ENVIRONMENTAL IMPACT ASSESSMENT

Coastal Protection at Paradise Island Resort, Kaafu Atoll, Maldives

Proponent: Paradise Island Resort

Consultant: Ahmed Zahid (EIA08/07)

Sandcays

July/August 2010
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Non Technical Summary

This report addresses the environmental concerns of the proposed coastal protection at Paradise Island Resort located on Lankanfinolhu in North Malé Atoll. The primary objective of the project is to protect the coastal infrastructure of Paradise Island Resort and also enhance the natural environmental of Paradise and to improve the services offered to guests thereby minimizing operational and environmental costs. As such the project encompasses the replenishment of approximately 200m of beach at the arrival jetty and swimming pool area on the western side and about 300m of shoreline on the eastern side at the base of the water villas jetty.

Paradise Island is surrounded by a large expanse of lagoon or reef flat on the eastern side and similar but not so great expanse of reef flat and lagoon on the western side. The western side beach is, therefore, much more prone to wave attack than the eastern side. The western side is exposed to wind generated waves during the southwest monsoon while the eastern side is exposed to wind generated waves during the northeast monsoon as well as swells during both monsoons. The eastern side reef flat has recently been subjected to anthropogenic changes during the construction of water villas which were destroyed by the tsunami of 2004 as a result of which the erosion of the eastern beaches at the foot of the water villa jetty has been severed. However, the western side beaches have been a victim of wave-induced erosion during the southwest monsoon for as long as the island existed. Therefore, regular beach nourishment by pumping sand from nearshore areas has helped to keep the beaches intact to some extent. Such frequent beach nourishment creates more sediment suspension and resuspension in the water column causing deterioration of the quality of the main product, which is the natural environment. Continuous beach nourishment would also provide little protection to these eroding areas without structural protection. Shore protection measures have, therefore, been evaluated and most practicable option(s) chosen to protect the eroding areas and minimize the frequency of beach nourishment. The proposed coastal protection structure is a breakwater that would be submerged at high tide. Such a breakwater is expected to provide adequate protection from wave induced erosion on both sides, which is the cause for concern at present.

The overall environmental impacts of the project have been assessed using appropriate matrices and the results indicated that the proposed project has a net positive impact. That is, the project has no major adverse impacts on the environment as far as current knowledge is concerned. Given that the project has major socio-economic benefits and some environmental benefits, it is advisable to allow the project to proceed as proposed. It is also recommended to continue to monitor the impacts of the proposed project by regular monitoring of shorelines and nearshore currents for at least two years and communicate and feed the data into the EIA system in the country.
1 Introduction

1.1 Introduction

This Environmental Impact Assessment (EIA) report has been prepared in order to meet the requirements of Clause 5 of the Environmental Protection and Preservation Act of the Maldives to assess the impacts of the proposed coastal protection structures namely breakwaters on the western and eastern areas complemented by beach nourishment in these areas because Paradise is faced with a serious problem of beach erosion on the island’s eastern and western shorelines. This report will identify the potential impacts (both positive and negative) of the proposed project. The report will look at the justifications for undertaking the proposed project components. Alternatives to proposed components or activities in terms of location, design and environmental considerations would be suggested. Measures to mitigate any negative impact on the environment would be suggested. Environmental monitoring programme is vital in order to demonstrate the long term benefits of the proposed project and to undertake mitigation before any impact is severed. Therefore, a coastal monitoring and protection plan would be suggested.

The major findings of this report are based on qualitative and quantitative assessments undertaken during site on 5-6 June 2010 as well as consultations, experience and professional judgment. Available long term data were collected from available sources, such as long term data on meteorology and climate from local and global databases. It may be necessary to note that consistent, regular coastal data for Paradise is lacking although there is a regular monitoring programme proposed for the island as part of Villa’s efforts to monitor the island. However, information shared by the management has been usefully applied in drawing up appropriate options for the protection of the eroding beach areas.

This EIA has been produced in accordance with the EIA Regulations 2007, issued by the Ministry of Environment, Energy and Water (now the Ministry of Housing and Environment).

1.2 Aims and Objectives of the EIA

This report addresses the environmental concerns of the proposed coastal protection measures for Paradise Island namely breakwater and beach nourishment on the western and eastern shoreline towards the middle of the island. The report helps to achieve the following objectives.

- Allow better project planning
- Assist in mitigating impacts caused due to the project
- Promote informed and environmentally sound decision making
To demonstrate the commitment by the proponent on the importance of environmental protection and preservation.

1.3 Methodologies

Internationally recognized and accepted methods have been used in this environmental evaluation and assessment. This EIA is based mainly on data collected during a field investigation mission on 5-6 June 2010 by a team from Sandcays Pvt. Ltd., Maldives. The data collection methods would be described in detail under Section 4.

1.4 EIA Implementation

This EIA has been prepared by Ahmed Zahid, a registered EIA consultant with a number of years of experience in Environmental Impact Assessment in the Maldives and has been involved in several coastal protection project EIAs undertaken in the Maldives. He was assisted by the following team members:

- Ibrahim Mizal Mohamed
- Abdulla Niyaz, and
- Hassan Jameel

The different steps involved in the implementation of the EIA and the time frame for those steps/activities are given below.

- EIA application submission 10 June 2010
- Scoping meeting 6 July 2010
- Submission of draft TOR 7 July 2010
- Approval of TOR 13 July 2010
- TOR Received by Consultant 13 July 2010
- Field mission 5-6 June 2010
- Draft report submission to Proponent 29 July 2010
- Submission of final EIA report 29 July 2010

Once the EIA has been submitted it is expected that the review process will not take more than 4 weeks. The review process may result in the requisition of additional information. However, all efforts have been made to ensure that adequate information has been provided with specific attention paid to meet all requirements of the Terms of Reference (TOR). The TOR for this EIA is given in Appendix 1.
2 \textbf{Project Description}

2.1 \textit{General context of the study}

The proposed project involves the construction of breakwaters followed by beach nourishment to protect the eroding areas on the eastern and western beaches of Paradise Island Resort and minimize the frequency of beach nourishment. This section will provide the details of the project including detailed methodologies of breakwater construction and beach nourishment using maps at appropriate scales.

2.2 \textit{The Proponent}

This project is proposed by Paradise Island Resort and Spa/Diza Travel and Trade Pvt. Ltd. Paradise is one of the first resorts to open in the Maldives and has been in operation for over two decades. Although Paradise Island, like many other resorts of its age, has literally lost its Maldivian island appeal over the past, today, environmental protection and preservation stands on top of its main operational agenda. Recently, a Resort Environment and Safety Management Action Plan (RESMAP) was developed which incorporates every single environmental aspect into the management of the resort. Paradise has good occupancy throughout the year and is considered to be one of the best resorts in the Maldives.

2.3 \textit{Project Location and Study Area}

Paradise Island Resort is located on the eastern rim of North Malé Atoll at 4°17’6”N and 73°33’14” sharing the same reef with Lankanfushi (Soneva Gili Resort) and Himmafushi (a local inhabited island) on the north of Paradise Island Resort. Paradise Island can be reached by a speedboat in 15-20 minutes from Malé International airport.

The study area is primarily the eroding areas on the northeast and mid western beaches. The impact areas would be the about 300m of nearshore and reef flat areas on the eastern side to the north of the arrival jetty and about 500m of beach and 400m of reef flat towards the centre of the western side. While these areas would be the main impact areas under the proposed project, the study will cover the entire coastal zone surrounding Paradise Island Resort. Therefore, the shoreline around the island, island levels, bathymetry of the lagoon and current flow around the island has been studied. Water quality in the affected sites has also been assessed to understand baseline conditions.
Figure 2-1: Project Location: Paradise Island Resort on Lankanfinolhu in North Malé Atoll

Figure 2-2: Satellite image of Paradise Island Resort (source: Google Earth, date: 23 August 2009)
2.4 The Project

The proposed project covers two civil components, namely:

1. Construction of breakwaters at the affected areas
2. Replenish eroding beach areas on the eastern and western sides by pumping sand from lagoon

The following subsections discuss the details of these two components and an illustrated summary of the adopted concepts is given in Figure 2-5. Discussions of the different alternatives are also given in Section 8 of this report.

2.4.1 Breakwater

The breakwater will be the largest component of the project in terms of cost (94% of the total cost). Two breakwaters will be constructed; one on the eastern side and the other on the western side. The details of these breakwaters are discussed here.

The breakwater on the eastern reef flat from the northeastern corner of the existing sandbed breakwater extends to about 320m up to the coral boulders placed on the reef flat behind the water villas. This breakwater has been made from coral taken from clearing an area around the water villas. This is exposed only at low tide and is uneven, therefore, the proposed breakwater may have to be further extended to fill the gaps in these coral boulders, if necessary. Due to the swell waves in the area, the design of the proposed breakwater takes into consideration a minimum height of 1.2m above mean sea level and a crest width of 2m to allow for 0.5m waves to break at high tide. Any of the designs given below can be used with Type 2 providing better aesthetics while Type 1 enhances the wave energy absorption under stormy conditions.

**Option 1/Type 1: Offshore breakwater**

- Present HTL: 1.3m from MSL
- Proposed shoreline at MSL: 1.6m above MSL

**Option 1/Type 2: Offshore breakwater**

- Present HTL: 1.3m from MSL
- Proposed shoreline at MSL: 1.2m above MSL

![Figure 2-3: Beach nourishment and breakwater on the eastern side](image-url)

Figure 2-3: Beach nourishment and breakwater on the eastern side
The breakwater on the western reef flat is proposed to be constructed from the corner of the restaurant at the Arrival Jetty head to about 300m north. This breakwater can be a submerged structure in order to avoid aesthetic impacts of the breakwater. Two designs are considered in this case too with Type 2 providing better aesthetics.

**Option 1/Type 1: Offshore breakwater**

**Option 1/Type 2: Semi-submerged offshore breakwater**

**Figure 2-4: Beach nourishment and breakwater on the western side**

### 2.4.2 Beach enhancement

The proposed beach enhancement involves the nourishment of the eroding areas on the east and west side shorelines as shown in Figure 2-5. This constitutes about 275m of the shoreline on the western side and 305m on the eastern side. The Ministry of Tourism, Arts and Culture and the Environmental Protection Agency allows beach nourishment for only up to 10m from the eroded shoreline. Therefore, this would be the extent to which the beach nourishment would be done. Given that the average depth in the area up to 10m off the shoreline is about 1.0m and that the average height of the island on both sides is about 1.3m above MSL, a total volume of about 20,000m$^3$ of fine sand has to be placed in the area. Three borrow areas have been identified during the field visit. These are areas from which sand has been pumped for previous beach nourishment. Of these the dredged area on the northwest tip of the island has been most dredged with average depths above 4.5m. The second one on the east side has average depths of about 3.5m while the third one on the northeastern side is quite small in area. Of these three spots the two on the eastern side is considered to be most effective with the smallest borrow pit towards the north providing adequate currents for silt to be dispersed quickly into the lagoon areas in the vicinity. This location is also at a considerable distance from the beach and in an area where beach material would not drift or the hole does not become a sediment sink for longshore transport. The northeast corner borrow pit is not expected to pose threats to the dynamic sediment transport patterns in the northern tip. However, this borrow pit would fill up over time from sediment from the reef flat.

