

N° 4

September 1997

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by G. Cambers

COAST AND BEACH STABILITY IN THE LESSER ANTILLES
COSALC



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UNESCO, 1997. *Planning for coastline change. Guidelines for construction setbacks in the Eastern Caribbean Islands*. CSI info 4, UNESCO, Paris, viii + 14 pp.

The 'CSI info' series was launched by the Organization in 1997. Information on CSI activities can be obtained at the following address:

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UNESCO, 1 rue Miollis,
75732 Paris Cedex 15, France.
fax: +33-1 45 68 58 08
e-mail: csi@unesco.org
website: <http://www.unesco.org/csi>

Published in 1997 by the United Nations Educational,
Scientific and Cultural Organization
7, place de Fontenoy, 75352 Paris 07 SP

Printed in UNESCO's workshops
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Printed in France

SC-97/WS/70

PREFACE

On the eve of the 21st century, some 60% of the world's population lives within 60km of the sea, and this figure is likely to rise to 75% by the year 2025. Of the world's 23 megacities, 16 are in the coastal belt. Coasts have always served as crossroads for peoples of many origins, and as a result these areas harbour intricate social and cultural mosaics. As for their ecological systems, the latter are among the most diverse, complex and productive on Earth. Notwithstanding this enormous socio-cultural and ecological wealth, many coastal areas have become flashpoints for conflict as a result of an ever increasing demand for limited resources.

Addressing the variety of problems facing coastal regions and small islands requires trans-disciplinary research and the careful formulation of policies for integrated action towards improved management of coastal resources. The UNESCO endeavour, 'Environment and Development in Coastal Regions and in Small Islands' (CSI), was launched in 1996 in response to these needs. Its goal is to serve as a platform for cross-sectoral action in order to assist Member States towards environmentally sound, socially equitable and culturally appropriate development in the regions concerned. The *CSI info* series offers an informal vehicle to disseminate pertinent information to managers and others in their search for solutions to coastal region and small island problems.

This volume contains guidelines for builders and other stakeholders, addressing the important aspect of coastal erosion. Coastlines, and beaches in particular, are dynamic fast-changing systems which are vitally important to the tourism-oriented economies of the smaller Eastern Caribbean Islands. The prudent use of coastal development setbacks, which establish a safe distance between the upper limit of wave action and new development, provides for beach conservation, reduction of erosion as well as improved vistas, access and privacy for beach users and property owners. These guidelines are based on various shoreline types and follow a methodology developed by the project entitled "Coast and Beach Stability in the Lesser Antilles" (COSALC).



This restaurant is a victim of coastline retreat. Construction setbacks should take adequate account of such potential encroachment of the sea.

PRÉFACE

À la veille du 21^{ème} siècle, quelque 60% de la population mondiale vit à moins de 60 km de la mer, et cette proportion passera probablement à 75% avant l'année 2025. Seize des vingt-trois mégapoles du monde sont situées dans la bande côtière. Les côtes ont toujours été des carrefours où se croisent des peuples de diverses origines, d'où les véritables mosaïques sociales et culturelles qu'elles abritent. Quant à leurs systèmes écologiques, ils figurent parmi les plus divers, les plus complexes et les plus productifs de la planète. En dépit de leur considérable richesse socio-culturelle et écologique, un grand nombre de zones côtières sont devenues des foyers de conflits potentiels en raison de la demande toujours plus forte d'accès à des ressources naturellement limitées.

Pour traiter les multiples problèmes auxquels les régions côtières et les petites îles doivent faire face, il faut recourir à la recherche interdisciplinaire et élaborer avec grand soin des politiques d'actions intégrées, seules capables d'améliorer la gestion des ressources côtières. L'initiative de l'UNESCO intitulée "Environnement et développement dans les régions côtières et les petites îles" (CSI) a été lancée en 1996 pour répondre à ces besoins. Son objectif est de servir de plate-forme pour une action intersectorielle visant à aider les États membres à réaliser un développement écologiquement rationnel, socialement équitable et culturellement approprié. La collection *CSI info* (publiée principalement en anglais) constitue un moyen simple et informel de diffuser, auprès des gestionnaires et autres responsables, des informations nécessaires lorsqu'ils recherchent des solutions aux problèmes de la région côtière et des petites îles.

S'adressant aux architectes et aux instances concernées par la construction en bord de mer, ce document propose des directives qui prennent en compte le problème de l'érosion des côtes. Car les côtes, et surtout les plages, ces systèmes dynamiques soumis à des changements rapides, sont chargées d'un potentiel économique capital pour les îles à vocation touristique des petites Antilles. Construire les nouveaux lotissements en retrait de la ligne de côte pour laisser un espace entre la limite supérieure atteinte par les vagues et les nouvelles constructions, c'est garantir la conservation de la plage, la réduction de l'érosion et l'esthétique du front de mer, l'accessibilité et la privauté pour les vacanciers et les propriétaires. Les directives prennent en compte une grande variété de types de côtes et sont fondées sur la méthodologie élaborée à partir du projet "Stabilité des côtes et des plages dans les petites Antilles - COSALC".

Légende:

Ce restaurant a souffert de la montée du trait de côte. Établir la construction en retrait devrait prévenir toute possibilité d'ennoyage.

