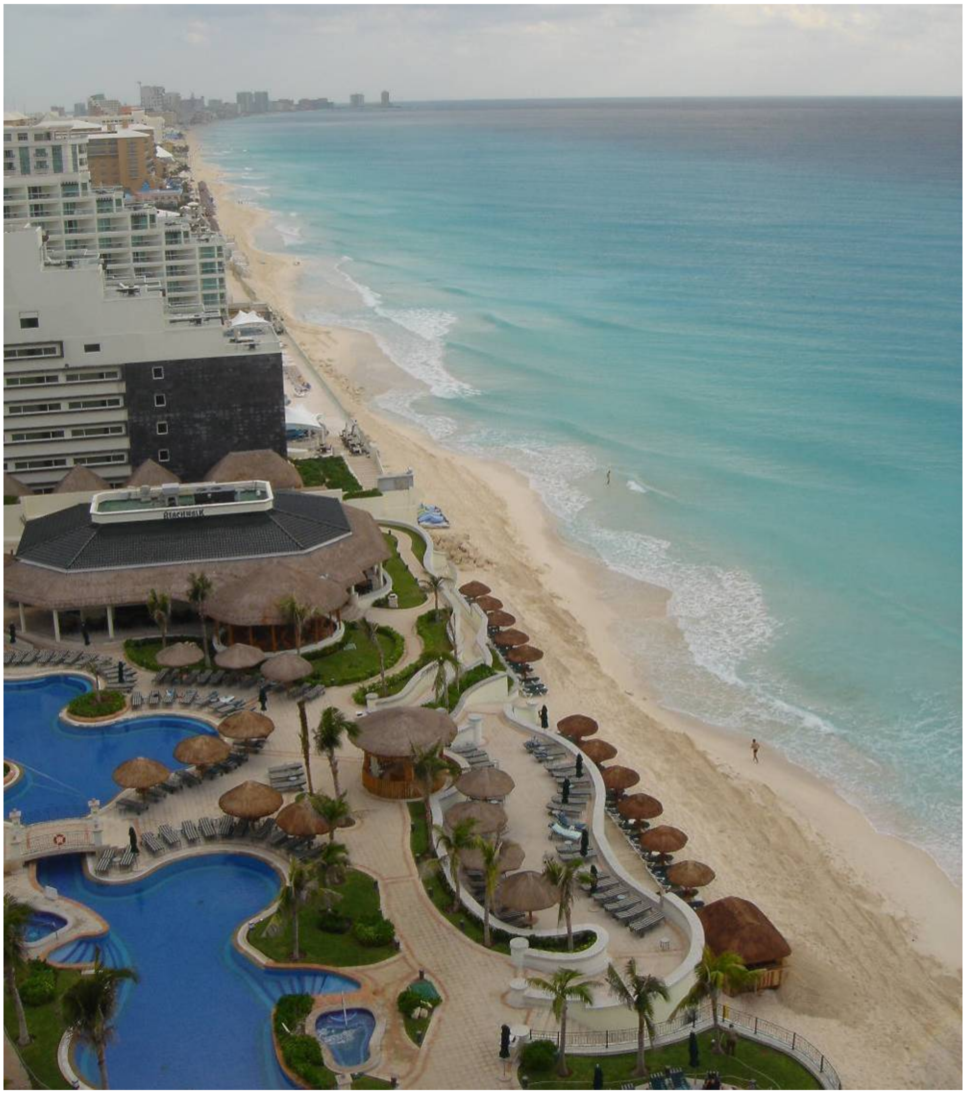
Options for Improving the Beach for J.W. Marriott and Casa Magna Resorts Cancun, Q.R., Mexico



November 2007 Photograph looking North from J.W. Marriott

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Options for Improving the Beach for J.W. Marriott and Casa Magna Resorts in Cancun, Q.R., Mexico

1 Introduction

This report presents the options for improving the beach conditions for the J.W. Marriott and Casa Magna Marriott Resorts, located in Cancun, Mexico. Existing conditions are documented, and alternatives for both short term and long term beach improvements are discussed.

2 Location

The J.W. Marriott and Casa Magna Resorts are side-by-side, and are located near the center of the eastern coast of Cancun, Mexico. Figure 1 shows the Cancun coastal area plotted in Google Earth, with the project location shown in Figure 2.

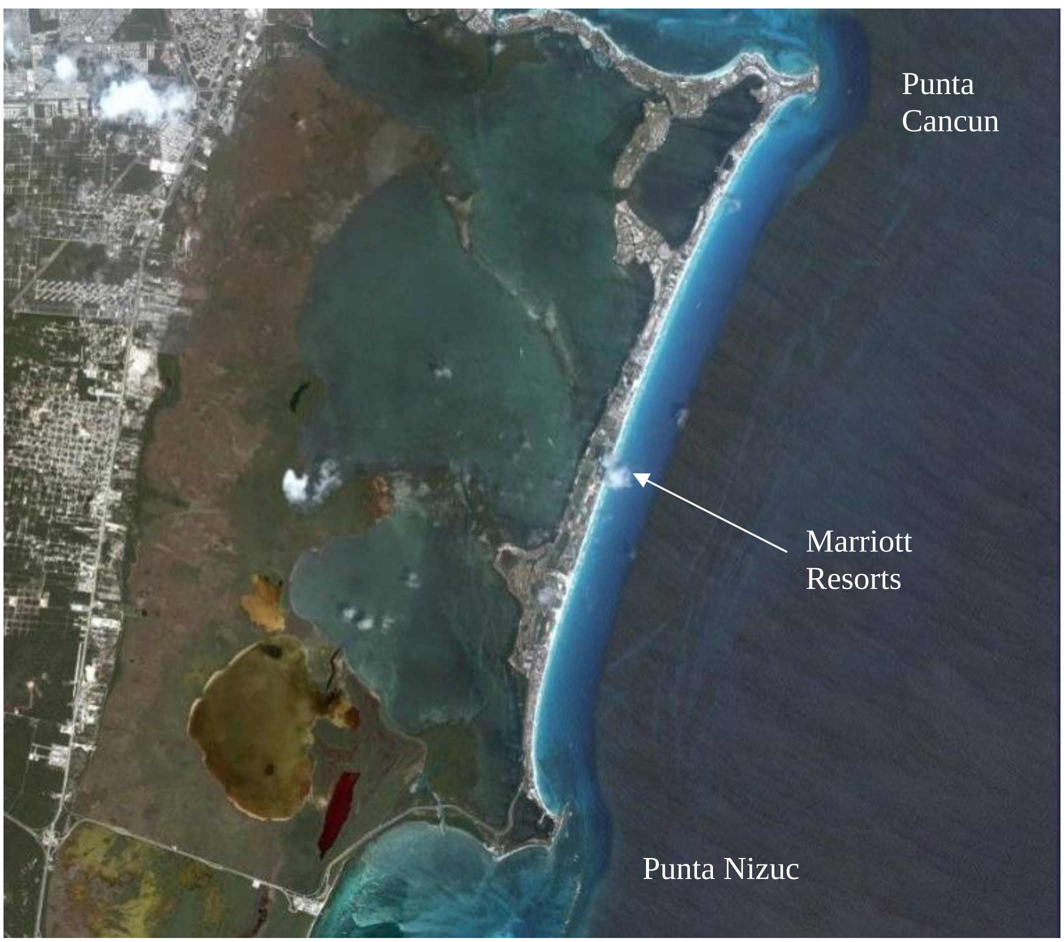

Figure 1. Cancun Coast with Location of Marriott Resorts (Google Earth)