Figure 2-5 shows the proposed beach fill areas and the borrow area. Alternatives to beach nourishment and borrow areas have been identified in Section 8 of this report.
2.5 Work Methods

2.5.1 Breakwaters

The proposed breakwater construction will be carried out using barge and excavators. The 5000 ton barge that will deliver rock boulders to site would be anchored on the eastern side. A ramp will be used to offload the material over the reef slope and part of the reef flat in the area in order to avoid damage to live reef areas. The material that has been offloaded to a single spot in this way would be spread along the length of the proposed breakwater using excavator (and small barge if necessary) that would work from the shoreward side of the reef flat. The work area may be scaffolded appropriately to avoid distractions and nuisance to guest arrivals.

For the eastern side a similar arrangement as for the western side may be adopted. However, as this may pose difficulties depending on meteorological conditions, material may be moved in small barge and excavator to the eastern side using the existing channel that has been already deepened from the western side up to the proposed breakwater on the eastern side.

2.5.2 Beach Enhancement

The beach enhancement or nourishment works will be done using sand pump and small dump trucks for transporting material to the other side. If it is possible, a small dredger may be used as it would take less time and the impact period can be greatly minimized. If sand pumps were to be used, a six or eight inch sand pump would be desirable given that fine sand without rubble needs to be placed on the beach. The rubble content, if any, can be manually removed upon completion of the nourishment works. If there is a lot of rubble in the pumped sand, it may be necessary to sieve it before spreading on the beach. The area into which sand will be pumped shall have a sand bund and preferably some silt screen at the mouth to minimize fine sediment entering the lagoon waters. Sand is proposed to be pumped to the northeastern thundi area given that the proposed borrow area is here. If the borrow area were to be changed to that of the southeast corner, then similar silt containment arrangement shall be provided in this area too.

2.6 Project duration

The project is expected to start soon after the approval of this EIA report, which should take less than 4 weeks from submission. The civil works are expected to take about two to three months depending on the availability of rock boulders on site. Therefore, it is expected that the project can be completed by the end of October or early November 2010. If delays occur, the works would have to be put off to be undertaken in 2011. It is important to ensure that the works are started within the normal duration of one year from the date of the EIA Decision Statement in order to avoid further environmental clearance. In case of any delays in the implementation of any of
the components described in this report, it would be necessary to write to the Environmental Protection Agency for an extension of the approval.

2.7 Project Inputs and Outputs

The project has inputs in terms of human resources and natural resources such as water and fuel. The main output of the project is the operational ease and socio-economic and environmental benefits associated with the different components. These inputs and outputs are summarised in Table 2-1 and Table 2-2.

Table 2-1: Main inputs of the proposed project

<table>
<thead>
<tr>
<th>Input resource(s)</th>
<th>How to obtain resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workers</td>
<td>Resort staff and contractor’s workforce</td>
</tr>
<tr>
<td>About 18,000 tons of rock boulders</td>
<td>Imported from India</td>
</tr>
<tr>
<td>About 20,000m³ of sand for beach nourishment</td>
<td>Using 6 or 8-inch sand pump/mini dredger/excavator</td>
</tr>
<tr>
<td>Food, water and other resources</td>
<td>Provided on site for workforce</td>
</tr>
<tr>
<td>Machinery</td>
<td>Contractor</td>
</tr>
<tr>
<td>Energy for machinery operation</td>
<td>Diesel fuel</td>
</tr>
</tbody>
</table>

Table 2-2: Matrix of major outputs

<table>
<thead>
<tr>
<th>Products and waste materials</th>
<th>Anticipated quantities</th>
<th>Method of disposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wastewater from workers</td>
<td>No. of workers x 95l/c/d</td>
<td>Through existing island sewerage system</td>
</tr>
<tr>
<td>Possible oil leak from excavator, etc</td>
<td>Trace amount</td>
<td>N/A</td>
</tr>
<tr>
<td>Sediment plumes (during sand pumping)</td>
<td>Moderate</td>
<td>Natural dispersion over a short period</td>
</tr>
<tr>
<td>Some rubble from beach works</td>
<td>Minute quantity</td>
<td>Disposed in deeper areas</td>
</tr>
</tbody>
</table>

2.8 Need and Justification

Paradise Island has solid breakwaters on the southern half from the southeast to west. This causes the currents in the northern half to intensify especially during a storm. Therefore, the northern half except the northern tip of the island needs protection. If a solid breakwater similar to the existing ones were to be created, the island lagoon would become highly silted with rapid water quality deterioration. Furthermore, they would further intensify the currents at the northern end making the northern sand spit (thundi) susceptible to erosion. Therefore, the proposed breakwater should have adequate cavities to allow flushing of the lagoon and at the same time absorb wave energy efficiently. For these reasons, breakwater with large rock boulders is proposed for the east and west. Aesthetics is also important, especially on the western side where the breakwater would be closer to the shore than the eastern side. Therefore, a structure that stands below the high tide (about 0.6m from MSL) is proposed for the western side. The eastern side has high swells and to combat the impact of high amplitude waves on this side, the height of the breakwater is considered to be at least 1.2m above mean sea level.

Sedimentation or fine silt in the water column due to regular beach nourishment is also an ever increasing cause for concern. Therefore, it is important to minimize the frequency of beach nourishment and the best way to achieve this would be to have structural protection, especially offshore breakwaters.
Figure 2.5: Proposed project components

**PARADISE COASTAL PROTECTION OPTIONS**

**WESTERN SIDE OPTIONS**
- **Option 1/Type 1:** Offshore breakwater
- **Option 1/Type 2:** Semi-submerged offshore breakwater

**EASTERN SIDE OPTIONS**
- **Option 1/Type 1:** Offshore breakwater
- **Option 1/Type 2:** Offshore breakwater

Proponent: Paradise Island Resort
Consultant: Ahmed Zalidi (EIA08/07)
3 The Setting

The project takes place in the Maldives environment. Therefore, the extent to which the project conforms to existing plans, policies, guidelines, regulations and laws of the Maldives needs to be considered. Hence, this section will look at the context in which the project activities take place and the legal and policy aspects relevant to those activities. It is important to note that the project is of a local scale but it also has some bearing at a national context.

3.1 Applicable Policies, Laws and Regulations

There are few environmental policies, regulations and standards of specific relevance to coastal protection or environmental protection related to coastal protection activities. The main legal instrument pertaining to environmental protection is the Environmental Protection and Preservation Act (Law No. 4/93) of the Maldives passed by the Citizen's Majlis in April 1993. This Act provides the Ministry of Environment with wide statutory powers of environmental regulation and enforcement. This umbrella law covers issues such as environmental impact assessment, protected areas management and pollution prevention. The following clauses of the Environmental Protection and Preservation Act (Law No. 4/93) are relevant to the project:

Clause 5a: An impact assessment study shall be submitted to the Ministry of Housing and Environment before implementing any development project that may have a potentially detrimental impact on the environment.

Clause 5b: The Ministry of Housing and Environment shall formulate the guidelines for EIA and shall determine the projects that need such assessment as mentioned in paragraph (a) of this clause.

Clause 6: The Ministry of Housing and Environment has the authority to terminate any project that has an undesirable impact on the environment. A project so terminated shall not receive any compensation.

Clause 9a: The penalty for minor offences in breach of this law or any regulations made under this law, shall be a fine ranging between Rf5.00 (five Rufiyaa) and Rf500.00 (five hundred Rufiyaa), depending on the actual gravity of the offence. The fine shall be levied by the Ministry of Housing and Environment or by any other government authority designated by that Ministry.

Clause 9b: Except for those offences that are stated in (a) of this clause, all major offences under this law shall carry a fine of not more than Rf100,000,000.00 (one hundred million Rufiyaa), depending on the seriousness of the offence. The fine shall be levied by the Ministry of Housing and Environment.
Clause 10: The government of the Maldives reserves the right to claim compensation for all damages that are caused by activities that are detrimental to the environment. This includes all activities mentioned in Clause No. 7 of this law as well as those activities that take place outside the projects that are identified here as environmentally damaging.

3.2 EIA Regulations

The EIA Regulations, which came into force in May 2007 has been developed by the powers vested by the above umbrella law. The EIA Regulations have been the basis for Environmental Impact Assessment in the Maldives and since its advent it had helped to improve the quality of EIAs undertaken in the country. Today, registered consultants are required to sign EIAs, the EIAs are reviewed by two independent reviewers and final decision is based on the reviews. This EIA would also be subject to these requirements and review criteria.

Schedule D of the EIA Regulations lists the different environmental projects that require an Environmental Impact Assessment study and coastal protection has been included in the list. The EIA Regulations sets out the requirements for the contents of Environmental Impact Assessment reports in Schedule E and format for monitoring reports have been given in Schedule M. Therefore, these requirements have been taken into consideration in preparing this EIA report.

3.3 Regulation on Protection and Conservation of Environment in the Tourism Industry

The Regulation on the Protection and Conservation of the Environment in the Tourism Industry came into effect on 20 July 2006. Clause 2.1 of the regulation requires that any coastal work in a resort including beach enhancement by pumping sand should be undertaken by obtaining permission from the Ministry of Tourism. Clause 2.4 requires that an EIA report be submitted to the Ministry in order to carry out the works. As part of submission for coastal modifications under clause 2.3, the Ministry of Tourism has also prepared an Application Form for Coastal Modifications. This form has been submitted to the Ministry as a first step towards the application.

Clause 2.14 is also of relevance to this project in that it requires that jetties must allow free flow of water and sand beneath it. Clause 2.15 requires that no coral be used in the construction of coastal protection structures.
3.4 Regulation on Coral, Sand and Aggregate Mining

This regulation addresses sand mining from uninhabited islands that have been leased; sand mining from the coastal zone of other uninhabited islands; and aggregate mining from uninhabited islands that have been leased and from the coastal zone of other uninhabited islands.

3.4.1 Ban on coral mining

Coral mining from the house reef and the atoll rim has been banned through a directive from the President's Office dated 26th September 1990. Under Article 7 (c) of the Regulation on Sand and Coral Mining issued by the Ministry of Fisheries, Agriculture and Marine Resources (MOFAMR) on the 13th of March 2000, it is an offence to mine sand or coral from the beach, lagoon or reef of any inhabited island and islands leased for the purpose of building a tourist resort. Coral would not be mined and used in this project.

