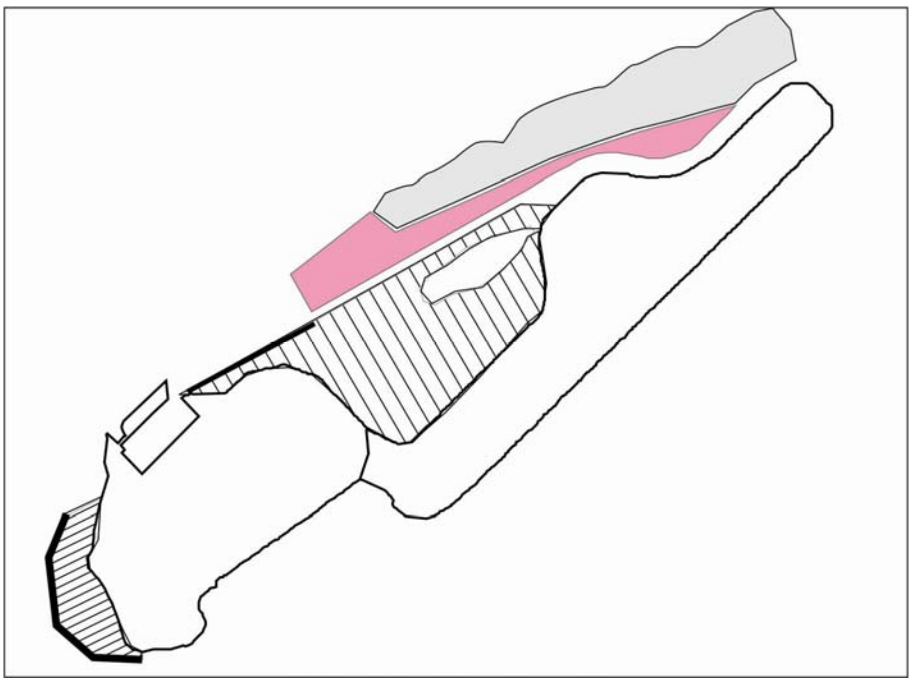
ENVIRONMENTAL IMPACT ASSESSMENT

For the proposed reclamation of 24 hectare at Thimarafushi, Thaa Atoll, Maldives



Proposed by

Ministry of Housing and Environment

Prepared by

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For Water Solutions Pvt. Ltd., Maldives

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3 Non Technical Summary

This report discusses the findings of an environmental impact assessment undertaken by Water Solutions Pvt. Ltd for undertaking the propose reclamation of 24 hectares in Thimarafushi island, Thaa Atoll.

An area of 240,000 square meters or24 hectares will be reclaimed in order to expand the available land space for Thimarafushi, mostly for housing and industrial activities. This EIA report discusses the findings of the reclamation project.

The project is proposed by Ministry of Housing and Environment. The biggest challenge facing Thimarafushi is lack of space and overcrowding. Reclamation is a real need for Thimarafushi as the island is saturated and there are no additional land for housing plots nor industrial activities. The presently reclaimed area, although it is quite huge, most of which cannot be used for domestic use as majority of this land will be allocated to develop an airport and its boundaries.

The present population of the island is 2817 and there are 350 households. This is 8 people on average per house. The island needs an additional 400 houses as existing houses are over crowded and too many families having to live in the same house is creating social and health issues.

Twenty hectares will be reclaimed from area 1 and approximately 50% of this area would be usable domestic purposes due to airport development restrictions. Further development of Thimarafushi can only be achieved through creating additional land. Reclamation is therefore very much a serious requirement for the people as lack of space is causing many problems.

Environmental impacts were assessed and most of the environmental impacts of the project have been identified as resulting mainly from the coral reef damage from dredging and reclamation works. Mitigation measures for the negative impacts have been identified and outlined in detail, especially sedimentation control methods. The most important mitigation measure is the use of bund walls in the fill areas. The proposed mitigation measures will have to be followed in order to minimize environmental damage. The measures proposed to minimize or mitigate environmental impacts may be considered to be quite appropriate, thereby minimizing the impact by about 90%. The main negative environmental impact of the proposed project would be sedimentation and destruction of the lagoon and some areas of the reef, which will cause death or partial death of corals. Coastal protection of the reclaimed area 2 will be undertaken in order to protect the shore. The project is mainly driven by the economic gain to the development of Thimarafushi, mainly through benefits achieved from increased land.

4 Introduction

This Environmental Impact Assessment report (EIA) has been prepared to fulfil the requirements of the Environmental Protection and Preservation Act, law no. 4/93 for the proposed reclamation of 24 heactares of land in Thaa Atoll Thimarafushi.

The report has been structured to meet the requirements of the EIA regulations 2007 issued by the Ministry of Environment, Energy and Water. This EIA report discusses the outcomes and findings with regard to reclamation of Thimarafushi.

This EIA has been prepared by a local environmental consulting firm, Water Solutions. Water Solutions have been chosen by the proponent as the environmental consultants for this project. The team members were:

- Abdul Aleem, BSc, MPH – Mapping and GIS
- Ahmed Jameel, B. Eng (Environmental), MSc – Environmental Engineer
- Mohamed Riyaz, - surveyor
- Hamdhulla Shakeeb, Surveyour

4.1 Terms of Reference

Terms of Reference for this assessment has been included in the Appendix of this report.

5 Project Setting

This section outlines the relevant environmental legislation pertaining to this project. The following table outlines a matrix of major environmental laws, guidelines, codes and standards, both local and international indicating the relevance to this project. Details of these regulations, what they cover and under what circumstances they apply are attached as an annex.

Name of legislation	**Area**	**relevant to this project (yes/no)**
Environmental protection and preservation act	Generally covering the Environment	Yes
Maldives vision 2020	Multi-sectoral	
Sixth and seventh national development plan	Multi-sectoral	Yes
Second national environment action plan (1999)	Environment	Yes
National biodiversity strategy and action plan	Environment	Yes
Protected areas and sensitive areas	Ecologically, sensitive areas, coral reefs, wetlands	
Waste management policy	Environment	Yes
Regulation on sand and aggregate mining	Coral reefs	Yes
Ban on coral mining	Coral reefs	Yes
Tourism act (law no. 2/99)	Environment	
Ministry of Tourism regulations and circulars	Environment and tourism related activities	
Framework for environmental assessment	Environment	Yes
Environmental impact assessment regulation 2007	Environment	Yes
Post EIA monitoring, auditing and evaluation	Environment	Yes
Guidelines for domestic wastewater disposal	Water and wastewater	
Transport master plan	Transportation	Yes
Protected areas and environmentally sensitive areas	Ecologically, sensitive areas, coral reefs, wetlands	Yes
Agriculture development master plan	Agriculture	

Name of legislation	Area	relevant to this project (yes/no)
Regulation on cutting down, uprooting, digging out and export of trees	Terrestrial environment, trees, sensitive and protected trees	
Guidelines for land use planning	Planning, environment	Yes
Land law	Planning, land use and environment	
Guidelines for domestic wastewater disposal	Water and wastewater	
Guidelines for import, produce and sale of bottled water in the Maldives for human consumption	Water	
General regulation for food establishment and services	Food security and safety	
Regulations for installing and operating desalination plants in the Maldives	Water	
General standard for bottled / packaged drinking waters (other than natural mineral water) codex stan 227-2001	Water	
General standard for the labelling of pre-packaged foods (codex stan 1 – 1985)	Water	
Relevant international conventions, treaties and protocols - The Montreal protocol on substances that deplete the ozone layer	Environment	
- United nations convention on biological diversity (uncbd)	Environment	Yes
- Marpol convention	Environment, Water	

6 Project Description

6.1 Project Proponent

The project is proposed by Ministry of Housing and Environment. Ministry of Housing and Environment has the mandate of the broader housing and environment sector and formulating plans and policies on housing infrastructure and strategies

6.2 Project Location and Study Area

The project location is Thimarafushi lagoon, north and south west of the island of Thimarafushi. It is the most populous island in Thaa Atoll and the region itself. Refer to the diagrammes attached at the end of this section for the location.

6.3 Need and Justification for the upgrading works.

Thimarafushi is proposed to be developed in to a regioinal airport. As such, an area has been reclaimed to develop a domestic airport. Although reclamation for the airport is complete, it has not solved the housing crisis currently facing the residents.

Reclamation is a real need for Thimarafushi as the island is saturated and there are no additional land for housing plots nor industrial activities. The presently reclaimed area, although it is quite huge, most of which cannot be used for domestic use as majority of this land will be allocated to develop an airport and its boundaries.

The present population of the island is 2817 and there are 350 households. This is 8 people on average per house. The island needs an additional 400 houses as existing houses are over crowded and too many families having to live in the same house is creating social and health issues.

Therfore an additional 400 houses are required for Thimarafushi in order to cater for the housing demands. As the new reclaimed area is not adequate to provide housing and other social needs of the present population, reclamation is urgently needed to lift the social status and prosper development. Without land industrial growth will not take place and the housing crisis will further exacerbate.

Although 20 hectares will be reclaimed from area 1 , approximately 50% of this area would be usable domestic purposes due to airport development restrictions. Hence, there is great need for housing development in Thimarafushi and this can only be achieved through creating additional land. Reclamation is therefore very much a serious requirement for the people as lack of space is causing many problems.

At present, industrial activities such as boat repair, boat building, commercial scale fish processing, drying etc cannot be undertaken in the island due to inadequate space. Thimarafushi has the greatest number of fishing boats in this region in comparison to other islands and the need for their repairs and continous maintenance is ever increasing as the size of fishing boats and their numbers increases. With these issues, the island is in need of such an area and reclamation is the only solution for industrial development.

Reclamation of 24 heactares of land will therefore increase the economic potential of the island in addition to the various social benefits gained by more space for housing. It is therefore one of the most urgently needed requirement for Thimarafushi.

6.4 Description of the Project Components

This project involves the following components:

- Dredging the shallow lagoon to a depth of 8.5 meters at mean sea level (MSL). Approximately an area of 95,000 sq meters will be dredged from the lagoon. This will be the source of sand for the reclamation.

- Reclamation of two areas:
  Area 1: A total of 20 Hectares or 200,000 square meters (SQM) of land on the west of the already reclaimed land (refer to the site plans and concepts attached).

  Area 2: A total of 4 Hectares or 40,000 square meters (SQM) of land on south west of Thimarafushi island.

- Construction of coastal protection (revetments) along area 2 in order to prevent and avoid erosion of this area.

Therefore, this project has three main components, namely reclamation, dredging and coastal protection. Following tables outlines the summary of the project component as well as key project statistics including volume of fill material, area of reclamation, height of reclamation and depth of dredging required.

6.4.1 Summary of the project components

The following table outlines the summary of the project components.

Project components	**Material type / details**
Reclamation of 24 Hectares or 240,000 square meters of land to a height of 2 m above mean sea level	By filling the area with sediments obtained from the borrow area. - The shallow lagoon will be dredged to a depth of 8.5 meters at mean sea level. Sand obtained from dredging will be used to fill area 1 and area 2.
Dredging of the lagoon	The shallow lagoon west of the presently reclaimed land will be widened by dredging along the western side between the land and the previously borrowed area. This additional area will be dredged and depths will therefore be similar to the previously borrowed area. Dredged material from this area will be used to fill the proposed reclamation areas, area 1 and area 2. A total of 676,400.00 cubic meters of sediment will be obtained from dredging an area of 95,000 square meters. A total of 675,040.00 cbm is required for both areas to be reclaimed. Hence, the project will generate an excess of 1,360 cbm of sand, which will be used to fill geo bags.
Coastal protection	Coastal protection will be constructed along the newly created shoreline in Area 2. 675 meters of coastal protection will be constructed using geo bags. A combination of two sizes of geobags will be used.

Table 1: Summary of the project component

RECLAMATION AREA, VOLUME AND CALCULATION OF SEDIMENT REQUIREMENT	
Area 1 to be reclaimed (north west)	
Length of area to be reclaimed (m)	
Width of area to be reclaimed (m)	
Total area to be reclaimed (m2) – 20 hectares sqm	200,000.00
Average depth in the lagoon to be reclaimed at MSL (m)	0.81
Height above MSL to which reclamation will be done (m)	2.00
Total fill height (m)	2.81
Total volume of sediment required for reclamation (cbm)	562,000.00
Area 2 to be reclaimed (south west)	
Length of area to be reclaimed (m)	
Width of area to be reclaimed (m)	
Total area to be reclaimed (m2) – 20 hectares sqm	40,000.00
Average depth in the lagoon to be reclaimed at MSL (m)	0.83
Height above MSL to which reclamation will be done (m)	2.00
Total fill height (m)	2.83
Total volume of sediment required for reclamation (cbm)	113,040.00
Total volume of sand required to fill both areas (Total 240,000 sqm or 24 heactares)	675,040.00
SEDIMENT BORROWING AREAS	
Borrow area	
Proposed length (m)	
Proposed width (m)	
Total area of dredging to be done (m2)	95,000.00
Average depth in the proposed drdging area (m) at MSL	1.38
Required depth of the dredge area at MSL (m)	8.50
Depth of dredging to be undertaken (m)	7.12
Total volume of sediment obtained from dredging the channel	676,400.00
Surplus sediment after reclamation	1,360.00

Table 2: Key project statistics

6.4.2 Proposed area for the reclamation

The proposed area 1 for the reclamation lies on the west of the existing reclaimed land. Area 2 lies on the south-west of Thimarafushi island. Refer to the project concept plans and site plans attached.

6.4.3 Layout and the location

Refer to the attached drawings

6.4.4 Concept plan for the project

Refer to the attached concept plan

6.4.5 Location and size of sand borrow areas on a map

Refer to the attached site plans and for details of the borrow site. For this project, sediment will be borrowed from the shallow lagoon.

6.4.6 Quantity, quality and characteristics of fill material

The sediment will be sourced from the shallow lagoon. A total of 676,400 cubic meters of sediment will be obtained from the lagoon which will be dredged to a depth of 8 meters at MSL. Refer to the attached concept plan. The sediment quality will be similar to the existing sediment at the sea bed of the lagoon as the source material is obtained from the same reef system. The core component of the sediment will be sand, with calcium carbonate as the main component.

6.4.7 Indication of guarantees for sufficient availability of fill material

Refer to the calculations in Table 2.

6.4.8 Method and equipments used for dredging, including description and operational control

The project will be implemented through a carefully managed plan. Reclamation will be initiated as soon as the EIA is approved. Dredging will be undertaken using a cutter suction dredger. The dredger is already mobilized to the site and the pipeline will be paid from the dredge. The filling area will be bunded initially from dredged sand and then filled inside. Hence, the filling areas will be adequately bunded in order to prevent sediment spilling in to the lagoon and the reef during the filling process.

6.4.9 Justification for selecting the methods and equipments

Since this is a large area and also the dredger has been mobilized for previous reclamation, this is the most cost effective method for the works. In addition, the reclamation works can be completed in minimal time period if a dredger is used. Excavators, dump trucks, loaders and bulldozers will be used to aid the reclamation for transporting, filling and levelling the sand.

6.4.10 Duration of dredging activity

The total duration of dredging and reclamation is expected to be 3 months. A project schedule is attached as an annex.

6.4.11 Labour requirements and labour availability

This project will be contracted to a qualified contractor who has also undertaken reclamation of the first phase. Hence, the contractor will be responsible for obtaining the required labour for this project. Already the technical and labour force is selected and some of the technical staff has been stationed in the island of Thimarafushi for more than one year.

6.4.12 Housing of temporary labour

Housing of labour will also be the responsibility of the contractor and they will be based in Thimarafushi island.