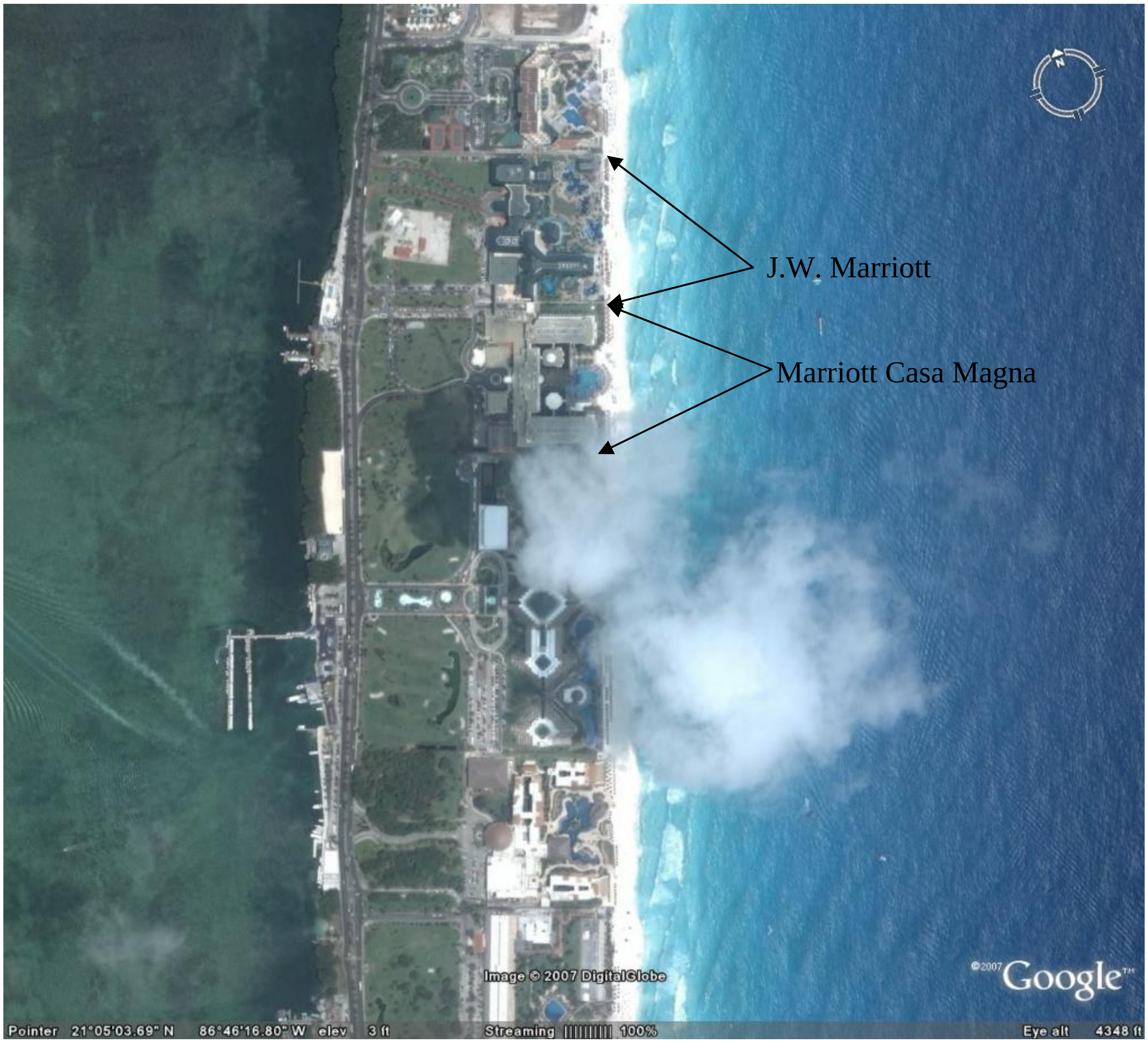

Figure 2. J.W. Marriott and Casa Magna Resorts (Google Earth)

Each of the Marriott Resorts has 200m of oceanfront. This stretch of coast is referred to as the Hotel Zone, and consists of numerous oceanfront beach resorts located along the shore. The beaches in this 12-km area are bounded on the north by Punta Cancun and on the south by Punta Nizuc, and have experienced severe erosion in recent years. Even though the beaches in this area were nourished with sand in a major beach nourishment project, recent storms and hurricanes have removed much of the sand that was placed.

3 Existing Conditions

The existing conditions for the project area are presented in this section of the report. This includes the meteorological and oceanographic conditions (winds, waves, tides, and currents) and the existing coastal geomorphology (beach topography and offshore bathymetry).

3.1 Oceanographic Conditions

The eastern Cancun coast is open to the Caribbean Sea, with complete exposure to waves coming from the east, northeast and southeast. There is considerable open ocean, with the winds capable of generating significant waves over fetch distances ranging from 200km to over 2,000km. In recent years the area has been subjected to several major tropical storms and hurricanes, which have caused extensive beach erosion.

3.1.1 Winds and Waves

The Tradewinds provide a dominant wind pattern for the area, with winds coming from the east most of the time, except when the weather is influenced by the passage of frontal systems or nearby tropical systems. This area is open to the east, so that it experiences both locally generated wind waves and swell waves from storms further east in the Caribbean Sea. Tropical storms and hurricanes produce the strongest winds and largest waves for this area.

3.1.2 Tides and Water Levels

Tides for the Caribbean coast of Cancun are semi-diurnal, with two high tides and two low tides per day. Predicted tides for Puerto Morelos during November 2007 are shown in Figure 3, which includes the survey dates for this report. The tide range is small, generally less than 0.3m, but may reach 0.5m or more during parts of the year. High water levels are possible and do occur due to tropical storms and hurricanes, that are able to produce storm surges that can greatly increase water levels.