3.5 Environmental Permits required for the Project

3.5.1 EIA Decision Statement

The only environmental permit to initiate proposed works would be a decision regarding this EIA from the Environmental Protection Agency (EPA). The EIA Decision Statement, as it is referred to, shall govern the manner in which the project activities must be undertaken. This EIA report assists decision makers in understanding the existing environment and potential impacts of the project. Therefore, the Decision Statement may only be given to the Proponent after a review of this document following which the EPA may request for further information or provide a decision if further information is not required. In some cases, where there are no major environmental impacts associated with the project, the EPA may provide the Decision Statement while at the same time requesting for further information.
4 Methodology

The section covers methodologies used to collect data on the existing environment. The key environmental and socio-economic components of the project that were considered are coastal environment, social and economic environment and coral reef areas as the marine environment. Hence, data collection was undertaken for the above components. In order to study the existing environment of the island, the following data collection methodologies were used during the field visit to Paradise on 5-6 June 2010.

4.1 Methods of data collection

Conditions of the existing environment of the study area were analysed by using appropriate scientific methods. Field surveys were undertaken to get further understanding of the existing environment of the island. Field surveys were carried out during field visit to the island in June 2010 to collect baseline data. Before the trip was undertaken all existing information regarding the project and site was gathered.

The following components of the existing environment were assessed.

- Coastal environment including coastal protection structures, longshore and offshore currents and levels
- Marine water quality
- House reef at the proposed locations
- Stakeholder views and grievances

4.1.1 Marine water quality

Marine water quality around the proposed dredging area was tested on site by using YSI water quality logger which can measure pH, electrical conductivity (salinity and TDS) and dissolved oxygen (DO). These measurements were done for house reef location as well as the jetty end. Samples were also taken from these locations for further testing at the laboratory for turbidity, BOD, COD, phosphates and nitrates.

4.1.2 Bathymetry and Ocean Currents

Bathymetry of the lagoon around the island, especially project specific areas was done using Sonarmite echosounder connected to Trimble GeoExplorer XH differential GPS. The results of the bathymetry are given in the Appendix while drogue lines are shown in Figure 5-5. A purpose built drogue with a GPS was made to create spaghetti diagrams of the ocean currents. Several drogues were done at different locations.
4.1.3 Condition of the house reef

Methodologies adopted for these surveys are internationally accepted and widely used to assess the status of coral reefs in the Maldives as well. Line intercept transect and visual observations of the reef and lagoon of the proposed development areas were carried out according to the methods described in English et al (1997). A Line Intercept Transect (LIT) was done at the western side reef flat area where the proposed breakwater will be constructed. Qualitative visual surveys were conducted for the dead reef flat area on the eastern side.

4.1.4 Stakeholder consultations

In the Terms of Reference for this EIA, stakeholder consultations is limited to the discussions held during the scoping meeting and consultations with resort management, and any other relevant parties. During the scoping meeting, ideas were shared on the possible options for coastal protection.
5 Existing Environment

This section covers the existing environmental conditions of the project site. The key environmental, social and economic components of the project under consideration are described below.

Vital Environmental, Social and Economic Components

- Topography
- Marine water quality
- Existing coastal defences
- Coastal resources
- Marine resources and protected marine areas
- Health and safety
- Employment and other economic benefits

Data was collected using internationally recognized methodologies discussed in the previous section.

5.1 Existing Coastal and Marine Environment

This section will describe the topography, marine water quality, existing coastal defences, seabed, beach and other coastal resources as well as marine resources and protected marine areas in the vicinity, especially potential impact zones of the project.

Paradise Island has undergone several coastal changes over the past including reclamation of the original island, construction of breakwaters using reclaimed fill material and rock boulders as well as regular beach nourishment by sand pumping from nearshore areas. As a result, the coral reef in the proposed project areas and possibly all around the island is literally dead. These features are separately looked at in the following subsections.

5.1.1 Formation and Topography

Paradise has a land area of about 40.25 acres inside its vegetation line. The island is about 0.8m above mean sea level on the south western side and about 0.9m above mean sea level on the northern side. The island is in a reef located on North West of Male’ about 12km away. There are 03 islands located in the reef; Paradise on the southern end of the lagoon, the local island of Himmafushi on the northern end with Soneva Gili resort in between. Paradise used to be a sandbank, which was later reclaimed to develop the existing resort of Paradise. The southern rim of the reef system is exposed to the swells coming from the east, through a 3.5km wide channel between paradise and full moon island resort. The eastern side, especially the southeast of the reef is prone to long-period swells from the Indian Ocean. The strong current in the channel together with the influence of swells
within the channel probably creates the dynamic conditions observed in the southeast and southwest sides of the island. Most islands in the Maldives are formed from sand produced and delivered to the coast by healthy coral reefs mainly by the action of waves and reprofiled by the action of longshore currents. Since Paradise was reclaimed from the sand dredged from the lagoon, the eastern reef of the island was observed to be damaged due to extreme silt exposure during dredging works. The natural protection provided by the healthy reef is ineffective at present.

Sediment deposition occurs mainly during the southwest monsoon while reprofiling of the beaches occurs during the northeast as well as the southwest monsoon. As a result sand accumulation is greatest on the northern and western side of the island. Due to the formation and shape of the reef and coastal structures including breakwaters placed on the southern rim of the lagoon, accumulation of sand is higher in the southwest of the arrival jetty and the south eastern region which is protected by the south eastern breakwater. The breakwaters on the southern half of the island also affects natural sediment movement to a great extent compared to other coastal structures such as arrival jetty, beach bar, and water villas, which have very little impact on the natural flow of sand due to longshore current. The breakwater, being a solid structure constricts the flow creating strong currents in the channel between the island and the breakwater, which takes away beach material to the trajectories of the current in the channel. As discussed earlier, the breakwater around the southern half also creates strong currents on the northern end of the island making the sand spit here susceptible to erosion. Hence, sand mainly moves along the northern shoreline from the west to the east and vice-versa according to the monsoons.

5.1.2 Coastal Resources

Lagoon exists on all sides of Paradise. However, the northeast and southeast lagoon is very shallow with an average depth of 1.2m below mean sea level. The south side has a 2m (below mean sea level) deep narrow channel between the island of paradise and the break water on the southeastern side. In general, the lagoon around the island is quite shallow with most of the areas less than 2m below mean sea level except for the dredged areas in different locations of the lagoon. For the use of supply vessels to Soneva Gili, there is a narrow channel dredged to a depth of 1.5m (below mean sea level) between Paradise and the neighbouring resort of Soneva Gili. This is just next to the boundary between the two islands. This represents a dredged area of 89,378.75sqm from entrance channel to the supply harbour. The impact of this on the coastline of the two islands have not been documented.

The lagoon consists of medium-fine silt like sandy floor, and rocks and rubble especially at the western region. There is also a lot of fines and low level growth of algae. The water quality is considered to be good with low levels of phosphates and nitrates. There is no sign of faecal contamination of the lagoon surrounding Paradise.
Bedrock from the reef flat from south eastern breakwater to water villas were removed and placed on the reef edge as breakwater to reduce wave and wave-induced longshore currents. However, this is quite low and may not be effective. Only large coral boulders remain once the wave action here dismantled the initial breakwater structure.

![Figure 5-1: Corals from the reef flat placed as a breakwater behind the water villas](image)

There is no distinctive variation in beach composition around the island. The beach material is mainly composed of loose skeletal carbonate sediments, mainly fragments of green calcareous algae *Halimeda* sp., encrusting and branching red algae, molluscs, foraminiferans, echinoderms and bryozoans. A minimum of 100m of white sandy beach exists on the northern tip of the island whereas the southern side has no natural beach but comprises of compacted sand from the dredging with rubble on the narrow natural beach line.

### 5.1.3 Coastal Defences and Borrow Pits

In order to protect the coastal area of the island there are about four breakwater structures. About 640m of reef flat on the southeastern corner of the island representing an area of 30,003.48m$^2$ of reclaimed material placed up to about 1.95m above mean sea level (MSL) by dredging the lagoon and part of the reef flat in this area has been made to form a breakwater. Similarly, an area of 23,226.05m$^2$ has been reclaimed to about 1.4m above MSL on the south western side of the lagoon. Between these two breakwaters, approximately 121m long rock boulder breakwater at a height of approximately 1.5m above from MSL has been placed on the southern rim of the reef. Removed coral boulders and bedrock from the reef flat is placed on the eastern reef edge near the water villas.

There are three borrow pits from which sand has been pumped for beach nourishment in the past. The northwest lagoon has the largest borrow pits of 16,500m$^2$ followed by 2,600m$^2$ pit on the southeast and 1,600m$^2$ on the northeast. The latter two pits have average depths of about 3.5m while the largest pit has about 5m depths on average.
Figure 5-2: Existing coastal protection works in the project area

5.1.4 Marine Resources

Paradise has an area of approximately 150 hectares inside its reefline. The lagoon area has a lot of rubble content on the south and mainly fine sand on the north. Healthy patches of Coral Branching (Seriatopora hystrix) were observed near the dredged area located at the north eastern side of the island. The reef-flat and near shore area
on the west side was mainly sandy with relatively poor diversity of species. The shallow lagoon on the western side forms a uniform sandy floor apart from the dredged areas. This lagoon on the western side is followed by a shallow reef flat before sloping steeply outside the atoll basin. Reef slope condition on the atoll-basin ward reef has an intermesh of coralline cover and fish and other marine life. The results of the LIT undertaken in this area is given below:

The reef flat on the northeast is very poorly developed with hardly any live coral cover in the area. This is due to the presence of the extensive shallow reef-flat (300m wide) which was dominated by sand, rubble, silt and un-consolidated rock. Corals namely Porites spp., Favites spp. were the dominant live coral types found in this area where the percent cover of such Porite species was less than 1. The reef slope is generally steep dropping off with conspicuous groups of reef fishes including parrot fish and pomacentrids. The reef slope on the eastern side was not easily accessible. Therefore, surveys were not carried out for this area. It should be noted that the proposed project would not have any sedimentation on the reef slope areas given that the wave-induced currents would take the sediment onshore rather than offshore.
5.2 Climate and Coastal Dynamics

The climate of the Maldives varies slightly from North to South of the country. Long term meteorological data for Hulhulé is available and has been used in this study.

The Maldives, in general, has a warm and humid tropical climate with average temperatures ranging between 25°C to 30°C and relative humidity ranging from 73 per cent to 85 per cent. The country receives an annual average rainfall of 1,948.4mm. Table 5-1 provides a summary of key meteorological findings for Hulhulé, which is also generally representative of the Maldives.

