1] It is therefore necessary to emphasize that the relatively rapid recession experienced here is largely a post - 1980 phenomenon.

The other receding section of the coast (St. Lawrence - Gravesend) suffered substantial losses after 1973. The St. Lawrence and Worthing coasts contracted by >1.5 m. Rockley Beach which has been widening from 1950 has since receded by some 2.4 m (Appendix 1(c)). This erosive phase became most apparent from about 1978, since which time requests for assistance have been made to the Parks and Beaches Commission.[2] Further, between 1979 and 1982 six

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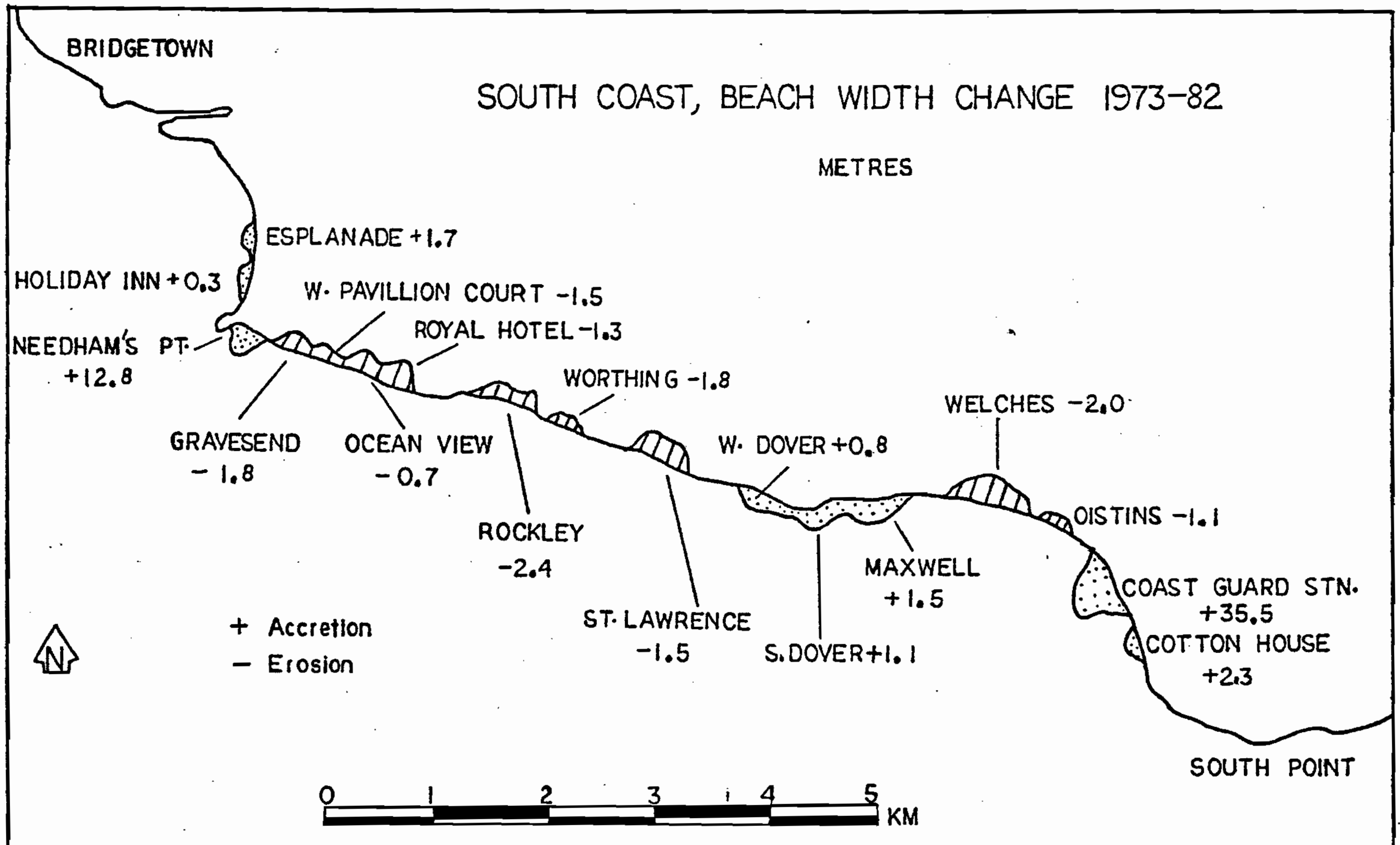
1. Personal communication with Mr. Anthony Hutchinson, consultant Engineer Consulting Engineers Partnership. This firm is responsible for the project.

1. Personal communication with Mr. D. Grant, former Manager, Parks and Beaches Commission.



(Data extracted from aerial photographs and topographic survey)

Figure 20

property owners from this area submitted applications to the Town Planning Office, seeking permission to erect coastal defences. It is therefore highly probable that this phenomenon only started during the last few years. Although estimates for the period 1973- 82 show net erosion, the earlier accretion phase must have persisted until about 1978.

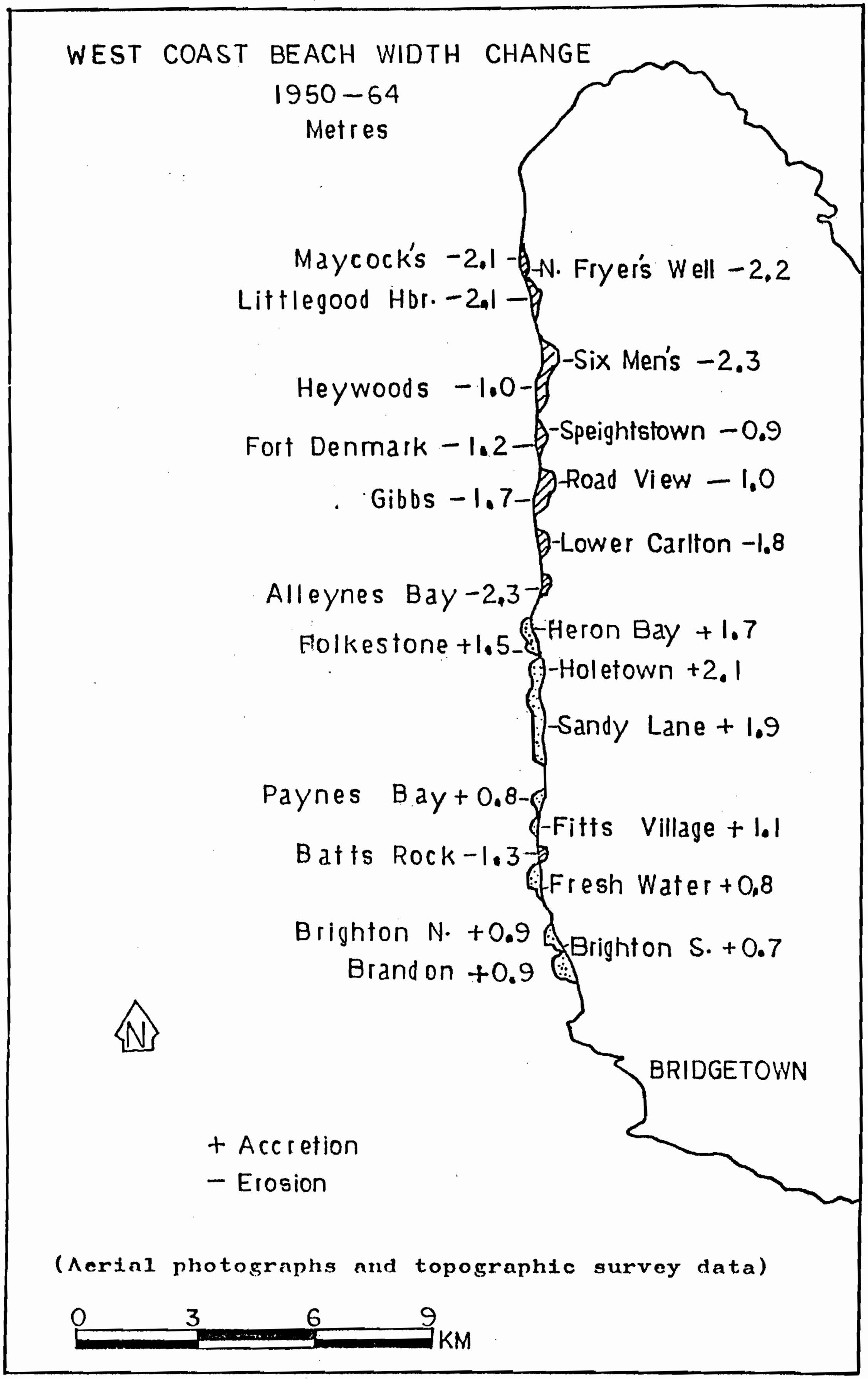
<u>West Coast</u>

<u>1950 -64</u>

Measurements indicate that beaches from Alleyne's Bay north to Maycock's narrowed, while those south of Alleyne's Bay widened during the period (Figure 21). However there are noticeable spatial differences in the degree of retreat and advance. Maximum erosion occurred between Maycock's and Six Men's, where beach loss at all locations exceeded 2.0 m. Values in the same range of magnitude were also recorded along the Gibbs - Alleyne's Bay area. Noticeably reduced retreat ($\approx$ 1.0 m) occurred on the Heywoods - Roadview coast. In sum, this receding section of the coast could be conveniently divided into three parts : two areas to the north and south which experienced moderate recession, and an intervening central zone retreating at a slower rate.

Sediment accumulation along the southern west coast has not been uniform either. The more northerly beaches from Heron Bay to Sandy Lane advanced by an average 1.8 m. In comparison, those further to the south prograded by

Figure 21



WEST COAST BEACH WIDTH CHANGE
1950—64
Metres
Maycock's -2.1
N. Fryer's Well -2.2
Littlegood Hbr. -2.1
Six Men's -2.3
Heywoods -1.0
Speightstown -0.9
Fort Denmark -1.2
Road View — 1.0
Gibbs -1.7
Lower Carlton -1.8
Alleynes Bay -2.3
Heron Bay +1.7
Folkestone +1.5
Holetown +2.1
Sandy Lane + 1.9
Paynes Bay + 0.8
Fitts Village + 1.1
Batts Rock -1.3
Fresh Water +0.8
Brighton N. +0.9
Brighton S. +0.7
Brandon +0.9
BRIDGETOWN
N
+ Accretion
— Erosion
(Aerial photographs and topographic survey data)
0
3
6
9
KM

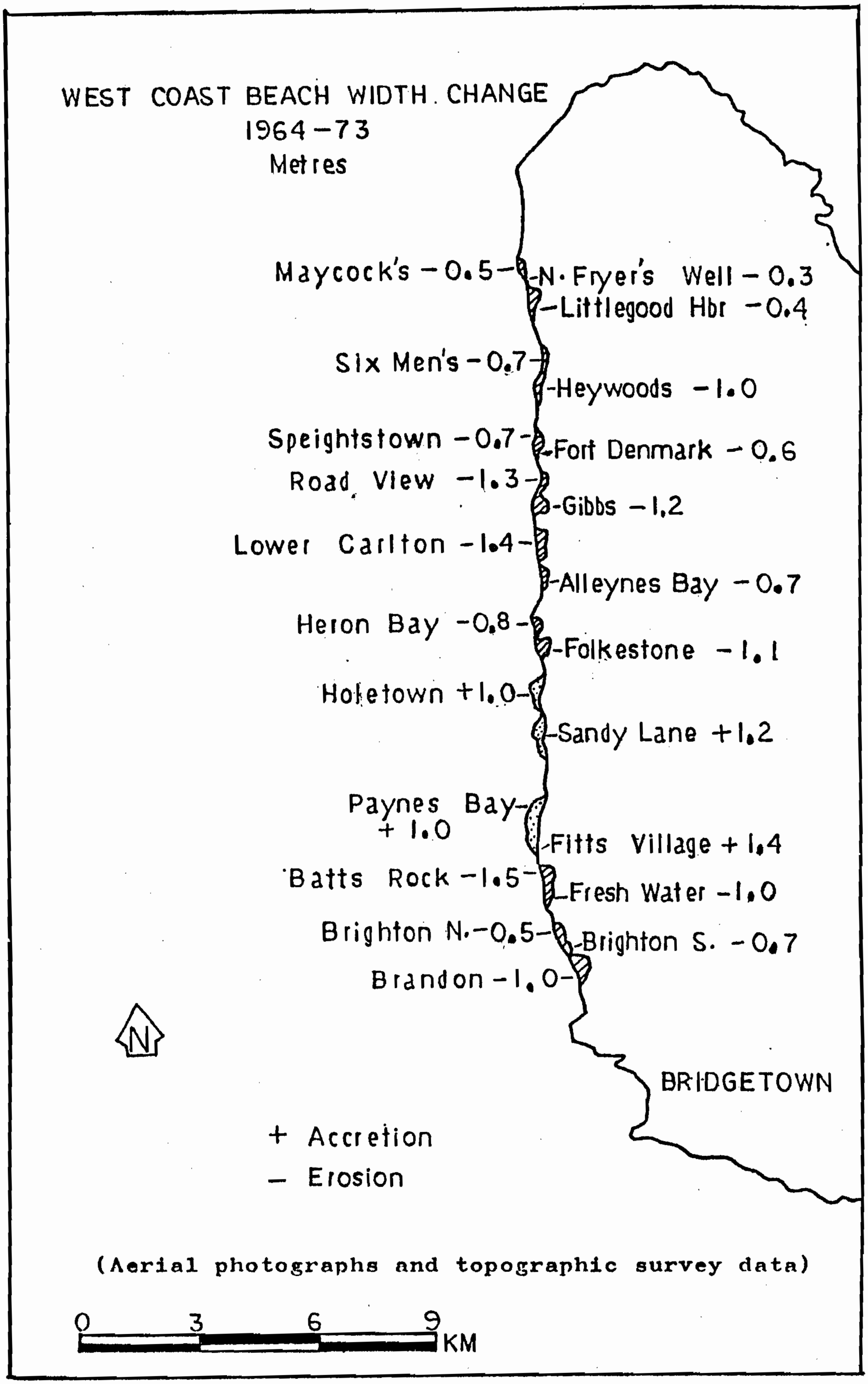
< 1.0 m (Appendix 1 (d)). Batts Rock beach is the only anomaly along this stretch of coast. For while the beaches to the immediate north and south have widened, there was a net loss of 1.5 m here. As will be evident later, this is the only point along the southern west coast where erosion has been continuous ever since 1950.

1964 - 1973

The spatial distribution of erosion and accretion during this period, presented a pattern somewhat different from what obtained earlier. The beaches to the north continued to retreat, while the more southerly sites (i.e. Holetown to Fitts Village) experienced accretion. A notable difference was that Heron Bay and Folkestone which had previously widened, suffered erosion ($\approx$ 1.0 m). This meant that the retreating northern portion of the coast now extended further south (Figure 22). The Six Men's - Lower Carlton area experienced the greatest retreat, an average 0.9 m (Appendix 1(e)).

Erosion also occurred from Freshwater south to Brandon, reversing the accretion trend of the earlier period. These beaches which had prograded earlier by about 0.8 m receded by between 0.5 - 1.0 m between 1964 and 1973. It is not certain whether this change is simply the result of increased destructive wave energy. Preliminary wave hindcast data suggest that the period 1965-75 was one of relatively low energy at the south-western quadrant of the

Figure 22


WEST COAST BEACH WIDTH CHANGE
1964-73
Metres
Maycock's -0.5
N. Fryer's Well -0.3
Littlegood Hbr -0.4
Six Men's -0.7
Heywoods -1.0
Speightstown -0.7
Fort Denmark -0.6
Road View -1.3
Gibbs -1.2
Lower Carlton -1.4
Alleynes Bay -0.7
Heron Bay -0.8
Folkestone -1.1
Holetown +1.0
Sandy Lane +1.2
Paynes Bay +1.0
Fitts Village +1.4
Batts Rock -1.5
Fresh Water -1.0
Brighton N. -0.5
Brighton S. -0.7
Brandon -1.0
N
BRIDGETOWN
+ Accretion
- Erosion
(Aerial photographs and topographic survey data)
0
3
6
9
KM

island[1]. In the absence of a detailed investigation, it would be impossible to offer a full explanation. However there is good reason to suppose that the construction of the Deep Water Harbour to the south in 1962, might have interfered with the mechanisms of sediment transport into the area. The harbour incorporated part of the offshore reef system, as well as a large section of the Pelican Shoals (Steven Hardtke Associates, 1972: Port Study Bridgetown Vol.3, section D6). Eroded sediment from the reef and the reservoir of sediment which constitute the shoals are a major sediment source for beaches adjacent to the harbour (Ibid). It is therefore likely that the construction of the breakwaters here, restricted the amount of sediment available north of the harbour.

1973 -82

Northern West Coast

Northern west coast beaches have shown little change in width since 1973. The greatest recession has occurred along the Maycock's - Speightstown coast, but does not exceed 0.5 m. At Six Men's and Speightstown there has been no measureable change (Appendix 1 (f)). These beaches appear to be in rough equilibrium at the present time. The negligible recession here is also related to the extensive beach rock outcrops which became evident during the 1950's and 1960's. Once exposed, beach rock helps to retard

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1. Information supplied by Dr. F.Farnum, hydrometeorologist, Caribbean Meteorological Institute. The Institute is presently working on a method for hindcasting wave data from weather charts.

further beach changes (Russell 1958, 1959). Extensive bands reflect and dissipate significant amounts of wave energy, thereby acting as a protective buffer to the rest of the beach. The fact that no new exposures have occurred since 1975 may also be indicative of some measure of stability along this coast.

Central West Coast

Measurable recession is occuring along the entire zone between Fort Denmark and Holetown (Figure 23), but is greatest in the vicinity of Folkestone. Here the sand step is said to have retreated by 14.0 m between 1973 and 1982, while the backshore position shifted some 8.0 m during the same period (Coastal Conservation Project 1984). There is considerable concern about the rate of erosion on this coast as there are large property investments here. It is therefore not surprising that 65% of all coastal defence works since 1975 have been erected here.[1]

Southern West Coast

In contrast, accretion has been occurring in the Sandy Lane - Fitts Village area as was the case since 1950. The zone of greatest sediment accumulation is the Paynes Bay - Fitts Village coast, where the beach has prograded by more than 1.0 m. The Batts Rock area continues to show evidence of erosion, with the beach retreating by almost 1.0 m. At

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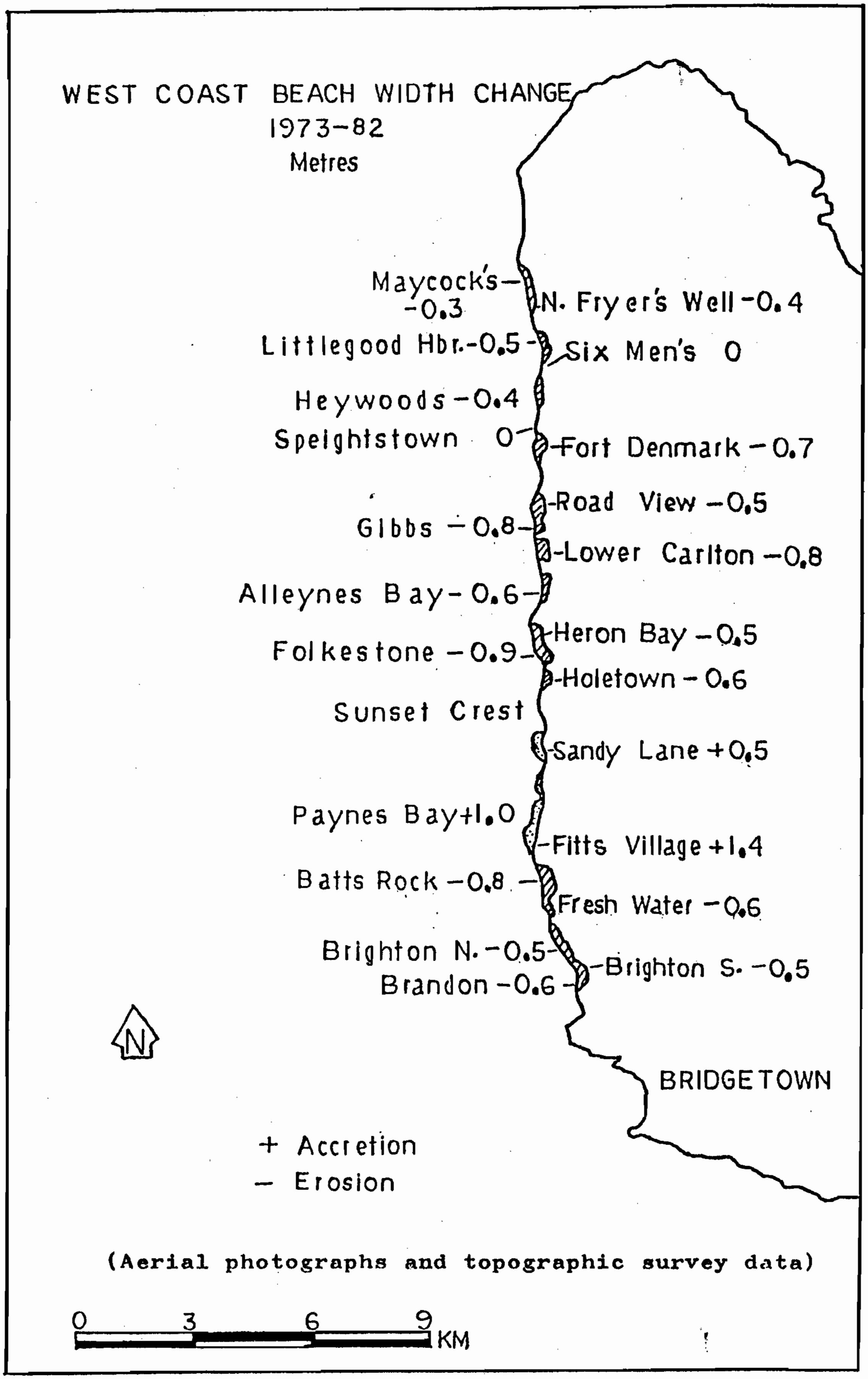
1. This information is based on field surveys conducted by the Town and Country Planning Office, and includes structures for which permission was not sought.

Figure 23



(Aerial photographs and topographic survey data) the same time, the sand step retreated by over 7.0 m. while the backshore narrowed although by considerably less than this amount (Coastal Conservation Project, 1984. See also figure 24). However the erosion trend at Brighton and Brandon has reversed; the average increase for this section of the coast is approximately 3.4 m (Appendix 1 (f)). Measurements from the Coastal Conservation Atlas show that the sand step extended by about 5.0 m in front of the Rum Refinery during this period, as is shown in figure 25. This increase indicates that a greater sediment load is now bypassing the installations at the Bridgetown Harbour and reaching these beaches. An increase in the frequency of dredging around the main breakwater,[1] particularly in the last 5 years supports this observation.

BEACH ROCK

The exposure of beach rock has long been considered a useful indicator of beach change, particularly beach loss (Revelle 1957; Russell 1958 1959; Emery 1959). The pioneering work of McLean (1963) and Bird (1977) provide a useful data base for a continuing study of the spatial distribution of beach rock in Barbados. In the summer of 1981/82 a survey of the west and south coasts was undertaken and linear measurements of beach rock were made.

Leeward Coast

Overall, beach rock increased by roughly 4% on this

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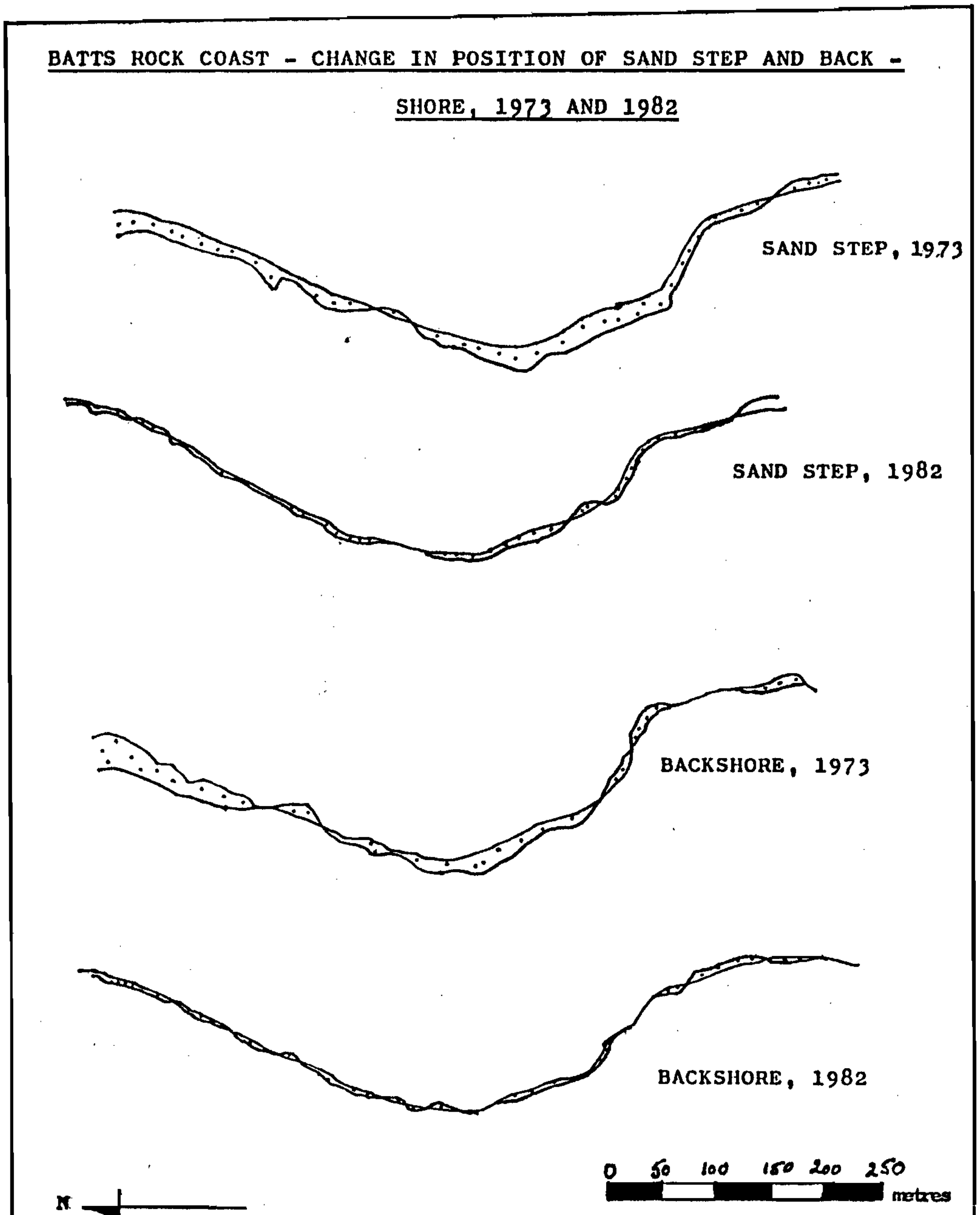
1. Information contained in a questionnaire sent to the Harbour Master, Captain S. Van Sluytman, June 1982.

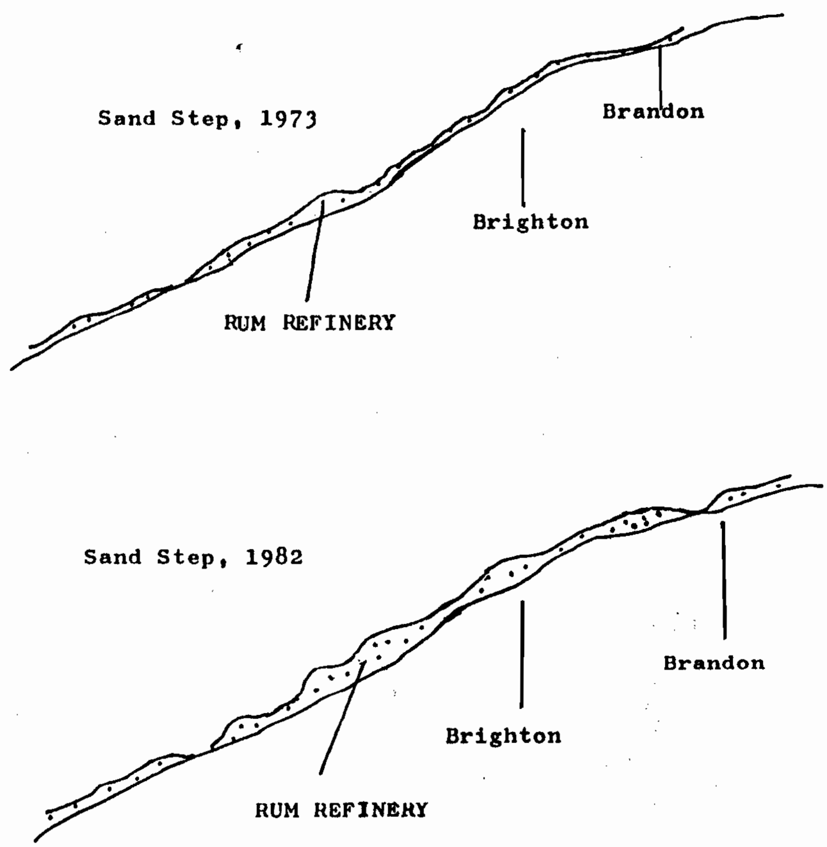
Figure 24



(From Coastal Conservation Project Atlas, 1984)

Figure 25

COMPARISON OF SAND STEP - BRIGHTON(RUM REFINERY), 1973 AND 1982



(From Coastal Conservation Project Atlas, 1984)

coast between 1975 and 1982 (Table 10). It is significant that there has been no apparent increase in beach rock north of Speightstown. In fact, there has actually been a decrease at Maycock's and Six Men's (2.0 and 5.0m respectively).

Between 1963 and 1975 the largest increases (525 m) were measured from Speightstown south to Alleyne's Bay, with a major concentration between Mullins and Lower Carlton (Bird 1977:39). Significantly large increases (236 m) also occurred in the Batts Rock - Freshwater Bay area. The zone of greatest continuous exposures was to be found between Six Men's and Speightstown (Ibid).

Table 10

Linear Beach Rock Exposure Along West Coast
By Sector (metres)

Sector of Coast	1963 (McLean)	1975 (Bird)	1981-82 (Nurse)
Harrison Point-Maycock's Bay	86	80	78
Littlegood Harbour	33	135	135
Six Men's-Speightstown	935	935	930
Goding's Bay-Gibbs	143	408	424
Lower Carlton-Alleyne's Bay	460	720	735
Holetown	0	15	40
Sandy Lane-N. Payne's Bay	390	255	240
S. Paynes Bay-Prospect	115	85	75
Batts Rock -Freshwater	254	490	580

Table 11

Linear Beach Rock Exposure Along South Coast (metres)

Sector of Coast	1963 (McLean)	1981-82 (Nurse)	Absolute Change 1963-82
Needham's Point	15	10	-5
Gravesend	0	32	+32
Hastings	0	20	+20
Welches	183	260	+77
Oistin Bay	76	93	+17
South Point	0	43	+43

Since 1975 there has been a 3% increase in beach rock between Godings Bay and Holetown. The sector north of Holetown (Heron Bay - Folkestone) should be viewed with some concern. No beach rock was recorded here by Bird in 1975. Now these data represent an increase of 2.1 m per annum over the last 7 years, compared to a rate of 1.25 m during the 12 years 1963 -75. Similarly, increased exposures are evident in Batts Rock Bay, amounting to 90 m over the last 7 years. This is another zone in which massive increases have occurred, apparently without interruption, since 1963. (Figure 26).

Not surprisingly, the areas which recorded the greatest increases in beach rock also showed the greatest beach recession since 1975. It was shown earlier that of all west coast beaches, those located in cells between Godings Bay - Holetown, and Batts Rock - Freshwater are receding the most actively. Empirical evidence has shown that on many tropical shores there is often a positive correlation between beach rock exposure and sediment loss (Russell, op. cit.). This correlation holds good for the Barbados West coast (Figure 27).

<u>South Coast Exposures</u>

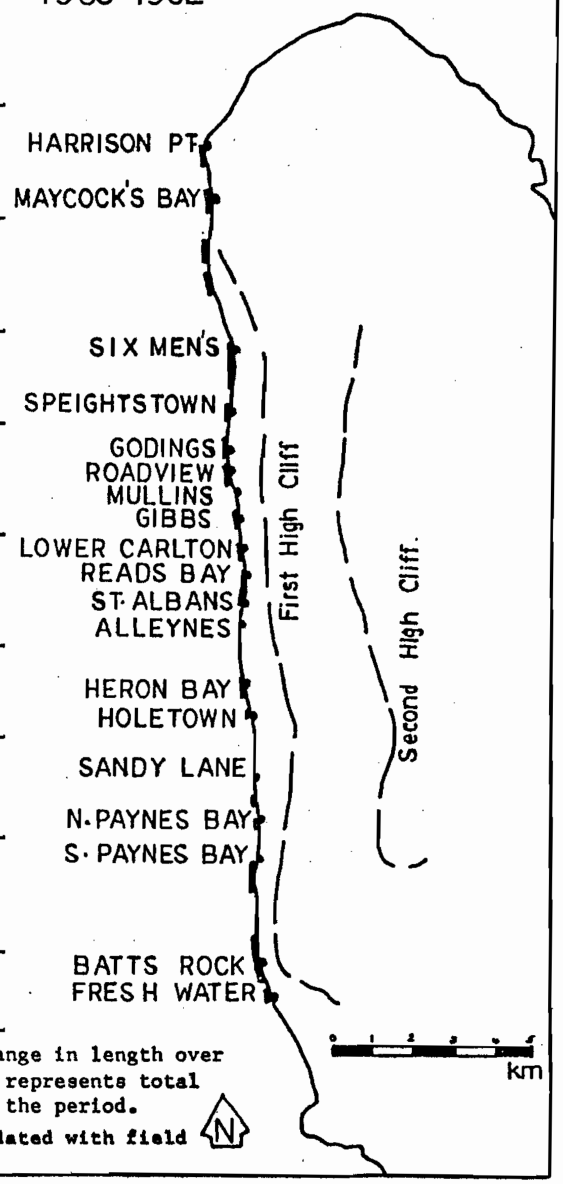
The survey conducted by Bird (1975) excluded the south coast. As a result, only McLean's data for 1963 and field measurements for 1982 are available. What is clear however, is that the cumulative length is now far greater than it was in 1963. The only sector of the coast where a reduction has occurred is at Needham's Point, which now has

Figure 26

WEST COAST BEACH ROCK

1963-1982

1963-1975 McLean - Bird (Metres)	1975-1982 Bird - Nurse (Metres)
-6/80	-2/78
+102/135	0/135
0/935	-5/930
+265/408	+16/424
+220/720	+15/735
+15/15	+25/40
-135/255	-15/240
-30/85	-10/75
+236/490	+90/580



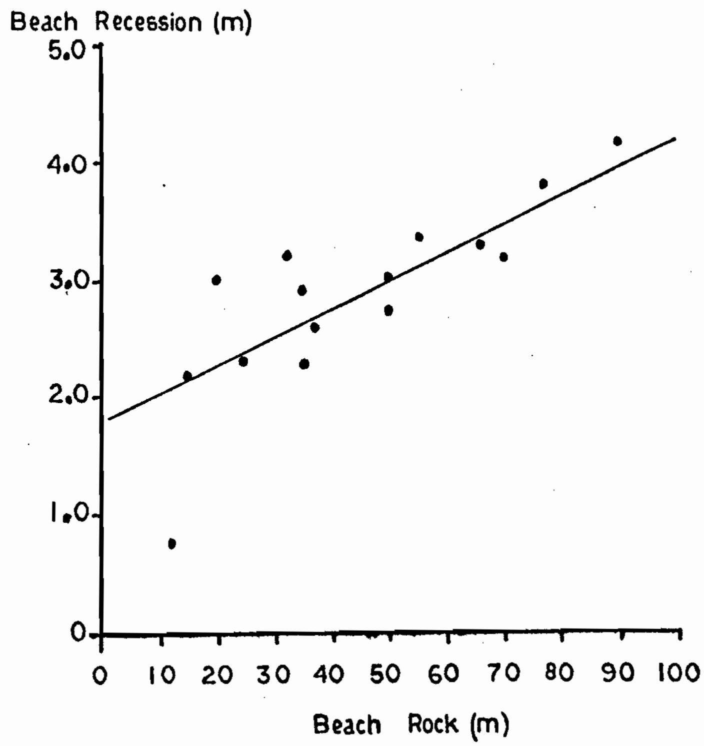
N.B. The first value represents change in length over the period. The second value represents total linear exposure at the end of the period.

