

PROJECT SYNOPSIS

Name of the Project: Environmental Impact Assessment for the Proposed Dredging Of Harbour and Entrance Channel at G DH. Fiyoari

Project Proponent: Ministry Of Housing and Infrastructure

Project Contractor: PWC

Project Value: -

Expected Duration: 80 days

EIA Consultant: Ahmed Saleem

EIA Date: January 2016

WEIGHTS AND MEASURES USED IN THE REPORT

1 metric tonne = 2,204 pounds (lbs.)

1 kilogramme (kg) = 2.2 lbs.

1 metre (m) = 3.28 feet (ft.)

1 square meter (m²) = 10.76 square feet (ft²)

1 millimetre (mm) = 0.03937 inches (")

1 kilometre (km) = 0.62 mile

1 hectare (ha) = 2.471 acres

LIST OF ABBREVIATIONS

ORP	Oxidation Reduction Potential
EPPA	Environmental Protection and Preservation Act
EPA	Environment Protection Agency
DO	Dissolved Oxygen
Hs	Peak Height
NEAP	National Environmental Action Plan
MoEE	Ministry of Environment and Energy
ES	Environmental Score
NSWMP	National Solid Waste Management Policy
EIA	Environment Impact Assessment
GoM	Government of Maldives
MEE	Ministry of Environment and Energy
EPA	Environmental Protection Agency
MTCC	Maldives Transport and Contracting Company
MWSC	Male' Water and Sewerage Company
MHI	Ministry of Housing and Infrastructure
PPG	Personal Protective Gear
RS	Range Values
LOQ	Limit of quantification
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
MSL	Mean sea level
EMP	Environmental Management Plan
GHG	Green House Gas
PPE	Personal Protective Equipment
DNP	Department of National Planning

DIRAM	Detailed Island Risk Assessment in Maldives
CO ₂ -e	GHG equivalent emission
DDRPM	Development of Disaster Risk Management Profile Maldives

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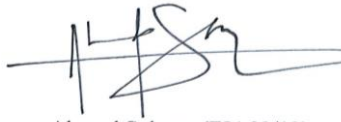
ACKNOWLEDGEMENT

The authors of this report would like to acknowledge the support given by the Ministry of Housing and Infrastructure and the Island Council of Fiyoari during field work and their assistance during the compilation of the report.

DECLARATION

Consultant

I certify that the statements made in this Environmental Impact Assessment are true, complete and correct to the best of my knowledge and available information at the time of writing this report.


Ahmed Saleem (EIA03/13)



Proponent

The proponent has elected to submit an Environmental Impact Assessment for the proposed harbour and channel dredging of G DH. Fiyoari harbour basin in accordance with Environmental Protection and Preservation Act (Act No. 4/93) and the EIA Regulations (2012)

Ministry of Housing and Infrastructure



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3012016

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3. **سەمەرىيە ئىلىمىي ئىنقىلابى** 25,699 ئىنقىلابىي سەمەرىيە ئىلىمىي ئىنقىلابى 5,350 ئىنقىلابىي سەمەرىيە ئىلىمىي ئىنقىلابى 11,800 ئىنقىلابىي سەمەرىيە ئىلىمىي ئىنقىلابى

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NON TECHNICAL SUMMARY

1. This report provides the finding of an environmental impact assessment conducted for a dredging project in G DH.Fiyoari, devised by Ministry of Housing and Infrastructure (MHI) in accordance with the Environmental Act and EIA Regulations 2012. The report was compiled by Maldives Environment and Energy Company (MEECO) to fulfil the requirements of law. The main objective of the project is to ease accessibility to the island.
2. In recent times, the harbour in Fiyoari, has become one of the biggest contributors to the local economy. An ice plant managed and run by Kooddoo Fisheries provides ice and water to fishing vessels that regularly birth at Fiyoari. The harbour is also frequented by safari vessels enroute to the surfing point located at the western coast of Fiyoari. The demand for the harbour has resulted in the harbour becoming congested and shallow areas '*giri*' that exist within the basin has made navigation and access difficult.
3. The proposed project encompasses dredging shallow areas from the harbour and entrance channel. The dredging is aimed at removing all the shallow areas in an area of 25,699 m² from the harbour basin and 5,350 m² from the entrance channel. Surveys concluded that a total of 11,800 m³ of dredge material would be obtained as a result of dredging these areas to – 3 m MSL.
4. Bathymetry surveys showed that two areas were shallower than – 3 m MSL in the proposed project area. They were a 2,642 m² shallow *giri* in the harbour basin close to quay wall and a 1,650 m² strip of shallow area at the southern side of the entrance channel. However, study area bathymetry and stakeholder consultations revealed that the proposed project area did not encompass all the significant shallow areas which were highlighted to cause navigational difficulties. Two main shallow areas were identified in the basin outside the project area which are shallower than – 3 m from MSL. These areas have been marked in the report.
5. Use of dredge material in the ongoing sports arena construction project at Fiyoari was determined to be the best option.
6. Environmental impacts were identified and assessed for both the construction phase (dredging) and operational phase of the project. The negative impacts of the project would be felt exclusively on the marine environment during the dredging phase of the project. No significant negative impacts have been identified due to the small scale of the project. Following careful evaluation of the minor negative impacts, appropriate and practical mitigation measures have been proposed to reduce these negative impacts. Significant positive impacts were identified for the implementation phase of the project. The project would not only address difficulty in navigation but it will also boost the economy of the island. Alternatives to the current scheme have also been provided in the report with their advantages and disadvantages discussed.
7. The Proponent, Ministry of Housing and Infrastructure is committed to undertake the necessary mitigation measures and monitoring during all stages of the project. The project is in line with the national development policies of the government and planned to be executed in compliance with the relevant laws and regulations of the Maldives pertaining to conservation of the environment.
8. In conclusion, this EIA has looked into the key factors that shall be taken into account during construction and operational stage of the project. Even though this project does have significant environmental impacts to the immediate marine environment, with appropriate measures, those negative effects can be mitigated to an acceptable level. It is also worth highlighting significant