Table 5-1: Key meteorological information

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Rainfall</td>
<td>9.1mm/day in May, November</td>
</tr>
<tr>
<td></td>
<td>1.1mm/day in February</td>
</tr>
<tr>
<td></td>
<td>1900mm annual average</td>
</tr>
<tr>
<td>Maximum Rainfall</td>
<td>184.5 mm/day in October 1994</td>
</tr>
<tr>
<td>Average air temperature</td>
<td>30.0°C in November 1973</td>
</tr>
<tr>
<td></td>
<td>31.7°C in April</td>
</tr>
<tr>
<td>Extreme Air Temperature</td>
<td>34.1°C in April 1973</td>
</tr>
<tr>
<td></td>
<td>17.2°C in April 1978</td>
</tr>
<tr>
<td>Average wind speed</td>
<td>3.7 m/s in March</td>
</tr>
<tr>
<td></td>
<td>5.7 m/s in January, June</td>
</tr>
<tr>
<td>Maximum wind speed</td>
<td>W 31.9 m/s (115km/h) in November 1978</td>
</tr>
<tr>
<td>Average air pressure</td>
<td>1012 mb in December</td>
</tr>
<tr>
<td></td>
<td>1010 mb in April</td>
</tr>
</tbody>
</table>

Monsoons of Indian Ocean govern the climatology of the Maldives. Monsoon wind reversal plays a significant role in weather patterns. Two monsoon seasons are observed: the Northeast (Iruvai) and the Southwest (Hulhangu) monsoon. Monsoons can be best characterized by wind and rainfall patterns. These are discussed in more detail in the following subsections. The southwest monsoon is the rainy season which lasts from May to September and the northeast monsoon is the dry season that occurs from December to February. The transition period of southwest monsoon occurs between March and April while that of northeast monsoon occurs from October to November.

5.2.1 Wind

Wind has been shown to be an important indirect process affecting formation, development and seasonal dynamics of the islands in the Maldives. Winds often help to regenerate waves that have been weakened by travelling across the reef and they also cause locally generated waves in lagoons. Therefore winds are important here, as being the dominant influence on the hydrodynamics in the project area (waves and currents). With the reversal of winds in the Maldives, NE monsoon period from December to March and a SW monsoon from April to November, over the year, the accompanying wave and current processes respond accordingly too.
The two monsoon seasons have a dominant influence on winds experienced across Maldives. These monsoons are relatively mild due to the country’s location close to the equator and strong winds and gales are infrequent. However, storms and line squalls can occur, usually in the period May to July; gusts of up to 60 knots have been recorded at Hulhulé during such storms.

![General wind rose diagram for the Maldives (source MEEW 2005).](image)

**Figure 5-3: General wind rose diagram for the Maldives (source MEEW 2005).**

The Maldives experience strong ocean winds at speed of 6m/s to 7.5m/s at a height of 10m during June, July and August (Elliott *et al.*, 2003). The southwest monsoon has the greatest impact on the project area on the west. Therefore, the beach nourishment works will be difficult to be undertaken during the proposed time period. Yet, the best period for such renovation works is during May to August which is considered the off-peak season for tourism. Therefore, it may be best if the beach nourishment works can be undertaken during the southwest monsoon. For this reason, the dredge pit on the eastern side has been chosen because it would be calmer in that area during the southwest monsoon.

### 5.2.2 Waves

Wave energy is also important for the movement and settlement of sediments and suspended solids and is also a crucial factor controlling coral growth and reef development.

Studies by Lanka Hydraulics (1988a & 1998b) on Malé reef indicated that two major types of waves on Maldives coasts: wave generated by local monsoon wind and swells generated by distance storms. The local monsoon predominantly generates wind waves which are typically strongest during May-July in the south-west monsoon period. During this season, swells generated north of the equator with heights of 2-3 m with periods of 18-20 seconds have been reported in the region. Local wave periods are generally in the range 2-4 seconds and are easily distinguished from the swell waves. Swell waves have the greatest impact on the proposed breakwater or project area on the eastern side while wind-generated waves during the southwest monsoon would have the greatest impact on the project area on the west.
The eastern side of Paradise is mainly exposed to “regenerated oceanic swells”. The swells that break on the reef loses most of their energy on the reef. However, the reef as it is only acts as a submerged breakwater, especially during high tides, do not absorb/reflect all the wave energy, but allows partially broken waves to travel in to the shallow reef flat. These partially broken waves regenerate on the reef flat and travel across the flat until they reach the shore of the island. The characteristics of these regenerated waves depend very closely on the tide level over the reef and the magnitude of the original waves. In general, for any given deep water wave, the magnitude of the regenerated wave is higher when the tide is high. The recent tidal surge (end of July 2010) also caused the greatest impact on the eastern shoreline which affected the guest rooms too.

Distant cyclones and low pressure systems originating from the intense South Indian Ocean storms are reported to generate long distance swells that occasionally cause flooding in Maldives (Goda, 1988). The swell waves that reached Malé and Hulhulé in 1987, thought to have originated from a low pressure system of west coast of Australia, had significant wave heights in the order of 3 metres. According to the annual wave height data reported by the US Navy for Area 12, a region containing southern Maldivian Atolls, indicate that long period waves with heights above 2m and 3m occur for 22% and 3% of the time respectively and arrive mostly from the south-east, south-west and westerly quadrants during the SW monsoon (see Environmental Assessment report of Sun Island Resort 1995). The US Navy data also suggest that the majority (67%) of long waves over 2m in height are from the south and southeast.

5.2.3 **Tides**

Tidal influence on net longshore current is also expected to be low due to the superficial nature of the lagoon. Tides affect wave conditions and wave-generated and other reef-top currents. Tide levels are believed to be significant in controlling amount of wave energy reaching an island, as no wave energy crosses the edge of the reef at low tide under normal conditions. In the Maldives, where the tidal range is small (1m), tides may have significantly important influence on the formation, development, and sediment movement around the island.
Tides also may play an important role in lagoon flushing, water circulation within the reef and water residence time within an enclosed reef highly depends on tidal fluctuations. However, there is greater flushing of the lagoon from the swell induced currents for Paradise Island than tidal currents. Therefore, it may be necessary to ensure that swell-induced flushing as well as tidal flushing is not obscured severely.

5.2.4 Currents

Studies on current flow within a reef flat in Male’ Atoll suggests that wave over wash and tides generate currents across the reef platforms, which are also capable of transporting sediments (Binnie Black & Veatch, 2000). However, available information suggests that tidal currents are not strong due to small tidal range.

Generally current flow through the Maldives is driven by the dominating two-monsoon season winds. Westwardly flowing currents are dominated from January to March and eastwardly from May to November. The change in currents flow pattern occurs in April and December. In April the westward currents flow are weak and eastward currents flow will slowly take place. Similarly in December eastward currents flows are weak and westward currents will take over slowly.

Studies on current flow process within a coral atoll have shown that waves and tides generate currents across the reef platforms, which are capable of transporting sediments on them. Currents, like waves are also modified by reef morphology. Under low-input wave conditions (0.5m heights) strong lagoonward surge currents (>60cm/sec) are created by waves breaking at the crest. Studies on current flow across reef platforms have shown that long-period oscillations in water level cause transportation of fine-grained sediments out of the reef-lagoon system, while strong, short duration surge currents (<5sec.) transport coarse sediments from the breaker zone to seaward margin of the backreef lagoon. Always sediment accumulates at the lee of high-speed current zones. Generally zones of high current speed (jets or rips, 50-80cm/sec) are systematically located around islands.

Drogues were done at different locations around the island and at the entrance channel as shown in Figure 5-5 in order to assess the movement of the water body around the island in order to determine seasonal current movement and sediment transport patterns around the island. The drogues indicated that the main component of longshore current around Paradise is due to swells from the east, i.e. a dominant westerly current. On the day of the field visit (6-7 July 2010), the wind was in an easterly direction, i.e. from the west. However, given the strength of the water body movement in a westerly direction, owing to swells mainly, it has been observed that the westerly current is dominant with about 0.28m/s at the entrance channel and out. There is also a moderate current at the northeast corner of the island. The currents are strongest on the south in the narrow channel between the reclaimed breakwater and Paradise Island. There is a similar current on the north between Paradise Island and Soneva Gili, which also causes a funneling effect for the body of water moving between these two
islands. The current in the south end as well as the north end is of similar magnitude of about 0.4m/s in a westerly direction. The safety signboard placed on the northern thundi points to this fact and advises Guests to avoid swimming in the channel. It is expected that the net westerly current will be even stronger during the northeast monsoon. Unfortunately, there is no site specific data to support this.

As has been observed in past studies, sediment generally accumulates at the lee of high-speed current zones. So, a great deal of sand accumulation occurs or is expected to occur on the western side. Currents induced by short period wind waves were observed only on the northwestern side during the field visit. This causes sediment movement on the northwest side and formation of the sand spit on the northern end. Due to the wave-induced currents here, it is quite possible that sand is lost from the western beach into the dredge pit on the northwest end. However, further studies are required to justify such movement and future monitoring shall focus on gathering such data at adequate intervals.

### 5.2.5 Marine Water Quality

The marine water quality tested at the two locations at project site is given in Table 5-2. The water quality results given in this table shows very little variation at the two locations. Both locations have water at its pristine state and does not show any signs of degradation due to biological or chemical contamination of any sort whatsoever.

**Table 5-2: Water quality results (7 July 2010)**

<table>
<thead>
<tr>
<th>Unit</th>
<th>WQ1</th>
<th>WQ2</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS Location</td>
<td>339207.8353E</td>
<td>339923.0326E</td>
</tr>
<tr>
<td>WGS1984, Zone43</td>
<td>474115.6669N</td>
<td>473641.9203N</td>
</tr>
<tr>
<td>Temperature °C</td>
<td>28.42</td>
<td>28.25</td>
</tr>
<tr>
<td>Salinity mg/l</td>
<td>34,530</td>
<td>34,760</td>
</tr>
<tr>
<td>DO mg/l</td>
<td>7.92</td>
<td>7.01</td>
</tr>
<tr>
<td>pH</td>
<td>7.94</td>
<td>8.11</td>
</tr>
<tr>
<td>BOD mg/l</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Nitrate mg/l</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Phosphate mg/l</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Figure 5.5: Illustrated representation of site conditions.
6 Stakeholder Consultations

Stakeholder consultations are limited to the discussions held during the scoping meeting and the staff and management of Paradise Island Resort.

6.1 Consultations with the Management and Staff

Discussions were held with the General Manager and Assistant Manager as well as the RESMAP Coordinator. Also, Managing Director at Malé Office provided relevant and useful information including details of the damages due to the tidal surge in late July 2010. Staff at the Water Sports Center also assisted in the field work and provided relevant information. The resort Management outlined the different options they had in mind and showed the areas that are prone to erosion. The areas of concern were the beach on the western side from the arrival jetty up to the Water Sports Center to the north. This is about 250m of beach of which the area at the swimming pool is most severely affected. It was believed that there is a current from the entrance channel that takes away the sand at this location. The most important area showed by the Management during the initial visit by the Environment Consultant was the beach area just below the water villa jetty. On either sides of this jetty, there is erosion. This is thought to be ever present but exacerbated due to the anthropogenic impacts of the recent scraping of the reef flat to form a breakwater on the eastern reef flat from coral rubble and boulders. At present, the rooms in the area are under threat of erosion and sandbags have been placed to protect from further erosion. The Management also raised concern that regular sand pumping is a costly process that also causes high level siltation in the lagoon and that it is undesirable to undertake continuous beach nourishment.

