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COASTAL WATER QUALITY AND ITS EFFECT ON BEACH EROSION: A CASE STUDY

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ABSTRACT

Beaches in Barbados are eroding at an average rate of 6 percent per year. Comparatively, the erosion on the west coast is less than the south coast because groynes and other protective measures are successfully maintaining the integrity of the beaches. Untreated and/or partially treated wastewater discharged into the coastal region has deteriorated the on-shore water quality. This has resulted in decay of coral reef, thus permitting greater wave energy to hit the off shore structures leading to shore erosion and other damages to buildings on the shore.

BACKGROUND

The Government of Barbados is concerned about the erosion and destruction of the beaches in intensively developed south and west coast regions (see Figure 1). The tourist accommodation in the last two decades has increased from 2,750 in 1964 to 14,400 in 1982 [1, 2]. Maximum tourism occurs during mid-December to mid-April. Most of the tourism is concentrated on the south and west coasts. In addition, 62 percent of the national population lives in Bridgetown and on the west coast.

According to recent estimates, the beaches on the west coast are being eroded at an average rate of 6 percent per year, with the possible exception of beaches between Brighton and Deep Water Harbour [3]. The aerial photographs show

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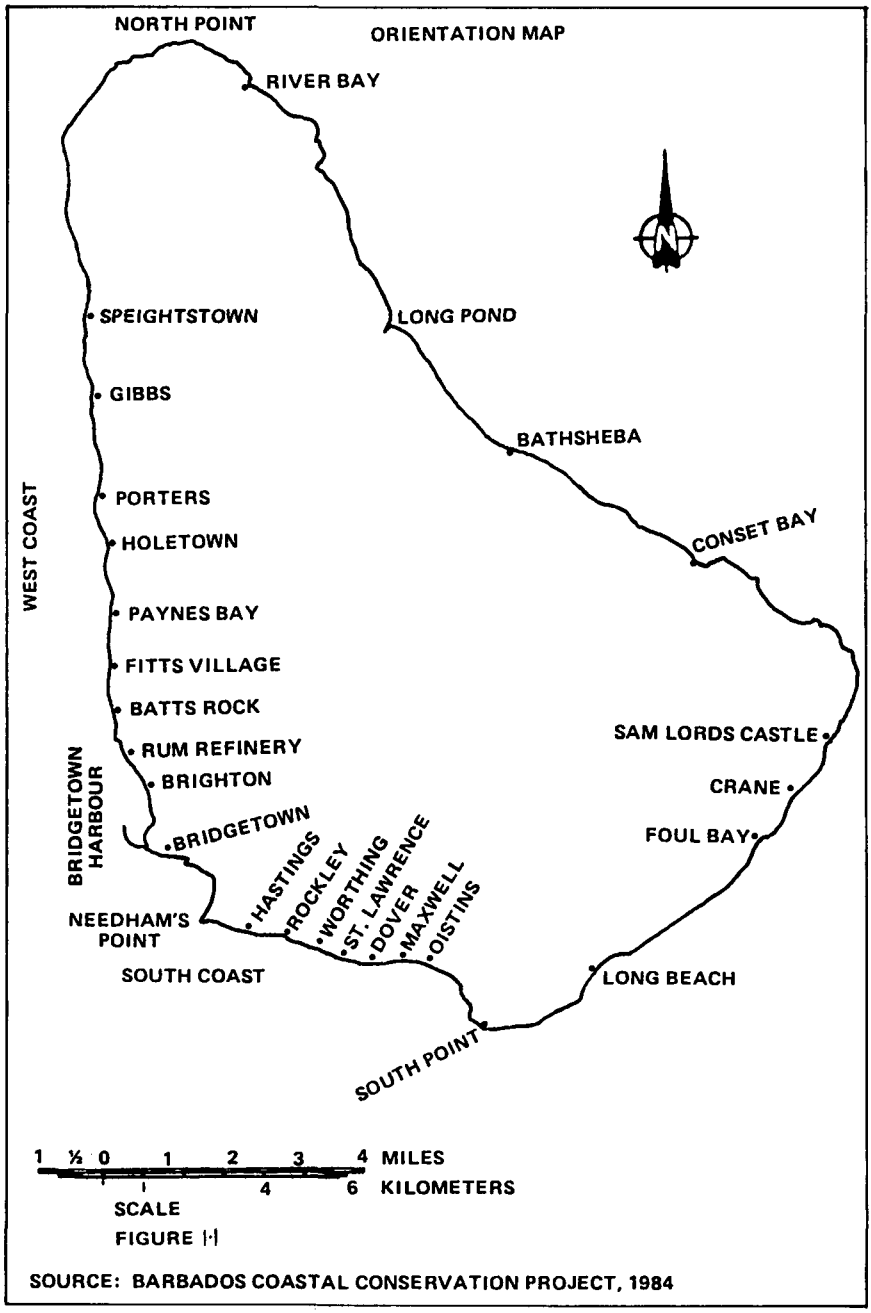

