

**Evaluation of Environmental Impact
Related to Proposed Beach Restoration
at Caneel Bay Resort, St. Thomas, U.S.V.I.**

A Report to

Caneel Bay Resort
Virgin Islands Office of Coastal Zone Management
Virgin Islands National Park

by

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ABSTRACT

The 1996 hurricane season has left the beaches of Caneel Bay Resort in various levels of disarray. Roots of coastal vegetation are exposed along all shorelines, the worst exposure being at Hawksnest and Turtle Beaches.

VI Marine Advisors was asked to evaluate the level of damage, make recommendations for remediation and analyze several possible sand sources for possible renourishment. Seven profiles were established and measured to determine the present character of Little Caneel, Caneel, Paradise, Scott, Turtle and Hawksnest beaches. Sand samples were taken from each profile for laboratory determination of mean grain size and sorting. Samples of sand obtained from Jost van Dyke, Barbuda, the Bahamas and Guyana were similarly analyzed. The nearshore area around the entire resort was examined by snorkeling to identify any potentially sensitive areas that might be damaged by increased turbidity.

Based on our field examination, the worst erosion remains in Hawksnest Bay. Roots are exposed along the entire shoreline to the extent that natural coastal defenses are threatened. As no local sand source exists within the bay, outside sand will be needed to cover exposed roots. In Turtle Bay, sand is returning to the beach rapidly. The beach is oversteepened to the point of instability. Sand from the uppermost beach berm could be safely moved landward to cover exposed roots. In Scott, Caneel, Paradise and Little Caneel Bays sand had come ashore to varying degrees. In many places, sufficient reserves exist that can be moved landward to cover exposed roots. In some areas, some additional sand may be needed. In particular, the exposed scarp in northeastern Scott Bay has no beach in front of it. If the scarp can be lowered slightly and a small quantity of sand added (ca, 100 - 150 cubic yards), this problem can be minimized.

Sands from Jost van Dyke and the Bahamas are unsuitable due to their high mud content. The Guyana sand is the optimal choice as 1) Corps of Engineers' tests show it to be stable and 2) it contains absolutely no mud. We have had great success with this sand on St. Croix. Unfortunately, the great distance involved makes this sand both expensive and logistically difficult to import. The Barbuda sand contains on average 2% mud. While this is sufficient to cause an aesthetically displeasing sediment plume over the short term, experience has shown that environmental damage is unlikely. Any sensitive environments that were identified exist some distance from the beaches. Most corals, sponges and other invertebrates are species that have shown considerable tolerance to short-term sediment stress. The only sediment-sensitive coral (*Acropora palmata*) inhabits distant and higher-energy areas where water motion prevents significant sediment settling and damage.

The management at Caneel Bay Resort has devised a plan which focuses on Hawksnest Bay with respect to adding outside sand. Efforts are still underway to identify a realistic supplier for Guyana sand in smaller quantities. If this can be done, Guyana sand will be used, thereby eliminating all environmental concerns. If this is not possible, the Barbuda sand will be stockpiled just behind the beach where it will be washed before being taken to the beach. The site slopes landward and all fine-grained material will be trapped naturally on land. It is anticipated that the mud content can be reduced from 2% to less than 1% by this plan. Some turbidity will still result during placement, but it should be no more significant than that caused by moderate Fall rains.

RECOMMENDATIONS

Based on our site surveys, discussions with DPNR, the National Park Service and resort staff, and our laboratory analyses, we make the following recommendations:

- Approximately 200-300 cubic yards of sand should be added to the beach in Hawksnest Bay. This sand will have to extend to mean low water to provide any significant protection.
- Wooden walkways should be added to high-traffic areas to reduce trampling of vegetation. These should not be footed in concrete or structures that would encourage erosion during storms.
- An aggressive vegetation program should be considered to extend the present vegetation out onto the new sand. This would improve coastal defense during future storms.
- If it can be obtained, sand from Guyana should be used
- If the Guyana sand is unobtainable, sand from Barbuda is acceptable, but every effort should be made to reduce the quantity of silt in the sand before it is placed on the beach. Specifically, the sand should be washed before placement if possible:
- Sand should be placed on the beach only during relatively calm days.
- In Turtle Bay, sand from the uppermost beach face should be moved landward to cover the exposed roots. This will encourage the further return of sand which is in abundant supply just seaward of the beach.
- In Scott, Paradise, Caneel and Little Caneel Bays, existing sand should be used to the extent possible. Some outside sand may still be required, especially in northeastern Scott Bay (i.e., past the seawall).
- Silt curtains should not be used to retain finer sediment on the beach during the project. Both field observations and laboratory experiments have demonstrated the resilience of corals when exposed to even high levels of sediment stress over the short term. If silt curtains are used, the beach will slowly "bleed" fine-grained material for several weeks or months after the curtains are removed, thereby exposing nearshore organisms to lower levels of stress, but for a much greater length of time. It must be remembered that this option is only realistic because of the small scale of the proposed project; this logic should not necessarily be extrapolated to larger projects.
- Some thought might be given to monitoring. Possible options range from an on-sight monitor during construction (designated by CZM or NPS) to follow-up examinations of the nearshore environments to determine downstream impacts. As an alternative to quantitative quadrats, we suggest tagging one or two dozen colonies in Hawksnest Bay and photographing/videoing them over some interval. Hawksnest bay is the logical site for monitoring as 1) it is the most confined, 2) it contains the best coral cover, and 3) it will receive the greatest amount of sand. This approach would minimize the effort (and cost) needed for monitoring while targeting the area where the input of sand will be greatest. It thus provides the most cost-effective means for collecting useful data from areas most likely to be impacted.

The profiles should probably be re-run after project completion (just to document the magnitude of the change) and at some interval thereafter to monitor natural recovery of the beach. In addition to providing direct information on the success of the project, these profiles can provide valuable information on natural recovery rates after storms. Given the likelihood that increased storm activity will be the norm for the next decade, such information will be come increasingly important for planning.

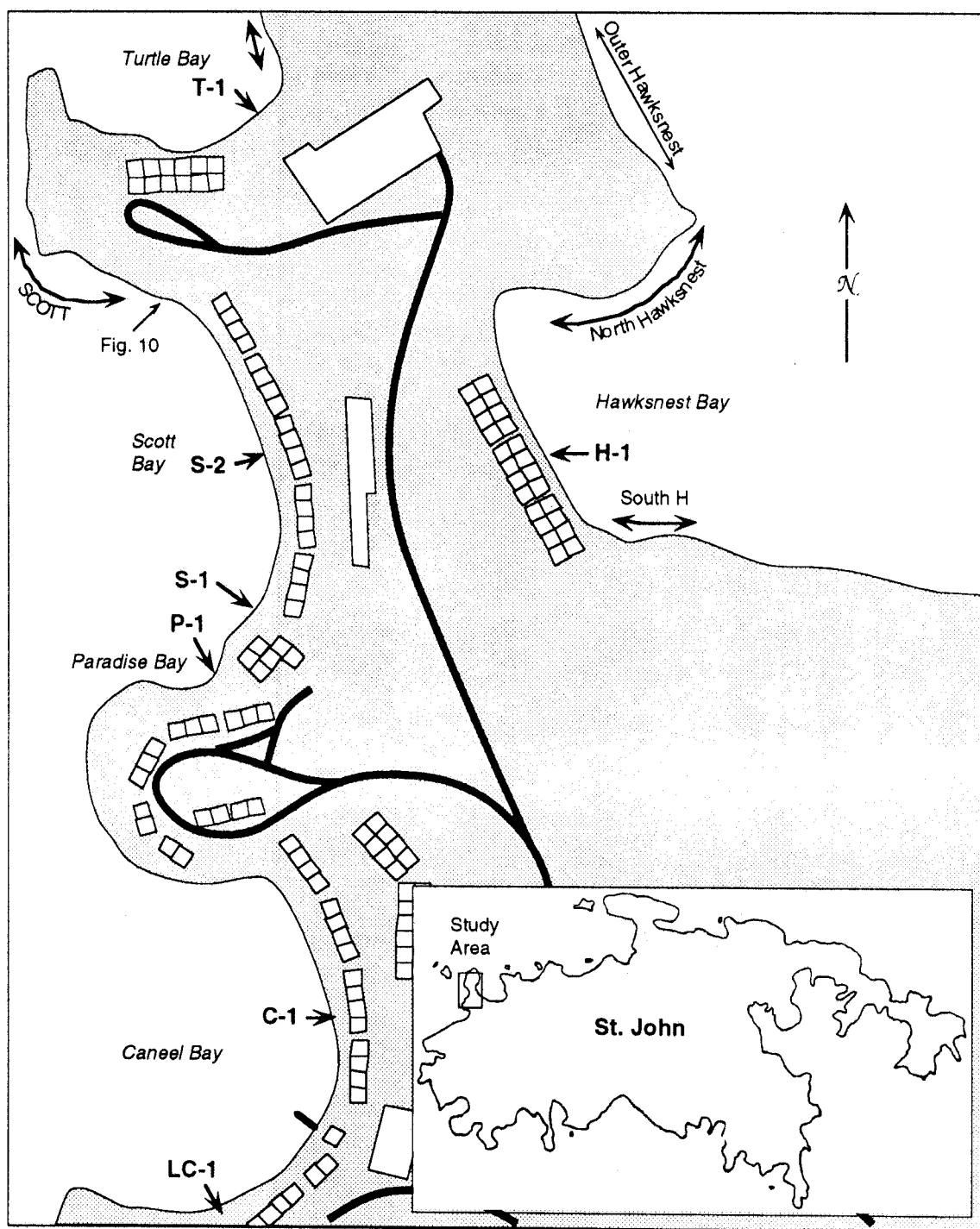


Figure 1. Map showing the locations of profiles and benthic-survey sites. The location of the area on St. John is shown on the inset.

INTRODUCTION

During the 1995 hurricane season, sand was eroded from all the beaches of the Caneel Bay Resort property on St. John, U.S. Virgin Islands (Fig. 1). This report describes the present condition of the beaches and makes recommendations for restoration, including a plan for environmental mitigation.

METHODS

Beach profiles

Seven permanent profiles were established across six beaches on the property (Fig. 1). Each profile was referenced to a semi-permanent or permanent feature so that the profile can be re-run at a later date. Measurements were taken using the Emery leveling method which uses the horizon as a vertical reference for surveying. Standardized photographs were taken at each profile site to document the location of the profile and the general character of the beach. Profile-data sheets are included in Appendix I.

Nearshore Benthic Survey

Before the field surveys were started, staff members from the hotel as well as researchers and managers from the Virgin Islands National Park were interviewed. Recent vertical aerial photographs and data tabulations provided by the National Park Service were also examined. Collectively, this information was used to prioritize areas for field inspection.