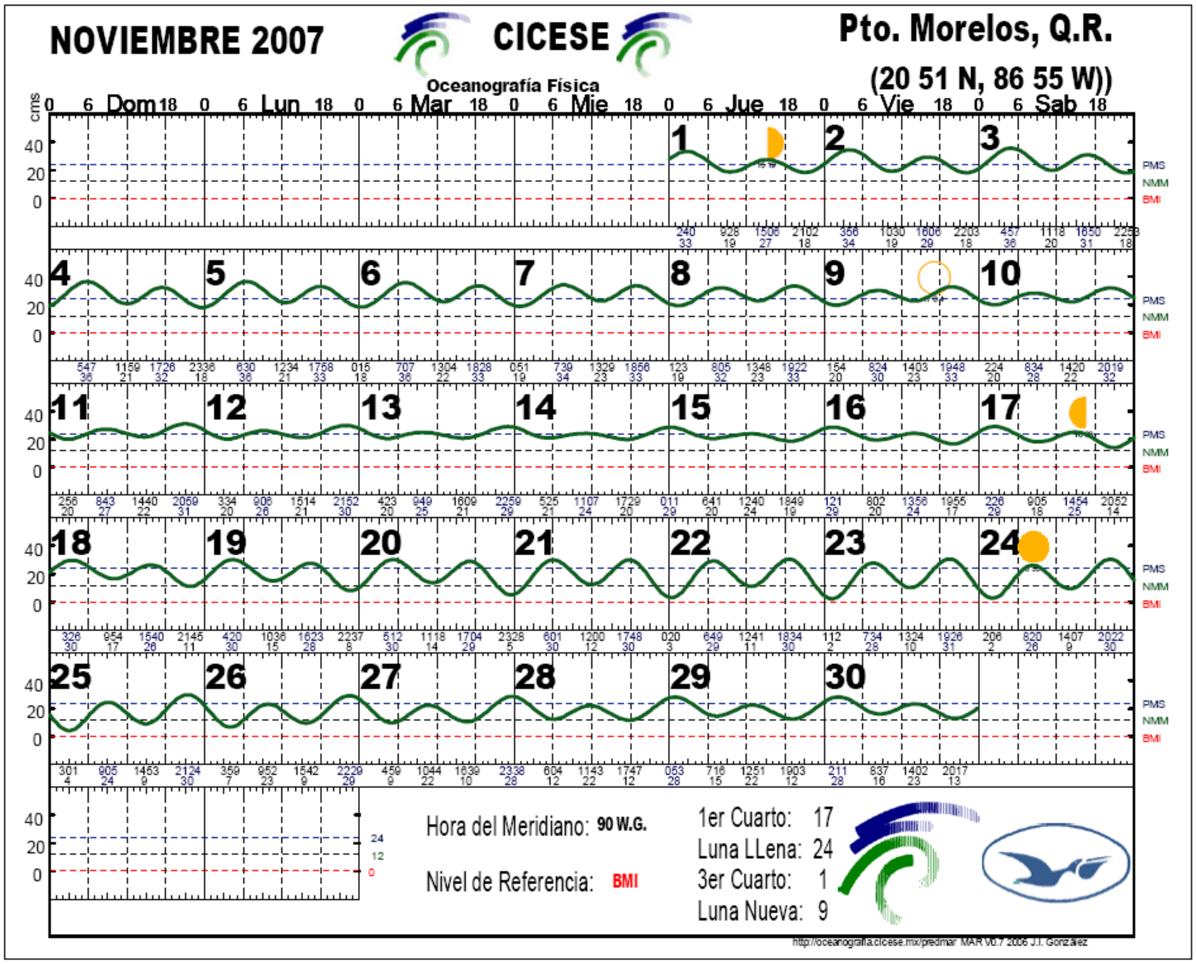

Figure 3. Predicted Tides for Puerto Morelos for November 2007

3.1.3 Ocean Currents

A major ocean current lies offshore of the area, with strong currents flowing from south to north. This current travels between Cozumel and the Yucatan Peninsula on its way up to Florida, where it becomes the Florida Current, which is part of the Gulfstream. This current is generally located further offshore so that it does not interact with the local beaches and coastal processes. Local longshore current can be produced by the winds and waves that affect the coast, which can produce longshore currents traveling in either direction.

3.2 Beach Topography and Offshore Bathymetry

Surveys of the J.W. Marriott and Casa Magna Marriott beaches and nearshore area were performed on 9 and 10 November 2007. Five profile lines were surveyed from the existing seawall out to a water depth of 11 to 12 feet (almost 4m). Figure 4 shows the locations of the profile lines. Table 1 summarizes the survey data for the existing beach, with upper beach widths that ranged from 15 to 20 feet seaward of the seawall, and distances from seawall to the water ranging from 35 to 60 feet at the time of the survey.

Figure 5 shows a graph of the five profile lines including the jet probes that were performed along PL-2 and PL-4 to determine the sand depth above underlying rock in the offshore area in which a breakwater may be considered. Sand thickness varied from 1 to over 6 feet in water depths from 3 to 8 feet. More detailed surveys of the sand thickness over the rock may be required for the consideration of offshore breakwaters discussed later.

Figure 4. Five Beach Profiles surveyed in November 2007

Table 1. Survey Data Beach Widths

Distances in feet seaward from the existing seawall.

Profile Number	Width of upper beach	Distance from seawall to water line
PL-1	15	35
PL-2	17	52
PL-3	20	53
PL-4	20	59
PL-5	20	60

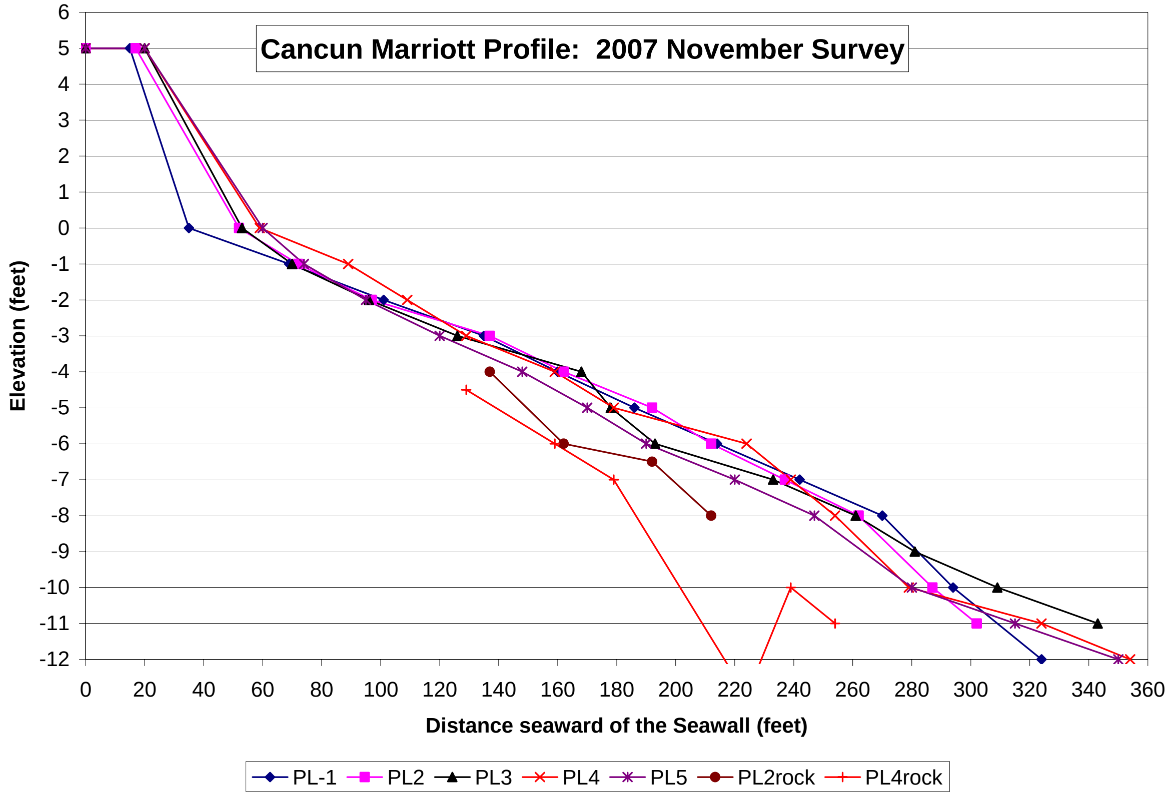

Figure 5. Graph of Beach Profile data and Jet Probes

Exposure of natural rock was observed at the water's edge in the center region of the two properties, as shown in the photograph in Figure 6.

Figure 6. Exposed natural rock at water's edge offshore of the Casa Magna Marriott.

Due to the continued erosion of the beach seaward of the seawall, rocks have been placed on the beach along the two properties, as shown in the photographs in Figure 7. The sizes of these rocks are not sufficient for them to remain stable, with the smaller rocks being transported down the beach (discussed in more detail later).