6.2 Scoping Meeting

The scoping meeting for Paradise was held on 6 July 2010 at Environmental Protection Agency. In the scoping meeting, Ahmed Ali Manik of Paradise Island, who is also in charge of the Water Sports provided details of the different options that have been considered. According to Ahmed, the breakwater option would be the most suitable. This was also supported by Paradise Manager, Gaisar Naseem. Ahmed also discussed the reasons for undertaking the project and details of the methodologies that would be adopted including the use of a ramp running over the reef flat to offload the material from the barge. The participants also discussed about the nature of the existing solid breakwaters and the dredged channel between Soneva and Paradise. Ahmed said that the channel could be responsible for the loss of sand from Paradise beaches. However, the consultant, Ahmed Zahid stated that it would have little or negligible impact on the beaches of Paradise. EPA indicated that the impacts of any of these projects have not been documented.
6.2.1 List of Participants

Following are the names and designation of persons who participated in the scoping meeting.

<table>
<thead>
<tr>
<th>Name</th>
<th>Office</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ibrahim Naeem</td>
<td>EPA</td>
<td>Director</td>
</tr>
<tr>
<td>2. Fathimath Reema</td>
<td>EPA</td>
<td>Assistant Director</td>
</tr>
<tr>
<td>3. Aishath Faznee</td>
<td>EPA</td>
<td>Environment Officer</td>
</tr>
<tr>
<td>4. Gaisar Naseem</td>
<td>Paradise Island</td>
<td>Manager</td>
</tr>
<tr>
<td>5. Ahmed Ali Manik</td>
<td>Paradise Island</td>
<td>Director</td>
</tr>
<tr>
<td>6. Ahmed Zahid</td>
<td>Sandcays</td>
<td>Consultant</td>
</tr>
</tbody>
</table>
7 Impacts and Mitigation Measures

This section covers potential environmental impacts due to the construction of breakwaters on the west and eastern sides of Paradise. The section also describes the mitigation measures for each identified impact. Methods of identification of potential impacts and possible mitigation measures have been described. Before proceeding on to the potential impacts from the project, it is considered worthwhile looking at the existing environmental concerns so that cumulative and residual impacts of the proposed project are better understood.

7.1 Impact Identification

Impacts on the environment from various activities of the proposed project have been identified through:

- A consultative process within the EIA team and the Proponent
- Purpose-built checklists
- Existing literature and reports on similar developments in small island environments and other research data specific to the context of the Maldives
- Baseline environmental conditions described in Chapter 5
- Consultants experience of projects of similar nature

Possible negative impacts on the environment have been considered in worst-case scenario to recommend mitigation measures in the best possible ways so that these impacts would be minimized and perhaps eliminated in the implementation phase. Potential positive impacts of the project have been considered on a moderate note so that the negative impacts are not ignored, especially during planning as well as implementation of the project.

7.2 Identifying Mitigation Measures

Where an impact identified can be mitigated, mitigation measures are identified and discussed along with the identification of the impact. The mitigation measures proposed will help to alleviate or eliminate environmental problems before they occur. Mitigation measures are important because if identified impacts are significant and/or important, it would be necessary to identify and implement mitigation measures. Mitigation measures are selected to reduce or eliminate the severity of any predicted adverse environmental effects and improve the overall environmental performance and acceptability of the project. Where mitigation is deemed appropriate, the proponent should strive to act upon effects, in the following order of priority, to:

1. Eliminate or avoid adverse effects, where reasonably achievable.
2. Reduce adverse effects to the lowest reasonably achievable level.
3. Regulate adverse effects to an acceptable level, or to an acceptable time period.
4. Create other beneficial effects to partially or fully substitute for, or counter-balance, adverse effects.
7.3 Existing Concerns

There are some existing environmental concerns apart from the erosion on the western and eastern sides. They include the solid breakwater made from dredged material placed on the reef flat on the southern half of the island, harbour access channel on the southwest, the borrow pits from which sand has been borrowed for beach nourishment, partial removal of seabed and coral to construct a breakwater on the eastern side and the channel on the north of Paradise which has been dredged by Soneva Gili for access by their supply vessels. These are anthropogenic impacts which are discussed in a bit of detail in this section.

It is noteworthy, that Paradise Island does not have any onshore structures except a wall that separates the supply harbour area from the Guest beaches. The absence of onshore structures gives the island beach environment, especially on the north, the natural aesthetic appeal.

7.3.1 Dredging and Reclaimed Breakwaters

A total of about 12.5 hectare area has been dredged including the supply harbour. This dredging has been done from the entrance up to the end of the reclaimed breakwater on the southeast side. The supply harbour is engulfed into the island at the southern end of the island. The average depth in the dredged area from the entrance to the supply harbour is about 4m while the depth in the channel on the southern and south-south-eastern side is about 2m. The water in the harbour appears to be of poor quality. Material from the dredging has been used to reclaim the island and to created the sandbed breakwaters on the southern half. These reclaimed breakwaters help to keep the strong waves breaking on this area away from the island beaches. However, there is poor flushing of the island lagoon as a result of which the lagoon areas including the southwest and southeast areas which are used by tourists also have been highly silted. However, an opening between the two solid breakwaters on the south-southwest of the island provides water circulation which minimizes the siltation and water quality deterioration. This gap is further protected by a 1.5m high breakwater made of rock boulders, which unlike the solid breakwaters caters for adequate circulation through the number of cavities in the structure.

7.3.2 Borrow pits

There are three borrow pits of which the largest pit is on the northwest side and the smallest on the northeast. All the pits have signboards indicating that it is deep and swimmers are to avoid the area. Of these three pits, the borrow pit on the northwest is quite close to the sandspit, especially during the northeast monsoon when the sand spit moves closer to the sandspit. Given that the swell-generated currents from the east as well as the wind-generated currents from the west converge close to this pit forming eddies in the area, it is possible that sediment loss from the beaches is mainly into this pit, which is acting as a sediment sink. However, this is has to be confirmed from long term monitoring.
7.3.3 **Rubble mound breakwater on the eastern side**

A rubble mound breakwater was recently created on the eastern and southeastern reef flat as part of the renovation works following damage due to the tsunami of December 2004. This breakwater was made by partial removal of seabed and coral from the reef flat here to create the rubble-mound breakwater. Apart from the large coral boulders, the breakwater had been collapsed due to strong wave action here.

7.3.4 **Channel between Soneva and Paradise**

There is a channel from the reef to the supply jetty of Soneva Gili which was made by dredging close to the boundary line between Soneva Gili and Paradise. It is believed that this channel could cause severe erosion on Paradise Island. While this impact is possible, the significance of this impact would be quite small. It is quite unlikely that the channel could cause severe erosion on the beaches of Paradise. However, there may be some degree of sand movement towards the channel and sinking into the channel. Such analysis requires long term data. There is no long-term site specific data related to this.

7.4 **Constructional Impacts and Mitigation Measures**

Breakwater construction and sand pumping to replenish eroded beach areas are the key components of the proposed project. The degree of adverse environmental impacts caused by this project depends on the timing, methodologies, and distance of ecologically sensitive areas or species and economically important areas. The impacts of the different project components are considered in the following subsections and mitigation measures are provided for those impacts which can be mitigated.

7.4.1 **Site mobilisation and demobilisation**

Site mobilisation will involve the mobilisation of excavators, lorries or dump truck, and workforce to site. In addition, the delivery of materials to site would also be part of mobilisation. The most significant of this would be the delivery in 5000ton barge with rock boulders to the site. It is estimated that about 18,000 tons of rock boulders will be mobilized to site, of which about 10,000 tons would be to the eastern side. Two loads will be delivered to the eastern side and two more to the western side. Excavators would be brought to the site in landing craft or small barges through existing dredged channels. Therefore, there will not be a need for any access channel dredging. However, during access to the eastern reef flat as well as the western reef flat, the excavators may encounter few live coral colonies. This impact would be insignificant.
7.4.2 Offloading rock boulders/breakwater construction

The big barge will not be able to and would not come closer to the reef. If small barges were to be used, they would also be anchored to offshore anchors during the unloading process. Therefore, there will not be any impact on the reef from the operations of any of the barges. Excavators working on the reef flat would not get closer to the live reef flat areas but would work on the dead reef flat areas only. Therefore, the impact on the reef from the machinery would be minor. In order to avoid excavator movement close to the live reef areas of the reef flat, it may be necessary to have a ramp between the barge and the reef flat area on which the breakwater will be constructed. According to Ahmed Ali Maniku, this has been done in some of the projects undertaken by Villa in the past.

Another impact during offloading of rock boulders that has been observed in some worksites in the past is the fine dusty sand that comes with the boulders. This dark humus sand is purposely kept on barges to minimize slipping of the boulders. However, when boulders are offloaded using excavator, the excavator takes this humus material with the boulders and dumps it into the marine environment. This degrades the quality of the sand in the area and water quality too. This can be avoided by taking appropriate mitigation measures such as not using such dust or using local sand instead of such dust and by taking extra precaution when the excavator places the stones in the water.

7.4.3 Machinery and Aesthetics

Since the works occur in a resort and close to another high-end resort, there will be visual or aesthetic impacts that should be clearly identified and dealt with accordingly. These impacts include:

1. The sight of the works or the visual impact of excavators, barges and other heavy machinery in the area
2. Noise from the machinery, especially the movement of rock boulders on the barge
3. Fuelling excavators and other machinery, which have the potential for spillage in to the environment
4. Siltation and resuspension of fines due to excavator movement in the lagoon and reef flat
5. Physical damage to the reef from equipment mobilisation
6. Lighting, when working at night, may be a nuisance to neighbouring resort

When the works are undertaken on the eastern side, these impacts are easier to mitigate. However, given that the breakwater on the west is just next to the arrival jetty and in front of the beach villas on the western side as well as the public area including swimming pool, the impacts would be really felt badly. The works on the western side can be seen and heard from the water villas of Soneva Gili on the north of the proposed worksite. Therefore, special attention must be paid to manage the civil works on the western side.

In order to avoid the afore-mentioned environmental impacts arising from the use of machinery, the following mitigation measures are suggested.
1. Scaffolding or separation of the work area so that they could not be accessed or seen by tourists
2. Fuelling of the machineries would not be done on the beach or in the marine environment but in the service harbour or some other area
3. Work will not be undertaken at night unless it is absolutely necessary. If it were necessary, works will be done under low light conditions. No flood lights would be used.
4. Excavator movements will be carefully planned to minimize excavator movement.
5. Neighbouring resort would be informed about the works
6. Noise would be kept low and no noisy activities would be undertaken at night, if any works were to be undertaken at night.

