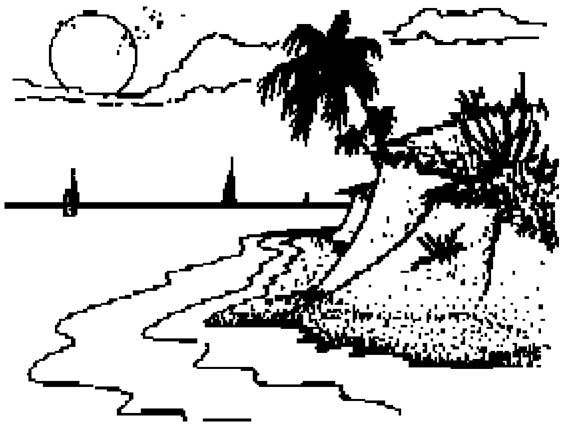
COSALC
COAST AND BEACH STABILITY IN THE CARIBBEAN ISLANDS

PLANNING FOR COASTLINE CHANGE

2b
SHORELINE MANAGEMENT IN NEVIS
A POSITION PAPER



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Pinneys's Beach, Jessup.
The rock revetment in front of the restaurant is providing some protection to the building, but the waves are continuing to erode the unprotected land on either side of the building. The rock revetment is also impeding access along the beach.

1. EXECUTIVE SUMMARY

Shoreline erosion has been recognized as a problem in Nevis for more than two decades, however, it is only as the beachfront lands have become increasingly developed for tourism and other uses that the need for a Shoreline Management Strategy has become apparent.

The major events and milestones leading to the present situation are described. These include two major hurricanes, several studies, the 1987 National Conservation and Environment Protection Act, the preparation of a Zoning Ordinance, and revised coastal development setbacks.

The difference between beach erosion and shoreline erosion is discussed. Shoreline change rates in Nevis for the period 1946-1997 are discussed. Gallows Bay and Pinney's Beach are the sites experiencing the most severe shoreline erosion on the west coast, as well as the shoreline between Nisbett and Camps on the north coast.

The different types and functions of coastal defence structures and measures are outlined. The existing coastal defence structures in Nevis are described.

Three shoreline management policy options are developed:

- *Protect beachfront lands;*
- *Conserve beaches;*
- *Protect beachfront properties built prior to 199_ (date of sea defence standards) and conserve beaches.*

Each option would require strict control and regulation which does not exist at present.

The option to protect beachfront lands attempts to maintain the current shoreline position by permitting beachfront property owners to protect their properties with hard structures such as seawalls, rock revetments, etc. This option would be very expensive and would ultimately fail during the next major hurricane to come close to Nevis

The second option, to conserve beaches, would have two main components: strict coastal development setbacks for new development and a ban on all new sea defence structures. Existing sea defences could be maintained, but not rebuilt. This option, while considerably less expensive than the first option, might be strongly opposed by owners of beachfront property.

The third option attempts to reach a compromise between the other two options, by conserving beaches and protecting existing beachfront properties. Thus strict development setbacks would be implemented for new development. Only the owners of properties built prior to 199_ (date of sea defence standards) would be permitted to build hard structures (such as rock revetments) to protect them, and these owners would be encouraged to use measures such as beach nourishment wherever possible.

Whichever option is chosen by Nevis, could well provide a blueprint for other Caribbean islands where similar problems also exist.

2. INTRODUCTION

Nevis is a small island of 36 square miles (92 km^2) with a population of 9,500 (1998 estimate), located in the northern Leeward Islands in the Caribbean Sea at Latitude 17° 10' north and Longitude 62° 35' west. Tourism is the major industry, followed by agriculture and construction. Nevis is part of the twin-island state of St. Kitts and Nevis. In common with other small Caribbean islands, Nevis is undergoing a period of rapid physical change. The effects of a tourist driven economy, changing lifestyles and increased infrastructural demands of the island community are combining to place unprecedented pressure on the environmental resources of the coastal zone (Robinson, 1997).

As the tourist industry has grown, problems relating to beach management have increased in number and magnitude. This situation has been recognized by the Nevis Island Administration who have expressed a desire to manage these problems.

As a first step, new coastal development setback guidelines have been prepared for Nevis (Cambers, 1998) within the project "Planning for Coastline Change." However, the government also realized that while setbacks could alleviate any potential problems caused by new development, they did not provide solutions to existing problems, e.g. where narrowing beaches had caused owners to build sea defences to protect their property. Therefore the government requested assistance to undertake a study of existing coastal defences and to prepare a comprehensive shoreline management strategy. This report represents the preliminary phase of that strategy.

This report is a position paper which tries to set the stage for the necessary discussions and consultations which are an essential part of any strategy development. The report was prepared as part of the regional project "Planning for Coastline Change" which is funded by UNESCO through their Environment and Development in Coastal Regions and Small Islands endeavour and the University of Puerto Rico Sea Grant College Program through their Multi-Program and Regional Development Facility.

A glossary has been included at the end of the report to assist the general reader with some of the technical terms.

2.1 Historical Background

This section identifies major events and milestones which have directly contributed to the present situation wherein there is a recognized need for a Shoreline Management Policy. Table 1 shows a time-line summary of the major events.

For more than two decades, concern has been expressed in Nevis about the relentless erosion at Pinney's Beach. Islanders have watched rows of palm trees disappear into the sea over the years. In the 1980s the Nevis Historical and Conservation Society (NHCS) took the lead by consulting several experts on the problem. At that time there was little beach development and the owners of the few coastal properties that were experiencing problems usually took matters into their own hands: in the 1970s a series of gabion groynes were erected at Nisbett Plantation on the north coast, and boulders were placed in front of Pinney's Beach Hotel.

Table 1. Time Line Showing the Major Events Influencing Shoreline Management

Year	Major Events and Milestones
1980s	Concern expressed by NHCS and others about the beach erosion especially at Pinney's Beach.
1983	Study of beach erosion in Nevis.
1987	Passage of the National Conservation and Environment Protection Act.
1987	Zoning plan prepared and guidelines drafted for coastal development setbacks.
1988	Beach monitoring programme commenced.
1989-91	Four Seasons Resort built at Pinney's Beach, opened in 1991.
1989	Hurricane Hugo caused considerable coastal damage in Nevis.
1991	Nevis Zoning Ordinance passed.
1993	Sand resources study conducted to identify alternatives to beach sand for construction.
1995-present	Gradual acceptance of the use of quarry products as an alternative to beach sand.
1995	Hurricane Luis (as well as Tropical Storm Iris and Hurricane Marilyn) caused considerable damage to the coast in Nevis.
1996	Beach Management Policy drafted.
1998	Coastal development setbacks revised.

In 1983, the government of St. Kitts and Nevis requested assistance from the Canadian High Commission to carry out a study of the beach erosion in St. Kitts and Nevis and to make recommendations for mitigative measures and sand availability. A study was conducted (Cambers, 1983), however, few of the recommendations were implemented mainly because of a lack of specialized expertise.

In 1987 the National Conservation and Environment Protection Act was passed, this provided for the conservation and protection of the natural and historical environment and the establishment of a Conservation Commission.

In 1987, a zoning plan was prepared which laid the foundation for physical planning in Nevis (Corker, 1988). Among other things, this plan prepared guidelines for tourism development on the beaches of Nevis which the Town and Country Planning Board attempted to implement. Among these guidelines were very generous coastal development setbacks:

- a zone of no development (high water mark to 120 feet inland),

- a zone where small individual buildings with no foundations would be permitted as well as other recreational facilities such as gardens and tennis courts (120 feet to 300 feet from the high water mark),
- a zone where buildings would be permitted under certain conditions (300 feet from high water mark and beyond).

These guidelines were incorporated into the Nevis Zoning Ordinance in 1991.

In 1988, the NHCS started a beach monitoring programme within the regional project entitled Coast and Beach Stability in the Caribbean Islands (COSALC). The purpose of this activity was to accurately measure beach changes. The Fisheries Division and the Physical Planning Unit also participated in this activity.

In 1989 work commenced on the construction of the Four Seasons Resort at Pinney's Beach. When completed in 1991, this development helped to change the pace of tourist development in Nevis by creating a large scale, up-market, beach resort. Now people started turning towards the beach and beach based tourism, whereas previously, tourist accommodation had been focused on the "Inns of Nevis", most of which were located inland.

In 1989, Hurricane Hugo, a Category 4 hurricane, passed over the island of Montserrat and within 13 miles (20 km) of the west coast of Nevis. This hurricane caused an average shoreline retreat (i.e. retreat of the land edge or dune edge) of 13 feet (3.9 m). There was also considerable damage to the island's infrastructure.

Up until the early 1990s the beaches and dunes of Nevis had supplied most of the island's construction sand. Historically this had not caused major problems for the beaches because much of the infrastructure was made of wood. However, as more people turned to concrete construction and therefore beach sand, the damage to the beaches became serious. Throughout the 1990s the NHCS mounted a campaign to warn the public about the dangers of beach sand mining, the data from the beach monitoring programme provided additional verification of what people could already see with their own eyes, e.g. extensive sand dunes at Indian Castle had been virtually destroyed as a result of mining. Following Hurricane Hugo, the reconstruction boom resulted in very serious erosion at several beaches, e.g. Fort Ashby at the northern end of Pinney's Beach.

A sand resources study, (Scott Wilson Kirkpatrick, 1993), identified three main alternatives to beach sand: rock crushing, offshore dredging and sand importation. In the past five years since this study, the construction industry has slowly turned away from the use of beach sand and emphasis has focused on rock crushing. There are now three quarries on the north coast producing various grades of fine aggregate. Some construction projects have also used imported sand. So gradually the pressure on the beaches and dunes for the supply of construction sand is lessening, although it has not completely stopped and there is still a need for continual vigilance by the government, the NHCS and others.

In 1995, Hurricane Luis, a Category 4 hurricane, passed 56 miles (90 km) east of Nevis (Cambers, 1996). There was extensive damage to the west coast, both to the beach itself and to coastal infrastructure (Physical Planning Unit, 1995). Almost every structure on the west coast within 100 feet (30 m) of the high water mark was destroyed (Barrett and Huggins, 1997). The beach monitoring data showed that the average shoreline retreat was more severe than during

Hurricane Hugo. This time the shoreline retreated an average 17 feet (5.2 m) inland (Cambers, 1996).