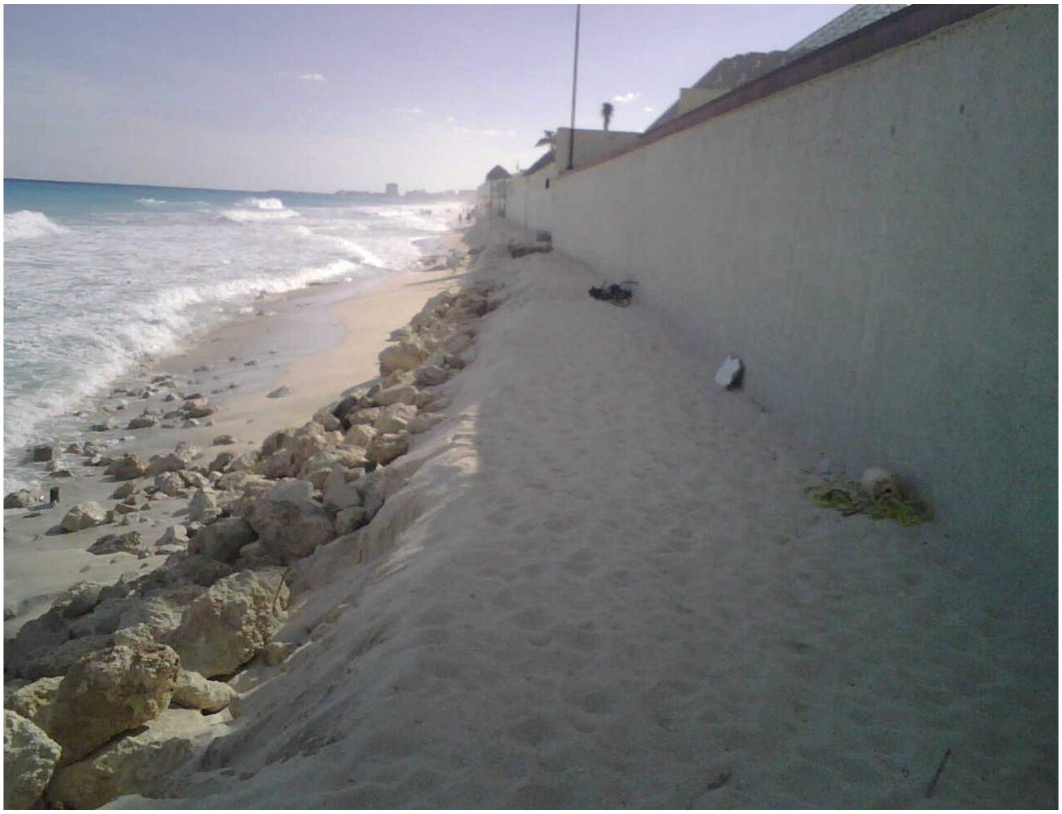

Figure 7. South end of Casa Magna Marriott Resort – Photo dates November 2007

Removal of some of these rocks was performed seaward of the J.W. Marriott Resort in November 2007, as shown in Figure 8. The proper design and installation of rocks for toe scour protection for the seawall is discussed in the next section.

Figure 8. Rock Removal Seaward of J.W. Marriott on 9 November 2007

4 Seawall Toe Protection

Toe protection is supplemental armoring of the beach surface in front of a structure, which prevents waves from scouring or undercutting it. Failure to provide toe protection invites almost certain failure (USACE). Figure 9 shows toe scour and accelerated erosion seaward of a seawall without toe scour protection (on left), and the use of rocks on filter cloth as toe protection (on right). Note that the toe protection is needed up against the wall, and not out on the beach. Also note that filter cloth or use of small rocks as foundation is needed, with large armor rocks on top (not just small rocks placed on the sand). In order to maintain a sand beach seaward of the seawall, the rocks should be installed in an excavated trench along the seawall, and buried with sand with the tops of the rocks below the desired beach level. The use of filters using graded rocks or a geotextile filter cloth is addressed in the following section.

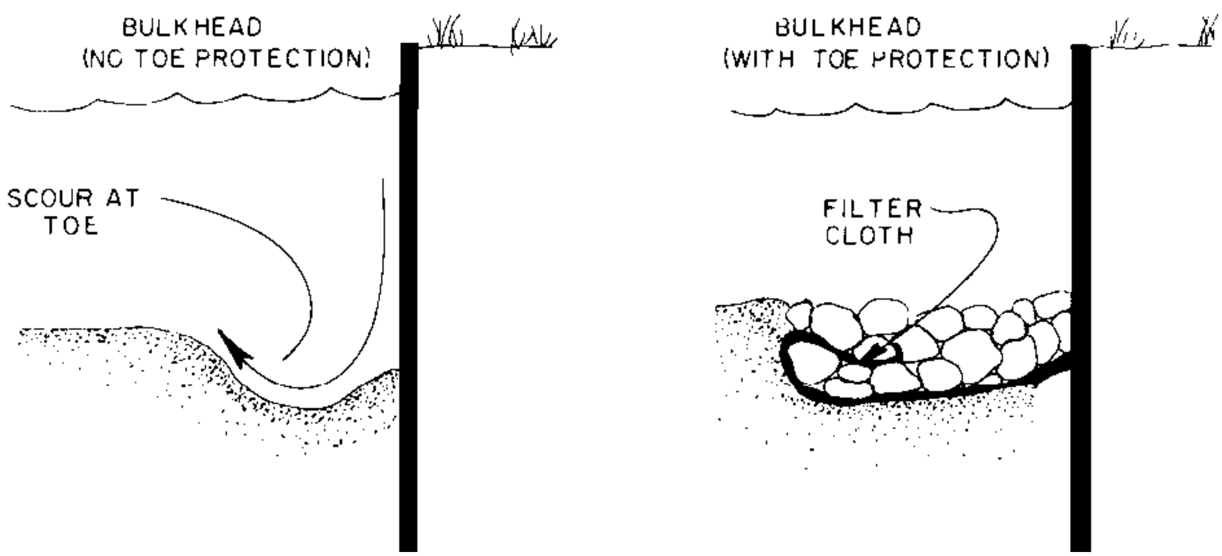

Figure 9. Toe scour seaward of a seawall (left); toe scour protection using rocks (right).
(From USACE)

4.1 Filtering

Filtering, although one of the most important technical design details of shore protection structures, is probably the most neglected, and leads to more failures than any other cause (USACE). The consequences of not providing proper filtering are illustrated in Figure 10 (on left). Without filtering, the soil particles are easily transported through the armor layer of rocks, and the rocks continue to settle as the sand erodes. A properly designed filter blocks the passage of the soil particles while still allowing for hydrostatic pressure relief beneath the structure. As shown in Figure10 (on right), the use of a graded stone filter or geotextile filter cloth is required to prevent the rocks from sinking into the sand, and to prevent sand from being eroded out from beneath the rocks. Filter cloth can also be used landward of seawalls, to prevent sand from being eroded out from underneath the seawall.