7.4.4 **Sand pumping and beach nourishment**

The proposed pumping of sand to the eastern side and northwest of the island and subsequent filling on the eastern and western shoreline areas would cause deterioration of water quality in the immediate vicinity and to some extent nearby areas depending on the direction and magnitude of the currents in the area. This is a short term impact given that the silt would be moved by the longshore and offshore currents on the northern half which does not have stagnant conditions like the southwestern side of the island. The impact of the sand pumping on the environment would be mainly that of fine silt spreading around the fill area and areas onto which the fines have been spread. The fines could accumulate in more stagnant areas in the vicinity and this could have some problems due to resuspension associated with it especially during the operational phase. This is the case at the southwestern side where the lagoon floor has quite a high degree of sediment settled on the seabed. However, given that the proposed borrow areas are on the eastern side which would take sediments towards the north end where the strong current in the channel would disperse the sediments quickly, the impact of silt retention on the seabed would be minimal. This is based on the longshore currents measured during the field mission undertaken in July 2010. It should also be mentioned that sand pumping from the eastern side would not cause siltation or sedimentation on live corals as there are no live coral colonies in the vicinity except, may be, a few porites.

The creation of several sand borrow pits would also cause dangers to swimmers/tourists. Therefore, it is important to dredge or pump sand from one single location and avoid all other locations. Although the two locations on the eastern side have been proposed for sand pumping, it is advisable to pump sand from the small borrow pit on the northeast and preferably fill the one on the southeast side. The northeast location is closer to the two eroding areas and also sand can be stockpiled on the northern thundi area where there are no guest rooms.
7.5 Operational Impacts and Mitigation Measures

7.5.1 Breakwaters

The impact of proposed breakwaters would be mainly related to changes to hydrodynamics and sand transport. The impact on sand transport around the island would be a significant impact but a desirable one. Presently, during the northeast monsoon, the eastern side beach is prone to the devastating effects of long period swells combined with short period wind waves causing erosion in the unprotected beach area on the east. This erosion is also present to some extent during the southwest monsoon due to the effects of swell waves. The eastern reef flat have been recently been scraped to construct a rubble mound breakwater. Therefore, the natural protection afforded by the reef flat previously has also been affected making the beaches more susceptible to erosion. Therefore, the proposed breakwater using rock boulders would provide protection from swell and wind waves. This would be the main impact of the proposed breakwater. Since it is an emerged structure, there would be some aesthetic impact, however, the use of natural stones (rock boulders) minimizes this impact considerably. Also, the structure is not solid and has several voids, thereby absorbing wave energy and helping to minimize the magnitude of flow or currents in its lee while at the same time allowing the water to flow through it helping circulation of the lagoon. The aesthetic impact is also small due to the distance from the beach to the breakwater. However, on the western side, the breakwater will be closer and easily visible from public spaces such as the bar, the restaurant, the swimming pool and the Water Sports Center. However, this side is not affected by swell waves, therefore, the design has been modified to consider aesthetic appeal. It is slightly below high tide so that wind-generated waves will break on its crest before passing on, thereby allowing the structure to absorb a great proportion of the incoming wave energy and letting water to flow. Such a design allows sedimentation in its lee (see Figure 7-1). Increasing the crest height of such a long breakwater may impound sand drifting alongshore and deny this sediment to the downdrift portion of the shoreline. Therefore, submerged structures would be worthwhile in order to reduce the sand trapping effect of the breakwaters.

Figure 7-1: The effect of submerged, rubble-mound breakwater

According to the US Army Corps of Engineers, traditional high-crested breakwaters may not be appropriate for a structure used to protect a beach or shoreline. Adequate wave protection may be more economically provided by a low-crested or submerged structure composed of a homogeneous pile of rubble or rock.
Since the rock breakwater can be dismantled and removed if necessary, the impact of constructing such breakwaters is also considered reversible. However, dismantling or removing such breakwaters would be more difficult than placing them. There are also other positive and negative impacts that can be summarised as follows:

In addition to the specific mitigation measures considered above, the following general mitigation measures are recommended:

- When and where possible, use small barges to place the breakwaters in order to minimize siltation from the movement of excavators on reef tops.
- It is important to undertake work at low tide hours if barges would not be used.
- Undertake appropriate monitoring to determine the effectiveness of the structures and any necessary design changes to incorporate unaccounted for meteorological phenomenon such as storm surges.

### 7.6 Overall Impact Evaluation

This section provides a summation of the impacts of the project components discussed above. The impacts of the project have been evaluated according to the following criteria:

1. **Magnitude (or severity):** the amount or scale of change that will result from the impact
2. **Significance:** importance of the impact. Reversibility is considered part of its significance
3. **Duration:** the time over which the impact would be felt
4. **Extent/spatial distribution:** the spatial extent over which the impact would be felt

The scales associated with the above criteria are given in the table below.
Table 7-1: Impact evaluation scale

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Scale</th>
<th>Attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnitude</td>
<td>-3</td>
<td>Major adverse</td>
</tr>
<tr>
<td>Change caused by impact</td>
<td>-2</td>
<td>Moderate adverse</td>
</tr>
<tr>
<td></td>
<td>-1</td>
<td>Minor adverse</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Negligible</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Minor positive</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Moderate positive</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Major positive</td>
</tr>
<tr>
<td>Significance/Reversibility</td>
<td>0</td>
<td>Insignificant</td>
</tr>
<tr>
<td>Impact implications/Reversibility of impact's effects</td>
<td>1</td>
<td>Limited implications / easily reversible</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Broad implications / reversible with costly intervention</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Nationwide or global implications / irreversible</td>
</tr>
<tr>
<td>Duration</td>
<td>0</td>
<td>Immediate</td>
</tr>
<tr>
<td>Duration / Frequency of Impact</td>
<td>1</td>
<td>Short term/construction period only</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Medium term (five years of operation)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Longterm/continuous</td>
</tr>
<tr>
<td>Extent/Spatial Distribution</td>
<td>0</td>
<td>None/within 1m from point of discharge/no affected party</td>
</tr>
<tr>
<td>Distribution of impact</td>
<td>1</td>
<td>Immediate vicinity/household level/developer/consumer</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Specific areas within the island/atoll/specific parties</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Entire island/atoll/nation/all stakeholders</td>
</tr>
</tbody>
</table>

Based on the above scale, an impact matrix was developed for the proposed or recommended option to determine that overall impact of the proposed project. This matrix is given in the table below.

Table 7-2: Impact matrix for the proposed project

<table>
<thead>
<tr>
<th>KEY COMPONENTS</th>
<th>Environment</th>
<th>Socio-Economic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PROJECT ACTIVITIES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breakwater on the west</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Breakwater on the east</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sand pumping and beach replenishment</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Machinery and construction equipment</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Workforce management</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breakwater on the west</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Breakwater on the east</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Periodic sand pumping and beach replenishment</td>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

KEY: M S Magnitude Significance
D E Duration Extent (spatial)
An impact potential index was then developed from the above table. The impact potential index table below represents a product of the magnitude (M), significance (S), duration (D) and extent/spatial distribution (E) given in the above table. The sum of all key component specific indexes for one activity (i.e. sum by rows) provides the Activity Potential Impact Index (API) and the sum of all activity specific indexes for one key component (i.e. sum by column) provides the Component Potential Vulnerability Index (CPVI) which gives an indication of the vulnerability of each key component to activity related impacts. The table below represent the impact potential indices for the proposed project.

**Table 7-3: Impact potential indices for the proposed project**

<table>
<thead>
<tr>
<th>KEY COMPONENTS</th>
<th>Environment</th>
<th>Socio-economic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reefs</td>
<td>LiveBait</td>
</tr>
<tr>
<td>Construction</td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>Breakwater on the west</td>
<td>0 0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Breakwater on the east</td>
<td>0 0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Sand pumping and beach replenishment</td>
<td>-0.02</td>
<td>0</td>
</tr>
<tr>
<td>Machinery and construction equipment</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Workforce management</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Operation</td>
<td>0.03</td>
<td>0.09</td>
</tr>
</tbody>
</table>

The table above indicates that the project has few negative environmental impacts during the construction phase which are not as strong as the positive outcomes of the project, as a result of which the total potential impact index for the project is considerably positive.

### 7.7 Uncertainties in Impact Prediction

The level of uncertainty, in the case of the proposed project in Paradise Island may be expected to be low due to the experience of similar projects in similar settings in the Maldives. Nevertheless, it is important to consider that there will be uncertainties and to undertake voluntary monitoring during and after project implementation as recommended in the monitoring programme given in this report.
### Table 7-4: Summary of negative impacts of proposed project

<table>
<thead>
<tr>
<th>Activity</th>
<th>Negative Impacts</th>
<th>Geographic Extent</th>
<th>Type of impact</th>
<th>Duration</th>
<th>Reversibility</th>
<th>Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction of western breakwater</td>
<td>• Sedimentation on the reef flat</td>
<td>&lt;8,000m² area</td>
<td>Direct and cumulative</td>
<td>Short term</td>
<td>Irreversible</td>
<td>Minor negative</td>
</tr>
<tr>
<td></td>
<td>• Sedimentation on the reef slope</td>
<td>Very little, esp during SW monsoon</td>
<td>Direct and cumulative</td>
<td>Short term</td>
<td>Irreversible</td>
<td>Negligible</td>
</tr>
<tr>
<td></td>
<td>• Loss of aesthetic quality</td>
<td></td>
<td>Direct</td>
<td>Long term</td>
<td>Reversible</td>
<td>Moderate negative</td>
</tr>
<tr>
<td>Construction of eastern breakwater</td>
<td>• Sedimentation on the reef flat</td>
<td>&lt;8,000m² area</td>
<td>Direct and cumulative</td>
<td>Short term</td>
<td>Irreversible</td>
<td>Minor negative</td>
</tr>
<tr>
<td></td>
<td>• Loss of aesthetic quality</td>
<td></td>
<td>Direct</td>
<td>Long term</td>
<td>Reversible</td>
<td>Minor negative</td>
</tr>
<tr>
<td>Sand pumping (borrow area)</td>
<td>• Sedimentation and sediment resuspension</td>
<td>Borrow area only</td>
<td>Direct</td>
<td>Short term</td>
<td>Irreversible</td>
<td>Minor negative</td>
</tr>
<tr>
<td></td>
<td>• Loss of beach sand/sediment sink</td>
<td>Borrow area only</td>
<td>Direct</td>
<td>Long term</td>
<td>Reversible</td>
<td>Minor negative</td>
</tr>
<tr>
<td>Beach replenishment</td>
<td>• Aesthetic quality (if compacted/not sieved)</td>
<td>Only nourishment area</td>
<td>Direct</td>
<td>Long term</td>
<td>Reversible</td>
<td>Moderate negative</td>
</tr>
<tr>
<td></td>
<td>• Sedimentation/sediment resuspension</td>
<td>Nourishment area and vicinity</td>
<td>Direct and cumulative</td>
<td>Medium term</td>
<td>Irreversible</td>
<td>Moderate negative</td>
</tr>
<tr>
<td>Site mobilization</td>
<td>• Impacts of workforce</td>
<td>Project areas only</td>
<td>Direct and cumulative</td>
<td>Short term</td>
<td>Reversible</td>
<td>Minor negative</td>
</tr>
<tr>
<td>Fuel consumption</td>
<td>• Global warming and climate change</td>
<td>Global</td>
<td>Indirect</td>
<td>Long term</td>
<td>Irreversible</td>
<td>Moderate negative</td>
</tr>
<tr>
<td></td>
<td>• Spillage into environment</td>
<td>Worksite only</td>
<td>Direct</td>
<td>Long term</td>
<td>Irreversible</td>
<td>Minor negative</td>
</tr>
</tbody>
</table>