The government realized that much of the infrastructural damage could have been avoided had the setbacks outlined in the 1991 Zoning Ordinance been implemented. However, despite the efforts of the Physical Planning Unit there had been considerable opposition to these setbacks which were viewed as unrealistic. The government therefore decided to revise the setbacks to take account of local variations and to maximize the use of land while at the same time providing coastal buffers to protect buildings during storms and hurricanes. The coastal development setbacks have been revised to take into account variations at individual beaches (Cambers, 1998), these are currently under review by the Nevis Island Administration.

Following Hurricane Luis, several coastal property owners took action to protect their properties and/or beaches. Sometimes this was done with the advice and approval of the Physical Planning Unit, e.g. the Four Seasons Resort undertook an offshore dredging project in the months after the hurricane to nourish the beach. This was at least partially successful. However, sometimes property owners did not seek any permission and there has been an increase in the number of seawalls and rock revetments since the hurricane. Some of these structures are already creating problems.

In 1996, The Nevis Island Administration drafted a Beach Management Policy. This was prompted by a water-sports accident. The policy had a wide scope including issues such as the regularization of water-sports, dive shops, horse riding on beaches, beach bars, setbacks, the use of Crown land and the enforcement of regulations.

3. SHORELINE CHANGES

3.1 Beach Erosion and Shoreline Erosion

It is important to distinguish between **beach erosion** and **shoreline erosion,** (Pilkey and Dixon, 1996, U.S. Army Corps of Engineers, 1984). Beaches change on a daily, monthly and seasonal basis mainly in response to changes in the incoming waves. For instance at Pinney's Beach, during the summer months the sea is usually calm and there is a wide beach seaward of the vegetation line. However, in winter, when high seas generated by Atlantic storms occur, the sand is eroded and the water may reach the vegetation line. These changes are called **beach changes**: **beach erosion** in winter and **beach accretion** (build-up) in summer.

Shoreline erosion, on the other hand, occurs when the waves reach the land behind the vegetation line and start eroding it. This land may consist of low lying plains, e.g. at Pinney's Beach, Nisbett Plantation; sand dunes e.g. White Bay; or cliffs e.g. Fort Charles. Shoreline erosion usually occurs during extreme winter swells or during tropical storms and hurricanes.

Beach changes can take place without causing the shoreline to erode. For instance at the north end of Mosquito Bay at the present time, the beach erodes during the winter months and accretes during the summer months, but the shoreline is not eroding. In contrast at Pinney's Beach, beach erosion is also taking place, but here the shoreline too is eroding. So **land** is actually being lost at Pinney's Beach, see Figure 1.

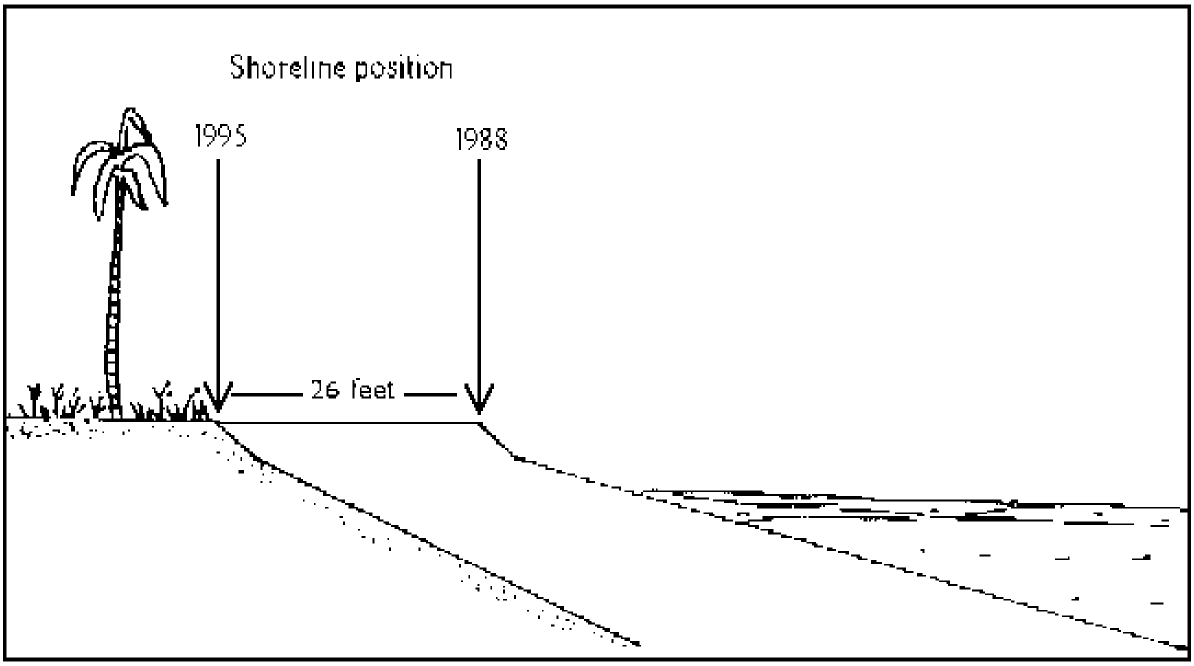

Figure 1. Shoreline Erosion at Pinney's Beach.
The shoreline, or land edge retreated inland 26 feet (8 m) between 1988 and 1995 at Golden Rock.

When shoreline erosion takes place on an undeveloped coast such as that shown in Figure 1, coastal land is lost, but the beach itself will remain. For in this case the beach retreats inland. However, if the shoreline or edge of the coastal land has been protected with a seawall or similar structure, then the beach cannot retreat inland and as a result, the beach will disappear over time, see Figure 2.

Beaches on a undeveloped coast maintain their natural width as they slowly retreat inland.

On a coast protected with a seawall, the beach will eventually disappear since it cannot retreat inland.

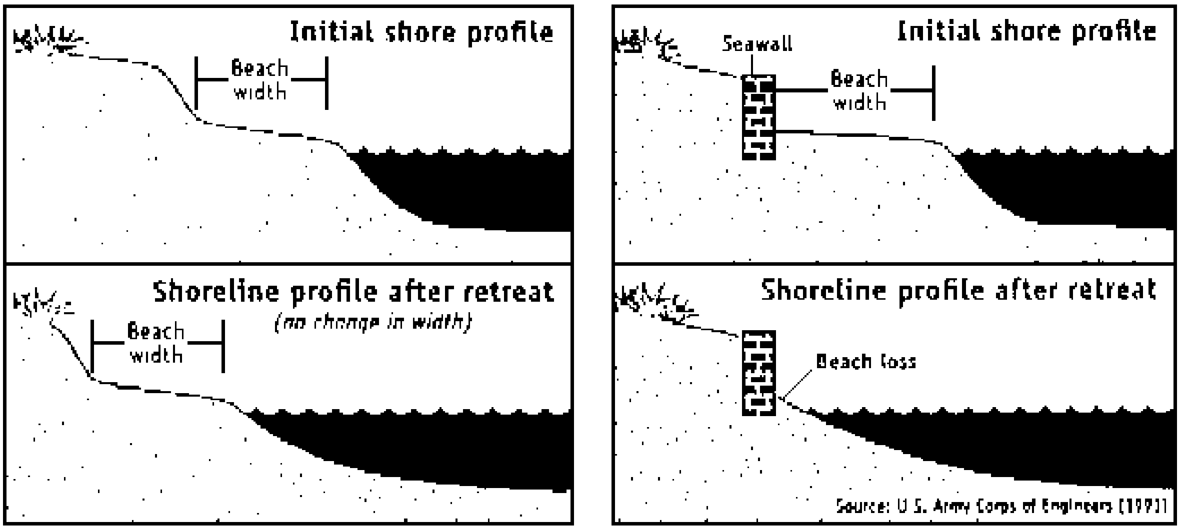

Figure 2. Shoreline Erosion on Unprotected and Protected Coasts.

While shoreline erosion has been described above, shoreline accretion can also occur, in this case sand deposits at the back of the beach become colonized with vegetation and the vegetation edge advances seaward.

3.2 Shoreline Changes in Nevis

Aerial photographs were used to determine shoreline changes in Nevis over the period 1946 to 1991. More recent changes (1988-1997) were calculated using the beach monitoring database. The data are shown in Table 2 and graphically in Figure 3. (Appendix I describes the methodology).

Over the period 1946-1991, the average shoreline retreat in Nevis was 1.2 feet per year, fourteen beaches/beach sections showed erosion, only one, Longhaul Bay showed accretion. The same pattern was evident during the more recent period, 1988-1997, when the average shoreline retreat was 2 feet/year, twelve beaches/beach sections showed erosion, two showed accretion and there was no data for the last section. The average rate of shoreline change was much higher during the period 1988-1997, this may be attributed at least in part to the influence of two major hurricanes during this period, Hurricane Hugo in 1989 and Hurricane Luis in 1995. (The figures calculated for 1946-1991 also include the impact of Hurricane Hugo).

Looking at the data in more detail, it is apparent that the most severe erosion is occurring along the west coast at Gallows Bay and along the entire length of Pinney's Beach (Pinney's Estate to Lawrence Estate) and along the stretch, Nisbett to Camps, on the north coast.

Table 2. Shoreline Change in Nevis Between 1946 and 1997.

Beach/Beach Section	**Shoreline Change feet/year 1946-1991**	**Shoreline Change feet/year 1988-1997**	**Shoreline Change metres/year 1946-1991**	**Shoreline Change metres/year 1988-1997**
Gallows Bay	-2.56	-4.43	-0.78	-1.35
Pinney's Beach 1, Hotel to Golden Rock	-2.46	-2.00	-0.75	-0.61
Pinney's Beach 2, Golden Rock to Jessup	-1.87	-1.87	-0.57	-0.57
Pinney's Beach 3, Jessup to Cotton Ground	-1.25	-2.43	-0.38	-0.74
Pinney's Beach 4, Cotton Ground to Lawrence Estate	-1.31	-2.66	-0.40	-0.81
Cades Bay	-0.89	-0.10	-0.27	-0.03
Jones Bay	-0.66	No data	-0.20	No data
Mosquito Bay	-1.67	+1.15	-0.51	+0.35
Hurricane Hill to Seahaven Estate	-1.02	-2.07	-0.31	-0.63
Seahaven Estate to Newcastle Bay	-1.05	-0.66	-0.32	-0.20
Nisbett to Camps	-2.72	-1.57	-0.83	-0.48
Camps to Burnaby	-0.16	No data	-0.05	No data
Longhaul Bay	+0.43	+0.10	+0.13	+0.03
White Bay	-0.16	-2.72	-0.05	-0.83
Indian Castle	-0.10	-6.53	-0.03	-1.99
Mean	-1.16	-1.98	-0.35	-0.60

At Gallows Bay the rate of shoreline erosion was 2.5 feet/year between 1946 and 1991, although over the past ten years the rate almost doubled to 4.5 feet/year. The 1946 photographs showed that the beach at Gallows Bay continued northwards in front of Charlestown, although the beach was narrower here. However, there did not appear to be any dry beach area between the Alexander Hamilton Museum and the headland where Pinney's Beach Hotel is now located. In the 1970s the jetty at Charlestown was reconstructed as a solid structure and this may have influenced the transport of sediment between Pinney's Beach and Gallows Bay although it is significant that neither beach has shown sustained accretion. By the 1980s the beach in front of Charlestown had disappeared and there was a wall protecting the buildings. This had been replaced by 1991 with a boulder revetment, part of which was reconstructed in 1995-1997.