Figure 1. Outline map of Barbados.

that the erosion rate was 1 foot (0.3 m) per year on the west coast between 1956 and 1984.[1]

Comparatively, the erosion on the south coast is less than on the west coast, presumably groynes and other similar structures have successfully controlled the drifting of sand, and thus the integrity of some of the beaches has been maintained.

Unhindered sea waves surge over and impinge with great energy against the shore causing beach erosion. The saltwater leads to corrosion of rocks and other structures. At present the condition of some of the buildings on the shoreline appears to be unsafe.

Untreated and/or partially treated wastewater effluents are discharged into the coastal water. This has reduced the quality of on-shore water. Contamination is introduced by various sources, including but not limited to sewage outfalls (Bridgetown), local drainage ditches, lagoons, and industrial waste streams. The discharge from point and non-point sources has increased the nutrient (nitrogen and phosphorus) concentrations in coastal waters. Nutrient enrichment has caused the growth of algae.

Evidence of decay of reef coral communities is quite apparent in certain regions of the coastline. The death and decay of coral reef may be interlinked to the quality of the water, because these communities are very sensitive to the "stresses" caused by the deterioration of the water quality and other environmental factors. The destruction of reefs allows greater wave energy to reach the shoreline and this eventually leads to shore erosion. The purpose of this article is to review the causes of such beach erosion.

WATER QUALITY

As mentioned earlier, the quality of shore water in Barbados has deteriorated over the last several years and according to reports the poor water quality zone has extended up to 1 km (0.62 miles). The principal pollutants are agricultural pesticides, insecticides, and industrial effluents. Domestic sewage has also been responsible for an increase in nutrient levels.

Refractory organics are primarily the synthetic organic chemicals with an inorganic component such as chlorine and/or metallic salts. Many pesticides and herbicides including 2-4-D and 2-4-5T are used in Barbados. These biodegrade slowly and persist for a long time in the receiving water. When these compounds are discharged into surface waters, they are diluted but not appreciably reduced in weight in the receiving water. Refractory compounds tend to biomagnify in the food chain and invariably have adverse health impacts. Industrial and agricultural activities generate refractory compounds. On the other hand,

[1] Seventy-six aerial photos: Maycocks Bay to Cement Plant, and Harrison Point to Friendly Hall.

degradable organics are reduced in weight in surface waters by biochemical processes.

In Barbados, the coastal water quality deteriorates further during the rainy season when contaminants are discharged from surface drains, stagnant river mouths and from other catchment zones to in-shore water. Coral reefs have been depleting and rapidly succumbing to death. The death zone has descended to 10 m (32.8 feet) or more to the south of Holetown.

Currently in Barbados there is no centralized and integrated wastewater collection system except in Bridgetown. Hence, most of the domestic wastewater is discharged into suckwells (deep disposal pits), and septic tanks, adding contamination to the ground water which is relatively close to the surface in most areas.