### Table 7-5: Summary of positive impacts of proposed project

<table>
<thead>
<tr>
<th>Activity</th>
<th>Positive Impacts</th>
<th>Beneficiaries/Geographic Extent</th>
<th>Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction of breakwaters</td>
<td>• Water circulation/flushing of lagoon is not affected</td>
<td>Guests</td>
<td>Major positive</td>
</tr>
<tr>
<td></td>
<td>• Wave energy is absorbed, minimizing erosion</td>
<td>Resort management</td>
<td>Major positive</td>
</tr>
<tr>
<td></td>
<td>• Employment opportunity during construction</td>
<td>Contractor</td>
<td>Minor positive</td>
</tr>
<tr>
<td></td>
<td>• Minimal beach maintenance in the long term</td>
<td>Resort management</td>
<td>Major positive</td>
</tr>
<tr>
<td></td>
<td>• Beach access to guests</td>
<td>Operator/operator/tourism sector</td>
<td>Major positive</td>
</tr>
<tr>
<td></td>
<td>• Reduces risk of flooding coastal areas</td>
<td>Operator</td>
<td>Major positive</td>
</tr>
<tr>
<td></td>
<td>• Reduces capital cost of coastal protection</td>
<td>Operator/developer</td>
<td>Moderate positive</td>
</tr>
</tbody>
</table>
8 Alternatives

This section looks at different alternatives for the proposed project. There are two basic options: (1) leave the problem as it is (no project option), or (2) take measures to resolve the problem (undertake the project options). If the project were to continue, it would be necessary to take economic, ecological and social aspects of the project into consideration and ensure that these concerns exist within a delicate balance. Neither the economic benefits nor the social and ecological concerns can be avoided. Therefore, it is important to consider all options and ensure that the best available option(s) is/are chosen to solve the issues/problems.

The different options for the three different components considered in this report have been discussed after a discussion of the no project option. There are a few options for coastal protection or combating beach erosion those for beach nourishment is limited.

8.1 No project option

It should be noted that the “no project” option cannot be excluded without proper evaluation. In this report this alternative was considered as the baseline against which to evaluate the other options. The no project option takes the following into consideration:

- It is alright to let beaches to erode and continue to nourish beaches frequently.
- Increasing levels of silt or sediment in the lagoon waters due to frequent beach nourishment can be ignored.
- Beach on the western side is not really necessary there is a swimming pool.
- Use of sandbags on the eastern side would continue although it may be an eyesore.
- Potential damage to villas or other infrastructure can be tolerated or repaired.

The main advantages and disadvantages of the no-project option are given in Table 8-1.

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continue frequent beach nourishment</td>
<td>Costs related to improving the situation may be avoided in the short term</td>
<td>Guest dissatisfaction; operational costs and difficulties and emissions</td>
</tr>
<tr>
<td>Use sandbags to stop erosion</td>
<td>Costs related to the project and environmental impacts avoided</td>
<td>Aesthetics of the beach environment will be affected</td>
</tr>
<tr>
<td>Repair damages to infrastructure such as villas</td>
<td>Costs related to the project and environmental impacts can be avoided</td>
<td>Regular repairs would be a financial and technical burden for a long time; there will be no beach on affected areas</td>
</tr>
</tbody>
</table>

A comparison of the no project option with the recommended and other evaluated options indicate that the no-project option is practicable but involves long term costs, tourist dissatisfaction, operational difficulties and would not provide the environmental benefits of the proposed project including reduction of silt or sediment levels in the lagoon waters.
8.2 Project Alternatives

The Proponent initially decided that the best option not entailing excessive costs would be adopted after an evaluation of the different options. Therefore, the different options for the project components were considered before finalising a particular option. These options for the breakwater component and beach nourishment component of the proposed project are discussed here.

8.2.1 Breakwater

The proposed breakwater has the following alternative options.

1. Breakwater using geotextile bags
2. Breakwater using concrete armour units such as tetrapod or Core-Loc units
3. Combination of geotextile bags and Core-Loc or tetrapod
4. Solid breakwaters such as the reclaimed breakwaters on the southwest and southeast

From the above alternative options, the impact of solid breakwaters can be easily seen at Paradise. Such breakwaters do not disintegrate the force of the incoming waves, therefore, does not reduce currents in the lagoon. Geotextile bags have a similar effect as they would also be refractive structures unless some gaps have been provided in the structure, which is difficult to achieve. Tetrapod and Core-Loc, especially Core-Loc provide several cavities and subsequently good wave energy absorption, however, they are not aesthetically as nice as natural rock boulders (the proposed option). These options, especially the solid breakwater options given here, have lower costs than the proposed rock boulders.

8.2.2 Borrow Areas

There are three borrow pits existing of which the smallest pit on the northeast has been considered as the proposed option. The other two areas are considered as alternatives. Of these alternatives, the southeastern alternative is preferable over the northwest borrow pit because the northwest borrow pit may be a potential sediment sink in the long term and may cause long term erosion of the beaches. It is, therefore, advisable to fill this area or let natural filling take care of the area over the long term without further increasing the borrow area from this pit.

The borrow pit on the southeast side is recommended as the alternative borrow area. No adverse environmental impacts are expected from using this borrow pit other than that this area would have less currents once the proposed breakwater is developed and therefore sediments would remain over a longer period than the northeast pit, where good current flow will take care of silt levels effectively.
8.2.3  Beach enhancement

There are no alternatives for beach nourishment as the areas in which beach nourishment will take place have been confined to the eroding areas only. No other areas are considered for beach nourishment.

8.2.4  Other shore protection structures

Groynes and other nearshore structures may be considered. However, it is important to note that Paradise does not have any nearshore structures and avoiding such structures help to minimize the aesthetic impact on the beach of Paradise from such structures. Therefore, no alternative nearshore structures can be recommended for Paradise but for the sake of alternative evaluation, the following structures have been considered as potential options.

8.2.4.1  Groyne Field

A groyne field on the erosion-prone area can be considered. A potential design for such structures would be 25m groynes spaced at 45 to 50m on both sides. On the eastern side there would be more groynes. Therefore, the groyne lengths may be increased on the east so that the spacing can be increased to provide smaller number of groynes. Such a groyne field would have aesthetic impacts and it may be useful to have a timber decking on top to make them look good.

8.2.4.2  Nearshore breakwater or submerged sill (SS)

Nearshore breakwater allows water to pass between the structure and the beach unless a tombolo connects the shoreline with the structure. In order to minimize the tombolo effect, it is important to ensure that the length of the structure is less than the distance between the structure and the beach and that the structure is submerged at mean tide. The structure acts similar to beachrock. Nearshore breakwaters can be made from rock boulders or geotextile bags. Neashore breakwaters are designed to remain emerged except during mean to high tide. As a result, the structures would have high aesthetic impacts compared to offshore breakwater.

8.3  Recommended Alternatives

Except for the borrow pits, there are no recommended alternatives for beach nourishment. As far as the borrow pits are concerned, either of the borrow pits on the east can be used, however, it is recommended to avoid borrowing any material from the borrow pit on the northwest as it has the potential to fill in with material from the island beaches.
For the alternative coastal protection measures discussed here, an impact matrix was developed by assigning indices to five parameters namely environmental impact, performance, maintenance, aesthetics and price. The maximum value assigned to each is 5 and the lowest is 1. Below is a discussion of the findings.

**Table 8-2: Net indices for the different options (a comparative analysis)**

<table>
<thead>
<tr>
<th></th>
<th>None</th>
<th>Groyne</th>
<th>Submerged sill</th>
<th>RBBW</th>
<th>GTBW</th>
<th>GT+CLBW</th>
<th>TPBW</th>
<th>DMBW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Impact index</td>
<td>1</td>
<td>2</td>
<td>2.5</td>
<td>4.5</td>
<td>4</td>
<td>4.2</td>
<td>4.2</td>
<td>3.5</td>
</tr>
<tr>
<td>Performance index</td>
<td>1</td>
<td>2.5</td>
<td>3.5</td>
<td>5</td>
<td>3.5</td>
<td>4.5</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Maintenance index</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4.5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Aesthetic index</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>3.5</td>
<td>3.5</td>
<td>3</td>
</tr>
<tr>
<td>Price Index</td>
<td>5</td>
<td>2.8</td>
<td>2.1</td>
<td>0.4</td>
<td>0.7</td>
<td>0.8</td>
<td>0.9</td>
<td>1.7</td>
</tr>
<tr>
<td>TOTAL</td>
<td>13</td>
<td>13.3</td>
<td>14.1</td>
<td>18.9</td>
<td>16.2</td>
<td>17.5</td>
<td>17.1</td>
<td>15.7</td>
</tr>
</tbody>
</table>

The results indicate that the offshore breakwater would be the appropriate solution although it may be expensive than groynes and submerged sills (SS). Rock boulder breakwater (RBBW), which is the proposed option, is the most preferable option among the breakwaters for Paradise although it is the most expensive. The recommended alternative would be the geotextile bags with core-loc units (GT+CLBW), which has higher aesthetic impact than rock boulders. The tetrapod breakwater (TPBW) and the geotextile breakwater (GTBW) may be considered to have the same overall effect although the geotextile breakwater would perform less effectively thereby necessitating the increase of the crest height which causes greater aesthetic impact. The Core-Loc units have higher permeability and lesser environmental and aesthetic impact than the tetrapod while the geotextile containers have no voids when placed together. However, Core-Loc units are not readily available in the Maldives, therefore, rock boulders or tetrapods would be most suitable since the project is to be carried out immediately.
9 Environmental Monitoring

Environmental monitoring is essential to ensure that potential impacts are minimized and to mitigate unanticipated impacts. The purpose of the monitoring is to provide information that will aid impact management, and secondarily to achieve a better understanding of cause-effect relationship and to improve impact prediction and mitigation methods. The proposed monitoring programme will yield beneficial results if it is undertaken for a longer period. Therefore, the proposed monitoring programme is recommended for at least four years from the onset of the proposed project. Longer term monitoring would also be useful.