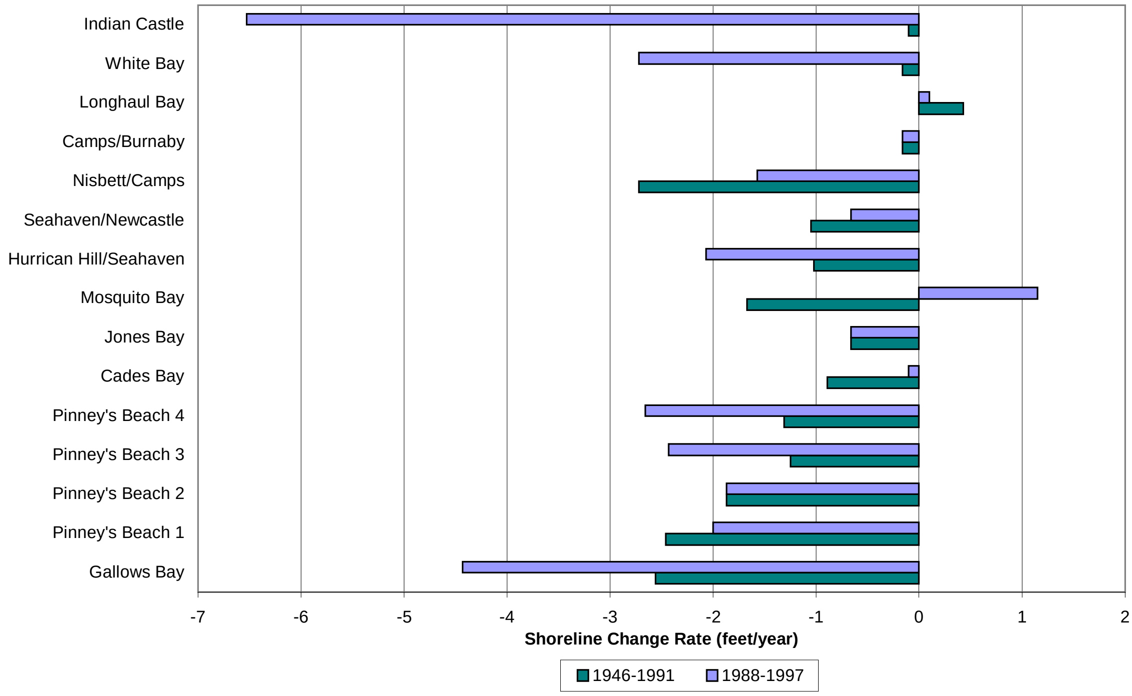

Figure 3. Shoreline Change in Nevis Between 1946 and 1997.

Pinney's Beach showed an average shoreline retreat of 1.7 feet/year over the period 1946-1991 with the most severe erosion taking place at the southern end. Again the rate had increased over the past ten years to 2.2 feet/year.

Along the remainder of the west coast shoreline erosion rates have been generally less than 1 foot/year. At the northern end of Mosquito Bay there has been significant accretion, at a rate of 1.2 feet/year, particularly over the past ten years.

Along the north coast from Hurricane Hill to Burnaby, the average shoreline retreat was again about 1 foot/year, with the exception of the stretch from Nisbett to Camps, where the rate was nearer 2.5 feet/year. In front of Nisbett several gabion groynes were constructed in the 1970s and these have had some success in stabilizing the beach along this stretch of coast, although at the expense of the coastal stretch downdrift. To the east of Nisbett Plantation there is a section of undeveloped coastline where trees may be seen lying in the water.

Longhaul Bay which is sheltered by surrounding reefs has shown accretion at the rate of 0.5 feet/year over the past fifty years and a small promontory has formed at the southeastern end of this bay.

The two beaches on the southeast coast, White Bay and Indian Castle, have shown low shoreline erosion rates over the period 1946-1991. However measurements over the past ten years showed higher erosion rates. In the case of Indian Castle, this may be related to the removal of an extensive system of sand dunes for construction sand between 1980 and 1991. (In the case of White Bay, the reason is unknown, however there is some doubt about the accuracy of the measurement data at this site over the last ten years).

4. SHORELINE STRUCTURES

4.1 Types of Shoreline Structures

Before describing the structures that exist in Nevis, a general outline of the main types of structures and shoreline enhancement measures as well as their functions will be provided, so as to give the general reader some background information. A glossary of terms is included at the end of this report.

Shoreline structures may be divided into two types: those that only protect beachfront land and those which promote beach build-up.

- measures which protect the land but which do not promote beach build-up, e.g. seawalls, rock revetments, bulkheads;

- measures which protect the land by promoting beach build-up, e.g. groynes, breakwaters, beach nourishment.

4.1.1 Measures which Protect the Land

These include seawalls, bulkheads and rock revetments, see Figure 4.

Seawalls are massive structures made of steel, rock or concrete. They may have a curved or vertical seaward face and are designed to protect land and buildings from the impact of the waves.

Bulkheads are similar to seawalls, they have vertical seaward faces and are designed to protect land from slumping and eroding into the sea. They are most suitable for quiet water areas such as lagoons.

Rock Revetments consist of armour rocks placed against a sloping face.

Gabions, which consist of stones packed in wire baskets, are often used as materials to construct walls, bulkheads, revetments and sometime “mattresses” extending under the beach. The wire enclosing the gabion basket is coated with plastic. However, without regular maintenance, water action results in the stones rubbing against each other and wearing away the plastic coated wire, creating holes through which the stones spill over the beach. Gabions are best for slope or channel stabilization where there is no danger of waves reaching them frequently.

Structures with a vertical seaward face such as some seawalls and bulkheads **reflect** wave energy and cause increased wave turbulence. This results in the water cutting downwards below the base of the structure and “digging” out the sand, this process is known as wave scour. On the other hand, a sloping rock revetment **absorbs** much of the wave energy.

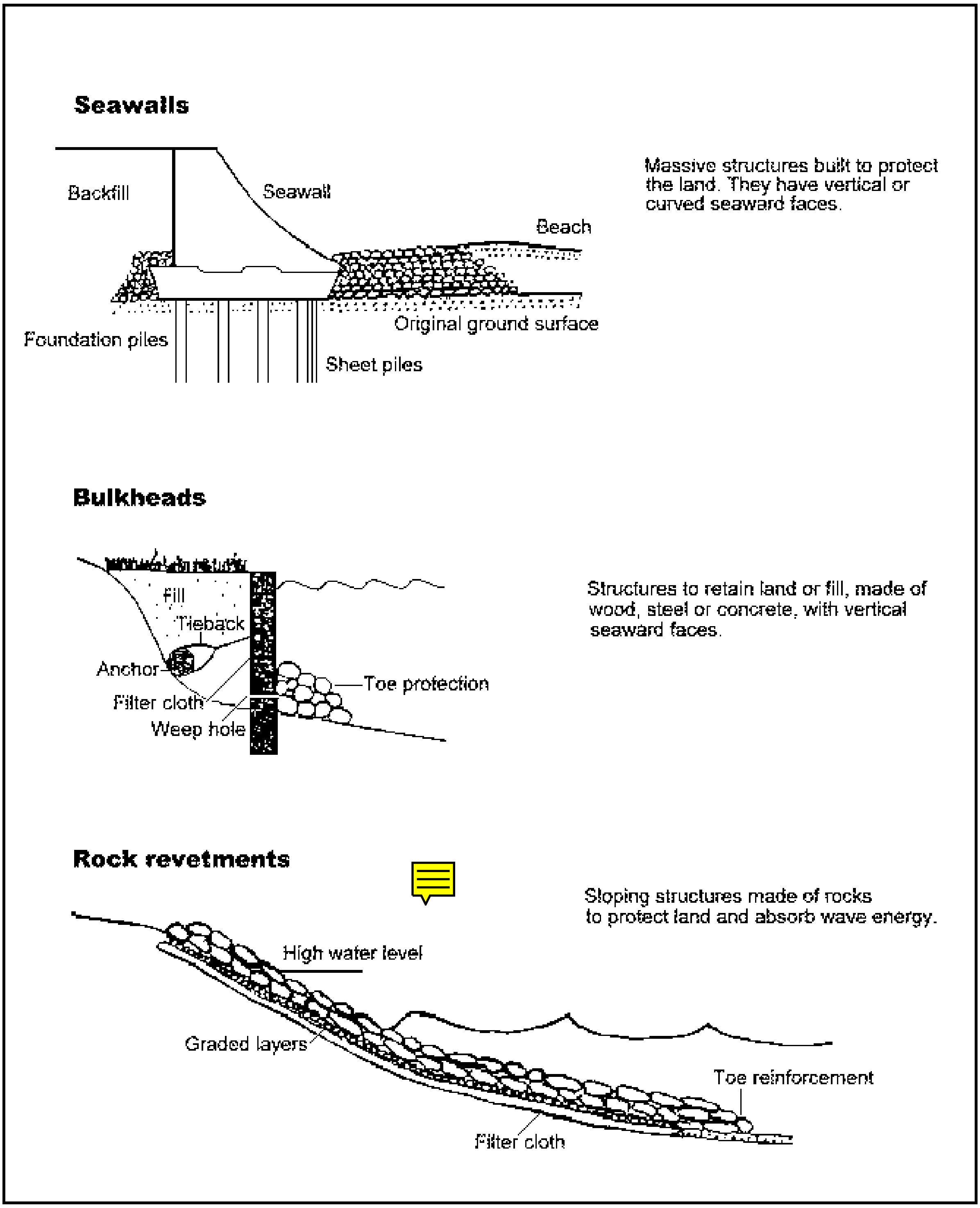

Figure 4. Structures to Protect Coastal Land and Property.
These structures, while protecting the land, do not usually promote beach build-up. (Figure adapted from U.S. Army Corps of Engineers,1981 and Bush et al 1995).