The entire shoreline off the resort was examined by snorkelers, with particular attention being paid to areas identified by resort or NPS personnel as having significant coral cover. General observations were made and species lists of corals and other invertebrates were made. Photographs were taken of representative areas within each bay and are provided in the body of this report. While this is by no means an exhaustive survey, it is felt to be sufficient to identify any areas that would be potentially threatened by project-related turbidity.

Sediment Collection - Sediment samples were taken along each profile at a point midway between high and low water. Samples were returned to the laboratory where they were washed in fresh water (3 times) to remove salts and sun dried to prevent grains from sticking together during drying. Each sample was subdivided with a commercial splitter until a subsample between 75 and 150 grams was obtained.

Samples were sieved at $1/2 \phi$ intervals according to Folk (1971). The sieves were agitated by a high-frequency vibration source for 15-20 minutes. Sediment statistics are reported in phi units, which are a logarithmic transformation of the size in millimeters ($\text{mm} = 1/2^{\phi}$):

$$\text{Mean} = \frac{\phi 16 + \phi 50 + \phi 84}{3} \quad (\text{Eq. 1})$$

$$\text{Sorting} = \frac{\phi 84 - \phi 16}{4} + \frac{\phi 95 - \phi 5}{6.6} \quad (\text{Eq. 2}),$$

where $\phi 5$ refers to the size below which 5% of the sample occurs, $\phi 16$ refers to 16% and so on.

Sand Comparisons

As a rough rule of thumb, sand to be used for beach replenishment should be as coarse or coarser than what occurs there naturally. The sand that is on the beach is stable because normal wave action cannot pick it up and remove it. Anything finer will be easily transported and will result in significant losses. Data sheets for sediment analyses are provided in Appendix II.

The testing protocol developed by the U.S. Army Corps of Engineers compares naturally occurring beach sand to that from the proposed source of replacement sand. The test compares the mean (average) grain sizes of both sands and their sorting (the extent to which all grains in a

sample are similar to the mean; samples with grains all near the same size are termed "well-sorted"; samples with a wide range of grain sizes are termed "poorly sorted"). The size and sorting of the "borrow" sand are designated by the subscript "b"; natural samples from the beach are designated by "n".

Using the grain-size information derived from sieving, the parameters $(M_b - M_n) / \sigma_n$ and σ_b / σ_n are determined, where:

M_b = mean size (in phi) of the borrow sand

M_n = mean size (in phi) of the natural sand

σ_b = sorting of the borrow sand

σ_n = sorting of the natural sand

These values are in turn plotted on a nomogram published by the Corps of Engineers to determine the "overfill ratio" (R_A), which can be thought of as the volume of sand that will be needed to end up with one cubic yard of sand after nature has winnowed out the portions of the sediment that are too fine to be stable. For instance, if you want to add 2000 yd³ to your beach and were using a sand with an R_A of 1.5, you would need to use 3000 yd³ (i.e., 2000 yd³ x 1.5). Another way of thinking about R_A is to consider it as a "performance index". If a storm of some intensity erodes 100 cubic yards of natural sand from the beach, then 150 cubic yards of the borrow sand with an R_A of 1.5 would have been lost.

Sand from Barbuda, Jost van Dyke (Jost-101A and Jost 103), the Bahamas and Guyana were considered as possible replenishment sources. Three samples from different shipments of Barbuda sand were taken to address concerns about quality control and the likelihood that the sand placed on the beach might differ from the samples that were tested for this report. The report concentrates on the Guyana and Barbuda sands as possible sources.

RESULTS

Present Condition of the Beaches

Seven profiles were run to determine the character of the beaches and the extent of the erosion (Fig. 1). Along profiles LC-1 (Little Caneel Beach: Fig. 2) and C-1 (Caneel Bay: Fig. 3, 4), erosion is slight. Approximately 30-45 cm (1.0-1.5 ft) of sand would be needed along the upper beach to cover exposed roots and to reduce wave reflection off the rocks along Little Caneel Beach. None of the sand would be placed in the water. Similarly, at Paradise Beach (Fig. 5) and southern Scott Beach (Figs. 6-9) only a thin veneer of sand would be needed to cover exposed roots.

A greater thickness of sand would have to be added along the northernmost end of Scott Beach (Fig. 10). In this area, a scarp that reaches nearly 80 cm (>2 ft) in height dominates the backbeach. Reflection off this vertical surface exacerbates erosion and should be minimized. This can be accomplished by a combination of adding sand and lowering the top of the scarp. The latter may be needed because the beach is very narrow in this area. If sand were added to cover the scarp as it presently exists, the resulting slope might be too steep to remain stable. If the upper portion of the scarp is lowered by only 30-40 cm (ca. 1 ft), the slope could be reduced to the point where the beach is more stable.

At Hawksnest Bay (Fig. 11), roots have been exposed by erosion and will probably not be covered by natural sand replenishment. A three-part remediation plan is recommended. First, sand should be added to cover the exposed roots. Second, a series of wooden steps should be

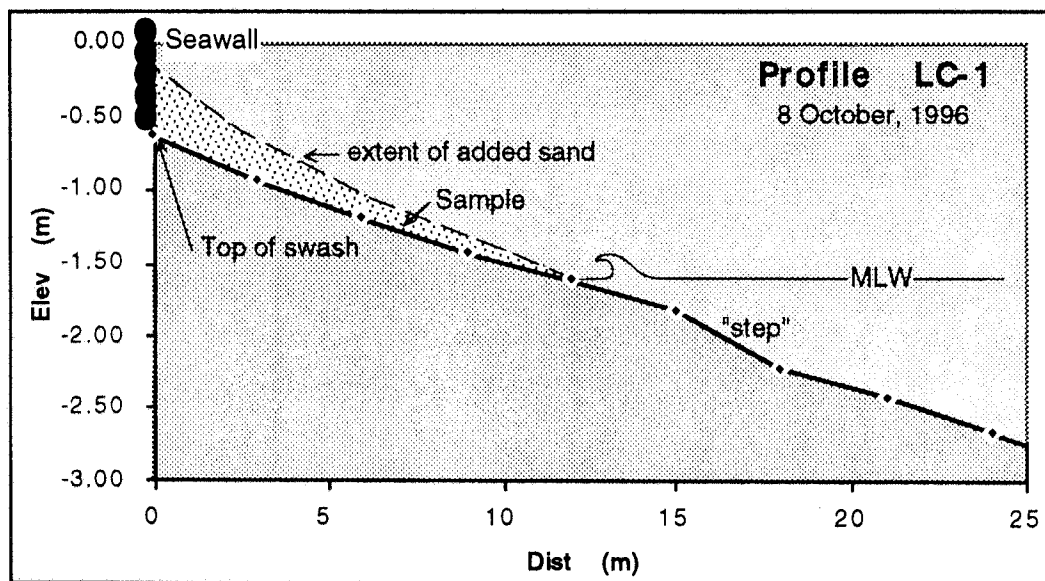


Figure 2. A (top). View looking south along Little Caneel Beach. The person is standing on profile LC-1. Note the exposed rocks at the left. The proposed plan will add just enough sand to cover these, thereby reducing wave reflection. B. Profile LC-1 on 8 October, 1996. The dashed line and stippled pattern show the extent of the sand to be added. See Figure 1 for profile location.

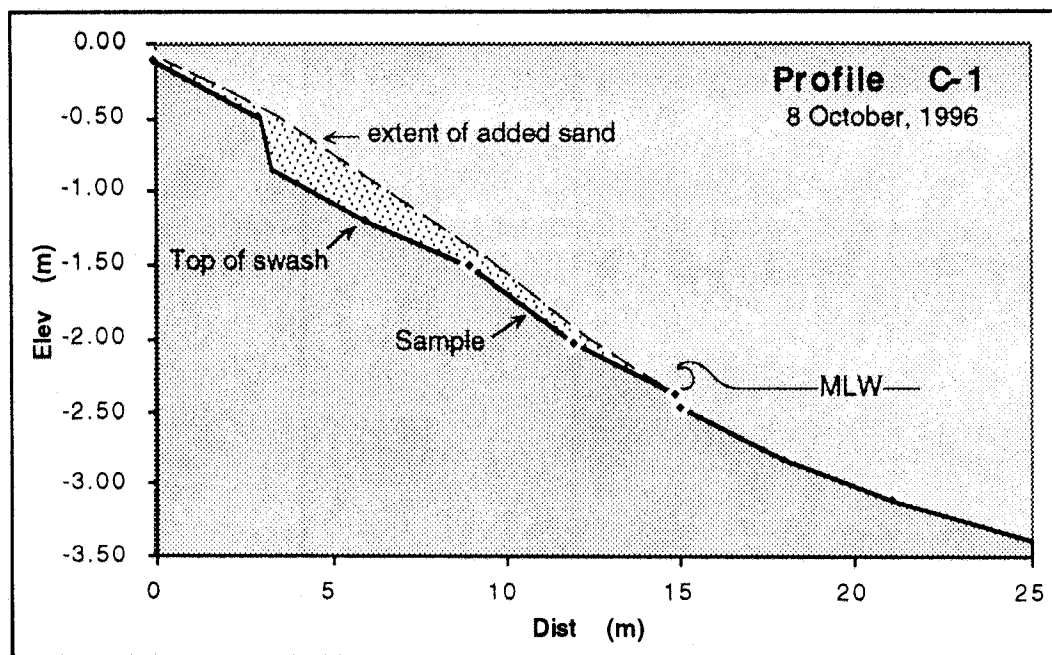


Figure 3. **A** (top). View looking south along Caneel Beach. The person is standing on profile C-1. Note the exposed roots at the left. The proposed plan will add just enough sand to cover these roots (ca 45 cm/1.5 ft). **B.** Profile C-1 on 8 October, 1996. The dashed line and stippled pattern show the extent of the sand to be added. See Figure 1 for profile location.



Figure 4. Closer view of the exposed roots along profile C-1. The proposed sand would be added only to the extent that it would be needed to cover and protect these roots.

added to restrict foot traffic to designated pathways in high-traffic areas (there are 7 walkways at present). Third, grasses and vines should be planted along the landward edge of the new beach to help hold sand during the next storm season. The wooden steps would help to protect both new and existing vegetation. The steps should be built in a way that does not require extensive footings (i.e., they should be sacrificial in the event of severe storms; perhaps they could even be taken in before storms).

The root structure at Turtle Beach is similarly exposed (Fig 13). In addition, several palm trees are toppling over as their roots are undermined (Fig. 14). Reorientation of their trunks infer that this problem has existed at least once in the past (i.e., note the two changes in growth direction shown in Figure 15).