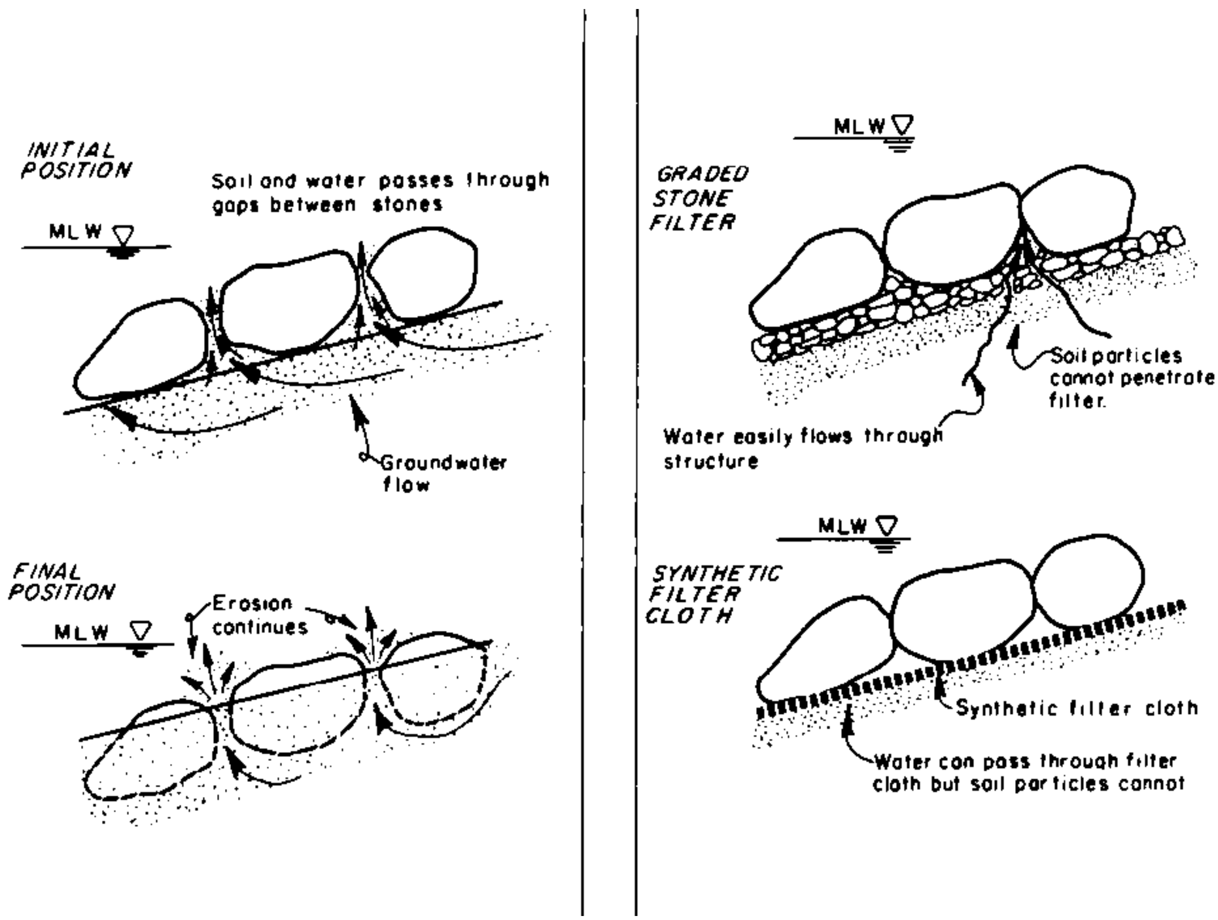

Figure 10. Erosion and rock settlement (left); Filter using graded stone or filter cloth to prevent erosion and settlement (right).
(From USACE)

5 Proposed Beach Improvements

This section of the report presents proposed improvements to the beach area for the two Marriott Resorts. This includes both short-term and long-term alternatives.

5.1 Short-term Alternatives

Short term alternatives include options that can be performed within a short time frame, where detailed engineering design and permitting are not expected to be required. These options include:

- Remove rocks
- Beach scraping
- Minor beach nourishment
- Emergent breakwater using sand-filled geotextile containers
- Submerged breakwater using sand-filled geotextile containers

If none of the above are done, the beach will continue to erode, exposing and moving the existing rocks. These options are discussed in the following sections.

5.1.1 Rock Removal

The existing rocks were placed on the beach without any filter foundation, so that they are expected to settle, and hence they do not prevent the sand from being washed out behind or beneath them. It would be best to remove the rocks that are out on the beach, leaving those that are up against the seawall. The rebuilding of the rock toe protection against the seawall using filter cloth and larger armor stones should be considered. That would require excavation of a trench along the seaward face of the seawall, installation of a filter cloth, placement of stones on top of the filter cloth, and placement of very large rocks on top as the armor layer. Each of the rocks in the armor layer should have sufficient weight to remain stable against wave attack, with a weight of each stone in excess of 2 tonnes = 2,000kg (exact design weight based on the design wave height). The smaller rocks that have been placed on the beach can be used underneath the armor rock as foundation.

5.1.2 Beach Scraping

Beach scraping is the terminology used to describe the taking of sand from near the water line and moving it further landward to build up the beach. If allowable, this can be performed as needed, but provides a limited volume of sand.

5.1.3 Minor Beach Nourishment

To be successful, beach nourishment must be performed over a large area, and should be of sufficient volume to substantially increase the beach width to provide a buffer against erosion. The 12km long Cancun eastern shoreline was already nourished with sand as part of a large beach nourishment project, but recent storms rapidly eroded the sand. Sand fill could be brought in either from an upland source or from offshore, but must be of sufficient grain size to be compatible and stable with the natural sand, as well as similar in color for appearances. Any sand put on the beach only along the 400m oceanfront of the two Marriott Resorts is expected to be temporary, but would provide a sand beach for the tourists.

5.1.4 Emergent Breakwater Using Sand-Filled Geotextile Containers

Traditional emergent breakwaters with the crests above the still water level can cause accretion in their lee, but also erosion of adjacent beaches. If the beach grows all the way out and connects to the breakwater (forming what is called a "tombolo") then the tombolo and breakwater will form a block to longshore sand transport, and deflect sand moving along the shore further offshore. Shoreline responses to offshore breakwaters are shown in Figure 11, with a specific example of erosion downdrift of an emergent breakwater at 32nd Street in Miami Beach shown in Figure 12.

In addition to the adverse effects on adjacent beaches, emergent breakwaters may not be acceptable in appearance. Examples of emergent breakwaters using sand-filled containers as offshore breakwaters may be found along beaches to the south of Cancun in the Riviera Mayan area, with numerous examples in the Playacar area located south of Playa del Carmen. Ponding of water due to wave overtopping of the structures can increase the currents around the structures, causing rip currents that can erode the beach and are hazardous to swimmers. Algae growing on top of the containers makes them slippery, which is also hazardous.