PREFACIO

En el alba del Tercer Milenio, alrededor del 60% de la población mundial vive a menos de 60 km del mar y probablemente alcanzará al 75% hacia el año 2025. Dieciséis de las 23 megaciudades del mundo están ubicadas en zonas costeras. Las regiones costeras son lugares de encuentro de pueblos de orígenes diversos, estableciendo así intrincados mosaicos sociales y culturales. Muchos de los ecosistemas más diversos, complejos y productivos del planeta se encuentran en regiones costeras. A pesar de esta enorme riqueza sociocultural y ecológica, muchas zonas costeras se han convertido en focos de conflicto debido a la creciente demanda por recursos en disminución.

La solución de la variedad de problemas que afectan a las regiones costeras e islas pequeñas requiere una investigación interdisciplinaria y la cuidadosa formulación de políticas para una acción integrada orientada a una mejor gestión de sus recursos. La iniciativa “Medio Ambiente y Desarrollo en Regiones Costeras e Islas Pequeñas” (CSI) de la UNESCO, lanzada en 1996, responde a estas necesidades. El objetivo principal es servir de plataforma para asistir a los Estados Miembros a través de acciones trans-sectoriales a alcanzar un desarrollo de sus regiones costeras que sea ecológicamente sano, socialmente equitativo y culturalmente apropiado. La serie *CSI info* ofrece así un vehículo informal de difusión de información pertinente, dirigida a los responsables de la gestión en búsqueda de soluciones a problemas en regiones costeras e islas pequeñas.

Este volumen contiene líneas directrices para empresas constructores y otros interesados, con especial atención al importante tópico de la erosión costera. Las líneas costeras, y en particular las playas, son sistemas dinámicos sujetos a rápidos cambios, de vital importancia para las economías de las islas pequeñas del Caribe orientadas hacia el turismo. El uso prudente de barreras costeras, que establecen una distancia razonable entre el límite superior de la acción de las olas y nuevas construcciones, contribuye a la conservación de las playas y a la reducción de la erosión, así como también al acceso y a la intimidad de los veraneantes y de los propietarios locales, al mismo tiempo que mantiene el paisaje del frente de mar. Estas directivas se adaptan a varios tipos de costa y están fundadas en una metodología elaborada dentro del marco del proyecto “Estabilidad de las Costas y Playas de las Antillas Menores - COSALC”.

Leyenda:

Este restaurant ha sido víctima de la erosión costera. La construcción a una distancia prudencial del agua debería evitar toda posibilidad de intrusión marina.

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ACKNOWLEDGEMENTS

This document further develops a setback methodology originally prepared for the island of Anguilla which was commissioned on behalf of the Government of Anguilla by the United Kingdom Dependent Territories Regional Secretariat.

I would like to thank the following persons for their contribution:

- Dr. J. Armstrong, United Nations Centre for Human Settlements, Barbados.
- Mr. R.W. Beales, British Development Division in the Caribbean, Barbados.
- Mr. L.A. Bourne, Athelstan King Architects Ltd., Barbados.
- Mrs. C. O'Brien Delpesh, Institute of Marine Affairs, Trinidad & Tobago.
- Mr. O. Proctor, Physical Planning Unit, Anguilla.
- Dr. A. Suzyumov, Environment and Development in Coastal Regions and in Small Islands, UNESCO, Paris, France.

1. INTRODUCTION

Beaches are one of the most dynamic systems in nature, they show visible changes over hours, days, months and years. They also represent one of the most important natural and economic resources to small island states. The tourism industry, the mainstay of the economy in many of the small Eastern Caribbean Islands, is still very much beach orientated.

Yet many islands have seen that the growth of the tourism industry, which depends largely on the beaches, often creates problems for those same beaches. All too often, developers wish to position their properties as close as possible to the water, having little regard for seasonal beach changes or the infrequent, yet catastrophic hurricanes. It is not only tourism properties which are positioned adjacent to the beach or coastline, but other infrastructure as well, such as houses, roads, airports and commercial enterprises. In many volcanic islands, the land adjacent to the beach is the only flat land available, hence its attractiveness for development.

One of the dominant characteristics of beaches is their constant changes in form, shape and sometimes the very material of which they are composed. The best way to conserve beaches is to allow them the space to move - in a seaward direction during accretionary phases and in a landwards direction during erosionary phases. The prudent use of coastal development setbacks or establishing a safe distance between buildings and the active beach zone can ensure that space is provided for a beach to move naturally, both during normal events and infrequent hurricanes, thereby ensuring the beach is conserved for all to enjoy and that coastal infrastructure remains intact.

This paper develops a methodology for coastal development setbacks, which was first developed for the island of Anguilla in 1996 as part of a study sponsored by the British Development Division in the Caribbean on the Impact of Hurricane Luis on the Coastal and Marine Resources of Anguilla. The guidelines developed for Anguilla (Cambers, 1996a) have been incorporated into the National Land-use Development Plan and are being implemented. The present paper further develops and generalizes these guidelines so that they can be applied to other small islands in the Caribbean. They may also be applicable to small island states in tropical regions in other parts of the world.

2. BACKGROUND

Coastal setback provisions ensure that development is prohibited in a protected zone adjacent to the water's edge.

A coastal development setback may be defined as a prescribed distance to a coastal feature, such as the line of permanent vegetation, within which all or certain types of development are prohibited.

Coastal development setbacks have several functions :

- they provide buffer zones between the ocean and coastal infrastructure, within which the beach zone may expand or contract naturally, without the need for seawalls and other structures, which may imperil an entire beach system. Thus in this sense they may actually reduce beach erosion.

- they **reduce damage** to beachfront property during high wave events, e.g. hurricanes;
- they **provide improved vistas and access** along the beach;
- they **provide privacy** for the occupiers of coastal property and also for persons enjoying the beach as a recreational resource.