(Extracted from Bird (1977), and updated with field measurements 1982).

Figure 27

RELATIONSHIP BETWEEN BEACH ROCK EXPOSURE AND BEACH RECESSION

1964-1982



$r = .51$

$t = 2.14$, significant at approx .05

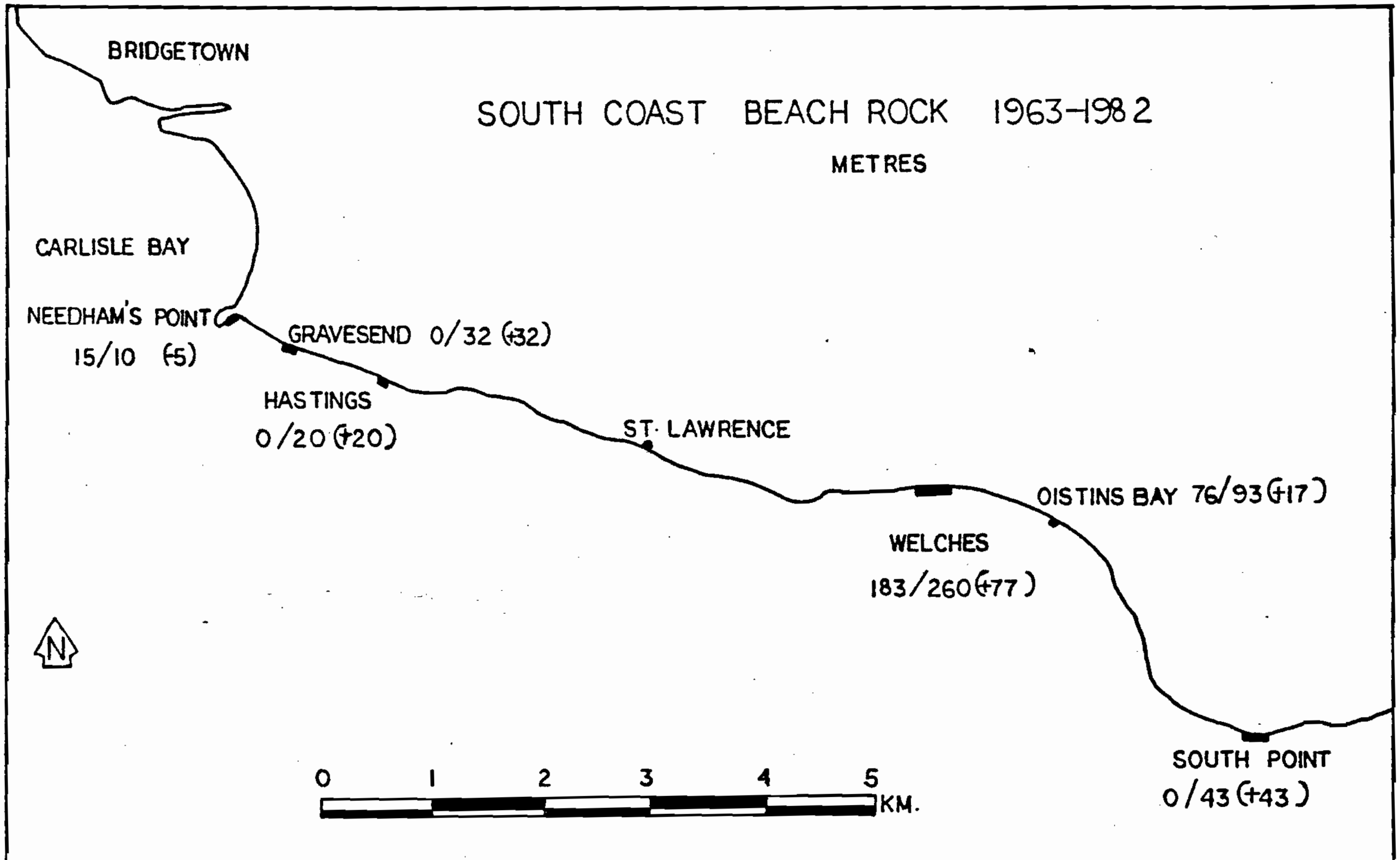
N.B. Each datum point represents one beach.

Data from McLean(1964), Bird(1977), aerial photographs, Nurse(1982)

< 5.0 m of beach rock. There has been a large accumulation of sediment here, as a result of a deliberate beach-building project. The most extensive beach rock zone on this coast (as in 1963) is at Welches, where an increase of 30% has occurred in nineteen years. Correspondingly, Welches beach has receded by approximately 3.2 m since 1964. A smaller but significant increase occurred at Oistin, approximately 18% (Table 11).

One immediate observation from the last field survey, is that new exposures have occurred. These are located at South Point, Gravesend and Hastings (Figure 28). At Hastings the outcrops are small and incipient. They are at first difficult to detect, as they are remarkably similar in appearance to the sediment which surrounds them. Closer visual examination reveals a loosely cemented, crumbly material, suggesting that the outcrops are of recent origin. At the other locations there is evidence of banding, the material is far more indurated, and has a characteristically pitted surface appearance. It is clearly at a more advanced stage of formation than at Hastings. The exposures at South Point and Gravesend are similar in appearance to those on the west coast. It is possible that they may be roughly the same age as most other exposures on the island, but may have been covered by sediment for a longer period of time.

At this stage it may be too early to interpret these new exposures as indicative of general coastal retreat.



(Data from McLean(1964), and field measurements, 1982).

Figure 28

However their immediate significance is clear. They are an obvious sign of perceived sand loss, although it may not necessarily be permanent. Moreover, they detract from the physical appearance of the beach.

LITTORAL VEGETATION

No evidence was found to indicate any substantial changes in the number of species in the immediate post-1950 era. Although no quantitative data existed prior to Randall's (1968) study, there is a qualitative similarity between what he found and what was described up to 1950. The most evident changes after 1950 were associated more with contractions of certain zones rather than with changes in species composition (Gooding 1974). Hence, Randall's work can be used as a valid base against which post - 1950 changes can be assessed.

Five beaches which had been previously studied by Randall were selected for analysing the present status of leeward coast vegetation. The sites are Maycock's, Heywoods, Holetown, Brighton and Rockley. These are good examples of littoral habitats which exhibit a wide range of species. Furthermore, they have been subjected within recent times to varying levels of development and human pressure. As it was not possible to locate Randall's sites precisely, transects were randomly selected within these areas of vegetated littoral. In most cases finding an appropriate site was not difficult, since vegetation was largely confined to one section of the beach. Transects were established perpendicular to the beach (from approximately mean high water) as far inland as the nearest road or cultivated field.[1] Contiguous one-metre square quadrats were marked off along the line. The species types were indentified in each quadrat and the percentage cover estimated using Kuchler's (1967) cover classification. These data are presented as histograms in figures 29-33.

Maycock's Bay

At Maycock's Bay it is still possible to discern five distinct zones. In the pioneer zone the only species present is Sporobolus virginicus. This low grass covers approximately 30% of this zone compared to about 15% in 1968. It is also well established in zones 2 and 3 where it previously accounted for < 5% cover. The Hippomane - Coccoloba association of zone 2 has contracted noticeably since Randall's study. These species which accounted for up to 30% cover in some quadrats, now represent a maximum of 15% in any quadrat (Figure 29). This decline is partly due to deliberate removal of the Hippomane which is poisonous. Often burning is the method of removal and Coccoloba uvifera, the other dominant, is lost in the process. The spread of Sporobolus into this zone is partly a response to the decline of this association. Patches of this grass colonise many burnt out sections of the zone.

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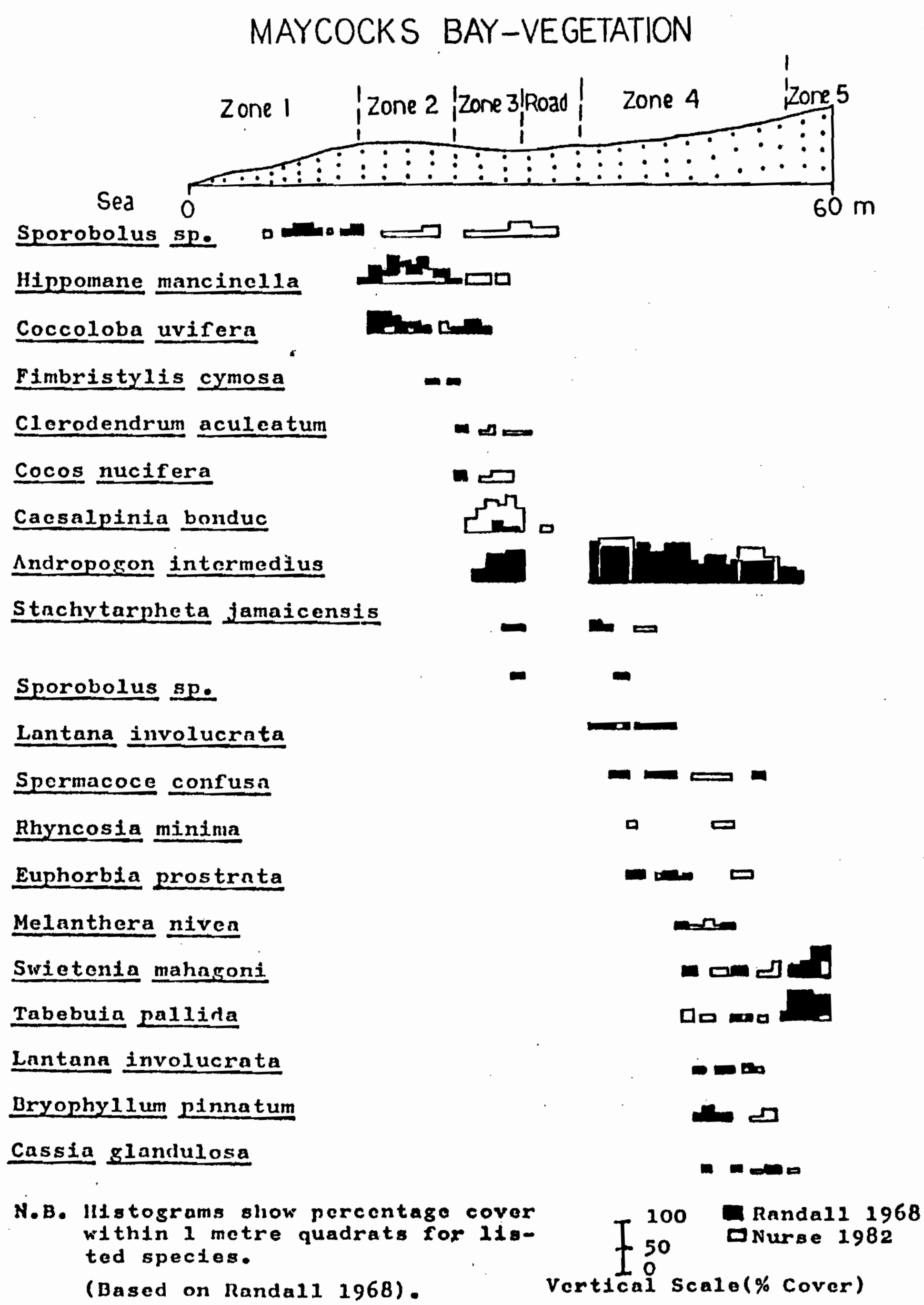
1. This decision was taken by Randall because such a transect orientation provided the greatest vegetation change, over the shortest distance.

Figure 29

MAYCOCKS BAY-VEGETATION



N.B. Histograms show percentage cover within 1 metre quadrats for listed species.

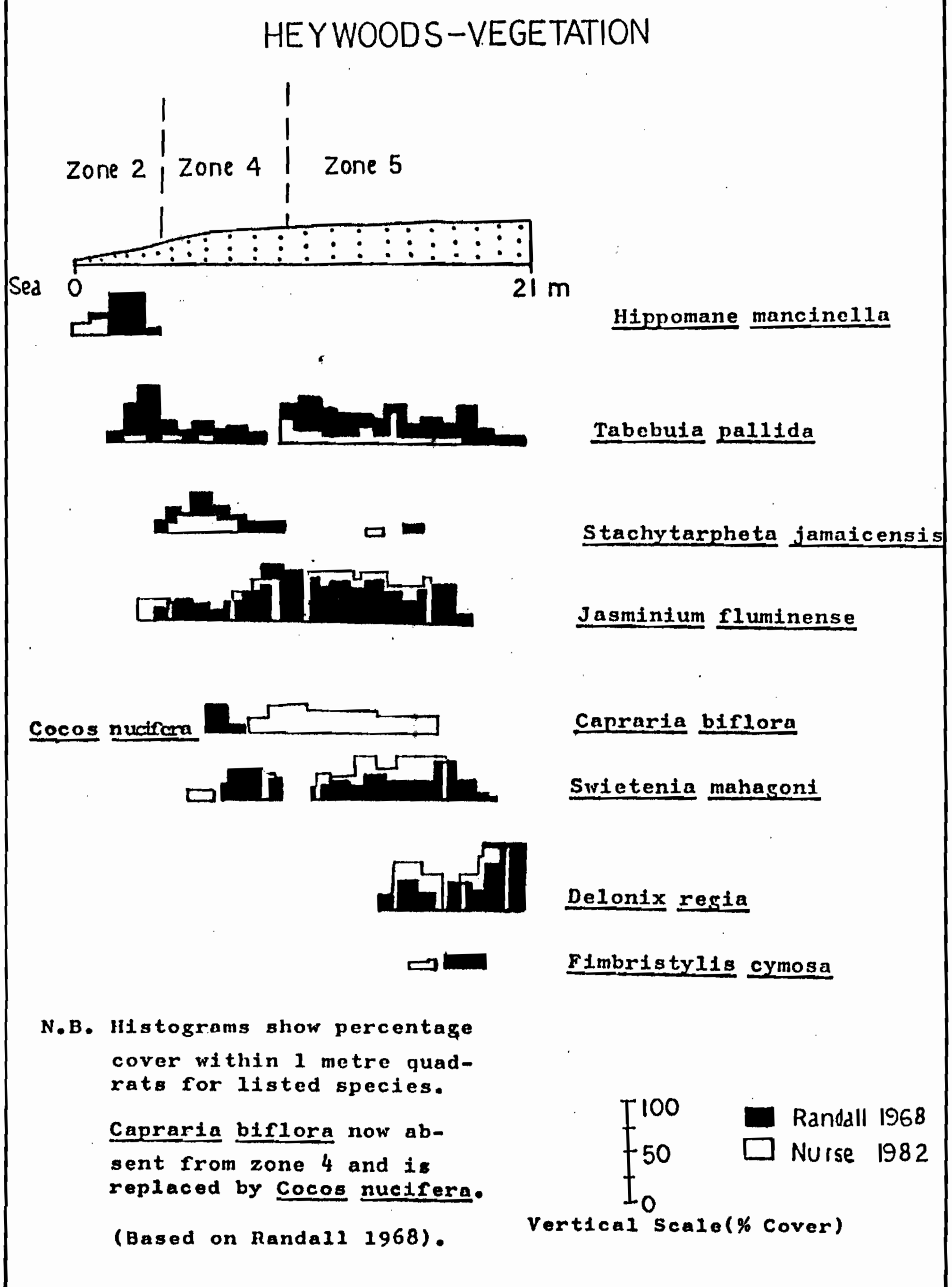
(Based on Randall 1968).

Practically all species identified in zone 3 in 1968 can still be found, although there are changes in the extent of their presence. For example, there is now 10% more Cocos and 15% more Andropogon intermedius but a noticeable reduction in Caesalpinia bonduc (approx. 45%). Zone 4 is still dominated by Andropogon, the fact that there was between 50-100% cover in each quadrat reflects this dominance. Swietenia is the most frequently found woody species in zone 5. Its increase over the last 14 years appears to have been at the expense of Tabebuia which now only covers about 10% of this zone.

Heywoods

Only three zones can be distinguished here as was the case in Randall's analysis of 1968. There is no pioneer zone and zone 2 which has contracted to about 1.5 m wide, is now barely identifiable. The zone consists of a few Hippomane and Tabebuia individuals which are often close to the water's edge. They account for < 5% cover and their existence is threatened by a receding coastline. In fact, some trees already have their roots exposed. Zone 4 is much more clearly defined with sharp increases in Swietenia and Stachytarpheta, forming a unique association. Tabebuia is now virtually confined to the zone 5 woodland, and almost absent in zone 4 (Figure 30). It is not as tolerant to salt spray as Hippomane (Gooding et al. 1965). With the decline of zone 2 therefore, it became exposed to higher levels of wind-borne salt; hence, the displacement to zone 5 is a response to changing habitat conditions. The

Figure 30



N.B. Histograms show percentage cover within 1 metre quadrats for listed species.

Capraria biflora now absent from zone 4 and is replaced by Cocos nucifera.

(Based on Randall 1968).

rest of zone 5 is much the same as it was in 1968, both in terms of species variety and cover. The only obvious change is the presence of Cocos, which was deliberately planted at the rear of the woodland. Individuals are beginning to appear haphazardly throughout the zone, as the plant is able to regenerate freely from fallen nuts. Capraria has disappeared from this zone.

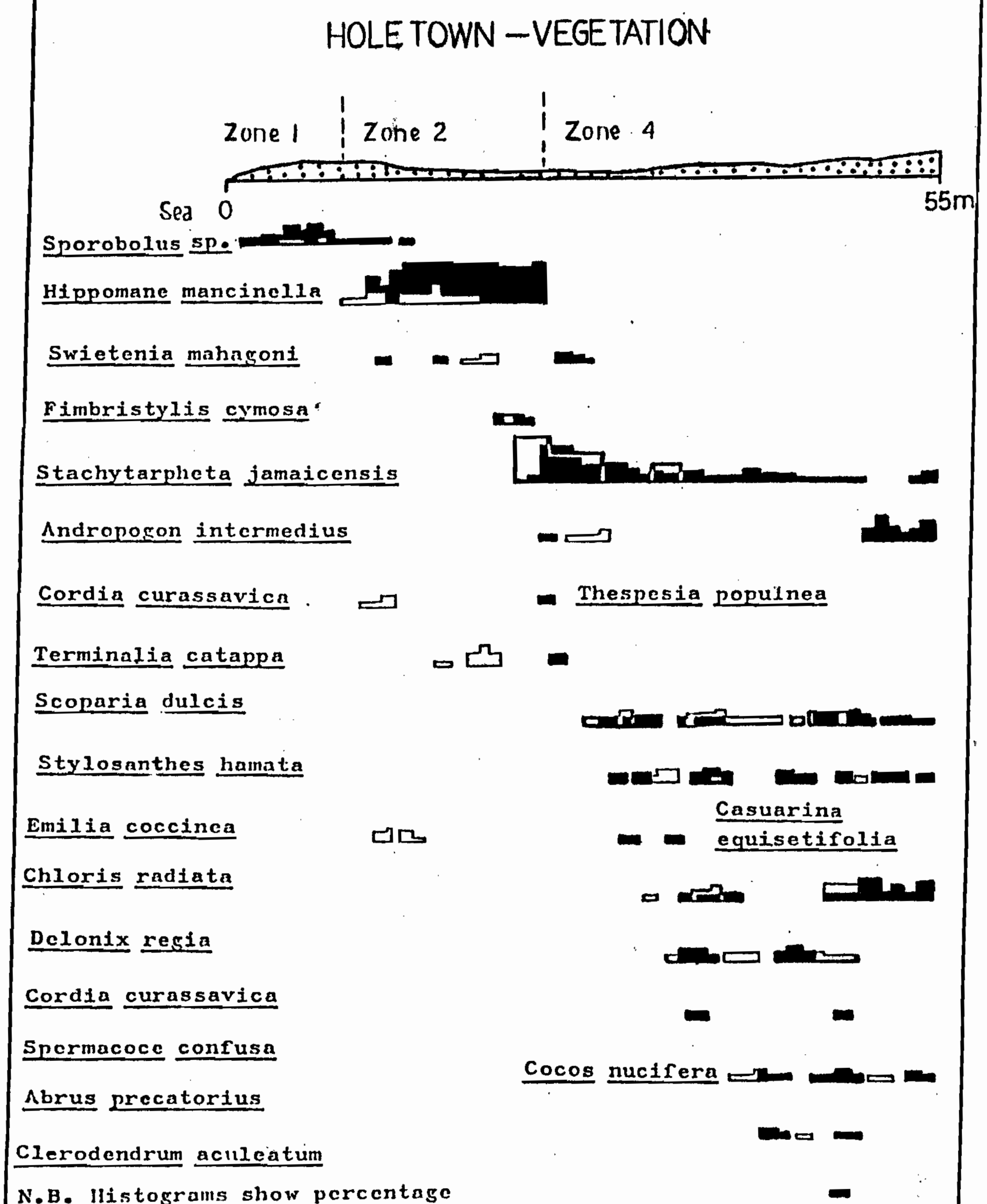
Holetown

In zone 1, the only species present is Sporobolus which occurs in discontinuous patches totalling < 5% cover. The small quantity of Hippomane present in the 1960's has disappeared, as is the case at most heavily used beaches. It is found only in zone 2 where cover has declined sharply to a few individuals. The original zone 2 has almost been eliminated and partly replaced by the ornamentals Casuarina equisetilolia and Terminalia catappa. The only originals which occur in any quantifiable abundance in zone 4 are Stachytarpheta, Chloris and Delonix (Figure 31). This contrasts quite sharply with the previous situation when over a dozen such species existed. Small quantities of Cocos are present. It is speculated that these may be 'escapees' from private property, where the species is widely planted on the sand terrace.

Brighton

There is still evidence of a pioneer zone here,

Figure 31



N.B. Histograms show percentage cover within 1 metre quadrats for listed species. Thespesia populnea and Cocos nucifera now present in zone 4. Spermacoce confusa absent.

(Based on Randall 1968)

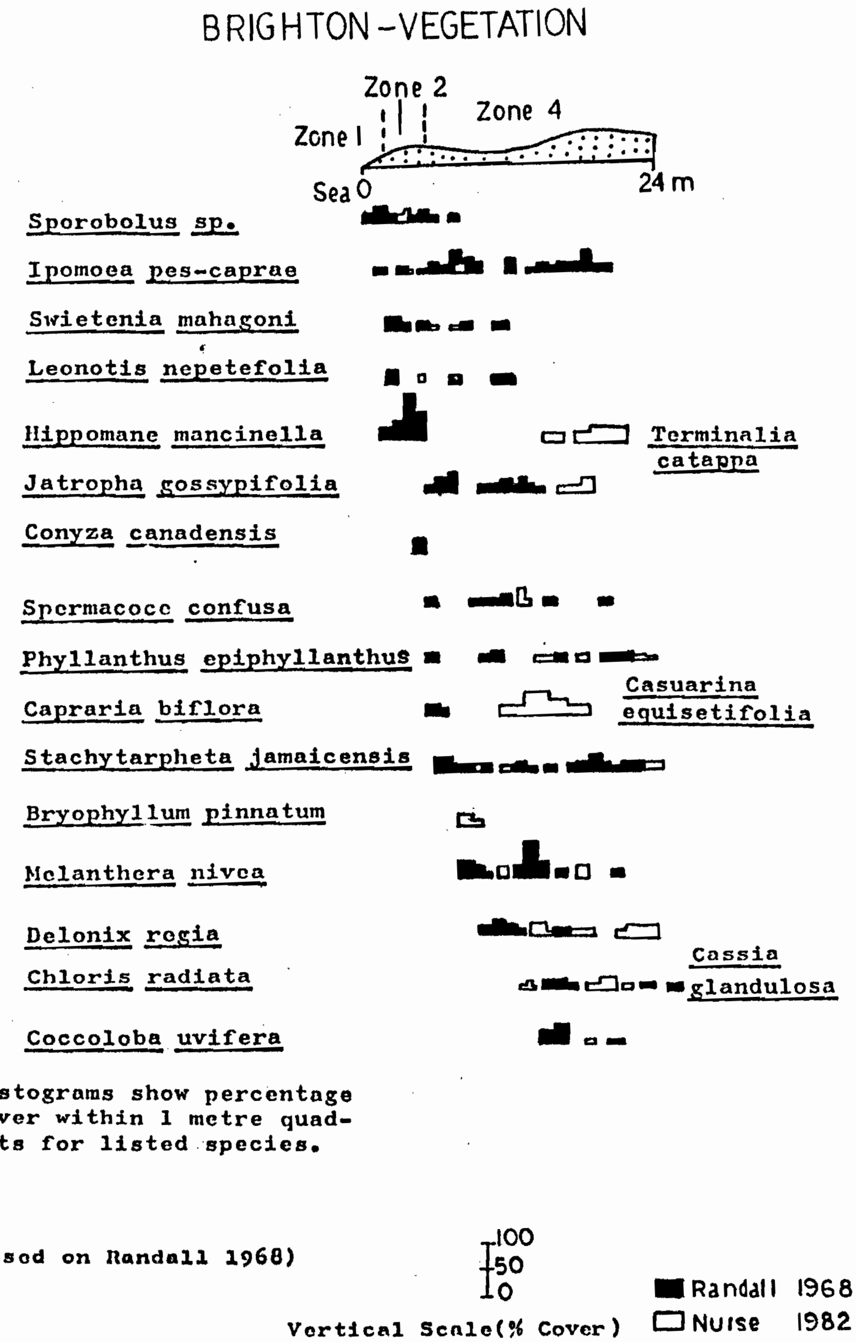
consisting of Ipomoea and Sporobolus, though their presence is much less evident than formerly. Hippomane is conspicuously absent, and its presence in zone 2 is reduced to a few widely scattered individuals. The main woody species in zone 2 is Swietenia (5%), while Ipomoea which occurs in all zones, accounts for about 8-10% of total ground cover.

The final 'band' of vegetation, zone 4, consists of as wide a variety of species as in 1968. However while most of the original cover has been reduced, shade and ornamental species have become more numerous. For instance Terminalia, Casuarina and Cassia whose presence was not recorded earlier, now occur throughout the zone (Figure 32).

Rockley

Randall identified 2 zones at Rockley beach in his 1968 study. Zones 1 and 2 were absent and zones 3 and 4, though still identifiable, were greatly disturbed by man (Randall, op. cit.: 138). As before, both zones are dominated by a grass cover of Sporobolus and Ipomoea, but the former is now more widespread than the latter (Figure 33). These two species are typical of zone 1 leeward coast beaches, but on account of the disturbed habitat, have found their way into the inner zones of the beach. As elsewhere, Coccoloba one of the primeval costal species, has all but disappeared. It now accounts for < 5% cover in this zone. There is an increased presence of Terminalia (2-5%), one of the species planted under the Government-

Figure 32

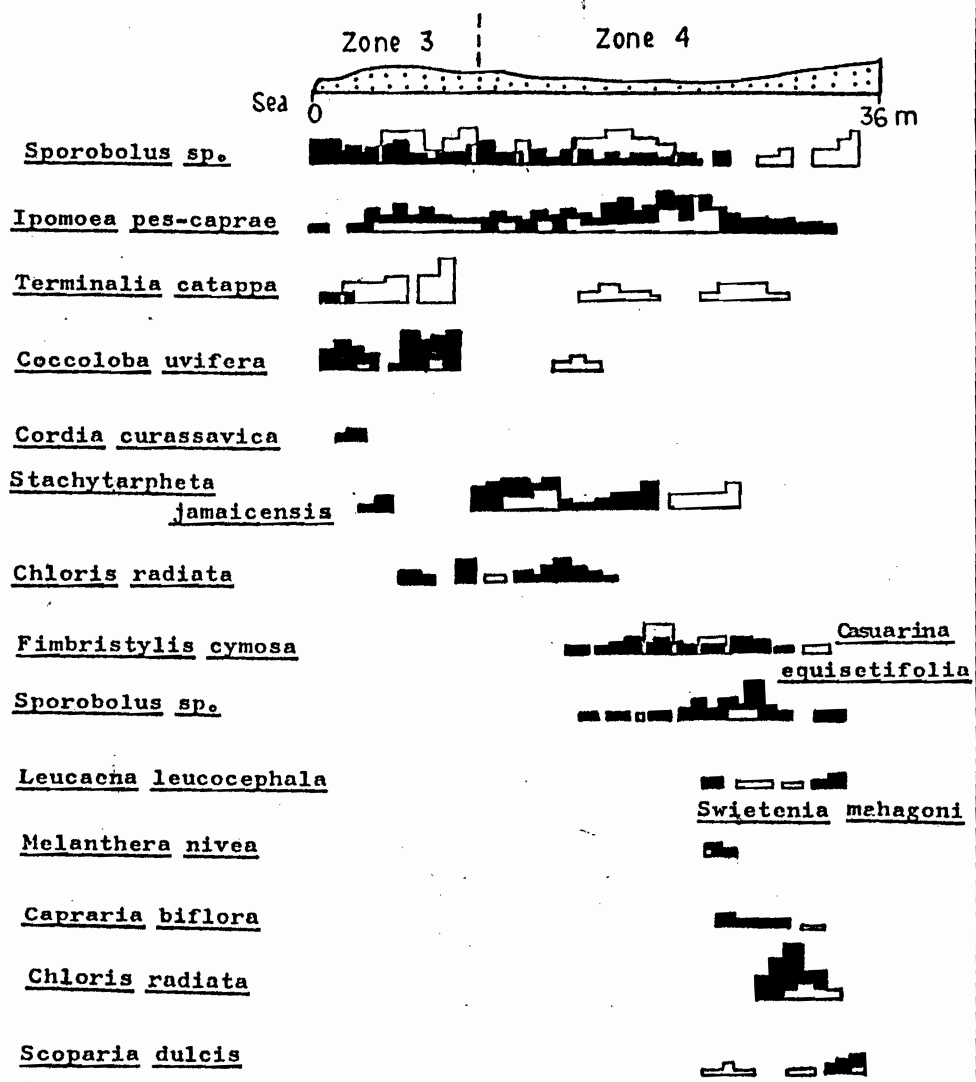


N.B. Histograms show percentage cover within 1 metre quadrats for listed species.

(Based on Randall 1968)

Figure 33

ROCKLEY–VEGETATION



N.B. Histograms show percentage cover within 1 metre quadrats for listed species. Fimbristylis ferruginea and Leucaena leucocephala are now replaced by Casuarina equstifolia and Swietenia mahagoni respectively.

(Based on Randall 1968)

100 / 50 / 0 — Vertical Scale(% Cover)

Randall 1968 (solid)

Nurse 1982 (open)

sponsored scheme of the 1960's.

Zone 4 which extended right up to the highway, has largely been replanted with Casuarina, Terminalia and Swietenia. The ground cover consists of a variety of grasses and short herbs, including Sporobolus, Scoparia dulcis, Chloris radiata and Stachytarpheta jamacensis. The last three have been designated as plants of 'waste places', i.e. habitats drastically altered by man (Gooding 1974: 95). Their increasing presence also reflects an ability to compete successfully with other well - established species (Ibid).

Some useful observations may be made from the vegetation data. With the exception of Maycock's Bay to the north, measurable changes have occurred both in terms of percentage cover of individual species and the areal extent of certain zones. Maycock's Bay remains undeveloped and is largely free of the human pressures exerted further south. It is noteworthy that all zones are still evident, whereas zone 2 for instance has virtually disappeared from Holetown and Heywoods. In addition, although the original Hippomane - Coccoloba association is now less evident at all sites, the highest percentage cover remains at Maycock's; fifteen percent in some quadrats compared to under five percent elsewhere. These differences must partly be the result of different levels of interference by man in the recent past.

It is also clear that the greatest increases in percentage cover are associated with those species deliberately introduced by man. Cocos nucifera and the ornamentals Terminalia catappa and Casuarina equisetifolia, have spread rapidly into many sites previously occupied by 'native' species such as Tabebuia pallida. While the former two ornamentals can survive in coastal habitats, Gooding et al. (op. cit.) have shown that Tabebuia pallida, Hippomane mancinella and Coccoloba uvifera are more effective agents for trapping and anchoring coastal sands. Furthermore with the onset of erosion, these three halophytes have demonstrated that they are able to survive longer, even with their roots exposed to direct wave attack. The continuing reduction of these natives is therefore likely to impact negatively on the long-term stability of the beaches. There is an increasing tendency towards the spread of weeds and grasses (e.g. Scoparia dulcis, Wadelia trilobata, Emilia coccinea and Cordia curassavica) and a decline in 'woody' plants. It is known that this tendency is usually evident at 'disturbed' sites where human interference is marked (Elton 1958; Harris 1962; Gooding et al. 1965). In the present case, highly disturbed sites such as Rockley and Holetown support this view. The incursion of these species therefore reflects the impact of continuing human pressure on the littoral.

SUMMARY

It is evident that most parts of the littoral have undergone noticeable change particularly in the last three decades. With a shift in emphasis in land use from agriculture to tourism, increasing human pressure became exerted on the coast. It has been shown that the number of tourist establishments grew by nearly 5000 percent during the period 1950 -1980. In addition the number of private residences and cottages increased to the extent that approximately 50 percent of all land along the leeward coast is now used for tourism and housing.

While beach accretion occurred at a few sites, notably at Needham's Point and Enterprise (former Coast Guard Station), beach erosion became more widespread. It has been shown that there were also increases in beachrock exposure along the west and south coasts. Significantly, the greatest increases occurred at Gravesend, Welches and Batts Rock where maximum beach erosion was recorded. Research elsewhere has shown that beachrock exposure is normally a reliable indicator of active beach recession. Simultaneously the coastal vegetation continued to be altered, not so much in number of species as much as the extent of their presence. With the increase in construction which accompanied tourism expansion, further land clearance continued. As a result some of the distinctive vegetation zones earlier identified by Randall (1968) contracted and others disappeared altogether.

These and other changes identified during the post-settlement period are important because of the impacts (real and potential) which they may generate on the quality of coastal amenity. An assessment of the significance of these changes will therefore be the subject of the next chapter.

CHAPTER 6

SIGNIFICANCE OF COASTAL CHANGES

So far a variety of coastal changes both natural and man-induced, have been documented, and some of the effects discussed. However because of their implications for the development and management of the coastal zone, it is necessary to analyse their overall significance within the context of environmental impact assessment . In so doing, one might achieve a clearer perspective on some possible cause-effect relationships, the recognition of which would be invaluable for future coastal resource planning.

Implications of Beach Changes

It would be generally true to say that beach recession on the west coast has been quantitatively small. The period for which the most accurate data exist (1950 - present), indicates that the average recession rate does not exceed 0.2 m/yr^{-1} for any beach.[1] Nevertheless because most leeward coast beaches are narrow, losses of even this limited magnitude must be viewed with some concern.

With the exception of those areas which were deliberately built up by man's intervention,[2] the island's

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1. This would be considered insignificant when compared with rates elsewhere. For instance, sections of the Florida and California coasts receded by amounts greater than 1.5 m/yr^{-1} and 2.3 m/yr^{-1} respectively, during roughly the same period (Kuhn and Shepard, 1979; Campbell and Spadoni, 1982). Since 1950 the Yorkshire coast of England has been retreating by more than 1.8 m/yr^{-1} (King, 1972); while the north coast of Japan is reported to have retrograded by 5.5 m/yr^{-1} between 1940 and 1975 (Horikawa, 1978).

2. For example Coast Guard and Hilton Beaches, which are 35.5 m and 45 m wide, respectively.

beaches generally do no exceed 12.0m. In addition, deposits of sediment on these beaches are relatively shallow varying between 2.0 and 3.0 m (Bird 1977:41). The sediment is underlain by coral rubble, and in some cases beach rock in varying stages of maturity. These have been exposed at the surface on many beaches, where scour has been the dominant force at work (Refer to figures 26 and 28). Given the width of the beaches and the shallowness of sediment, quantitatively small changes often have disproportionately great effects. The problem is clearly manifested where coastal defence works such as groynes are erected. These can function as sinks in the sediment budget of downcast beaches, causing overall net losses. The obvious visible deterioration in quality of amentity at Gravesend, Folkestone and Hastings, is partly the result of such interference. Here modest reductions in sediment, between 3,000 - 5,000 m^3 , have been sufficient to produce coral rubble and beach rock exposures during the last 7-8 years.[1] Even on the island's east coast (e.g. Walker's, Lakes, Morgan Lewis) where the depth of sediment is >5.0 m and beach width greater than 30.0 m, losses of this magnitude would not produce such striking effects. This has obvious implications for any beach management scheme which the Government may wish to initiate. It demonstrates that for most leeward coast beaches, any action which alters the sediment regime even slightly, over an extended

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1. Parks and Beaches Commission estimates.

period, could be disastrous for the beaches.