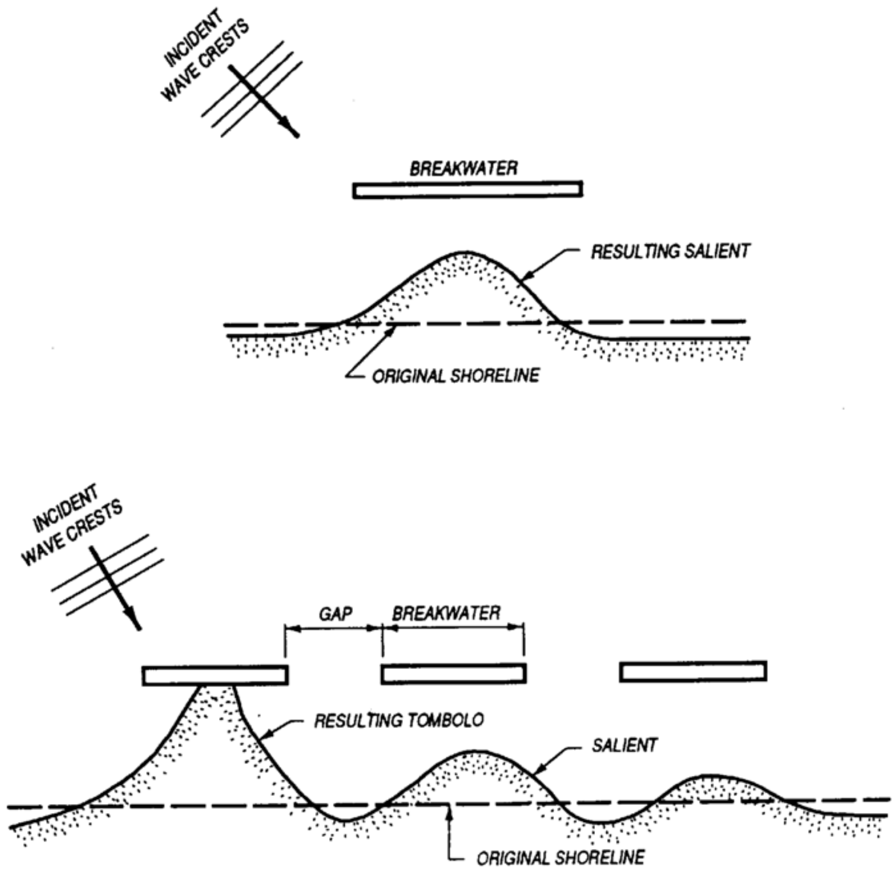

Figure 11. Shoreline Responses to Offshore Breakwaters (USACE)

Figure 12. Miami Beach 32nd Street Offshore Breakwaters (Google Earth)

5.1.5 Submerged Breakwater Using Sand-Filled Geotextile Containers

A submerged breakwater can stabilize the beach by decreasing the wave energy reaching the beach, but since it allows some of the wave energy to pass over the structure, a tombolo may not form, and sand may be able to continue to move along the shore landward of the breakwater. The beach landward of the breakwater may form what is called a "salient" which is a protrusion of the shoreline, due to less wave energy affecting the beach landward of the breakwater compared to the adjacent beaches. The effectiveness of submerged breakwaters in reducing wave energy depends on the degree of submergence of the structure (less depth above the breakwater results in more effective wave attenuation), and also the width of the structure (the wider the breakwater the more effective in wave attenuation).

The use of offshore submerged breakwaters constructed of sand-filled containers is already being considered for the northernmost and southernmost areas of the 12km Cancun eastern shoreline. These would be located 100m to 150m offshore with the tops of the breakwaters submerged to a depth of 1.5m. At this depth, the submerged breakwaters will not have significant wave energy reduction unless they are very wide, but they may act as a sill in stabilizing the beach profile landward of the breakwater.

Using sand-filled geotextile containers has both advantages and disadvantages. The advantages are that they can be deployed relatively easily on the existing sea bottom, and since they are constructed out of fabric, they can be easily removed. However, the major disadvantage is that since they are constructed using fabric, the materials are subject to puncture and tear by waterborne debris, as well as to damages due to vandalism. When part of a geotextile container is cut or torn, pieces of the fabric may break off and are transported offshore and down the coast. These fabric pieces are synthetic materials that can harm the environment, entangling and damaging reefs and wildlife. If this alternative is considered, the strongest possible materials should be used for the containers, with regularly scheduled inspections and repairs of any damages to the containers.

Possible locations of an offshore breakwater for the Marriott Resorts are shown in Figure 13. To be effective in wave energy reduction, the submerged breakwaters will need to be much wider than an equivalent emergent breakwater. A width of 33' = 10m or more may be necessary to provide the desired wave attenuation. For a narrow structure, the overtopping may produce ponding of water in the lee of the structure, which can create rip currents that remove sand from the beach and may be a hazard to swimmers. A porous breakwater using artificial reef units reduces the likelihood of ponding compared to that due to a nonporous breakwater such as sand-filled geotextile containers.

The deeper breakwater location shown in Figure 13 is similar to the location of the submerged offshore geotextile breakwaters that have been proposed for the northern and southern areas of the eastern Cancun shoreline. The water depth of 1.5m above the breakwater has been proposed so as not to create a hazard to navigation, but a breakwater submerged that much will be less effective at wave energy reduction compared to a shallower breakwater.

The shallow breakwater location shown in Figure 13 is also shown in the plan view in Figure 14. With the shallow water depth = 1 foot = 0.3m above the structure, it would be much more effective in reducing wave energy, but would need to be marked with buoys (although located only 160 feet = 50m offshore is landward of boat traffic).

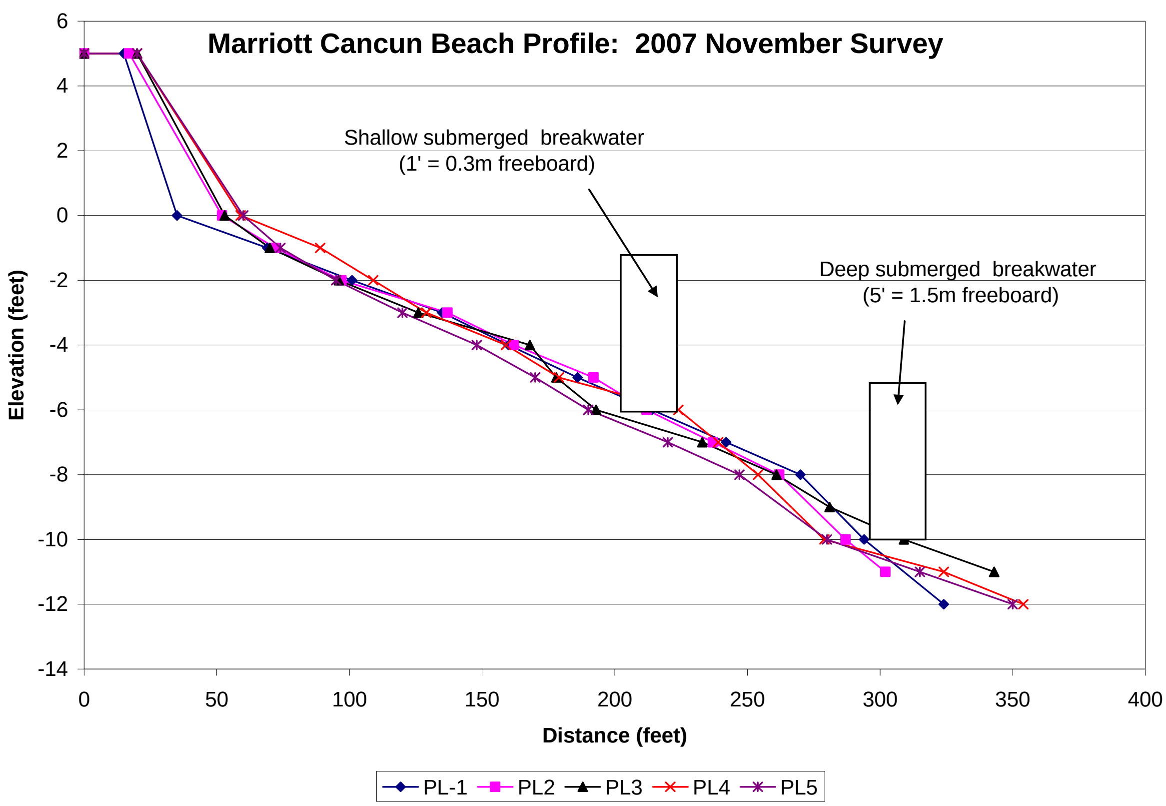

Figure 13. Profile View of Proposed Submerged Artificial Reef Breakwaters
Two alternative locations are shown for 1.5m = 5' high breakwaters.