Most Caribbean Islands use the high water mark as the baseline for measurement. For example, the planning standards developed for the countries belonging to the Organization of Eastern Caribbean States (OECS) (Wason & Nurse, 1994) use it for measurement. However, there are several problems with the use of this criterion. For instance the position of the high tide mark varies from day to day, sometimes its position can change by more than 10 m from one day to the next, particularly if there is a winter swell event. It is also somewhat subjective unless defined by an accurate vertical height, which is not the case in the Caribbean Islands. Thus developers and planners may differ in the interpretation of high tide mark as a baseline.

Actual setback distances vary worldwide from 8 m in Ecuador to 1 - 3 km in Denmark (Clark, 1996). Most Caribbean Islands have one fixed setback for all their beaches, e.g. the setback for new development in Barbados is 30 m (100 feet) from high tide mark, in the British Virgin Islands it is 15 m (50 feet) from high tide mark. These setback distances are rather low, particularly if there is a major event such as a tropical storm or hurricane.

Nevis, on the other hand has developed a setback policy for major tourism beaches whereby a much greater distance is left between new buildings and the high water mark. Here all development is prohibited in the zone extending 37 m (120 feet) from high tide mark, piled structures such as beach bars are allowed in the zone 37 m to 91 m from high tide mark and major hotel structures have to be 91 m (300 feet) from the high tide mark. From a beach dynamics perspective, these setbacks are beneficial, however, from a developer's viewpoint, these setbacks leave a lot of valuable land tied up and unavailable for development, and they have met with considerable resistance in Nevis.

Wason & Nurse (1994) have suggested the following preliminary guide to setbacks from high water for the OECS:

slopes less than 1:20	30 m (100 ft);
slopes 1:4 to 1:20	15 m (50 ft);
coastal cliffs 1:1 or greater	8 m (25 ft).

These guidelines are qualified with the statement that they are subject to studies to determine the highest contour normally reached by high seas.

Some states in the USA utilize variable setbacks which make allowances for natural variations in shoreline trends from one beach to another. For instance in South Carolina, the width of the setback is prescribed as a distance 40 times the annual erosion rate measured from the most seaward dune (National Research Council, 1990).

Since there is a need for further development in the coastal zone in the interests of the islands' economic well-being, setback policies must be designed to ensure that new development is sustainable. The concept of variable setbacks, which make allowances for differences in the behaviour, characteristics, erosional history and use of beaches, can best fulfill this function in the Caribbean Islands.

However, it must be recognized that it is one matter for planners to prescribe setbacks, but in order for them to be successful, groups such as architects, draftsmen, developers and the general public, must be shown the rationale and the need for such planning tools. As with other facets of coastal area management, the need for education, participation and communication is of paramount importance.

3. METHODOLOGY

3.1 General Concepts

Based on the coastal geomorphology of the small Caribbean Islands, four major coastal types can be identified:

- a) cliffs;
- b) low rocky shores;
- c) small sandy offshore cays;
- d) sand or stone beaches.

The following setback guidelines are based on geomorphological, geological and oceanographic characteristics as well as observed rates of change and socio-economic factors.

3.1.1 Cliffs

Geological composition and wave processes are major factors determining cliff retreat. "Hard" rock cliffs composed of volcanic and limestone rocks will generally erode much slower than cliffs composed of "soft" rocks such as clays and sandstones, where erosion rates may be as high as several metres a year. Cliff retreat rates are generally higher on windward coasts where wind and wave action is more intense. Cliff erosion is usually not a gradual process, but a sudden one as large blocks collapse especially in fractured rocks such as limestone.

Most of the cliffs in the Eastern Caribbean Islands are composed of limestone or volcanic rocks and generally cliff retreat rates are low, although as indicated above, cliff collapse is often a sudden process. A setback of 15 m from the cliff edge is adequate for the economic life (30 years) of most development projects.

On volcanic or limestone cliffs, all new developments should be set back 15 m (50 ft) from the cliff edge.

3.1.2 Low Rocky Shores

These shores are usually composed of limestone in the Eastern Caribbean Islands. They may be composed of ancient coral reefs marking previous higher sea level stands. Generally they show low levels of retreat, however, development in these areas is vulnerable to seawater inundation during tropical storms and hurricanes, thus a setback of 30 m from the vegetation line has been suggested.

On low rocky shores, all new development should be set back 30 m (100 ft) from the natural vegetation line.

3.1.3 Small Sandy Offshore Cays

Small sandy offshore cays exist in several countries e.g. Anguilla, the British Virgin Islands and the Grenadines. These cays are usually sandy, or they may consist of sand over a rock base. They often cover less than 10,000 square metres (100 m by 100 m), and they are usually anchored by coral reefs. Experience during Hurricane Luis in Anguilla (Cambers, 1996b) showed that these cays may completely disappear during such a catastrophic event. Furthermore, they may reform after the hurricane in a different location. For these reasons it is recommended that if development is permitted on these cays, then it should be of a temporary nature with wooden piles and all wooden construction. Actual setback distances should be determined using the methodology developed for beaches, see Section 3.1.4, appropriately modified for the small size of the particular cay.

On small sandy offshore cays, if new development is permitted, it should be of a temporary nature with wooden piles and with all wooden construction.

3.1.4 Sand and Stone Beaches

Due to the complexity of beaches and their changes, and their importance for tourism, recreation and development, it is recommended that setbacks be determined individually on a beach by beach basis. This will allow for greater setbacks on eroding beaches, which will in turn allow for conservation of the beaches, protection of beachfront property and the reduction of erosion caused by certain beach protection structures.