There are eight sewage treatment plants on the south and west coasts. All of the plants are the extended aeration type. The capacities of these plants vary from 28 m^3/day (0.007 MGD) to approximately 300 m^3/day (0.08 MGD). Most of these plants perform poorly.

In essence, raw and/or partially treated domestic wastewater is discharged to the on-shore waters. Ships also discharge sewage into the harbors and especially at the Deep Water Harbour. Various outfalls to the sea and groundwater seepage have increased the concentration of nutrients in near-shore waters.

Bridgetown is served by sewage treatment facilities (see Figure 2). The plant was originally designed to handle the following conditions [4]:

Hydraulic Capacity	–	7568 m^3/day (2 MGD)[2]
BOD	–	4000 lbs/day
Suspended Solids	–	5000 lbs/day

THE PROBLEM

At present, the hydraulic flow through the gravity sewerage system is about 0.7 mgd. In addition to this, a substantial load of septage is added daily to the raw sewage at the treatment plant. The quantities usually vary, the average quantity is 22,000 gpd, with a maximum of 53,000 gpd (83 m^3/day to 200 m^3/day). Septage is tanked to the plant, pre-chlorinated and added just before the splitter box. The septage problem started in 1985. The solids in the septage vary from 5 to 20 percent. Its COD also varies, sometimes it is close to 109,000 mg/ℓ, the dissolved oxygen is invariably zero. Records are not maintained on the precise doses of prechlorination of septage. Before starting the addition of septage, the COD of raw sewage influent in October 1985 was 554 mg/ℓ, and the treated effluent had a COD of 66 mg/ℓ.

It is customary to pre-chlorinate raw sewage, which is in septic condition at time of arrival because the dissolved oxygen is zero. Currently the plant uses

[2] 1 MGD = 3785 m^3/day.