Effects of Construction in the Active Beach Zone

Serious concerns over beach erosion in Barbados are quite recent, dating back to just over a decade. Yet beach recession of an order comparable to what is presently being experienced, has been occurring since 1900. In reality, beach erosion is only perceived as a problem when permanently fixed property and other installations are threatened. On the Barbados coast, the large-scale construction of residences and tourist accommodation mostly post-dates 1960. The failure to recognize the existence of a naturally fluctuating coastline led to construction seaward of the mean high water mark, and in some cases on the berm. This meant a diminution in the buffering effect of the beach, as there is now a reduced surface area for dissipation and absorption of wave energy. The result has been increased beach scour in some areas and property damage.

Many such cases are well documented in the literature. One such example, the Florida case study, has already been considered in chapter 1. Recently Gonen (1981) has shown how rapid coastal development in Spain and North Africa led to the destruction of numerous beaches, pollution of coastal waters and vegetation clearance. In the United States Virgin Islands where tourist facilities have been built on 90% of the beaches, lagoon reclamation and construction "...threatens to induce further environmental decay on the entire southwestern coast" (McEachern and Towle, 1972:155). Similarly, Omholt (1980) provides a vivid account of erosion on the shores of Long Island Sound, as a result of man-induced changes in the beach sediment budgets.

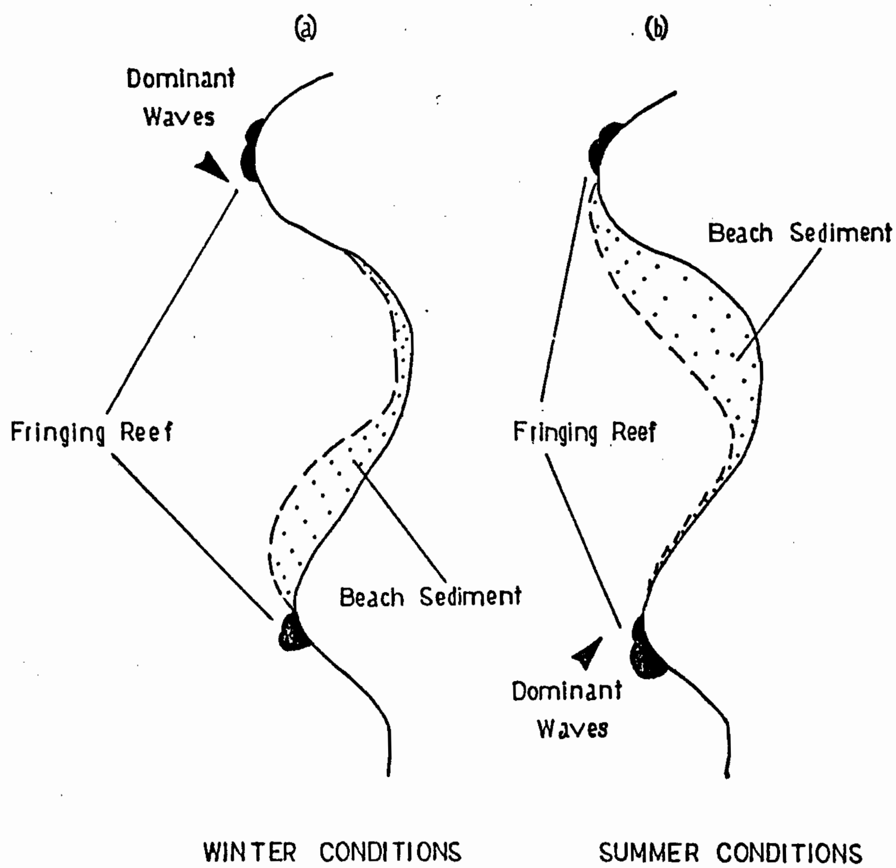
The impact of construction within the active beach zone becomes more significant when it is considered that nearly one-third of all structures have been placed in the most sensitive areas of the beach. The headlands and limbs of the beach cells experience the greatest annual sediment changes (Bird, 1977). Refracted energy is more concentrated at these points, resulting in greater shifts of sediment from these sections of the cells. During the 'winter' part of the year when dominant wave energy arrives from the northwest, the shift of sediment manifests itself as pronounced erosion at the north end of the cell, and accretion at the south limb. In summer when the dominant waves are from the southwest, the southern limb of the cell in turn experiences temporary sand loss, while accretion occurs at the north limb (Ibid). These changes simply represent an equilibrium beach, adjusting seasonally to changes in the wave energy regime (Figure 34).

Construction near the northern and southern headlands has gradually upset this delicate balance. Now in some cells (e.g. Gibbs, Holetown, Freshwater Bay) while the cyclical rhythm is still noticeable, there is evidence for permanent loss of the sediment to the offshore zone.

Figure 34

SEASONAL BEACH CHANGES — WEST COAST

AS DESCRIBED BY RICHARDS AND BIRD (1970)



For explanation see text.

Unless the trend reverses, these leeward coast beaches are likely to continue contracting until a new equilibrium is reached. Depending on how long this takes, significant portions of the beach could be lost in the process.

A healthy beach environment has been shown to be a key consideration in tourists' decision to visit the island. In 1981 the Caribbean Tourism Research Centre undertook the North American Demand Study for Caribbean Tourism. Results indicate that "when selecting their accommodation, travellers to Barbados are more interested in a place on the beach and expressed less interest in the availability of sports activities and night life" (Vol. 3, p. 31). Moreover, approximately 86% of the tourists coming to Barbados identified 'beach activities' as the single most important attraction (Vol. 3, p. 28). These findings are confirmed by the Coastal Conservation Project (1984). The assumption must therefore be made that continual beach loss will adversely affect tourists' perception of Barbados as a holiday destination.

Increased Vulnerability of the Beaches to Storms

The change in land use on the coast from agriculture to tourism led to uncontrolled construction of properties. As noted above, 33% of the building has occurred near the unstable parts of the beach. Field research undertaken by the writer in 1981 indicates that another 40% of the remaining property is located within 2.0 - 5.0 m of the 'normal' mean high water mark. This renders 73% of all leeward coast property highly vulnerable to any unusual geophysical event, such as a hurricane or heavy storm surge. So far in this century the island has been fortunate to escape the effects of hurricanes, except 'Janet' in 1955. Even then the hurricane passed so quickly that it did not cause permanent damage to the beaches. However there is a very real possibility that the island can be struck by an intense, fully developed hurricane in any one season. Contrary to the belief of many property owners and locals, Barbados lies well within the main Caribbean hurricane tracks. Probability calculations indicate that the island can expect to be affected by a hurricane once every 26 years (Admiralty Pilot Chart, No. 71, 1961). If such an event were to occur, roughly three quarters of all west and south coast property would be at serious risk.

Calculations by Deane et al. (1973) have also shown that on average, wave heights on the west and south coast are less than 1.0 m. Projections are that waves between 2.5 - 3.5 m could give rise to long-term beach modification, and considerable property damage (Ibid). In August 1979 hurricane 'David' with sustained winds > 240 km/hr (150 m.p.h.) left many eastern Caribbean islands officially declared as 'disaster areas'. Reports from the National Hurricane Tracking Centre in Miami indicate that waves > 5.0 m were recorded. If such conditions were experienced at Barbados and were coincident with astronomical high tide, considerable damage would have resulted.

Evidence from other densely settled beach front areas shows that when even moderately strong hurricanes coincide with high tide, one can expect almost total destruction of property (Tanner 1961; Warnke 1966; Schramm et al. 1980). Such experiences emphasize the importance of maintaining adequate building set-back limits, in order to minimize damage when events of this nature occur. An adequate set-back would ensure greater protection for coastal property and a more stable beach.

Some Consequences of Deforestation

A variety of changes in the coastal flora have been traced from early settlement up to the present. However in terms of coastal stability, two of the most significant changes involved the elimination of the important Hippomane - Coccoloba association and the disappearance of mangroves.

It was demonstrated in previous chapters that these species formed one of the most widespread associations anywhere on the coast. Ecological evidence indicates that Hippomane and Coccoloba were ideally suited to the sandy, saline conditions of the coast (Hughes 1750; Hardy 1934; Gooding et al. 1965). Furthermore, they were able to coexist in the same habitats without significantly affecting each other's range (Hughes, Op. cit.). Today only small remnants of this association remain as a result of deliberate clearance by man over the last three centuries.

In terms of their functional utility, both Coccoloba and Hippomane can survive relatively long periods with their roots exposed. This is especially important during periods of temporary beach recession, when available beach sediment is reduced. Hence they are important in that they can help to stabilise beach sands (Hardy 1934). Their removal would therefore have led to increased susceptibility of the beaches to scour.

The disappearance of mangroves from the island's shoreline is of environmental significance. Mangroves are essentially halophytic and well adapted to tropical coastal environments. It is well documented that their presence has a stabilising influence on tropical shorelines, primarily because of their ability to trap large quantities of sediment (Richards 1952; Eyre 1968; Polunin, op.cit.). To this extent, they provide over several years, an additional reservoir of sediment for the natural beach-building process.[1]

There is evidence that mangroves once existed at 11 locations along the west and south coasts (Refer to figure 6). Practically all the mangroves have vanished, except for patches at Graeme Hall and Holetown. Of the 4 species for which there is definite proof of existence, only two are now present on the island (*Rhizophora mangle* and *Conocarpus erectus*). The draining of the swamps and the removal of the mangroves would thus have deprived some sections of the coast of a vital source of sediment. In turn this would have altered the littoral sediment budget and

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1. This is true at Graeme Hall, where sediment from the swamp is a source of nourishment for the beach.

increase the likelihood of beach recession.

It should be borne in mind that the island's beaches undergo changes not only from marine processes, but also from terrestrial forces (Bird 1977: 35). In the latter case, runoff after heavy summer rainstorms can modify the beach profile. The permanence of such profile changes depends on the intensity ot the runoff. The presence of vegetation helps to retard the rate of runoff and the amount of erosion possible over any surface area (Schumm 1977: 86). It is therefore clear that the overall reduction in vegetation from the island's shoreline, would increase the possibility of scour on the beaches.

The importance of maintaining a vegetation cover cannot be overstated. Maintainance of the littoral vegetation has long been acknowledged as essential for comprehensive coastal zone management (Oosting 1954; Beach Erosion Board 1957; U.S. Army Corps of Engineers 1977; Burk et al. 1981). It is imperative that indiscriminate clearance of the little vegetation which remains, be halted. At the same time Government should look into the feasibility of implementing afforestation schemes along appropriate sections of the coast. Although it is unlikely that the full effects of this strategy will be felt in the short-term, its long-term influence on shoreline stability would justify implementaion.

Deterioration of Coastal Water Quality

During the last 10 years or so, much concern has been raised over increasing evidence of marine pollution along the coast. Although there was no systematic water quality sampling prior to 1973, the evidence available suggests that most of the bathing beaches were pollution-free up to about 1970. Periodic monitoring by the Environmental Engineering Unit of the Ministry of Health, shows that micronutrient concentrations and coliform presence were extremely low during the 1960's. On average, total coliform was estimated to be <5 colonies/100 ml.[1]

The only sections of the coast where there was an unacceptable level of pollution was in the vicinity of Carlisle Bay, the Inner Basin and the Careenage (Figure 35). Here pollution levels were so high that the area was becoming a health risk.[2] Since the 1960's conditions in Carlisle Bay have deteriorated with toxic levels of sulphur, nitrate + nitrite, ammonia and phosphorus. In addition oxygen levels have decreased, while the input of solid and particulate waste has increased. Total coliform count often exceeded 11,000 colonies/100 ml. Pollution along this stretch of coastline is well documented by Vezina (1974) and Turnbull (1979).

The World Health Organisation (WHO) determined that coliform count is the single most important indicator of quality for swimming and recreational waters. The WHO

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1. Report by the Senior Public Health Officer to the Minister of Health 1970; and personal communication with M. W. Conliffe, Senior Public Health Engineer, July 1982.

2. Statement made by the Chief Public Health Officer, and quoted in the Advocate-News, August 20, 1968.

suggests that more than 1,000 colonies/100 ml is unsafe (American Public Health Association 1976). The maintenance of healthy beaches is of the greatest significance to Barbados which depends so heavily on the tourist industry. Ironically, the expansion of tourism itself, has led to an increase in the amount of domestic sewage and waste disposal at the coast. In turn this has caused some deterioration at recreation sites, although for the most part, most beaches are safe by WHO standards. The Ministry of Health attributes much of the deterioration of coastal waters to the discharge of effluent from hotels and other tourist accommodations, < 5% of which have sewage treatment plants.[1]

From the limited samples taken at 12 sites, coliform concentrations tended to be higher in successive years from 1979 to 1982 (Figure 35 and Appendix 2). Data for the years 1979-81 were supplied by the Ministry of Health. The 1982 data were obtained from two sets of field samples taken on July 12 and 19, 1982. Autoclaved sampling bottles were provided by the Government Laboratory, who also conducted the microbiological analysis.

The graphs (Figure 36) demonstrates that with the exception of one site (Ocean View), there has been a noticeable upward trend. Although only 2 sites (Hilton and Esplanade) do not meet WHO standards, the general trend reflected should be a cause for concern. Increases in this range of magnitude were reported during the 1960's along

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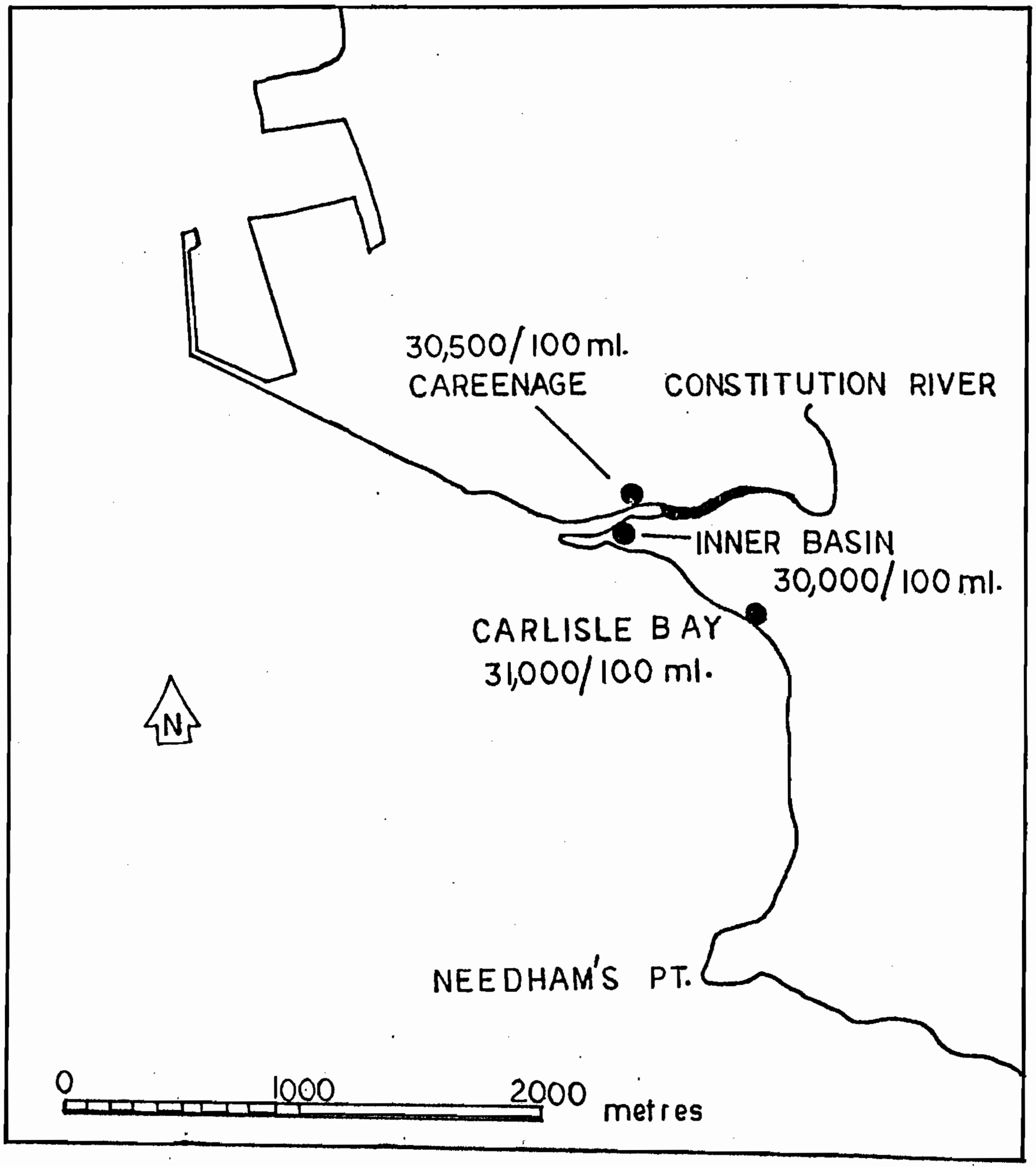
1. Report of the Senior Public Health Engineer, November 1981.

Figure 35

TOTAL VIABLE COLIFORM COUNT AT THREE SITES



Source: Ministry of Health, Barbados.

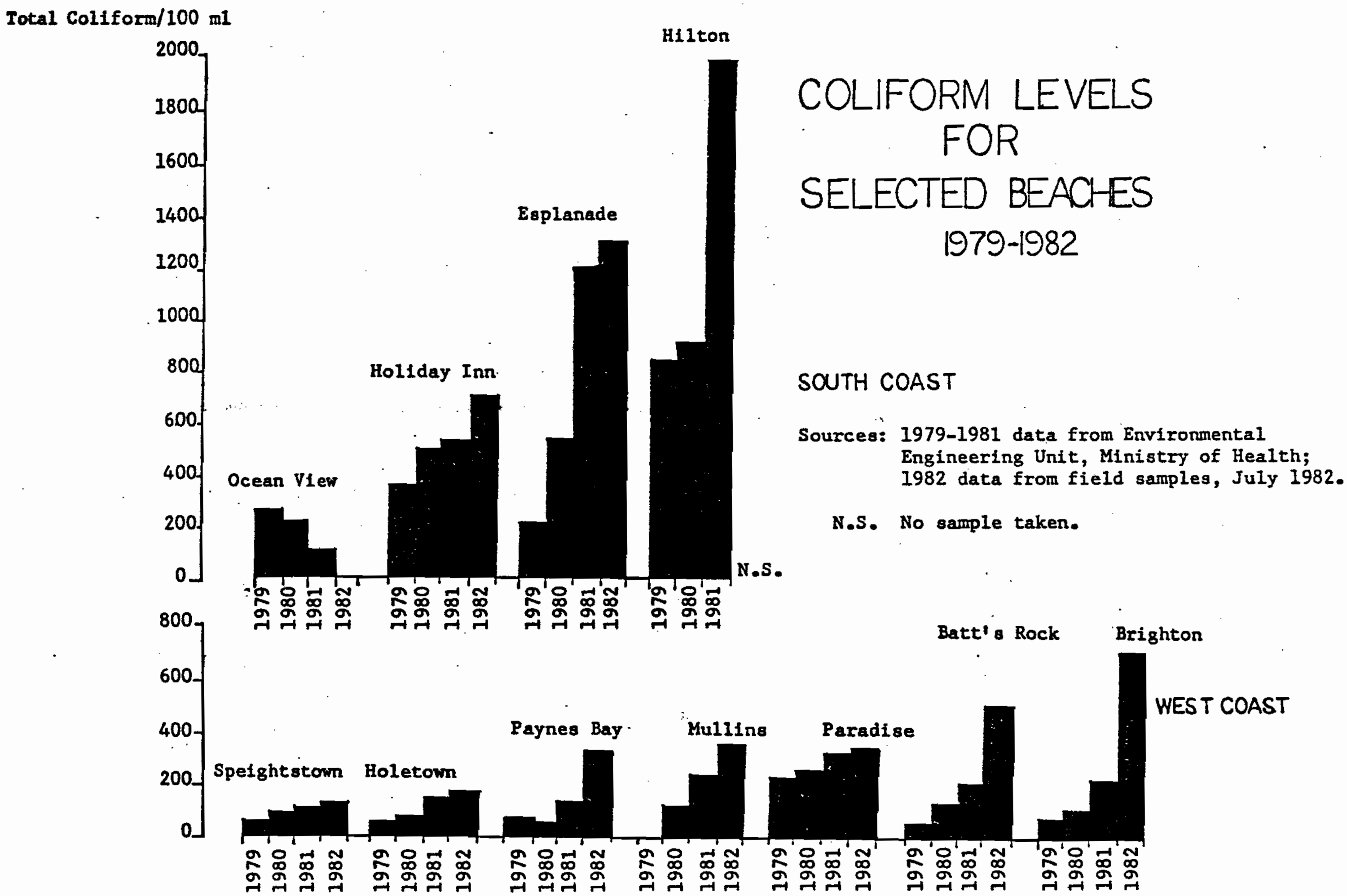

COLIFORM LEVELS FOR SELECTED BEACHES 1979-1982
Total Coliform/100 ml
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Ocean View
Holiday Inn
Esplanade
Hilton
N.S.
1979
1980
1981
1982
SOUTH COAST
Sources: 1979-1981 data from Environmental Engineering Unit, Ministry of Health; 1982 data from field samples, July 1982.
N.S. No sample taken.
800
600
400
200
0
Speightstown
Holetown
Paynes Bay
Mullins
Paradise
Batt's Rock
Brighton
WEST COAST

Figure 36

the Jamaica north coast, from Montego Bay to Ocho Rios (Barnes 1973). By 1972, bacterial counts 16 times greater than WHO regulations, were recorded in the vicinity of some hotels. This problem resulted from the dumping of domestic waste from a rapidly expanding tourist area (Barnes, op. cit.: 104). Similar levels of water quality deterioration occurred along the Melbourne coast of Australia, in the early 1970's. As a result many of the most popular beaches had to be closed for an extended period.

The lesson to be learnt from these experiences is obvious. A healthy marine environment can only be maintained where there is control over development and where standards are enforced. Fortunately, the Barbados coast has not up to this point, experienced the levels of deterioration reported elsewhere. However, if the present trend is not reversed, this must be seen as a distinct possibility in the near future.

<u>Variation in Coliform Levels - West and South Coasts</u>

There is a substantial difference in the level of bacteria on the west and south coasts. The samples were taken in the vicinity of hotel sewage outlets. With the exception of Batts Rock and Brighton (highest counts), all west coast samples came from hotels which had installed small treatment plants within the last 5 years. A search through the files of the Ministry of Health reveals that none of the 6 hotels and guest houses within the Batts Rock - Brighton area have this facility.

On the south-west coast, the Hilton and Holiday Inn have treatment plants. However, an investigation by the Environmental Engineering Unit in 1981, indicates that the two plants can only handle 50-75% of the effluent discharged by these establishments. The sewage from other south coast locations is untreated. The substantially higher levels of coliform on the south coast (Figure 36) reflect the absence of treatment facilities. There is evidently a clear relationship between low coliform concentrations and the presence of treatment plants.

Impact of Pollution on the Coral Reefs

The impact of domestic effluent on reef populations has also been researched (Marshall and Orr 1931; Johannes 1970; Barnes 1973). It has been shown that the presence of bacterial populations, detergents, greases and other domestic waste, can be lethal to certain types of coral. Laboratory tests indicate that healthy specimens of the coral *Montastrea cavernosa* die within 24 hours when exposed to concentrations of Palmolive detergent as low as 0.05% (Barnes, op. cit.: 104). Other species became lethargic and died over longer time periods (Ibid).

The relevance of these findings for the stability of the Barbados coast should not be overlooked. The role of *Montastrea* and other corals in the formation of reefs, has been studied by Lewis (1960). Alteration of their habitat beyond certain ranges of tolerance will have detrimental effects on reef growth. The discharge of untreated effluent (now a widespread practice on the west and south coasts) can lead to such habitat changes. A similar warning was given in 1978 during a seminar sponsored by the Barbados National Trust :

> "The present degree of pollution is having an adverse effect upon the coral reefs, which not only act as a protective barrier against wave energy on the shore, but are also important sources of sand for the beaches."[1]

Dependence on Tourism

The land use changes which occurred particularly since the 1960's, have had a number of social and economic effects as well. One such indirect impact has been the heavy dependence on tourism as a major foreign exchange earner. Gross earnings rose from $Bds. 10.0 million in 1960 to $Bds.80.7 million in 1970, and $Bds.330 million in 1980 (Figure 37). Currently tourism is the leading foreign exchange earner accounting for 40.7% of all receipts from external sources. In addition, each person directly employed by the industry generates approximately $Bds 15,000 annually.[2] Hence labour productivity in this industry is three times higher than in commerce, the next most important sector in terms of dollar output per employee.

Working on the assumption that tourist arrivals (hence earnings) would continue to increase because there was virtually no limit to the market, Government invested

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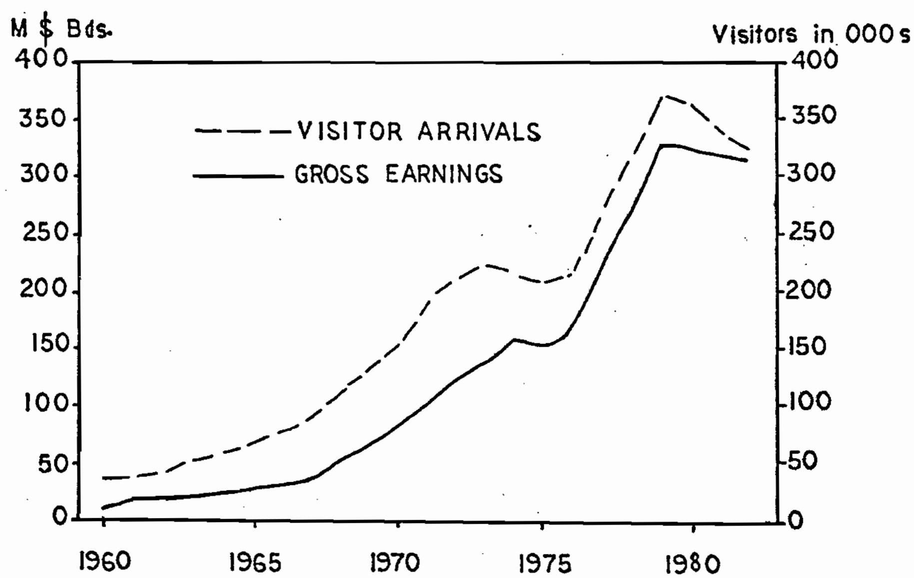
1. Paper by J.B. Lewis at the seminar Planning for 1980 - An environmental Study of Barbados, U.W.I., Cave Hill, Barbados, 1978.

2. Government Statistical Office, 1982 data.

VISITOR ARRIVALS AND GROSS EARNINGS FROM TOURISM 1960-82



Data Sources: Ministry of Tourism, Barbados and Central Bank of Barbados.

Figure 37

heavily in the sector. Consequently, the island's economy became highly vulnerable to downturns in the industry. Such declines can be caused by a variety of factors including changes in tourists' destinations preferences, manipulation of the market place by multinationals and large tour operators, and economic recession in the main markets.

This vulnerability is demonstrated by the recession in the international economy during the years 1973-76. Annual visitor arrivals dropped by an average of 1.7%, with a maximum of 4% reduction in 1975 (Phillips 1982 : 119). Correspondingly, receipts from tourism fell by an annual average rate of 3%. Reductions in visitor arrivals and earnings of roughly the same magnitude occurred in Jamaica, Bermuda, the Bahamas and Antigua.[1] The present worldwide recession has had a similar impact. Since 1979 visitor arrivals have fallen by nearly 12% and dollar earnings by an average 2.4%.[2] In addition nearly 2500 persons have been laid off, representing 35% of all job losses since 1979.[3] Thus dependence on tourism has generated severe economic impacts not only in the coastal zone, but throughout the island as a whole.

Concomitant with the high level of tourist spending during the 1960's and 1970's, there was a marked increase

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1. Caribbean Tourism Research Centre estimates.
2. Central Bank of Barbados statistics.
3. Ministry of Tourism, Research Dept., 1982.

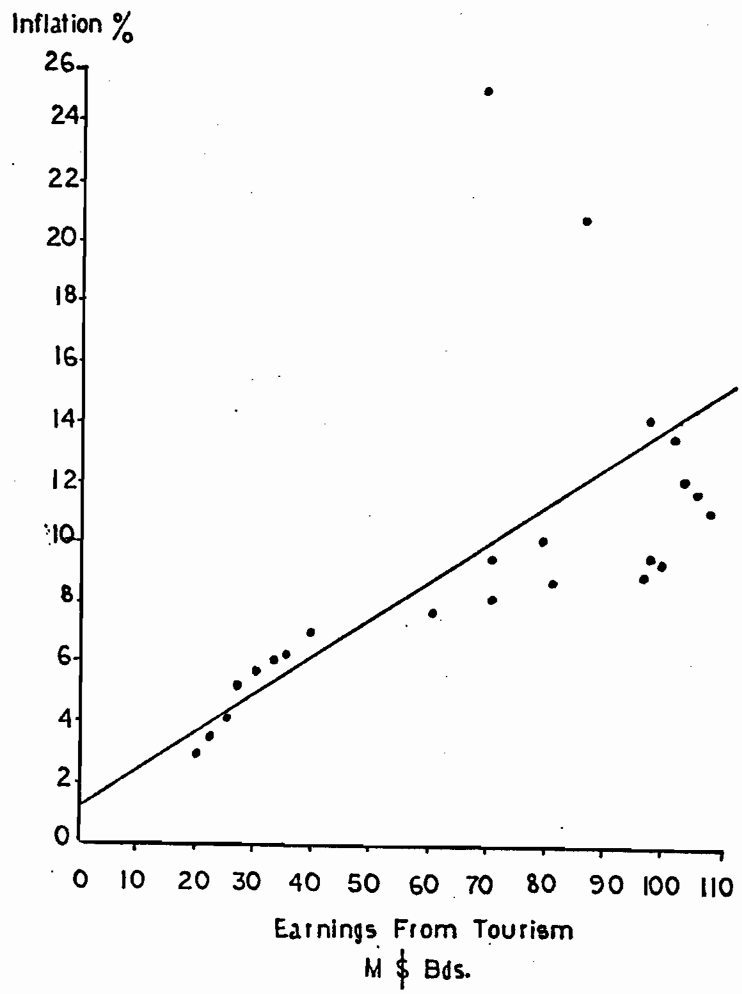
in the level of domestic inflation. Figure 38 and Appendix 3 show a positive correlation between these two variables. The tendency towards high inflation rates had the effect of placing a range of goods and services beyond the reach of many locals. As a result it led to the creation of distinct 'social spaces' particularly in the late 1960's. For instance, there were certain stores, night clubs and restaurants which became known locally as 'tourist spots', because they effectively excluded most locals.

Reduction in Number of Fishing Villages

There are indications that developments along the coast were partly responsible for the demise of certain fishing sites. Historical evidence demonstrates that after the turn of the century, places such as Holetown, Mullins, Freshwater Bay and the area now known as Welches were important bases (Sinckler 1913; Barton 1953). While they did not constitute fishing villages as such, they were used extensively for beaching and repairing boats. The fishermen came mainly from the surrounding tenantries, which developed out of the plantation system. As the coast became built up, operations either shifted location to other areas involved in fishing, or eventually ceased altogether. This situation was disruptive for two reasons. First the inconvenience of moving to other locations meant

Figure 38

RELATIONSHIP BETWEEN EARNINGS FROM TOURISM AND DOMESTIC INFLATION 1960–82



Data source: Central Bank of Barbados.

that fishermen now had to travel longer distances to and from their villages.[1] Secondly, those who for whatever reasons were unwilling to shift to new sites, had to seek alternative employment.

It is not certain how many sites were displaced. However the process almost certainly continued up to at least the mid-1960's. This writer recalls the existence of one such base at Freshwater Bay which disappeared around 1968. Since then Paradise Beach Hotel expanded three times, into what is now a large 334-bed luxury operation. The owners, Cunard Lines, bought additional beach front property, building cottages and guest houses north and south of the main hotel. By erecting enclosures they effectively controlled the beach in the vicinity of the hotel, making it difficult for the fishermen to operate. Most of the displaced fishermen now operate from Fitts Village and Paynes Bay, 2.5 and 3.5 km respectively to the north.

Change in Traditional Access to Beach

One of the most immediate social impacts created by coastal development, was a reduction in the traditional beach access. Access to beaches such as Paradise, Sandy Lane, Worthing and Hastings could only be gained by entry at other points, and then a walk along the beach.

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1. The writer encountered fishermen who now travel between 3.0 and 3.5 km from Trents and Molyneux to Paynes Bay. Previously they operated from Holetown, a distance of only 1.0 and 2.0 km respectively from the two villages. Paynes Bay is the nearest convenient fishing site now that they have been displaced from Holetown.

Eventually local opposition became so great, that in 1966 Parliament gave the Ministry of Lands the neccessary authority to regularise accesses, and create them where they did not exist.

There is now a good system of accesses for locals within the main tourist areas. Nevertheless field research reveals that approximately 35% of them are difficult and inconvenient. Because of the physical layout of some hotels, Government could only negotiate narrow tracks, in some cases no more than 0.6 m (2ft) wide. In such cases entry must be by foot, as no public parking facilities can be provided at these locations. The only other access from the highway would be across private property (e.g. hotels) which constitutes trespass. In 1976 the Town Planning Office stipulated that all new establishments must provide adequate public access to the beach. However by the time this provision was enforced, public access rights had already been violated at some sites.

The rapid development of the coastal zone has produced a range of other impacts. For instance, it has placed the island's water and electricity supplies under severe pressure (Lewsey, 1978). Similarly there has been some alienation of scarce land from other sectors to satisfy the needs of tourism (Barbados Physical Development Plan 1967,1972); but the common significance of all these impacts, is that they demonstrate an urgent need for more comprehensive management of the island's coastal resources.

CHAPTER 7

PROPERTY OWNER RESPONSE TO BEACH CHANGES

As a result of the various changes which occurred, particularly during the last decade, many property owners responded by implementing protection works. Most defences were erected illegally, partly because of Government's tardiness in responding to requests for assistance. Unfortunately, some of these measures were responses to perceived rather than real erosion threats, and have contributed to the deterioration of the beach environment in those localities.

There is a large body of empirical research to support the hypothesis that a person's response to a particular hazard, is largely conditioned by that person's perception of the nature of that hazard (White 1945, 1973; Kates 1962; Burton et al. 1968; Saarinen 1966; Mitchell 1974). It was considered therefore, that some knowledge of property owners' perception of recent shoreline changes, would lead to a better understanding of their response to the phenomenon. Moreover, the results from such a survey would be useful in establishing some meaningful basis for future participation in beach management.

The main objectives of the investigation were to ascertain :

(1) the degree of awareness of the erosion hazard and the perceived magnitude of the phenomenon

(11) the perceived causes of beach scour

(111) the methods used to combat it and

(1V) problems associated with these methods.

METHOD OF SAMPLING : THE SELECTION OF RESPONDENTS

It was decided that only those locations with properties built directly onto the beach or sand terrace, would be included in the survey. This meant that most of the coastal fringe north of Speightstown, as well as points such as Gravesend and Esplanade were excluded. In addition, places where major restoration or development projects had occurred, drastically altering the configuration of the beach were ignored. Locations such as Needham's Point, Coast Guard Station and Oistin, were therefore excluded.

Those sites where measurements of beach width were taken, were used as a basis in the selection of respondents (See Chapter 5). This decision was taken because it was imperative to have some reliable measure of actual beach change, against which to assess the relative accuracy of what respondents perceived. On the basis of the above criteria, 22 of the 39 locations were retained; 12 on the west coast and 10 on the south coast.

A questionnaire was prepared and mailed, with a self-addressed return envelope to two (2) respondents at each of the twenty-two (22) sites. Each property selected was in close proximity to the point where measurements of beach width were taken. In most cases, the measurements had been taken in front of the properties themselves. Of the forty-four (44) property owners interviewed, thirty-seven (37) returned completed questionnaires. However six (6) of these were discarded since the respondents had only been occupying the properties for periods $\leqslant$ 5 years. Since the purpose of the survey was to assess perception of changes over the previous decade, it was thought that such short periods of occupancy could not yield reliable responses. The analysis which follows is therefore based on a 70% response. A copy of the questionnaire is given in Appendix 4.