It is recommended that the line of "permanent" vegetation be used as the baseline for measurement. This is the tree line or scrub line and can be easily defined and agreed by different observers, also it shows only slight change apart from the relatively rare tropical storms and hurricanes. Features such as high water mark vary according to the tidal cycle and are very subjective especially when used by untrained observers. In addition, the use of the vegetation line as a baseline provides for the preservation of the most seaward sand dunes (where such dunes exist), these provide the first line of natural defence during a major storm event.

The line of permanent vegetation should be used as the baseline for setback determination for beaches.

Setbacks are developed for each beach based on the following parameters:

- Historical changes in the coastline position using the aerial photographs dating back to the 1960's when available.
- Recent beach changes using the beach monitoring databases developed within the Coast and Beach Stability in the Lesser Antilles project (COSALC).
- Changes in the position of the dune line/coastline likely to occur during a major (category 4) hurricane.
- Changes in coastline position likely to occur as a result of the predicted rise in sea level.
- Offshore features and changes.
- Coastal geomorphological features such as exposed beachrock and anthropogenic factors such as dune mining.
- Planning considerations such as lot size, national park designations.

These parameters are combined to provide a setback value for each beach. This represents the setback for all permanent development, e.g. residences (wood and cement), hotels, villas, swimming pools, roads.

No development should be permitted seaward of the baseline, that is the "permanent" vegetation line, with the obvious exceptions of jetties and docking facilities.

Obviously blanket setbacks, which cover all types of development are easiest to enforce. However, in some islands it may be desirable to make special cases for some types of development. For instance in Anguilla, a special provision was made for piled, wooden beach restaurants, on the grounds that their economic viability depended on their proximity to the beach. In the past they had sometimes been permitted on the beach itself, however, it was stipulated that they should be set back at least 8 m (25 feet) landwards of the vegetation line.

In most cases one setback value is calculated for each beach, however, there may be exceptions for very long beaches such as Shoal Bay in Anguilla, Pinney's Beach in Nevis, where because of their length and particular characteristics, the beach may be divided into more than one section for setback calculation.

3.2 Methodology for Beach Setback Calculation

Seven parameters are used in the setback determination for an individual beach, these are described in detail below.

(i) Historical Changes in Coastline Position Using the Aerial Photography Dating back to the 1960's.

Historical changes are determined for each beach using the aerial photographs. Stereoscopic pairs of photographs are studied and major changes regarding each beach recorded, e.g. the disappearance of a sand dune. Then reference points close to the beach such as buildings, road intersections are selected, these reference points have to be visible on each set of photographs. Measurements are made from these reference points to the vegetation line and the offshore step, this is the seaward toe of the beach. It is marked in the field by a vertical downwards step near the wave breakpoint and is a distinctive feature on some beaches. It can usually be picked out on aerial photographs and is a more constant parameter than a low or high water line.

The number of points per beach depends on the number of reference points that can be identified on the sets of aerial photographs, in some of the less developed areas there may only be one or two measurement points per beach. These measurements are then compared and changes in the position of the vegetation edge and the offshore step determined over time.

There are many errors involved in this technique e.g. distortion towards the edge of the photographs, difficulty in identifying fixed locations (reference points), and difficulty in fixing the position of the offshore step.

Besides possible errors in the measurements, there are other factors which must be considered when using aerial photographs for assessing coastal change. For most islands there will be no more than three sets of photographs for the period 1960's to the 1990's, these represent just three time series. Beaches change dramatically from week to week and also seasonally, especially during winter when measurements may vary considerably from one week to the next if a major winter swell or "groundsea" event occurs. Additionally, tidal variations also

exist, although tidal range in the Eastern Caribbean is very low, and in these measurements the offshore step was used rather than a particular water line

Based on the foregoing, the assessment of shoreline change using aerial photograph measurements provides only an estimation of the actual change. Usually major changes can be picked out with this method. Figure 1 shows a comparison of the 1954 and 1982 shorelines at Crane Beach on the southeast coast of Barbados (Proctor & Redfern, 1982), here major changes have taken place. However, in this paper, historical shoreline change represents only one of several factors included in the setback calculation.

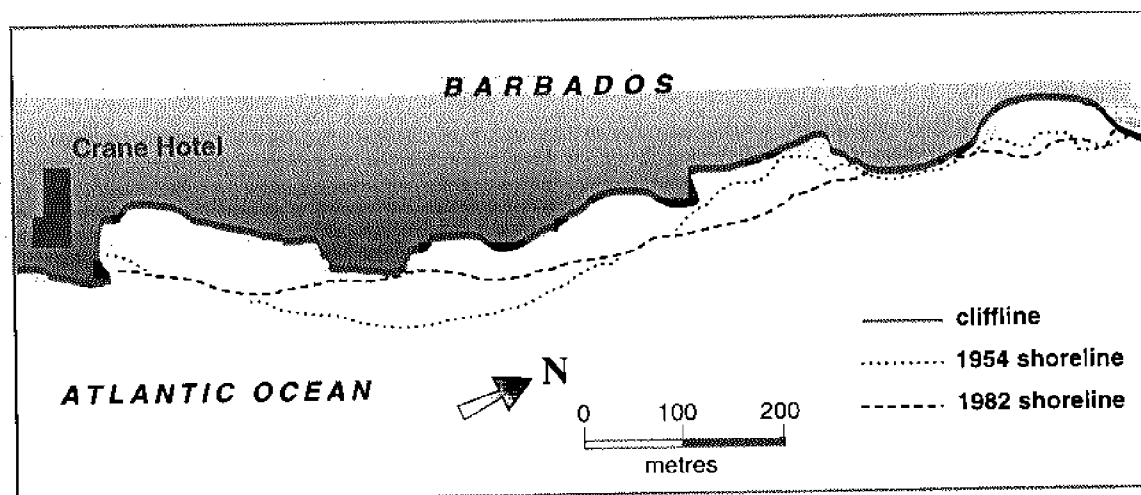


Figure 1. Comparison of the 1954 and 1982 Shorelines at Crane Beach, Barbados (Proctor & Redfern, 1982).