The history of this beach and its impact on man-made structures is not obvious. Clearly erosion has been widespread on this beach in the past. The roots in Figure 13 are colored near their bases and white near the top. The position of the color change is interpreted as the elevation of the beach before the 1996 hurricane season. The concrete walkway to the beach is footed well below the level of the color change in the roots. To further complicate the picture, the base of this walkway is below the present sand level (Fig. 14: note man standing in hole dug to the base of the steps).

An important factor in choosing a remediation strategy for this beach is its rapid natural recovery. At present, a broad expanse of loosely packed sand likely reflects newly added sediment (Fig. 16). In some areas, the beach is oversteepened, again inferring rapid recovery. Based on these factors, plus the high ambient wave energy at this site, it is recommended that any remediation plan use natural sand that already exists on the beach.

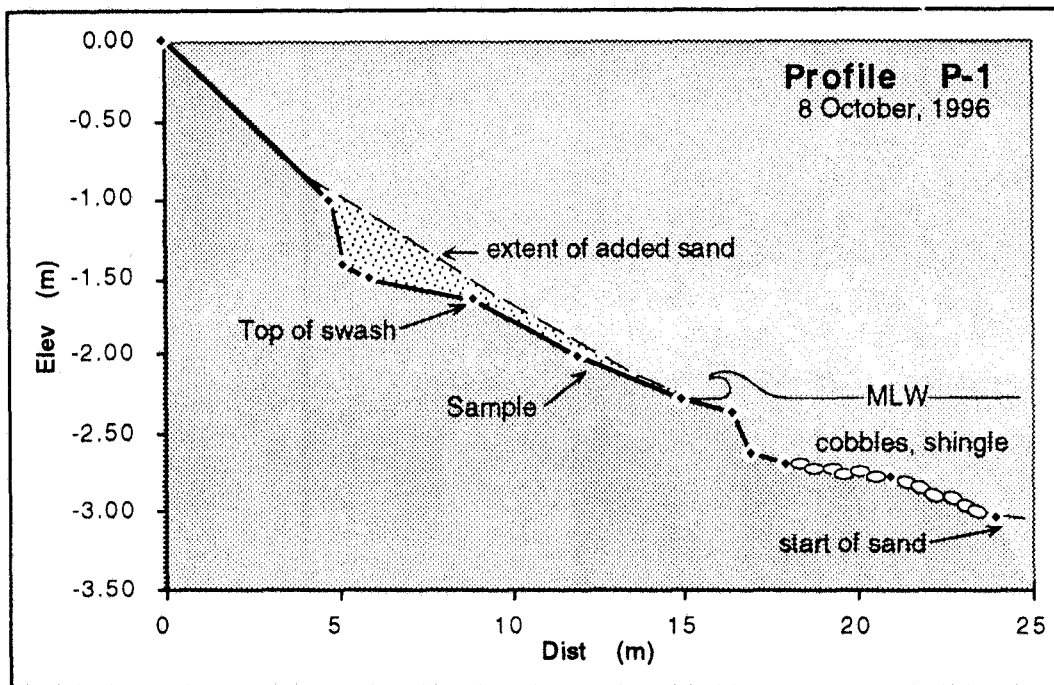


Figure 5. A (top). Exposed roots near profile P-1. The proposed plan will add just enough sand to cover these (ca 45 cm/1.5 ft). B. Profile C-1 on 8 October, 1996. The stippled pattern shows the extent of the sand to be added. See Figure 1 for profile location.

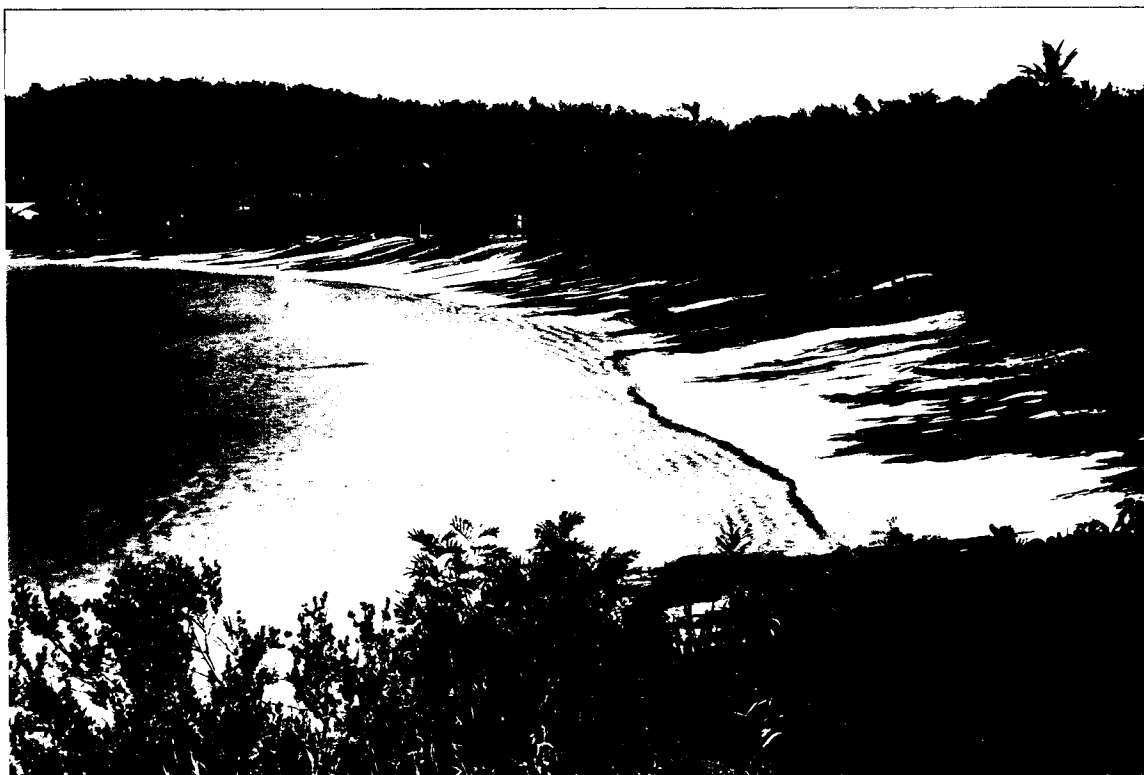


Figure 6. Panoramic view looking north across Scott Beach. Profile S-1 is located just south of the beachrock near the center of the photograph. Profile S-2 is located near the center of the seawall at the top left (where the beach narrows).



Figure 7. Close-up of exposed roots near profile S-1 along southern Scott Beach. The new sand would be used to protect these roots.

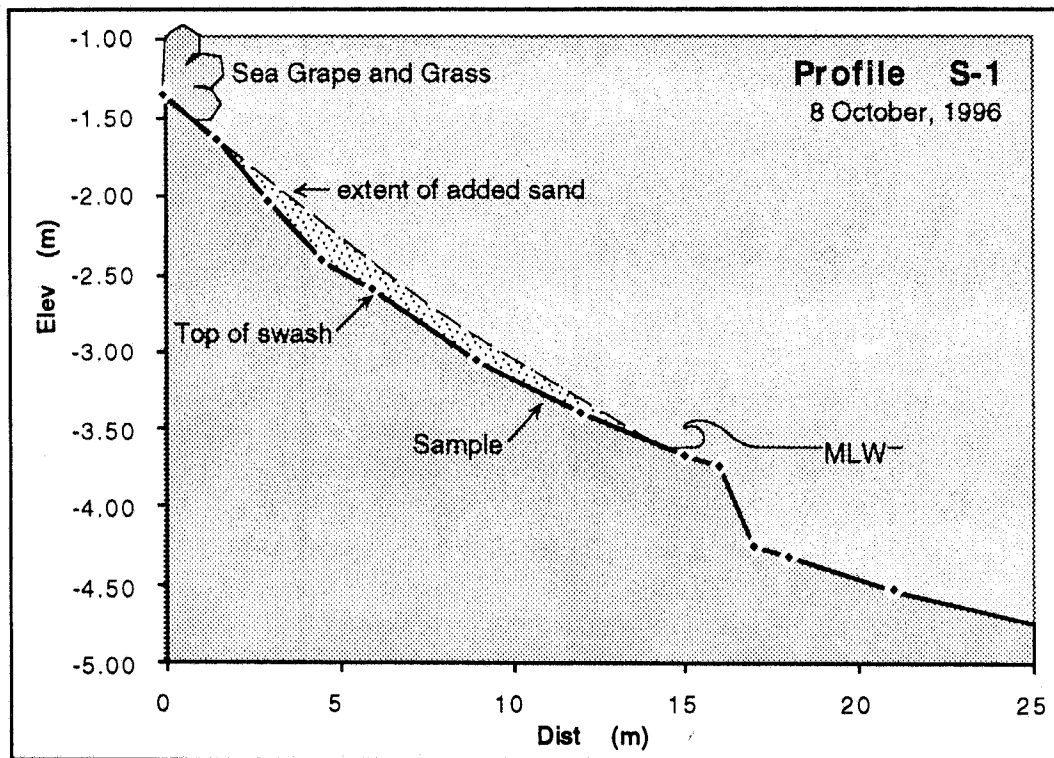


Figure 8. A (top) View looking north along southern Scott Beach. The person is on the profile. B. Profile S-1 on 8 October, 1996. The stippled pattern shows the extent of the sand to be added. See Figure 1 for profile location.

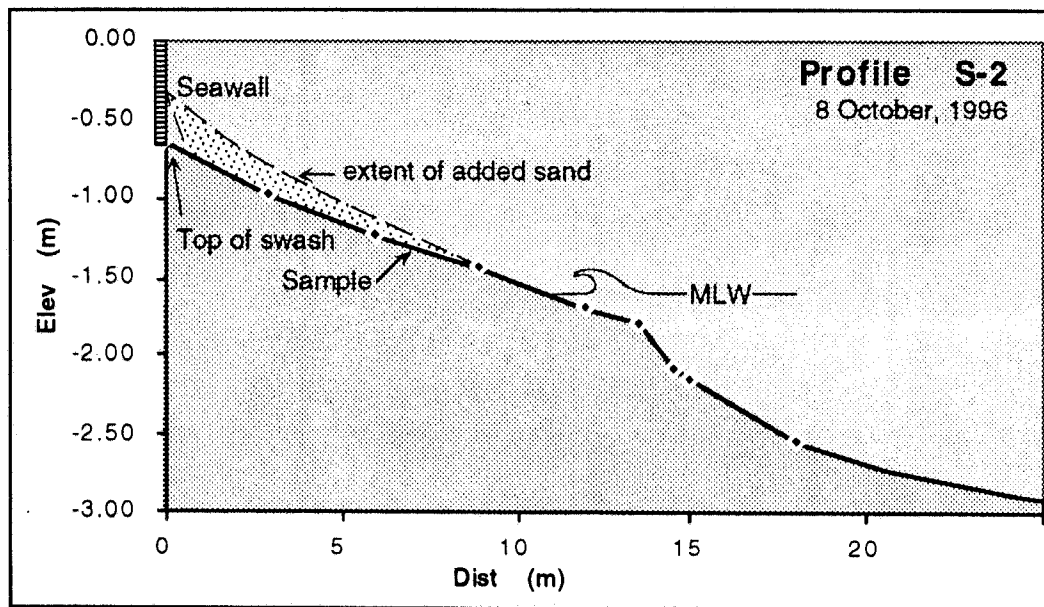


Figure 9. A (top) View looking north along northern Scott Beach. The person is on the profile. Note the seawall to the right. Sand needs to be added behind the wall to backfill areas eroded by wave action. A thin veneer of sand would also be added to cover the base of the wall. B. Profile S-2 on 8 October, 1996. The stippled pattern shows the extent of the sand to be added. See Figure 1 for profile location.