6.4.13 Emergency plan in case of spills (diesel, grease, oil)

Spillages can be an issue in this project if adequate measures are not taken. Hence, oil, grease and other fuel storage will be held on land within the port boundary. Refuelling of dredger will be required only on a monthly basis and this will be done with caution and care as to prevent any spillage to the lagoon.

6.4.14 Measures to control sedimentation

Refer to the impacts and mitigation section for more details.

6.4.15 Detailed project schedule of implementation

A detail project schedule is attached as an annex.

6.5 Project Inputs and Outputs

6.5.1 Project Inputs

The types of resources that will go into the project and from where and how these will be obtained are given in the following table.

INPUT RESOURCE(S)	SOURCE/TYPE	HOW TO OBTAIN RESOURCES
Construction workers (15+)	Maldivians +foreign labours	Already the contractor is choosen.
Water supply (construction period)	Desalinated water / mineral water / rainwater	Available from Thimarafushi
Electricity/Energy (construction period)	Mobile Diesel generators and from the existing power grid.	Contractor
Construction machinery	Dredgers, Excavators, barges, general construction tools, dump trucks and loader.	Contractor
Telecommunications	Mobile Phones, and radio two-way communications.	Contractor
Transport (sea)	Materials to be transported in dhoni's to the island. Those available from the island will be transported using land vehicles.	Contractor
Food (during construction period)	From Thimarafushi island.	Contractor
Fuel,	Diesel, Petrol, Lubricants	Contractor to obtain from Thimarafushi island.

Table 3: Matrix of major inputs during construction period

6.5.2 Project Outputs

The type of outputs (products and waste streams) and what is expected to happen to them are given in the following table.

PRODUCTS AND WASTE MATERIALS	ANTICIPATED QUANTITIES	METHOD OF DISPOSAL
Sewage and wastewater	Grey water/laundry wastewater Estimated to be at 50 litres/person/day	Contractor will be based in the island which has toilet facilities. In addition, the port itself has toilets which will be used by the contractor.
Waste oil and grease (hazardous waste)	Approximately 100 litres per month	Stockpiled in the reclamation area (phase 1) and later will be disposed at Thilafushi after they are transported during demobilization.
Noise	Localised to the project site including the surrounding areas.	Unavoidable during the construction stage but will be minimized.
Air pollution	Limited quantities of dust, oxides of Nitrogen and sulphur from use of machinery in the construction zone.	Mainly arising as a result of emission from the construction work such as from the dredgers, excavators and machinery. Only localised.
Dredged spoil	A total of 676,400.00 cbm from the borrow area dredging.	Used as reclamation material

Table 4: Matrix of major outputs of environmental significance during construction stage

6.5.3 Reclamation or filling methods

Reclamation or filling will be undertaken by disposing sediment into the area to be filled. The disposed sediment will be spread evenly at the end of filling using excavators, loaders, trucks and bulldozers. The reclamation works will be undertaken in a similar manner to that described below.

- Reclamation will be done in sections.
- Mark the perimeter of the area to be filled.
- Erect a temporary seawall of adequate height using sand bunds around the area to be filled to minimize sediment flow onto the reef. This will be done initially from the very first materials obtained from dredging.
- Fill the area and create a similar bund around the second bunded area.
- Continue filling to fill the enclosed area.

- Undertake levelling.

6.5.4 Management of Waste

All wastes will enter the present waste management cycle in Thimarafushi, that is domestic garbage. All other such as hazardous wastes like waste oil and grease will be stockpiled and transferred to Thilafushi.

6.5.5 Expected Environmental Conditions during the Project Implementation Period

The project activities will take place in north-east monsoons, and hence environmental conditions are expected to be mostly favourable during the construction period. Dredging and reclamation works will be undertaken on the south west and western side which will be mostly calm in NE monsoon and hence, the impact on weather would be less significant. Calm conditions on the southern and western sides will therefore create more favourable conditions during dreding and reclamation which will mitigate the reef damage to some extent. Nevertheless, the filling and dredging would have a greater influence as winds will not always be calm during the reclamation works. Therefore, the strategy would be to complete the reclamation works with proper bunding and within the shortest possible duration and possibly during the north-east monsoon.

6.5.6 Risks Associated with the Project

There are few risk factors associated with this project that could possibly have both financial and environmental implications. The most significant risk associated is damage and destruction of the lagoon and the reef caused by direct destruction of the these habitats as well as indirect affects. In addition, there is also the risk of not completing the work on time and causing delays in project completion.

There is also the risk of project delays caused by bad weather, especially the reclamation and the dredging component. If the works gets delayed and moves towards the south-west monsoon, then the risks are far greater. During the south-west monsoon which is the wet season, unpredictable rainfall, storms, swells and strong waves and generally rough conditions are expected. This risk can be minimized if the works could be completed within the minimum period and avoid the project extending to SW monsoon.

As indicated earlier, the most important risk associated with this project is the possible damage to the marine environment as a result of dredging and reclamation. Although the dredging and filling areas do not have significant amount of live corals, there will be indirect coral reef damage to the nearby areas through sedimentation. The marine surveys conducted indicate high percentage of live corals and very healthy areas of the reef that are in close proximity to the reclamation areas. These areas will therefore be totally or almost totally destroyed.

Hence, sedimentation will be an issue but will be minimized by limiting the dredging work hours as well as undertaking work during low tide hours. Sedimentation will be an issue for the coral reef, but not expected to spread to the nearby reefs. Therefore, sedimentation risk is high and it is also something that cannot be avoided in total. Evidence from similar dredging and reclamation works undertaken in other island indicates that such work creates lot of sedimentation of the area, and it poses a serious dispersion hazard to the nearby areas of the same coral reef.

The first phase of reclamation of Thimarafushi has already posed significant threats to the healthy areas of the reef as outlined and discussed in the marine environment section.

7 Methodology

This section outlines the methodologies used in this environmental assessment. The following table outlines a matrix of methodologies used in this project. Details of these methodologies and their descriptions are attached as an annex.

Methodology type	Area / environmental aspect	Used in this project (yes/no)
General methodologies of data collection	Generally covering the broader Environment	Yes
Mapping and location identification	Coastal, terrestrial and marine environment.	Yes
Marine Environmental survey	Marine environment	
- 20 m Line Intercept transect (LIT)	Marine environment	No
- 50 m photo quadrate analysis	Marine environment	Yes
- Qualitative assessment of the reef	Marine environment	Yes
- Permanent photo quadrate	Marine environment	No
- Ref fish visual census	Marine environment	Yes
- Marine Water Quality	Marine environment	Yes
Coastal Environment	Coastal Environment	
- Shoreline and vegetation line mapping	Coastal Environment	Yes
- Coastal structure mapping	Coastal Environment	Yes
- Erosion and accretion areas mapping	Coastal Environment	
- Beach profiles	Coastal Environment	No
- Drogues and current	Coastal Environment	Yes
Terrestrial Environment	Terrestrial environment	
- Terrestrial floral survey	Terrestrial environment	
- Terrestrial faunal survey	Terrestrial environment	
- Groundwater assessment	Terrestrial environment	
Bathymetry	Marine / Coastal Environment	Yes
Aerial Photos	Generally covering the broader Environment	Yes
Long term weather data	Generally covering the broader Environment	Yes

8 Existing Environment

8.1 Existing General Environment of Maldives

This annex outlines the general environmental conditions in Maldives, including the climatic settings, tides, wind and wave. As there are no specific such data for individual islands, these data will form the basis for describing the conditions for the islands of the Maldives. The data collection on climate, tide and waves are undertaken from weather stations based strategically throughout the Maldives, including Male' international airport, Gan International airport, Kaadehdhoo Airport and Hanimaadhoo airport.

8.2 Meteorological Conditions

Meteorology at Maldives is monitored by the Maldives Meteorological Service (MMS) through three stations as detailed below. The stations monitor rainfall, temperature, wind and tide levels at the islands. The secondary data presented in this section has been sourced from recordings of MMS monitoring stations.

Location	Latitude	Longitude	Tide gauge
National Meteorological Centre, Malé	04.19°N	73.53°E	Yes
Haa Dhaal Hanimaadhoo Meteorological Office	06.75°N	73.17°E	Yes
Laamu Kadhdhoo Meteorological Office	01.86°N	72.10°E	No

Table 5: Geographical Coordinates of the Meteorological Centres in Maldives (Source: Maldives Meteorological Service)

Hourly meteorological data was also collected for Hulhule (MIA) for the period 1990-2009. The data includes parameters such as atmospheric pressure, temperature, humidity, wind speed and direction and precipitation which is provided in the subsequent section

8.3 Climatic Setting

Maldives is located at the equator and experiences monsoonal climate. Maldives has two distinct seasons; dry season (northeast monsoon) and wet season (southwest monsoon). In these two seasons the temperature remains more or less the same. . Northeast monsoon extends from January to March. Since Maldives consists of small islands and are surrounded by sea, hot days are often tempered by cooling sea breezes and evening temperatures drops. Throughout the year, temperature remains almost same in the Maldives. However, daily temperature ranges from around 31°C in daytime to 23°C in night-time. The mean daily maximum temperature for Central parts (Hulhule) of the Maldives is 30.5°C and minimum temperature is 25.7 °C. On the other hand, mean daily maximum and minimum temperature for South (Gan) is 30.9°C and 24.5 °C, respectively.

The wet season- southwest monsoon runs from mid-May to November. In this season Maldives experiences torrential rain. Central, Southern and Northern parts of the Maldives receive annual average rainfall of 1924.7mm, 2277.8mm, and 1786.4mm, respectively. The highest rainfall ever recorded in the Maldives with in 24 hour period was on 9th July 2002 at Kaadedhdhoo

Meteorological Office and amounts to 219.8mm of rainfall. Maldives being located at the equator, receives plentiful of sunshine throughout the year. On average Southern atolls (Gan) of the Maldives receives 2704.07 hours of sunshine each year. Furthermore, on average central (Hulhule) parts of the country receives 2784.51 hours of sunshine per year. The relative humidity in Maldives ranges from 73% to 85%.The monthly average sunshine and rainfall is presented in the figure below:

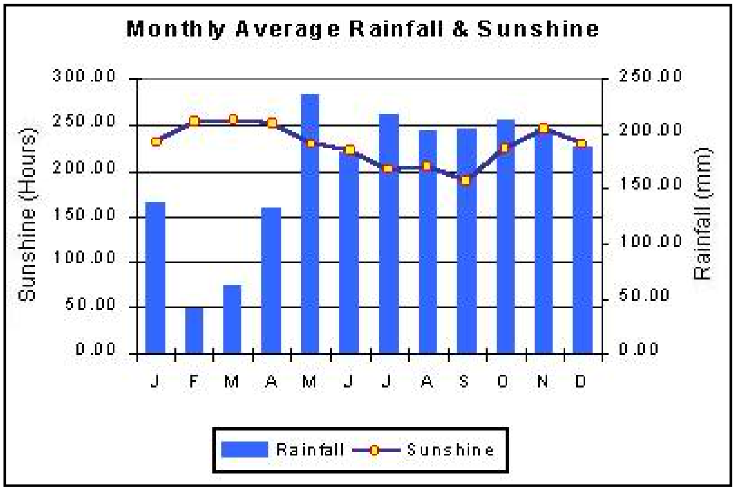


Table 6: Monthly Average Rainfall and Sunshine(Source: Maldives Meteorological Service)

The month wise rainfall data for Maldives recorded for the month of 2009 is as provided below:

Locality	Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Male'	2,201	85.2	12.8	36.8	86.6	175.1	213.3	275.9	416.4	193.3	107.5	409.2	189.4
Hanimaadhoo	1,635	2.6	7.6	31.5	55.5	145.4	156.6	218.7	234.8	177.3	83.9	234.4	286.9
L.Kadhdhoo	2,158	58.3	193.1	30.9	149	244.5	187.7	42	295.3	165.4	203.8	336.1	252.5
Kaadedhdhoo	2,023	242.7	50	60.5	124.3	307.3	32.5	83.2	318.1	180.8	188	155.2	280.6
S.Gan	2,307	247.3	23.6	54.1	134.6	253.7	105.1	252.8	165.2	224.9	322	261.3	263.1
Source: Maldives Meteorological Service													

Table 7: Month-wise Rainfall Data for Maldives, 2009

8.4 Temperature

Daily temperatures of Maldives vary little throughout the year with a mean annual temperature of 28°C. The annual mean maximum temperature recorded for Male' during the period 1967-1995 was 30.4°C and the annual mean minimum temperature for the same period was 25.7°C. The highest recorded temperature for Male' was 34.1°C on 16th and 28th of April 1973. The hottest month recorded was April 1975 with a maximum monthly average temperature of 32.7°C, the next highest being 32.6°C in April 1998. The lowest minimum average temperature of 23.7°C was recorded in July 1992.

Locality	Yearly Avg	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AVERAGE OF DAILY MAXIMUM TEMPERATURE (oC)													
Male'	31.1	30.5	31.0	31.9	31.7	31.7	31.2	31.2	30.3	30.7	31.6	30.6	30.6
HDh.Hanimaadhoo	31.3	30.7	31.5	32.4	32.1	32.1	31.1	30.9	30.6	30.8	31.6	31.0	31.1
L.Kadhdhoo	31.3	30.6	30.7	32.1	32.3	32.2	31.3	31.4	30.6	31.3	31.4	30.8	30.9
GDh.Kaadedhdhoo	31.1	30.8	31.0	31.8	31.6	31.6	31.1	31.1	30.4	31.1	30.9	30.2	30.9
S.Gan	31.1	30.7	31.1	31.7	31.5	31.2	31.1	30.9	30.6	31.2	31.1	30.5	31.3
AVERAGE OF DAILY MINIMUM TEMPERATURE (oC)													
Male'	26.3	25.8	26.1	27.1	26.9	26.7	26.6	26.2	25.2	26.1	26.7	25.8	26.0
HDh.Hanimaadhoo	25.5	24.6	24.2	25.5	26.3	27.3	26.0	25.4	25.5	25.8	25.3	25.2	24.7
L.Kadhdhoo	25.7	25.8	24.6	26.0	26.6	26.7	26.1	26.1	25.0	26.1	25.6	25.1	24.7
GDh.Kaadedhdhoo	24.6	24.6	24.5	24.6	25.4	25.1	25.2	24.4	23.8	24.6	24.2	24.4	24.6
S.Gan	25.4	25.2	25.5	25.9	25.8	26.0	25.8	24.9	24.7	25.6	25.0	24.9	25.2
Source: Maldives Meteorological Service													

Table 8: provide details of the average daily maximum and minimum temperature of Maldives for 2009.

8.5 Monsoons

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. 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.

8.6 Rainfall

Annual average rainfall in Maldives is about 1900mm. There is a marked variation in rainfall across Maldives with an increasing trend towards south. The annual average rainfall in north is 1977mm and for south is 2470mm. The southwest monsoon is known as the wet season with monthly average rainfall ranging from 125-250mm. The northeast monsoon is known as the dry season with average monthly rainfall of 50-75mm.

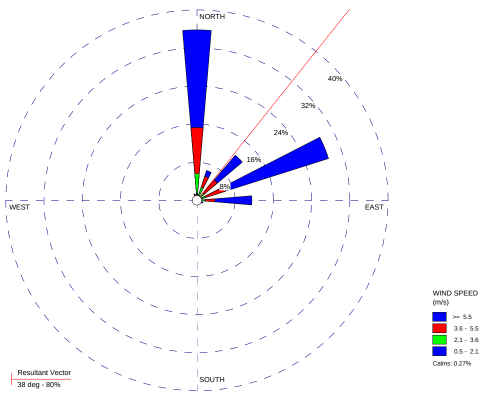
Rainfall records indicate an average annual rainfall of 2500mm. The intensity of rainfall is a concern in the Maldives since intensity is high with low frequency. Excessive rainfall is not a concern for Ziyaaraifushi since the island does cup towards the middle.