The historical changes may also include hurricane changes if a hurricane passed over a particular island during the period of historical record. This may represent an over-estimation in the setback calculation, since hurricanes are factored in separately, see (iii) on the following page. Adjustments for this can be made in the overall setback calculation.

(ii) Recent Changes using the Beach Monitoring Data

In most of the Eastern Caribbean Islands beach profiles have been surveyed as part of the COSALC project every three months since the early 1990's or before. These data are detailed and far more accurate than those described in (i) above. However, they only cover a short time period, less than ten years, and do not always include all the beaches in a particular island. Figure 2 shows the changes in beach width that have taken place on a west coast beach in Nevis, here there has been dramatic erosion over a seven year period.

The beach profile database is used to determine trends and changes in beach width, which is used as an indicator of short term shoreline change.

(iii) Changes in the Position of the Dune Line/Coastline likely to occur during a Major (Category 4) Hurricane

In view of predictions for more intense and more frequent hurricanes over the next two decades, it is likely that each island in the Eastern Caribbean will be impacted by a major hurricane passing directly over or nearby in the next 30 years, thus it is especially important to build this factor into the setback determination. The actual retreat of the dune edge or land edge resulting

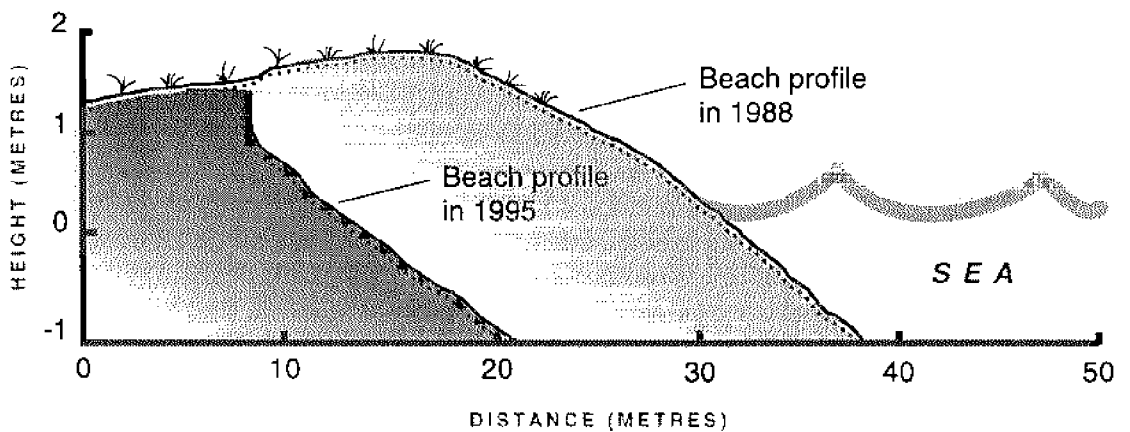


Figure 2. Changes in Beach Width on the West Coast of Nevis

from a category 4 hurricane has been documented for Hurricane Hugo in 1989 and for Hurricane Luis in 1995 (Cambers, 1996c). This is viewed as a "permanent" change, since sand dunes and land take decades to form. **Figure 3** shows the type of changes in the seaward sand dunes that were recorded after Hurricane Luis in 1995. Data for dune/land edge changes in 1989 (Hurricane Hugo) exist for Dominica and Nevis, and in 1995 (Hurricane Luis) for Anguilla, Antigua-Barbuda, Dominica, Montserrat, Nevis and St. Kitts. For these islands this factor can be determined on a beach by beach basis.