Figure 10. Photo of an 80-cm high scarp along the back of northern Scott Beach. Because the beach is so narrow in this area, simply adding sand to cover the scarp would result in an oversteepened and unstable beach. One possible remedy is to slightly lower the top of the scarp. See Figure 1 for location.



Figure 11. Photo of exposed roots in Hawksnest Bay. It is recommended that this problem be remedied by adding sand and building wooden steps along high-traffic areas to reduce damage to vegetation. This plan would be combined with an aggressive re-vegetation program along the upper beach.

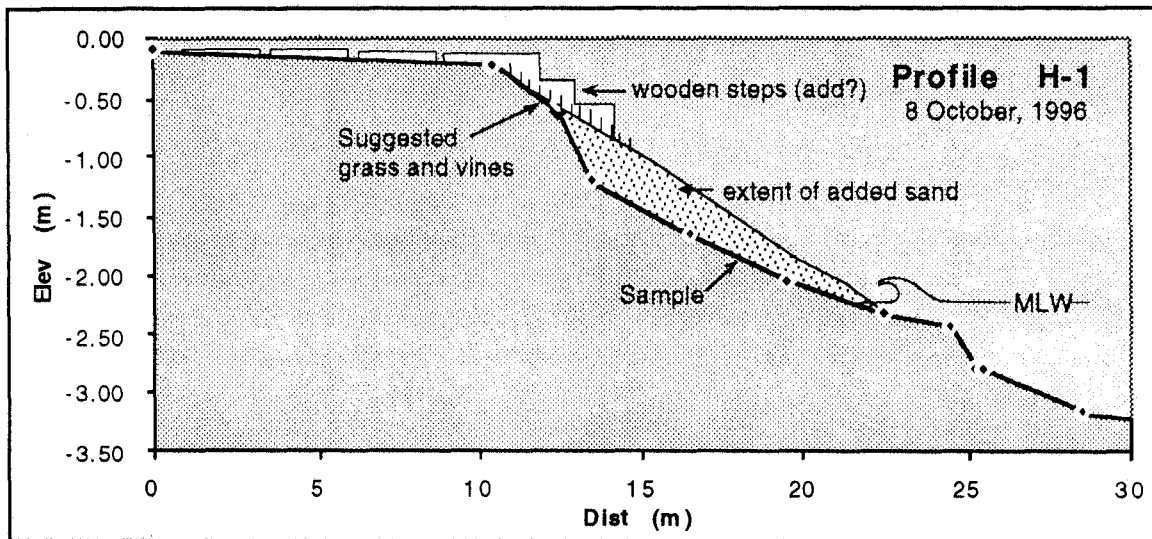


Figure 12. A (top) View looking north along Hawksnest Beach. The person is on the profile. Note the exposed roots all along the beach. We recommend that sand be added to cover the roots. As a follow-up, wooden steps should be added along high-traffic areas to reduce damage to vegetation. In addition, new vegetation needs to be added. B. Profile H-1 on 8 October, 1996. The stippled pattern shows the extent of the sand to be added. See Figure 1 for profile location.



Figure 13. Close-up view of the exposed roots along Turtle Beach. Note the change in color from top to bottom. The redder roots were probably exposed in the 1996 hurricane season.



Figure 14. View of the landward edge of profile T-1. The person is standing in a hole that was dug to determine the level of the lowermost step (below the present sand level). Note the toppling palms all along the shoreline.



Figure 15. Palm tree near profile T-1. Note that the orientation of the trunk has changed several times, presumably related to shifts in the orientation of the tree as it was undercut by successive storms.

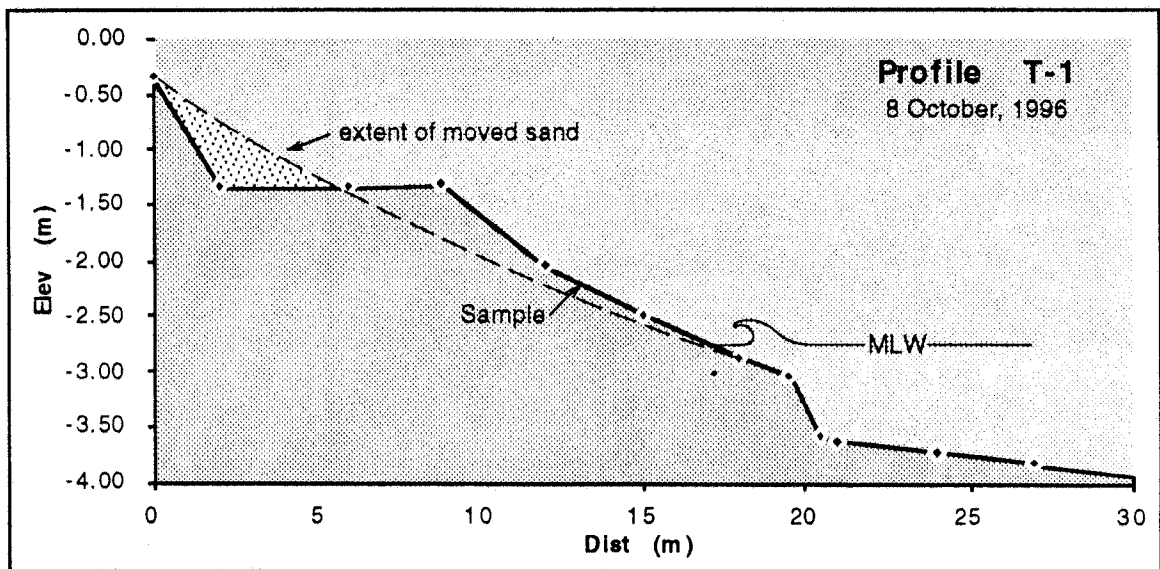


Figure 16. A (top) View looking north along Turtle Beach. The person is on the profile. Note the exposed roots all along the beach. We recommend that naturally occurring sand be moved up from the lower beach to cover the roots. By lowering the existing beach slope to cover the exposed roots, beach stability would be increased and new sand would be encouraged to come ashore. B. Profile across Turtle Beach. The stippled pattern shows the extent to which existing sand would be moved to the upper beach. See Figure 1 for profile location.



Figure 17. Vertical aerial photograph of the site taken by the National Ocean Survey in 1983. North is roughly to the upper right; refer to Figure 1 for locations of specific sites discussed in the text. Reefs are confined to thin fringes around major headlands. In Caneel Bay (upper left), a narrow and largely depauperate pavement extends around the northern point. The dark area in the center of the bay is probably sea grass that no longer exists today. In Scott Bay (upper center), a triangular section of depauperate pavement fronts the northern third of the bay and extends around the point outside Turtle Bay. The dark area north of Turtle Bay (upper right) is largely a barren pavement except for its seawardmost limits. This feature extends around the point and into northern Hawksnest Bay (lower right). The area described as "South Hawksnest" is the narrow, fringing pavement on the point just south of the hotel units (the point in the center of the Hawksnest Bay shoreline in this view). Descriptions from each area are included in the body of the text below. Refer to Figures 1 and 18 for locations and environmental interpretations of this photograph.

Nearshore Benthic Environments

Figures 17 and 18 summarize the nearshore benthic communities that existed offshore of Caneel Bay Resort in 1983. The information in Figure 18 is derived from ground-truth surveys done by the College of the Virgin Islands and the National Park Service (Beets, *et al.*, 1986). The environments have been simplified to include only sand, submerged bedrock, reef pavement and grass beds. Table 1 summarizes the observed invertebrate populations and provides very limited data on fishes.

The maps of Beets, *et al.* (1986) show reefs and reef pavements that are confined to the bedrock promontories between bays. These are generally steep substrates that form narrow fringes. With the exception of dramatically reduced sea-grass cover, the distribution of environments described in Beets, *et al.* (1986), was identical to what was observed on 9 October, 1996. Our surveys focused on the reef/pavement areas as they represented the greatest potential for sediment-intolerant organisms.