The parameters that are most relevant for monitoring the impacts that may arise from the proposed project are included in the monitoring plan. Therefore, the monitoring programme will cover the following aspects of the proposed project:

- coral cover and nektonic fauna
- marine water quality
- beach and hydrodynamic changes
- Incidents/accidents
- Fuel consumption during construction
- Tourist satisfaction (especially repeaters) and staff opinions

9.1 Recommended Monitoring Programme

Outlined here are minimum project specific monitoring requirements that can be considered. This monitoring programme for the proposed project includes at least three monthly monitoring and covers the three stages of the project implementation.

Stage 1: Immediately before starting works

Stage 2: During construction

Stage 3: Operational phase

The monitoring needs of each stage are discussed in detail below:

Stage 1 (before construction)

- Marine water quality for pH, Conductivity(mg/l), dissolved oxygen(mg/l), turbidity (NTU) and Salinity
- Shorelines (low tide, mean tide and high tide) immediately before the project.
- Currents using drogues at the baseline locations given in the EIA and preferably more
Stage 2 (during construction)

- Marine water quality for pH, DO, EC, salinity, turbidity at possible reef areas into which sediment plume is expected to move.
- Shorelines (low tide, mean tide and high tide) immediately before the project.
- Currents using drogues at the baseline locations given in the EIA and preferably more

Stage 3 (operational phase)

Three monthly monitoring starting from the completion of proposed works shall be undertaken.

- Shorelines (low tide, mean tide and high tide) starting immediately after beach enhancement.
- Drogues at the same locations given in this report and possibly additional locations
- Marine water quality – pH, DO, salinity and turbidity.

In addition, it may be worthwhile undertaking a tourist satisfaction survey aimed at understanding the environmental or aesthetic improvements targeted by the proposed project at the end of each monitoring year.

9.2 Cost of monitoring

The following table outlines a cost estimate for annual monitoring assuming the monitoring will be undertaken by environmental consultants and most of the parameters would be tested in-situ.

Table 9-1: Costs of the annual monitoring programme

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Details</th>
<th>Unit cost (US$)</th>
<th>Total (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Field allowance for 2 consultants for 1 day</td>
<td>200.00</td>
<td>800.00</td>
</tr>
<tr>
<td>2</td>
<td>Monitoring equipment depreciation and other charges</td>
<td>230.00</td>
<td>920.00</td>
</tr>
<tr>
<td>3</td>
<td>Laboratory charges</td>
<td>50.00</td>
<td>200.00</td>
</tr>
<tr>
<td>4</td>
<td>Compliance reporting (annual report)</td>
<td>1,000.00</td>
<td>1,000.00</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>2,920.00</td>
</tr>
</tbody>
</table>

9.3 Monitoring Report

A detailed environmental monitoring report is required to be compiled and submitted to the Environment Protection Agency of the Ministry of Housing and Environment. The report must be based on the data collected for monitoring the parameters included in the monitoring programme given in this report.

The report will include details of the site, strategy of data collection and analysis, quality control measures, sampling frequency and monitoring analysis and details of methodologies and protocols followed. The Proponent’s commitment to undertake monitoring and to report annually is attached with this report.
10 Declaration of the consultant

This EIA has been prepared according to the EIA Regulations 2007. I certify that the statements in this Environmental Impact Assessment study are true, complete and correct to the best of my knowledge and abilities.

Name: Ahmed Zahid (EIA 08/07)

Signature:

Date:
11 Sources of Information

Binnie Black and Veatch (1999), Environmental/Technical Study for Dredging/Reclamation Works under the Hulhumalé Project, Maldives


Environmental Guidelines for Reclamation in Coastal Areas, Environment and Heritage Division, Department of Land, Planning and Environment, January 1999


Land and Marine Environmental Resource Group Pvt Ltd. (LaMer) 2005. ADB, DMTP (TA4394-MLD) Ecosurvey, LaMer, Maldives, 46pp.


The United Kingdom Hydrographic Office (2005), *Admiralty Tide Tables – Indian Ocean and South China Sea*, Vol3 (NP203)


UNDP (2006) *Developing a Disaster Risk Profile of the Maldives*, UNDP, Male', Maldives


USACE (1992), *Coastal Groins and Nearshore Breakwaters*, USACE, Washington


Environmental Protection Agency
Ministry of Housing, Transport and Environment
Male', Republic of Maldives

Terms of Reference for Environmental Impact Assessment

The following is the Terms of Reference (TOR) for undertaking the EIA of the proposed coastal protection project in Paradise Island Resort and Spa, Kaafu Atoll, Maldives. This TOR is based on the issues raised in the scoping meeting held on Tuesday, 6 July 2010 at Environmental Protection Agency.

1. Introduction - This TOR has been prepared for the Environmental Impact Assessment of the proposed coastal protection and beach enhancement at Paradise Island Resort located on Lankanfinolhu, Male Atoll.

2. Study Area - The study involves the western shoreline from the arrival jetty up to the water sports centre and the eastern shoreline about 150m on either side of the water villa jetty. Protecting these beach areas, which are under threat from severe erosion during the respective monsoon, would require structural protection together with beach nourishment. In order to understand and define a possible solution to the problem the hydrodynamics of the entire island has to be studied.

3. Scope of Work - The following tasks will be performed:

Task 1. Description of the Proposed Project - Provide a full description of the relevant components and nature of the project using maps at appropriate scales where necessary. This is to include: brief description of the proponent, justification of the proposed project, a clearly labelled site plan and drawings, a detailed description of how the project activities will be undertaken including work method for installing breakwater or other potential options, a matrix of project inputs and outputs, details of beach nourishment and coastal modifications including any coastal protection structures (and any borrow areas) and a detailed project schedule. The boundaries of the study area for the EIA shall be provided.

Task 2. Description of the Environment - Include a description of the existing environmental conditions of the project site with photos of the site where relevant. Consideration of likely monitoring requirements should be borne in mind during survey planning, so that data collected is suitable for use as a baseline. As such all baseline data must be presented in such a way that they may be usefully applied to future monitoring.

Specific emphasis should be placed on the following activities of the project or related to the project:

- Installation of breakwaters, groynes or other coastal protection structures
- Beach nourishment
- Machinery and construction equipment as well as workforce management

ToR for the Proposed Coastal Protection at Paradise Island Resort and Spa
As such the following field investigations must be considered for baseline data collection:

- Mapping of existing shorelines, vegetation line, coastal structures including the jetties, existing breakwaters and other relevant structures using differential GPS.
- Long shore currents around the island.
- General climatic and oceanographic conditions in the project area.
- Bathymetry of the island lagoon, especially in project areas.
- Sea water quality at the proposed locations. Water quality parameters shall specifically include dissolved oxygen, salinity, pH, temperature, BOD and turbidity.
- Condition of the reef at the project areas.
- Beach profiles (at least 4).

Characterise the extent and quality of the available data, indicating significant information deficiencies and any uncertainties associated with the prediction of imports. All available data from previous studies of the island, if available should be presented. Geographical coordinates of all sampling locations should be provided. All water samples shall be taken at a depth of 1m from the mean sea level or mid-water depth for shallow areas. The report should outline the detailed methodology of data collection utilized to describe the existing environment. Baseline conditions should be presented for the marine environment.

An average of at least 5 measurements must be given for each parameter tested and analyzed from a certified laboratory. Provide details of calibration for any onsite data analysis.

**Task 3. Legislative and Regulatory Considerations** - Describe the pertinent national regulations and standards, and environmental policies that are relevant and applicable to the proposed project, and identify the appropriate authorities and jurisdictions that will specifically apply to the project.

**Task 4. Impacts** - Provides an assessment of the impacts including the constructional and operational impacts.

During the constructional phase, impacts of installation of coastal protection structures such as breakwaters, beach nourishment, borrow areas, etc. needs to be considered. During the operational phase, impacts on the coastal processes and shoreline (i.e. sediment movement), impacts on the neighbouring island and the socio-economic impacts from the proposed structures including aesthetics and increased sediment levels in the water due to resuspension from nourished beaches shall be discussed. Impacts of any proposed changes to existing coastal structures shall be identified.

In addition to negative impacts, positive socio-economic impacts and enhancement to natural environment (if any) shall be identified.

**Task 5. Mitigation measures** - Identify possible measures to prevent or reduce significant negative impacts to acceptable levels with particular attention paid to sediment control and construction methods and materials that would minimise impact on the environment. Discuss the feasibility and cost effectiveness of each mitigation measure and provide the costs of mitigation and the commitment to it.

**Task 6. Alternatives** - This section must include the proposed development scenario evaluated against the no-project option and other alternatives. These include alternative technologies and materials, alternative borrow areas (for pumping sand required for beach nourishment) and alternative coastal protection measures. The report should discuss how the recommended alternative was selected.

**Task 7. Environmental Monitoring Plan** - Environmental monitoring shall focus on the construction as well as the operational stage. Constructural monitoring shall cover sea water quality to understand sedimentation by including monitoring of pH, DO and turbidity at regular intervals before, during and sometime after the construction phase. Operational stage monitoring should focus on the effectiveness of the beach nourishment programme and shore protection measures. The report should also provide a detailed cost breakdown for
implementing the monitoring plan. Provide commitment of the Proponent to conduct the monitoring programme.

Task 5: Stakeholder Consultation — Stakeholder consultations are limited to consultations with the management of the resort and any other relevant parties who may be directly involved with the project. Views of line government agencies have been discussed at the scoping meeting, which shall be incorporated in the EIA report and list of participants of the scoping meeting shall be provided.

Presentation — The environmental impact assessment report, to be presented in print and digital format, shall be concise and focus on significant environmental issues. It shall contain the findings, conclusions and recommended actions supported by summaries of the data collected and citations for any references used in interpreting those data. The environmental assessment report will be organized according to, but not necessarily limited by, the outline given in the Environmental Impact Assessment Regulations, 2007.

Timeframe for submitting the EIA report — The developer must submit the completed EIA report within 3 months from the date of this Term of Reference.

11 July 2010
Dear Sir,

This is in reference to the Environmental Impact Assessment (EIA) report for the proposed coastal protection at Paradise Island Resort and Spa.

As the Proponent of the project, we assure you our commitment to undertake the mitigation measures and monitoring programme outlined in the EIA report. We would also take all necessary precautions and measures to ensure that the negative environmental impacts of the project are minimized and all positive impacts of the project are enhanced.

Thank you,

Yours faithfully

Ibrahim Zahir
DIRECTOR
Appendix 3: Bathymetry of the Project areas