It is important to understand the consequences of building structures which only protect the land or beachfront property. While these structures protect the land, they do not promote the deposition of sand.

It has been found that as the erosion continues, the beaches in front of structures such as seawalls or revetments become narrower and in some cases disappear altogether.

A seawall, bulkhead or revetment protects **only** the land and buildings immediately behind it. Erosion will continue in front of the unprotected land on either side of the seawall, bulkhead or revetment and the waves will eventually cut in behind the structure, see Figure 5. So it is usually necessary to build return walls, which provide flank protection.

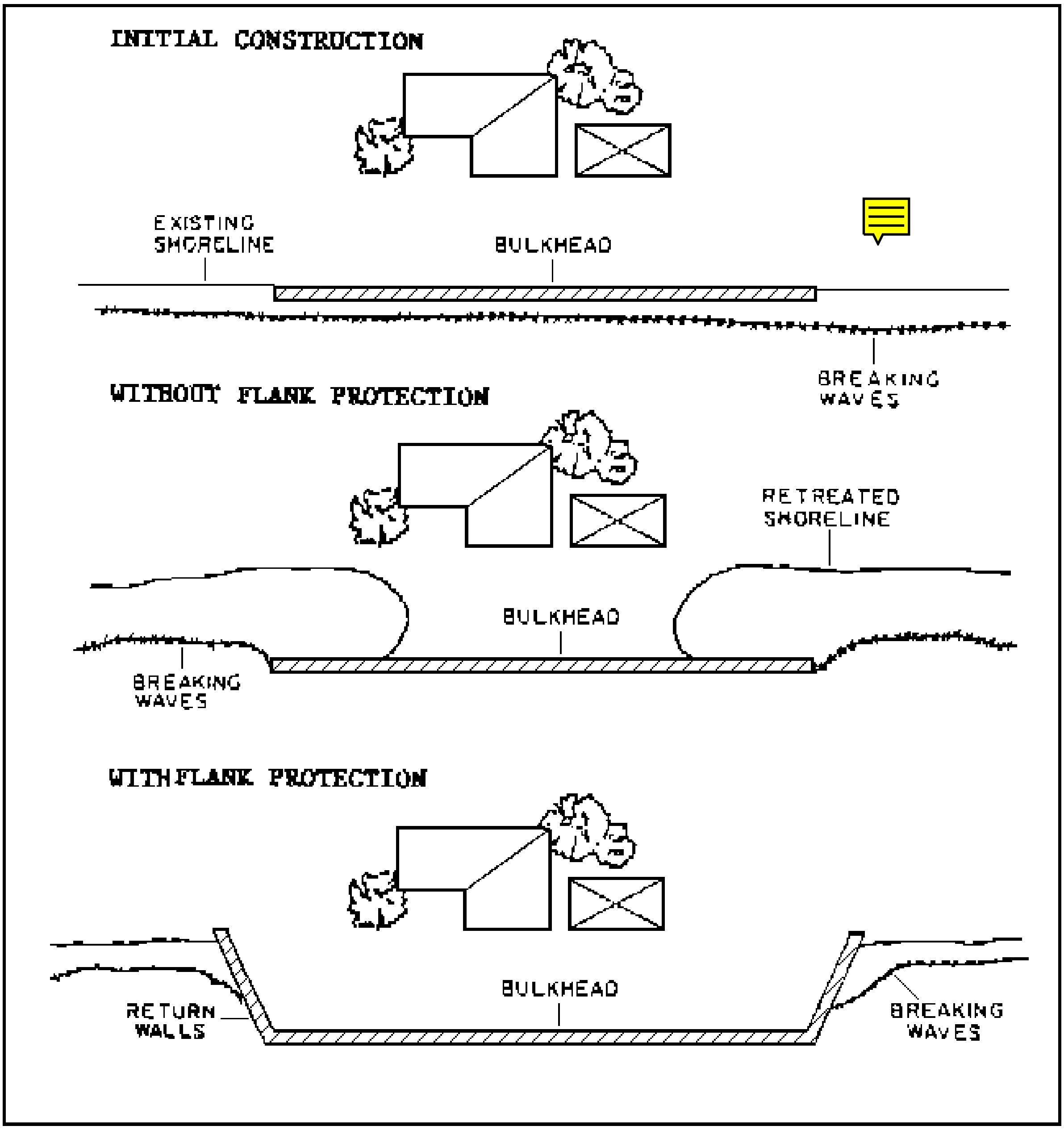

Figure 5. Bulkheads and Flank Protection..
Without flank protection the waves will eventually cut into the land behind the bulkhead, seawall or revetment. (Figure adapted from the U.S. Army Corps of Engineers, 1981).

As erosion continues, however, the protected section of coast will form a small headland projecting seaward of the main coastline. Beachcomber's Restaurant on Pinney's Beach provides an example of this situation, here the waves are eroding the beach and land on either side of the rock revetment and pedestrian access along the beach is difficult.

4.1.2 Measures which Protect the Land by Promoting Beach Build-up.

Such measures may consist of hard structures such as groynes and offshore breakwaters. Another measure, beach nourishment, consists of adding sand to the beach, usually from an offshore source.

When waves approach the shoreline at an angle they generate a longshore current which transports sand suspended in the water along the shore, see Figure 6. In addition wave action moves sand along the beach face.

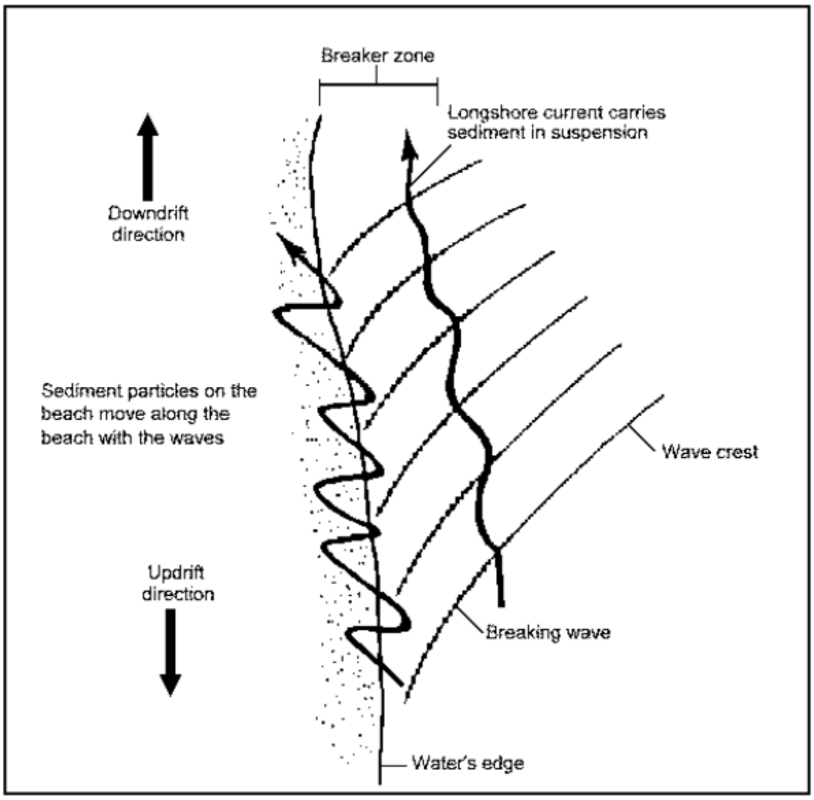

Figure 6. Longshore Sediment Transport.
When the waves approach at an angle to the shoreline, the sediment on the beach face is moved along the beach. (Figure adapted from U.S. Army Corps of Engineers, 1981).

Structures designed to trap this moving sand are called groynes. They are low walls constructed perpendicular to the shoreline which extend out into the water. Their main function is to promote beach build-up by trapping sand or slowing down its movement along the beach. In the Caribbean islands groynes are usually constructed of rock or concrete. Sometimes gabions are used, e.g. at Nisbett Plantation. However, gabions are not recommended as materials for groyne construction because of the need for continual maintenance. Wood or steel may also be used for groyne construction and groynes may be built singly, see Figure 7, or in groups known as groyne fields.

While groynes trap sediment on one side, they cause a sand deficit and therefore erosion on the other side, see Figure 7. So in effect one property owner may gain at the expense of his neighbour.

Groynes usually result in sand accretion on one side and erosion on the other side.

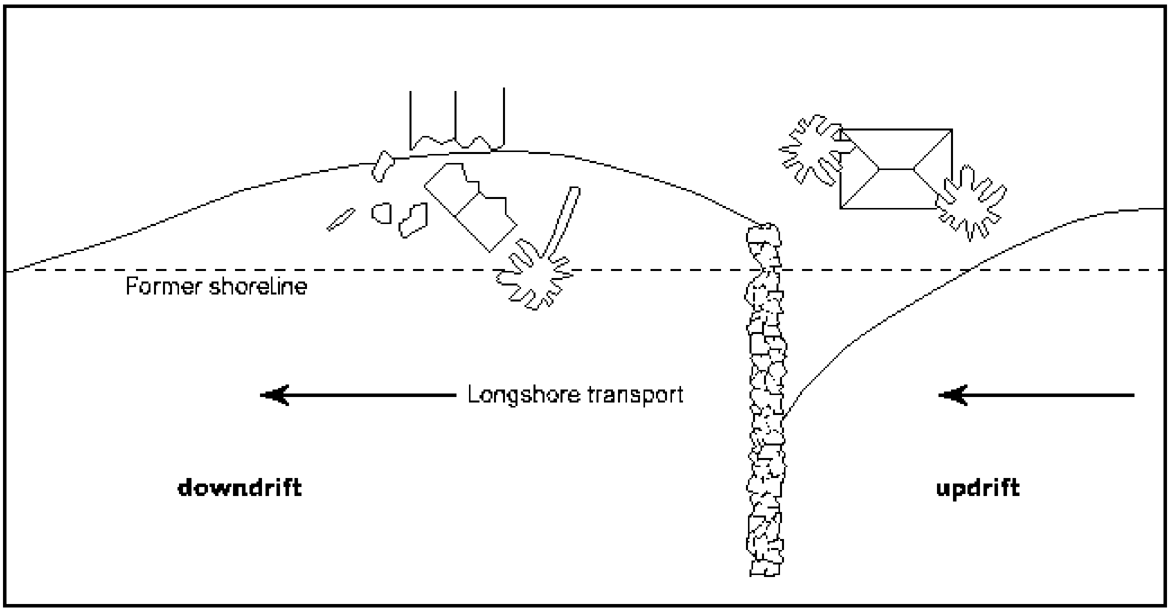

Figure 7. Effect of a Single Groyne.
The beach has built up on the updrift side and eroded on the downdrift side. (Figure adapted from Bush et al, 1995).