8.7 Wind Conditions

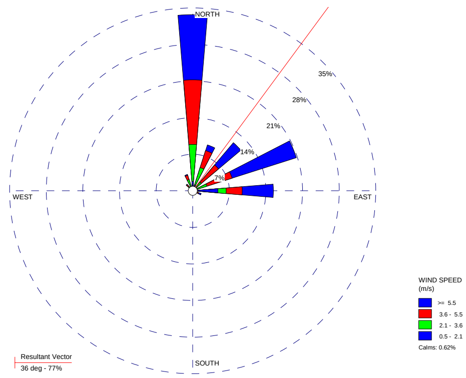
The National Meteorological Center for Maldives provides data for wind speed as recorded at Hulhulé meteorological station, for the period 1990-2010. The month wise windrose for the period of 20years

Table 9: Monthly Wind Rose Diagrams for Hulhulé Station, 1990-2010

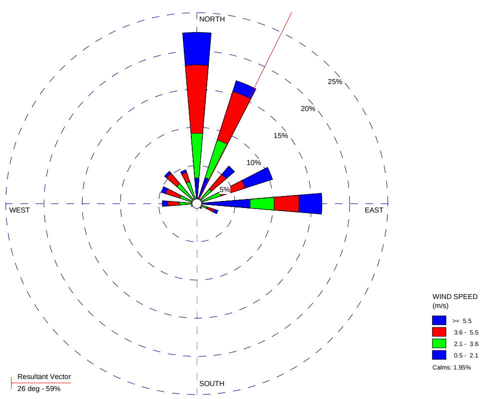
January



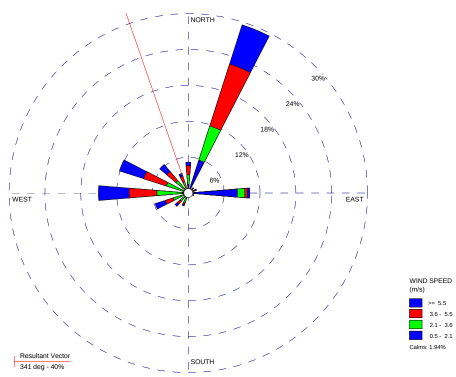
February



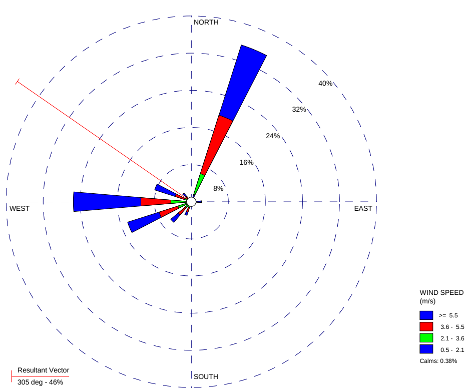
March



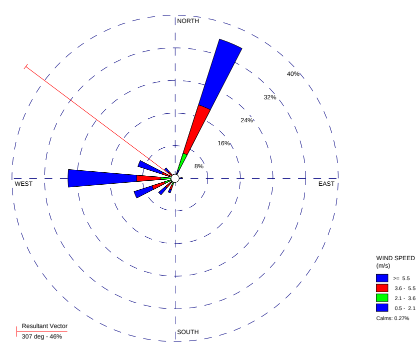
April



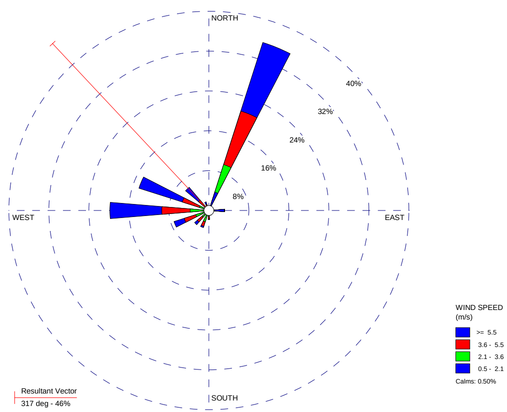
May



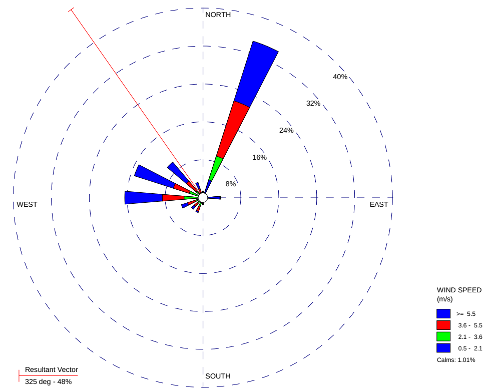
June



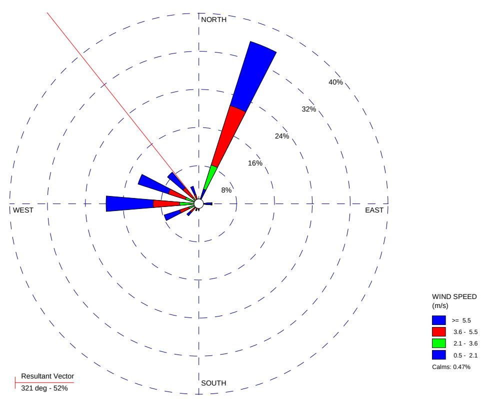
July



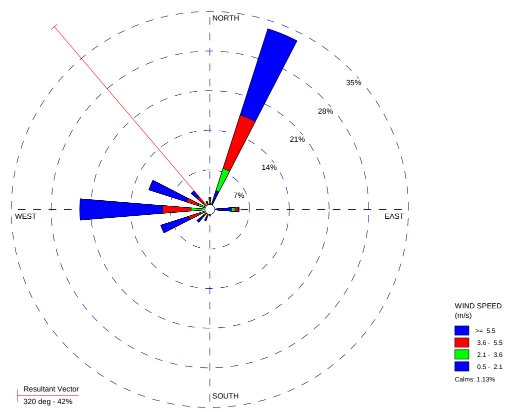
August



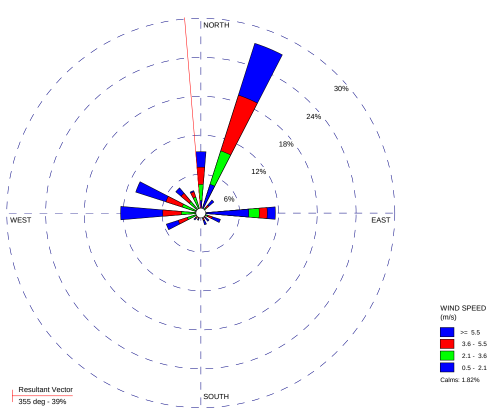
September



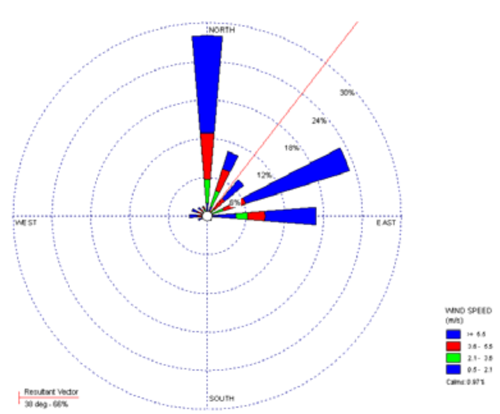
October



November



December



Source: National Meteorological Center, Maldives

The figure below illustrate the wind rose for Kaadhehdhoo from 1980 to 2006.

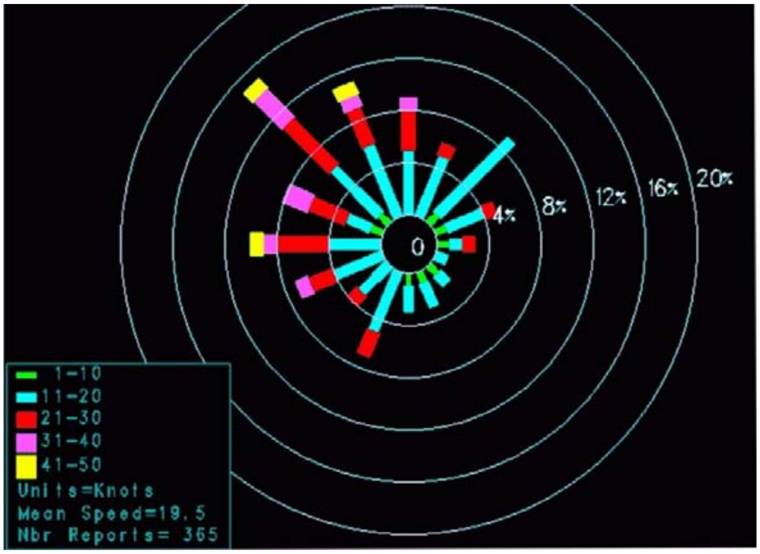
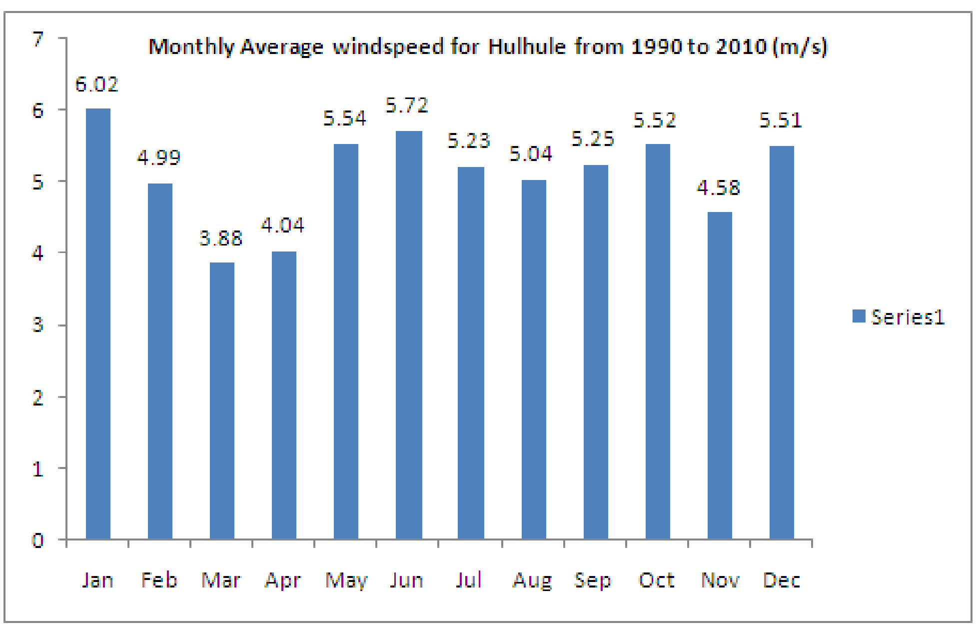


Table 10: Percentage of average wind direction for Kaadhedhoo (1980-2006)

8.8 Wind Speed

The average monthly wind speed over last 10 years at Hulhulé has been derived from the above windrose diagrams and presented in table below. The maximum average wind speed has been observed in the month of January and lowest in March.

Table 11: Average Monthly Wind Speed of Hulhulé (1990-2010)



8.9 Wind Direction

The predominant wind direction throughout the year is from North and North-East. The calm periods are low at less than 2% throughout the year. The month wise breakup of the wind direction and the resultant vector for Hulhule is provided in the following table.

Month	Predominant Directions	Calm Percentage	Resultant Vector
January	North (36%) Followed by East North East	0.27%	North East (35°)
February	North (34%) Followed by East North East	0.62%	North East (36°)
March	North (22%) Followed by North North East	1.95%	North North East (26°)
April	North North East (29%) Followed by West	1.94%	North North West (341°)
May	North North East (36%) Followed by West	0.38%	North West (305°)
June	North North East (36%) Followed by West	0.27%	North West (307°)
July	North North East (36%) Followed by West	0.50%	North West (317°)
August	North North East (36%) Followed by West	1.01%	North West (325°)
September	North North East (36%) Followed by West	0.47%	North West (321°)
October	North North East (34%) Followed by West	1.13%	North West (320°)
November	North North East (28%) Followed by West	1.82%	North West (320°)
December	North (36%) Followed by East North East	0.97%	North East (38°)

Table 12: Monthly Wind Direction (1990-2010)

The above table presents the seasonal distribution of wind statistics, sourced from Globocean database. The following periods have been defined in the database:

- December to March: NE Monsoon
- April: Transitional season - 1
- May to October: SW monsoon
- November: Transitional season - 2

Season >		NE Monsoon	Transitional Season 1	SW Monsoon	Transitional Season 2
Wind Directional Sectors		Dec. to March	April	May to Oct.	November
S1	N15°-N105°	71.35	15.28	1.43	23.96
S2	N105°-N225°	6.13	16.55	17.65	17.62
S3	N225°-N315°	8.42	56.74	77.61	41.11
S4	N315°-N15°	14.10	11.44	3.32	17.31
Source: Globocean database from 1993 to 2004					

Table 13: Wind Occurrence Frequency per Directional Sectors (%)

These results clearly indicate the prevailing directional sectors during the monsoon seasons:

- N15° to N105° during the NE monsoon, with about 71% of the observations,
- N225° to N315° during the SW monsoon, with about 78% of the observations.

8.10 Waves

Wave energy is important for sediment movements and settlement, and it is also a crucial factor controlling coral growth and reef development. Waves have been attributed to the diversity and the abundance of coral and algal species. These aspects have implications for the type and perhaps the supply of sediment s into the island.

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 April-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.

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 Hulhule 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.

In addition, Maldives has recently been subject to earthquake generated tsunami reaching heights of 4.0m on land (UNEP, 2005). Historical wave data from Indian Ocean countries show that tsunamis have occurred in more than one occasion, most notable been the 1883 tsunami resulting from the volcanic explosion of Karakatoa.

Season	Total	Long Period	Short Period
NE - Monsoon	Predominantly from E-S. High Waves from E	From S-SW	Mainly E-NE. High waves from E
Transition Period 1	Mainly from SE-E	From S-SW	Mainly from NE-SE
SW - Monsoon	From SE-SW. Mainly from S. Medium waves also from W	From S-SW	Mainly from SE-S. High waves from E
Transition Period 2	As SW monsoon	From S-SW	From SE-W. Higher waves from E

Table 14: Summary of Wave Condition for Hulhule region

8.11 Tides

Tides affect wave conditions, 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 process 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.

8.12 Tide Datum

Tide data is important information in any costal development project as it determines the elevation of the structures relative to a datum. A permanent tidal record stations has been established at Malé International Airport by Maldives Meteorological Services. The maximum tidal range recorded at this tide station is 1.20m. The highest astronomical tide level is +0.64m (MSL) and the lowest astronomical tide level is -0.56m (MSL).The following table gives a summary of the tide levels for the tide datum that has been widely used in Maldives.

Tide level	Water level referred to Mean Sea Level (MSL) (m)
Highest Astronomical Tide (HAT)	+0.64
Mean Higher High Water (MHHW)	+0.34
Mean Lower High Water (MLHW)	+0.14
Mean Sea Level (MSL)	0
Mean Higher Low Water (MHLW)	-0.16
Mean Lower Low Water (MLLW)	-0.36
Lowest Astronomical Tide (LAT)	-0.56

Table 15: Summary of the Tide Levels Hulhule Island, Male Atoll

8.13 Tide levels

The tidal regime is semi-diurnal with diurnal inequalities (twice daily). That means 2 high tides and 2 low tides per day, with different heights. Typical spring and neap tidal ranges are approximately 1.0 m and 0.3 m, respectively.