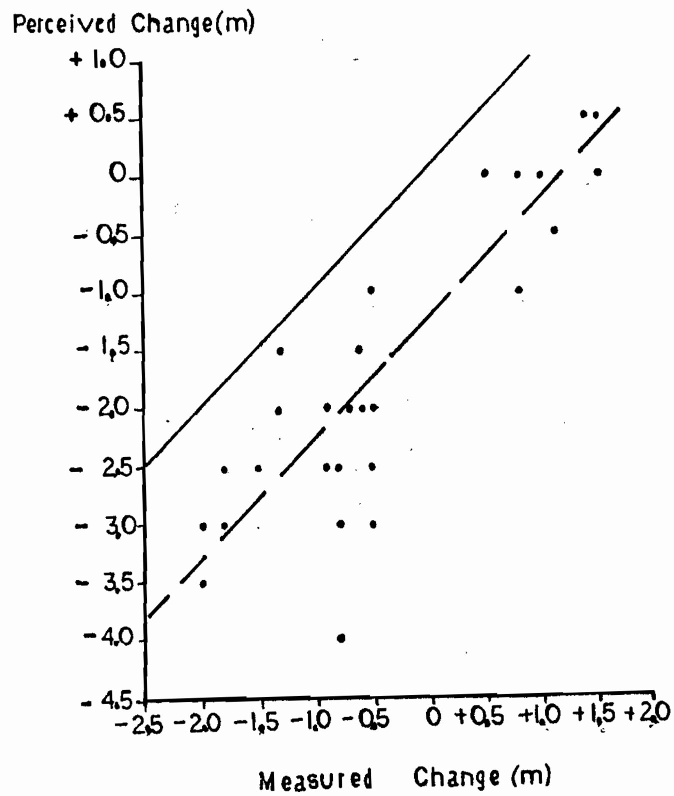
RESULTS AND DISCUSSION

Respondents' Awareness of Coastal Changes

Generally speaking, the survey results indicate a high level of awareness of changes occurring since 1972. Of all respondents 87% accurately recalled there being either scour or accretion near their properties. In fact, in the 13% of cases where owner's perception appeared to be at variance with reality, only small quantitative changes were involved (Appendix 5).

However, although owners were for the most part accurate in what they perceived to be the direction of change, there was a consistent error in their estimate of the magnitude of change. Figure 39 is a scattergram illustrating the relationship between actual (measured) and perceived change in beach width for all locations. It is evident from the diagram that respondents in practically all cases, overestimated the amount of erosion that occurred. In most instances, the discrepancy varied between 1.0 and 1.5 m, but in one case it exceeded 3.0 m.

Figure 39



RELATIONSHIP BETWEEN MEASURED AND PERCEIVED CHANGE IN BEACH WIDTH

N.B. The solid line represents a perfect correlation; the broken line is the actual correlation. The difference suggest that respondents generally overestimate beach loss.

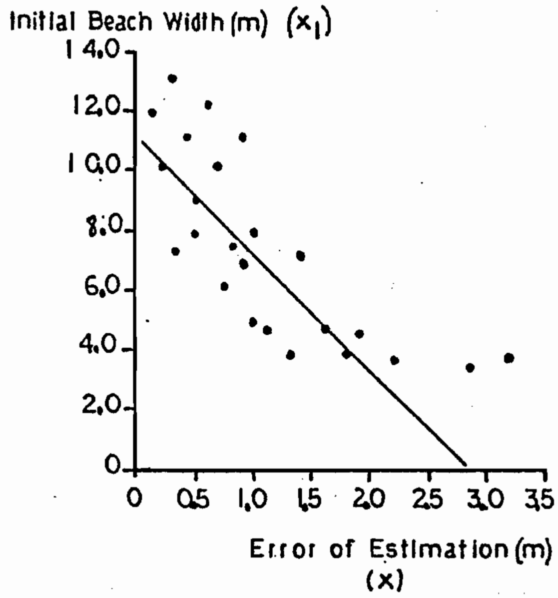
Data from field measurements, aerial photographs and questionnaire.

Having thus perceived beach scour to be greater than it really was, it is not surprising that so many property owners built coastal defences during the last decade or so.

At the same time, there is the tendency to underestimate accretion when it occurs, as is also demonstrated in Figure 40. Although accretion has been recorded at six (6) of the locations since 1973, only two (2) of these beaches were perceived as having widened. Three beaches which expanded by amounts > 0.5 m were described by property owners as 'stable'; while two others (Dover west and south) were perceived to have receded by between 0.5 and 1.0 m. This has serious implications for beach management; for in many cases, owners relying on their own judgement, have erected unwarranted protection works, which have affected the distribution of sediment within certain beach cells. It should be noted that even in the three cases where the beach was viewed as being stable, owners still adopted structural measures against property damage. The general view expressed by these owners, is that they have responded to what they expect will be the direction of longer-term change. Hence the defences are an early precaution against such an eventuality.

These findings are similar to the results obtained by workers such as Tuan (1971), Lowenthal (1972) and Burton and Kates (1964). They demonstrated that response to a hazard is primarily conditioned by one's personal perception of that hazard. Hence even though a particular

Figure 40



RELATIONSHIP BETWEEN ERROR OF ESTIMATION

AND INITIAL BEACH WIDTH

(Data from aerial photographs and questionnaire).

response might appear unwarranted when all available information is assembled, that response may be quite consistent with the individual's own perception (Kates 1962). The tendency for Barbadian property owners to underestimate accretion and overestimate erosion is also more consistent with findings reported elsewhere. By so doing, they can more easily justify the action they have taken in the face of the perceived threat (See White 1958; Burton 1968; Saarinen 1974).

Factors Affecting Owners' Perception of Erosion

Closer analysis would seem to suggest that a negative relationship exists between the error of estimation (x), and initial beach width (x_1)[1] (Figure 40). In other words, the wider the beach the smaller the discrepancy between perceived and actual beach scour. This may well be explained if it is hypothesized that any given magnitude of recession on an already narrow beach, is likely to be judged more threatening than on a wider beach. Consequently, it would be reasonable to expect a greater tendency to overestimate beach loss among property owners with narrow beaches. Similarly Figure 41 suggests that the longer the Period of residence at a given location (x_2), the more accurately do property owners estimate beach loss.

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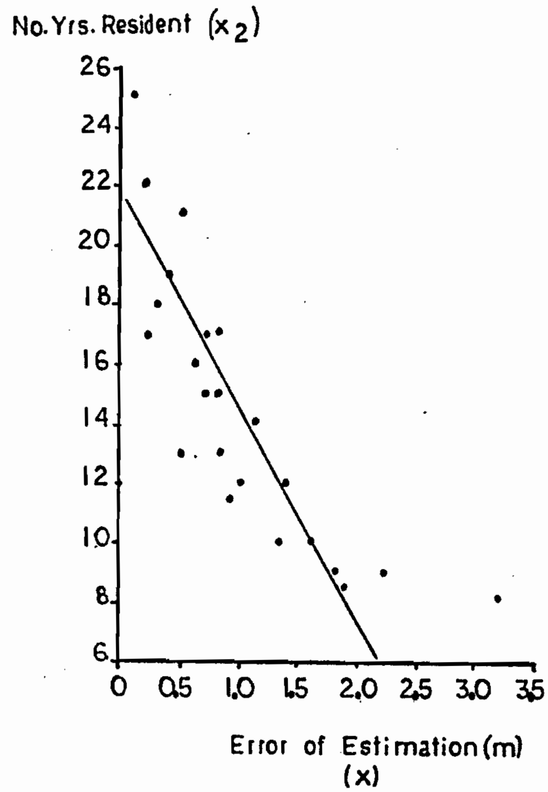
1. This refers to the width of the beach in 1973, as determined from aerial photographs.

Figure 41



RELATIONSHIP BETWEEN ERROR OF ESTIMATION AND NUMBER OF YEARS RESIDENT

(Data from aerial photographs and questionnaire).

It is not intended to suggest that these are the only important factors. Nevertheless they seem to be significant, if only statistically, in helping to explain the degree of accuracy of respondents' perception of erosion magnitude.

This type of investigation could prove valuable to future research and planning. There are stretches of the island's coast for which no beach measurements exist, and the photographic coverage is not always sufficiently detailed to provide reliable estimates on its own (e.g. Bathsheba coast). If coastal residents can be effectively screened according to various relevant criteria (e.g. familiarity with the area), they could become important data sources. In this way it might be possible to fill 'data gaps' which now exist, once the limits of statistical reliability are acknowledged.

<u>Adjustment to Perceived Erosion Threat</u>

Altogether 68% of the property owners surveyed resorted to at least one method of coastal defence during the last ten years. Among the other respondents 16% sought professional advice (i.e. from engineers or construction companies), and 10% requested government assistance (Table 12). The action taken by the owners may be seen as a clear indication of the seriousness with which they view the problem. This being the case, it is not surprising to find segments of the coast (e.g. Welches - St. Lawrence; Rockley - Hastings), where nearly all owners have deemed it necessary to erect defences.

It should be of immediate concern to Government that 35% of the respondents said they intend to take further action in the future.[1] Whether this means additional installations or extensions to existing ones, there is a real possibility that other negative impacts will result. In addition only 10% of the owners regard erosion as posing no immediate threat; but 18% consider it to be 'very serious', while another 32% think erosion is a serious threat (Table 13).

It has already been established that an individual's response to a hazard is strongly influenced by the way he perceives that threat, which may often be at variance with reality. The data in Tables 13 and 14 were plotted according to actual beach changes, and some of these discrepancies became evident (Figure 42). For instance 9% of the respondents are from locations which have been experiencing the greatest net accretion since 1972 (1.5 m), yet more than half of these owners built sea defences. Similarly, in areas where there was moderate progradation over the last ten years (+0.6 - + 1.4 m), half of the owners erected structures on the beach, while as many as 28% thought erosion to be a serious problem, which was

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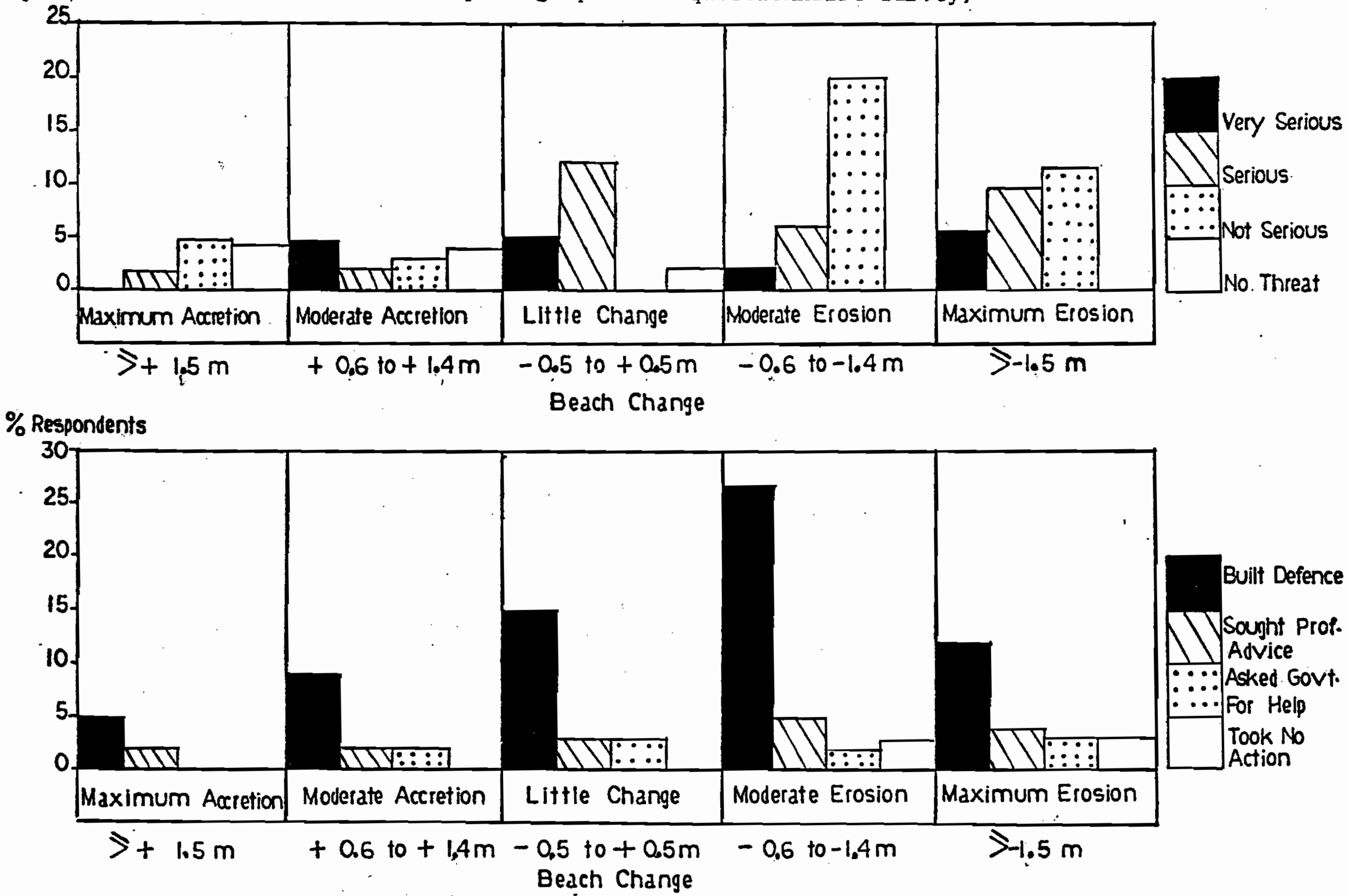
1. Another 48% were 'not sure', while only 17% said definitely they would take no further action.

Figure 42

RELATIONSHIP BETWEEN ACTUAL BEACH CHANGE, RESPONDENTS' PERCEPTION OF EROSION THREAT, AND STRATEGY ADOPTED

(Sources: aerial photographs and questionnaire survey)



clearly not the case. This being so, there is no reason to presume that Barbadian property owners will cease erecting structures of their own accord.

Table 12

Strategy Adopted by Property Owners

Action Taken	No.	%
Built defence	21	68
Sought professional advice	5	16
Asked Government for help	3	10
Took no action at all	2	6

Table 13

Respondents' Perception of Erosion Threat

Erosion Perceived As:	% Respondents
Very serious	18
Serious	32
Not serious	40
No threat	10

Meanwhile, 52% of all owners taking positive action (35% survey sample), undertook construction work at least twice during the period under study (Table 14). The effects of this unplanned increase in coastal defences have been brought to Government's attention. In an attempt to deal with the problem, Government has now made it clear that legal action will be taken against persons building structures illegally along any section of the Barbados coastline.[1]

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1. This warning was given by the Minister responsible for the Environment in a message to mark World Environment Day, June 6, 1982. The full text of the address is reported in the Nation newspaper, June 7, 1982.

Table 14

Number of Times Owners Erected Coastal Defences

Undertook Construction	No. of Owners	% Survey Sample	% Owners Who Built Defences
Once only	10	32	48
Twice	6	20	29
Three Times	3	10	14
Four Times	2	6	9
Total	21	68	100

Reasons Given as Justification for Response

In order to understand what motivated owners to erect coastal defences, respondents were asked why they took protective action. Slightly more than half of the respondents cited the 'amount' or 'extent' of 'erosion' or 'sand loss' as a valid reason for their action. The tendency for individuals to overestimate beach recession has been noted. Hence, perceiving the situation to be worse than it is, this becomes a predictable response. Clearly in their own judgement, their assessment of the magnitude of beach loss vindicates their action.

The responses from the remaining 45% provide further reason for concern. 25% gave as their reason, the fact that adjacent owners had previously built defences. This group evidently interpreted this as indicative of certain erosion, and consequently followed suit. This 'demonstration effect' must therefore be seen as supportive of an earlier contention, that action is often taken when there is little justification for doing so. Another 15% view their action as 'precautionary' in the event that the problem should worsen. Local experience has shown that a number of these so-called precautionary measures either themselves create the anticipated situation, or magnify existing problems.

The series of groynes built along the Dover Coast in the last four years are a case in point. This is one of the few places on the south coast where long-term net accretion has been occurring. While these groynes have trapped additional sediment at Dover, they have contributed to the beach erosion now being experienced 'downcoast' at St. Lawrence, Worthing and Rockley. At present these three beaches are the fastest receding sections of the south coast; they have experienced losses of approximately 1.5, 1.8, and 2.4 m respectively, since 1973.

The action taken by property owners is consistent with responses given regarding their assessment of whether the beach changes are temporary or permanent. Approximately 59% indicated that most of the observed changes appeared to be permanent, 26% described them as temporary, while the other 15% were not sure. It will be recalled that 68% of the owners built defences, some 9% more than the number of persons describing the changes as permanent. These responses indicate that some owners erect defences even when they reasonably expect the beach to recover. This reinforces the point earlier made, that structural measures are often implemented without any sound reason for doing so.

Approximately 47% of the respondents who built defences recalled specific events which influenced their decision. 'High seas' (Hastings, February 1974), 'severe wave action' (Holetown, January 1978), 'excessive sand loss' (Folkestone, July 1979), and 'heavy rains' (Paynes Bay, August 1980) are a few examples. It is clear that such unusual, sudden phenomena trigger a positive response from property owners; but these effects are usually temporary. In some cases the beaches build back by natural processes in a matter of days (Deane et al.1973). In essence, premature action could thwart the recovery process, and may even render the initial effect 'permanent' (locally).

Significantly only one-quarter of the respondents recognize the bulk of the changes to be temporary. Previous work has demonstrated definite seasonal, and other short-term shifts and or imbalances, in the sediment budget of south and west coast beaches. Richards and Bird (1970) have shown that on the west coast, there is temporary seasonal erosion at the north and south limbs of the beach cells (winter and summer respectively). However there is no material sand loss, as the sediment shifts backward and forward in response to annual cyclical changes in wave energy direction (Refer to chapter 6 and figure 34 for a fuller explanation of the process). Similarly, most south coast beaches experience seasonal sand loss on account of increased wave energy between June and November. Normally the beaches recover within weeks thereafter (Deane et al., 1973, op. cit.).

Yet the fact that only 26% of the owners recognize these temporary changes, means that most of them are likely to continue responding in a manner detrimental to the beaches. The implications for any comprehensive beach management scheme should be obvious. The Government will have to make property owners far more aware of basic coastal processes, if the effects of unwarranted action are to minimised.

Types of Sea Defences Adopted by Property Owners

With few exceptions, property owners in Barbados rely on structural remedies. Four types of defences are popular: groynes, concrete retaining walls, coral rubble and gabion revetments.[1] Field observations reveal that about 2 in 5 owners employ a combination of measures, rather than rely on a single structure. For example, retaining walls at the seaward extremity of the property combined with coral boulders or gabions at the base of the wall, are most frequently used. Table 15 summarises the relative frequency with which various structures are used. It shows the importance of coral rubble as a viable option. A field survey of all west and south coast built-up locations was undertaken during the summer of 1982. The results of

1. These are rectangular wire-mesh baskets, which are tightly packed with stones of various sizes.

that survey indicate that approximately 35% of all defences are of this type. This figure is not substantially different from the percentage response given by the questionnaire survey; and therefore suggests that the questionnaire responses are representative in this respect. The other defences are used with roughly the same degree of frequency, which is also supported by field observations (Refer to Table 15).

Table 15

Relative Frequency of Coastal Defences, Based on Questionnaire Responses and Field Survey

Type of Defence	Questionnaire Response (%)	Field Survey (%)
Coral Boulders	32	35
Gabions	21	18
Groynes	20	20
Retaining Walls	24	25
Other	3	2
Total	100	100

The rising popularity of coral rubble defences seems to be influenced by the factor of cost. On avereage, these may cost between $Bds 2000 - 4000[1], though the figures vary depending on the source and size of the boulders and the distance they have to be transported. Furthermore, a number of owners reduce this cost by adopting a 'do-it-yourself' approach, rather than seeking the costly expertise of an engineering or construction company. In

1. Based on data supplied by individual property owners. It would seem that only in cases which require extensive work (e.g. Paradise and Cobblers Cove Hotels), would these figures be substantially exceeded.

comparison, groynes, gabions and retaining walls require far more technical advice to ensure a minimun level of effectiveness. Hence their low cost and relative ease of installation, make rubble revetments an attractive option.

Nevertheless most property owners recognize that rubble revetments are not necessarily the most efficient means of shore protection at their disposal. Respondents were asked to give their opinion as to the most effective method(s) of coastal protection. If more than one answer was given owners were requested to rank them in order of effectiveness. Of the respondents 71% (including those who did not build defences) believed groynes afforded the best protection, whereas only 15% expressed similar confidence in rubble revetments. Although the responses may seem contradictory at first, they can be reconciled by the same 'cost factor' discussed above. This view is supported by Marshall (1982) and Burton et al. (1978) who suggest that practical considerations such as economics may affect the final decision, in choice of adjustment to hazard. For it appears to be the only logical reason why owners would resort to a measure which, in their perception, is less effective.

Problems Associated With Defences

Groynes

While it is true that some measures have functioned efficiently, many others have had undesirable effects on the island's beaches. The effect of groynes on 'downcoast' locations is well documented, and throughout this thesis examples from the Barbados coast have been highlighted. Figure 43 illustrates the effect of a groyne on the coast. The structure disrupts the movement of sediment trapping it on the 'updrift'side (Figure 43 (a)). Since the source of sediment is cut off, scour will occur downcoast. It is only when the groyne 'fills out' on the updrift side, that sediment will move further alongshore (Figure 43 (b)). This could happen in a few months, or it may take years, depending on the rate of littoral drift, and the amount of sediment available for transport. In Barbados there are sections of the coast where very little sediment moves alongshore. The Hastings coast is one such example (Deane et al., op. cit.). A poorly executed groyne could therefore impose long-lasting, if not 'permanent' erosion here.

For this reason, groynes should not be built in piecemeal fashion, but on a systematic basis (Lillevang, 1966; U.S. Army Corps of Engineers, 1977). Furthermore, when establishing such a 'groyne field', only those structures at the downcoast end should be built initially. This procedure recognizes the fact that no downdrift structure can be filled until all the preceding updrift ones fill out. Only when artificial filling is being contemplated, should all groynes be erected simultaneously. On the west and south coast of Barbados, groynes are not planned in this way. Consequently, many serve no practical purpose, as there is no sediment available to fill them.

Figure 43

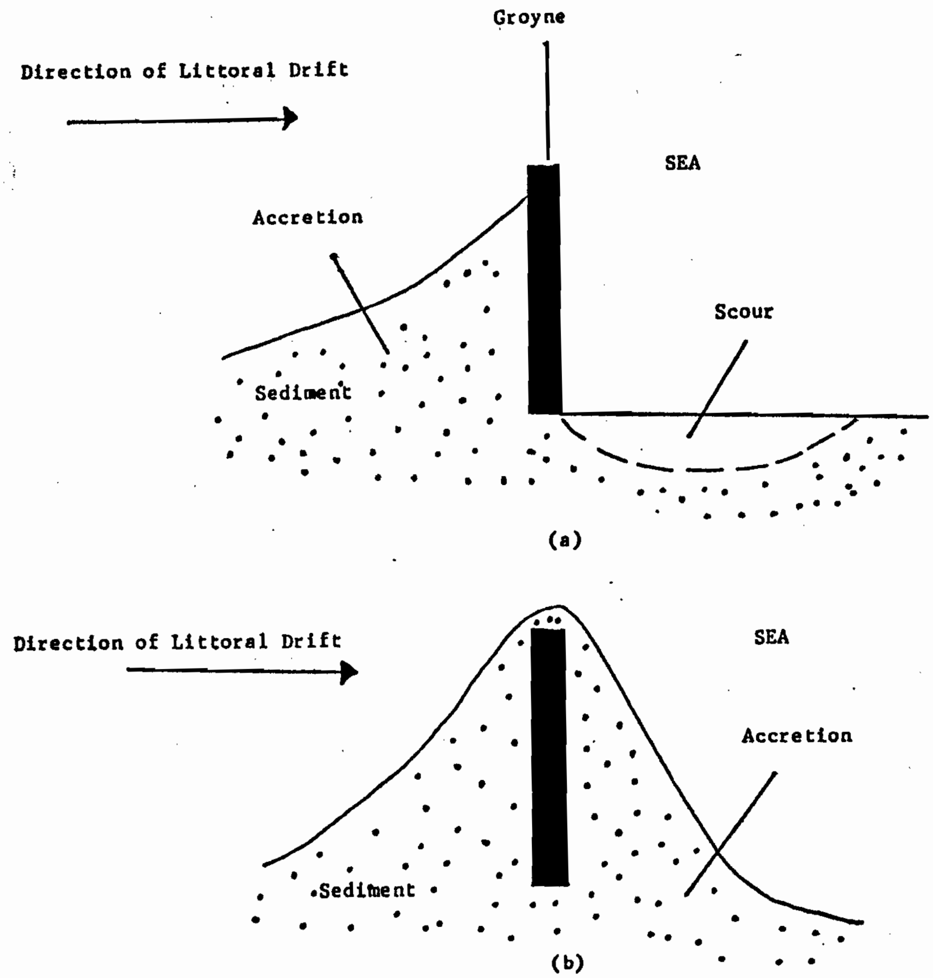

__Diagram Illustrating The Sequence of Sediment Accumulation Around An Impermeable Groyne__

Initially sediment piles up on the updrift side of the structure, while thereis a reduction downcoast(Diagram (a)). It is only after the updrift side becomes 'filled' that sediment can bypass the groyne, to reach downcoast sites(Diagram (b)).

(L.A.N.)

In addition, most of the groynes used locally are impermeable. During the field survey, permeable structures were only observed at Six Men's and Dover, representing less than one-tenth of all groynes erected. A permeable groyne allows deposition on both sides of the structure, so that abrupt changes in beach alignment may be minimised. Greater thought ought to be given to the possibility of using this type of groyne on a more widespread basis in the future.

Retaining walls

The main problem with retaining walls, is that they often produce scour at the toe of the structure particularly in the case of vertical walls, the type most commonly used in Barbados. When waves break against a wall energy is deflected upward and downward. It is the downward component of energy which is responsible for the scouring action at the base of the wall (Komar, 1976:328). Severe scouring will lead to undermining and collapse of the wall. Engineering evidence indicates that a curved, concave wall is most effective in reducing scour (U.S. Army Corps of Engineers, 1977; Deane et al., 1973). Sometimes local property owners place gabions or coral boulders at the foot of the wall, to cushion the impact; but as will be shown later, these measures tend to be of limited effectiveness over time.

Another limitation of the wall is that even when functioning efficiently, it can only protect the land and property immediately behind it. It is of little or no value in combatting erosion along a beach. Empirical evidence has shown that seawalls, if built on already retreating coasts, often accelerate the erosion process in up - as well as down-coast directions (Stamp; 1939 Barnes and King 1953; U.S. Army Corps of Engineers, op. cit.).

Gabions

This form of flexible protection is widely used in the Caribbean. However, the method has proven to be of questionable utility, even under conditions of low to moderate wave energy. As the stones become subject to wave action, they move around in the baskets, thus rupturing the protective coating covering the wire. Subsequently, the wire cage becomes corroded, and the rocks are dispersed all around. Not only is the structure rendered ineffective, but the scattered rocks become a menace to beach traffic.

The life of a gabion will vary according to the degree of exposure to wave attack, level of wave energy, and the efficiency of its engineering. Local experience suggests that in many cases, collapse in less than five years is common. Like retaining walls, gabions are normally built parallel to the shore, immediately in front of properties. Similarly, they promote scour at the base of the structure, causing locally abrupt changes in the beach profile.

Rubble Revetments

These also fall under the category of flexible defences, since the rubble may be realigned by the force of the waves. The problem encountered locally with this form of defence stems more from the way it is implemented, than from any fundamental weakness of the measure itself. Field experiments have shown that when properly placed, this type of revetment can absorb and reflect large amounts of wave energy. In addition, rubble revetments are relatively easy to repair, and the overall cost of installation is relatively low (Deane et al., op. cit.). Moreover, although they do not cause much accumulation of sediment, they considerably reduce or halt recession (Ibid).

However many property owners in Barbados do not employ engineers; rather they build the structures themselves at greatly reduced costs, at least in the short term. Frequently the revetments fail, and the property behind, which they were designed to protect, is suddenly threatened by flooding and structural damage. Furthermore they are unsightly, and detract considerably from the aesthetic attractiveness of the beach. More seriously, they restrict, and in cases, block access from one section of the beach to another. Not only is this an inconvenience to beach users, but it is also illegal.

Finally, it should be pointed out that many defences appear to be built without the benefit of even preliminary investigation. Parameters such as design wave criteria, net direction and rate of sediment transport, are evidently not fully taken into account. The results are quite obvious where 'do-it-yourself' measures have been implemented. This practice must be discouraged; for it becomes costly to the property owner in the long run, and causes unnecessary damage to the beach.

Perceived Causes of Erosion

Owners were also questioned about the possible causes of beach erosion. The responses are categorized in Table 16. The largest percentage of respondents (30%) assumed increased wave action to be the main cause of the problem, but the physical evidence contradicts this. Recent studies have found no overwhelming evidence to support this belief (David Lashley and Partners 1980; Oistins Fisheries Project 1979); neither is there any evidence of a greater frequency of storms which might have affected the island's beaches. Furthermore, since 1955 only one hurricane ('David,' 1979) passed close enough to the island to generate any noticeable changes on the beaches. Even that event was not catastrophic, and the beaches recovered in a matter of weeks.

The fact is that prior to the mid - 1960's the coastal fringe was not heavily settled; consequently, the normal processes of beach advance and retreat were either unnoticed or of little concern. The situation has since changed drastically. Beach morphological changes now assume a greater significance, on account of the possible threat posed to property; hence 'high seas' and 'severe wave action' (as reported by owners), may be perceived as being more frequent and severe than previously. The perception of an increasing threat is therefore likely to have arisen out of a closer association with the coast.

Burton et al. (op. cit.), Kates (1971) and Lowenthal (1972) have shown that personal experience and familarity with the hazard determine the level of response to the hazard.

Table 16

Perceived Causes of Beach Erosion

Cause	%Respondents
Increased wave action	36
Construction elsewhere along beach	31
Increased wave action and construction	20
Not sure	5
Other	8
Total	100

Almost one-third of the respondents put the blame solely on the action of other property owners, while 20% attribute erosion to increased wave action in combination with construction along the beach. The fact that 51% see the problem as being related in some way to man's intervention, is clear recognition of the potentially negative impacts of their own action. This problem is highlighted by the Town and Country Planning Office. Property owners have been filing between 5-10 complaints annually against other owners, since 1976.[1] The most serious to date have been against the owners of Golden Palm Hotel, who erected a recurved groyne in March 1980. By July of the same year, the beach downcoast from the groyne was experiencing such severe recession that the safety of properties was threatened. Officers from the Town Planning Office and the Ministry of Works were sent

1. Personal communication with Deputy Chief Town Planner, Town and Country Planning Office, 1981.

in to assess the situation. They ordered the removal of a section of the groyne, which was effected within months of the request. In June 1981 when the site was revisited, there had been noticeable accretion downdrift from the groyne.

Yet in spite of this awareness, a considerable amount of construction is still being carried out in the active beach zone. Naturally, the owners' major concern is to protect their property from what is perceived as a serious threat; preservation of the beach is not necessarily their primary aim. It would be unfair to suggest that owners are totally indifferent about beach conservation. Obviously they have a vested interest in the resource, particularly the hoteliers. The beach is one of the assets which attracts visitors in the first place. In addition owners must be aware that the safety of their property depends in large measure on the stability of the beach system. Perhaps it is this recognition which led 94% of the respondents to indicate that beach preservation should be the responsibility of Government and property owners alike. However, when asked if owners should help bear the 'costs' of coastal protection, some 58% answered 'no'. Although a variety of reasons was given, the consensus is that since the beaches are public property, Government should absorb all costs. This response supports the contention that beach preservation is only a secondary consideration when owners invest in defence works.

It is evident therefore that the decision by property owners to build coastal defences is not always based on reliable information. While some of these structures have functioned effectively, many others have caused additional problems elsewhere along the beaches. It is precisely for this reason that Government must take the initiative in designing and implementing a comprehensive beach management scheme. It is the only way to ensure a lasting beach resource.

CHAPTER 8

ROLE OF GOVERNMENT IN COASTAL MANAGEMENT

In the preceding chapter, it was demonstrated that there was a noticeable, though uncoordinated public response to the changes occurring in the beach zone. Perhaps the most positive outgrowth of this, was the fact that it impressed upon the government the need for stricter control of coastal development. Prior to the 1970's, there was not a single Government ministry or agency with any specific responsibility for coastal matters. There was little systematic planning and any beach protection measures required were implemented on an ad hoc basis.

Considerable pressure was brought to bear on the Government from various quarters including the hoteliers and other property owners, conservation groups and the public at large. In the perception of many people, the condition of some beaches had deteriorated to such an extent, that immediate remedial action was necessary. One of the strongest pleas for government action was made in the Physical Development Plan 1967. It called for the

"...establishment of a competent authority to deal with the design of comprehensive works for the protection and development of the beaches...to eliminate the tedious procedures by which generally unsatisfactory results are obtained by private developers in the attempt to exploit the advantages of seashore property" (P.123).

In many parts of the world Governments have had to respond to the challenge of resolving the conflicts arising between development of coastal resources and maintenance of a healthy environment. Given the variety of resources and interests in the coastal zone many departments are often involved in the process of management. In the United States and Canada there are numerous federal, state, provincial and local departments involved, backed by countless items of legislation (McNeill 1973). In the United States for example, the principal statutes include the National Environmental Policy Act, the Marine Protection, Research and Sanctuaries Act, the Water Pollution Control Act and the Fishery Conservation and Management Act (Graber 1981). Similarly in Britian and most other countries of Europe the management function is shared over a large number of specialist agencies and departments. However, overall responsibility for coordinating all coastal work is vested in a single authority, usually the Town and Country Planning Office or the Department of the Environment (Allison 1975).

For most of the Caribbean, coastal management is a new concept and in most islands there is no separate authority established specifically for managing coastal resources (U.N. Caribbean Environment Project 1979). Coastal planning functions are carried out by many government ministries among which there tends to be little coordination (Ibid). One country, Trinidad and Tobago, has taken the lead in developing a programme for coordinating all matters relating to the marine environment. In 1978 the Government established the Institute of Marine Affairs, an interdisciplinary body, to supercede all other departments carrying out coastal management functions[1]. In Barbados as elsewhere, Government became more aware of its responsibility for coastal protection and attempted to broaden the existing institutional structure, thus rendering management policy more effective. A few new agencies were established and the responsibilities of some existing ministries were increased. In addition new legislation was enacted in an attempt to enforce certain aspects of the policy. These 'new' developments are outlined below.

Ministry of Transportation and Works

One of the first moves by Government was the decision to broaden the functions of the Ministry of Works. Previously the work of this ministry was only marginally related to the control of coastal land use. In this respect, the main duties were two-fold. The first involved the supervision of land clearance in cases where public structures were to be erected on the littoral. Secondly, the Ministry was occasionally requested to canalise sections of drainage channels which reached the coast. This function became necessary especially after heavy rainstorms, which led to accelerated erosion, collapse of stream banks, flooding of the sand terrace and property damage. Today, the Ministry of Transportation and Works has the responsibility for erection and maintenance of all

1. See Government of Trinidad and Tobago, Institute of Marine Affairs Report 1979.

structures in the coastal zone which are deemed necessary for the control of beach erosion. Since 1970 this Ministry has constructed a number of groynes and revetments along the St. Lawrence-Dover coast and at Six Men's, St. Peter.

Parks and Beaches Commission

Following the recommendations of the *Physical Development Plan 1967*, Government set up the Parks and Beaches Commission. The ultimate role of this body was to design a coastal management programme for the island. The Commission was officially established with the passage of the Parks and Beaches Commission Act 1970. It was set up to advise the Government on

(i) The erection of beach and ancillary recreational facilities;

(ii) The removal of coral and sand (or any other material) from the coast, which might cause the encroachment of the sea;

(iii) all other matters pertaining to beach control and the protection of the sea-coast of Barbados from erosion by the sea (Laws of Barbados, vol.4 1971, Cap. 233A).

Quite recently, the terms of reference of the Commission were broadened to include the provision of beach accesses and lifeguard facilities at the beaches.[1] The body is also supposed to be responsible for carrying out periodic surveys of the island's beaches, especially after unusual events, such as hurricanes, tsunamis or severe swells.

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1. The National Conservation Commission Act, 1982. The former Parks and Beaches Commission has since been dissolved, but its functions have been taken over by the National Conservation Commission.

Ministry of Health

As far as coastal management is concerned, this Ministry's role is to control water pollution in the nearshore zone. This is the department responsible for enforcing water quality standards and the removal and control of oil slicks. In Barbados, the major sources of pollutants are domestic and some industrial effluents, urban street runoff, and agricultural chemicals[1] which reach coastal waters after heavy rains. It appears that there has never been too much concern about coastal water quality prior to 1970. Water sampling was haphazard, and was only conducted at a few locations. It was only from about 1978 that a properly designed water quality monitoring programme was instituted[2].