Groynes function most effectively on coasts where the direction of longshore transport is constant. In Nevis and the Caribbean islands with their prevailing Northeasterly Trade Wind regimes, the predominant longshore transport direction is from east to west. Experience has shown that groynes work best on north or south facing coasts and are least effective on east or west facing coasts. For example groynes have worked reasonably effectively on the north coast of Nevis, and on the south coast of Barbados.

Sometimes solid structures built as jetties or piers, essentially used for boat docking, have inadvertently functioned as groynes. Piled structures are recommended for jetties used for boat docking. Groynes are often seen as a "cure-all" for any erosion situation. However, this is not the case. Groynes are just one of several ways to control beach erosion.

Groynes only function well under certain specific conditions, they are not a "cure-all" for every beach erosion problem.

Another structure designed to promote beach build-up is the offshore breakwater. Offshore breakwaters are placed out in the water and are designed to intercept the energy of the approaching waves thereby sheltering the shoreline on their landward side, see Figure 8.

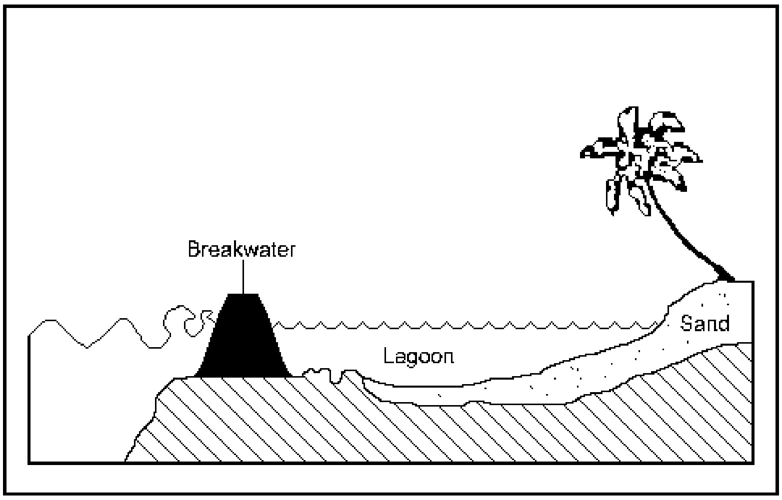

Figure 8. Cross Section of an Offshore Breakwater.

The sheltering effect of the breakwater results in a reduced rate of longshore sand transport and encourages sand accumulation behind the structure, see Figure 9. However, as with groynes, downdrift beaches may suffer erosion if they are deprived of their sand supply.

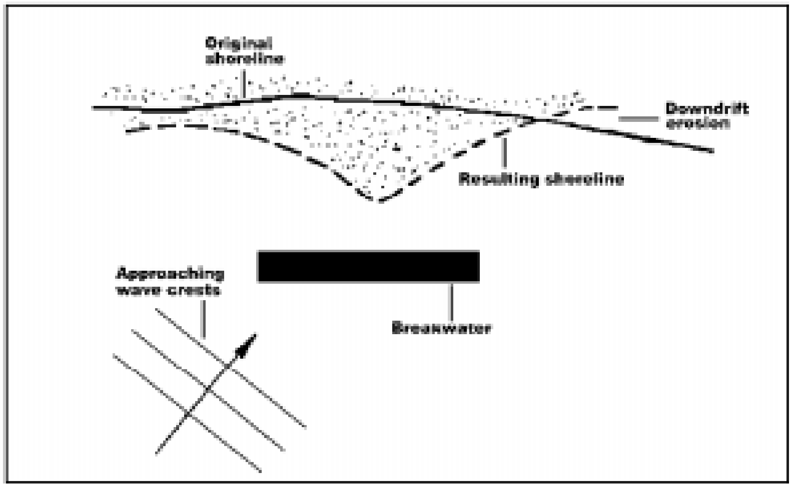

Figure 9. Plan View of an Offshore Breakwater.
The sand builds up in the area behind the breakwater which is sheltered from the high waves. (Figure adapted from U.S. Army Corps of Engineers, 1981).

Breakwaters are built out in the sea, usually parallel to the coast or sometimes angled to the shoreline. They are usually made of interlocking concrete shapes or large boulders. Generally they are more expensive than groynes or seawalls because they are of massive construction designed to withstand breaking waves. Also they must be constructed in the sea, rather than placed on land. This requires the placement of materials from a barge or the construction of a temporary ramp from the land out to the location in the sea. Breakwaters may emerge above the sea surface or they may be submerged.

Floating breakwaters, which are constructed of buoyant materials such as used tyres, may be used in sheltered wave environments such as marinas to reduce the wakes caused by passing boats. They are not suitable for open water conditions.

A third measure to promote beach accretion consists of adding large volumes of sand to the beach. This technique, known as beach nourishment, can be used to increase the size of a beach or to replace a lost beach. The sand may be obtained from an inland or offshore source. In the Caribbean islands, where land sources of sand are limited, the sand is usually obtained from the offshore zone. A suction dredge is used to pump the sand and water mixture via a floating pipeline onto the shore, see Figure 10.

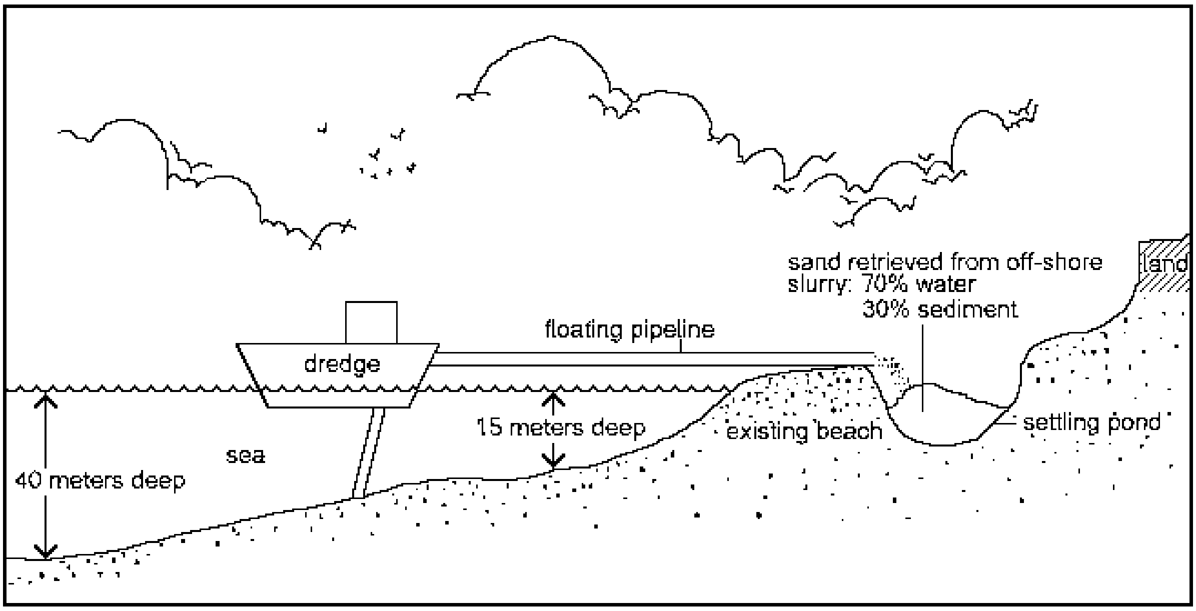

Figure 10. Beach Nourishment with Dredged Sand.
A sand and water mixture is pumped from the offshore zone into a settling pond on the beach, from which the water will drain back into the sea. The sand in the settling pond is then spread along the beach.

This technique has been little used in the Caribbean islands, although it is widely used in North America and other parts of the world. Detailed studies of bathymetry, wave climate, currents, and biological features such as coral reefs and seagrass beds, are required prior to embarking on a beach nourishment project. Beach nourishment should not be viewed as a "once only" operation, since in all cases periodic renourishment will be required at intervals of between 2 and 8 years, depending on the dynamics at a particular beach.

Beach nourishment has been used once in Nevis at the Four Seasons Resort on Pinney's Beach in November 1995. Sand which had been moved offshore by Hurricane Luis was pumped back onto the beach.

Periodic renourishment is required after the initial beach nourishment.

Table 3 provides some generalized, order of magnitude costs for various beach protection measures in the Caribbean islands. (These figures are not specific to Nevis).

Table 3. General Cost Ranges for Sea Defence Measures in the Caribbean Islands.

Type of structure/measure	**Cost per metre length of structure (US $)**
Rock revetments	650 - 975
Groynes (rock)	650 - 975
Groynes (pre cast concrete)	680 - 1 170
Offshore breakwaters (rock)	2 925 - 3 900
Offshore breakwaters (precast concrete)	3 250 - 4 225
Beach nourishment	\$5-17 per m^3 + dredge mobilization costs.

4.2 Inventory of Shoreline Structures in Nevis

The main types of shoreline structures in Nevis are groynes and rock revetments. This section will briefly describe the location, type of structure and any observed shoreline problems. Details regarding the shoreline structures are contained in Appendix II. Figure 11 shows the location of the structures.

At the southern end of Gallows Bay there is a short section of boulder revetment and a boulder ramp, these do not appear to be causing any shoreline problems at present.

At Charlestown there is a reclaimed area south of the main jetty, which is protected by a recently constructed sea wall fronted by a rock revetment. The main jetty, which is a solid structure, is 394 feet (120 m) long. North of the jetty, another seawall and revetment structure continues for 525 feet (160 m). North of this, the rest of the Charlestown frontage up to and including Pinney's Beach Hotel is protected with a variety of rock revetments. The entire Charlestown sea frontage is fully armoured and now projects into the sea forming a headland. As the adjacent beaches (Gallows Bay and Pinney's Beach) continue to retreat, the return walls, which consist of rock revetments), will have to be extended to prevent outflanking, see also Figure 5. This has already happened at Pinney's Beach Hotel where the return wall (revetment) had to be extended at least once (between 1988 and 1989) and possibly on other occasions.

