IMPACT OF CLIMATE CHANGE ON THE BEACHES OF THE CARIBBEAN
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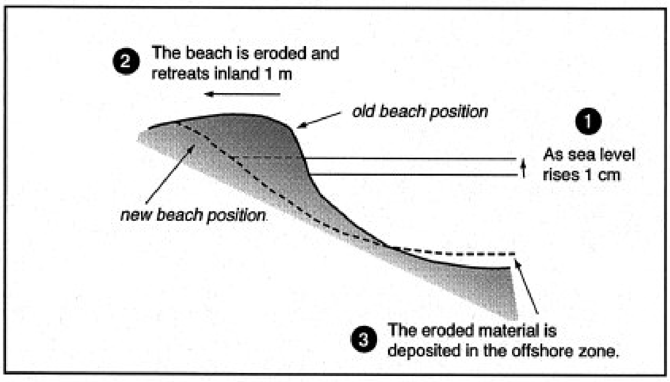
Arrow shows position of wall, Nevis,1988


Wall is out in the sea in 1995

All the ongoing scientific research points towards increased beach erosion as one of the consequences of climate change. As the global temperature rises, the oceans expand, and the Arctic and Antarctic ice sheets melt at a faster rate than before, causing sea levels to rise worldwide. Beaches respond to rising sea levels by re-positioning themselves further inland. On a low lying coast where the land behind the beach is in a natural and undeveloped state, then as sea level rises the beach will adopt a new position further inland. However, when structures such as roads, seawalls and houses prevent the beach from repositioning itself further inland, then over time the beach disappears. This has serious consequences for the islands of the Caribbean, where beaches are an important part of the island heritage and provide places for residents and tourists to relax and enjoy the coastal environment, as well as functioning as sites for boat launching and fish landing, and forming protective barriers to protect coastal lands from sea flooding during high seas and hurricanes.

Sea level has been rising throughout the Caribbean during the 20th century, at an average rate of 1 mm per year. This represents about 4 inches total rise in sea level over the 20th century. The Intergovernmental Panel on Climate Change (IPCC) has predicted that the average global rate of sea level rise in the 21st century will be four times that amount, a rise of about 12 inches or 1 ft by 2100. Whilst these amounts may seem small, research has show that for every 1 foot of sea level rise the shoreline will retreat inland by 100 times that amount (Bruun Rule). So if the sea level rises by 1 ft during the 21st century, shorelines can be expected to retreat inland by about 33 yards.



As sea level rises by 1 centimetre, the position of the beach retreats inland by 1 metre.

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This will have very serious impacts for the region's beaches many of which are already undergoing erosion due to other factors such as high waves during winter swells and hurricanes, mining sand from the beach, poorly designed sea defence structures, people building too close to the dynamic beach zone, pollution and deteriorating health of coral reefs and seagrass beds. Regular monitoring of beach changes in ten Caribbean islands over the period 1985-1995[2] showed 70% of the measured beaches were eroding and retreating inland at an average rate of 0.3 m/year. Islands directly impacted by hurricanes in this period showed erosion rates three times higher.

Furthermore, tropical storms and hurricanes cause significant beach erosion and may also damage sand dunes and infrastructure behind the beach. Sand is moved inland by the very high waves or is lost to deep water offshore where it cannot return to the beach system. The IPCC 2007 report has predicted that future hurricanes will become more intense with higher wind speeds and heavier precipitation. This too has serious implications for the region's beaches.

Waves impacting the seawall at Rincón Balneario during Tropical Storm Jeanne, September 2004

Whilst there are many actions that must be taken on individual, community, national and global levels to reduce our carbon emissions, the impacts described above are already in progress and cannot be stopped in the immediate or even in the long term future. It has been determined that sea level rise will continue for centuries even if greenhouse gas emissions are stabilized. Our task must be to learn how to cope with these changes.

Some islands in the Caribbean began developing such coping mechanisms in the 1990s. The year 1995 was for the small islands of the eastern Caribbean a wake-up call. In a three-week period in September, two hurricanes and one tropical storm moved through the chain of Windward and Leeward Islands: Tropical Storm Iris, Hurricane Luis and Hurricane Marilyn. Hurricane Luis was a category 4 hurricane, which affected the northern islands from Dominica to Puerto Rico. After two decades of little hurricane activity (with some significant exceptions such

2 Cambers, G. 1997. Beach changes in the eastern Caribbean islands: hurricane impacts and impacts for climate change. Journal of Coastal Research, Special Issue No. 24.

as Hurricanes David and Frederick in 1979, and Hurricane Hugo in 1989) islanders had to come to terms with the realization that hurricanes were likely to affect their islands more frequently in the future.

Anguilla, in the northeastern Caribbean, was in the direct path of Hurricane Luis in September 1995. The winds battered the island for almost two days and the damage was intense and widespread. Residents however, thought they were safe for another two or three decades, since the previous hurricane to hit the island had been Hurricane Donna in 1960. So the perception was that they had another 20-30 hurricane-free years ahead. They were soon disillusioned when 1997, 1998 and 1999 brought more hurricanes to this part of the Caribbean.

Following surveys of the hurricane impact in Anguilla in 1995, it quickly became apparent that most of the severe damage was in the coastal area where the port facilities, hotels, tourism villas, condominiums, restaurants and bars were located. The Government of Anguilla requested assistance from the then British Development Division in the Caribbean in planning their rebuilding efforts so that similar damage scenarios would not be repeated in the future.