Table below gives the tidal levels in islands of Maldives, including Malé, as sourced from Admiralty Tide Tables for 2007.

	Geo. Coordinates		LAT	MLLW	MHLW	MSL (ML)	MLHW	MHHW	HAT
	Lat. (°N)	Long. (°E)							
Standard Port: Cochin (West coast of India)	9° 58'	76° 16'	-0.2	0.3	0.6	0.6	0.8	0.9	1.2
Maldive Islands									
Ihavandhoo	6° 57'	72° 55'	-	0.3	0.6	0.68	0.9	1.0	-
Goidhoo Atoll	4° 51'	72° 55'	-	0.3	0.5	0.6	0.8	0.9	-
Girifushi	4° 19'	73° 55'	-	0.3	0.4	0.58	0.7	0.9	-
Malé	4° 11'	73° 31'	-	0.3	0.5	0.65	0.8	0.9	-
Vattaru	3° 15'	73° 24'	-	-	-	0.7	0.9	1.0	-
Source: Admiralty Tide Tables, 2007									
Note: LAT - Lowest Astronomical Tide; MLLW - Mean Lower Low Water; MHLW - Mean Higher Low Water; MLHW - Mean Lower High Water; MHHW - Mean Higher High Water; HAT - Highest Astronomical Tide									

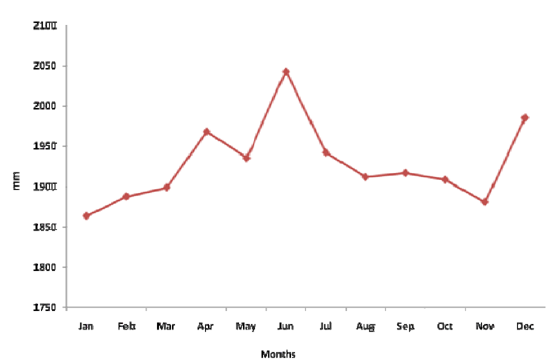
Table 16: Maldives Tidal Level (in mm)

8.14 Sea Level Rise

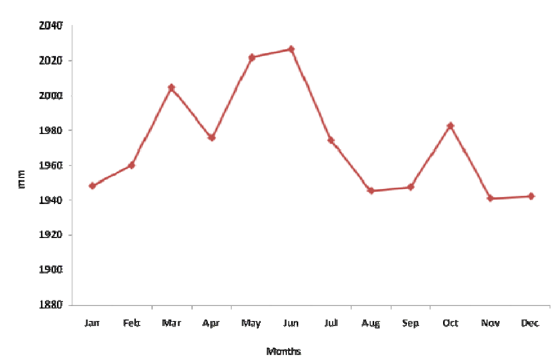
The Maldives, being a low lying small island state, is very vulnerable to climate change and its associated impacts, especially sea level rise. Although the country contributes only 0.001% of global GHGs, it is one of the most susceptible to climate change impacts. The average elevation of Maldivian islands is 1.5 m above mean sea level (MSL). More than 80% of the land area of Maldives is less than 1 m above MSL. The Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report predicts that sea-level rise of up to 0.88m by 2100 will submerge the Maldives completely.

Malé International Airport on Hulhulé Island is the only gateway to the Maldives. The height of the runway is only 2 m above MSL and is extremely vulnerable to climate change related sea level rise. The University of Hawaii Sea Level Center (UHSLC) monitors and gathers data on mean sea level for several stations including Hulhulé. The following graphs show the trend of monthly mean sea level as monitored at Hulhulé station for the period 2007 to 2010.

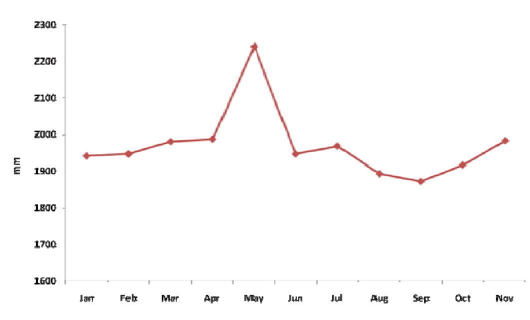
Year 2007



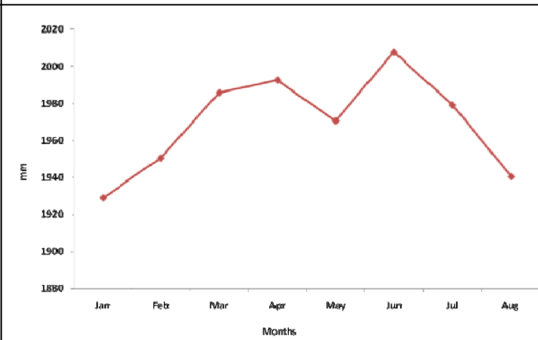
Year 2008



Year 2009



Year 2010



Source: University of Hawaii Sea Level Center (UHSLC)

Table 17: Mean Sea Level (in mm) from University of Hawaii Sea Level Center

The present estimates for the sea level rise at the Maldives due to the climatic changes are in order of about 0.5 cm per year. This is based on the fact that the sea level has risen 20cm over the past century (MHHE, 2001).

8.15 Currents

Several currents affect the Maldives Islands. These currents are divided mainly into ocean currents and tidal currents. The ocean currents are stronger than the tidal currents.

A general view of the seasonal current patterns in the Indian Ocean is shown below. The currents flow westward during the northeast monsoon period, and they flow eastward during the southwest monsoon period.

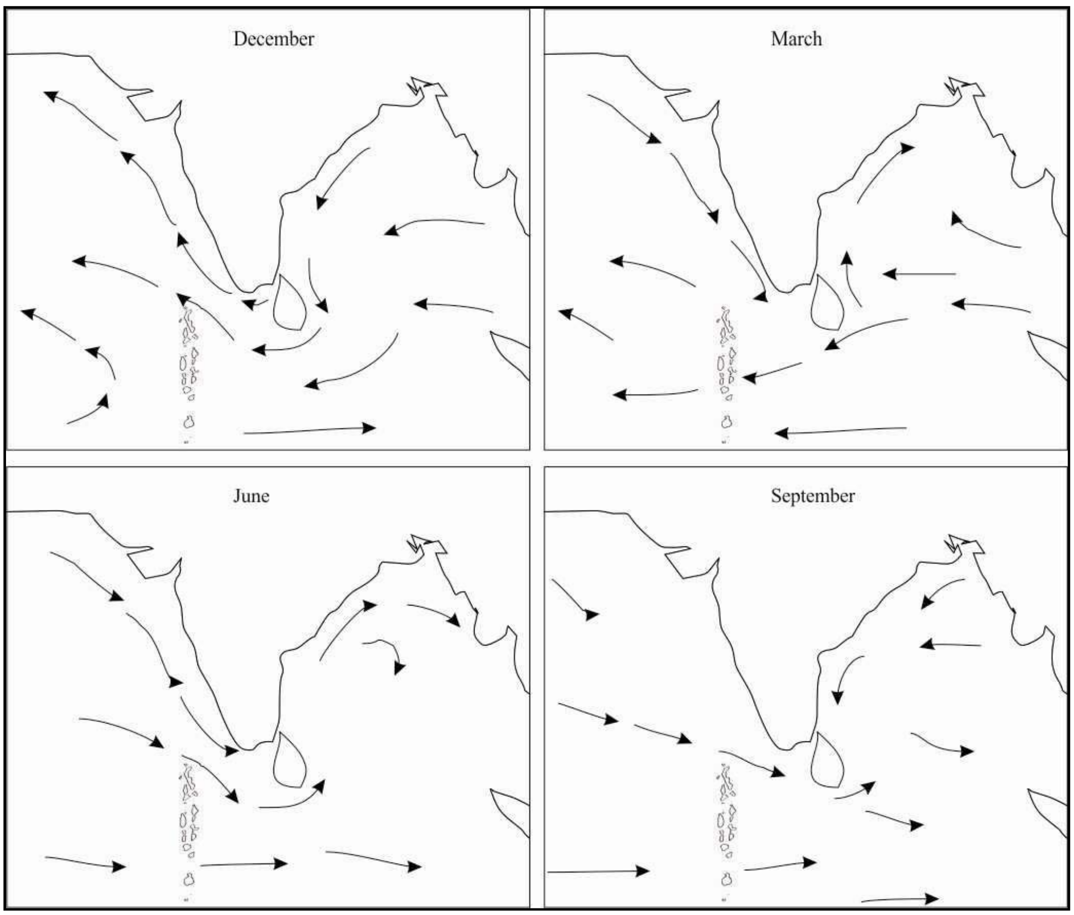


Table 18: Surface Currents around Maldives (by JICA, 1992)

The ocean currents flowing by the Maldives islands are also driven by the monsoonal winds. In the northern part of the Maldives, constant currents flow westward during the northeast monsoon period from December and April and eastward during the southeast monsoon period from May to August.

General, the tidal currents are eastward in flood and westward in ebb, the velocity, however varies by island areas. The current patterns result from reef forms.

Currents tend to be monsoonal in origin, generally setting W during the NE Monsoon (January to March) and E during the SW monsoon (May to October). During the transition months, the currents are variable. Ocean currents flowing through channels between the atolls are driven by the monsoon winds. Current speeds of 1 to 1.5 knots are reported in the Admiralty pilot. However, the current in the E/W channels of the Maldives may attain 5 knots.

8.16 Tidal Currents

Generally, tidal currents in the Maldives are Eastward in flood and Westward in ebb.

8.17 Offshore Wave Conditions (in deep water)

The swells and wind waves experienced by the Maldives are conditioned by the prevailing biannual monsoon and are typically strongest during April and July in the SW monsoon period. During this season, swells generated north of the equator with heights of 2-3 m and periods of 18-20 sec have been reported in the region. However swells originating from cyclones and storm events occurring well south of the equator may occur. Local wave periods are generally in the range 2 to 4 sec and are easily distinguished from the swell waves.

8.18 Cyclones

This paragraph presents information extracted from (UNDP- Developing a Disaster Risk profile for Maldives – May 2006) presenting the characteristics of cyclones in the Maldives.

The islands of the Maldives are less prone to tropical cyclones. The northern islands of the country have been affected by weak cyclones that formed in the southern part of the Bay of Bengal and the Arabian Sea. The number of cyclones directly crossing the Maldives is small. Only 11 cyclones crossed the islands over the entire span of 128 years between 1877 and 2004.

Most of the cyclones crossed the Maldives north of 6.0°N and none of them crossed south of 2.7°N during the period.

All the cyclones that affected the Maldives were formed during the months of October to January except one, which formed in April. The Maldives have not been affected by cyclones since 1993.

In the northern islands, the probable maximum storm tide due to cyclones has been estimated to be around 1.82 m (storm surge of 0.84 m) for a return period of 100 years. This storm surge was computed taking into account probable maximum winds and probable maximum pressure drops.

Chlorophyll Concentration/Productivity for Marine Water

Chlorophyll concentration/ Productivity is an index of phytoplankton biomass and it is the most common property that characterizes marine first tropic level. Chlorophyll concentrations derived from satellite remote-sensing images of ocean colour, provide a unique synoptic view of the marine ecosystem including eutrophication, fisheries.

A major value of ocean colour lies in the long-term monitoring of the marine environment which will improve the understanding of the ecosystems functioning. It also helps to assess the response to anthropogenic pressures like agriculture, urban development and global change. It was observed that the Chlorophyll concentration was higher along the periphery of Male' Atoll which may be attributed to increase in the concentration of nutrients due to sewage disposal in coastal waters. Nutrient enrichment of the waters stimulates the growth of phytoplankton, leading, in certain circumstances, to the phenomena of algal blooms and to anoxia in the lower part of the water column with destruction of the benthic fauna and flora. In addition, insufficient and selective sewage treatment can increase the input of nutrients into coastal marine waters and modify the natural ratio between them (removal of phosphorous compared to nitrogen) that may lead to changes in algal quantity and composition.

Aqua Satellite with MODIS sensor provides daily chlorophyll data in the Maldive area. The data provides the Chlorophyll range between).01 to 10 mg/cu m. Weekly composites of chlorophyll concentration were prepared using the AQUA Satellite data.

Year 2008		
Location	Week	Chlorophyll Concentration/Productivity range (mg/m3)
November (Post monsoon)		
Male Atoll	1st week	0.5- 2.0 (almost 1 mg/m along the periphery of atolls)
Male Atoll	2nd week	0
Male Atoll	3rd week	0.5-0.75
South of Male Atoll	4th week	0.7-0.85
Male' Atoll	4th week	0.6-0.8 with patches of zero (0) productivity
December (Post monsoon)		
Male Atoll	1st week	0.6-1.5
Male Atoll	2nd week	0.6-1.5
Male Atoll	3rd week	0.6-1.5
Male Atoll	4th week	0.8-2.5
Year 2009		
Location	Week	Productivity range (mg/m3)
January (Winter season)		
Male Atoll	1st week	0.7-3 (3 mg/m Along the periphery of Male Atoll
Male Atoll	2nd week	0.7-3 (3 mg/m Along the periphery of Male Atoll
Male Atoll	3rd week	0.7-2.5 (2.5 mg/m Along the periphery of Male Atoll
East of Male Atoll	4th week	0.1-0.4
West of Male Atoll	4th week	0.5-0.8
Male Atoll	4th week	0.7-1.0
February (Winter season)		
Male Atoll	1st week	0.7-2.0 with decreasing productivity towards east
Male Atoll	2nd week	0.7-1.0 with decreasing productivity towards east
March (Pre Monsoon)		
Male Atoll	1st week	0.7-2.0 with patches of zero productivity towards east side
Male Atoll	2nd week	0.7-2.0 with decreasing productivity towards east of atoll

Male Atoll	3rd week	0.7-2.0 with decreasing productivity towards east of atoll
Male Atoll	4th week	0.7-2.0 with decreasing productivity towards east i.e around 0.10 mg/m
April (Pre Monsoon)		
Male Atoll	1st week	0.6-1.5 with decreasing productivity towards east i.e around 0.10 mg/m
Male Atoll	2nd week	0
Male Atoll	4th week	0.7-2.5 with decreasing productivity towards east i.e around 0.10 mg/m
May (Pre Monsoon)		
Male Atoll	1st week	0.7-2.0
Male Atoll	2nd week	0.7-2.0 with patches of zero productivity
Male Atoll	3rd week	0.7-1.5 with mostly large patches of zero productivity
Male Atoll	4th week	0.7-3.0 with small patches of zero productivity
June (Southwest Monsoon)		
Male Atoll	1st week	0.7-2.5 (2.5 mg/m Along the periphery of Male Atoll
July (Southwest Monsoon)		
Male Atoll	1st week	Mostly zero productivity with value of 0.7-0.8 towards north
Male Atoll	2nd week	0.7-2.0 with patches of zero productivity
Male Atoll	3rd week	0.7-2.0
Male Atoll	4th week	0.7-2.0
August (Southwest Monsoon)		
Male Atoll	1st week	0.3-1.0
Male Atoll	2nd week	0
Male Atoll	3rd week	0.6-1.5 with decreasing productivity towards west of atoll
September (Southwest Monsoon)		
Male Atoll	1st week	Mostly zero productivity with patches of 0.7-0.8 around Male Atoll
Male Atoll	2nd week	Mostly zero productivity with patches of 0.7-0.8 towards SE direction
Male Atoll	3rd week	0.7-2.0
Male Atoll	4th week	Mostly zero productivity with patches of 0.7-0.8 around and south of Male Atoll
October (Post monsoon)		
Male Atoll	1st week	0.6-1.5 with decreasing productivity towards west of atoll
Male Atoll	2nd week	0.7-2.0
Male Atoll	3rd week	0.6-1.5 with decreasing productivity towards west of atoll and patch of zero south of Male atoll
Male Atoll	4th week	0.7-1.5 with small patches of zero productivity
November (Post monsoon)		
Male Atoll	1st week	0
Male Atoll	2nd week	0.7-2.0
Male Atoll	3rd week	0.7-1.5
Male Atoll	4th week	0
December (Post monsoon)		
Male Atoll	1st week	0.7-2.0

Male Atoll	2nd week	0.7-1.5
Male Atoll	3rd week	0.8-2.0 with large patches of zero productivity
Male Atoll	4th week	0.8-2.0 with large patches of zero productivity
Year 2010		
Location	Week	Productivity range (mg/m3)
January (Winter season)		
Male Atoll	1st week	0
Male Atoll	2nd week	0.7-1.0 (almost 2.5 mg/m Along the periphery of Male Atoll
Male Atoll	3rd week	0.7-2.0 with patches of zero (0) productivity
South of Male Atoll	3rd week	1-2.5
Male Atoll	4th week	0.7-2.5 with patches of zero (0) productivity
February (Winter season)		
Male Atoll	1st week (day 1)	0
Male Atoll	2nd week (day 9)	0
Male Atoll	3rd week (day 22)	0.1-0.5
Male Atoll	4th week (day 28)	0.1-1.0
March (Pre Monsoon)		
Male Atoll	1st week	0.1-0.5
Male Atoll	2nd week	0.1-0.5
Male Atoll	3rd week	0.1-0.4
Source: INCOIS		

Table 19: Productivity Data for Chlorophyll for Male Region, 2008-2010

The chlorophyll data suggests that the productivity in and around Male-Hulhule area is lowly productive with the max Chlorophyll vale of maximum 3 mg/ cum. The productivity is more during January to May and rapidly decreases with the onset of monsoon. The productivity is maximum between January and February months.