Figure 14. Plan View of Proposed Submerged Artificial Reef Breakwater
The locations shown is for the shallow breakwater submerged 1' = 0.3m below low tide.

5.2 Longer-term Alternatives

Longer term alternatives include options that need more detailed engineering design and permitting, so that more time is required for their implementation. These options include:

- Beach nourishment
- Groins to stabilize the beaches
- Offshore breakwater using artificial reef units

5.2.1 Major Beach Nourishment

The 12km long Cancun eastern shoreline was already nourished with sand as part of a major beach nourishment project, but recent storms rapidly eroded the sand. As with all nourishment projects, periodic renourishment is required, and should be part of the design of a major beach nourishment plan. Renourishment intervals of other projects vary from 2 to 10 years, but major storms often require the beach renourishment to be performed earlier than anticipated. This seems to be the case for the Cancun eastern beaches. To be successful, the entire 12-km of Cancun's eastern shoreline would need to be included in the beach renourishment, which like the original nourishment project, will be very expensive. The amount of time that the sand will remain on the beach depends on the wave action, especially that from tropical storms and hurricanes. Structures may be used in conjunction with the beach nourishment, such as groins and breakwaters that are discussed in the following sections.

5.2.2 Groins

The use of shore perpendicular structures known as groins can trap sand and prevent the longshore transport of sand. As such, they can create extremely adverse impacts on adjacent beaches, by blocking the longshore transport of sand. Therefore, the use of groins would need to be designed to encompass the entire 12km shoreline of the eastern Cancun beaches. Beach nourishment in addition to the groins would be required to create sufficient beach widths and to pre-fill the groin compartments to prevent erosion of adjacent beach areas.

Shore perpendicular groins do not stop sand from being taken offshore from the beach, so that the use of T-head groins may be required. The T-head acts similar to an offshore breakwater, reducing wave action in its lee and helping to stabilize the sand on the beach.

5.2.3 Submerged Offshore Breakwater Using Artificial Reef Units

The use of artificial reef units for creating submerged breakwaters has been successfully used for beach stabilization in other parts of the Caribbean. Using hollow and/or porous breakwater units such as artificial reef units reduces the likelihood of ponding compared to that due to a more nonporous breakwater such as sand-filled geotextile containers.

Where a rock bottom exists, reef units can be stabilized by drilling into the substrate and pinning the units into the bottom. This has proved to be successful for breakwaters that have been exposed to direct impacts by major hurricanes (including Category 3 and 5 storms). For a sand bottom, a design using articulated mat for the foundation has been developed form Miami Beach, as part of the US Army Corps of Engineers Section 227 program (information available on the Internet). That design uses five rows of Reef Ball artificial reef units that are incorporated into an articulated mat, as shown in Figure 15.

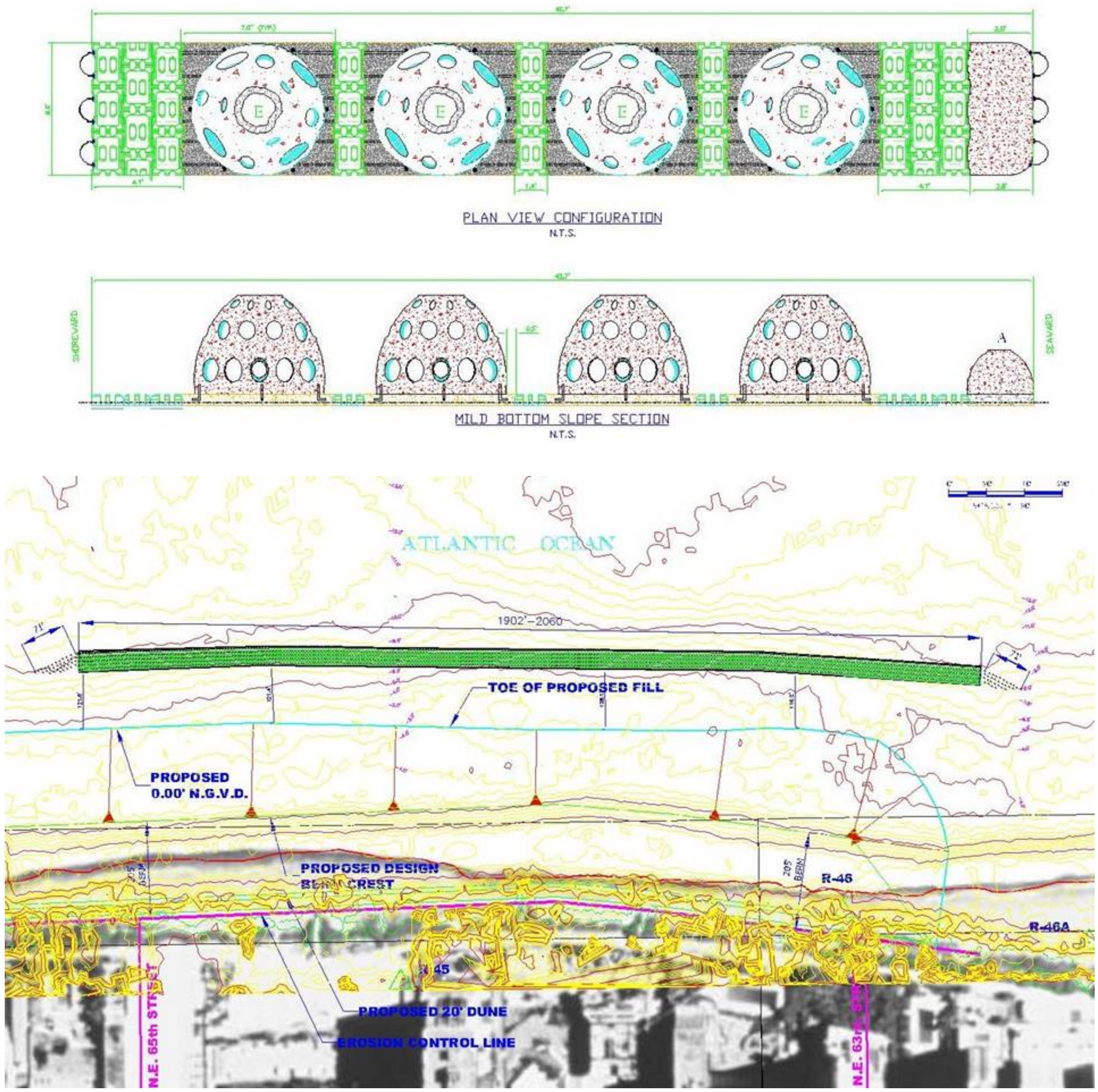

Figure 15. Proposed Miami Beach Offshore Submerged Artificial Reef Breakwater

The submerged artificial reef breakwater for Miami Beach at 63rd Street has not been constructed, but the preliminary design, physical model tests at the USACE facility in Vicksburg, MS and the detailed designs have been completed. This design could be used for the Cancun beaches, due to the similar tide range and wave climate as that in Miami Beach.

Figure 16 shows the 5-row reef Ball that was constructed offshore of the Marriott on the west coast of Grand Cayman in 2002. This system has stabilized the beach, and provides environmental enhancement and a snorkeling attraction for the tourists. The before and after photographs shown in Figures 17 and 18 show the successful beach stabilization, even with Hurricane Ivan impacting the area in 2005 and other wave impacts from more distant storms.

Figure 16. Grand Cayman Marriott Five-Row Reef Ball Submerged Breakwater

Figure 17. Grand Cayman Marriott before and after Reef Ball Breakwater Installation
Fall 2002 on the left, February 2003on the right.