There are only a few sea defence structures located at Pinney's Beach. The revetment at the southern end at Pinney's Beach Hotel has already been noted. At Golden Rock a former beach bar foundation now forms a small breakwater in the inter-tidal zone and is promoting some very localized accretion. At the Four Seasons Resort, there is a wooden piled jetty, north of which some boulders have recently (1998) been placed to protect a water-sports shop. The Four Seasons Resort beach frontage was replenished with 150 000 cubic feet (5 000 m^3)of dredged sand in November, 1995. Immediately north of the Four Seasons Resort and the beach access at Jessup, the Beachcomber is protected with a rock revetment which projects into the inter-tidal zone and makes pedestrian access along the beach difficult at all states of the tide. Erosion is continuing on the unprotected land on either side of this revetment.

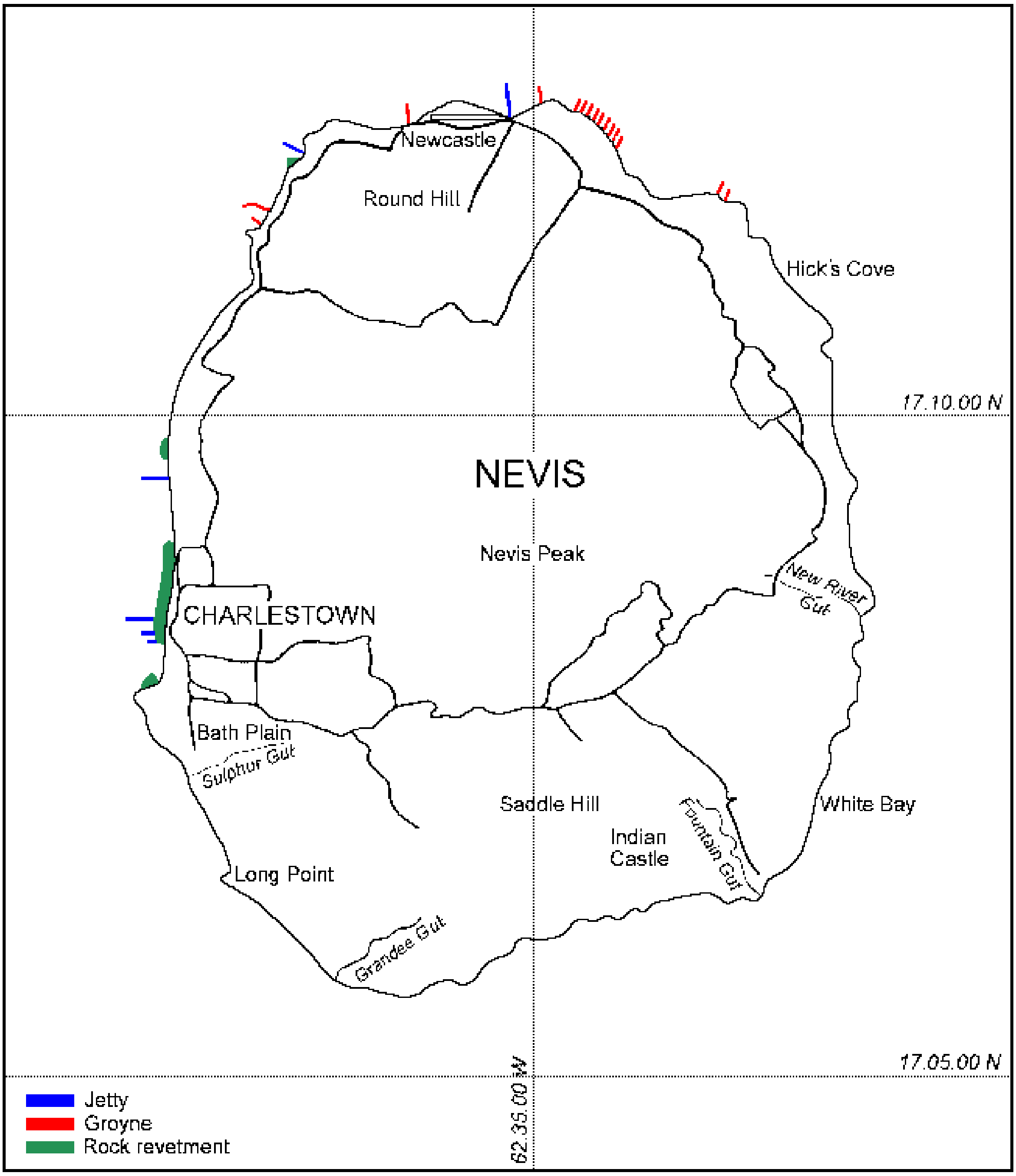

Figure 11. Major Sea Defences in Nevis

Between Cades Point and Jones Bay there are two groynes. The southern one is made of small boulders and is 20 feet (6 m) long. The northern one is 56 feet (17 m) long and is made of interlocking concrete units, it is almost completely submerged. (This structure was the site of a planned marina some years ago). Both groynes have resulted in some slight accretion, 10-16 feet (3-5 m) seaward on the northern, updrift side.

At the southern end of Mosquito Bay there is a rock revetment protecting a private house. This structure was recently constructed and projects onto the beach.

On the north coast there are several groynes, some built as individual structures and some as groyne fields. Near the western end of the airport runway there is a 46 feet (14 m) long groyne which is impeding access along the beach. Near this site there are also some deteriorated gabions on the beach. East of the Newcastle jetty there is another similar groyne structure.

At Nisbett Plantation there are nine groynes, these were originally made of gabions, but some have been rebuilt with boulders. The Nisbett groyne system has had some success in stabilizing the beach there, however, there is considerable erosion to the west of this groyne field and near the Camp River mouth, dead mangrove trees can be seen in the water.

The individual groynes along this coast are causing localized erosion problems for some property owners particularly on the downdrift (west) side. All the groynes are causing some problems with access along the beach.

On the east coast at Potwork Estate there are two 33 feet (10 m) long groynes, which were built to create a semi-enclosed area for washing the silt out of crusher dust from one of the quarries.

In general the number of shoreline structures is still small in Nevis, however, the total beach length is also small. The increase in structures built by individuals in recent years is a matter for concern especially since these are often built without permission and have had adverse impacts on adjacent properties e.g. the Beachcomber revetment and the individual groynes on the north coast.

5. SHORELINE MANAGEMENT OPTIONS

Against the background described in the proceeding sections, there are two main options in Nevis:

a) Do nothing;

b) Adopt a Shoreline Management Policy.

The "Do nothing" option will result in the proliferation of *ad hoc* sea defence structures as individuals seek to protect their beachfront properties. As has been seen in Section 4, beaches often disappear when structures such as seawalls and rock revetments are built, e.g. there used to be a wide beach in front of the Beachcomber restaurant at Pinney's Beach, similarly a beach used to exist in front of Charlestown. Furthermore, such defences are often temporary measures which afford insufficient protection during hurricanes. In addition, these structures result in reduced access along the beach.

One of Nevis' main attractions, the beaches fringed by palm trees, will ultimately disappear. This will reduce the quality of life for the residents of Nevis and will detract from its unique appeal to tourists. Tourists complain only once about a tourist destination, then they go elsewhere. The time scale for such a scenario depends on several factors, but suffice it to say that such a scenario could become reality early in the 21st century if Nevis were impacted by one or two more events like Hurricane Luis.

The alternative is to develop and implement a Shoreline Management Policy. Such a policy should include the entire coast: beaches, cliffs and rocky shores. This paper, however, concentrates on beaches because of their economic importance to the island's development. Three policy options
are developed:

- Protect beachfront lands;
- Conserve beaches;
- Protect beachfront properties built prior to 199_ (date of sea defence standards) and conserve beaches.

Each policy will require strict control and regulation. This does not exist at present, for individual beachfront property owners often build structures on and near the beach without seeking permission from the Physical Planning Unit. Such practices inevitably lead to shoreline management problems.

The three policy options will be discussed in general terms and then as they relate to a specific coastal stretch namely the southern part of Pinney's Beach from Pinney's Beach Hotel to the Beachcomber. This stretch has been selected because it contains developed and undeveloped beachfront lands. Table 4 summarizes the key points of each option.

Table 4. Summary of Shoreline Management Options.

Option 1: Protect Beachfront Lands	
Primary goal:	Maintain the existing shoreline position.
Secondary goal:	Conserve beaches where possible.
Controls	1. Property owners will be permitted to protect their beachfront properties with hard structures (revetments, groynes, breakwaters etc). 2. Beach enhancement measures (groynes, offshore breakwaters, beach nourishment) would be recommended where appropriate.
Option 2: Conserve Beaches	
Primary goal:	Keep existing beaches.
Controls:	1. New development will be set a safe distance from the beach through the implementation of coastal development setbacks. 2. New developers/land owners will be advised that no hard structures will be permitted in the future in front of their properties. 3. Owners of existing properties will not be allowed to construct new sea defence structures to protect their properties, only measures such as beach nourishment would be permitted. 4. Sea defence structures built prior to 199_ (date of sea defence standards) can be maintained but not rebuilt.
Option 3: Protect Beachfront Properties Built Prior to 199_ (date of sea defence standards) and Conserve Beaches	
Primary goal:	Keep existing beaches.
Secondary goal:	Protect existing beachfront properties built prior to 199_(date of sea defence standards).
Controls:	1. New development will be set a safe distance from the beach through the implementation of coastal development setbacks. 2. Developers and land owners will be advised that no hard structures will be permitted in the future in front of properties built post 199_ (date of sea defence standards).. 3. Owners of beachfront properties built prior to 199_ (date of sea defence standards) will be permitted to build structures to protect their properties, beach enhancement structures and measures (groynes, offshore breakwaters, beach nourishment) will be recommended wherever possible.

5.1 Protect Beachfront Lands

The primary goal of this option is to protect beachfront lands, thus the shoreline position (the edge of the land) will be maintained in its present position. A secondary goal is to conserve beaches wherever possible.

This policy will result in a combination of structures such as seawalls and rock revetments to protect beachfront properties and beach enhancement measures such as groynes, offshore breakwaters and beach nourishment to help conserve the beaches.