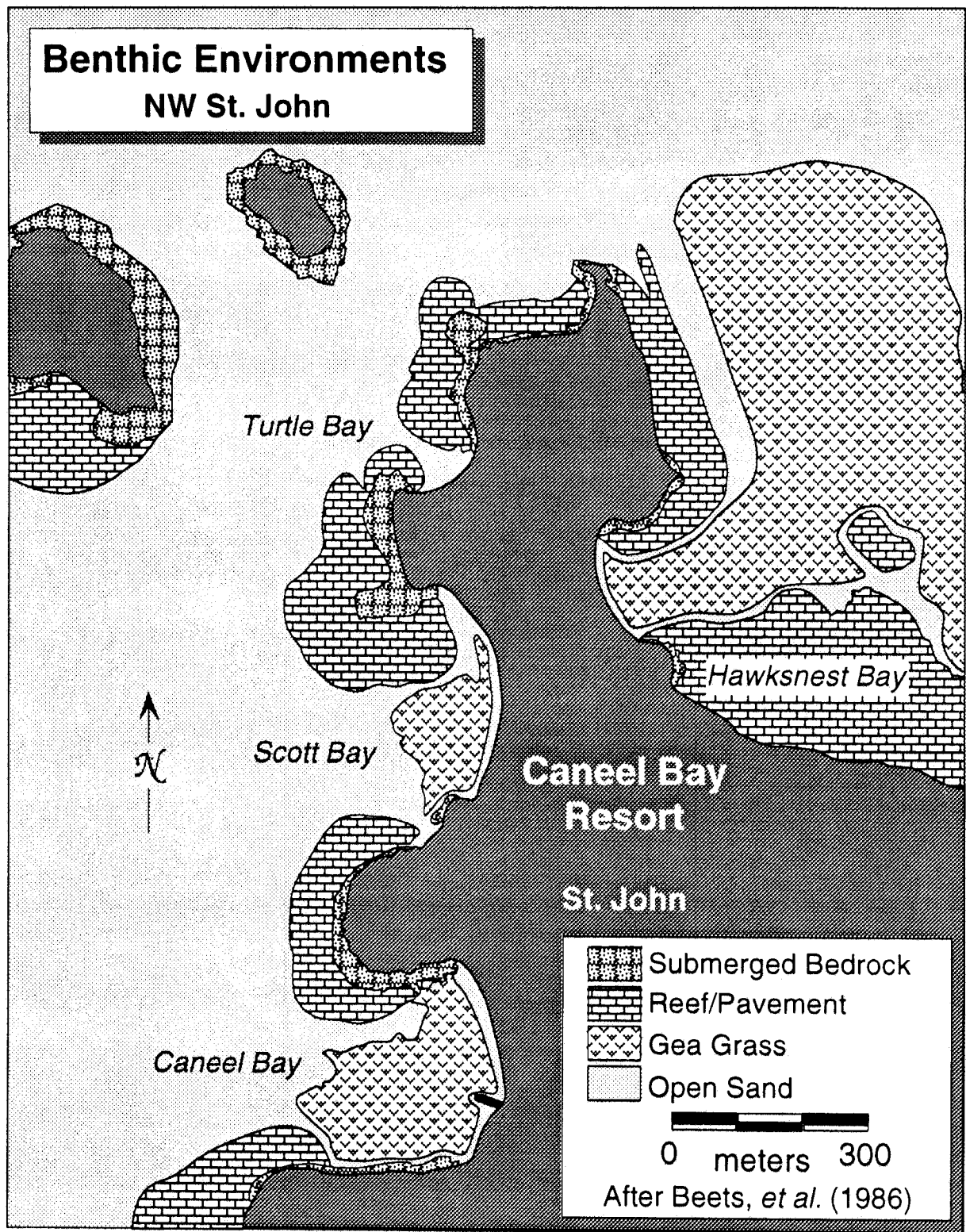


Figure 18. Map of benthic environments offshore of the Caneel Bay Resort property. This is a simplified version of the maps appearing in Beets, *et al.* (1986).

Table 1. Summary of limited benthic observations. Fish data are based on approximately 20-minute swim-throughs and should be considered as only very general. More-detailed surveys were not made as fishes are mobile and would not be impacted by short-term increases in sedimentation. Refer to Figure 1 for general locations of observation sites.

South Hawksnest (all species are scattered to widely scattered)

Acropora palmata (widely scattered; up to 1 m across)

Diploria clivosa

Diploria labyrinthiformis

Diploria strigosa

Millepora spp.

Montastrea annularis

Montastrea faveolata

Porites astreoides

Siderastrea siderea

Cryptic *Halimeda opuntia*

Several species of sea fans and gorgonians

Scattered sponges

Central Hawksnest Bay

Mostly open and barren sand, occasionally bound with brown algal mats, diatom mats and filamentous green algae.

Occasional, very widely scattered, single rhizomes of *Halophila* sp. (*decipiens*?)

widely scattered *Halimeda* sp. (*incrassata*?)

Penicillus capitatus in occasional patches up to 50-cm square, with densities up to 5-10/m²

One 30-cm turtle was observed feeding on the bottom

One 15-cm cowfish (*Lactophrys* sp.) was observed.

Otherwise, no vertebrates were seen in the open bay.

North Hawksnest

Acropora palmata (confined to shallow areas closest to shore)

Diploria clivosa (cover is up to 20-25% in isolated patches on vertical surfaces)

Diploria labyrinthiformis

Diploria strigosa

Millepora spp.

Palythoa sp.

Porites astreoides

Siderastrea radians

S. siderea

Several species of sponges

Several species of gorgonians and sea fans

1 school (ca. 40) blue tangs (*Acanthurus coeruleus*)

1 royal gramma

1 Red Hind (*Epinephelus guttatus*)

3 species of parrotfish (small to moderate population)

Schoolmaster Snapper (*Lutjanus apodus*)

Several French Grunts (*Haemulon flavolineatum*)

Table 1 (continued).

Outside Hawksnest Bay

Acropora cervicornis
Acropora palmata
Diploria clivosa
D. strigosa
Millepora spp.
Montastrea annularis
M. faveolata
Palythoa spp.
Siderastrea radians
S. siderea.
Numerous gorgonians
Numerous parrotfish and other scarids
Large schools (>50) of blue tangs
1 Lobster
2 squid
1 large (>40 cm) Yellowtail Snapper (*Ocyurus chrysurus*)

NE Turtle Bay

Acropora palmata (widely scattered and confined to outermost bay)
Dendrogyra cylindrus (few colonies)
Diploria clivosa
D. labyrinthiformis
D. strigosa
Siderastrea sp.
Montastrea annularis
M. faveolata
M. franksi
Porites astreoides
P. porites

Northern Scott Bay (all colonies widely scattered and in low abundance)

Diploria strigosa
Montastrea annularis
Porites astreoides
Diadema antillarum

North Caneel Bay (all coral colonies very widely scattered)

Porites astreoides
P. porites

Several schools of Striped grunts (*Haemulon striatum*)
Several schools of Jacks (*Caranx* sp.)

In Hawksnest Bay, limited cover by invertebrates was found. Along the point just south of the hotel units, branching *Acropora palmata* occurs in widely scattered colonies up to 1 meter across (Fig. 19). Also present are scattered colonies of *Millepora* spp., *Montastrea* spp., *Porites astreoides* and *Diploria* spp., along with several species of sea fans, gorgonians and sponges (fig. 19, 20). To the north, bottom cover is both higher (up to 20%) and more diverse. *Acropora palmata* occurs in isolated patches, mostly on toppled boulders in the outermost portions of the bay (Fig. 21). Colonies of *Montastrea franksi*, *Porites astreoides*, and *Diploria* spp. (Figs. 22, 23) can be found scattered all across the pavement in water depths up to 3m (10 ft); some colonies are quite large (Fig. 24). As an aside, it was particularly odd that the NPS boat channel seems to pass directly over this reef/hardground area, apparently avoiding the more depauperate, sandy bay.

In the open central bay, bare sand dominates. Occasional patches of *Halimeda incrassata* and *Penicillus capitatus* were observed in small patches, with densities occasionally reaching 5-10 plants per square meter. Widely scattered, single strands of *Halophila decipiens* were the only grasses that were observed. While Beets, *et al.* (1986) noted grass beds in this area, nothing beyond these widely scattered plants could be found in 1996. This may reflect seasonal changes in grass cover, but more likely reflects the large-scale decline in sea grasses all along St. John's north shore (Caroline Rogers, pers. comm.). The abundance of fishes and other vertebrates was generally low, although one small (ca. 30 cm/1 ft) turtle was observed grazing on the bottom.

Outside the bay, in a more-exposed and wave-swept environment, the bottom dropped abruptly to a gorgonian-dominated pavement at a depth of about 4 meters (15-18 ft). When seen, *Acropora palmata* was typically more stunted in its growth form and often dead or damaged. Other coral genera included *Diploria*, *Montastrea* and *Siderastrea*. In more-exposed areas, mobile cobbles dominated (Fig. 25). The highest abundances and densities of fishes were seen along this exposed margin well away from the sandy beaches.

Turtle Bay - Reef organisms are confined to the outer reaches of Turtle Bay. Near the tip of the eastern point, larger colonies of *Montastrea franksi* (Fig. 26) plus smaller and widely scattered *Acropora palmata* (Fig. 27) were found. Midway along the eastern point, moderate-sized colonies of sediment-tolerant *Montastrea annularis* also occur, along with several species of gorgonians, widely scattered *Acropora cervicornis* and *Millepora* sp. (Fig. 28). Other corals include *Dendrogyra cylindrus*, a few scattered colonies of *Diploria* spp. and *Porites astreoides*.

Scott and Caneel Bays - Visibility was barely above 6 meters (20 ft) in either of the western bays (it was not significantly better in either Hawksnest or Turtle Bays). Along the northern pavement, coral cover was extremely sparse and consisted of scattered colonies of *Porites astreoides* (Fig. 29) and *Montastrea annularis* (Fig. 30). Most of these had colonized large cobbles that are probably mobile during storms. The long-spined sea urchin, *Diadema antillarum*, seemed more abundant in this area than in either Turtle or Hawksnest Bay where few urchins were seen.

Along the shoreline north of the seawall, an outcrop of beachrock protects the beach (Fig. 31). This feature is covered with small and scattered colonies of *Diploria clivosa* (max size = 30 cm), *Millepora* sp. and *Siderastrea* sp. along with several small sea fans and widespread *Dictyota*. This community reflects frequent disturbance.

In Caneel Bay, bottom cover is even lower on submarine pavements. *Diploria* spp. (mostly *D. clivosa*), *Porites astreoides* and *P. porites* were observed. Several schools of Grunts and Jacks were noted along the point north of the bay. On the open bottom of both bays, little or no sea grass was found. Again, this likely reflects a decline in grasses throughout northern St. John and cannot be tied to specific events within the two bays. The bottom had a stickier feel to it, in part due to algal mats but also related to an apparently higher mud content. Litter from palm trees and other shore vegetation was ubiquitous.

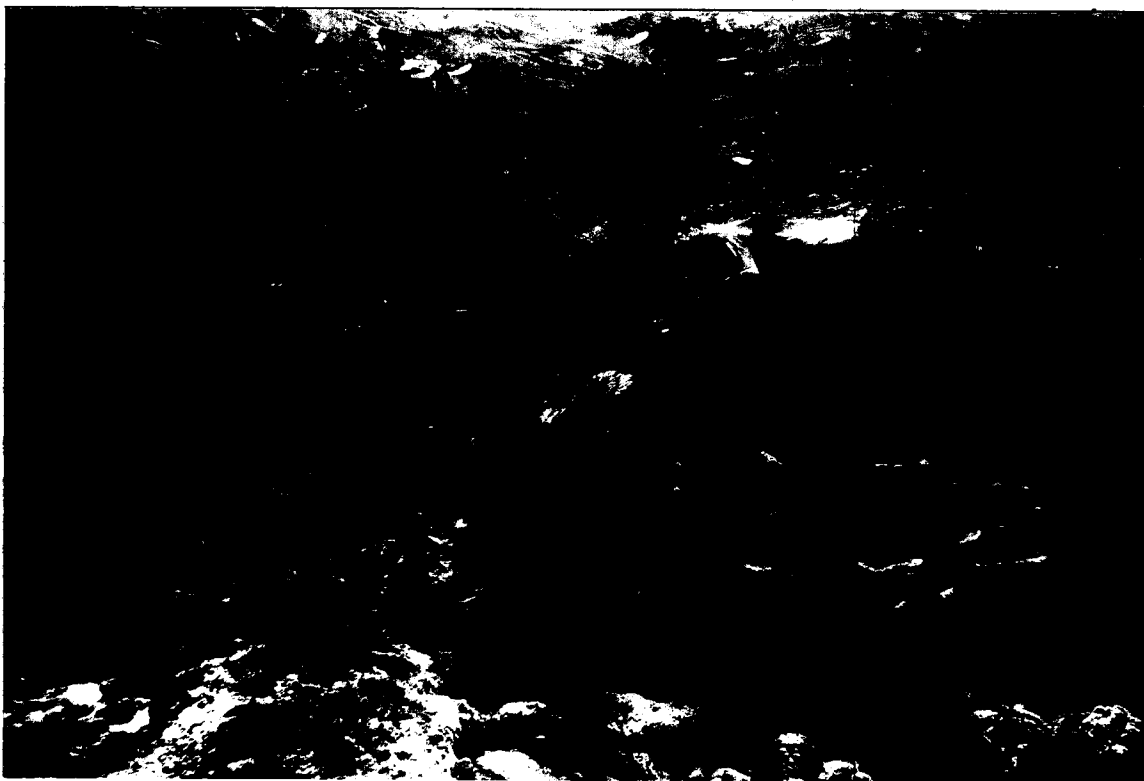


Figure 19. Photograph of the narrow pavement on the point south of the Hawksnest hotel units. The branching *Acropora palmata* seen in this photo are the best-developed and only large colonies in the area. Also visible are colonies of *Porites astreoides* (mustard brown) and two species of sea fans. Most of the bottom is bare or algal-covered pavement.