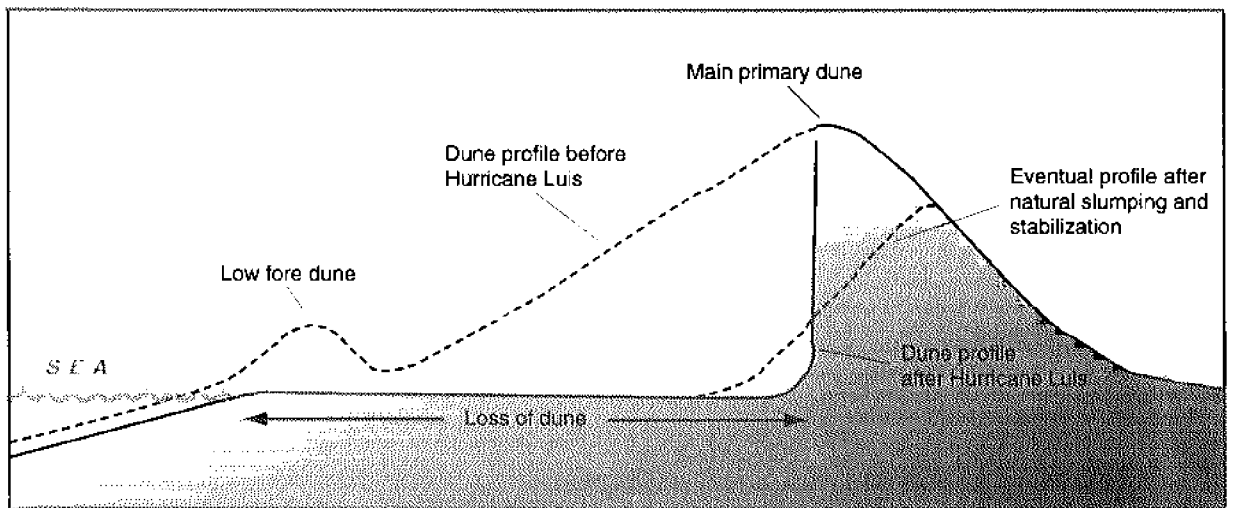


Figure 3. Schematic Representation of Dune Retreat after Hurricane Luis

For other Eastern Caribbean Islands, where such information does not exist, the data can be extrapolated from the northern islands pairing islands with similar geographical and geomorphological characteristics e.g. data exist for Dominica and Nevis for the hurricanes of 1989 and 1995, this can be applied to the other mountainous volcanic islands such as Grenada, St. Vincent and St. Lucia. Similarly the 1995 hurricane data for low islands such as Anguilla, Antigua and Barbuda can be applied to other comparable locations e.g. the Turks and Caicos Islands and some of the cays in the British Virgin Islands. Factors which controlled the hurricane response variation between beaches, such as coastline orientation and indentation, the width of the offshore shelf and past history of anthropogenic alterations, can also be built into this prediction. Based on a particular island's hurricane record, it may be necessary to develop a

worst case climate scenario, for it is possible in the light of hurricane predictions for the next two decades that a particular island may be subjected to more than one severe hurricane.

(iv) Sea Level Rise

A causal relationship between the retreat of sandy shorelines and general global sea level rise has been established over the last century (Bird, 1976; National Research Council, 1991). This relationship was first formulated by Bruun (1962) and is known as the Bruun Rule. It is based on the concept of an equilibrium beach profile which is a statistical average profile that maintains its form apart from small fluctuations including seasonal effects. This shows that as sea level rises, material is eroded from the upper beach and deposited on the nearshore ocean bottom. **Figure 4** shows a schematic representation of the Bruun Rule. Consequently the ocean moves landwards or in other words there is shoreline recession. However, it is a difficult concept to confirm, for while the beach erosion/recession can be relatively easily quantified, the offshore sedimentation may be spread over a very broad zone. Notwithstanding the above, the Bruun Rule has been tested with a fair level of success along the southeast coast of Florida and in the Great Lakes (National Research Council, 1991).

The shoreline recession resulting from predicted sea level rise over the next 30 years is factored into the setback calculation.

Shoreline recession resulting from predicted sea level rise is calculated as follows: a rise of sea level of y metres causes a shoreline recession of y times 100 m.

Based on a predicted sea level rise of 0.3 m by the year 2100 (this is one of the lower estimates), this translates to 0.1 m by the year 2030, the shoreline recession is $0.1 \times 100 = 10$ m. Most development has an economic life of 30 years, so this time period is used for the calculation.

Some of the tectonically active Caribbean Islands may actually be rising, so their coastal areas may not be affected by sea level rise. However, until tide gauge records can be established for each island, it is recommended that the shoreline recession as calculated here be applied.

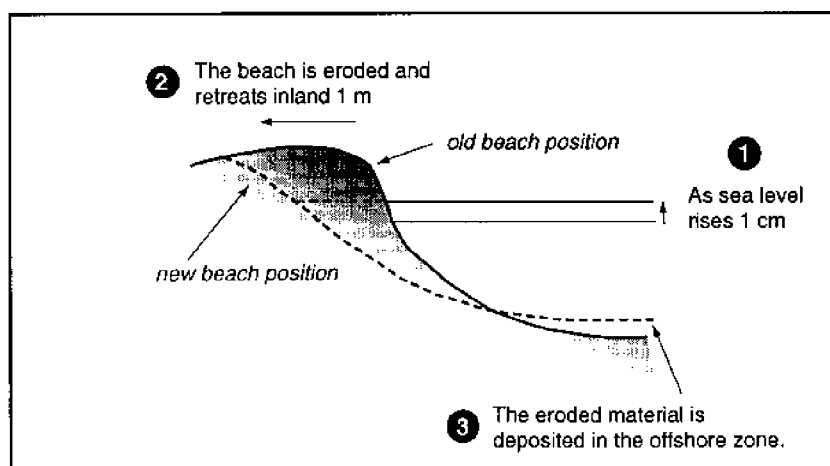


Figure 4. Schematic Representation of the Bruun Rule

(v) Offshore Features and Changes

Offshore characteristics and changes are used qualitatively to weight the calculated setback. Coral reefs and wide shallow offshore shelves often provide protection to particular beaches. Evidence from Anguilla, Antigua and Nevis (Cammers, 1996c) has shown that bays protected by nearshore reefs often experienced less erosion during the 1995 hurricanes than those which were more exposed.

Coastline shape was another factor, e.g. in Antigua, which has a very indented coastline where there are small bays within larger bays, the more sheltered bays suffered less damage during Hurricane Luis (Black *et al*, 1996).

Changes in offshore ecosystems are another variable used qualitatively, to weight the calculated setback. In Anguilla many bays were protected by dead intact *Acropora palmata* reefs (elkhorn coral reefs) prior to Hurricane Luis. These reefs provide an important natural breakwater function.