The programme is not yet fully operational, but by the time it enters its second phase a wide range of parameters will be monitored. These include turbidity, temperature, particulate matter, pH, salinity, dissolved oxygen, phosphorus and coliform. The windward coast is not included in the programme. The west and south coasts have been designated as 'priority areas', on account of the rapid pace of development taking place there. In all 32 sampling sites have been selected, based on such criteria

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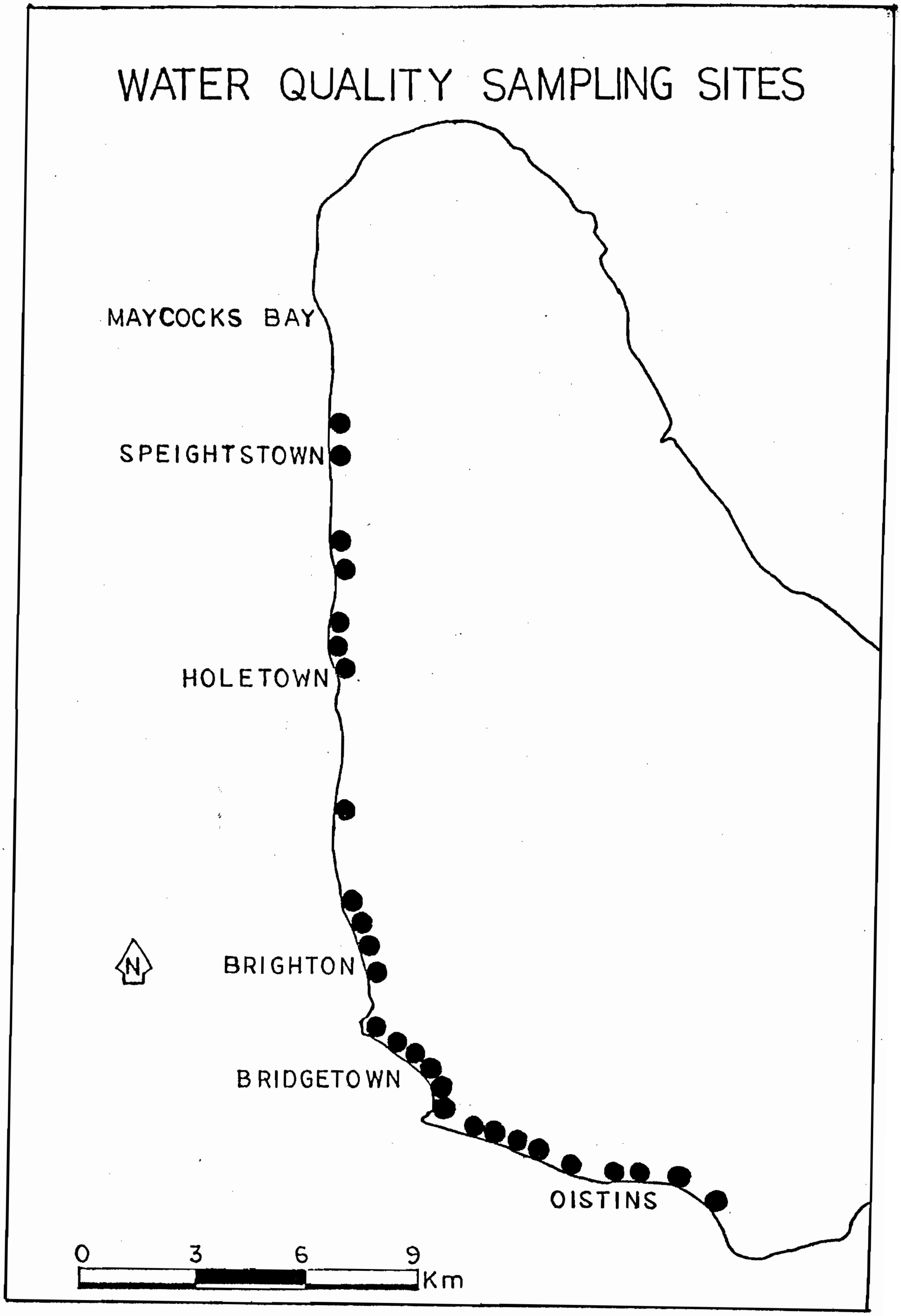
1. Report to Minister of Health, from Chief Public Health Engineer, 1980.

2. Personal communication with Mr. W. Conliffe, Public Health Engineer, Environmental Engineering Unit, June 1982.



Source: Ministry of Health, Barbados.

as intensity of use and type and source of effluents (Figure 44). In addition a set of water quality standards have now been adopted. These are regarded as the minimum standards required to maintain a safe, healthy aquatic environment. These standards are largely based on the criteria recommended by the World Health Organization for evaluating recreational water quality (Appendix 6).

Town and Country Planning Development Office

This office was established in 1965, with overall responsibility for the control of all development on the island, including the physical development of the coast. It is also responsible for the preparation of long term development plans for the island, and as such is directly involved in the regulation of coastal land use.

Since 1970 the Town and Country Planning Office has been preparing a set of land use zonation maps for the island. Most sections of the west and south coasts have been designated as 'tourist/recreational', but it was not until 1972 that building set-back limits were enforced. Previous to this date, no formal guidelines existed and construction took place without any fixed points of reference. The Town and Country Planning Development Order 1972, stipulates that the Chief Town Planner

> "Shall not authorise any development closer than 100 feet from the high water mark" (p.29).

Similarly, it is required that 'no gate, fence, wall or other means of enclosure shall be erected closer than 30 feet from the high water mark' (Ibid). Prior to the passage of this act, certain conditions were placed on building applications but the Chief Town Planner had no legal authority to enforce them. The act therefore represented another positive step toward the rationalization of coastal land use planning, if only from the point of view of its intent.

Lands and Surveys Department

This department controls and supervises all land surveys carried out on the island. In the littoral zone, it has the specific responsibility of defining the seaward limit of land plots. However, there are no commonly employed guidelines for property boundary delimitation along the coast. The current practice is to use the high water mark as the seaward limit of the property.

Land Valuation Division

The Land Valuation Division is the sole body authorised to appraise land and property for taxation purposes. One of its primary functions is to control land speculation and the inflation of land values. The latter function has become important in Barbados, particularly on the west and south coasts. In the last two decades, these have become the choicest locations on the island. Here land prices have risen by over 500% in the last twenty years.[1] In turn this has led to the inflation of island-wide real estates prices. High taxes are imposed on hotels and residences on the coast, as a means of curbing the

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1. Land Valuation Division Estimates, 1982.

tendency to inflate resale values. Government is presently considering the imposition of 'ceilings' on land values on the coast. This department therefore has the potential to exert a strong influence on development policy in the littoral. To that extent, it must be included among those agencies which have an important input to make in a comprehensive coastal management programme.

Ministry of Housing and Lands

The above ministry is responsible for acquiring land, compulsorily or via the real estate market, for the provision of public amenities. Its main function in coastal management thus far, has been the purchasing of land for providing additional public access to west and south coast beaches. The first such acquisition took place at Prospect and Paynes Bay in 1969.[1] In August 1980 additional land amounting to 204.38 sq. m. was purchased at Fitts Village for a similiar purpose. More recently, there was compulsory acqusition at Enterprise, Christ Church (635.8 sq.m., 1978), Rockley (5 960 sq.m., 1981), and Bay Street (7298.04 sq. m., 1981). All the purchases are for the sole purpose of providing "access roads" and "open windows" to the sea.[2] (Figure 45).

In 1977 the Government took a decision to create a separate section of the ministry which would oversee all

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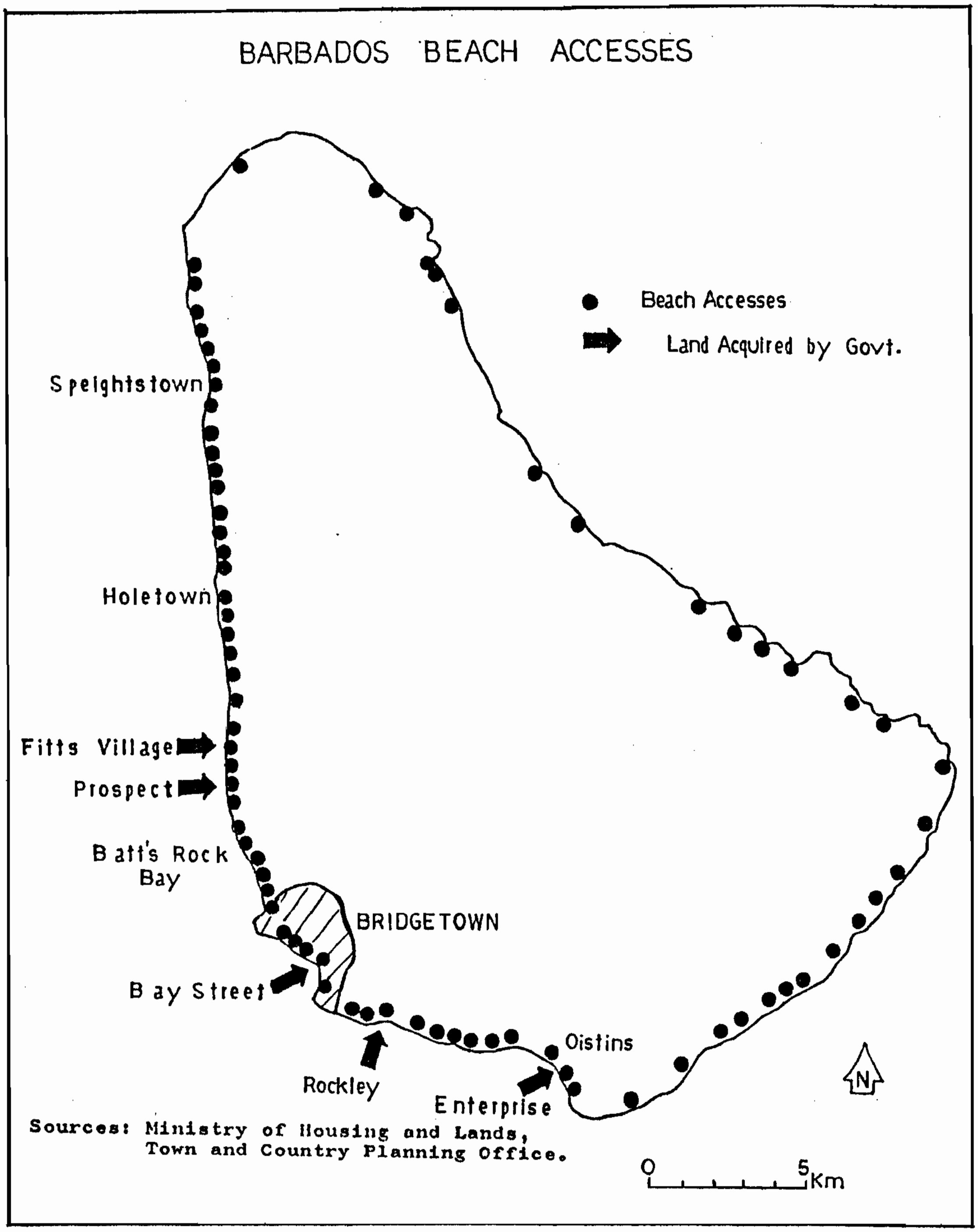
1. House of Assembly Debates 18th February, 1969:10-14.

2. See Govt. of Barbados Cabinet Papers nos. (78)1036/MHL85; (80)741/MHL86; (81)187/MHL23; and (81)13/MHL3.

Figure 45



BARBADOS BEACH ACCESSES
Beach Accesses
Land Acquired by Govt.
Speightstown
Holetown
Fitts Village
Prospect
Batt's Rock Bay
BRIDGETOWN
Bay Street
Rockley
Oistins
Enterprise
N
0
5
Km
Sources: Ministry of Housing and Lands, Town and Country Planning Office.

environmental affairs. Naturally, coastal and beach management were listed among the new department's responsibilities. However the new body never became fully operational, although until 1981, the ministry was referred to as the Ministry of Housing, Lands and The Environment.

Recent Legislation

Since the 1970's, various interest groups and statutory bodies have pressured government to take a firmer stand on the preservation of the island's natural assets. The former Parks and Beaches Commission, the National Trust and the Caribbean Conservation Association, were in the vanguard of this movement. The island's leading daily, the Advocate-News, started a column entitled 'the Need for Conservation.' As a result of the work of these organizations two important items of legislation gained passage.

The Trees Preservation Act 1981, though not defined specifically with the littoral in mind, has particular significance for coastal land use planning and beach management. The effects of the indiscriminate removal of the coastal flora have been discussed in Chapter 6. In this context, legislation of this type must be seen as a useful instrument in the future management of the shoreline. The act makes it a punishable offence to clear land anywhere on the island without permission from the Chief Town Planner.[1]

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1. Trees Preservation Act 1981-49. Supplement to the Official Gazette 14 December. 1981.

It is worth noting that a similar law existed as far back as 1868. The details of the act are discussed elsewhere (Nurse 1981:9). It was however repealed sometime during the eary 1900's for reasons not immediately clear.

The Marine Areas (Preservation and Enhancement) Regulations act was also passed in 1981. It is designed to protect marine reserves of special scientific or recreational interest (e.g. Folkestone Underwater Marine Park). The regulations state that anyone who

> "...destroys, injures, disturbs or removes any sand, gravel, mineral, coral, shell fish or other marine invertebrate,... or breaks any bottom formation of growth, is guilty of an offence, and is liable on summary conviction to a fine of one thousand dollars or to imprisonment for six months or to both."[1]

This enforcement is aimed at halting the widespread practice of harvesting marine organisms, particularly corals. Since the 1970's the rapid increase in tourist arrivals created a market for shell and coral ornaments. This led to indiscriminate harvesting of these products without the slightest understanding of the probable impact on coastal ecology. It is also known that some divers use explosives to detach healthy segments from the coral reefs, to supply the growing craft industry. It is these very reefs which supply much of the sediment to west and south coast beaches.

DEFICIENCIES IN EXISTING MANAGEMENT POLICY

In spite of the input from many government agencies and the existence of various legal provisions, beach and

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1. See Supplement to the Official Gazette Dec. 14, 1981.

coastal zone management is still largely ineffective. It is a concern which must be urgently addressed. This is imperative at a time when there is increasing evidence that the quality of the island's shoreline, and its beaches in particular are deteriorating. It is against this background that the major weaknesses of the present system of management will be examined.

Legal Provisions

The existing beach protection act was passed in 1958, and is aimed at restricting the removal of sand from the island's foreshore. The law states that

> "It shall be lawful for any person to dig, take and carry away sand, stones, shingle or gravel from any part of the foreshore for domestic purposes, provided that no vehicle or boat is used in, or for the removal of any such sand, stones, shingle or gravel."[1]

Passage of this law came as a result of the practice by construction companies of taking large quantities of sand and rocks from the seashore during the 1950's. However no effective system of 'policing' the beaches was ever instituted; hence the lack of enforcement renders the law ineffective. West coast residents are aware of a number of hotels and cottages built during the 1960's, which used large amounts of beach sand. Yet there is no record of litigation resulting from any such breaches of the act. It should be added that the penalty for contravening the law is a mere $Bds 250.00 for each vehicle used. It is therefore questionable how effective a deterrent this is,

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1. Laws of Barbados vol. 4, 1971. Cap. 222.

in the case of large construction companies.

Since removal of sediment by means other than by vehicle or boats is legal, it is still quite possible to mine large quantities of sand. Complaints by residents and concerned visitors during the 1960's, demonstrate that this was perceived to be the case. It is suggested that even if the law were properly enforced, it would still be somewhat shortsighted in so far as it allows sediment removal, albeit in restricted quantities.

Another section of the act renders it

> "...lawful for the Crown, its officers, servants and all persons acting under their orders, to dig, take and carry away any sand, stones, shingle or gravel from any part of the foreshore for the uses of the Crown, for the public works and buildings of this island, and for the highways."[1]

In restrospect, this too appears to be ill-advised, as many public projects have in the past relied too heavily on the beaches as a source of sand. It is not possible to detail the specific impacts of sand mining on the Barbados coast, but experience elsewhere in the Caribbean[2] suggests that excessive sand mining not only leads to depletion of the resource itself, but also disturbs the equilibrium of the naturally-sorted sediment.

Legal Definition of 'Beach'

Under the Parks and Beaches Commission Act 1970, the beach is defined as

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1. Laws of Barbados vol. 4, op. cit. Cap. 222.

2. This has been the case in St. Lucia, Grenada and St. Vincent (Deane et al., 1973).

"The land adjoining the foreshore of Barbados and extending not more than one hundred feet beyond the landward limit of the foreshore."[1]

This definition, though generally reasonable for most of the island's shoreline, is inadequate is some respects. Measurements taken during the summer of 1981 and 1982, indicate that there are a number of beaches on the island, whose width extends more than one hundred feet (33 m), 'beyond the landward limit of the foreshore' (See Table 17). This would mean that the land in excess of the prescribed amount (unmistakenly beach from a geomorphological perspective) would not legally constitute part of the beach.

Table 17

A selected List of Beaches Which Extend Beyond 33 m (100 ft) Landward of The Foreshore

Beach	Location (Coast)	Width (m)
Enterprise	South	35.5
Foul Bay	South-east	45.0
Green Pond	North-east	52.0
Lakes	East	50.0
Long Bay	South-south-east	46.0
Morgan Lewis	North-east	53.0
Needham's Point	South-west	45.0
Walker's	North-east	58.0
Woman's Bay	South	37.0

N.B. All figures are derived from field measurements, June-August 1982. Only two of these beaches are in the study area, but this is of little relevance, since the legal definition of 'beach' applies to all sections of the island's shoreline.

It might be recalled that the Town Planning Office is charged with the duty of forbidding construction on the beach, but according to the above definition, a land owner

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1. Parks and Beaches Commision Act 1970, op.Cit. Cap.233A.

could request permission to build on an actual beach site without contravening the law. This has already occurred at Long Bay and Woman's Bay on the South-east, where four guest houses have been constructed legally on the beach. The Town Planning Office was only recently[1] made aware of this weakness in the law; but in the meantime, until the legislature sees the necessity to change this definition of 'beach', land developers will continue to exploit it.

Property Boundary Delimitation

In Barbados, the high water line is, by law, the seaward extremity of land plots in the coastal zone. However, neither the Land Surveyors' Board nor the Land and Surveys Department has atttempted to standardize the procedure for determining high water. One of the following two practices is generally adopted:

Either (i) Some semi-permanent indication of high water, such as berm crest, is chosen. Where this cannot be identified, the landward limit of beach drifting is used.

or (ii) Some surveyors take the water's edge as indicative of the high water mark, regardless of tide.[2]

One is willing to concede that any attempt to delimit the high water mark will at best, be a difficult task. Still, this very fact should provide a compelling reason for standardization.

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1. The writer pointed this out to the Deputy Chief Town Planner, in the Summer of 1981.

2. Personal communication with Mr. Anthony Griffith, Deputy Director, Lands and Surveys Dept., July 1981.

The former of the two methods would appear to be more rational; for the berm crest and the upper limit of swash transport can often be taken as an indication of the highest point reached by waves. The other method is far less satisfactory, and can only have meaningful application where the coast is bounded by cliffs. Clearly the so-called water's edge will shift back and forth (perhaps significantly) depending on whether it is spring or neap tide or high or low tide. Consequently, there are adjacent land plots on sections of the Barbados west coast, along linear uniform stretches of beach, whose seaward boundaries differ by as much as 0.8 - 1.5 m approximately. Obviously this reflects the biases and varied subjective judgements of individual surveyors.

Building Set-Back Limits

The legal set-back limit for retaining walls and other enclosures is 30 feet from the high water mark. The rationale for selecting 30 feet as an adequate distance, was based on a consensus that this would allow unimpeded movement along the beaches. In other words the act was more concerned with preserving beach accesses than with beach conservation. In many cases, it effectively permits the erection of enclosures seaward of the berm, in the active beach zone. Where this occurs, it often impacts on natural wave processes, causing scour in front of the the structure (See Chapter 7). At Folkestone and along the Hastings coast, the erection of retaining walls on the beach has produced so much local scour, that it is now virtually impossible to walk from one section of the beach onto the other. Hence even the aim of maintaining easy access along the beach may be jeopardized by the inadequacy of the regulation itself.

The other law which stipulates that buildings must be set back 100 feet from the high water mark also needs re-examination. It would seem that this specification is logical and consistent with the definition of 'beach' as given in the 1970 act (i.e. land not extending more than 100 feet beyond the landward limit of the foreshore). The weakness of this definition has already been discussed. Bearing this in mind, it is evident that on some coasts, construction has occurred post - 1970, on sections of the foreshore, which in a strict geomorphological sense, constitute beach. If therefore the purpose of the set-back limits as indicated, is to prohibit construction in the active beach zone, then surely some meaningful adjustment to the existing regulations would be required.

One must also draw attention to the fact that since the practice of establishing the seaward boundary of properties has not been regularized, the set-back lines of 30 and 100 feet (for enclosures and buildings respectively) will show measureable variation from place to place. It was earlier indicated that some surveyors choose the water's edge as an arbitrary high water mark. In effect, this means that often enclosures and buildings are not erected 30 and 100 feet respectively from the high water mark; but rather 30 and 100 feet from the sea itself. By extension, it also means that construction can legally take place even further seaward than originally intended, or ecologically desirable.

It is problems like these which underline the need for a systematic approach to coastal management. In the above case, the Town Planning Office and the Lands and Surveys Department have adopted without consultation, a set of standards which are at variance with the overall aims of proper management. The very lack of standardization by the surveyors renders Town Planning set-back limits ineffective at some locations. Even if more stringent set-back limits were imposed, they would need to be complemented with a uniform method of delimiting the mean high water mark.

MAJOR WEAKNESSES OF GOVERNMENT DEPARTMENTS

The Ministry of Works is largely unequipped to play the role in coastal management assigned to it, mainly because of a lack of competent staff. There are no trained coastal engineers, hence it is the civil engineers, trained in other specialties, who are involved in the decision-making process.[1] Under such circumstances the scope for error is great. In the coastal zone such errors can be costly. A poorly erected structure for instance, could result in extensive damage in the long term, as has already occurred at Sunset Crest and Lower Carlton, where the concretized drainage canals have precipitated the erosion

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1. Personal communication with Mr. B.Seliah, U.N. Civil Engineering Consultant, assigned to Barbados, 1982.

of the beach face.[1] Here the outfalls were built beyond the seaward edge of the berm and now function partially as groynes, disrupting the movement of sediment alongshore.

The National Conservation Commission is similarly understaffed for dealing with the various areas of beach management for which it is responsible. Up to 1982, there were no technocrats on the staff, trained in any of the environmental sciences. Even during the era of its predecessor, the Parks and Beaches Commission, the agency functioned primarily in an administrative and advisory capacity.[2] In cases where technical information and advice are requested by Government (e.g. for the Heywoods Holiday complex, and the Oistins Fisheries Terminal), trained personnel had to be recruited as consultants on temporary assignments.

The main area of competence is in the provision of amenities such as picnicking facilities, lifeguard stations and parking lots. Ironically, the commission has been guilty on occasions of clearing beach vegetation at some sites, in order to provide these facilities. Such was the case at Brandon and Holetown where lifeguard stations were erected, and easier access provided for motorists to drive directly onto sections of the beach.

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1. Personal communication with Mr. B. Seliah, U.N. Civil Engineering Consultant, 1982.

2. Interview with Mr. D. Grant, former Manager, Parks and Beaches Commission, September, 1981.

The setting up of the Commission is in itself a necessary step; but Government has been unrealistic in expecting it to perform tasks for which it is not staffed. Its functional capabilities are so constrained that much of the agency's work must of necessity be relinquished to other departments, some of which are not technically capable of doing the work either.

Lack of personnel is also a problem for the Ministry of Health. This more than anything else has delayed the full implementation of the water quality monitoring programme. According to the Chief Public Health Engineer, the programme requires, in addition to present staff, at least two engineering assistants, three laboratory analysts and a laboratory technician.[1] Up to the present, Government had not given any formal approval to the ministry for creating and filling these posts. The impression is that Government is deliberately delaying its decision because the Bridgetown sewage treatment plant is soon to be fully operational. Since many sources of effluent will be fed into the system, Government believes that this will be the panacea to all coastal water quality problems.[2] Government should be aware that the advent of the sewage plant is not an automatic guarantee of healthy coastal waters. A programme of monitoring should be considered a priority.

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1. Report of the Chief Public Health Engineer to Minister of Health, 1980.

2. Interview with Mr. H. Conliffe, Public Health Engineer, June 1892.

At present the large hotels and guest houses discharge the highest percentage of effluent into the sea. On occasions it has been found that these direct discharges are capable of contaminating coastal waters. Unfortunately the Environemntal Engineering Unit has no legal authority to collect samples at the hotel site itself. Permission must either be sought from the management, or the samples taken from the sea in front of the property. The latter alternative is not always the best choice, since dilution of sample may give an inaccurate record of the quality of the effluent. Evidently, there is an urgent need for legal provisions to deal with this problem.

The Land Valuation Division faces a similar problem. Although one of its assigned functions is to control the inflation of land and property values, it has no direct legal authority to do so. It attempts to achieve this goal indirectly by imposing high taxes; but even so this strategy is only marginally successful as realtors often opt to pay the high taxes, and sell at even more inflated prices. For example, properties bought in 1978 for between $Bds 400,000 and $Bds 500,000 at Rockley and Holetown, were sold in 1981 for between $Bds 800,000 and $Bds 1,000,000.[1] The Land Valuation Division is one of the few departments which has the necessary staff to function effectively; but it is also one of the few without any legal apparatus at its disposal to maximise its efficiency.

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1. Land Valuation Division statistics, 1982.

Final approval to carry out 'special programmes', such as coastal conservation projects comes from a centrally administered fund. For some reason the administrative process tends to be long. Experience suggests that it could take up to three months before any urgent work can actually be carried out.[1] With this kind of delay, the particular problem can worsen, and individual property owners often feel compelled to resort to their own remedies. For example, during the early part of 1977 and 1978, Folkestone and adjacent beaches experienced heavy scour. Property owners applied to Government for assistance but only got a positive response in 1979 when a study was commissioned.[2] In the meantime the owners of the Coral Reef Hotel and neighbouring residences built gabion revetments and rubble mounds to protect their properties. The action led to increased scour in front of the properties, to the extent that a section of the beach has almost disappeared.

Although about 75% of all land developments along the west and south coasts are tourism-related, the Ministry of Tourism has no direct input in coastal land use planning. Traditionally, its main role has been in the promotion and marketing of tourism, rather than regulation and control. The ministry is responsible for setting annual targets for

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1. Interview with Mr. B. Seliah, U.N. Civil Engineering Consultant to Government of Barbados

2. See Cambers (1980) A Study of Coastal Erosion at Folkestone Beach St. James, Barbados (Unpub.).

the industry; but these targets are often set without any serious evaluation of the possible impact on the resource base. Unfortunately the Ministry of Tourism seems insensitive to the fact that it is these very targets which help determine the type and pace of development in the coastal zone.

Table 18

Projected Tourist Arrivals and New Establishments Built, 1969-75

Year	Projected Arrivals	Projected % Increase	Units Built
1969	120,000	-	20
1970	135,000	11	23
1971	145,000	7	10
1972	180,000	20	9
1973	210,000	14	6
1974	240,000	13	4
1975	270,000	11	8

Sources: Ministry of Tourism and Civil Aviation; Town and Country Planning Development Office.

For example, in 1968 it was projected that there would be at least 270,000 tourists by 1975.[1] This information was communicated to the Barbados Hotel Association and publicized overseas to attract foreign entrepreneurs. These projections encouraged the construction of additional physical plant to handle the anticipated increase in visitor arrivals. In the space of seven years, eighty new units were built (Table 18), thus placing additional stress on an already heavily exploited resource base.

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1. Ministry of Tourism, Projected Arrivals 1968.

EMPHASIS ON REMEDIAL PLANNING

One of the most negative features of coastal management policy in Barbados is its 'after-the-fact' approach. Since no environmental impact analysis or other such requirements are a prerequisite for development permission, there is no scientific basis for predicting possible impacts. Consequently the emphasis is on remedial rather than preventive measures. Often by the time a particular impact manifests itself, considerable damage has already been done. For instance, in 1979, Paradise Beach Hotel extended its beach bar and terrace facilities seaward encroaching on the berm. In the two years that followed, practically all the sand in front of the buildings was removed by wave action, and the foundation of the buildings began to collapse. The owners of the hotel ended up having to invest another $Bds 15-20,000 in coastal protection works.[1] Much of this damage would have been avoided if the extensions were designed to allow a sufficiently wide beach to absorb the wave energy.

In 1981 Government embarked on a $Bds 60 million tourism complex at Heywoods beach, providing an additional one thousand rooms for visitors and extensive service facilities. No one knows precisely what impact this additional pressure will have on the beach environment. For instance, concerns such as the effect of additional

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1. Interview with Assistant Manager, Paradise Beach Hotel, July 1981.

sewage on the reefs and on water quality have not been properly addressed. This information is indeed disturbing, especially since it is a public project; for the Government must set a better example in the preservation of the island's natural assets. Here again the need for some form of impact evaluation as a criterion for project implementation is clearly demonstrated.

In addition there is the tendency to tackle coastal problems on a 'piecemeal' basis. As a result many of the remedial measures, while partially successful for the immediate problems being tackled, often trigger undesirable impacts along adjacent sections of the coast. In 1979, a long groyne was built in front of the Golden Palm Hotel to combat what was perceived to be an erosion threat. Within two years, the beach in front of the hotel had widened by about 1.0 m. However during the same period the beach to the immediate north retreated approximately 0.7 m, creating problems at one hotel and two private residences. At the insistence of the latter, the Town Planning Office recommended that the groyne be shortened to allow some sediment transfer northward. In other words the apparent erosion threat was not averted but rather transferred to another section of the beach cell. The lesson to be learnt from this experience is that the coastal area must be

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1. Interview with Mr. W. Conliffe, Public Health Engineer, Environmental Engineering Unit, June, 1982.

2. Information supplied by Deputy Chief Town Planner, July 1982.

managed as a natural system without discrete boundaries. Hence the present uncoordinated 'problem-by-problem' approach is likely to produce negative feedback through the system.

STRUCTURAL SOLUTIONS

Overall there is too much emphasis placed on structural remedies as a means of protecting the beaches. Discussions with government officials and property owners as well as field observations, have shown that beach conservation is taken to be synonymous with the erection of groynes, retaining walls and revetments. The results of the questionnaire survey reveal that over 90% of the property owners believe that structural measures are the best solution to the island's beach erosion problems (See Chapter 7). Clearly there are cases where engineering structures are both necessary and effective; but more favourable consideration must be given to non-structural solutions (e.g. maintenance of coastal vegetation, tighter control on set-back limits, prevention of construction at the limbs and headlands of beach cells), especially when long-range planning is being considered. These should no longer be regarded as 'secondary' measures.

SUMMARY

It is evident that most of the government agencies responsible for management of the island's coasts, lack the necessary resources to function effectively. Moreover, the duties of each department are not always clearly defined, so that there is some degree of overlap in areas. For example, the Town Planning Office, the Ministry of Lands and the National Conservation Commission are all, to some extent, responsible for providing and maintaining public access to the beaches. Similarly, both the National Conservation Commission and the Environmental Engineering Unit, are responsible for the dispersal and removal of toxic substances (e.g. oilslicks, industrial chemicals) from the coastal waters. Such duplication is unnecessary and can be confusing to the extent that, in cases, it is difficult to determine where one jurisdiction ends and the other begins.

The legal provisions which form the backbone of coastal management policy have limited effectiveness. This situation stems either from the lack of practical means of enforcement or weaknesses in the legislation itself, rendering it in some cases self-defeating. If proper management of the coastal zone is to become a reality, then effective legislation must be an area of priority. It is therefore suggested that some reassessment of present laws be undertaken, in the overall context of the island's needs and projected future development. More importantly, any amendments to old acts as well as the drafting of new legislation, must reflect a better understanding of the mechanics of coastal and other processes, which impact on the littoral environment as a whole.

CHAPTER 9

A PROPOSED FRAMEWORK FOR COASTAL ZONE MANAGEMENT

Globally the task of coastal conservation has presented many challenges. Because of the complexity of coastal systems and the variety of interest groups competing for those resources, effective coastal management has been difficult to achieve. Numerous strategies have been adopted by different countries with varying degrees of success. Along stretches of the New England, Florida and New Jersey coasts zoning is a major strategy, whereby specific types of development are confined to certain areas (Hughes 1982; Lewis 1980; Bruha 1981). Here this policy is combined with the setting aside of ecological reserves and regulatory mechanisms which control the rate of development along the coast (Lewis 1980, op. cit.; Florida Coastal Coordinating Council 1971; Ketchum 1972). Other countries designate specific sites as scientific and natural reserves but allow the rest of the coast to be developed free of regulatory controls. Similar policies have become widespread in the Pacific, Africa and parts of the Mediterranean (United Nations 1981; Okidi 1978, op. cit.; Gonen 1981). In the United States Virgin Islands during the 1970's, governments embarked on a policy of "dichotomizing resource allocations into 'develop' or 'preserve' categories", but with minimal success (McEachern and Towle, 1972:158). There are also extreme cases in which a moratorium has been placed on all forms of coastal development, as in the San Jose and San Diego areas of

California[1] and parts of New Jersey (Hughes 1982, op. cit.).

In spite of the range of strategies, few regions can claim to have achieved success in coastal management. The problem does not stem from any inherent weaknesses of the individual strategies. Practices such as the designation of reserves, zoning and other regulatory mechanisms are sound options to pursue. The problem is that in most cases these policies have not been incorporated into a comprehensive management plan. Most countries have tended to implement the measures 'as the need arises' and as solutions to isolated problems at chosen localities (Ketchum 1972; Lewis 1980). Efficient management requires a holistic approach to planning, which embodies all aspects of coastal resource use. It is with this principle in mind that the present chapter seeks to develop a framework for comprehensive coastal zone management in Barbados.

Initial Constraints

In designing a coastal management plan applicable to Barbados, three important factors must be considered. First, one is dealing with a very limited resource base, which makes it necessary to reconcile as many competing (but compatible) uses as possible. Secondly, much of the littoral has already been heavily committed to a particular type of land use, with high investment in physical plant and infrastructure, peculiar to that land use. For all practical purposes, this must be treated as

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1. See the Economist, November 17, 1973.

'irrevocable'. Thirdly, the strategy must be efficient but at the least possible cost. This is not to suggest that effectiveness should be traded off against cost. However, the reality of the island's scarce financial resources must be considered a constraining factor.

Application of the Multiple - Use Concept

From the outset it should be emphasized that Barbados is an island with limited resources. Consequently, it is essential to maximise all benefits (economical and social) which may be derived from those assets. Yet in doing so, it is also necessary to minimise as far as possible, any undesirable impacts which such resource development may cause. In the case of small islands like Barbados, the concept of 'multiple-use'provides an appropriate base on which to plan the development of the littoral. This approach, though relatively recent, has proved to be an efficient way of rationalizing resource development strategies. It owes much to the work of Sorensen (1971), Ross (1974) and Hayakawa (1979). Such an approach is currently being tried in Kenya, Florida and parts of New England where industry, mining, recreation, housing, commercial fishing and ecological preservation are proceeding simultaneously (Okidi 1978; Lewis 1973; Bruha 1981).

Present Uses of the Barbados Littoral

The island's coast is used in a variety of ways by different interest groups. Fishing is a traditionally important occupation, on a full - as well as part-time basis. The beach serves three main functions in this respect. It is used for 'hauling up' and 'beaching' the boats. Secondly, some species of fish (e.g. Clupea sprattus and Caranx latus)[1] migrate seasonally along the waters of the foreshore zone, and are caught by fisherman who cast nets from the beach. In addition, the traditional markets are located on the beach as for example Speightstown, Paynes Bay and Oistins (Figure 46).

Private housing and tourist accommodations occupy a substantial part of the island's west and south coasts. The post-1960 real estate boom transformed sections of the coast which previously had been either little developed or 'untouched'. At the same time special service and ancillary facilities were provided to complement these developments. Restaurants, night clubs, boutiques and specialty shops all occupy valuable coastal space. Further, recreational activities such as swimming, water skiing, diving and sport fishing are pursued along the coasts.