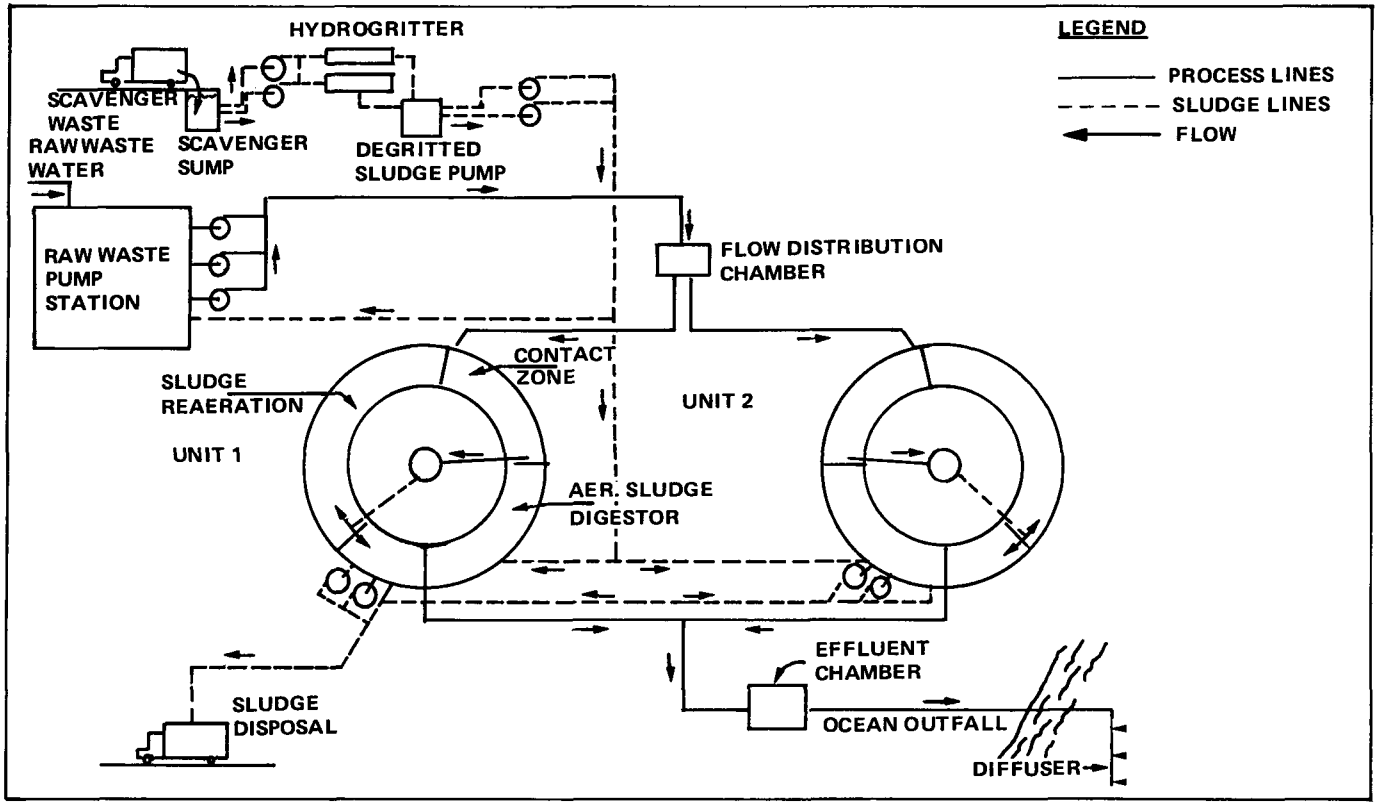

Figure 2. Sewage treatment plant—Bridgewater (source: Stanley/CEP).

chlorine in the neighborhood of 300 to 500 mg/ℓ. It includes pre-chlorination of raw sewage, septage, and post-chlorination of final effluent. (The precise doses used at each step were not available.) Although detailed information is currently lacking, chlorine doses are abnormally high, thus posing health complications due to the formation of chloramines and/or trihalomethanes [4]. Trihalomethanes are carcinogens.

The final effluent flows to the ocean just off Princess Alice Highway. The ocean outfall is 300 m long and the maximum depth at the outlet is 12 m. Along the last 45 m length of the outfall, several diffused jets are placed which provide mixing and spreading of the effluent by dilution. The estimated dilution is 200-fold [5].

There is no doubt that the septage provides a "shock load" several times a day for which the plant was not designed or equipped.

In conclusion, the plant is hydraulically underloaded and perhaps organically overloaded. It is discharging high quantities of BOD_5 in the effluent. Assuming that the treatment efficiency is 90 percent and influent COD is 110,000 mg/ℓ, the plant is still discharging about 11,000 mg/ℓ of COD. In 1986, the operational and maintenance budget was 2.3 million dollars and it was estimated that the cost of electricity varied from B$720,000 to B$840,000,[3] which was about 34 percent of the total operational and maintenance cost. The cost of treatment comes to about B$5.03/100 U.S. gallons. The usual cost in the United States for a similar plant size, secondary treatment plant is about B$1.20 per 1000 U.S. gallons.[4] Considering the existing high cost of operation and maintenance of the treatment plant, future expansions and/or additional treatment facilities should include designs which consume less energy and operate more efficiently.

INDUSTRIES

There are sugar factories, rum refineries, and many other types of industries, including pesticide and insecticide formulation in Barbados. One rum distillery discharges its wastewater via a 500 m outfall to the sea. The wastewater is highly polluted. Usually rum refinery waste is septic, has a high BOD, and a rather low pH. The spent waste may contain several chemicals, mainly water and yeast with a mixture of methanol, aldehydes, ketones, and esters. The spentwash without any treatment is pumped through a 3,200 foot outfall into the sea. The spentwash is approximately 72,000 U.S. gallons per day. The overall BOD varies between 38,000 to 40,000 mg/ℓ. On a working day the refinery discharges about 2,100 pounds of nitrogen, 265 pounds of phosphate, and significant amounts of mercury (0.013 mg/ℓ), zinc (less than 0.1 mg/ℓ), and copper (1.33 mg/ℓ). All of these metals are toxic.