However, many of these reefs were reduced to rubble by the hurricane, thus water depths may have increased providing the potential for higher wave action and beach erosion.

(vi) Coastal Geomorphological and Anthropogenic Features

Certain coastal features are also used qualitatively to weight other factors. Features such as exposed beachrock provide indicators of long term erosion. Also practices such as sand dune mining remove protective barriers and sand reservoirs from the beach system.

(vii) Planning Considerations

These include factors such as lot size, existence of marine parks and designations such as pristine coastal areas and vary from country to country. Some coastal lots may be very narrow, less than 100 ft in depth. Setbacks may cause some of these lots to become unsuitable for development. Government acquisition may be a solution in some of these cases, but for economic reasons, it is rarely a feasible option in the Eastern Caribbean Islands. Thus setback guidelines must take such limitations into account.

By their very nature, these considerations are subjective and therefore difficult to generalize. Two examples from the Anguilla methodology can be used to show how such considerations are included (Cammers, 1996a).

Along the northern and central sections of Road Bay, the recommended setback was 29 m, however, parcel size and shape would prevent the implementation of this setback. So instead a setback of 18 m was recommended, a reduction of 11 m. In a second case, the initial recommendation in Anguilla was for all new development to be positioned at the established setbacks.

However, a special case was made for beach bars and restaurants, whose owners felt that unless they were as near to the beach as possible, their commercial viability would be endangered. Therefore an exception was made and all new beach bars or restaurants have to be positioned 8 m (26 feet) landward of the permanent vegetation line.

The actual setback for a particular beach is determined by adding three components :

Changes in coastline position (p), this includes the historical changes, described in Chapter (i), and the recent changes, described in Chapter (ii). Where these two measurements conflict, e.g. historically a site shows erosion but within recent years the beach profile data has shown accretion, local information is used to determine which time frame should take precedence. Usually this is the historical data because it covers a much longer time period. But if there has been a recent coastline alteration such as a groyne or breakwater, the more recent trend may take precedence.

Changes in the position of the dune line/coastline resulting from a major (category 4) hurricane (h), this is based on Chapter (iii).

Changes in the position of the coastline resulting from coastal recession as a result of predicted sea level rise over the next 30 years (s), this is based on Chapter (iv).

The setback is calculated as follows :

$$\text{setback} = (p) + (h) + (s)$$

The setback will always be measured landwards from the line of "permanent" vegetation or tree line.

Once the setback is calculated using the above equation, offshore features and changes, geomorphological and anthropogenic factors, and planning considerations are subjectively included in the calculation by multiplying the setback value by a certain factor. Appendix I contains a setback calculation for a sample beach.

3.3 Setback Applications

Once the setbacks have been determined for each beach, a table can be prepared listing the values. However, from a planning perspective this may provide too much detail and prove too complicated for a planning board or development control authority.

In Anguilla, where this methodology has been used and is being implemented, it was decided to group the beaches into several setback categories. Based on the data for individual beaches, four categories were determined:

- Category 1: Setback is 18 m (60 feet) landward of the vegetation line;
- Category 2: Setback is 30 m (100 feet) landward of the vegetation line;
- Category 3: Setback is 45 m (150 feet) landward of the vegetation line;
- Category 4: Setback is 92 m (300 feet) landward of the vegetation line.