Figure 20. Cobble- and boulder-strewn pavement along the point south of the Hawksnest Bay hotel units. This view, which includes sea fans, gorgonians, *P. astreoides*, *Millepora* sp., turf/fleshy algae and sponges is fairly representative of the area.

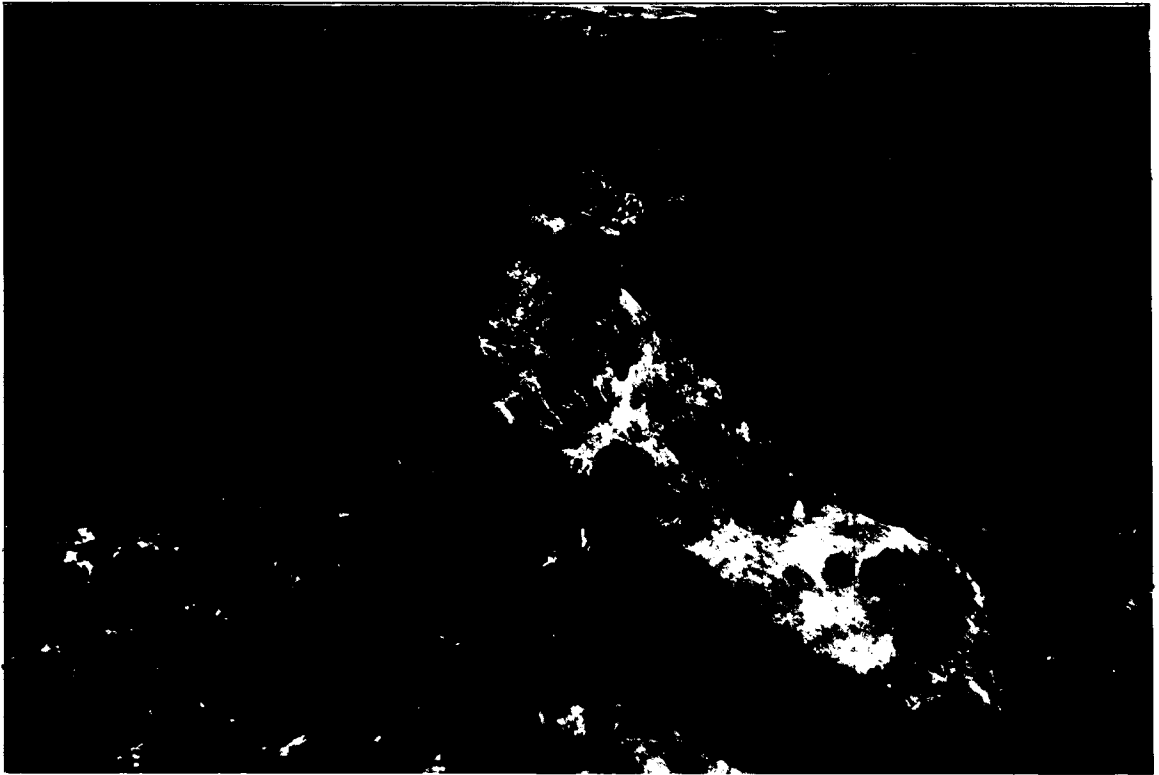


Figure 21. Photo of an isolated *Acropora palmata* colony along northern Hawksnest Bay. In the inner bay, this coral is rare, but healthy when found. Further seaward, it is more often damaged or dead.

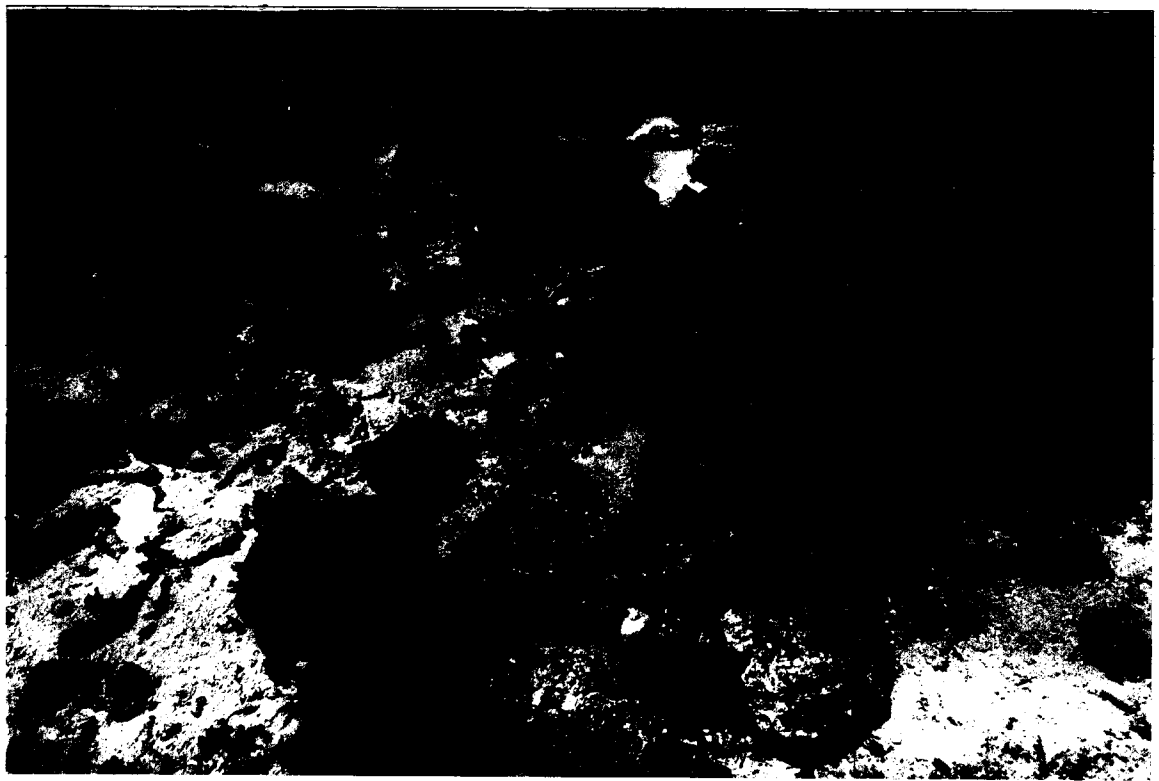


Figure 22. Underwater photo of colonies of *Diploria strigosa*, *Montastrea franksi* and various sponges. Note the fish bites on the *M. franksi* colony in the foreground.



Figure 23. Underwater photograph showing the general character of the pavement in northern Hawksnest Bay. Visible are *Montastrea franksi*, *Porites astreoides*, *Diploria strigosa* and several species of sponges and gorgonians. Cover averages well below 20%.



Figure 24. Photo of a complex and large (ca. 75 cm/2.5 ft across) colony of *Diploria strigosa* in northern Hawksnest Bay. Such large colonies are generally rare.



Figure 25. Photo of cobbles and small boulders that are mobile only during episodes of higher wave action.



Figure 26. A large colony of *Montastrea franksi* near the outer limits of Turtle Bay. Larger corals such as this occur well away from the beach and in a vigorous wave climate.

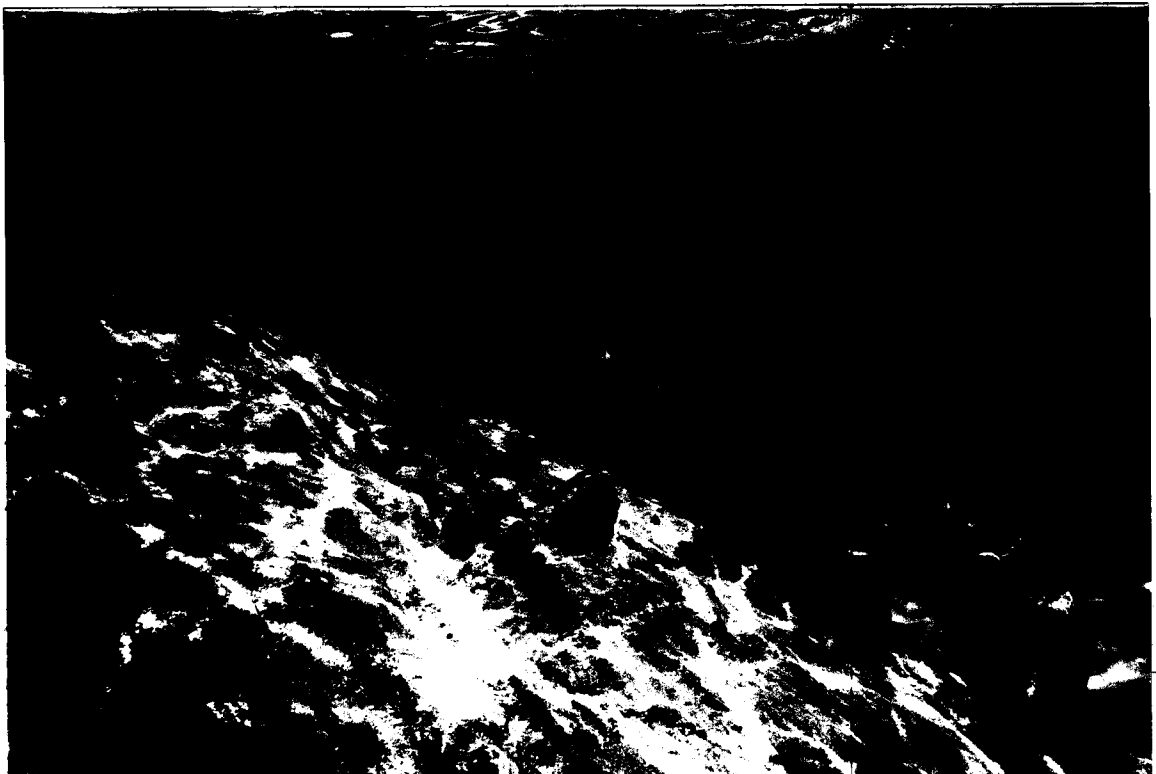


Figure 27. *Acropora palmata* colony on toppled bedrock near the outer reaches of northeastern Turtle Bay.