Although there are presently few coastal scientific reserves and parks in Barbados, serious consideration must also be given to this area of planning. Although there is no single accepted approach to coastal management, most authorities agree that the designation of unique areas as scientific reserves should be given the highest priority in

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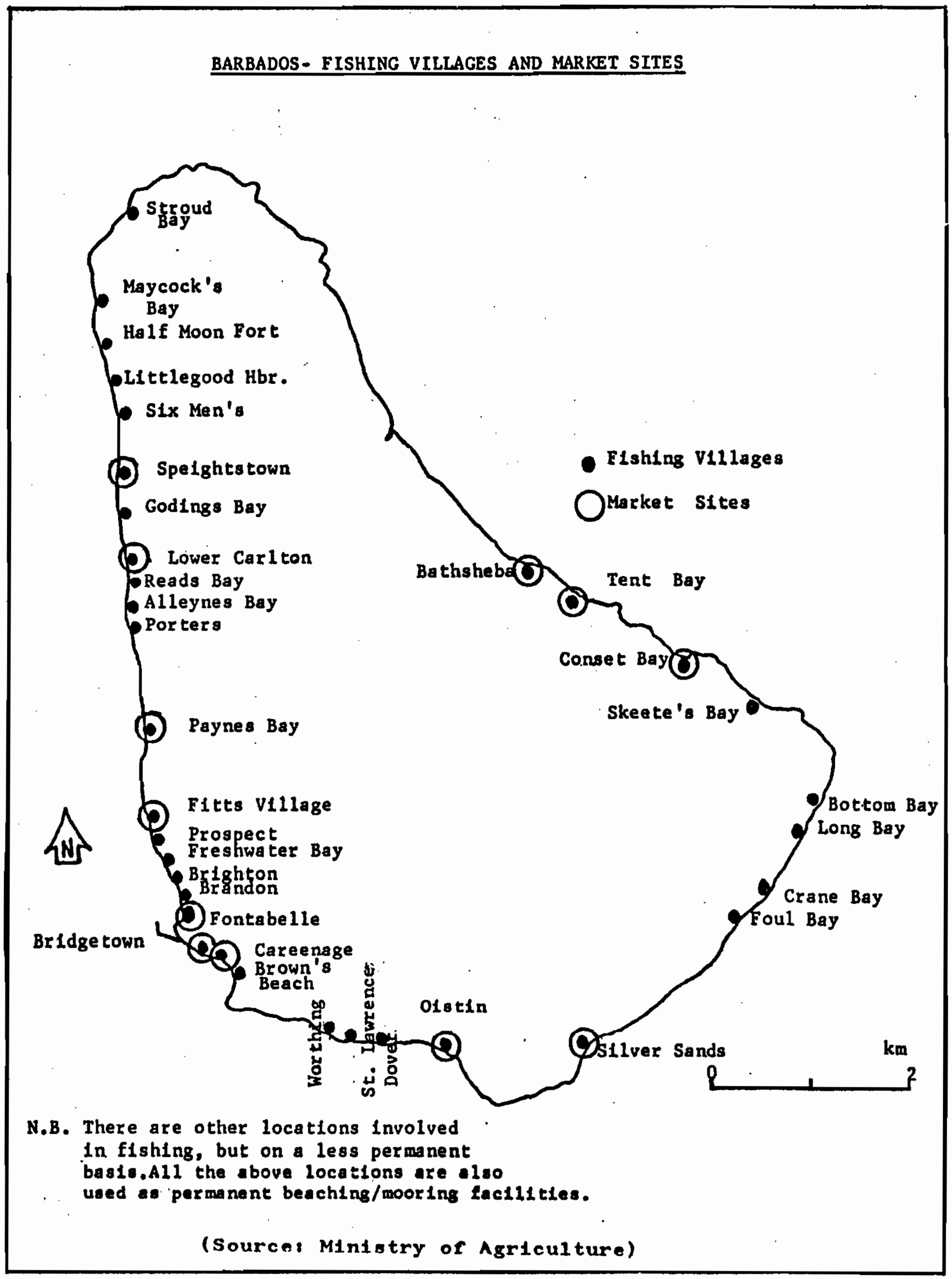
1. These are known locally as 'sprat' and 'jack' respectively

Figure 46


BARBADOS- FISHING VILLAGES AND MARKET SITES
Stroud Bay
Maycock's Bay
Half Moon Fort
Littlegood Hbr.
Six Men's
Speightstown
Godings Bay
Lower Carlton
Reads Bay
Alleynes Bay
Porters
Paynes Bay
Fitts Village
Prospect
Freshwater Bay
Brighton
Brandon
Fontabelle
Bridgetown
Careenage
Brown's Beach
Worthing
St. Lawrence
Dover
Oistin
Silver Sands
Foul Bay
Crane Bay
Long Bay
Bottom Bay
Skeete's Bay
Conset Bay
Tent Bay
Bathsheba
Fishing Villages
Market Sites
km
0
2
N
N.B. There are other locations involved in fishing, but on a less permanent basis. All the above locations are also used as permanent beaching/mooring facilities.
(Source: Ministry of Agriculture)

planning (Fosberg 1965; Clark 1977; McEachern and Towle op. cit.; Krause 1978; U.N. Caribbean Environment Project 1979). The Barbados Government signalled its intention to do so in 1981, by passing legislation to designate Folkestone Underwater Park a marine reserve. It is planned that other areas of scientific interest such as Animal Flower Cave, might also be protected by similar legislation. The remaining patches of mangrove vegetation (Holetown estuary and Graeme Hall) should be similarly designated, before they too become extinct.

The coastal zone is also used as a waste disposal outlet. Domestic effluent from private residences and hotels account for the bulk of this waste. However, significant amounts of effluent are also deposited in coastal waters from industrial sources. For instance, the West India Rum Refinery discharges approximately 0.049 million gallons of organic waste daily off Brighton; nearly 0.01 gallons come from Mobil Oil Refinery into Carlisle Bay; the Barbados Light and Power Company discharges about 0.045 million gallons of thermal waste at Spring Garden in Freshwater Bay[1]; while Barbados Flour Mills Limited is responsible for an undisclosed amount of partially treated effluent.

The fundamental issue therefore is the need to reconcile these competing uses, to understand the interrelationships among them and to evaluate the potential

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1. See Report of the Senior Public Health Engineer, Environmental Engineering Unit, 1981.

impacts which they have on each other. The ultimate aim is to resolve potential conflicts in such a way that coastal degradation would be at a minimum and user benefits and satisfaction would be preserved and maximised. The only effective way to achieve this goal is by adopting a holistic appraoch to planning.

ESTABLISHING THE BASIS OF A COASTAL MANAGEMENT PLAN

It is suggested that a first requirement is the preparation of a coastal land use inventory. The inventory should be as comprehensive as possible and must include 'intangibles' such as the aesthetic use of the beach. It would be mandatory that such a catalogue contain present as well as potential uses (Wise 1969; O'Riordan 1971; Mitchell 1979). It would not be unrealistic to include activities such as desalinization, wave energy generation and mariculture in the inventory. In fact the island's potable water resources are reaching such critical limits, that projections are that by the year 1995 demand will exceed supply.[1] Given this projection, desalinization is an option which cannot be completely ruled out for the future. At the same time, there is a wave energy pilot study under way to determine the viability of harnessing this energy source.[2] Similarly a study is presently being undertaken at the Bellairs Research Institute on the feasibility of

1. Water Works Department, Barbados, W.I., Water Resource Development Plan until 1995.

2. Potential sites on the island's east coast have already been identified.

producing sponges commercially. Clearly the implementation of any or all of these would impact upon, and be themselves affected by other uses. The land use inventory would minimise the foreclosure of other potential uses, as well as ensure that their impact on other uses is evaluated. The importance of leaving options open is emphasized in the following warning:

> "Management in a world of uncertainty involves risks about future outcomes. The danger of making a wrong allocation decision in the environment sphere lies in the irreversibility of the bad decision. Most environmental resources, once committed cannot be reclaimed for other alternative uses. It a sensible insurance policy to guard against the foreclosure of future options". (McEachern and Towle, 1972 : 158).

The coastal land use inventory would therefore fulfil three major functions. It would serve as (i) a preliminary planning tool for assessing the overall development potential of the coast, (ii) a means of identifying groups of potentially compatible (and incompatible) uses, and (iii) a flexible 'checklist' to which other potential uses may be added, as the need arises.

During the summer of 1981 and 1982, field surveys were undertaken and all recognizable land uses on the Barbados littoral itemized. Table 19 is an abridged version of that list. The full inventory is reproduced in Appendix 7.

<u>Nature and Scope of Project</u>

Using the inventory as a general planning guide, the specifics of any given project or action can then be considered. Essentially, this should take the form of a preliminary assessment of the aims and nature of the

Table 19

Abridged Version of Coastal Land Use Inventory

Fishing	Cast Netting From Beach; Seining; Bottom lining etc. Market Sites; Beaching and Mooring Boats.
Housing	Traditional Villages; Government Low-cost Housing; Private Cottages etc.
Tourism/ Recreation	Hotels; Guest Houses; Apartments; Condominiums; Ancillary Services; Water Sports.
Industrial	Rum Refining; Cement Manufacture; Oil Refining; Power Generation.
Waste Disposal	Industrial and Domestic Sewage and Wastewater.
Transport	Port Facilities; Coast Guard Station; Highways.
Sea Defences	Groynes, Revetments, Gabions etc.
Marine and Scientific Reserves	Folkestone Underwater Park; Graeme Hall Inch Marlowe/Chancery Lane Swamps* (Aquatic Vegetation and Bird Sanctuaries).

* Potential/Planned Use.

(See Appendix 7 for full inventory).

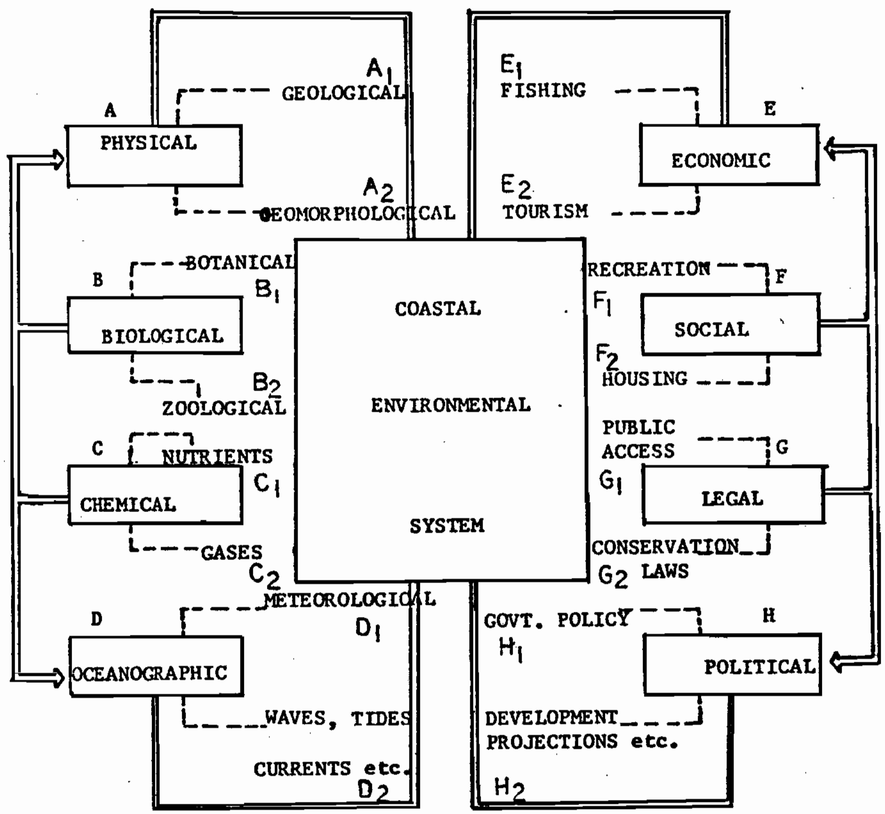
project. Two important factors to consider at this point are (i) the type and intended location and (ii) the scale of the project. These will help to identify potential areas of conflict with other proposed, or existing land uses as given in the inventory. In addition, the geographic space to occupied and influenced by the project, will be crucial in determining the overall feasibility of that project.

For example, the siting of an oil refinery in the centre of a popular recreational beach, would constitute one level of incompatibility. The noxious fumes and waste to be discharged at the coast would obviously reduce the quality of the existing amenity. Hence alternative sites would have to be considered even at this early stage of planning.

Identification of Initial Impacts

The next logical stage should be the preparation of a list of environmental conditions, which are likely to be affected by the proposed action. It should be stressed that for such a list to be meaningful, it must contain not only physical, biological and chemical elements, but social and economic parameters as well (Figure 47). It is also essential to include all possible impacts, whether negative or positive. This would ensure that a comprehensive range of 'costs' and 'benefits' are considered in the final decision-making process. These data can then be combined to produce an interaction matrix of the type shown in Table 20.

Figure 47



SCHEMATIC DIAGRAM SHOWING THE COMPONENTS OF THE BARBADOS COASTAL ENVIRONMENTAL SYSTEM

The letter designations(A,B,C, etc.) identify general subsystems; while the subscripts(1, 2, etc.) represent various inputs into those subsystems. (L.A.N.)

Table 20

POSSIBLE ENVIRONMENTAL IMPACTS														
Geomorphological/ Oceanographic				Biological			Economic			Socio-Cultural				
Levelling of Berm	Construction in Active Beach Zone	Effect on Beach Sediment Distribution	Disruption of 'normal' Wave Processes	Removal of Vegetation	Water Pollution from Sewage and Waste	Destruction of Coral Reefs	Creation of Jobs	Disruption of Fishing	Stimulation of Local Crafts	Reduced Beach Access	Improved Facilities and Services	Visual and Aesthetic Landscape	Crowding of Beach	Alienation of Villagers
-	-	-	-	-	-	-	+	-	+	-	+	-	-	-

Some Potential Impacts Which Could be Produced by the Proposed Construction of a Large Hotel Complex.

- = Adverse Impact

+ = Beneficial Impact

Consequent Impacts

It is clear that the matrix so far developed cannot adequately identify anything other than primary or first-order impacts. It is unrealistic to assume that an action or use can only produce a single impact. This misleading assumption underlines most interaction matrices, such as those proposed by Leopold et al. (op. cit. 1971) and Rajotte (op. cit. 1978). The reality of natural and man-made systems demonstrates that successive impacts may be triggered by a single action; and that a combination of two or more actions could produce one or more impacts.

To partially offset this difficulty, it is suggested that where necessary, sequences of impacts be traced systematically from an initial action or actions. This is similar to the network method developed by Sorensen (op. cit. 1971). However, unlike Sorensen's theoretical ideal, it seems unnecessary to proceed beyond fourth or fifth-order impacts. This modification is proposed for the following reasons:

(i) Given the present state of knowledge of most natural and man-made systems, lower levels of impact become increasingly uncertain or tenuous, or may even be remote;

(11) Such a large number of networks could be generated, that their proper analysis would be unmanageable without a high investment in personnel and other resources. In the context of Barbados and in the light of (i) above, the benefits might not justify the expenditure;

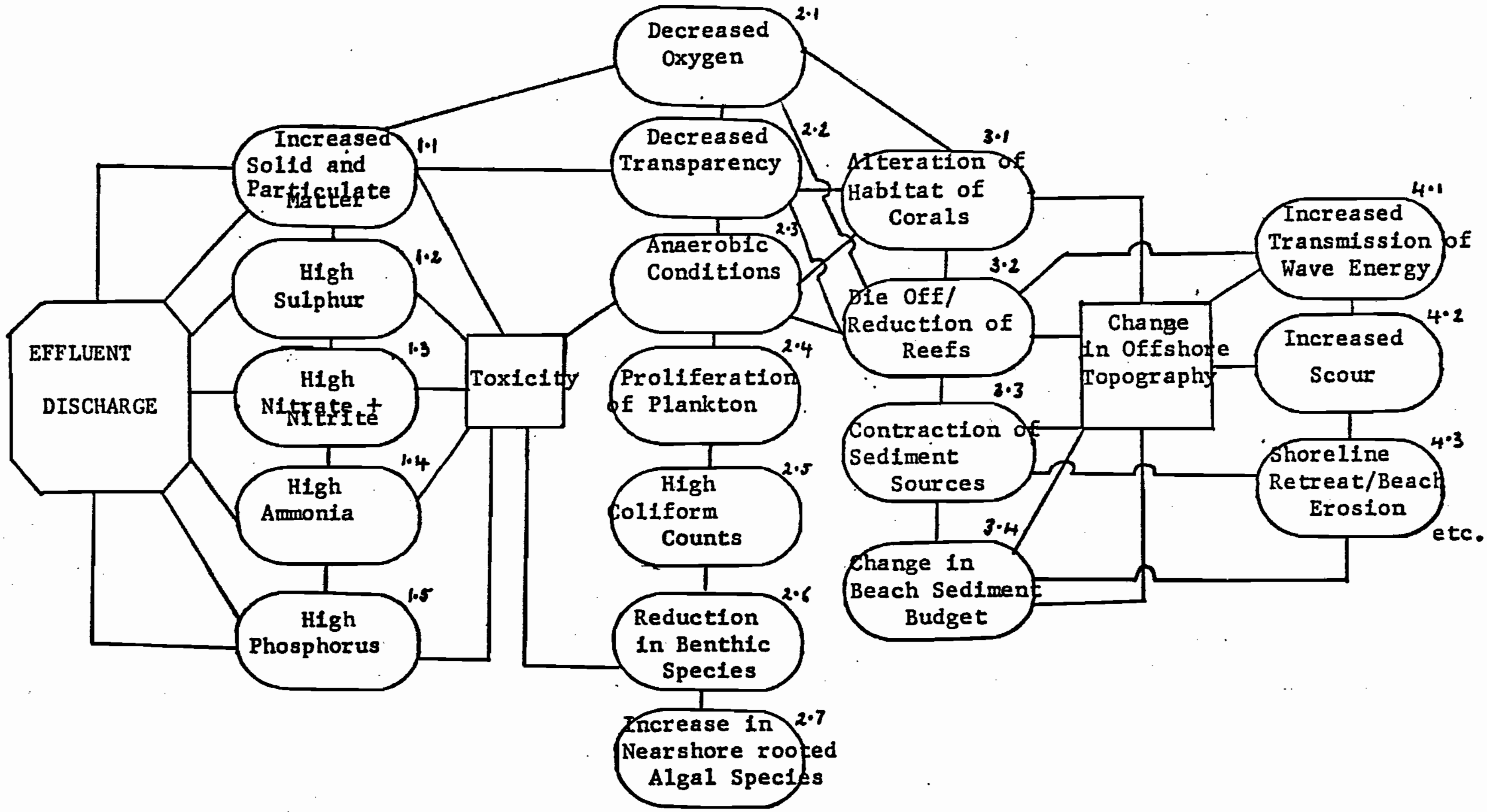
(iii) If higher-order impacts can be successfully alleviated, it is assumed that most associated lower-order effects would also be mitigated.

Figure 48 is a network for one type of impact frequently produced on the Barbados coast.

<u>The Need To Distinguish Between Short and Long-Term Effects</u>

When assessing the effects of a contemplated action, a clear distinction should be made as to whether these impacts are short or long-term (adverse and beneficial). For instance, the construction of a groyne in an area where a large amount of sediment is moving alongshore, will only have a short-term effect on downcoast beaches. However, if very little sediment is being transported, the effect would be long-term. Similarly, the present coastal highway project (Fontabelle-Freshwater) has generated great economic benefits now that it is in the construction stage. It has stimulated the sale of construction supplies, and provided over 200 jobs; but these are merely short-term impacts, as there will be negligible employment after the project is completed.

The weight of such short-term benefits is often over-emphasized when cost-benefit studies are being undertaken. This is particularly true in small developing states like Barbados, where there is great pressure to create jobs. In the final analysis, the ratio of economic benefits to environmental costs might seem more favourable than it really is. The political gains to be made from justifying projects on such spurious economic grounds are widely acknowledged in Barbados. A more meaningful evaluation would require that such 'benefits' be placed in proper perspective. The danger of implementing projects which



A NETWORK DIAGRAM showing sequence of changes produced by effluent discharge. The first and second order impacts(1.1 - 1.5; 2.1 - 2.7) are based on the work of Vezina (1974) and Turnbull(1979). These workers conducted detailed research on the effects of pollution in the vicinity of Carlisle Bay.

Figure 48

yield short-lived economic benefits was highlighted recently in a number of studies on the Pacific. The concentration on mass tourism as a panacea for economic development has precipitated the loss of lagoon, reef and mangrove habitats, and caused the partial disappearance of many aspects of Pacific culture (Bains 1977; Rajotte 1978; Unesco 1981; Gomez 1980).

Some Criteria for Determining Impact Magnitude and Importance

One of the most serious weaknesses encountered in impact assessment is the determination of magnitude and significance. Most methodologies suggest the use of a numerical weighting system as a solution to the problem (Leopold et al. 1971; Krauskopf and Bunde 1972; Dee et al., 1972; University of Georgia 1971; Rajotte 1978). However, the mere use of a number value system does not overcome the subjectivity of the method. There is the real possibility that similar impacts might be weighted differently by different analysts. To this extent, the factor of 'bias' could produce a low level of replicability of results.

Although it seems almost impossible to produce a totally objective measure, it is proposed that a set of specific guidelines could reduce the level of subjectivity. Answers to the following questions would serve as a basis for these guidelines.

(i) How widespread will be the impact? (e.g. in terms of geographic area, trophic levels and number of persons affected).

(ii) Is it likely to be an 'irreversible' effect?

(iii) Are there any mitigating measures available which can satisfactorily reduce or offset the anticipated impact?

After careful consideration of these questions, a numerical weighting system can then be applied thus:

Very low/ Negligible	Low	Moderate	High	Very High
± 1	± 2	±3	±4	±5

For instance any impact which is 'irreversible' (such as the blasting of a coral reef) whether widespread or not, would automatically be assigned a score of -5. On the other hand, if the impact could have potentially widespread, long-term consequences (e.g. constant discharge of effluent), but may be satisfactorily mitigated (e.g. by the erection of an efficient treatment plant), then it would score -1.

It is conceded that two important conditions must be met if the above system is to be reasonably objective. First, a reliable set of data is necessary on which to base the evaluation. Secondly, it presupposes that the evaluation is being carried out by qualified analysts. If these conditions can be fulfilled, a more objective measure of impact magnitude and significance can be achieved.

MITIGATION PLANNING

At every stage of impact identification it would be appropriate to list any mitigating measure(s) it might be necessary to implement. Remedial action should be evaluated as early as feasible in project development. Depending on the evaluation, alternative or modified remedial plans might have to be sought. Much too often the adoption of a particular measure is considered (albeit erroneously) to have mitigated a given impact; but the proposed mitigation itself could trigger subsequent impacts. For example many groynes along the Barbados leeward coast do not solve the perceived erosion problem but transfer it to adjacent properties which in turn have to take action. The structures built at Golden Palm and Barbados Beach Village hotels on the St. James coast have caused considerable sand depletion at downcoast beaches. In the late 1970's the resulting beach loss necessitated structural remedies further downcoast (Coastal Conservation Project 1984).

More recently a multi-million dollar Bridgetown Sewerage Treatment Plant was constructed in order to improve water quality along the Bridgetown and southern west coasts. Post-project surveys indicate that while BOD and suspended sediment loadings have been reduced by 50% and 80% respectively, nutrient contamination has increased (Meynall 1982). Preliminary results show that nitrate and phosphate concentrations are 3-4 times higher in the treated effluent now discharged (Ibid). It was also discovered that organic sedimentation downcurrent from the plant is causing stress in fish populations and further mortality of west coast reefs (Ibid). Such occurrences emphasize the need for assessing the impact of proposed remedial measures as well. They demonstrate that mitigation must be viewed as part of a coordinated management plan, rather than adopted on a haphazard basis.

Mitigation does not necessarily imply that burdensome 'costs' will be incurred by a project. It could be a slight redesigning of an original plan, scaling down of a project, observing building codes and set-back limits, or relocation. But whatever is required, it is essential to give it full consideration before the project proceeds further. If relocation is necessary for instance, it could mean the acquisition of land not readily available or at prohibitive costs to the project. Such considerations could weigh heavily on the final outcome of a proposal.

The timing of a mitigation act could be crucial in determining the success of that measure. For instance the waste and effluent from the new factories planned for the Bridgetown Harbour site can be controlled, once remedial action is taken early enough. If however there is too long a delay between the operation of the factories and the implementation of control regulations, toxicity could reach such a high level, that aquatic organisms might have their habitats severely altered. From an environmental viewpoint, the safest approach would be to enforce regulatory controls early in the operational phase. It is therefore essential to recognise that 'correct' strategies could have strong temporal limitations. In other words, a supposedly appropriate mitigation measure could become equally inappropriate, if its implementation is improperly timed.

Some Criteria to be Considered in the Final Evaluation

This procedure is designed to determine the final outcome of the proposed action or project. A proposal may be (i) accepted 'as is'. i.e. without further alterations (ii) conditionally accepted or (iii) rejected.

Acceptance Criteria

In deciding to implement a project, careful study of all adverse impacts, especially those assigned high scores, must be made. The appropriate authority must be fully satisfied that no important details of the proposals are overlooked, and that mitigation measures suggested are the most effective options available. In addition, it is recommended that the following conditions must be met:

(i) The benefits anticipated should far exceed any environmental costs;

(ii) If there are any adverse effects which appear unavoidable, they should be of a magnitude such that no severe environmental degradation occurs;

(iii) All available alternatives are thoroughly considered before a project is judged to be the most viable option;

(iv) The project is consistent with the island's overall development goals and needs.

Conditional Acceptance

This would apply where the overall feasibility of the project or action is sound, but where certain modifications would either enhance it, or allow it to fulfill the conditions set out above. These requirements would have to be satisfactorily effected, and the proposal resubmitted before approval is granted.

Project Rejection

This course of action would be indicated where

(i) any or all of the acceptance criteria cannot be fulfilled, even after project modification;

(ii) adverse long-term or permanent effects are likely;

(iii) the capacity of the coastal resource base to be productive in the long-term, is threatened.

It is cautioned that extreme care should be exercised, to ensure that a potentially beneficial project or action is not rejected. Figure 49 summarizes the final evaluation procedure.

A FRAMEWORK FOR ESTABLISHING A PROGRAMME OF MONITORING

After a proposal is accepted, a system of monitoring feedback between the project and the environment must be instituted. Ideally, this should be done during and after implementation. In a sense, monitoring is a recognition that errors in assessment, prediction and mitigation are possible, given the present level of understanding of many systems.

Recognition of Dynamic Nature of Systems

A major requirement of any monitoring system, should be a capacity for detecting and 'measuring' project-related changes as distinct from 'natural changes'. This is absolutely necessary if ill-advised 'corrective' measures are not to be implemented. Often changes in a system which may be perceived as undesirable, may be functional

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1. Here 'natural changes' refer to those which would still have occurred, assuming there was no project.

DIAGRAMMATIC SUMMARY OF COASTAL MANAGEMENT FRAMEWORK

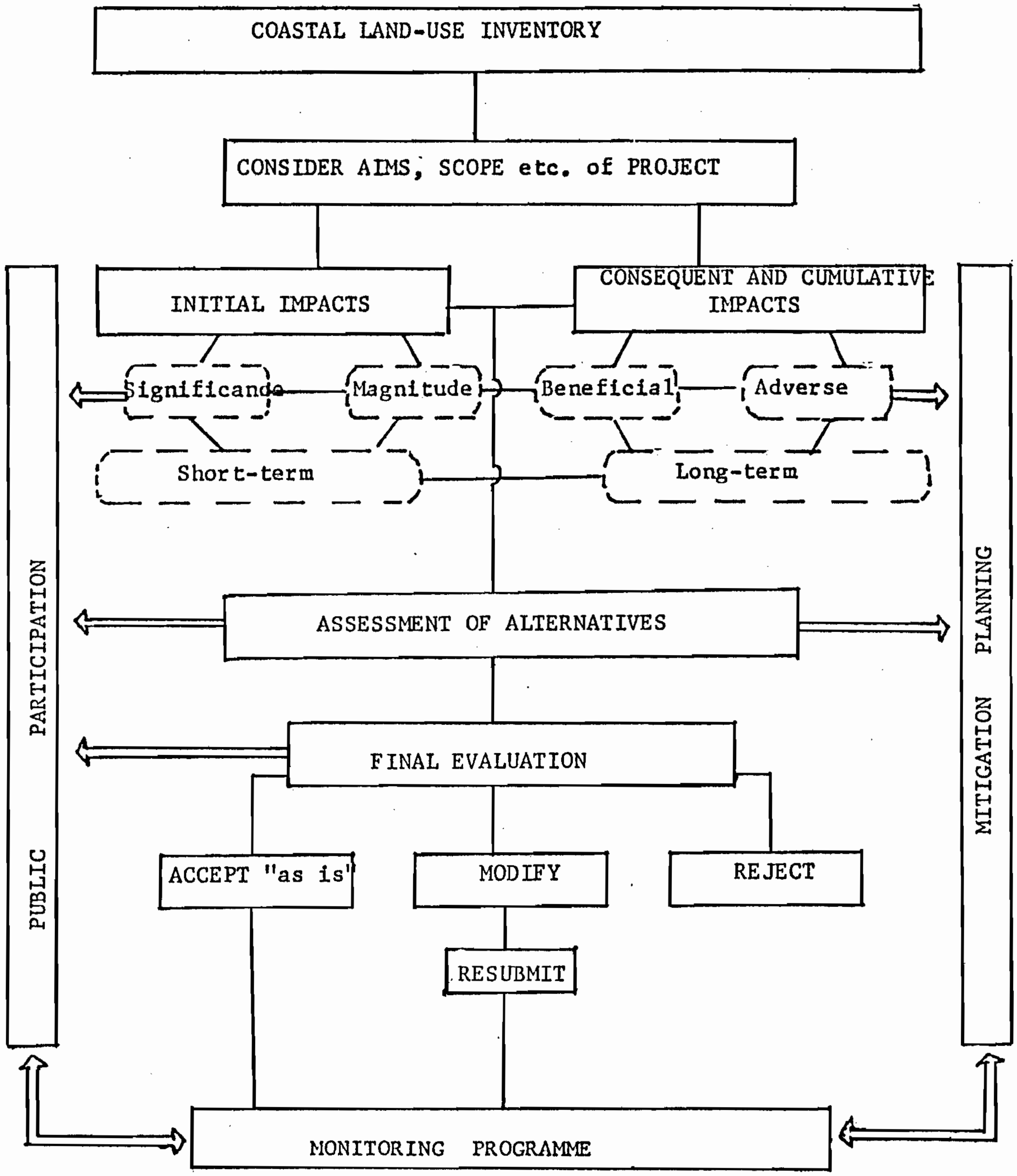

Figure 49

mechanisms in the system's attempt to achieve a state of dynamic equilibrium. The seasonal shift of sediment from one part of the west coast beach cells to another is one such regulatory mechanism. The annual sediment budget remains fairly constant, as the sediment moves back and forth in response to wave energy changes. It is the failure to recognize this seasonal cycle, that led to erection of sea defences at the limbs of the beach cells. At many locations this steady-state has been disturbed, and permanent sediment changes are now being experienced.

Enforcement of Standards and Other Conditions

It is proposed that a complete list of coastal environmental standards be researched and implemented. The maintenance of certain minimum standards is the very raison d'etre behind monitoring. At present the only comprehensive list relates to coastal water quality (refer to Appendix 6). There are other sub-systems of the littoral environment for which no formal standards exist.

There are no laws governing the use and preservation of ecological reserves such as Graeme Hall Swamp, which contains the last remnants of mangroves on the island. Neither are there any regulations governing the type and quantity of birds shot in the vicinity of this and other coastal swamps. No guidelines presently exist for the operation of speedboats and water-skiing, which cause 6-8 cases of serious injury to swimmers every year. Surely such activities should be confined to distances beyond the normal range of most swimmers. Tourists and locals alike can legally drive vehicles onto the beach, in many cases damaging the vegetation. Standards must be enforced to control these and other matters, if a conflict-free and long-lasting environment is to be preserved.

In other cases where standards exist, they are either ineffective or not enforced. The inadequacies of present building set-back limits and the law governing the removal of sand from the beach, have already been discussed. There are statutes against the use of explosives as a fishing method and the harvesting of *Tripneustes esculenta*[1] out of season. Yet, reefs are still blasted and the stocks of *Tripneustes esculenta* have been severely depleted.

The officers from the National Conservation Commission who are routinely sent out to inspect the beaches, could be retrained as beach wardens to deter such abuses. This can be done at very low cost to Government. Such a programme would not require the creation of several new jobs, simply the maximization of services already in existence.

How to Monitor

There are accepted scientific methods for measuring various physical, chemical and biological parameters, including oxygen, biological oxygen demand, salinity, nitrate and coliform bacteria. The full range of methodologies is given in Strickland and Parsons (1972), and the American Public Health Association (1976). These

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1. Referred to locally as 'sea egg.'

parameters have been singled out by the World Health Organization as indices of the health of coastal waters. Beyond certain levels, they not only indicate human health risks, but also a degree of stress which most marine organisms cannot tolerate (Johannes 1970).

Greater difficulty will be encountered in monitoring variables for which no standard or reliable tool exist. It is difficult for example to measure accurately, levels of user satisfaction or the deterioration of aesthetic attractiveness of the coastal environment. These are subjective but vital indices, which must be carefully monitored if the 'productivity' of the coastal zone is to be maintained. One way of measuring such 'environmental intangibles', is by conducting periodic perception studies covering all groups with a vested interest in the coast. These would include locals, tourists and hoteliers. This method is proposed on the premise that groups actively using the coast, are likely to be highly sensitive to changes in environmental quality.

<u>When to Monitor</u>

The issue of deciding when to monitor is still largely unresolved among specialists in the various fields (Ketchum 1972; Clark 1977; Holling 1978; Erickson 1979; Sonntag et al. 1982). However monitoring may often be determined by the nature of the project itself. For example the new Spring Garden Highway recently constructed along the southern west coast would require little or no post-project monitoring. On the other hand, waste from the rum refinery at Brighton should be routinely monitored to determine its effect on water quality and marine organisms. Indeed Meynall (1982, op. cit.) has shown that the proliferation of algae and phytoplankton at the latter location has resulted from the waste emanating from the refinery.

In Barbados the frequency of monitoring will partly be dictated by financial and personnel constraints. Nevertheless once determined, it is recommended that monitoring be regularly spaced to avoid any biases likely to be produced by irregular sampling. This policy would ensure an effective time series of data from which more reliable judgements might be made. However if there is any unusual occurrence (e.g. an oil slick, the breakdown of a sewerage treatment plant, a hurricane) monitoring should be implemented immediately until the effects are properly evaluated. For instance, an oil slick could be lethal to organic life and might necessitate the temporary halting of fishing or swimming. A hurricane might have catastrophic effects on coastal vegetation, the beach itself and property, so that special contigency measures may have to be implemented.

Where to Monitor

It is essential to know where to monitor, if one is to obtain the kind of data on which decision-making can be based. It has been shown for instance, that spatial gradients exist in the concentration of dispersed pollutants (Vezina 1974; Clark 1977), organic populations (Geldreich 1966; Wade et al. 1972; Turnball 1979) and man-made systems such as recreation areas (Williams and Zelinsky 1970; Matley 1976; Whyte and Burton 1980). Immediately, important questions arise: should monitoring be done at points of weak or strong gradient or both? Should random locations be chosen and if so, would they yield reliable data about the parameter being monitored? Ideally, to satisfactorily resolve such issues would require monitoring at many sites. This exercise would be too costly an undertaking for a small island like Barbados to contemplate. It would however be premature at this point to offer a clear-cut solution to the problem. Any solution will have to be based on interdisciplinary discussion and research. In the meantime it is recommended that consideration be given to as wide a spatial coverage as present resources would allow. Perhaps such a proposal might necessitate a reduction in the density of monitoring sites in some areas, but it is a sacrifice that will have to be made given the obvious resource constraints.

In addition monitoring would be indicated at locations where 'abnormal' changes or occurrences are observed. A dying coral reef, an uncommon abundance of phytoplankton or a sudden diminution in dune species are obvious signs of stress and may be evidence that tolerance levels are being exceeded. Similarly, the incursion of tourists onto a particular beach traditionally the preserve of locals, could lead to resentment and friction between the two groups. New or modified strategies will be required to 'mitigate' these impacts.