Hazards and Disasters

8.19 Vulnerability to Natural Disasters

The islands of the Maldives are less prone to tropical cyclones and are only impacted in the northern part of the country by weak cyclones that formed in the southern part of the Bay of Bengal and the Arabian Sea. Since 1877, only 11 cyclones crossed the archipelago (Maniku, 1990). Most of the cyclones crossed Maldives north of 6.0o N and none of them crossed south of 2.7o N during the period. All the cyclones that affected Maldives were formed during the months of October to January except one, which formed in April (UNDP, 2006).

Table 20: Cyclonic Wind Hazard Map (source: UNDP, 2006)

The northern atolls have a greater risk of cyclonic winds and storm surges. This reduces gradually to very low hazard risk in the southern atolls (see **Error! Reference source not found.**). The maximum probable wind speed in Zone 5 is 96.8 knots (180 kilometres per hour) and the cyclonic storm category is a lower Category 3 on Suffir-Simpson scale. At this speed, high damage is expected from wind, rain and storm surge hazards (UNDP, 2006).

Table 21 shows historical earthquakes around Maldives; and three events of magnitude above 7.0 struck the region which had their sources in the Indian Ocean (UNDP, 2006).

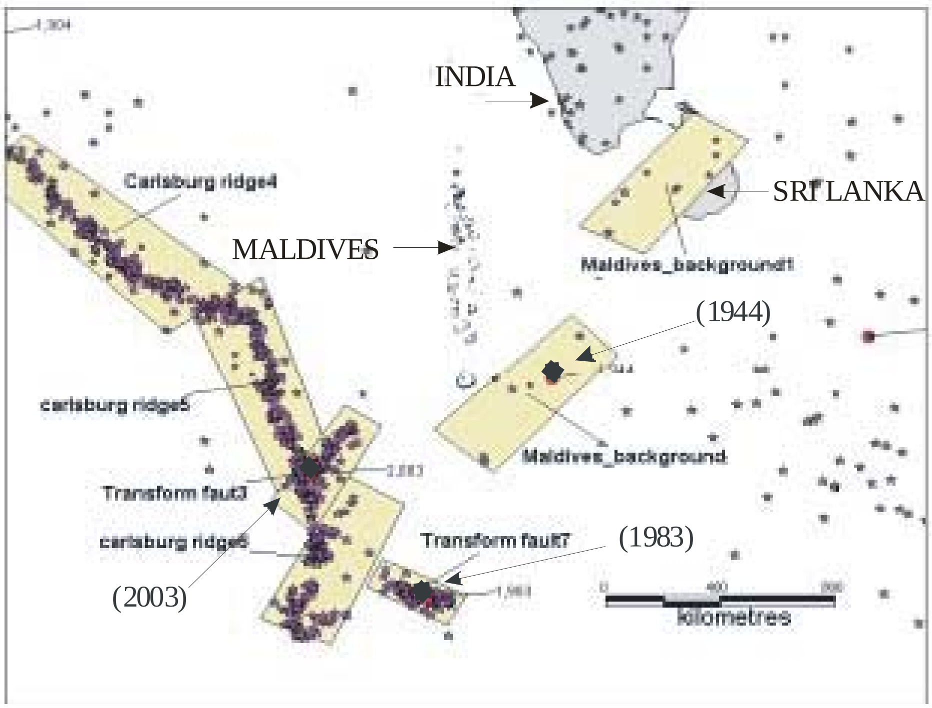


Table 21: Earthquake Epicentres around Maldives (Source: UNDP, 2006)

UNDP (2006) identified that hazard risk from earthquake is low for the Maldives and considered as a disaster risk for only islands located in the south of the country. See **Error! Reference source not found.**.

Table 22: Earthquake Hazard Zone (source: UNDP, 2006)

Maldives faces tsunami threat largely from the east, and lower threat from the north and south. Islands along the eastern fringe of the atolls are more prone to tsunami hazard than those along the northern and southern fringes. Islands along the western fringe experience a relatively low tsunami hazard. Historically, Maldives has been affected by three earthquakes which had their sources in the Indian Ocean. Of the 85 tsunamis generated since 1816, 67 originated from the Sumatra Subduction zone in the east and 13 from the Makran Coast Zone in the north and

Carlsburg Transform Fault Zone in the south. The probable maximum tsunami wave height is estimated at 4.5 metres.

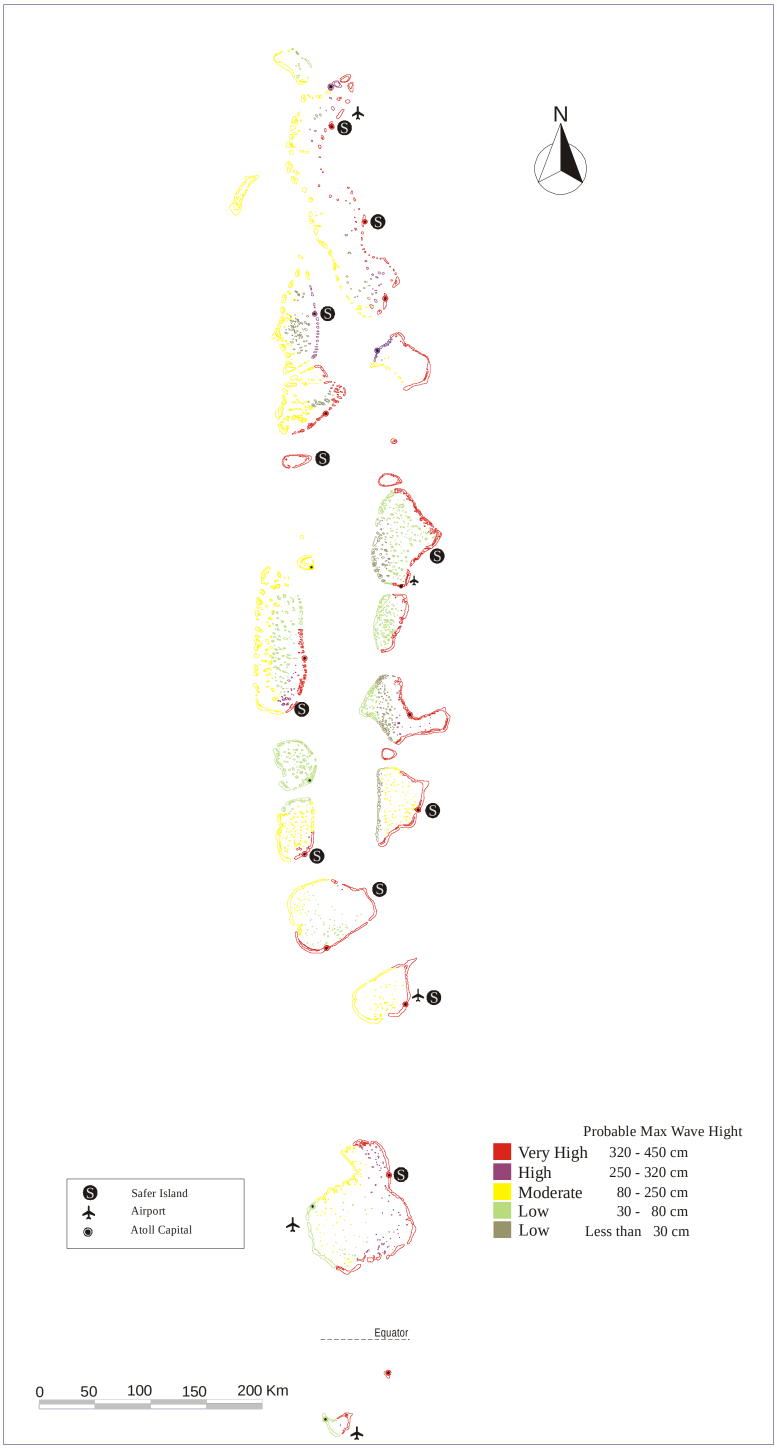


Table 23: Tsunami Hazard Zones (adopted from UNDP, 2006)

8.20 Natural Vulnerability of the Islands

The islands of the Maldives have natural characteristics which make them vulnerable to disasters such as tsunami. An island's Natural Vulnerability depends on geographic and geomorphologic characteristics of the island. These include geographic features of the island like the side of the country where the island is located, the formation of the island, location of the island respect to the atoll, orientation of the island, region of the country where island is located, level of shadow to the island from the reefs and other islands; area of the inland lake found on the island, width of the island's house reef, coastal defence structures on the island, shape of the island and the area of the island. A Model to Integrate the Management of Hazards and Disasters in the National Sustainable Development Planning of the Maldives which was developed as part of the Masters of Science (Hazard and Disaster Management) thesis at the University of Canterbury (Jameel 2007) identified the relationship between natural characteristics of the island and the natural vulnerability of the islands using the data that was collected following the Indian Ocean Tsunami.

8.21 Existing Marine Environment

The marine environmental survey at Thimarafushi was focused on seven sites. These sites area indicated in the following pages.

Site selection was based on specific areas to be reclaimed, borrow sites and possible indirectly impacting areas.

8.22 Methodology of marine surveys

The methodologies used for the assessment were quantitative complimented by qualitative methods. Photo transects of 50 meters each was undertaken at each site. In addition, photos were also taken from these locations to support and assess the marine environment. Fish counts were also undertaken to get a snapshot of the fish population. Details of these methodologies are discussed in the methodology section.

General impression and quantitative results of the sites surveyed are described in the following pages. The diagrammes in the following pages illustrates the marine survey locations and their GPS coordinates as well as reef status.

8.23 Coral reef

Seven sites were surveyed to assess the marine environment as baseline for reef benthic community. The geographical coordinates and the locations are outlined below. The survey results indicate that only sites 5, 6 and 7 have live corals. Sites 1 to 4 does not have any live coral cover as these areas have been destroyed during the first phase of land reclamation.

Site 1	2°12'52.95"N	73° 9'14.20"E
Site 2	2°12'47.94"N	73° 9'5.82"E
Site 3	2°12'34.44"N	73° 8'50.69"E
Site 4	2°12'12.45"N	73° 8'23.83"E
Site 5	2°12'18.72"N	73° 8'17.16"E
Site 6	2°12'37.11"N	73° 8'37.77"E
Site 7	2°12'45.26"N	73° 8'47.66"E

Figure 1: GPS coordinates of the survey locations (November 2011).

The following graph illustrates the percentage of live coral cover recorded at sites 5, 6 and 7.

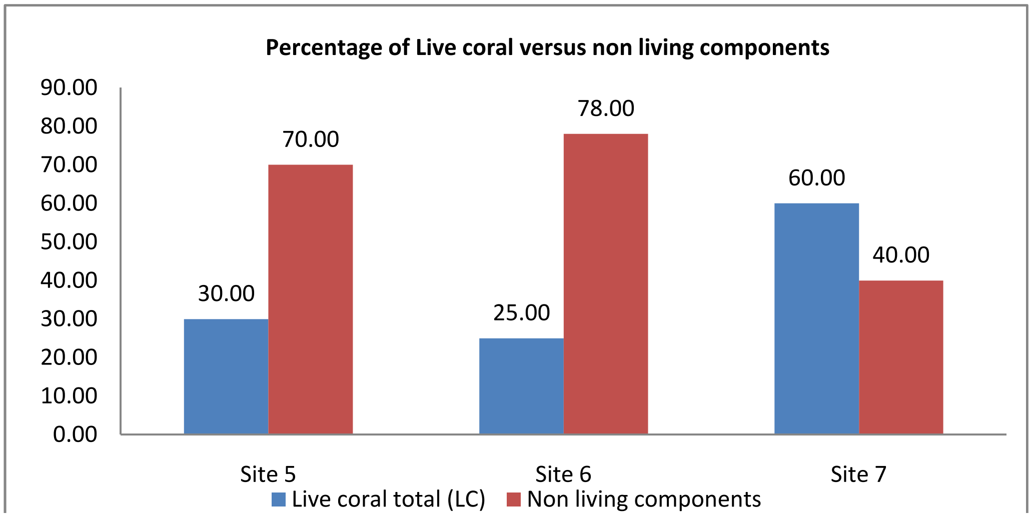


Figure 2: Percentage of live corals versus non living components at all the sites surveyed (October 2011).

In terms of live coral cover, Site 6 has 25% live corals which is the lowest in terms of live coral cover in comparison to sites 5 and 7, while the non living components attributed to over 78%. Site 7 was the highest percentage in terms of live coral cover which accounted for 60% with 40% of the site being covered with non living components. Site 7 was considered to be very healthy as the percentage of live corals is very high. Site 5 has 30% live corals and 70 percent non living components.

8.24 Status of coral reef at site 1

Site 1 lies in close proximity to the already deepened area from the first phase of reclamation. This is also the location where the second phase of reclamation will dredge for borrow material. There are no live corals in this site as the site has been completely destroyed from dredging. The site has not had time to recover and for new corals to regenerate, it will take some time. As a result, the entire area is filled with sediments. There is also a high degree of suspended sediment in the water column. The following photos illustrate the poor status of the reef at site one. No fish species were also observed during the survey.

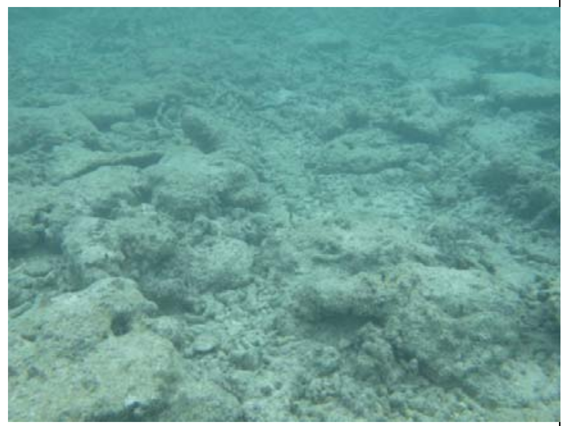
Status of coral reef at site 1	
	
The reef is completely destroyed from reclamation and there are no live corals no any fish species observed during the survey.	The bottom is filled with dead corals, rubble and suspended sediments. The reef will require time for new corals to regenerate.