[3] B$1.00 = US$1.50.
[4] U. S. gallons.

In 1980-81, Tomascik reported on ten-fold increase of nitrate concentration since Vezina measured these in 1972-73 in the north of Deep Water Harbour [6]. Tomascik recorded nitrate concentration of about 1803 mg/ℓ [7]. Phosphate levels have also shown a rise of about ten-fold during 1972-82.

REEF DECAY

The coral reefs on the west coast and to the south of Holetown are dead, and to the north of Holetown reef species are depleting rapidly. At the same time, certain species of algae have increased. However, in 1960 Lewis reported an abundance of coral reefs [8]. Evidently the decay is a rather recent phenomenon that occurred in the last decade or so. The reef recession is up to a depth of 10 m. Beach erosion has extended to in-shore land. Reef deterioration is an important factor causing beach erosion, and factors such as high wave energy during winter swell events and hurricane/tropical storm waves are also contributory causes of beach erosion. Backshore erosion has reached coastal buildings, jeopardizing the stability of these structures. The beaches in some zones have narrowed, and there is continuous scouring of structures. The question is, "What has caused the death and decay of the reefs?" Another question arises, "Is the water quality related to this phenomenon of reef deterioration?"

Causes of Reef Deterioration

The last ten years have witnessed a gradual and continuous depletion in the quality of near-shore water caused by industrial and domestic pollutants including pesticides and insecticides. The water today is more turbid than several years ago. The sewage in Barbados has 25 mg/ℓ of nitrogen. It is postulated that under high concentration of nutrients, luxuriant eutrophication occurs in the upper layers where various species of algae grow. However, in lower water depths, associated with sediment, the conditions are oligotrophic and a naturally decreasing eutrophication gradient is created. The algal bloom in upper layer obstructs the penetration of sunlight. Consequently, habitats that occur in high nutrient concentrations obstruct the growth of coral reefs. The dead debris of algae and other phytoplanktons tend to settle down, but remain in suspension along with other particulate matter. Some of the additional particulate matter may be resuspended from the bottom sediment. These particles in suspension also obstruct the penetration of sunlight essential for the growth and propagation of coral reefs. Land derived (eroded soil) particulates also augment this situation. The suspended particles drift from one location to another until they are ejected on the shore. In essence, the oligotrophic condition together with the loss of sunlight has caused the death and decay of fringe reefs. Reefs provide a protective shield and once this shield disappears, the storm waves surge and impinge against the shore resulting in beach erosion.

An independent study was conducted by the Bellair Research Institute, Barbados, on the biological behavior of coral reefs and the quality of coastal waters. In essence, the Institute research supports the above hypothesis. The results are summarized below.

Wastewater discharge and seepage in coastal waters in Barbados has shown an increase in the nutrient levels. According to Lewis, the NO_3^--N loading was 179 kg per day [8]. Elevated nutrient levels and increased organic production along the west coast was reported earlier by Sanders and Steven in 1973 [9]. The increase in nutrients is considered as the prime source of enhanced coastal production. Later in 1981-82, Tomasick and Sanders measured several water quality parameters and concluded that "an environmental gradient exists as a result of increased eutrophication of coastal waters" [7]. The authors establish a significant correlation between various environmental variables and community descriptors and conclude that reduced species diversity, through elimination of certain species, is due to the effects of eutrophication processes and stress situation caused by the deteriorating coastal water quality.

Based upon limited research, it is evident that adverse water quality may have caused the decay of the fringe reef. If so, attempts to revive the growth of reefs may not be fruitful unless coastal water quality improves. Several actions are recommended:

1. reduce or eliminate the unsewered section of the city;
2. incorporate appropriate wastewater treatment to reduce the point contamination of the entire area; and
3. enforce existing regulations directed to eliminate the use of chlorocarbon pesticides.

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