Figure 28. Colonies of *Montastrea annularis* along eastern Turtle Bay. These corals are well away from the beach and occur along the updrift shore.



Figure 29. Widely scattered colonies of *Porites astreoides* on loose rocks north of Scott Bay.



Figure 30. *Montastrea annularis* and *Porites astreoides* colonies in northern Scott Bay. Note the overturned colony of *M. annularis* near the center of the photo.



Figure 31. Beachrock exposed along the northern end of Scott Bay. The submarine pavement described in the text is located along the point in the background.

Suitability of Available Sand Supplies

Table 2 summarizes the grain-size statistics for beach samples from Little Caneel (LC-1), Caneel (C-1), Paradise (P-1), Scott (S-1 and S-2), Turtle (T-1) and Hawksnest Bays (H-1). Sand was coarsest on Turtle Beach (1.46 phi; 0.36 mm) and finest at Caneel Bay (2.33 - 2.48 phi; 0.18 - 0.20 mm). In general, sand from all beaches was well- to very well-sorted (Sample T-1 from Turtle Beach was moderately well-sorted).

Four possible sources of artificial sand were evaluated. Jost van Dyke (BVI) samples were coarser on average than those from St. John, but contained a significant quantity of fine sand and mud. The poor sorting and the high mud content make this sand unsuitable. In addition, our experience has shown that the quality of the sand from this site can vary significantly from shipment to shipment. Sand from the Bahamas similarly contained high amounts of mud and was poorly sorted; it was likewise unsuitable. Three samples from Barbuda ranged in size from 1.27 phi to 1.51 phi (0.35 - 0.42 mm); sorting ranged from 0.84 to 0.88 phi (moderately sorted). These were somewhat different than Barbuda sand that was available in 1989 (Barbuda-89 in Table 2). The sand that is presently available is slightly coarser and better sorted; it also contains a significant quantity of shell material.

Barbuda sand - Using an average of the three values for the presently available Barbuda sand (Barbuda-96 in Table 2), the suitability of this sand for nourishment was evaluated using the nomograms provided in the latest version of the US Army Corps of Engineers *Shore Protection Manual*. Based on these analyses, the Barbuda-96 sand is quite close to what already exists on Caneel and Little Caneel Beaches (Tables 2 and 3; Fig. 32). Beach losses would be increased during storms by less than 2% compared to the sand that presently exists. At Hawksnest, Scott and Turtle Beaches, losses would be higher (12-17% above natural) but still acceptable. These

Table 2. Grain-size statistics for sand from Caneel Bay, Barbuda (1989 and 1996), Jost van Dyke, Guyana and the Bahamas. Size is reported in ϕ -units, a geological size measure. To convert to millimeter, use the formula, $[mm = 1/2\phi]$.

Sample	Mean		Sorting [ϕ]
	[ϕ]	[mm]	
Barbuda-96*	1.39	0.38	0.86
Barbuda-89*	1.53	0.35	0.93
Jost 101A	1.32	0.40	1.38
Jost-103	1.04	0.49	1.20
Guyana	1.17	0.44	1.04
Bahamas	1.69	0.47	1.09
C-1	2.48	0.18	0.40
H-1	1.67	0.31	0.46
LC-1	2.33	0.20	0.45
P-1	1.54	0.34	0.47
S-1	1.53	0.35	0.31
S-2	1.87	0.27	0.31
T-1	1.46	0.36	0.62

Table 3. Summary of size statistics and overfill ratios (R_A) for sand presently available from Barbuda when compared to each sample from Caneel Bay.

Sample	$(M_p - M_n)$				R_A	Loss	Suitability
	M_z	σ	σ_n	σ_p/σ_n			
C-1	2.48	0.40	-2.75	2.15	<1.02	<2%	Excellent
H-1	1.67	0.46	-0.70	1.87	1.14	13%	Acceptable
LC-1	2.33	0.45	-2.09	1.91	<1.02	<2%	Excellent
P-1	1.54	0.47	-0.32	1.83	1.21	17%	Acceptable
S-1	1.53	0.31	-0.40	2.77	1.36	26%	Unacceptable (?)
S-2	1.87	0.31	-1.55	2.77	1.13	12%	Acceptable
T-1	1.46	0.62	-0.11	1.39	1.13	12%	Acceptable

anticipated losses should be considered when adding sand (i.e., additional sand should be added to these beaches to allow for expected losses). Losses from southern Scott Beach could be up to 26% and the proposed sand is, therefore, considered to be only marginally suitable for use at this site.

In considering these quantitative values, several factors need to be understood. First, the Corps of Engineers tests provide only estimates of behavior and should not be considered as exact predictors. Allowances need to be made for the size distribution that contributes to the mean and sorting values of a particular sand. Also, grain composition (i.e., is it made of coral fragments, terrigenous rock chips, etc.?) can play an important role in overall grain stability. And finally, information on the behavior of a particular sand in previous applications can provide significant insight into its possible behavior on a particular beach.

With respect to composition, the Barbuda sand is comprised almost exclusively of whole and broken mollusk shells. As such, the flat shape of individual grains may make it easier for waves to pick up and move the mollusk bits when compared to round grains of the same median diameter. On the positive side, the denser composition of shell matter and the lack of intragranular porosity

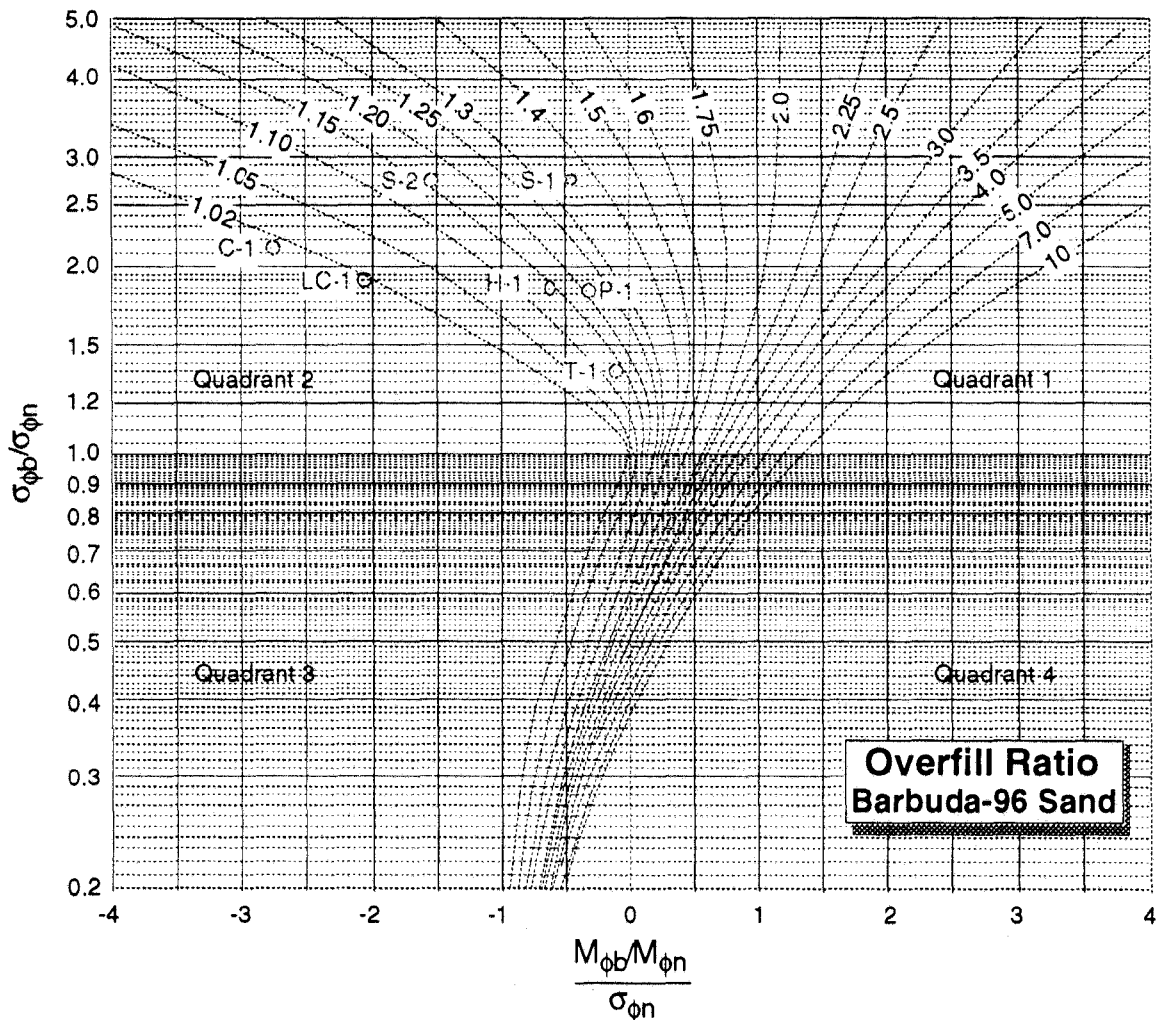


Figure 32. Overfill ratios (R_A) for sand from Barbuda when compared to natural sand on the beaches of Caneel Bay Resort. Excellent results are predicted for Caneel and Little Caneel Beaches. The sand would also be acceptable for all other beaches except southern Scott Beach (S-1), where losses of up to 26% can be anticipated. While a 26% loss is generally considered acceptable by the Corps of Engineers, this level may be too high in an area with reefs nearby. However, it should be kept in mind that no reefs or coral pavements were found anywhere near southern Scott Beach where these elevated losses might occur. Possible environmental impacts are to some extent naturally mitigated by distance.

will tend to make individual grains more stable. In all likelihood, these two factors cancel each other out and the predictions of this test will probably be borne out in actual practice.

Of primary importance, the Barbuda sand does contain mud (0.87 - 2.39 percent by weight). Taking the higher end of this range, nearly 12 cubic yards of mud will be contained within the 500 cubic yards of sediment proposed to be added to these beaches. While this amounts to less than 0.5 mm of material spread over the nearshore areas fronting the hotel's beaches, it does raise the possibility of a short-term sediment plume of considerable dimensions. To put this into perspective, we are probably talking about less material than would be delivered by a moderate Fall rain.