Figure 3: Photos indicating reef status at site 1 (November 2011)

8.25 Status of coral reef at site 2

Similar to site 1, site 2 is also completely destroyed and there are no live corals. This is also the location where the second phase of reclamation will dredge for borrow material. There are no live corals in this site as the site has been completely destroyed from dredging. The site has not had time to recover and for new corals to regenerate, it will take few years. The entire area is filled with sediments. There is also a high degree of suspended sediment in the water column. The following photos illustrate the poor status of the reef at site one. No fish species were also observed during the survey. From the scale of the reclamation and the proximity of this site to the borrow area of phase 1, it is no surprise that the reef has been damaged severely.

Status of coral reef at site 2	
	
The reef is completely destroyed from reclamation and there are no live corals no any fish species observed during the survey.	The bottom is filled with dead corals, rubble and suspended sediments. The reef will require time for new corals to regenerate. There is also very poor visibility from the high percentage of suspended sediments.

Figure 4: Photos indicating reef status at site 2 (November 2011)

8.26 Status of coral reef at site 3

Site 3 is no different and consists of mainly coral rubble, sand and dead corals. The following photos illustrate the status of the reef at site 3. Site 3 is very shallow and is the proposed reclamation area for phase one. This area has also been rendered very stagnant after the reclamation which prevents any water flow from the atoll inside to outside. As a result, locals complain of foul odour from this area which is caused by the decaying sea grass and dead corals which emit foul odour, especially during low tide, when most of the lagoon bottom is exposed.

Status of coral reef at site 3	
	
Site 3 is also completely destroyed and considered dead. During low tide, most areas are exposed	

Status of coral reef at site 3	
with rotting sea grass and dead corals which emits foul odour in this area. The growth of sea grass in this area is considered to have caused the growth of sea grass. Seen on the right is a gobie taking refuge among the sea grass and the coral rubble.	

Figure 5: Photos indicating reef status at site 3 (November 2011)

8.27 Status of coral reef at site 4

Site 4 is also considered dead and does not contain any live corals. There is growth of sea grass to some extent. The coral reef status of this site is not considered to be caused by the first phase of reclamation as the reef slope areas (site 5) has very high coral cover.

Status of coral reef at site 4	
	
Site 4 is also considered to be very unhealthy and mainly consists of coral rubbles, sand and sea grass. The status of the reef is not considered to be a result of the first phase of reclamation.	

Figure 6: Photos indicating reef status at site 4 (November 2011)

8.28 Status of coral reef at site 5

Site 1 was observed to have a very high percentage of live coral cover spanning the entire reef slope and reef flat areas, although their numbers were less in comparison on the lagoon side. This area is alive with a multitude of corals, mostly hard corals and a diverse variety of fishes. This area has remained intact despite the massive reclamation undertaken in the island's reef system. The reef slope is very healthy as can be seen from the photos taken during the survey illustrated in this report. It was observed that most of the live corals growing were attachd to large dead corals or rocks. There is also plenty of young coral colonies growing from everywhere, indicating that this area is in a state of very healthy growth.

The proposed reclamation of the southern side of the island will have major negative and direct impact on the reef benthos in this area. It is anticipated that most of these corals will be destroyed during the reclamation. GPS locations were recorded for future monitoring purposes. Using 40 photos taken over a length of 50 meters line transect along a 5 meter belt, the live coral covers as well as other elements were estimated, and details are outlined in the following graphs. The fish population was estimated using time swim surveys undertaken for a period of 15 minutes and from the same location.

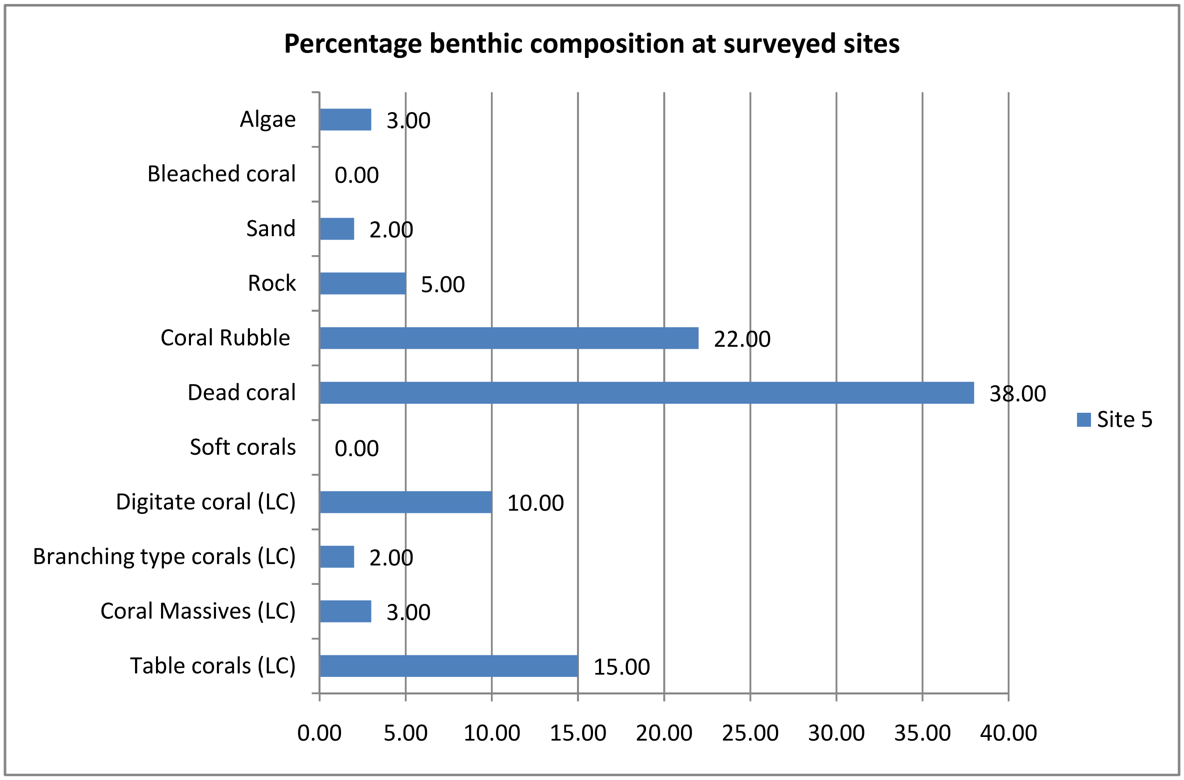


Figure 7: Percentage benthic composition at site 5 (October 2011)

Live coral cover at site 5 was 30%. The dominant type of corals recorded was Acropora tabular. Other live coral types recorded were Coral Massives (3%), Coral Branching (2%) ad Acropora Digitate (10%). Of the non living components, dead rocks dominated this area with 38%. Percentage of rock was 5% and coral rubbles constitute 22%, sand 2% and algae accounting to 3%. No bleached corals were recorded or found.

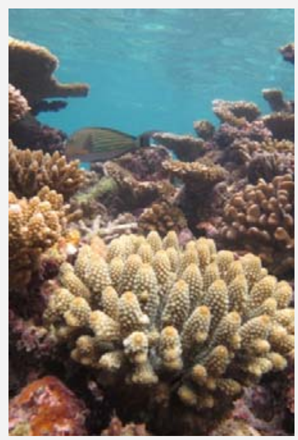
	
Site 5 has a very high percentage of live corals, mostly table corals as indicated in these photographs.	Most of the reef at this site is covered with hard corals.
	
The phot illustrates the coral coverage at this site. Despite the reclamation that has been undertaken in Thimarafushi, this site does not seems to have been affected as can be seen with the healthy coral population. However, the second phase of reclamation is going to destroy all or most of these corals.	Digitate coral colony growing among the numerous live corals.

Figure 8: Photos indicating reef status at site 5 (November 2011)

8.29 Status of coral reef at site 6

Site 6 has very poor visibility and high sedimentation considered to be arising from the reclamation. Fines suspended and dispersed form the reclamation area gets transported to the ref slope which are dispersed in the entire region creating very poor visibility. Although this area has lot of live corals, they are being affected by suspended sediments and are under lot of stress. During the survey, a lot of dead sea grass were found which was coming from close to the shore where sea grass beds are present. They are mostly found between the shore and the reef slope.

This site is considered to be very healthy in terms of live coral cover as a lot of live coral growth is present, but is not likely to last long as they are under threat from suspended solids as well as from the proposed reclamation. Coral patches are numerous ion this region and survey was concentrated on these coral patch areas. Moving towards the lagoon, the percentage of live coral cover get reduced.

The site also has very large colonies of coral massive which were also covered in sediments. There is diverse range of corals in this area, but mostly hard corals. It was also observed to have sustained a lot physical damage to corals, most likely by small boats as freshly broken pieces of corals were observed. The area is dominated by Table corals and the survey was carried along the live coral patches and not inside the lagoon. Visibility during the survey was about 3 m and the fish population is considered to be very less.

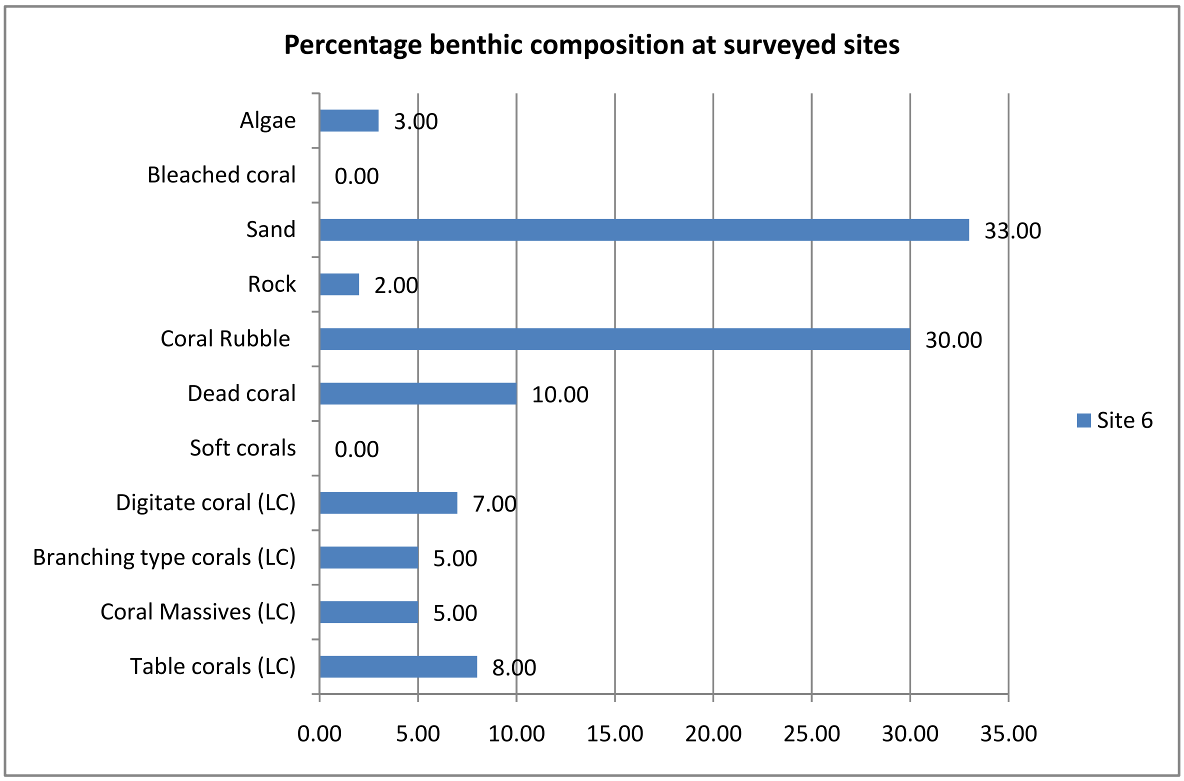


Figure 9: Percentage benthic composition at site 6 (November 2011)

Live coral cover at site 6 was 25%. The dominant type of live corals recorded were Acropora Tabular which accounted for 8%. Five percent (5%) were coral massives, while braching corals accounted for 5% and Digitate Corals accounted for 7%. Of the non living components, coral rubble dominated this site with 30%, Hard rocks / rock base accounted to 2% and sand taking up 33%, bleached corals 0% and 3% algae along the transects. During the survey, visibility was very poor and so survey results are expected to have some bias.

	
Table coral colonies at site 6. Despite the high coral cover, this area is heavily affected by reclamation mainly through sedimentation. .	Branching coral colony under stress from excessive sedimentation.

Figure 10: Photos indicating reef status at site 6 (November 2011)

8.30 Status of coral reef at site 7

At site 7, the reef slope is very healthy, and accounts to more than 60% live coral cover. There was lot of sedimentation from the suspended fines mainly arising from the reclaimed area. The corals in this area are under intense stress due to high suspended fines which prevents adequate light from reaching the corals. Some bleached corals were also observed which is a bad sign that the corals are dying in this area. The proposed reclamation is only going to exacerbate this issue and it is likely that the corals in this area will be entirely killed. Despite these factors, there is diverse range and variety of fish life at site 7. Some areas of the slope contains more than 100 percent live corals as the reef bottom cannot is entirely covered with live corals, mostly branching corals. Hence, this is a very healthy area of the reef but severly affected by the reclamation and it is going to be worse in the second phase of the reclamation. The area will sustain more damaged during the reclamation of the additional area

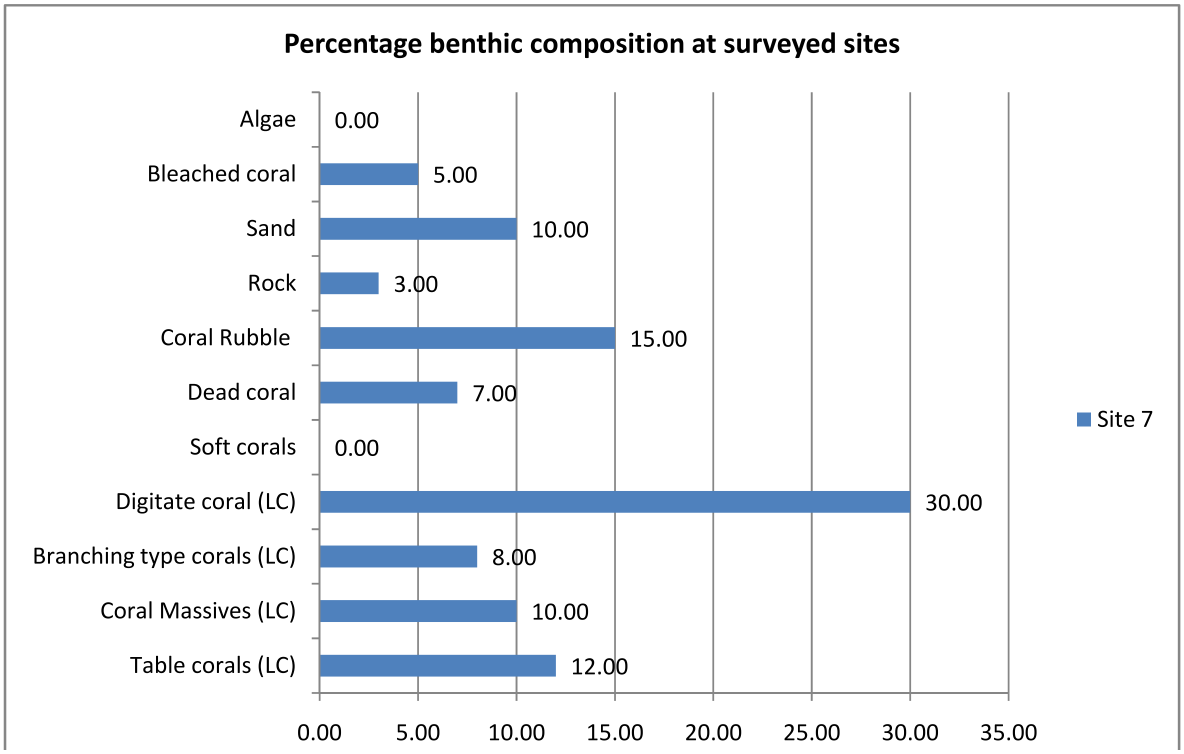


Figure 11: Percentage benthic composition at site 7 (November 2011)

Live coral cover at site 6 was 60%. The dominant type of live corals recorded were Acropora Digitate which accounted for 30%. Ten percent (10%) were coral massives, while branching corals accounted for 8% and Table Corals accounted for 12%. Of the non living components, coral rubble dominated this site with 15%, Hard rocks / rock base accounted to 3% and sand taking up 10%, bleached corals 5% and 0% algae along the transects. During the survey, visibility was very poor and so survey results are expected to have some bias.