Additional Considerations for Monitoring

Various critical parameters have been identified in this study as positive indicators of coastal deterioration. Beach width measurements will indicate the extent to which beaches are prograding or contracting and the effectiveness of any structural measures which have been implemented. Similarly measurements of beachrock should be periodically taken, as these exposures are indicative of beach erosion (Revelle 1957, op. cit; Russel 1959, op cit; Bird, 1977, op. cit.). The results of such a survey would indicate whether or not early action should be taken to restore sediment loss. In addition the fringing coral reefs must be surveyed routinely in order to assess growth rates and mortality. Reef mortality is a sign of deteriorating water quality and habitat change. The reefs are also a source of sediment for leeward coast beaches. Recent interpretation of past shoreline changes demonstrates that where the shoreline was fringed by live, vigorous reefs accretion occurred, but reef mortality is often accompanied by erosion (Coastal Conservation Project 1984). The North American Demand Study for Caribbean Tourism conducted by the Caribbean Tourism Research Centre in 1981, shows that the intensity of beach use in Barbados varies with beach quality. The study points out that 'high' quality beaches are a key attraction in Barbados tourism and that tourists are sensitive to beach deterioration. Patterns of beach use should therefore be closely monitored since they can reflect user satisfaction and beach quality at certain sites. The list is by no means exhaustive, but the parameters identified should be given a high priority rating in any programme which is implemented.

It is suggested that consideration be given to the use of infra-red aerial photography as one of the tools for monitoring. Since infra-red film is sensitive to a portion of the non-visible spectrum, the photographs will display information which would not be visible on panchromatic film (American Society of Photogrammetry 1975; Avery 1977). Infra-red photography is better able to penetrate haze and cloud cover than conventional film and can produce sharp images even where some cloud cover is present (Avery, op.cit.). The effectiveness of infra-red film has been demonstrated by the United States National Ocean Survey (formerly Coast and Geodetic Survey) in wave and sediment transport studies, marine resources assessment and in vegetation studies (Ritchie et al., 1976; Lo 1976). Studies have shown that the range of reflectance of vegetation is extended in the infra-red, making it much easier to analyse structure and distinguish between different species (Ritchie et al., op. cit: 172). Periodic aerial surveys would therefore be efficient and cost-effective, given the range of variables which could be studied from a single set of photographs. While infra-red aerial photography should not be used as a replacement for ground surveys, it would reduce manpower needs considerably in designing a programme for coastal monitoring.

The cost of thirty-six exposures of infra-red colour film is approximately Bds.$12.00.[1] The Barbados Light Aeroplane Club estimates that 25 rolls of film (thirty-six exposures each) would be adequate for surveying the entire coastline, giving a 60% overlap for stereoscopic analysis. The cost of rental of an aircraft for such a survey would be Bds. $300.00 per hour, and the Light Aeroplane Club indicates that the coast could be surveyed in four hours. At current rates therefore, an aerial survey would cost approximately Bds. $1500.00. The benefits to be derived from such an operation would more than outweigh the cost. Not only would the information be useful for monitoring purposes, but it could also be used to build up a coastal data base which the island presently lacks.

OTHER RECOMMENDATIONS

There are other important considerations if the proposed framework is to be an effective tool for managing the island's coastal resources.

The Need for Flexibility

That the model should be flexible is a recognition that natural and man-made systems are not static. As changes occur in the 'natural order' and as the island's perceptions and goals become modified over time, there will be a need to readjust options. Allowance for flexibility must be built into the overall plan as a means of ensuring continued preservation of the resource base. We must

1. Information supplied by A.S. Bryden and Sons Ltd., Bridgetown, the only company that imports infra-red film into the island.

concede also that we have only an imperfect understanding of various environmental subsystems. As Sonntag et al. (1982) point out, there is no model of environmental planning which should be promoted

> "...as a panacea for predicting the fate of society and its environment. We must recognize that decisions are often made under uncertainty, ignorance and unpredictability" (Sonntag et al., 1982:3-4).

As such, management strategies and monitoring methods will require further modification as new research findings fill existing data gaps.

Resolution of the Trade-offs

In most situations in order to arrive at a viable solution, certain trade-offs will have to be made. It is suggested that given our imperfect knowledge, these should be resolved in favour of the physical environment when uncertainty exists. Consider for example the present building set-back limits of 30 m from mean high water. These limits are based on British land law with little relevance to some parts of the Barbados coast. The inadequacy of these limits has encouraged construction on the beach itself; diminishing the effectiveness of this buffer against scour. As a result significant sand loss has occurred in some areas. If the set-back regulations were more stringent initially, this situation would have been avoided; and if need be the conditions could be later relaxed without affecting the beach sediment budget. The fact is that even if the regulations are made more stringent, evidence of permanent erosion already exists.[1]

Inter-Disciplinary Approach

It is clear that the programme suggested will require a trained inter-disciplinary team of analysts. Past experience in Barbados shows an overreliance on the advice of economists and engineers in the allocation of coastal resources. Projects such as the former Coast Guard Station (south coast), and the dumping of derelict vehicles offshore to form artificial reefs (west coast), were judged to have economic and engineering feasibility. There were few other considerations and both fiascos are now history. No single discipline could presume to have a monopoly on the understanding of the principles governing natural or man-made systems. It is only by drawing on various disciplines and by basing planning strategies on tested, scientific principles that resource management can be successful (Mitchell 1979; Dansereau 1975; Jantsch 1972). This approach to planning has no precedent in Barbados. Certainly it will call for additional trained staff in some under-represented fields, such as costal engineering and microbiology; but mostly it will require coordination of available highly-trained personnel, who are presently spread over many fragmented departments.

The Importance of Public Participation

Public participation should be regarded as desirable and necessary at all levels of resource planning. Public

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1. The continuing exposure of tree roots, beach rock and beach scars support this observation.

involvement should be combined with an educational programme which seeks to enlighten the community about the basic principles of, and reasons for, coastal management. An effective, inexpensive system can be set up using presently available resources, such as the media and the Government Information Service. In turn the public could provide a wealth of usable information which might improve the effectiveness of management. For instance the new Oistin's Fisheries Terminal should not have been implemented without some meaningful dialogue with the fishermen, the group which will be most affected by the project. Similarly, dialogue should have been initiated with the residents of Maycock's, in whose traditional village a cement plant has been sited. Indeed the social, economic and perhaps physical health of the village could be affected by a project of that scale.[1]

Moreover, some types of monitoring can be conducted by the public at no additional cost to Government. For example oil slicks could be monitored (i.e. detected and reported) by residents on the spot, and therefore the appropriate authorities might be alerted sooner than they would otherwise have been. The five mile long oil slick left by a passing tanker along the east coast in August

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1. Already the residents are complaining about the level of dust from the cement plant, which has led to increased property maintenance costs in some cases. The writer was so informed in the summer of 1984 during a resurvey of beach and vegetation conditions at Maycock's.

1981 was first detected by residents at Bathsheba.[1] After the alert, the Ministry of Health and National Conservation Commission quickly despatched teams to perform a clean-up operation. It is in ways such as these, that public participation must be encouraged and meaningfully incorporated into the management plan.

A Case for Centralized Management

At present the authority for coastal management is vested in a number of government agencies. A recurring problem is the definition of boundaries which often creates confusion as to who is responsible for what. These agencies are fragmented to the extent that there is little inter-departmental exchange.[2] Hence there are no readily available lines of communication or consistent flow of information between departments. It is therefore proposed that the responsibility for coastal management be brought under a single agency. In this way better coordination can be achieved, as there will be an accessible, interdisciplinary staff *in situ* to deal with all coastal matters. Centralization would also be cost effective in the long-term, since some duplication of personnel and equipment might be avoided.[3]

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1. See the *Nation* newspaper, August 5, 1981.

2. Personal communication with Mr. Wilton Conliffe, June 1982.

3. It is hoped that the Project Office which now functions as a base for the Coastal Conservation Project, would ultimately be expanded as the central agency for coastal management.

SUMMARY

It is proposed that the above framework could provide a basis for coastal resource allocation in Barbados. It is recognized that some sections of the coast are already 'developed' and therefore will have to be dealt with 'as is'. In such cases, certain requirements of the proposal might have to be relaxed, modified or even abandoned. For instance very little can now be done about the building line already established on many parts of the west and south coasts. Nevertheless any 'new developments' could still be assessed along the lines prescribed by the proposal. The overall thinking behind the model is based on the need to minimise conflict and degradation in the coastal zone, while maximising the scarce resources which the littoral offers.

Finally, there is a recent body of literature which implies that there is futility in adopting structured management strategies of the type proposed, given imperfect knowledge and the complexity of natural systems (Oelschlaeger 1979; Junger 1979). This writer does not share that view. These limitations do not constitute a sufficiently valid reason for abandoning the framework of systematic and comprehensive planning. As Farvar and Milton (1972) suggest, if we wait until we have perfect knowledge, particularly in the case of small island systems, we might run the risk of not having any resources to manage. It is therefore necessary to exploit what knowledge we have, while recognizing some probability of error. For this very reason flexibility has been stressed as a cornerstone of the proposal. In this way the management process would benefit from any new, relevant, scientific information which becomes available.

CHAPTER 10

CONCLUSION

Landscape changes on the Barbados leeward coast have been documented from the immediate post-settlement era to the present. While some changes were the result of 'natural' forces, the weight of the available evidence indicates that man was the dominant agent of change. Almost uninterruptedly since the settlement in 1627 the coastal zone has been the focus of development on the island. The resulting human pressure exerted on the littoral led to numerous changes in the physical landscape, some beneficial, but others so drastic as to be adverse and permanent.

Deforestation

Deforestation must be regarded as one of the most important post-settlement changes to affect the island's shores. The removal of the original flora, particularly the stabilising plant associations, has no doubt left sections of the coast more susceptible to scour. For instance the previously ubiquitous *Hippomane* - *Coccoloba* association is shown to have played an effective role in the stabilisation of the beach sediment and dune systems. The ability of these and other species (e.g. *Tabebuia pallida*) to coexist in sandy, saline habitats and regenerate easily under such conditions, made them a functional element of the littoral environment. At the same time their ability to survive for long periods with their roots exposed rendered them vitally important species in times of temporary beach retreat.

The removal of vegetation has left the shoreline not only vulnerable to marine processes, but also to terrestrial forces. Damage often occurs during the summer after heavy rains, as runnoff from streams and canals cut rills across the beach. The presence of a vegetation cover helps to retard the rate of runoff, as well as reduce the amount of sediment removed from the sand terrace, berm and beach face. Along sections of the Barbados coast the absence of such a cover must be held partly responsible for some of the permanent rills and 'scars' which now exist.

The draining of swamps and consequent elimination of the mangrove communities had a similar negative impact on the shoreline. Over relatively short periods of time mangroves trap sediment landward of the beach, thereby creating additional sediment sources for the natural beach-building process (Richards 1952; Polunin 1960). Of the eleven known sites where mangroves existed (refer to figure 6) only two have survived.[1]

Beach Changes and Beach Stability

Beach changes on the west and south coasts have been quantitatively small. The average rate of beach recession for the period 1950-82[2] was approximately 0.3 m/yr , and the mean rate does not exceed 0.4 m/yr for any beach.

1. These are now mere remnants of their former extent, occurring at Graeme Hall (south coast) and Holetown River estuary (west coast). Only a few dozen trees are present at the latter location.

2. This is the period for which a reliable data base (aerial photographs and detailed maps) exist.

Hence in terms of actual sediment changes most beaches appear to be in dynamic equilibrium, although some have experienced continuous, small amounts of erosion since 1950. But it is this very condition that helped to encourage developers to build on the sand terrace and beyond the mean high water line from about 1950. Unfortunately once this delicate balance is upset, even quantitatively small sediment changes can have disproportionately great effects on the beaches. The beaches are narrow, generally not exceeding 12.0 m and the layer of sediment is shallow, between 2.0 - 3.0 m deep. A slight negative balance in the littoral sediment budget can therefore lead to the exposure of underlying coral rubble and beach rock, which detract considerably from the physical appearance of the beach.

Builders have often failed to recognize that the beaches are dynamic, experiencing cyclical changes in wave energy and sediment movement. Figure 34 demonstrates that the limbs and headlands of the beach cells record the greatest sediment changes. The concentration of energy from the north-west in 'winter' and from the south-west in summer makes these the most sensitive parts of the beach (Bird 1977). During the winter progradation occurs at the south limb, while recession takes place at the north limb; in summer the reverse is true (Ibid). But this shift of sediment is temporary and simply represents a natural response to wave energy changes. Construction in these sensitive zones of the beach has altered this regime, and permanent sand loss is now being experienced at some localities.

Similarly, construction in other areas of the active beach zone has diminished the buffering effect of the beach, as much less wave energy can now be absorbed and reflected. In turn coastal property is placed at serious risk. The failure to adopt appropriate building set-back limits leaves expensive coastal property vulnerable to heavy swells or storms. Indeed it has already been pointed out that a fully-developed, slow-moving hurricane which coincides with astronomical high tide would be disastrous for three-quarters of all coastal property. Although the island is fortunate not to have experienced such an event so far this century, the probability of such an occurrence cannot be ruled out. The beach is the best form of defence against marine erosion. To that extent every effort must be made to preserve the maximum beach area possible.

<u>Property Owner Response to Beach Changes</u>

Having built properties in such vulnerable situations, owners must often resort to the erection of sea defences to prevent flooding and structural damage. These measures often accelerate the erosion process, or transfer the problem to adjacent sections of the shore (Refer to chapter 7). In many cases the results are disastrous for the entire beach cell in the long-term. Evidence of sediment loss such as the exposure of tree roots, scour at the toe of structures and the appearance of beach 'scars' have recently become more noticeable in the Batts Rock, Sandy

Lane and Hastings cells for example.

It is indeed disconcerting that many of the defences built are either unnecessary, poorly designed or badly sited. It has also been shown that property owner response is often based on a perceived rather than a real threat. Tighter control must therefore be exerted on the indiscriminate erection of sea defences. The effectiveness of any such controls however, would probably be enhanced by a simultaneous programme of public education.

Impact of Tourism on the Coastal Environment

One of the most recent changes on the coast (i.e. since 1950) has been the concentration of tourist accommodation and ancillary facilities. Hotel construction increased 20% between 1950 - 60, 35% between 1960 - 70 and approximately 55% between 1970 - 80. In addition tourism land occupancy increased by over 60%, 30% and 25% respectively during the corresponding periods. Long-stay visitors[1] increased from 35000 in 1960 to 153000 in 1970 and 370000 in 1980 (figure 38). Most of this stimulus came from Government who provided various incentives for entrepreneurs, including loans at favourable interest rates, duty-free imports and tax-free rebates. Unfortunately this over-stimulation was not based on a proper assessment of the carrying capacity of the resource base. It led to a building boom especially in the post-1960 era, which placed the shoreline under extreme human

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1. These are defined as all tourists remaining on the island for at least three days.

pressure. Remnants of the original vegetation which had persisted were cleared, and developers began to build properties seaward of the high water mark and onto the beach itself. The quantity of untreated effluent and other waste discharged in coastal waters increased and had a debilitating effect on the coral reefs.[1]

Meanwhile the expansion of tourism also impacted heavily on the social and economic life of the country. On the positive side, there were improvements in infrastructure on the coast (roads, utilities etc.), the creation of jobs and an overall improvement in the standard of living. However mass tourism adversely affected domestic inflation as a result of the increased spending by tourists and locals alike.[2] Domestic inflation rose from 2.8% in 1960 to 8.5% in 1970, and to 13.5% in 1982. At the same time the boom of the 1960's and early 1970's encouraged excessive private and public investment, leaving the island's economy vulnerable to fluctuations in the tourist industry. It is demonstrated that economic recession in the main markets between 1973 - 76 and in the last five years have caused economic hardships in the island. Government revenues from the industry fell, many hotels closed, and a large number of workers became redundant. Until the economic situation

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1. See Address given by J.B. Lewis at the seminar <u>Planning for 1980 -An Environmental Study of Barbados,</u> U.W.I., Cave Hill, Barbados 1978.

2. The reader is referred to figure 39 and Appendix 3 which show a statistically significant correlation between domestic inflation and earnings from tourism.

in the main market areas improves, the island is likely to continue experiencing negligible economic growth.

<u>Deterioration of Coastal Water Quality</u>

Increasing human settlement on the littoral (both permanent and transient) has caused some concern about coastal water quality and its impact on marine organisms. Up to 1970 most of the coast was largely pollution-free, and the island's bathing beaches were considered to be among the safest in the world, according to World Health Organization standards.[1] Within the last decade this situation has changed, and up to 1982 there was evidence that pollution at some beaches was reaching unsafe limits.

One of the most serious indicators from a recreational viewpoint, is the increase in coliform bacteria at west and south coast locations. The World Health Organization has determined that more than 1000 colonies/100 ml is unsafe for recreational waters. At present there are only two sites where these standards are not met; but it must be a matter of concern to recreation planners that coliform concentrations have been increasing noticeably at some of the most popular bathing beaches since 1979 (See figure 36). It is expected that this trend should reverse when the Bridgetown Sewerage Treatment Plant becomes fully operational. However in the meantime, careful monitoring and enforcement of standards are imperative.

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1. Report by Senior Public Health Officer to Minister of Health, 1970.

Effect of Pollution on Coral Reefs

The impact of domestic and industrial effluent on reef communities is well documented. It is known for instance that reefs have narrow ranges of tolerance to critical factors such as water transparency, temperature, sediment load and pollutants including domestic waste (Johannes et al., 1970; Barnes 1973). Experience in the Caribbean and elsewhere has shown that domestic effluent, detergent and greases can significantly alter coral habitats (Barnes op. cit.; Hughes 1974).

On the Barbados leeward coast, the reefs are the main source of sediment to the beaches. They also absorb and reflect incoming waves, thus helping to protect the beaches from the direct effects of destructive wave energy. Active reef growth was reported to be occurring only along the west coast (Lewis 1960), and it is known that since then many reefs have died and there are few signs of regeneration.[1] These data suggest that long-term supply of sediment is limited, a fact which is likely to have a disastrous effect on the beaches in the future. It is therefore necessary to ensure that there are no further changes in water quality which would be harmful to present reef growth. For it is clear that the preservation of the beaches is inextricably linked to the growth and maintenance of the fringing reefs.

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1. Personal communication , J.B. Lewis, July 1983

Weaknesses of Existing Approaches to Coastal Management

The attempt by Government to offset the negative effects of rapid development on the coast has been largely ineffective. The government ministries and agencies responsible for coastal management are fragmented and the flow of information between them is limited. Many lack adequately trained personnel, which often makes it difficult to perform roles assigned to them. Some of the laws relating to coastal land use are inadequate. For instance the inherent weaknesses of the legislation governing building set-back limits and mining of beach sediment make it possible to build on the beach and remove large quantities of sand legally, under certain circumstances (See chapter 8). These provisions are certainly contrary to the intended aims of the legislation. In other instances where legislation is adequate, as in the case of the law governing the use of explosives in the nearshore zone, there is no properly authorised system in place to ensure its enforcement.

There is little comprehensive planning for the development of the island's coastal resources. Developments are usually implemented on a 'project-by-project' basis, without adequate reference to environmental constraints. Coastal protection measures are also adopted in a piecemeal fashion, and not as part of a systematic management policy. In addition, there is little post-project monitoring to determine whether minimum required standards are continually being observed, or to detect unforeseen, adverse environmental effects.

The nature of the changes documented in this dissertation emphasizes the need for an alternative approach to coastal management. An effective management scheme, while based on the concept of 'multiple-use', must seek to minimise conflict between competing land uses. Mitigation and monitoring procedures must complement the overall plan and should not be implemented as ad hoc measures as is presently the case. The approach to management should be a flexible one, to allow for the relatively easy adjustment of strategies. Such adjustments may become necessary as the coastal system is better understood, and as the island's development goals change. A flexible model would therefore minimise the premature foreclosure of future options. Public participation must also be encouraged. Since many groups have different interests in the coastal zone, the decision-making process must reflect and reconcile such interests. These objectives can be achieved with the help of meaningful citizen involvement.

For these reasons the recently implemented Coastal Conservation Project must be regarded as an important initiative. Government must however move beyond the pre-feasibilty stage of the project, and set the necessary machinery in motion for feasibility studies and implementation. Similiary the status of the Coastal Conservation Office should be upgraded to that of a permanent department of Government, and equipped with the necessary staff to enable it to function more effectively than it presently does.

It is evident therefore that the approach to shoreline development in Barbados has for too long neglected many fundamental environmental considerations. As Krause warns:

> "The natural environment of coastal areas is the most complex in the world, because coastal areas consist of intricate terrestrial systems and marine systems, plus manifold interactions between the systems and the variations of the subsystems from place to place. Although a given environment may appear to be quite stable, this stability is in fact typically a state of delicate balance. The management of human activities in coastal areas must be based on a thorough knowledge of the environment" (Krause 1978:230).

In Barbados there is an urgent need to implement a comprehensive coastal management plan along the lines suggested in chapter 9. Fortunately the present magnitude of coastal deterioration is not generally great. Nevertheless, we should not wait until there is further deterioration before we act. Experience elsewhere suggests that it is less costly to prevent degradation than to repair environmental damage. The coastal zone is an area of diverse resources, whose development if carefully regulated, can bring continuing economic and social benefits to the island. Surely our better judgement would seem to dictate that we should not sacrifice the long-term good for quick, short-term benefits.

APPENDIX 1(a)

BEACH WIDTH ESTIMATES FOR SOUTH COAST LOCATIONS 1950 and 1964 (meters)

	1950	1964	Net Change
Cotton House	12.5	10.2	-2.3
Oistins	12.0	9.8	-2.2
Welches	10.0	7.4	-2.6
Maxwell	12.5	9.7	-2.8
South Dover	12.0	14.2	+2.2
West Dover	11.7	14.0	+2.3
St. Lawrence	11.2	13.3	+2.1
Worthing	12.3	14.5	+2.2
Rockley	12.6	15.3	+2.7
Royal Hotel	10.0	13.0	+3.0
Ocean View Hotel	10.1	12.7	+2.6
West Pavillion Court	9.8	12.3	+2.5
Gravesend	9.4	12.0	+2.6
Needham's Point	10.9	9.2	-1.7
Holiday Inn	11.0	13.5	+2.5
Esplanade	10.6	12.2	+1.6

APPENDIX 1 (b)

BEACH WIDTH ESTIMATES FOR SOUTH COAST LOCATIONS 1964 and 1973 (meters)

	1964	1973	Net Change
Cotton House	10.2	9.5	-0.7
Oistins	9.8	9.3	-0.5
Welches	7.4	6.2	-1.2
Maxwell	9.7	8.9	-0.8
South Dover	14.2	15.2	+1.0
West Dover	14.0	15.3	+1.3
St. Lawrence	13.3	14.4	+1.1
Worthing	14.5	15.2	+0.7
Rockley	15.3	18.8	+3.5
Royal Hotel	13.0	14.2	-1.2
Ocean View Hotel	12.7	11.0	-1.7
West Pavillion Court	12.3	11.3	-1.0
Gravesend	12.0	9.3	-2.7
Needham's Point	9.2	32.2	+23.0
Holiday Inn	13.5	15.5	+2.0
Esplanade	12.2	13.6	+1.4

APPENDIX 1(c)

BEACH WIDTH ESTIMATES FOR SOUTH COAST LOCATIONS 1973 and 1982 (meters)

	1973	1982	Net Change
Cotton House	9.5	11.8	+2.3
Coast Guard Station*	-	35.5	+35.5
Oistins	9.3	8.2	-1.1
Welches	6.2	4.2	-2.0
Maxwell	8.9	10.4	+1.5
South Dover	15.2	16.3	+1.1
West Dover	15.3	16.1	+0.8
St. Lawrence	14.4	12.9	-1.5
Worthing	15.2	13.4	-1.8
Rockley	18.8	16.4	-2.4
Royal Hotel	14.2	10.5	-1.3
Ocean View Hotel	11.0	10.3	-0.7
West Pavillion Court	11.3	9.8	-1.5
Gravesend	9.3	7.5	-1.8
Needham's Point	32.2	45.0	+12.8
Holiday Inn	15.5	15.8	+0.3
Esplanade	13.6	15.3	+1.7

* Did not exist prior to 1974.

APPENDIX 1(d)

BEACH WIDTH ESTIMATES FOR WEST COAST LOCATIONS 1950 AND 1964 (meters)

	1950	1964	Net Change
Maycock's Bay	9.6	7.5	-2.1
N. Fryer's Well Bay	8.8	6.6	-2.2
Littlegood Hbr.	10.4	8.3	-2.1
Six Men's	10.5	8.2	-2.3
Heywoods N.	11.8	10.8	-1.0
Speightstown	10.7	9.8	-0.9
Fort Denmark	8.7	7.5	-1.2
Road View	11.0	10.0	-1.0
Gibbs	9.0	7.3	-1.7
Lower Carlton	10.3	8.5	-1.8
Alleyne's Bay	9.7	7.4	-2.3
Heron Bay	10.0	11.7	+1.7
Folkestone	10.3	11.8	+1.5
Holetown	10.2	12.3	+2.1
Sandy Lane	9.3	11.2	+1.9
Paynes Bay	7.2	8.0	+0.8
Fitts Village	8.3	9.4	+1.1
Batts Rock	8.6	7.3	-1.3
Freshwater Bay	7.7	8.5	+0.8
Brighton (Rum Refinery)	11.2	12.1	+0.9
Brighton S.	8.0	8.7	+0.7
Brandon	9.1	10.0	+0.9

APPENDIX 1(e)

BEACH WIDTH ESTIMATES FOR WEST COAST LOCATIONS 1964 AND 1973 (meters)

	1964	1973	Net Change
Maycock's Bay	7.5	7.0	-0.5
N. Fryer's Well Bay	6.6	6.3	-0.3
Littlegood Hbr.	8.3	7.9	-0.4
Six Men's	8.2	7.5	-0.7
Heywoods N.	10.8	9.8	-1.0
Speightstown	9.8	9.1	-0.7
Fort Denmark	7.5	6.9	-0.6
Road View	10.0	8.7	-1.3
Gibbs	7.3	6.1	-1.2
Lower Carlton	8.5	7.1	-1.4
Alleyne's Bay	7.4	6.7	-0.7
Heron Bay	11.7	10.9	-0.8
Folkestone	11.8	10.7	-1.1
Holetown	11.3	12.3	+1.0
Sandy Lane	10.0	11.2	+1.2
Paynes Bay	7.0	8.0	+1.0
Fitts Village	8.0	9.4	+1.4
Batts Rock	7.3	5.8	-1.5
Freshwater Bay	8.5	7.5	-1.0
Brighton (Rum Refinery)	12.1	11.6	-0.5
Brighton S.	8.7	8.0	-0.7
Brandon	10.0	9.0	-1.0

APPENDIX 1(f)

BEACH WIDTH ESTIMATES FOR WEST COAST LOCATIONS 1973 AND 1982 (meters)

	1973	1982	Net Change
Maycock's Bay	7.0	6.7	-0.3
N. Fryer's Well Bay	6.3	5.9	-0.4
Littlegood Hbr.	7.9	7.4	-0.5
Six Men's	7.5	7.5	0
Heywoods N.	9.8	9.4	-0.4
Speightstown	9.0	9.0	0
Fort Denmark	6.9	6.2	-0.7
Road View	8.7	8.2	-0.5
Gibbs	6.1	5.3	-0.8
Lower Carlton	7.1	6.3	-0.8
Alleyne's Bay	6.7	6.1	-0.6
Heron Bay	10.9	10.4	-0.5
Folkestone	10.7	9.8	-0.9
Holetown	11.3	10.7	-0.6
Sandy Lane	10.0	10.5	+0.5
Paynes Bay	7.0	8.0	+1.0
Fitts Village	8.0	9.4	+1.0
Batts Rock	5.8	5.0	-0.8
Freshwater Bay	7.5	6.9	-0.6
Brighton (Rum Refinery)	11.6	11.1	-0.5
Brighton S.	8.0	7.5	-0.5
Brandon	9.0	8.4	-0.6

APPENDIX 2

Coliform Count For Selected Beaches 1979 -82 (Colonies/100ml.)

Beach	1979		1980		1981		1982
Speightstown	50	(2)	75	(4)	80	(2)	105
Mullins	0	(2)	100	(3)	225	(2)	350
Holetown	10	(7)	60	(3)	120	(2)	150
Paynes Bay	40	(7)	30	(4)	120	(2)	300
Batts Rock	50	(2)	125	(4)	200	(2)	510
Paradise	210	(10)	240	(2)	315	(2)	330
Brighton	65	(4)	90	(2)	210	(3)	700
Holiday Inn	359	(17)	500	(4)	540	(4)	700
Esplanade	210	(2)	550	(4)	1200	(5)	1303
Hilton Hotel	850	(4)	916	(2)	2000	(4)	N.S
Ocean View	250	(2)	210	(3)	80	(2)	O
Oistin	N.S		115	(2)	180	(4)	250

Note: (1) The figures in parenthesis represent the number of samples taken, from which the averages were derived.

(11) Data for 1982 are the means of two samples.

(111) N.S = No sample taken.

APPENDIX 3

Correlation Between Real Tourist Earnings (Million $Bds) and Domestic Inflation (1960 -82)

Year	*Real Earnings from Tourism(x)	Domestic Inflation % (y)
1960	20.0	2.8
1961	21.3	3.5
1962	25.2	4.0
1963	25.5	4.8
1964	30.2	5.5
1965	33.0	5.9
1966	35.0	6.2
1967	39.7	6.7
1968	60.1	7.5
1969	69.9	8.0
1970	80.7	8.5
1971	95.9	8.8
1972	99.3	9.3
1973	97.2	9.5
1974	79.3	10.2
1975	70.5	9.5
1976	69.3	25.2
1977	86.7	20.8
1978	97.2	14.0
1979	108.0	11.0

APPENDIX 3 (Contd')

Correlation Between Real Tourist Earnings (Million $Bds) and Domestic Inflation (1960 -82)

Year	*Real Earnings from Tourism(x)	Domestic Inflation % (y)
1980	105.0	11.5
1981	103.5	12.0
1982	101.2	13.5

*Real earnings is here defined as the net revenue remaining in the island, after leakages (e.g. for imported food, souvenirs etc) are deducted.

APPENDIX 4

Bellairs Research Institute,
McGill University,
St. James.

Dear Respondent,

A survey on some aspects of public awareness and perception of beach problems, is being conducted by a Ph.D candidate from McGill University. This is part of the researcher's programme of fieldwork, which attempts to assess the nature of coastal problems, along the west and south coasts during the last ten (10) years.

The information is purely for research purposes. We would be grateful if you would kindly assist us, by completing the enclosed questionnaire, and returning it as soon as possible, to the Institute.

Thanking you in advance.

Location (Please specify) ______________________________

1. Do you (a) Own ____________ (b) Manage ______________ (c) Lease __________ the property?

2. How long have you been living at, or associated with, this property? __________________________

3. What sort of problems have you experienced here during the last ten (10) years?

   (a) Beach loss ________ (b) Property damage __________
   (c) Flooding from seawater _______ (d) Flooding from runoff after heavy rains _____ (e) Other (Please specify) ____________

4. Do you think the beach has become (a) wider_______ (b) narrower____(c) or remained stable _______________ during the last (10) years?

5. By approximately how much do you think the beach has widened or narrowed? ___________________

6. To the best of your knowledge, when erosion occurred in the past, did the beach later build back or was the change 'permanent'?
(a) Build back_______(b) Permanent_____(c) Not sure____

7. If the beach did build back, approximately how long, on average, did it take to do so?

____

8. In your view, is erosion more evident at any particular time of the year? Please be as specific as possible.

____

9. What, in your opinion, is (are) the cause(s) of erosion?

(a) Increased wave action________(b)Construction somewhere else along the beach_________________
(c) Combination of (a) and (b) above
(d) Other (Please specify)_____________________

10. Has any action been taken to protect your property from possible damage by the sea? (a) Yes____________ (b) No____________

11. If the answer to the previos question is 'yes', what specific action have you taken?

(a) Retaining wall_______(b) Coral Boulders__________
(c) Groynes________(d) Gabions_________(e) Asked Government for aid and/or advice______(f) Sought other professional advice______(g) Other (Please specify).____________________________________

12. Why did you think it necessary to take protective action?____

____

13. How many times have you built protective works during the last ten (10) years?______________________________

14. Do you intend to take any further action in the near future?____

15. Was (were) there any specific event(s) which led you to take steps to protect your property? ____________

____

16. What, in your opinion, is(are) the most effective method(s) of coastal protection? Please be as specific as possible. If more than one answer is given, kindly list in order of importance.__________

____

17. Who do you think should be responsible for protecting the beaches from erosion?

(a) Government________(b) Property owners__________
(c) Government and property owners_________________

18. Do you think that property owners should help bear the costs of coastal protection? (a) Yes____(b) No________
If 'yes' why?____
If 'no', why not?____

19. How serious a threat, in your opinion, is beach erosion at the present time? (a) Very serious________
(b) Serious_______(c) Not serious____________________
(d) No threat______________

20. Are there any final comments you would like to make?

End of Questionnaire.

APPENDIX 5

DATA FOR MEASURED AND PERCEIVED CHANGE (meters) AT SELECTED BEACHES

	Measured Change (m)	Perceived Change (m)
Welches	-2.0	-3.5/-3.0
Maxwell	+1.5	0.0/+0.5
S. Dover	+1.1	-0.5
W. Dover	+0.8	-1.0/0.0
St. Lawrence	-1.5	-2.5
Worthing	-1.8	-2.5/-3.0
Rockley	-2.4	-1.5
Royal Hotel	-1.3	-2.0/-1.5
Ocean View	-0.7	-2.0
Brighton S.	-0.5	-2.0
Brighton N.	-0.5	-1.0
Freshwater	-0.6	-1.5
Fitts Village	+1.4	+0.5
Sandy Lane	+0.5	0.0
Holetown	-0.6	-1.5/-2.0
Folkestone	-0.9	-2.0/-2.5
Heron Bay	-0.5	-2.0
Alleyne's Bay	-0.6	-1.5
Lower Carlton	-0.8	-2.5
Gibbs	-0.8	-4.0/-3.0
Road View	-0.5	-2.5/-3.0
Paynes Bay	+1.0	0.0

APPENDIX 6

Coastal Water Quality Standards - Barbados

1. Purpose and Scope:

   Coastal Water Quality Standards will be enforced and administered by the Ministry of Health. They are intended to preserve the quality of coastal waters and coral reefs.

2. Classification of water uses:

Class 1. waters	Oceanographic Research, Conservation of Coral Reefs. Support and Propagation of Marine Life. Compatible Recreation including fishing swimming, bathing and water sports. Aesthetic Enjoyment.
Class 2. waters	Support and Propagation of Marine Life. Compatible Recreation including fishing, swimming, bathing and water sports. Aesthetic Enjoyment.
Class 3. waters	Harbour Activities. Commercial and industrial shipping. Support and propagation of Marine Life. Aesthetic Enjoyment. Note: *Class 3 designation shall apply to only limited areas next to boat docking facilities in Bays and Harbours.

3. <u>Quality Standards of Coastal Waters</u>
   <u>Physical Parameters</u>

Items	Standards		
	Class 1. waters	Class 2. waters	Class 3. waters
a) Clarity/Turbidity-"Extinction Coefficient" determination using Secchi disk	Not altered from natural conditions by more than 5%	Not altered from natural conditions by more than 10%	Not altered from natural conditions by more than 20%

APPENDIX 6 (CONT'D)

		Class 1 waters	Class 2 waters	Class 3 waters
b)	Temperature	Not altered by more than 1.5 °F from natural conditions	Not altered by more than 1.5 °F from natural conditions	No standards

4. Chemical Parameters

Items		Standards		
		Class 1 waters	Class 2 waters	Class3 waters
a)	pH	Not more than 1/2 unit difference from natural conditions but not lower than 8.0 nor higher than 8.5 from other than natural causes	Not more than 1/2 unit difference from natural conditions but not lower than 7.0 nor higher than 8.5 from other than natural causes	Not more than 1/2 unit difference from natural conditions but not lower than 7.0 nor higher than 8.5 from other than natural causes
b)	Salinity	Shall not vary more than 10% from natural or seasonal changes considering hydraulic input and oceanographic factors	Shall not vary more than 10% from natural or seasonal changes considering hydraulic input and oceanographic factors	Shall not vary more than 10% from natural or seasonal changes considering hydraulic input and oceanographic factors
c)	Dissolved Oxygen	Not less than 5mg/1	Not less than 4.5mg/1	Not less than 4mg/1
d)	Total Nitrogen	Not greater than 0.10 mg/1	Not greater than 0.15 mg/1	Not greater 0.20 mg/1
e)	Total Phosphorus	Not greater than 0.020 mg/1	Not greater than 0.025 mg/1	Not greater than 0.030 mg/1

APPENDIX 6 (CONT'D)

5. Toxicity

Items	Class 1 waters	Class 2 waters	Class 3 waters
a) Toxic waste, corrosive and deleterious substances, residues in combination sufficient to be toxic to human, plant or aquatic life.	none	none	none
b) As a minimun evaluation of a 96 hour bio-assay shall be conducted. Survival of test species shall not be less than that in controls which utilise appropriate experimental water.	none	none	none

6. Micro-biological Parameters	Class 1 waters	Class 2 waters	Class 3 waters
a) Organisms of Coliforms	The median coliform bacteria shall not exceed 70 per 100ml during any 30 day period nor shall samples exceed 230 per 1000ml at any time.	The median coliform bacteria shall not exceed 1000 per 100 ml nor shall more than 10% of samples exceed 2400/100ml during any 30 day period.	Same as for class 2 waters

7. Specific Standards Applicable to Marine Bottoms

Coral Reef Flats and Reef Communities

a)

(1) Oxidation - Reduction Potential in the upper most 10 cm. (4 inches) of sediments shall not be less than + 100 mv.