This policy will result in very high costs for sea defence structures. Ultimately the policy will fail, for there is no way that all the beachfront lands in Nevis can be protected. When the next major hurricane hits Nevis, or passes close to Nevis, many of the coastal defence structures, as well as beachfront buildings, will be damaged or destroyed, as happened in Hurricane Luis in 1995. However, implementation of such a policy, if it were economically feasible, could provide Nevis with protection for between one and three decades depending on the timing of the next major hurricane.

At the south end of Pinney's Beach, owners of the existing beachfront restaurants at Golden Rock and at Jessup would be permitted to construct protective structures such as revetments. The Four Seasons Resort might also seek to protect their buildings with similar structures, although a combination of offshore breakwaters and beach nourishment might be considered here because of the importance of conserving the beach in front of the hotel. These measures might in time reduce the volume of sand reaching the Pinney's Estate area (which is presently undeveloped). If Pinney's Estate were also developed, its owners would in the future be able to take measures to protect their investment. Ultimately, perhaps in two to three decades, the existing tree lined beach stretch would be replaced with a variety of rock/concrete structures, narrow and in some places non-existent beaches, and restricted access along the beach.

5.2 Conserve Beaches

The main goal of this option is to conserve beaches. The main components of this policy are strict controls for new development and a ban on all new sea defence structures.

Coastal development setbacks, such as those proposed by Cambers, 1998, would be applied to all new development applications. So new development would be located well behind the active beach zone leaving the beach space to retreat inland. Furthermore new developers would be advised that no sea defence structures would be permitted in the future, only soft engineering options such as beach nourishment would be allowed.

Owners of existing beachfront buildings would not be permitted to construct new seawalls or revetments to protect their properties. Under such a policy existing sea defences (groynes, revetments, seawalls) built prior to 199_ (date of sea defence standards) could be maintained but not rebuilt. For instance a gabion groyne could be repaired, but could not be replaced with boulders.

Along the southern Pinney's Beach section, this policy would allow the owners of the

Beachcomber to maintain their revetment, but not to re-build it. The owners of the beach restaurant at Golden Rock would not be permitted to build a revetment since there is no existing structure. The owners of the Four Seasons Resort would not be permitted to build structures to protect their property, only measures such as beach nourishment would be considered.

Under the umbrella of this policy the existing beach would be maintained much as it presently exists and at considerably less cost than the option in 5.1. The existing problems, e.g. the reduced beach access at Beachcomber would remain for a time, but ultimately as the shoreline continued to erode this coastal defence structure would fall victim to high seas and under the policy it could not be rebuilt. If and when the Four Seasons Resort experienced beach erosion problems, then the owners would be advised to consider beach nourishment as a solution. The beachfront at Clark's Estate would remain intact since any future development here would be situated well back from the active beach zone through the implementation of coastal development setbacks.

5.3 Protect Beachfront Properties Built Prior to 199_ (date of sea defence standards) and Conserve Beaches.

This policy is essentially a compromise between the first two options. This option would have as its main goal the conservation of beaches, but beachfront properties built prior to 199_ (date of sea defence standards) could be protected with hard structures. The main tools would be the implementation of coastal development setbacks for new properties and a ban on all coastal structures except at those beachfront properties built prior to 199_ (date of sea defence standards).

Coastal development setbacks, such as those proposed by Cambers, 1998, would be applied to all new development applications. So new development would be located well behind the active beach zone leaving the beach space to retreat inland. Furthermore new developers would be advised that no sea defence structures would be permitted in the future, only soft engineering options such as beach nourishment would be considered.

Owners of beachfront property built prior to 199_ (date of sea defence standards) would be permitted to protect their buildings with structures such as revetments, offshore breakwaters. However, all applications for coastal defence structures would be carefully assessed and wherever possible beach enhancement options such as beach nourishment and offshore breakwaters would be recommended.

Application of this policy to the southern Pinney's Beach section, would see the existing trouble spot at the Beachcomber remaining until the revetment is ultimately destroyed by a future hurricane. If and when the Four Seasons Resort experienced serious shoreline erosion and wished to take action, they would be permitted to construct sea defence structures. However, they would be advised to implement beach enhancement measures such as offshore breakwaters and /or beach nourishment rather than rock revetments. This would be in their own interest since they also wish to conserve the beach, not just protect the hotel property. The beachfront at Clark's Estate would remain as it is now, any future development would be situated well back from the active beach zone through the implementation of strict coastal development setbacks. Also developers here would not be permitted to construct new coastal defence structures.

6. CONCLUDING REMARKS

Nevis has long been at the forefront of successful environmental management in the Caribbean. This stems from the people's pride in their natural and cultural heritage and a desire to conserve this legacy while at the same time improving their lifestyles. A previous report in this series (Cambers, 1998) has proposed new coastal development setback guidelines for Nevis on a beach by beach basis. Once these become part of Nevis' planning legislation, the next stage of shoreline management will be to consider which of the three options discussed in this report would be appropriate for the individual beaches.

Similar shoreline management problems to those discussed in this paper can be found in almost every Caribbean island, and the decisions and policies adopted in Nevis may well provide a blueprint for the region.

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Glossary

Accretion: accumulation of sand or other beach material at a point due to the natural action of waves, currents and wind. A build-up of sand.

Armour: providing structural protection for the shoreline.

Back beach: the section of beach extending landwards from the high water mark to the point where there is an abrupt change in slope or material, also referred to as **backshore**.

Bar: fully or partially submerged mound of sand, gravel or other unconsolidated material built on the bottom in shallow water by waves and currents.

Beach: zone of clay, silt, sand, gravel or boulders extending from the low water line to a point landward where either the topography abruptly changes or permanent vegetation first appears.

Beach nourishment: artificial process of replenishing a beach with material from another source, either inland or dredged offshore.

Beach profile: side view of a beach extending from the top of the dune line into the sea.

Beach recovery: process whereby accretion takes place at a beach usually after a major storm or hurricane.

Bluff: high steep bank at the water's edge. Often used to refer to a bank composed primarily of soil. See also **Cliff**.

Boulders: large stones with diameters more than 10 inches (256 mm).

Breaker: a wave as it collapses on a shore.

Breakwater: structure parallel to the shore, usually positioned in the sea, that provides protection to the shore from waves.

Bulkhead: structure that retains or prevents sliding of land or protects land from wave damage.

Bypassing, sand: movement of sand from the accreting up-drift side of a structure, inlet or harbour entrance, to the eroding downdrift side.

Clay: rock particles smaller than 0.00015 ins (0.004 mm).

Cliff: high steep bank at the water's edge. Often used to refer to a bank composed primarily of rock. See also **Bluff**.

Coast: stretch of land bordering the sea or a large tract of water.

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

Coastline: intersection of a specific water height with the shore or beach, in this report: intersection of the beach with the land immediately behind, usually marked by a change in material or natural physiographic form, see also **shoreline**.

Conservation: the political/social/economic process by which the environment is protected and resources are used wisely.

Current: flow of water in a given direction.

Deep water: area where surface waves are not influenced by the bottom.

Downdrift: Direction of longshore movement of beach materials.

Dredging: excavation, digging, scraping, drag-lining, suction dredging to remove sand, silt, rock or other underwater bottom material.

Dune: Accumulations of wind-blown sand in ridges or mounds, landward of the beach and usually parallel to the shoreline.

Equilibrium: state of balance.

Erosion: Wearing away of the land usually by the action of natural forces.

Estuary: mouth of a river, where the fresh river water mixes with the seawater.

Filter cloth: Synthetic textile with openings for water to escape, but which prevents passage of soil particles.

Flank protection: angled section of wall at the end of a shore protection structure such as a seawall or revetment.

Foreshore: section of the beach between high water and low water marks.

Gabions: wire mesh rectangular containers filled with stones.

Gravel: rock particles 0.18 - 3 ins (4.6 - 77 mm)

Groyne: Shore protection structure built perpendicular to the shore, designed to trap sediment.

Groyne field: Series of groynes acting together to protect a section of beach.

High water mark: the highest reach of the sea at high tide.

Hurricane: intense, low pressure weather system with maximum surface wind speeds that exceed 74 mph (118 km/hr).

Jetty: structure projecting into the sea for the purpose of mooring boats; solid structure projecting into the sea for the purpose of protecting a navigational channel.

Land reclamation: process of creating new, dry land on the seabed.

Lee: sheltered.

Leeward: direction toward which the wind is traveling.

Leeward coast: coast sheltered from the waves.

Longshore current: a movement of water parallel to the shore, caused by waves.

Longshore drift: movement of material parallel to the shore, also referred to as **longshore transport.**

Longshore transport: movement of material parallel to the shore, also referred to as **longshore drift.**

Low water mark: the highest reach of the sea at low tide.

Mean sea level: average height of the sea surface over a 19 year period.

Monitoring: systematic recording over time.

Northeast Trade Winds: dominant wind regime in the Caribbean region, the winds blow from directions between north and southeast.

Nourishment: process of adding material.

Oceanic current: flow of water in a given direction in the ocean.

Offshore breakwater: structure built in the sea, parallel to the shore, designed to protect the shore from wave action.

Offshore step: break in the offshore slope positioned near the wave breakpoint.

Piled: a structure supported by long, heavy section timber, concrete or metal, driven into the earth or seabed.

Pollution: contamination that in certain concentrations will harm the environment.

Retaining wall: wall built to hold back the earth.

Retreat: movement backwards, towards the land.

Revetment: shore protection structure made with stones laid on a sloping face.

Sand: coarse grained soils with particle sizes between 0.003 and 0.18 ins (0.08 and 4.6 mm).

Scour: removal of underwater material by waves or currents, especially at the toe of a shore protection structure.

Seagrass bed: area of the offshore bottom colonized by seagrasses.

Seawall: massive structure built along the shore to prevent erosion and damage by wave action.

Sediment: particles of rock covering a size range from clay to boulders.

Settling pond: man-made depression created to receive water and sand mixture directly from dredging operation.

Silt: fine grained soils with particle diameters between 0.00015 and 0.003 ins (0.004 and 0.08 mm).

Silt curtain: fine meshed material suspended in the water to prevent silt escaping from a construction site.

Siltation: deposition of silt sized particles.

Shore: narrow strip of land in immediate contact with the sea.

Shoreline: intersection of a specific water height with the shore or beach, in this report**:** intersection of the beach with the land immediately behind, usually marked by a change in material or natural physiographic form, see also **coastline.**

Slope: degree of inclination to the horizontal.

Slurry: mixture of water and sand/silt/clay size particles, term used in dredging.