While likely to have little or no real environmental impact, short-term aesthetic considerations may argue against using the sand from Barbuda. Primary among these are the public perception that an

Table 4. Summary of size statistics and overfill ratios (R_A) for sand presently available from Guyana when compared to each sample from the Caneel Bay Resort property.

Sample	M_z	σ	$(M_b - M_p)$		R_A	Loss	Suitability
			σ_n	σ_b/σ_n			
C-1	2.48	0.40	-3.28	2.60	1.03	3%	Excellent
H-1	1.67	0.46	-1.09	2.26	1.14	12%	Acceptable
LC-1	2.33	0.45	-2.58	2.31	1.03	3%	Excellent
P-1	1.54	0.47	-0.79	2.21	1.18	15%	Acceptable
S-1	1.53	0.31	-1.16	3.35	1.28	22%	Marginal (?)
S-2	1.87	0.31	-2.26	3.35	1.15	13%	Acceptable
T-1	1.46	0.62	-0.47	1.68	1.13	12%	Acceptable

environmental disaster is in the making, even though the real level of impact is small or nonexistent. It takes very little suspended sediment to create the illusion of severely reduced water quality. This factor may play an even greater role when we consider the relationship that exists with the National Park.

If the Barbuda sand is used, then the question becomes whether or not to use a silt curtain or similar device to retain what mud does exist while beach restoration is being completed. Experimental evidence shows that marine organisms are well adapted to short-term, single pulses of sediment stress. This natural adaptation allows them to survive seasonal rains, and the short bursts of runoff that are common in the tropics. In a sense, the short-term release of sediment related to the proposed project is the same thing but on a smaller scale. Using a silt curtain will result in lower levels of sediment stress over a much longer period as the muds trapped by the silt curtains "bleed" out of the beach on each ensuing high tide.

Therefore, if a final decision is made to use the Barbuda sand, we recommend that no silt curtain be used. History has shown that lower doses of sediment spread over longer periods of time have far more deleterious effects than higher levels over shorter intervals. Sand from Jost van Dyke that was placed on the beach at Sugar Bay Resort (St. Thomas) caused a significant plume that greatly reduced water quality for over a week. Long-term monitoring revealed no impact to nearshore coral or grass communities and visibility returned to background levels in a few weeks with no further turbidity related to the new beach. Like the St. Thomas project, the elimination of silt curtains is made possible by the small scale of the project, both spatially and temporally.

Guyana sand - Data from a previously analyzed sand sample from Guyana was used as a comparison to the Barbuda sand. The likely behavior of the Guyana sand is summarized in Table 4 and Figure 33. The behavior of this sand is similar to or better than that of the Barbuda sand. With the exception of southern Scott Beach and Paradise Beach, anticipated losses are all below 15%. In addition to the slightly better stability that is predicted, the Guyana sand contained absolutely no mud, thereby eliminating any potential for environmental impact.

Roughly 2,500 yd³ of this sand was placed on the beach at Davis Bay (St. Croix) in November of 1995. Wave energy along this narrow, exposed shelf is generally higher than that on northwestern St. John, although periodic ground swell may have a greater impact on some St. John beaches. The Guyana sand remained stable throughout the remainder of 1995 and the first half of 1996, despite attack by heavy swell passing through the Anegada Passage on several occasions. A significant quantity of the Guyana sand was lost from the beach during the 1996 hurricane season. Unlike the sand that previously occupied the beach, however, the Guyana sand moved only a short distance offshore and is now returning to the beach naturally. In all regards, the Guyana sand has exhibited greater stability than the sand that existed there previously. This is in large part due to the roundness of the individual grains plus the fact that the sand from Guyana is pure quartz.

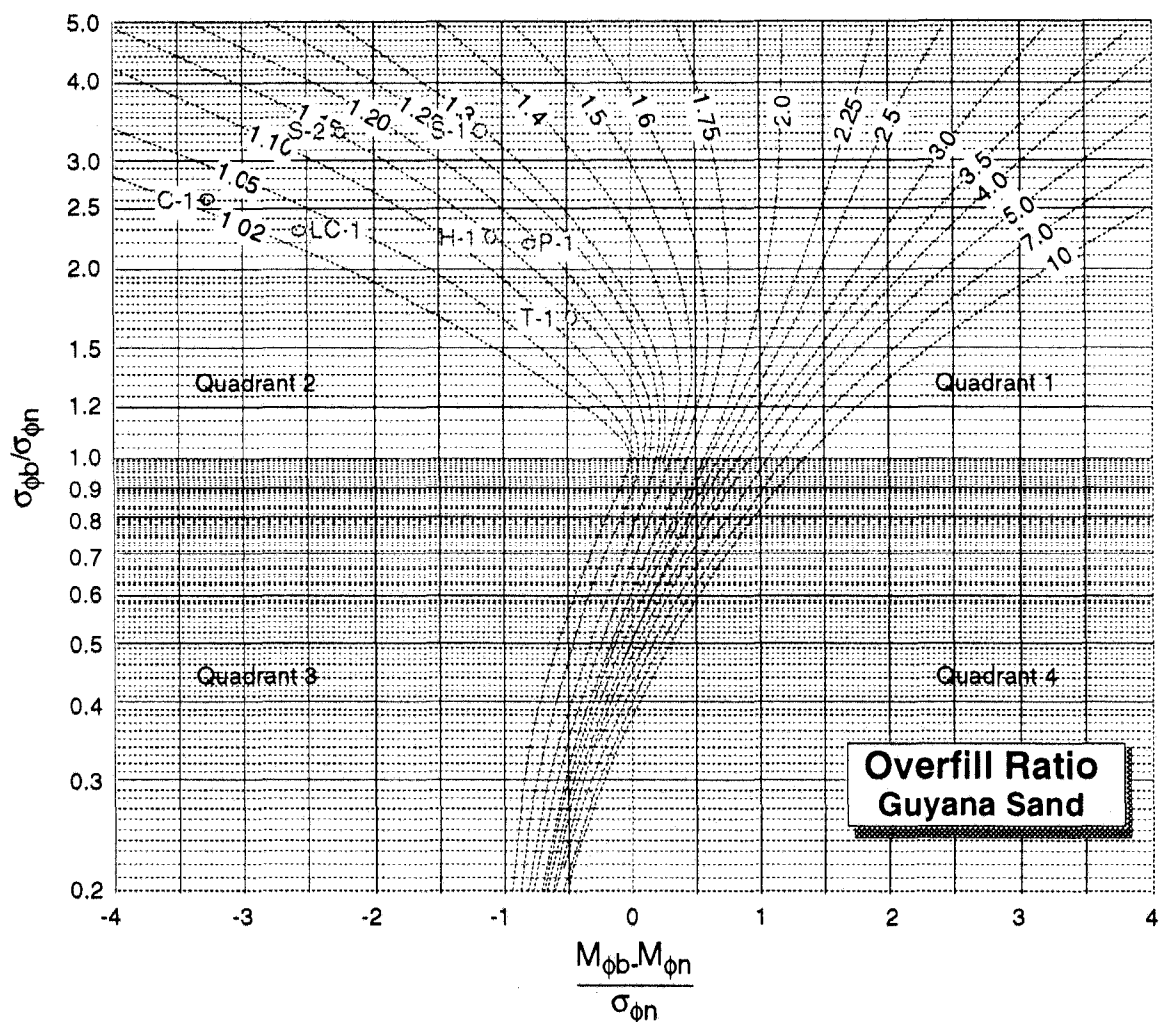


Figure 33. Overfill ratios (R_A) for sand from Guyana when compared to natural sand on the beaches of Caneel Bay Resort. In general, the artificial sand can be expected to behave slightly better than that from Barbuda (Fig. 32).

The main problem with the Guyana sand is its "whiteness". The beaches on the Caneel Bay property contain significant quantities of material derived from adjacent uplands; the beaches thus carry a strong brown coloration. The pure white Guyana sand would markedly contrast what exists naturally, thereby reducing its desirability unless it is mixed in with existing sands. In Hawksnest Bay, the Guyana sand is an excellent option. The area to be nourished is small and self contained. The beach could be completely covered with pure, white sand by adding only 200 - 300 cubic yards of new material. The resulting white beach would eventually mix with natural sand and grow progressively "dirtier" looking. However, no sharp color contrasts are likely to occur if the entire beach is covered.

SUMMARY

The 1996 hurricane season has left the beaches on the Caneel Bay Resort property in varying degrees of disrepair. While sand is returning to all the beaches by natural processes, the rate of recovery is slow. This, combined with the long-term erosional trend for these beaches, has left many root systems exposed to the point that natural defenses to erosion are increasingly threatened.

The goal of the proposed restoration is two-fold. First, adding sand to these beaches would improve their aesthetic character. More important, additional sand would provide valuable protection to exposed root systems, thereby reducing the likelihood that the natural defense mechanisms that exist will be destroyed in the near future.

The general restoration plan proposed by the hotel has been reviewed. The proposed strategy combines adding sand and redistributing existing sand, depending upon the extent to which specific beaches have recovered naturally. On Turtle Beach, existing sand supplies are probably sufficient and additional sand is not needed. On Scott, Caneel and Little Caneel Beaches, available supplies are considerably lower and some new sand is probably needed. In Hawksnest Bay, erosion is sufficiently advanced and recovery is so slow that additional sand represents the only hope for protecting exposed vegetation.

Several sources of potential sand were evaluated. Samples from the Bahamas and Jost van Dyke contained large amounts of mud and are considered to be unsuitable. In addition to the turbidity that would undoubtedly result, the high mud content may cause the sand to naturally cement together, leaving a wholly unsatisfactory surface on the beach.

The sand from Barbuda yielded results that were much more acceptable. Mud content was lower and the likely stability of the sand is considerably greater. The sand does contain mud, however, in sufficient quantities that increased nearshore turbidity would probably occur over the short term. The likelihood of environmental damage from this plume is extremely small. All corals exist far enough from the beaches to naturally mitigate the impacts of a short-lived sediment plume. Also, historical evidence has shown that corals, sponges and other reef-related invertebrates can survive significant levels of stress when applied in short, discrete doses (e.g., each time it rains more than a few inches over a 24-hour period). Nevertheless, the possibility does exist for an adverse public reaction. This cannot be ignored in the context of either a tourist facility or a National Park.

Sand from Guyana would behave slightly better than that from Barbuda. In addition, it contains no mud and the possibility of even a short-lived reduction in water quality is avoided. Observations from a nearby beach on St. Croix have demonstrated the stability of this sand under observed wave conditions. In a confined bay like NW Hawksnest, the potential to cover the entire beach eliminates any problems with matching the pure white Guyana sand to the "dirtier" sand that exists there naturally.

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