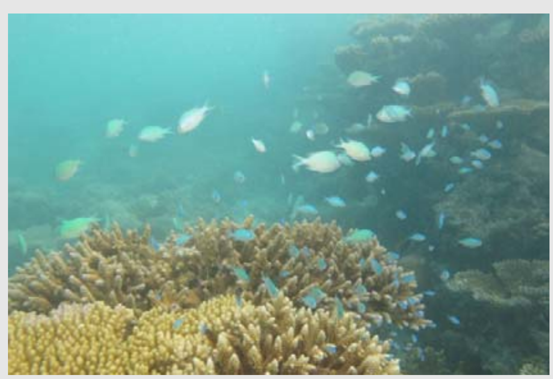
	
High percentage of hard corals under stress at site 7.	School of chromis taking refuge around a coral colony. The site is heavily affected by sedimentation.

Figure 12: Photos indicating reef status at site 7 (November 2011)

8.31 Status of fish abundance

The amount and type of fish present at a given site can be a good indicator of the marine environment. For example, increased grazers are generally a sign of increased nutrients in the area, thus decreased coral cover and increased algal cover.

The following table outlines the fish count survey at all the sites.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Family	-	-	-	-	R	-	-
Angelfishes (Pomacanthidae)	-	-	-	-	R	R	-
Anthias	-	-	-	C	A	A	-
Batfish	-	-	-	-	R	C	-
Bigeyes (Priancanthidae)	-	-	-	C	R	R	-
Blennies	-	-	-	-	-	-	C
Butterflyfishes (Chaetodontidae)	-	R	R	-	A	R	-
Damselfishes (Pomacentridae)	-	-	-	C	A	A	-
Emperors	-	-	-	-	A	C	R
Fusiliers (Caesionidae)	-	-	-	-	-	-	-
Goatfishes	-	-	-	-	-	A	A
Gobies	-	-	-	A	A	C	A
Groupers	-	-	-	C	C	R	-
Hawkfishes	-	-	-	R	R	-	-
Jacks	-	-	-	R	-	C	-
Lethrinidae (Emperors)	-	-	-		R	R	R
Moorish idol (Zanclidae)	-	-	-	-	-	-	C
Parrotfishes (Scaridae)	-	R	C	C	-	-	R
Pipe fish	-	-	-	-	-	R	-
Rudderfishes (Kyphosidae)	-	-	-	-	-		C
Snappers (Lutjanidae)	-	-	-	C	C	R	A
Soldier fish	-	-	-	A	-	C	C
Squirrelfishes (Holocentridae)	-	-	-	C	C	C	R
Surgeonfishes (Acanthuridae)	-	-	-	C	R	C	C
Sweetlips	-	-	-	R	C	C	A
Triggerfishes (Balistidae)	-	-	-	-	-	C	A
Wrasses (Labridae)	-	-	-	-	-	R	R

Table 24: Fish abundance based on the fish survey at survey sites (November 2011)

8.31.1 Marine water quality and bathymetry

The primary objective of the marine water quality sampling was to determine the baseline conditions of the marine water in the project site. Qualitative and quantitative assessments were made on seawater from two locations. The bathymetry of the proposed reclamation area as well as sediment borrow site is attached as an annex. Table 25 illustrates the result of the marine water quality test.

Water Quality	Site 1	Site 2	Optimal range	Ref
Physical appearance	Clear	Clear		
Electrical Conductivity (us/cm	55100.00	55500.00		
Temperature C	28.00	28.00	18 - 32 Degree Celcius	GBRMPA 2009
Salinity (mg/l) or PPT	33500.00	33500.00	3.2% - 4.2%	GBRMPA 2010
pH	8.10	8.40	8 to 8.3. Levels below 7.4 will cause stress	
Turbidity (NTU)	0.00	0.00	3 to 5 NTU. > 5 NTU causes stress	Cooper et al 2008
Suspended solids (mg/l)	8.00	2.00		

Table 25: Results of the marine water quality tests undertaken in Thimarafushi

9 Environmental Impacts

9.1 Impact Identification

Environmental Impact identification has been undertaken by considering the proposed activities and examining the level of impact the dredging and reclamation will have on the environment. To assess the impacts of this project, an Impact Assessment Tool (IAT) was designed to help provide an assessment and screening of the potential environmental impacts of this project.

This IAT considers 14 potential environmental factors. Indicators are listed for each factor and these are used as a checklist. These points are then used to assess the project/proposal against each factor, scoring them on a scale of 1 to 10. To enhance visual representation the scale is colour coded as follows:

Scale Score 1-3 (RED): Negative Environmental Impact

Scale Score 4-7(AMBER): Neutral Environmental Impact

Scale Score 8-10(GREEN): Positive Environmental Impact

The completed matrix; a summary of the positive, neutral and negative environmental impacts; and any recommendation are then considered.

This tool contains:

- An Impact Assessment matrix which lists all of the 14 environmental factors and allows, for each one, to provide a score (1-10) and any additional comments.
- A summary sheet which can be used to provide an overview of the impacts of the project (positive, neutral and negative)

All types of projects that are listed in the EIA Regulation of 2007 can be assessed using this tool.

9.2 Impact Assessment results

Impacts are assessed by giving a score for each factor on a scale of 1 to 10 where a score of:
1 = significant adverse environmental impact
2 or 3 = negative adverse environmental impact
4 to 7 = neutral environmental impact
8 = good positive environmental impact
9 = very good positive environmental impact
10 = excellent positive environmental impact

1	2	3	4	5	6	7	8	9	10
Significant	Negative		Neutral				Good	Very good	Excellent

The summary of the Impact Assessment is given in the following table.

Name of Project: Reclamation 240,000 sq meters in Thimarafushi, Thaa Atoll				
Client: Ministry of Housing and Environment.				
	Total score	+ impacts	Neutral impacts	- Impacts
Air pollution	5.32		x	
Waste	4.8		x	
Water pollution	1.2			x
Noise/Vibration	7.0		x	
Amenity	3.0			x
Water conservation	5.0		x	
Energy	3.9			x
Energy efficiency	4.0		x	
Access to quality green space	4.0		x	
Flooding	5.0		x	
Transport	9.0	x		
Biodiversity	3.0			x
Local environmental quality	3.0			x
Resource depletion	7.40	x		

9.3 Uncertainties in impact prediction

Environmental impact prediction involves a certain degree of uncertainty as the natural and anthropogenic impacts can vary from place to place due to even slight differences in ecological, geomorphologic or social conditions in a particular place. There is also limited data and information regarding the particular site under consideration, which makes it difficult to predict impacts.

However, the level of uncertainty, in the case of this project at Thimarafushi is expected to be low as reclamation has been undertaken within the past one year by modifying the existing coral reef environment significantly. Therefore, a lot of damage has occurred to the coral reef and comparison of the scale of the project and the damage to the coral reef can be made based on the marine environment surveys conducted for this EIA. In addition, similar projects have been undertaken elsewhere in the Maldives.

However, despite this, in the marine environment, there is slightly elevated degree of uncertainty as the marine environment is more sensitive in extreme cases such as severe weather conditions. The areas where filling will be undertaken is the south west side lagoon with very less percentages of live corals. There is only very small percentage of live coral cover in this area. Hence, limited percentage of live corals on south west side will not have an adverse impact, but filling will completely destroy and alter the lagoon bottom as well as cause indirect impacts. Nevertheless, sedimentation will affect the coral reef on the south west side which has very high percentage of live corals.

Dredging and reclamation activities are developments that had been undertaken in other parts of the Maldives and their impacts are well known and have been well documented. Therefore, there is very little uncertainty involved in this project.

The following matrix outlines the impacts and mitigation measures and their significance.

Table 26: Summary of the impacts and their mitigation measures

Activity	Potential Impacts	Mitigation measures	Cost of Mitigation
Dredging of the lagoon	Impact of dredging In this project, cutter suction dredger will be used to borrow sand and therefore sedimentation will be an ultimate outcome which will be unavoidable. All corals in the foot print of the dredging area will be destroyed. Despite this, it has to be noted that this is only a short term effect and will only last during the dredging period. The borrow area will be dredged to a depth of 8.5 m. The predominant currents during NE monsoon, mainly wind generated from north to north-east side will ensure that sediment dispersion take place towards west. Therefore, during dredging, sediment dispersal will be the most significant impact. Sediment dispersal will be affected by tide, wind and current movement on the day of dredging. In addition, sediment dispersion will vary according to the time of the year work is carried as currents will vary between the two monsoons. The majority of the impacts will be the sedimentation of the western lagoon and damage to corals as a result of high levels of sedimentation in the water column.	During dredging process, bund walls (sand) will be placed along the perimeter initially to contain sediments. Once the dredging is completed, the bund walls will be removed. This is the most common method of containing sediment dispersion in dredging projects, but are also limited by the type of environment. Although silt screens are not used commonly in Maldives, it is encouraged to use silt screens to contain the sediment plume from dispersing in to coral reef areas. Completing the dredging works in the shortest possible time period is also a mitigation that can greatly reduce negative impacts.	Cost included in the contract document. Contractor to follow the mitigation measures, including bund wall. Contractor will also be required to time the work to low tide hours.
Energy generation	Energy for construction (dredging, filling and coastal protection works. Use of energy for construction activities has an indirect negative impact on the environment through consumption of fuel.	Energy generation will be controlled and monitored. Contractors will be required to use the power from the island grid to avoid separate generator sets, which will increase emission of green house gases as much as possible and in practical situations where it can be used.	

Activity	**Potential Impacts**	**Mitigation measures**	**Cost of Mitigation**
Impact of the temporary workforce	During the construction stage, the large number of workforce and their behavior could have significant impact on the environment. It is not expected that any damage would be caused by workers fishing or walking on the lagoon, as the environment does not encourage such behavior. Improper and indiscriminately dumping solid waste to the reclamation area, especially the marine environment can impact the marine environment, such as throwing garbage, plastics etc.	Fishing from the house reef of the project site will be banned during the construction stage. The contractor and all construction staff will been informed of this. Due to the fragile nature of the coral reef, walking on corals while swimming and working in the lagoon environment will also banned. This preventative measure will also be informed to all staff. In Thimarafushi, live corals are in deep areas, close to the reef slope, so damage to corals in this way is almost impossible. Appropriate signs will be placed to keep the site clean. Fines and discharges for not obeying the environment protection rules. Workers will be briefed about proper disposal of litter and avoid damaging the surrounding environment.	
Noise and air pollution	Noise impacts will be localized.	Noise is not expected to be a concern due to the intermittent nature of noise sources such as dredger, excavators and other construction heavy vehicles. However construction workers, who are prone to high noise levels such as machinery operators, will be provided with proper personal protection equipments (PPE) such as ear muffs.	No cost

Activity	**Potential Impacts**	**Mitigation measures**	**Cost of Mitigation**
Reclamation of the lagoon	Sedimentation Reclamation of the lagoon will permanently alter the seabed and disperse sediment plumes to the coral reef areas. This is an inevitable result of reclamation activities. Corals can tolerate sedimentation to a certain extent. However, coral growth and recruitment will be affected in the moderate term. Prolonged exposure will eventually lead to death of the corals. The impacts of excessive sedimentation on corals include; • Direct physical impacts like smothering of corals and other benthic organisms, • Reduced light penetration reducing the productivity and growth, calcification and reproduction rates of corals. • Formation of false bottoms characterized by shifting of sediments. • Eutrophication due to increased fine sediments leading to algal blooms. • Formation of anoxic (black) bottoms under the fine sediments.	The following mitigations measures are proposed 1. Reclamation shall be undertaken by creating a sand bund around the reclamation area to reduce sedimentation impact. These can be sand bags or sand and will only be removed once the works are completed. This activity will be undertaken during calm weather at low tides. 2. Proper timing of reclamation works, most importantly the filling to be carried during low tide.	Cost to be included in the contract document. Contractor to follow the mitigation measures, including bund wall and silt curtain.
Reclamation of the lagoon	Changes to the hydrodynamic regimeWhen areas of the lagoon, whether connected to an existing island or detached are reclaimed, there will be a huge impact on near-shore current and wave patterns, as well as bottom hydrodynamics. This can lead to; • Erosion and loss of vegetation at the low energy areas during either monsoons • Sedimentation and turbidity resulting poor water quality which negatively impacts vitality of marine organisms • Alteration of bottom substrate topography • Degradation of sea water quality due to turbidity • Continual re-suspension of dredged sediments leading to sedimentation and formation of dredge silts • Degradation of sea water quality due to alteration to littoral sediment transport regime causing turbidity. • Alteration of current patterns on the leeward side leading to changes to existing island.	There are not many options that can be undertaken to reverse this as reclamation and its effects on hydrodynamic regime. However the following mitigation measures will help and will be undertaken. 1. Undertake coastal protection of fill area using revetments to absorb the wave energy as well as reduce erosion. 2. Revetments are proposed on the southern side as well as part of the north-west side (Area 2). 3. Revetment will prevent erosion and reduce the percentage of suspended fines in the water column.	Coastal protection measures are proposed in this project and hence mitigation cost is included. This mitigation cost is reflected as the cost for coastal protection.

Activity	**Potential Impacts**	**Mitigation measures**	**Cost of Mitigation**
Reclamation of the lagoon	Habitat loss Filling of the reclamation area will lead to direct loss of habitat for corals and marine organisms in the fill area. The habitat will be modified permanently. Habitats such as sea grass and live corals in the fill area will be totally destroyed. Direct habitat loss is very small as the percentage of live corals in the fill area is very less. Indirect impacts to live corals along the western side will be high due to sedimentation.	1. Only fill the required area in order to limit the direct impact foot print. 2. When sand bunds are created, the bund should be created inside the reclamation area as it will be destroyed anyway. 3. Designate one location to load and unload goods, materials and machinery rather than using a large area. 4. Undertaking coastal protection to avoid sediment loss from erosion that will impact a large area.	
Reclamation and dredging	Deterioration of marine environment and water quality Transportation of equipment, heavy machinery, people and fill material for the site and materials all require transportation processes which increases the following risks;• Accidental spillage of construction materials.• Accidental oil and other chemical spills, including oil leaks from vehicles etc.• Accidental grounding of large vessels on the reef and lagoon.In addition, Pollution of the lagoon and reef system can be caused by waterborne and windblown debris escaping from the construction as well as accidental oil/chemical spills. Waste and residue arising from the project activities can also affect the marine environment. These can include hazardous waste such as used filters, empty luboil cans and oil filters as well as various solid waste arising from humans. No major solid waste is expected to be generated from the reclamation work. Re-suspension of fine sediments and dispersal of sediments induced by erosion can also lead to turbidity and deterioration of water quality in the immediate vicinity of the project site.	1. Providing bund wall before filling can take place. 2. Undertake work in low tide hours. 3. Avoid work during bad weather. 4.Educate the workers and create awareness about good waste management and responsible behavior with regard to environmental care.	