One of the components of the assistance programme was to design new guidelines for coastal development setbacks, so that new development would be situated a “safe” distance from the active beach zone. At that time, many of the Caribbean islands already had coastal development setback guidelines included in their planning laws although they were often not implemented.

A coastal development setback may be defined a prescribed distance to a coastal feature, such as the line of permanent vegetation, within which all or certain types of development are prohibited. Such setbacks fulfil many functions; in particular they provide buffer zones so the beach has the space to erode or accrete and can thereby protect beachfront property during high waves and hurricanes without the need for expensive sea defence structures. They also allow for improved vistas and access along the beach, and provide privacy to coastal property owners and beach users alike.

Expecting that the frequency and intensity of hurricanes would likely increase in the Caribbean, and knowing that sea level rise was already a factor in the region, a protocol for coastal development setbacks was designed in 1995-6 that included adaptation to these two aspects of climate change.

Recognizing that there was considerable variation from one beach to another, it was determined that coastal development setbacks needed to be calculated on a beach-by-beach basis thereby providing greater setbacks on eroding beaches and smaller setbacks on stable or accreting beaches.

A methodology was developed whereby development setbacks were determined for each beach based on (1) historical coastline changes; (2) projected changes likely to result from a major hurricane; (3) coastline retreat resulting from sea level rise in the next 30 years; and (4) specific geographical and planning factors. The methodology was based on the assumption that historical erosion rates would continue, and would increase as a result of increased frequency and intensity of hurricanes and accelerated sea level rise. The period of 30 years was selected since it represented the average economic life of a building or structure. The following formula was developed:

Coastal Development Setback = (a + b + c)d

Where the setback is measured from the line of permanent vegetation (the tree line or equivalent) and

> **a** is the projected change in coastline position over the next 30 years based on historical changes determined from beach monitoring data or aerial photograph comparison

b is the projected change in coastline position likely to result from a major hurricane (based on field measurements after the most recent major hurricane)
c is the predicted coastline retreat by 2030 resulting from sea level rise (based on the Bruun Rule)
d represents other factors of an ecological, planning and social consideration (essentially qualitative, but too important to be omitted) specifically:

Coastline shape and wave exposure
Features such as sand spits and bars
Offshore features e.g. coral reefs
Anthropogenic factors such as sand mining and offshore dredging
Planning considerations such as lot size, national park designations

No development is permitted seaward of the vegetation line with the obvious exception of docking facilities such as jetties.

Using this methodology[3], coastal development setback distances were calculated for each beach in Anguilla. These guidelines have been used since 1996 by the Department of Physical Planning when considering applications for coastal development. In some cases the recommended setback distances listed in the guidelines have been applied exactly as recommended, but for the majority of proposals, the Department has found it necessary to customize on a site-by-site basis, the setback distances outlined in the guidelines.

A similar approach has been used in the island of Nevis, which was also severely impacted by the 1995 hurricanes. Here setback distances were determined in 1998 using the same methodology as developed in Anguilla. These setback distances have been applied for the past 9 years and will shortly be included in the Building Regulation Schedule. A paper discussing the different ways the setbacks have been applied in Anguilla and Nevis and the lessons learnt will shortly be published.[4]

Strengthening coastal barriers is another proactive measure that coastal communities and residents can take. Planting deep rooting trees, creating coastal green belts and coastal forests are other positive measures that help the beach. The roots penetrate deep into the sand and help promote beach stability and slow down erosion. In addition new trees and coastal forests contribute to biodiversity conservation, remove carbon dioxide from the atmosphere, and provide much needed shade for beach users.

[3] 1997, Planning for coastline change. Guidelines for construction setbacks in the Eastern Caribbean Islands. Author: Cambers, G. CSI info 4, UNESCO, Paris, 14 pages, http://www.unesco.org/csi/pub/info/info4.htm
[4] 2008. Cambers, G., Richards, L., Roberts-Hodge, S. Conserving beaches and planning for climate change in the Caribbean islands. In Press. Tiempo

Newly planted. deep rooting almond trees at Maria's Beach, Rincón, Puerto Rico

This coastal forest at Sandy Beach, Rincón, Puerto Rico helps stabilize the beach, provides habitat for birds and other animals, and shade for beach users

An ongoing project in Puerto Rico seeks to combine the creation of a coastal forest with an existing buffer zone. On the west coast of the island a condominium development has been built behind a low dune which is stabilized with one line of trees. The owners of the condominiums are planning to work with other partners, including government agencies and the private sector, to establish a coastal forest several trees thick and using deep rooting trees such as sea grapes and almonds. It is hoped that this will become a demonstration site for other coastal property owners.

Coastal property owners at this development in Puerto Rico are planning to expand the existing line of trees to form a wide green belt or coastal forest on the low dune in front of their condominiums.

At some beaches, where sand dunes may have existed in the past or are perhaps forming today, building permeable wooden fences may help promote the formation of sand dunes. These dunes together with the beach act as protective barriers.

Sand fence at Barceloneta, Puerto Rico 1996

Sand fence one year later (1997), note the fence has been nearly buried by wind blown sand and a new dune created

Similar sand dune fences in Anguilla have also had some success (left).

Wise coastal planning, reducing pollution, protecting coral reefs and seagrass beds, planting deep rooting trees behind the beach, restoring sand dunes, stopping sand and gravel mining from the beach and dunes are all measures that can strengthen beach systems, buying time to conserve the region's beaches for now and the future. Against the growing threat of sea level rise and climate change these measures are now more important than ever. Planners have a very critical role to play in this process.