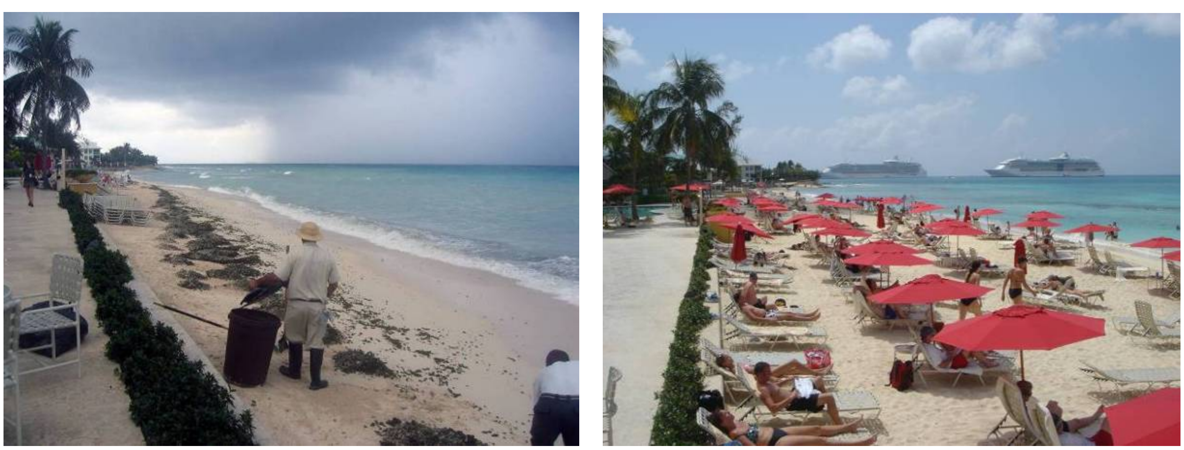

Figure 18. Grand Cayman Marriott - November 2006 (L) and February 2007 (R)

The Grand Cayman breakwater is located on the lee side of the island, so that it is more sheltered from wind waves generated by the Tradewinds. Due to the frequency of wind waves at the Cancun Marriott Resorts, the construction of an offshore breakwater would be more difficult, and would require a large barge and crane, particularly if the design using the articulated mat is used. The Cancun breakwater would provide environmental enhancement, including both benthic growth and fish, but due to the wave climate would not be suitable for snorkeling by tourists except during calm sea conditions. However, the area landward of the breakwater would have reduced wave energy, which would create calmer conditions for swimming.

6 Conclusions and Recommendations

The severe beach erosion along the Cancun eastern shoreline presents a major problem to tourism. Solutions are expensive and not easy, as demonstrated by the recent beach nourishment project that eroded away quite quickly. Due to the 12km long shoreline, any construction of structures such as breakwaters or groins must consider the effects on the adjacent shorelines. Proper foundation for any structure is required, which can be accomplished by removing the sand above the existing rock bottom prior to construction, or using a properly designed foundation that resists scour and settlement. The consistent waves from the east make construction offshore of the Cancun area difficult, and the use of a large barge to provide a protected area in its lee would offer the best chance for successful construction.

The options for beach improvements for the J.W. Marriott and Casa Magna Marriott Resorts were presented with short-term and longer-term alternatives. Careful consideration of these alternatives and proper construction techniques are required in order to prevent increasing rather than decreasing the available beach use area, and avoiding any adverse effects on neighboring beaches and the environment.

6.1 Short-term Recommendations

6.1.1 Removal of Rocks

The short-term alternative that is recommended is the continued removal of the small rocks from the beach, as they provide a hazard to beach users and reduce the available beach area. These rocks were not installed with any foundation, and the small sizes of most of the rocks are insufficient to prevent their movement. These rocks can be used to reconstruct toe scour protection for the seawall, as discussed in the body of this report. Sand can be added to sustain a useable beach area for the tourists, either from beach scraping, pumping from offshore or from an upland source. However this added sand will provide only a temporary mechanism for sustaining the beach, and may have to be performed often.

6.1.2 Sand-filled Container Breakwaters

The use of sand-filled geotextile containers to construct a submerged breakwater may be more easily permitted due to the fact that similar structures are already proposed for the southern and northern beach areas in Cancun, and because they can be removed relatively easily. However the susceptibility of the fabric materials to puncture and tear requires maintenance and repair to ensure that the breakwater remains in place, and that the torn materials do not cause damages to the environment. Only the best and strongest geotextile materials should be used, and the installation should be performed by a contractor that has experience working offshore and filling geotextile containers. The layout and construction of the breakwater should be supervised by an engineer to ensure proper placement and uniform crest height that is below the lowest astronomical tide level, so that the breakwater remains submerged, except in the troughs of larger waves. Another consideration is scour and settlement of the containers if they are placed on sand. Excavation of the sand down to rock prior to deployment of the sand-filled container would eliminate this problem.

A breakwater could be constructed along the entire 400m shoreline fronting the Marriott Resorts, but one 200m long breakwater (or shorter breakwaters separated by small gaps) located near the center of the two properties may be sufficient to stabilize the beach in the center of the properties, to provide adequate beach area for use by the hotel guests. The crest height of the breakwaters should be submerged a minimum of 0.3m and a maximum of 0.6m below the lowest astronomical tide level so that significant wave attenuation is achieved. The width of the breakwater should be on the order of 10m, which may require more than one row of containers. When using more than one row of containers, they should be butted up against one another with no gap in between, and filled so that a consistent crest height is achieved to maximize wave breaking on the structure. Due to the consistent waves coming from the east, this breakwater construction would be best performed using a large barge, so that the construction can be performed in the lee of the barge.

6.2 Longer-term Recommendations

The recommended long term alternative is the submerged artificial reef breakwater. The reef units are stronger and more porous than the sand-filled containers, giving this option advantages of longevity, lack of rip currents, and environmental enhancement. Since the reef units are constructed of concrete, they are not subject to puncture and tear. However, they must be fabricated using special concrete and additives to increase the strength of the units and resistance to breakage. They also must be adequately anchored to prevent movement during large waves. If the articulated mat is used, a large barge and crane with a spreader bar would be required to lift and deploy the 10m long by 2m wide mats that would each weigh over 10 tonnes. The articulated mat can be anchored into the bottom using screw anchors at each end of each mat.

The design layout for the artificial reef breakwater would be similar to that of the sand-filled geotextile container breakwater. The breakwater could be constructed along the entire 400m shoreline fronting the Marriott Resorts, but one 200m long breakwater (or shorter breakwaters separated by small gaps) located near the center of the two properties may be sufficient to stabilize the beach in the center of the properties, to provide adequate beach area for use by the hotel guests. The crest height of the breakwaters should be submerged a minimum of 0.3m and a maximum of 0.6m below the lowest astronomical tide level so that significant wave attenuation is achieved. Using 5 rows of the largest Goliath Ball reef units, the width of the breakwater would be approximately 10m.

6.3 Next Steps

The removal of rocks and the addition of sand to the beach can be performed as they have already been done. The rocks can be used as toe scour protection for the seawall, as discussed in detail in this report. For the pursuit of any of the other alternatives, a more detailed survey of the beach and nearshore area should be performed. A detailed jet probe survey is needed to determine the sand depth over the rock for the design and construction of a breakwater offshore. Cost estimates for the alternatives can be requested from contractors, and permitting agencies can be contacted to ascertain permit requirements and conditions.