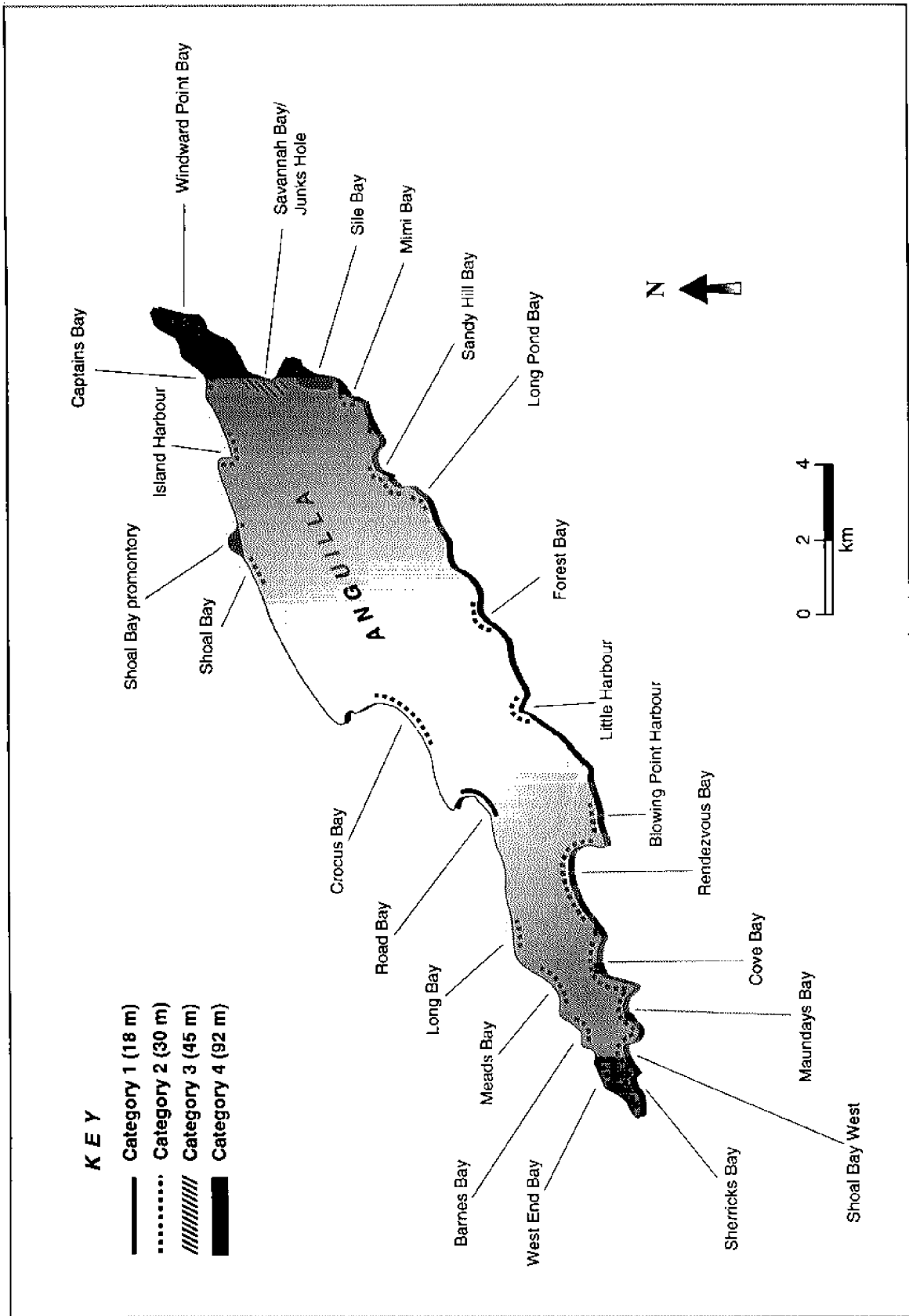


Figure 5 Coastal Setback Categories for Beaches in Anguilla (all development except for beach bars).

Most of the beaches fell into category 2. A map was prepared showing the proposed setback categories for beaches, see Figure 5. These generalized categories will allow for ease of implementation by the Planning Board in Anguilla. Table 1 summarizes coastal development setbacks in Anguilla.

The detailed setback determination for each beach, proposed in this methodology, will provide planners with the necessary information and justification for some flexibility. This is essential for planners who have to deal with socio-economic factors as well as those of a physical nature. However, interpretation of the coastal setback guidelines should not be so flexible that they become meaningless. These setbacks, which can be fully justified and explained to developers, should facilitate future coastal development.

Table 1 Coastal Development Setback Guidelines in Anguilla

Category	Development Setback
Cliffs	12 m (40 feet) from the cliff edge
Low rocky shores	30 m (100 feet) from the vegetation line
Sandy cays	Development restricted to piled, wooden structures, actual setbacks as for beaches.
Sand and stone beaches	<ol style="list-style-type: none"> 1. Beach bars and restaurants 8 m (25 feet) from the vegetation line. 2. All other development categorized by beach, see Figure 5, as follows: <ul style="list-style-type: none"> Category 1: 18 m (60 feet) landward of the vegetation line; Category 2: 30 m (100 feet) landward of the vegetation line; Category 3: 45 m (150 feet) landward of the vegetation line; Category 4: 92 m (300 feet) landward of the vegetation line.

However, it must be emphasized that any setback policy must be combined with an education and awareness campaign so that members of the public as well as special interest groups such as architects, contractors and politicians, fully understand the need for such setbacks.

4. CONCLUDING REMARKS

The proposed setback guidelines for coastal development provide a flexible framework within which the planning authorities can work to ensure that coastal development is sustainable and beach erosion is reduced. It is envisaged that the setbacks for a particular island can be revised as new information becomes available. As the Eastern Caribbean Islands move to develop an integrated coastal area management approach, the implementation and further revision of these setback guidelines may provide an important tool for use by coastal planners.

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SETBACK CALCULATION FOR A SAMPLE BEACH

Basic formula for setback calculation :

$$\text{setback} = (p) + (h) + (s)$$

where, **(p)** is the change in coastline position,
(h) is the change in coastline position likely to result from a category 4 hurricane,
(s) is the predicted coastline retreat resulting from sea level rise.

Changes in coastline position (p)

This parameter is based on historical and recent changes.
 Historical changes in the position of the offshore step between 1968 and 1991 were:

East section	=	-0.7 m/yr
West section	=	+0.1 m/yr
Mean	=	-0.3 m/yr

Recent changes in beach width based on the beach profile data between 1992 and 1994 were +2.6 m/yr

Based on local information and the existence of beachrock ledges (an indicator of longterm erosion), the historical trend takes precedence at this beach.
 Therefore the projected change over the next 30 years = (-0.3) x 30 = -9.0 m

Changes in coastline position likely to result from a major (category 4) hurricane (h)

The average dune retreat at this beach during Hurricane Luis was -18 m.

Predicted coastline retreat resulting from sea level rise up to the year 2030 (s)

The predicted coastline retreat resulting from sea level rise up to the year 2030 is -10 m.

Other Factors

This bay is fronted by seagrass beds; however, there were reefs composed of dead *Acropora palmata* at the western headland. These were largely reduced to rubble by Hurricane Luis and thus the western section of the beach in particular may be vulnerable to increased wave action. The dunes at this beach were heavily mined in the 1980's.

Setback Calculation $(p) + (h) + (s) = (-9) + (-18) + (-10) = -37 \text{ m}$

Local factors such as the loss of the *Acropora palmata* reef and the history of dune mining make this beach especially vulnerable to future erosion. The calculated setback was therefore increased by 20%.

Average setback for the entire beach = 44 m landward of the "permanent" vegetation line.