Storm surge: a rise in the sea surface on an open coast, often resulting from a hurricane.

Swell: waves that have traveled out of the area in which they were generated.

Tidal current: movement of water in a constant direction caused by the periodic rising and falling of the tide. As the tide is rising a flood-tidal current moves in one direction, and as the tide is falling the ebb-tidal current moves in the opposite direction.

Tide: periodic rising and falling of large bodies of water resulting from the gravitational attraction of the moon and sun acting on the rotating earth.

Toe protection: material, usually large boulders, placed at the base of a sea defence structure such as a seawall, to prevent wave scour.

Tropical storm: low pressure weather system with maximum surface wind speeds between 35 and 74 mph (56 - 119 km/hr).

Tsunami: wave caused by an underwater earthquake or landslide, can rise to great heights and cause catastrophic damage to the coast.

Turbidity: reduced water clarity resulting from the presence of suspended material in the water.

Updrift: direction opposite to the predominant movement of longshore transport.

Water table: the upper surface of groundwater, below this level the soil is saturated with water.

Wave: undulation of the surface of a liquid.

Wave direction: direction from which a wave approaches.

Wave refraction: process by which the direction of approach of a wave changes as it moves into shallow water.

Wetlands: low lying areas that are frequently flooded and support vegetation adapted to saturated soils e.g. mangrove swamps.

Wind waves: waves formed in the area in which the wind is blowing.

Windward: direction from which the wind is blowing.

Windward coast: coast exposed to wave action.

Please note: Not all the terms in the glossary are used in the body of the text. The glossary is intended as an introduction to the language of beach management.

APPENDIX I

METHODOLOGY USED IN SHORELINE CHANGE CALCULATION

The aerial photographs used to determine shoreline change were:

1946 black and white aerial photographs flown by the USAAF at a scale of 1:17,500. These covered the entire island.

1982 black and white aerial photographs flown by J.A. Storey and Partners, U.K., at a scale of 1:17,500. These covered the entire island.

1991 colour aerial photographs flown for CIDA at a scale of 1:10,000 covering the entire island.

Stereoscopic pairs of the photographs were studied and general changes regarding each beach were recorded. Then reference points close to the beach such as buildings and road intersections were selected, these reference points had to be visible on each set of photographs. Measurements were made from these reference points to the offshore step, this is the seaward toe of the beach. It is marked by a vertical downward step near the wave breakpoint and is a distinctive feature on some beaches and can also be distinguished on the photographs usually as a colour change or shade change. The number of points per beach depended on the number of reference points that could be identified on the two sets of photographs, in some of the less developed areas there were only one or two measurements per beach. These measurements were then compared and changes in the position of the offshore step were determined and calculated as a distance per year figure (metres/year).

Fore the determination of shoreline change, the edge of the vegetation line should have been used rather than the offshore step. However, the vegetation edge was difficult to determine because of the effects of shadow especially at Pinney's Beach. Since most of Nevis' beaches are relatively undeveloped the offshore step was substituted for vegetation edge in this calculation based on the assumption that as the shoreline retreats inland so too will the offshore step.

There are many errors involved in aerial photograph comparison e.g. distortion towards the edge of the photographs, difficulty in identifying fixed locations (reference points), and difficulty in identifying 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. Three sets of photographs were used, these represent just three time series: January, 1946, January-March, 1982, and January-March, 1991. Beaches change dramatically from week to week and also seasonally. All the photographs were taken during the winter months which to some extent reduces the variation resulting from seasonal changes. However, beach profile measurements show that during the winter, measurements may vary dramatically from one day to the next especially if a major winter swell event occurs. Tidal variations also exist, although tidal range in Nevis is very low, and in these measurements the offshore step was used rather than a particular water line.

For each beach/beach section a shoreline change value was calculated in metres per year using the 1946, 1982 and 1991 photographs.

Beach profiles are surveyed on a regular basis every three months at eighteen sites around Nevis. These data are detailed and far more accurate than the historical changes determined from the aerial photographs. However, they only cover a relatively short time period, 1988-1997. The beach monitoring data were used to calculate shoreline change by comparing the average width (from a fixed point behind the beach to the offshore step) for the baseline year of 1988 with the average width for all the following years (1989-1997). So all the variations between 1988 and 1997 were included.

APPENDIX II

SHORELINE STRUCTURES IN NEVIS
(BASED ON A FIELD SURVEY CONDUCTED IN MARCH, 1998)

Gallows Bay South

Location: South end of the bay, south of the Bath Stream where the coastline orientation changes from north/south to east/west.

Structure: 100 feet (30m) long sloping, boulder revetment in front of a house belonging to Mr. Hendrick Wade, 32 feet (10 m) long boulder ramp extending into the sea. (Revetment built around 1997).

Problems: None observed, although the area is rather unsightly.

Charlestown

Location: Reclaimed area south of the jetty to Pinney's Beach Hotel.

Structure: Reclaimed area south of the main jetty consists of 558 feet (170 m) of seawall protected with a sloping rock revetment (armour units 2-5 tons). There is a return revetment extending for 125 feet (38 m). At the southern end of the reclamation is a 85 feet (26 m) piled jetty for fishermen. North of this is a 220 feet (67 m) piled jetty for small boats and north of this is the 394 feet (120 m) main jetty, which is a solid structure. North of the main jetty the land is protected with 525 feet (160 m) of seawall fronted by a sloping, rock revetment (armour units 2-5 tons). From this point to Pinney's Beach Hotel the land is protected with a variety of rock revetments, some well constructed, some consisting of a few armour stones placed against the land edge. (Seawall and revetment near the main jetty built 1995-1997 and replaced an earlier revetment. Northern revetments built by individuals over the period 1970 to now).

Problems: The seawall and revetments provide protection for Charlestown, however, some of the revetments at the northern end of Charlestown are poorly constructed. As erosion continues, the return walls (revetments) at Pinney's Beach Hotel and Gallows Bay may need extension.

Pinney's Beach Golden Rock

Location: South of the public access at Golden Rock.

Structure: Foundations of a former beach bar, stretch for 66 feet (20 m) in the inter-tidal zone. (Beach bar originally constructed at the end of the 1980s).

Problems: As the beach retreats this structure forms an offshore breakwater and is causing some very localized accretion. It is not causing a problem at the present, but it could form a barrier to longshore transport in the future. It is not impeding access along the beach.

Pinney's Beach Four Seasons Resort

Location: Water-sports building.

Structure: A few isolated boulders have been placed in front of the building along a distance of 33 feet (10 m). (Boulders placed in 1998). South of the restaurant there is a wooden piled jetty 98 feet (30 m) long, this was re-built after Hurricane Luis in 1995.

Problems: None at the moment, however, any attempt to incorporate the boulders into a proper structure (revetment) could create problems.

Pinney's Beach Beachcomber

Location: North of the public access at Jessups.

Structure: 82 feet (25 m) long, sloping rock revetment (armour units 2-3 tons) built in front of the restaurant. (Built 1996-1997).

Problems: The unprotected land on each side of the revetment has retreated about 10 feet (3 m) inland leaving the revetment in the inter-tidal zone and this makes access along the beach difficult. Return walls will be necessary to protect the restaurant building and some arrangement must be made for easier access over the revetment to solve the immediate access problems.

Cades Point

Location: North of the headland at Cades Point and south of Jones Bay.

Structure: One 20 feet (6 m) groyne made of small boulders less than 1 ton constructed between 1990 and 1993. One 56 feet (17 m) groyne made of concrete units with six arms constructed in the 1970s as part of a marina project. This structure is now mostly submerged.

Problems: There has been some accretion on the northern side of both groynes, the shoreline has prograded seaward about 10 feet (3 m). These structures are not creating any major access problems since the shoreline from Cades Point to Jones Bay is a rocky cliffed shoreline for the most part.

Mosquito Bay

Location: South end of the beach in front of a private residence.

Structure: A 175 feet (53 m) rock revetment with armour units 2-3 tons and placed at a vertical angle (no seaward slope), no evidence of a filter cloth or filter material. Revetment constructed 1997-1998. At the northern end of Mosquito Bay there is a wooden piled jetty about 98 feet (30 m) long built in 1997-1998.

Problems: The toe of the revetment is in the inter-tidal zone, its construction is likely to result in increased erosion of the beach immediately in front of it.

Newcastle

Location: One groyne is near the western end of the airport runway, another is east of Newcastle jetty.

Structure: The western groyne (constructed around 1995) consists of boulders and is 46 feet (14 m) long, to the east of this groyne there are broken gabions on the beach along a distance of about 98 feet (30 m). The groyne east of the disused jetty at Newcastle is 49 feet (15 m) long and also made of boulders (constructed in the early 1990s). The piled jetty is made of wood, is 98 feet (30 m) long and is disused. (It was built in the 1960s).

Problems: Both groynes are impeding pedestrian access along the beach. The western groyne has resulted in some accretion in front of Mr. Hart's property, but the shoreline has retreated some 10 feet (3 m) on the western side eroding the beachfront land there.

Nisbett

Location: In front of Nisbett Hotel Plantation.

Structure: West of the restaurant/bar there are two partially submerged, short gabion groynes (#1,2), each about 33feet (10 m) long. There is a third groyne (#3), made of boulders and about 33 feet (10 m) long, also west of the restaurant. In front of the restaurant there is a boulder groyne (#4) 141 feet (43 m) long. East of this there is another boulder groyne (#5) 82 feet (25 m) long. Further east there are two submerged, old gabion groynes (#6,7), each approximately 82 feet (20 m) long. Then there is a 33 feet (10 m) long boulder groyne (# 8) and finally a 49 feet (15 m) long boulder groyne (#9). Originally gabion groynes were built in the 1970s, some of these were replaced with boulder groynes in 1990-1993.

Problems: There is severe erosion to the west of the groyne system near the Camp River mouth. The beach has also retreated significantly west of groyne #4, the longest boulder groyne. However, the groynes have been successful in trapping some sand and slowing down the rate of erosion at Nisbett Plantation over the past two decades. (Over the period 1982-1997 the erosion rate was less than for the period 1946-1982).

Potwork Estate

Location: South of Potworks Estate.

Structure: Two 33 feet (10 m) long boulder groynes built to create a semi-enclosed area for the washing of quarry dust in the mid 1990s.

Problems: No significant accretion or erosion near these groynes, there is little development in this area.

List of Reports in the Series "Planning for Coastline Change"

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3. Coastal Development Setback Guidelines in St. Lucia.

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