(2) No more than 50% of the grain size distribution of sand patches shall be smaller than 0.125 mm in diameter.

(3) Deposits of flood-borne soil sediment shall not occur in quantities exceeding equivalent thickness for longer than 24 hours after a heavy rainstorm as follows:

(a) Not thicker than an equivalent of 2 mm (.08") on living coral surfaces;

(b) Not thicker than an equivalent of 5 mm (0.2") on other hard bottoms;

(c) Not thicker than an equivalent of 10 mm (0.4") on soft bottoms.

8. Recreational Waters

(1) Oxidation - Reduction Potential in the uppermost 10 cm. (4 inches) of sediment shall not be less than + 100 mv.

(2) No more than 50% of the grain size distribution of sand patches shall be smaller than 0.125 mm in diameter.

(3) Deposits of flood-borne soil sediment shall not occur in quantities exceeding an equivalent thickness of 10 mm (0.040 inches) 24 hours after a heavy rainstorm.

APPENDIX 7

A COASTAL LAND-USE INVENTORY FOR BARBADOS, BASED ON FIELDWORK, SUMMER 1981 and 1982.

FISHING	Cast Netting from Beach Seining Potting Bottom Lining Sea-egg Harvesting and Preparation Market Sites Beaching and Mooring Boats Boat Building Jetties, Wharves etc.
HOUSING	Private Cottages and Residences Govt. Low-Cost Housing Traditional Villages
RISM	Hotels Condominiums Guest Houses Specialty Shops Boutiques Night Clubs

BIBLIOGRAPHY

Adams, J.W.R. (1980) 'David on the Beaches.' Shore and Beach, 48 No.3, pp. 3-5.

Alleyne, W. (1978) Historic Bridgetown. Barbados National Trust, 117p.

Allison, L. (1975) Environmental Planning. London: Allen & Unwin, 134pp.

American Public Health Association (1976) Standard Methods. New York: American Public Health Association, 1134pp.

American Society of Photogrammetry (1975) Manual of Remote Sensing . Virginia, 2144 pp.

Avery, T.E. (1977) Interpretation of Aerial Photographs. Minneapolis: Burgess, 428pp.

Bains, G.B.K. (1977) "The Environmental Demands of Tourism in Coastal Fiji.' In J.H. Winslow The Melanesian Environment, Australian National Library; Canberra: University Press, 1977. 562pp.

Ball, M.M., E.A. Shinn and K.W. Stockman (1967) 'Geologic Effects of Hurricane Donna in South Florida'. Journal of Geology LXXV, pp.583-97.

Barbados Government (1984) Coastal Conservation Study -Pre-Feasibility Draft Report. 122 pp.

Barnes, E.S. (1973) 'Sewage Pollution from Tourist Hotels in Jamaica.'Marine Pollution Bulletin 4, no.7, pp. 102 - 105.

Barnes, F.A. and C.A.M. King (1935) 'The Lincolnshire Coastline and the 1953 Storm-Flood.' Geography 38, pp. 141-160.

Barrows, H.H. (1923) 'Geography as Human Ecology.' Annals of Association of American Geographers 13, pp. 1-14.

Barton, G.T.(1953) The Pre-History of Barbados. Barbados: Advocate Co. Ltd., 88 pp.

Bates, G.H. (1935) 'The Vegetation of Footpaths, Sidewalks, Cart-tracks and Gateways.' Journal of Ecology 23, pp. 470-487.

Bayfield, N.G. (1973) 'Use and deterioration of some Scottish Hill Paths.' Journal of Applied Ecology 10, pp. 635-44.

Beanlands, G.E. and P.N. Duinker (1983) An Ecological Framework for Environmental Impact Assessment. Institute for Resource and Environmental Studies; Dalhousie University, 132pp.

Beard, J.S. (1949) The Natural Vegetation of the Windward and Leeward Island. Oxford: Clarendon Press, 192pp.

Beardsley, W.G., R.B. Herrington and J.A. Wagar (1974) 'Recreation Site Management - How to Rehabilitate a Heavily Used Campground without Stopping Visitor Use.' Journal of Forestry 72, pp. 279-81.

Bell, de G. (ed.1970) The Environmental Handbook Prepared for the First National Environmental Teach-in. New York: Ballantine Books, 352 pp.

Bird, J.B. (1970) 'Evolution of the Shores of Western Barbados'. Unpublished Manuscript, Barbados: Bellairs Research Institute, 3 pp.

Bird, J.B. (1977) 'Beach and Recreational Planning on the West Coast of Barbados, West Indies.' Geographia Polonica, 36, pp. 31-41.

Bird, J.B., A. Richards and P.P. Wong (1979) 'Coastal Subsystems of Western Barbados, West Indies'. Geografiska Annaler 61 A, pp. 221-225.

Blalock, H.M. (1970) An Introduction to Social Research. New Jersey: Prentice-Hall, 152 pp.

Bloom, A.L., W.S. Broecker, J.M. Chappell, R.K. Matthews and K.J. Mesolella (1974) 'Quaternary Sea-level Fluctuations on a Tectonic Coast.' Quaternary Research, 4, pp. 185-205.

Broecker, W.S., D.L. Thurber, J.Goddard, T. Ku, R.K. Matthews and K.J.Mesolella (1968) 'Milankovich Hypothesis Supported by Precise Dating of Coral Reefs and Deep-sea Sediments.' Science 159, pp. 207-300.

Brown, C.W. (1939) 'Hurricanes and Shoreline Changes in Rhode Island.' Geographical Review 29, pp. 416-430.

Bruha, T.C. (1981) 'New England, Its Shore Protection Program and Federal Involvement.' Shore and Beach 49, no.1, pp. 3-7.

Burk, C.J., H.A. Curran and T.M. Czernial (1981) 'Dunes and Vegetation : Natural Recovery on a Damaged Barrier Island.' Shore and Beach 49, no.1, pp. 21-25.

Burton, I, R.W. Kates, and G.F. White (1968) The Human Ecology of Extreme Geophysical Events. Natural Hazards Research Working Paper No.1, Department of Geography; University of Toronto, 196pp.

Burton, I., and R.W. Kates (1964) 'The perception of Natural Hazards in Resource Management.' Natural Resources Journal 3, pp. 412-441.

Burton, I., and G.F. White (1978) The Environment as Hazard. Oxford University Press, 258pp.

Burton, I., R.W. Kates, and G.F. White (1968) The Human Ecology of Coastal Flood Hazard in Megalopolis. Research Paper No. 115, Dept. of Geography; University of Chicago, 196pp.

Byrne, R. (1980) 'Man and the Variable Vulnerability of Island Life.' Atoll Research Bulletin 240, pp. 1-200.

Campbell, J.K. and D.J. Hwang (1982) 'Beach Erosion at Waimea Bay, Oahu, Hawaii.' Pacific Science 36, no.1, pp. 35-43.

Campbell, T.J. and R.H. Spandoni 1982) 'Beach Restoration - An Effective Way to Combat Erosion on The Southeast Coast of Florida.' Shore and Beach 50, no.1, pp. 11-12.

Caribbean Tourism Research Centre (1981) North American Demand Study for Caribbean Tourism. 7 vols., 1164pp.

Carter, R.W.G. (1978) 'The Effect of Human Pressures on the Coastlines of County Londonderry and County Antrim'. Irish Geography 8, pp. 72-85.

Chapman, V.J. (1944) '1939 Cambridge University Expedition to Jamaica Part 111: The Morphology of Avicennia nitida and Function of the Pneumatophores.' Journal of Linnaeus Society 52, pp.487-533.

Clark, J.R. (1977) Coastal Ecosystems Management. New York : John Wiley & Sons, 928pp.

Colt, H. (1631) Voyages of Sir Henry Colt. Massachussetts University Library, 126pp.

Cook, P.J. and H.A. Polach (1973) 'A Chenier Sequence at Broad Sound, Queensland, and Evidence Against a Holocene High Sea Level.' Marine Geology 14, pp.253-268.

Curray, J.R. (1965) 'Late Quaternary History, Continental Shelves of the United States' In H.E. Wright and D.G. Freys (eds) The Quaternary of the United States. Princeton University Press, pp. 723-735.

Dansereau, P.(1957) Biogeography: An Ecological Perspective. New York: Ronald Press, 394. pp.

David Lashley and Partners (1980) Oistins Fisheries Project. Unpublished Document Prepared for Government of Barbados, 110pp.

Davis, J.H. (1940) The Ecology and Geologic Role of Mangroves in Florida. Publication of The Carnegie Institute no. 517, 412pp.

Davis, J.H. (1957) Dune Formation and Stabilization by Vegetation and Plantings. U.S. Beach Erosion Board. Tech. Memoradum 101, 147pp.

Davis, R.K. (1963) 'Recreational Planning as an Economic Problem' Natural Resources Journal 3, 239-249.

Davy, J. (1954) The West Indies Before and Since Slave Emancipation. London: Frank Cass Ltd.,551pp.

Deane, C.M., M. Thom and H. Edmunds (1973) Eastern Caribbean Coastal Investigations (1970-73). Faculty of Engineering, U.W.I., St Augustine, Trinidad, 5 vols, 388pp.

Dee, N. et al. (1972) Environmental Evaluation Systems for Water Resources Planning. Report to the U.S. Bureau of Reclamation, Columbus, Ohio Batelle Memorial Institute, 25pp.

Dee, N. et al. (1973) 'An Environmental Evaluation System for Water Resources Planning.' Water Resources Research 9, pp. 523-535.

Ditton, R.B. and T.I. Goodale (1972) eds. Environmental Impact Analysis, Philosophy and Methods. University of Wisconsin Press. 528pp.

Donn, W.L. and W.T. McGuinness (1959) 'Barbados Storm Swell.' Journal of Geophysical Research 64, pp.2341-2349.

Elton, C.S. (1958) The Ecology of Invasions by Animals and Plants. Methuen. 216pp.

Erickson, P.A. (1979) Environmental Impact Assessment: Principles and Applications. New York Academic Press, 395pp.

Essink, K. (1978) The Effects of Pollution by Organic Waste on Macrofauna in the Eastern Dutch Wadden Sea. Netherlands Institute for Sea Research Publication Series no.1, 135pp.

Eyre, S.R. (1968) Vegetation and Soils. New York Edward Arnold, 328pp.

Eyre, S.R. (1971) 'Man the Pest: The Dim Chance of Survival.' The New York Review, November 18 1971, pp. 18-27.

Fischer, D.W. and G.S.Davies, (1973) 'An Approach to Assessing Environmental Impacts. Journal of Environmental Management 1, pp. 207-227.

Florida Coastal Coordinating Council (1971) Coastal Zone Management in Florida. Tallahassee, Florida, 115pp.

Fonaroff, L.S. (1966) 'Geographic Notes on the Barbados Malaria Epidemic'. Professional Geographer 18, pp. 155-163.

Geldreich, E.E. (1966) Sanitary Significance of Fecal Coliforms in the Environment. Water Pollution Control Research Publication WP-203, 122pp.

Gilbert, C.G., G.L. Peterson and D.W. Lime (1972) 'Toward a Model of Travel Behaviour in the Boundary Waters Canoe Area' Environment and Behaviour 4, pp. 131-158.

Ginsberg, R.N. (1935) 'Beachrock in South Florida'. Journal of Sedimentary Petrology 23, pp. 85-92.

Gleason, H.A. and M.T. Cook (1926) Plant Ecology of Puerto Rico. Scientific Survey of the Virgin Islands. Part 1. New York: Academy of Sci., 149pp.

Godwin, H., R.P. Suggate and E.H. Willis (1958) 'Radiocarbon Dating of the Eustatic Rise in Ocean Level'. _Nature_ 181, pp. 1518-1519.

Gomez, E.D. (1980) _Direct and Indirect Impacts of Tourism on the Coastal Environment_. Paper presented at UNESCO Seminar held at University of Papua New Guinea, July 14-17 1980. 15pp.

Gonen, A. (1981) 'Tourism and Coastal Settlement Processes in the Mediterranean Region'. _Ekistics_ 290, pp. 378-381.

Gooding, E.G.B. (1942) 'Turner's Hall Wood'. _Journal of Barbados Museum and Historical Society_ 10, pp.74.

Gooding, E.G.B. (1947) 'Observations on the Sand Dunes of Barbados'. _Journal of Ecology_ 34, pp. 111-125.

Gooding, E.G.B. (1966) 'Turner's Hall Wood'. _The Bajan_. no.14, Bridgetown: Bajan, 17 pp.

Gooding, E.G.B. (1974) _The Plant Communities of Barbados_. Bridgetown: Govt. Printing Office, 243 pp.

Gooding, E.G.B., R.A. Loveless and G.R. Proctor (1965) _Flora of Barbados_. London: H.M.S.O, 456pp.

Graber, P.H.F. (1981) 'The Law of the Coast in a Clamshell: Part 11'. _Shore and Beach_ 49, no.1, pp. 16-20.

Gregory, S. (1976) 'The Geographer and Natural Resources Research'. _South African Geographer_ 4, pp. 371-382.

Guppy, H.B. (1917) _Plants, Seeds and Currents in the West Indies and Azores_. London: Williams & Norgate, 105pp.

Hardy, F. (1934) _Some Aspects of the Flora of Barbados_. Bridgetown: Advocate Co. Ltd., 96pp.

Harlow, V.T. (1926) _A History of Barbados. 1625-1685_. London. 185pp.

Harris, D.R. (1926) 'The Invasion of Oceanic Islands by Alien Plants: An Example From the Leeward Islands, West Indies'. _Transactions Institute of British Geographers_ 31, pp. 67-82.

Harris, D.R. (1965) Plants, Animals and Man in the Outer Leeward Islands, West Indies. University of California Publications in Geography, no.18. 164pp.

Harrison, J.B. and A.J. Jukes-Brown (1890) The Geology of Barbados. Barbados Legislature, 98pp.

Hayakawa, K. (1979) 'The Management of Land as an Environmental Resource'. Ekistics, 278, pp. 296-301.

Hills, T.L. (1974) 'The Savanna Biome: A Case Study of Human Impact on Biotic Communities'. In Manners, I.R. and M.W. Mikesell (eds) Perspectives on Environment. Association of American Geographers, pp. 342-374.

Holling, C.S. (1978) Adaptive Environmental Assessment and Management. New York: John Wiley & Sons Ltd., 398pp.

Horikawa, K. (1978) Coastal Engineering: An Introduction to Ocean Engineering. New York: John Wiley & Sons Ltd., New York. 402pp.

Hudson, B.J. (1979) 'The End of Paradise. What Kind of Development for Negril?' Caribbean Review 8, no. 3, pp. 32-33.

Hughes, G. (1750) The Natural History of Barbados. London, 314pp.

Hughes, D. (1974) 'Sunshine, Golden Beaches and Bacteria'. Marine Pollution Bulletin 5, no. 3, p. 35.

Hughes, W.J. (1982) 'Comments on the New Jersey Shore Protection Master Plan'. Shore and Beach 50, no. 2, pp. 15-16.

Humboldt, A. Von (1850) Views of Nature. London: H.G. Bohn, 482pp.

Hunte, G. (1974) Barbados. London: Batsford, 219pp.

Hwang, D.G. (1980) Beach Changes on Oahu Revealed by Aerial Photographs. Msc. Dissertation, University of Hawaii, 145pp.

Isaac, W.E. (1968) 'Marine Botany of Kenya Coast, 11: Second List of Kenya Marine Algae'. Journal of the East African Natural History Society 27, pp. 1-6.

Jain, R.K. (1975) A Review and Analysis of Environmental Impact Assessment Methodologies. Springfield, Virginia: N.T.I.S., 22pp.

James, N.P. (1971) Late Pleistocene Reef Limestone, Northern Barbados. Unpublished PhD. Disseration; Montreal: McGill University, 155pp.

Jantsch, E. (1972) Technological Planning and Social Futures. New York: Halstead Press, 256pp.

Johannes, R.E. (1970) 'Coral Reefs and Pollution'. In M. Ruivo (ed.) Marine Pollution and Sea Life. London, pp. 364-371.

Jones, D.E. (1978) 'Housing and Related Coastal Programs: Current Practices Offer Improved Solutions'. Shore and Beach 46, no.1, pp. 8-14.

Junger, P.D. (1979) 'The Inapplicability of Cost-Benefit Analysis to Environmental Policies'. Ekistics 276, pp. 184-194.

Kates, R.W. (1962) Hazard and Choice Perception in Flood Plain Management. Res. Paper No. 78, Dept. of Geography; University of Chicago, 210pp.

Kershaw, K.A. (1964) Quantitative and Dynamic Ecology. London: Edward Arnold, 183pp.

Ketchum, B.H. (1972) The Water's Edge: Critical Problems of the Coastal Zone. M.I.T. Press, 393pp.

King, C.A.M. (1972) Beaches and Coasts. London: Edward Arnold, 570pp.

Komar, P.D. (1976) Beach Processes and Sedimentation. New Jersey: Prentice-Hall, 429pp.

Krause, D.C. (1978) 'Scientific Basis for the Development and Management of Coastal and Offshore Marine Resources'. In C.O. Okidi and S. Westley (eds.) Management of Coastal and Offshore Resources in Eastern Africa. Institute for Development Studies; University of Nairobi. Occasional Paper No. 28, pp. 230-245.

Krauskopf, T.M. and D.C. Bunde (1972) 'Evaluation of Environmental Impact Through a Computer Modelling Process'. In R. Ditton and T. Goodale (eds.) Environmental Impact Analysis: Philosophy and Methods. University of Wisconsin Press, Madison, pp. 107-125.

Kuchler, A.W. (1967) _Vegetation Mapping_. New York: Ronald Press Co., 472pp.

Kuhn, G.G. and F.P. Shephard (1983) 'Newly Discovered Evidence from the San Diego County Area of Some Principles of Coastal Retreat'. _Shore and Beach_ 51, no.1, pp. 1-3.

Lapage, W.F. (1963) 'Some Sociological Aspects of Forest Recreation'. _Journal of Forestry_ 61, pp. 32-36.

Leopold. L.B., F. Clark, B. Hanshaw and J. Balsley (1971) _A Procedure for Evaluating Environmental Impact_. Geological Survey Circular 645, Washington, D.C., 13pp.

Lewis, J.B. (1960) 'The Coral Reefs and Coral Communities of Barbados'. _Canadian Journal of Zoology_ 38, pp. 1133-1145.

Lewis, T.E. (1973) 'Coastal Zone Management - The Florida Experience'. _Shore and Beach_ 41, no.2, pp. 12-14.

Lewsey, C.D. (1978) _Assessing the Environmental Effects of Tourism Development on the Carrying Capacity of Small Island Systems: The Case for Barbados_. Unpublished PhD. Dissertation, Cornell University, 218pp.

Ligon, R. (1657) _A True and Exact History of the Island_ of Barbados. London, 114pp.

Likens, G.E., F.H. Bormann, N.M. Johnson, D.W. Fisher and R.S. Pierce (1970) 'Effects of Forest Cutting and Herbicide Treatment on Nutrient Budgets in the Hubbard Brook Watershed-Ecosystem'. _Ecological Monographs_ 40, pp. 23-47.

Lillevang, O.J. (1966) 'Groynes and Effects: Minimizing Liabilities'. In _Coastal Engineering, Santa Barbara Conference, October 1965._ American Society of Civil Engineers, pp. 749-754.

Lime, D.W. and G.H.Stankey (1971) 'Carrying Capacity: Maintaining Outdoor Recreation Quality'. In _Recreation Symposium Proceedings_, Northeastern Forest Experiment Station, Forest Service. U.S. Department of Agriculture. Upper Darby; Pennsylvania, pp. 174-184.

Lo, C.P. (1976) 'Geographical Uses of Aerial Photography'. In _Manual of Remote Sensing_. American Society of Photogrammetry, 2724pp.

Lowenthal, D. (1972) 'Research in Environmental Perception and Behaviour: Perspectives on Current Problems'. Environment and Behaviour 4, pp. 251-254.

Lucas, R.C. (1964) 'Wilderness Perception and Use: The Example of the Boundary Waters Canoe Area'. Natural Resources Journal 3, pp. 394-411.

Manners, I. and M.W. Mikesell (1974) Perspectives on Environment. Association of American Geographers, 395pp.

Marsh, G. P. (1864) Man and Nature: Or Physical Geography as Modified by Human Action. New York: Scribner, 504pp.

Marshall, D. (1982) ed. Studies on Population Development and the Environment in the Eastern Caribbean. UNESCO/UNFPA/ISER Man and the Biosphere Project, 174pp.

Marshall, S.M. and A.P. Orr (1931) 'Sedimentation on Low Isles Reefs and Its Relation to Coral Growth'. Scientific Report of British Museum 1, pp. 94-133.

Matley, I.M.(1976) The Geography of International Tourism. Association of American Geographers, 40pp.

McBryde, F.W. (1947) Cultural and Historical Geography of South west Guatemala. Institute of Social Anthropology; Publication no.4, Smithsonian Institution, 184pp.

McEachern, J. and E.L. Towle (1972) Resource Management Programs for Oceanic Islands. Island Resources Foundation; Occasional Paper no.1, 159pp.

McLean, R.F. (1964) Mechanical and Biological Erosion of Beachrock in Barbados, West Indies. Unpublished PhD. Dissertation; Montreal: McGill University, 266pp.

McNeill, J.W. (1973) Environmental Management. Ottawa: Information Canada, 191pp.

Meadows, D.H. et al. (1972) The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind. New York: Universal Books, 250pp.

Merriam, L.C. and C.K. Smith (1974) 'Visitor Impact on Newly Developed Campsites in the Boundary Waters Canoe Area.' Journal of Forestry 72, pp. 627-630.

Mesolella, K.J. et al. (1969) 'The Astronomical Theory of Climatic Change: Barbados Data'. Journal of Geology 77, pp. 250-274.

Meynall, P. (1982) A Report on the Baseline Survey on the Marine Environment Around the New Sewage Outfall, Barbados. Paper Prepared for Commonwealth Secretariat, Pall Mall; London, 20pp.

Milliman, J.D. and K.O. Emery (1968) 'Sea Levels During the Past 35,000 Years'. Science 162, pp. 1121-1123.

Mitchell, J.K. (1974) Community Response to Coastal Erosion. Research Paper No. 156, Dept. of Geography; University of Chicago, 209pp.

Mitchell, B. (1979) Geography and Resource Analysis. London: Longman, 399pp.

Nelson, J.G. L.D. Cordes and J. Masyk (1972) 'The Proposed Master Plans for Banff National Park: Some Criticisms and an Alternative'. Canadian Geographer 16, pp. 29-49.

Nurse, L.A. (1977) Recent Climatic Fluctuation on a Small Tropical Island: The Case of Barbados, West Indies. Unpublished Msc. Dissertation; Newfoundland: Memorial University, 137pp.

Nurse. L.A. (1981) Beach and Coastal Zone Management, Barbados - Legal Provisions. Tourism Working Paper Series. No.5, Montreal: Dept. of Geography; McGill University, 15pp.

Oelschlager, L. (1979) 'Cost-Benefit Analysis: A Philosophical Reconsideration'. Ekistics 276, pp. 171-176.

Okidi, C.O. (1978) 'Conservation and Development of Coastal and Offshore Resources in Eastern Africa: Agenda for Research'. In Management of Coastal and Offshore Resources in Eastern Africa Institute of Development Studies, University of Nairobi. Occasional Paper no.28, pp.1-3.

Oldfield, F. et al. (1973) Report of Investigations into Erosion and Accretion Along the Coastlines of County Londonderry. The New University of Ulster Press, 47pp.

Oldmixon, L. (1708) The British Empire in America. 2 Vols., London, 340pp.

Omholt, T. (1974) 'Small Groins on the Shores of Long Island Sound'. Shore and Beach 42, no.1. pp. 11-14.

Oosting, H.J. (1954) 'Ecological Processes and Vegetation on the Maritime Strand in the South-eastern United States'. Botanical Review 20, pp. 226-262.

O'Riordan, T. (1969) 'Planning to Improve Environmental Capacity: A Case Study in Broadland.' Town Planning Review 40, pp. 39-58.

O'Riordan, T. (1971) Perspectives on Resource Management. London: Pion, 183pp.

Owens, E.H. and G. Drapeau (1973) 'Changes in Beach Profiles at Chedabucto Bay, Nova Scotia, Following Large Scale Removal of Sediments'. Canadian Journal of Earth Science 10, pp. 1226-1232.

Phillips, E. (1982) 'The Development of the Tourist Industry in Barbados, 1946-1980'. In D. Worrell (ed) The Economy of Barbados - 1946-1980. Bridgetown: Central Bank of Barbados, 199pp.

Pittman, E.D. (1974) 'Porosity and Permeability Changes During Diagenesis of Pleistocene Corals, Barbados, West Indies'. Geological Society of America. Bulletin 58, pp. 1811-1820.

Polunin, N.V. (1960) Introduction to Plant Geography. London: Longmans, 640pp.

Poyer, J. (1808) A History of Barbados. London, 688pp.

Rajotte, F.(1978) A Method for the Evaluation of Tourism Impact in the Pacific. California: Centre for South Pacific Studies, 15pp.

Randall, R.E. (1968) Vegetation Zones and Environment on the Barbados Coast. Unpublished Msc. Dissertation; Montreal: McGill University, 192pp.

Revelle, R. (1957) Chemical Erosion of Beach Rock and Exposed Reef Rock. U.S. Geological Survey. Professional Paper 260-T, 10pp.

Richards, A. and J.B. Bird (1970) Beach Studies on the West Coast of Barbados, 1967-1969. Montreal: McGill University, 83pp.

Richards, P.W. (1952) The Tropical Rain Forest. Cambridge University Press, 450pp.

Ritchie, W.R. et al. (1976) Mapping for Field Scientists. David and Charles Publishers, 327pp.

Ross, J.H. (1974) Quoted in Mitchell, B (1979) Geography and Resource Analysis. London: Longman, p. 239.

Russell, R.J. (1958) Beach Rock. Unpublished Document. Coastal Studies Institute; Baton Rouge: Louisiana State University, 13pp.

Russell, R.J. (1959) 'Caribbean Beachrock Observations'. Zeits. Fur Geomorphologie 3, pp. 227-236.

Russell, R.J. (1962) 'Origins of Beachrock.' Zeits. Fur Geomorphologie 6, pp. 1-16.

Saarinen, T.F. (1966) Perception of the Drought Hazard on the Great Plains. Research Paper no. 106, Dept. of Geography; University of Chicago, 183pp.

Saarinen, T.F. (1969) Perception of Environment . Resource Paper no. 5. Commission on College Geography; Association of American Geographers, 262pp.

Saarinen, T.F. (1970) 'Environmental Perception'. In Bacon, P.(ed) Focus on Geography: Key Concepts and Teaching Strategies. Washington: National Council for the Social Studies, pp. 63-99.

Saarinen, T.F. (1974) 'Environmental Perception'. In Manners, I.R. and W.M. Mikesell Perspectives on Environment, pp. 253-289.

Sauer, C.O. (1938) 'Theme of Plant and Animal Destruction in Economic History'. Journal of Farm Economics, pp. 765-775.

Sauer, J.D. (1960) Coastal Plant Geography of Mauritius. Technical Report no.15, Part A: Coastal Studies. Baton Rouge: Louisiana State University, 122pp.

Sauer, J.D. (1967) Plants and Man on the Seychelles Coast: A Study in Historical Biogeography. University of Wisconsin Press, 132pp.

Savage, R. (1937) Barbados. London: J.B. Lippincott, 205pp.

Schlesinger, B. and Daetz, D. (1973) 'A Conceptual Framework for Applying Environmental Assessment Matrix Techniques'. Journal of Environmental Science 16, pp. 1-16.

Schomburgk, R.K. (1848) History of Barbados. London, 722pp.

Schramm, W.E., S. Penland, R. Gerdes and D. Nummedal (1980) 'Effects of Hurricane Frederic on Dauphin Island, Alabama'. Shore and Beach 48, no.3, pp. 20-25.

Schumm, S (1977) The Fluvial System. New York: John Wiley & Sons, 338pp.

Senn, A. (1940) 'Paleogene of Barbados and Its Bearing on History and Structure of Antillean-Caribbean Region'. Bulletin American Association of Petroleum Geologists 24, no. 9, pp. 1548-1610.

Senn, A. (1946) The Groundwater Resources of Barbados. London: British Union Oil Co., 110pp.

Sewell, W.R.D. (1971) 'Environmental Perceptions and Attitudes of Engineers and Public Health Officials'. Environment and Behaviour 3, pp. 23-59.

Sinckler, E.G. (1913) Handbook of Barbados. London, 205pp.

Skeete, C.C (1963) An Historical Description of the Weather of the Island of Barbados, W.I., During the Period 1901-1960. Bridgetown: Barbados Government Printery, 284pp.

Sonnenfeld, J. (1969) 'Equivalence and Distortion of the Perceptual Environment'. Environment and Behaviour 1, pp. 83-99.

Sonnenfeld, J. (1972) 'Social Interaction and Environmental Relationship'. Environment and Behaviour 4, pp. 267-277.

Sonntag, N.C., R.R. Everitt and M.J. Staley (1982) Adaptive Environmental Assessment and Management : An Integrated Approach to Resource Impact Evaluation in Land and Water Issues Related to Energy Development. Ann Arbor Science Publishers, 469pp.

Sorensen, J.C. (1971) A Framework for Identification and Control of Resource Degradation and Conflict in the Multiple Use of the Coastal Zone. Dept. of Landscape Architecture; Berkley: University of California, 31pp.

Speed, R.C. (1979) Geology of Barbados - Implications for Accretion. U.W.I., 7pp.

Stamp, L.D. (1939) 'Some Economic Aspects of Coastal Loss and Gain'. Geographical Journal 93, pp. 496-503.

Starkey, O.P. (1939) The Economic Geography of Barbados. Unpublished PhD. Dissertation, Columbia University, 288pp.

Stehle, A. (1935) 'Essai d'Ecologie et Geographie Botanique -Flora de la Guadeloupe et Dependences. 1 Basse Terre; Guadeloupe, 157pp.

Stoddart, D.R. (1963) 'Effects of Hurricane Hattie on the British Honduras Reefs and Cays, October 30-31, 1961'. Atoll Research Bulletin, 59, pp. 1-142.

Stoddart, D.R. (1969) 'Post-Hurricane Changes on the British Honduras Reefs and Cays: Re-Survey of 1965'. Atoll Research Bulletin 131, pp. 1-25.

Stoddart, D.R. and J.R. Cann (1965) 'Nature and Origin of Beachrock'. Journal of Sedimentary Petrology 35, pp. 243-247.

Streeter, D.T. (1971) 'The Effect of Public Pressure on the Vegetation of Chalk Downland at Box Hill, Surrey'. In E. Duffrey and A.S. Watt (eds) The Scientific Management of Animal and Plant Communities for Conservation. Oxford: Blackwell Scientific Publications, 576pp.

Strickland, J.D. and T.R. Parsons (1972) A Practical Handbook of Seawater Analysis. Ottawa: Fisheries Research Canada, 310pp.

Taafe, E.J. (1974) 'The Spatial View in Context'. Annals Association of American Geographers 64, pp. 1-16.

Tanner, W.F. (1961) 'Mainland Beach Changes Due to Hurricane Donna'. Journal of Geophysical Research 66, no.7, pp. 2265 - 2266.

Tanner, W.F. (1970) 'Significance of Camille'. Southern Geology 12, no.2, pp. 95-104.

Taylor, F.T. (1974) 'Helium Uranium Dating of Corals From Middle Pleistocene Barbados Reef Tracts'. Quaternary Research 3, pp. 20-39.

Trechmann, C.T. (1933) 'The Uplift of Barbados'. Geological Magazine 70, pp. 19-46.

Tree, R. (1972) A History of Barbados. London: Rupert-Hart David, 185pp.

Trefhethen, P. (1972) 'Man's Impact on the Columbia River'. In R.T. Ogles, C.A. Carlson and J.A. McCann (eds) River Ecology and Man. Academic Press, pp. 77-98.

Tuan, Yi-Fu (1968) 'Discrepancies Between Environmental Attitude and Behaviour: Some Examples From Europe and China'. Canadian Geographer 12, pp.170-191.

Tuan, Yi-Fu, (1971) Man and Nature. Washington, D.C.: Association of American Geographers, 272pp.

Turnbull, D.A. (1979) The Water Quality and Distribution of Benthic Invertebrates in a Polluted Harbour, Barbados, W.I. MSc. Dissertation, Montreal: McGill University, 287pp.

United Nations (1981) Marine and Coastal Area Development in the Wider Caribbean Area: Overview Study. New York, 65pp.

UNESCO (1981) Marine and Coastal Processes in the Pacific: Ecological Aspects of Coastal Zone Management. Paris, 20pp.

U.S. Army Corps of Engineers (1977) Shore Protection Manual. -3rd. ed., Washington. 3 vols., 1262pp.

U.S. Beach Erosion Board (1957) Dune Formation and Stabilization by Vegetation and Plantings. Technical Memorandum no.101, 47pp.

University of Georgia (1971) Optimum Pathway Matrix Analysis Approach to the Environmental Decision-Making Process: Test Case: Relative Impact of Proposed Highway Alternatives. Institute of Ecology, University of Georgia, 110pp.

Vale, T.R. (1977) 'Forest Changes in the Warner Mountains, California'. Annals Association of American Geographers 67, pp. 28-45.

Vezina, R.R. (1974) Seawater Quality and Phytoplankton of Inshore Waters of Barbados. MSc. Dissertation, Montreal: McGill University, 95pp.

Wade, B.A., L. Antonio and R. Mahon (1972) 'Increasing Organic Pollution in Kingston Harbour, Jamaica'. Marine Pollution Bulletin 3, no. 7, pp. 106-111.

Warnke, D.A. (1966) 'Beach Changes Caused by Hurricane Betsy'. Journal of Geophysical Research 71, no.1, pp. 2013-2016.

Warnke, D.A. (1967) 'Conditions of Beach Retrogression in a Low Energy Environment'. Zeits. Fur Geomorphologie 11, pp. 47-61.

Warnke, D.A., V. Goldsmith, P. Grose, and J. Holt (1966) 'Drastic Beach Changes in a Low Energy Environment Caused by Hurricane Betsy'. Journal of Geophysical Research 71, no.1, pp. 2013-2016.

Watson, J.G. (1928) 'The Mangrove Swamps of the Malaya Peninsula'. Malaya Forest Records 6, pp. 1-215.

Watts, D. (1963) Plant Introduction and Landscape Change in Barbados, 1625-1830. Unpublished PhD. Dissertation, Montreal: McGill University, 476pp.

Watts, D. (1966) Man's Influence on the Vegetation of Barbados, 1627-1800. University of Hull Publications, 96pp.

Welch, H.W., and G.D. Lewis (1976) 'Assessing Environmental Impacts of Multiple Land Use Management'. Journal of Environmental Management 4, pp. 197-210.

White, G.F. (1945) Human Adjustment to Floods. Research Paper no. 29, Dept. of Geography; University of Chicago, 165pp.

White, G.F. (1958) Changes in Urban Occupance of Flood Plains in the United States. Research Paper no. 57, Dept. of Geography; University of Chicago, 160pp.

White, G.F. (1972) 'Environmental Impact Statements'. Professional Geographer 24, pp. 302-309.

Whittaker, R.H. (1967) 'Gradient Analysis of Vegetation'. Biological Review 42, pp. 207-264.

Whyte, A.V. and I. Burton (1980) Environmental Risk Assessment. New York: John Wiley & Sons, 157pp.

Williams, A.V. and W. Zelinsky (1970) 'On Some Patterns in International Tourist Flows'. Economic Geography 46, pp. 549-567.

Wise, M.J. (1969) 'On Utilization of Resources'. Geography 46, pp. 257-270.

Wulff, E.V. (1943) An Introduction to Historical Plant Geography. Massachusetts: Chronica Botanica, 221pp.