Activity	**Potential Impacts**	**Mitigation measures**	**Cost of Mitigation**
Reclamation of the lagoon	Material Handling Materials such as fuel for dredger, excavators, barges and trucks have the potential to damage to the marine environment. Since fuelling is required for the machinery, spillage would be a possibility. Therefore, appropriate care has to be taken in handling fuel.	1.Fuel will be handled with care at all times 2. No waste fuel will be disposed into the marine environment 3. Fuel handling area will be kept free from spills and every effort must be made to minimize spills.	
Reclamation of the lagoon	Storm water drainage and coastal flooding Reclamation of land will increase the risk of storm water flooding to adjacent land / lagoon.	The reclamation area will be filled to the same height as the existing reclaimed area in Thmarafushi.. Already there are drains constructed at the interface between the already reclaimed area and the existing island to drain off the water in to the lagoon.	Contractor to level the island to 2 meters from mean sea level.
Site mobilization	Majority of the impacts will be felt through mobilization works Land clearing will not be required and there will not be any need for the construction of temporary structures, fuel storage and other facilities. Dredger is already mobilized on site and therefore, no further damage to the reef or the lagoon is expected.	1. If additional machinery is to be mobilized, mobilize only the required materials. 2.Only required workforce and machinery to be mobilized.	No cost, but the contractor will be required to follow proper protocols.
Waste management	Impact of solid waste This can be detrimental to the marine and the terrestrial environment if they are not managed properly. Solid waste generated during the construction stage will include organic, inorganic and hazardous materials and all of which require adequate disposal.	Work force will be provided with RO or rain water water for drinking thereby reducing the need for mineral water and hence reducing the impact of plastic bottles and their management and disposal. Furthermore, workforce will be based in Thimarafushi island and therefore waste generation at construction site will be minimal. All garbage or domestic wastes generated on site will be transported to Thimarafushi waste disposal site.	

10 Stakeholder Consultations

For the purpose of this project, stakeholder consultations were limited to the following groups. The following section outlines the outcome of the discussion.

10.1 Consultation with Thimarafushi Island Council

Participants: Mr. Ibrahim khaleel - vice president, Mohamed liushan, Councillor, and Deputy Director, Ahmed Ali.

Date: Monday, 21 November 2011
Venue: Thimrafushi Council Office
Time: 8:30 pm

The following are the outcomes of the consultations held with the island council.

- The council expressed some concerns regarding the discrepancy in how the reclamation will be undertaken on the south-west side.
- The present plan is to reclaim an area on the south-west side and have revetments.
- The council wants a beaching area on the south western side with a channel cut to allow boats to be beached in to and out of water. This area will be used as a boat repair area in future. This issue was discussed with the Gaumee Idhaaraa.
- Reclamation is a real need for Thimarafushi as the island is saturated and there are no additional land for housing plots nor industrial activities. The presently reclaimed area, although it is quite huge, most of which cannot be used by locals as majority of the land will be allocated to develop an airport.
- Presently an additional 400 houses are required for Thimarafushi in order to cater for the housing demands. Hence, there is therefore a huge need to reclaim additional land.
- The new reclaimed area is not adequate to provide housing and needs of the present population as industrial growth rate is hindered by lack of space in addition to housing crisis
- From the proposed 20 hectares to be reclaimed (area 1) , only a limited area approximately 50% would be usable due to airport development restrictions.
- The present population is 2817 n 350 households and additional 400 houses are required as existing houses are over crowded and too many families having to live in the same house is creating social and health issues.
- Hence, there is great need for housing development in Thimarafushi and this can only be achieved through creating additional land. Reclamation is therefore very much a serious requirement for the people as lack of space is causing many problems.
- At present, industrial activities are limieited due to lack of space and therefore additional land is needed for the island.

- With regard to a boat repair area on the south west side (area 2), the council informed that Thimarafushi has the greatest number of fishing boats in this region in comparison to other islands and so the need for their repairs is also much high. With this, a beaching area is required in order to be used as a boat repair and maintenance area in the island.

- Fisherman from the nearby islands also dock in this region, especially in Thimarafushi and so there is need for boat repair area.

- During the first phase of reclamation, the contractors were housed in the island and they are still residing in the island. They have been there for more than a year and have been very cooperative and no social issues have arisen because of them. The islanders are very happy with the contractors.

- The south-west side reclamation is proposed for the industrial area whereas part of area 1 will be for housing.

- At present 14 hectares boor area has reclaimed 41 hectares of airport land.

- The existing reclamation was done in 3 months (for the airport runway and airport).

10.2 Consultation with general public of Thimarafushi

Consultations were held with two groups of 10 to 15 people through an informal type discussion regarding the reclamation project. People were generally very cooperative and shared many thoughts about the reclamation project. The following are the major outcome of the discussions.

- Generally people were very positive about this project as lack of space in Thimarafushi has been a major issues causing social as well as development issues.

- Most people raised the issue of many families living in the same house due to lack of space for additional land. Hence, large extended families were living in the same house.

- The islanders being fisherman, large fish catch and their management is difficult. Fish drying or salting process requires empty space away from residential areas and this is something that is not possible in the island.

- Development of the airport was also very positively taken by people as sea transport is tough and expensive and time consuming. The nearest airport is in Laamu Kadhdhoo, which has to be reached by boat, which is also very costly and there are no regular ferries to the airport.

- People generally feel that reclamation together with the development of airport will boost the local economy.

- People are very positive about the project and feels that the project will increase the quality of life of people.

10.3 Consultations with relevant stakeholders

Consultations with the relevant stakeholders were also undertaken during the scoping meeting which were attended by various stakeholders. Following stakeholders were present in the scoping where most of the discussions were based around the justification to the proposed project. There were issues raised in the scoping meeting that questioned the real need. Representatives from central Gaumee Idhaaraa, EPA, Thaa Atoll Council and representatives from Environment Ministry were present.

10.4 Consultations with a coastal engineer

Coastal protection on the south-west side of the harbour was discussed with Mr. Naufal, Civil Engineer at Ministry of Housing. Consultations were mainly discussed for the proposed revetment at south-west side and the issue of creating a beaching area for the boats as requested by the island council. Following are the main outcomes.

- Housing Ministry is not aware of a beaching area for dhonis on the south-west side, however, if this is to be done, the length of revetment will be reduced and the costs.
- If the islanders require this, then this can be accommodated, as this does not involve an additional cost.
- Geobags will be used for revetments, as this is a cost effective way to control erosion.

11 Alternatives

EIA Regulation requires two alternatives to be suggested for such developments and therefore two alternatives have been suggested in addition to the no project alternative. These alternatives are discussed below:

11.1 No Project Option

The no project option considers the following.

- No additional reclamation will be done in Thimarafushi.
- No additional land will therefore be available for housing and industrial activities.
- Less cost to the proponent.
- No further damage to the coral reef of the island and to the lagoon.

The main advantages and disadvantages of these are given in Table 27.

Table 27: Advantages and disadvantages of the no project option

Strategy	Advantages	Disadvantages
No reclamation of 24 hectares of land in Thimarafushi island	Environmental damage related to the development can be avoided No capital costs to the proponent, short term benefit. No indirect effects on the coral reef through sedimentation. Already stressed coral reef will get time to grow. Already destroyed areas of the lagoon will get time to recover. The lagoon and coral reef will get ample time to flush and clear the suspended sediments, thereby assisting in the regeneration of corals.	Thimarafushi residents will have a very limited space for housing from the previously reclaimed land as majority of that land space will be utilized for the airport. Housing issues will get worse and over crowding of houses will continue to get worse. Lack of an appropriate land for industrial activities will hamper development and limit the potential of local fishing industry and will affect development of the island and people.

11.2 Alternative borrow areas

There are no appropriate alternative borrow sites for this project as the present proposed borrow site is the most ideal in terms of cost and distance with regard to the filling areas.

11.3 Alternative methods to protect the reclaimed land

Coastal protection of the reclaimed island has been considered in this project and hence alternatives have been considered for coastal protection.

There are a number of alternative options for shore protection on the proposed reclaimed areas, most importantly area 2 which is on the south-west of the island. Since wave action and long shore sediment transport will be the main concern, a structure that protects the area in its lee from wave attack, i.e. a breakwater or a revetment type sea wall is considered as the most suitable solution. Geobags have been considered as coastal protection for area 2, but there are few other options that can be considered.

Some suitable alternative options that may be considered during the design are:

- Concrete L type walls
  Concrete L type walls are more suitable as quay walls and not desirable in areas with high waves breaking. They are very poor in absorbing wave energy. They are also more appropriate for harbour basins or areas requiring depths. For these reasons, they have not been considered for the proposed project.
- Sheet piling
  Although a good choice, this type is not suitable for the proposed reclaimed area as it is poor in absorbing wave energy and creates standing waves through continuous reflection of waves without any being absorbed. Their high cost is also a major factor for not considering them.
- Sand bags
  The cheapest of the options, but have a limited life. They are also not as good as rock boulders in absorbing waves.
- Rock boulders
  A good choice, but very costly and time consuming for their import. Their high cost is the number one reason why they cannot be adopted.

11.4 Alternative materials for coastal protection

There are three options as materials for coastal protection structures. First, there is coral rubble. However, coral mining is banned and this option shall not be considered. Second option is the use of tetra-pods, which would be strong enough to survive strong waves.

The third option is the use of geotextile tubes or bags. Of these, the geotextile tube is a cost effective solution, but visually not appealing. The main advantage of geotextile bags or geobags over the rock boulders or rubble mound structures is that it can be manufactured in white colour to blend with the white sandy shores. However, despite their white appearance, they are visually not appealing as the material itself is artificial and does not blend with the environment unlike rocks, which is suitable for the coastal environment and nature of Maldives. Hence, rocks blend in with the environment much better than geotextiles. As Thimarafushi is an inhabited island, a cost effective and a sustainable solution for coastal protection will override the visual appeal, geobags are very ideal for Thimarafuhi.

11.5 Preferred options

The preferred alternative for this project is to construct revetment style seawalls using geobags. Use of geobags is the preferred material.

11.5.1 Mitigation measures for the proposed alternative

Following mitigation measures are proposed for preferred alternative.

- They are to be reconstructed and re-aligned as per the newly formed shoreline with adequate steepness.
- Need to be undertaken with care so as to ensure that their dimensions are right.
- Undertake the construction during low tide hours.

- Geotextile material should be placed to trap the sediment underneath the revetment.

12 Environmental Monitoring

12.1 Introduction

Environmental monitoring is essential to ensure that potential impacts are minimized and to mitigate unanticipated impacts. Monitoring will be carried out as part of the environmental impact assessment and monitoring requirements addressed in this EIA report. The following table summarizes the aspects of monitoring.

12.2 Cost of Monitoring

The proponent has committed fully for the monitoring programme outlined in this report. A commitment letter has been attached as an appendix.

12.3 Methods of Monitoring

Environmental monitoring will be undertaken using standard methods described in the Methodology section. Monitoring is only recommended for marine and coastal environment.

12.4 Monitoring Responsibility

Monitoring responsibility will be with the client and financial provisions will be made in the project to undertake the monitoring.

12.5 Monitoring Report

A detailed monitoring report will be compiled after the completion of the civil works.

The following table outlines the monitoring scheduled proposed.

12.6 Monitoring Schedule

The monitoring schedule is as follows. The most critical component of monitoring is coastal and marine environment including the shoreline changes as well as water quality. Dredging and reclamation will create sedimentation and it is therefore important to know how the coral reef copes. Hence, monitoring will concentrate greatly on the coastal and marine aspects.

Monitoring Attribute	Indicator	Methodology	Monitoring Frequency		Cost during (construction phase).	Cost Per annum (operational phase)
			Construction stage	Operational stage		
Marine environment						
Marine water visibility at site 2,3,4,5, and 6	Visibility	Secchi Disc & Tow line distance	Every other day during construction period.	-	No cost. Contractor to undertake this during construction period.	
Coral cover at survey sites 5,6, and 7	Percentage live cover	Qualitative & Quantitative	Once during the construction stage.	Annually	$2,500.00	$2,500.00
Coral recruitment at survey sites 5,6, and 7	Recruit/m²	Qualitative & Quantitative	Once during the construction stage.	Annually	$3,500.00	$2,500.00
Marine water quality at survey sites 1, and 2	Physical appearance, turbidity, pH, Suspended Solids, Temp & EC	Onsite or Lab analysis	Every two months during period.	Twice annually	$600.00	$200.00
Siltation	Sediment deposited on reef substrate	Qualitative & Quantitative	Every other day during work.	Four times annually	No cost. Contractor to undertake this.	$2,000.00
Coastal Environment						
Sand transport	Nearshore currents	Drogueon the western side and southern side.	Every three months	Every three months	$600.00	$400.00
Sand transport	Shore line mapping	Using DGPS	No need	Once after completion	-	$550.00

Monitoring Attribute	Indicator	Methodology	Monitoring Frequency		Cost during (construction phase).	Cost Per annum (operational phase)
			Construction stage	Operational stage		
Sand transport	Erosion	Physical inspection and shoreline mapping	No need	Annually	-	$550.00
Social Environment						
Public consultation	Feedback	Interviews/Questionaire	-	Annually		$200.00
Stake holder consultation	Feedback	Interviews/Questionaire	-	Annually		$200.00
Proponent consultation	Feedback	Interviews/Questionaire	-	Annually		$200.00
Number of new houses developed from the reclaimed area	Number of houses	Council records		Annually		$200.00
Number of industrial acitivities established in the newly reclaimed land	Number of plots	Council records		Annually		$200.00
Average population density per heactare	Heads per house	Council records		Annually		$200.00
					$8,400.00	**$10,550.00**

Table 28: Environmental Monitoring outline

13 Conclusion

This EIA report has identified the main impacts of the proposed reclamation works. It has been assessed that the project will have its main negative impact on marine environment and several positive social impacts. Environmental impacts appear to be major but with multiple social benefits.

Mostly reclamation projects have impacts arising from both dredging and reclamation works. In this project, there will be both dredging and reclamation. Hence, the significance of the impacts are quite significant, but the project site is already a modified environment and hence, environmental impacts will not be as significant as a project on a pristine site.

The main factors to justify this project are lack of space in the island of Thimarafushi. Thimarafushi is proposed to be developed in to a regional airport. As such, an area has already been reclaimed to develop a domestic airport. Although reclamation for the airport is complete, it has not solved the housing crisis currently facing the residents. Reclamation is a real need for Thimarafushi as the island is saturated and there are no additional land for housing plots nor industrial activities. The presently reclaimed area, although it is quite huge, most of which cannot be used for domestic use as majority of this land will be allocated to develop an airport and its boundaries.

Once the dredging and reclamation is finished, the additional 24 heactares of land increase will stimulate the development of the island and open new opportunities in many areas such as better housing, industrial activities and social development among other.

Therefore, it appears justified from a technical and from a developmental point of view, to carry out the proposed reclamation. There are good reasons from economic and environmental points of view to undertake the project. There will definitely be negative environmental impacts, but they are unavoidable and balanced by economic gains on the other hand. The negative environmental effects of the project therefore appear to be acceptable, but will be quite significant.

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15 Annex: Terms of reference

16 Annex: Bathymetry of the lagoon

17 Annex: Commitment from the proponent