positive impacts that the project is expected to bring to the community would translate into improved living conditions and overall social well-being of the community.

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2 INTRODUCTION

2.1 BACKGROUND

Ministry of Housing and Infrastructure (MHI) requested the services of Maldives Energy and Environmental Company (MEECO) to commission an Environmental Impact Assessment for the proposed dredging of harbour and entrance channel at GDH, Fiyoari. The project aims at addressing navigation issues that have resulted in physical damages to the vessels due to the shallow areas found within the harbour basin and entrance channel. Hence the aims of the project are to:

- Remove navigational hazards; and
- Facilitate easier access to the island.

The dredged material from the harbour and entrance channel is proposed by MHI to either be used as beach nourishment or stockpile at a designated area west of quay wall.

2.2 PURPOSE OF THE EIA

Given the potential adverse environmental impacts associated with dredging works, the proponent has requested consultancy services for preparation and submission of an Environmental Impact Assessment (EIA) report to EPA which complies with the Environmental Protection and Preservation Act (4/93) and EIA Regulations 2012.

The objectives of the EIA study are:

- a) To promote environmentally sound and sustainable development through the identification of appropriate alternatives and mitigation measures;
- b) To protect the human health and safety during the project construction;
- c) To avoid irreversible changes and serious damage to the environment;
- d) To safeguard valued resources, natural areas and ecosystems;
- e) To enhance the social aspects of the project;
- f) To improve the environmental design of the project;
- g) To ensure that resources are used appropriately and efficiently; and
- h) To facilitate informed decisions making.
- i) To develop an effective monitoring plan to account for the holistic nature of environmental systems and to keep track of significant environmental parameters to assess the condition of the environment through a continuous monitoring to better manage and understand the negative environmental impacts.
- j) To provide necessary information to EPA applicable to the proposed dredging project;

2.3 EIA REPORT AND EIA IMPLEMENTATION PROCESS

The process followed in preparing this report is as per the process outlined in the EIA Regulations. The process started with the proponent developing the project concept following which a draft TOR and EIA application form was submitted to EPA. Following this a scoping meeting organised and project was discussed at the meeting. Based on the discussions TOR was further refined and TOR was approved. For collecting the necessary baseline information on the existing environment and the socio-economic conditions, a site visit was organised. The draft report was then submitted to the Proponent for comments. Once the proponent approved the report, it was then sent to Fiyori Island Council and GDh. Atoll Council for their information. The final step was submission of the report to EPA.

2.4 PROJECT SETTING

Fiyoari island is located approximately 0°13'28.12"N and 73° 8'17.40"E in South Huvadho Atoll. It is approximately 439 km SSW of capital city, Malé. Fiyoari is located in the southernmost part of Huvadho Atoll. It lies on a relatively large reef platform that is NNW – SSW oriented stretching at a distance of approximately 34.6Km. Numerous islands are situated on this reef platform; four of which are inhabited islands and the rest being uninhabited. *Fiyoari Kandu* lies to the southeast of the island, which separates Fiyoari house reef from the house reef of Faresmaathodaa Island. The closest inhabited island to Fiyoari is Rathafandho to the northwest located approximately 5 km away from Fiyoari. The next closest island to Fiyoari is Faresmaathoda to the southeast located approximately 6 km from Fiyoari. Fiyoari is a relatively large island with an approximate area of 943,000 m². The island has a significant wetland on the South of the island approximately 0.4 km away from settlements (See Annex 1 – Geographic Setting of project).

Unlike other inhabited islands, the harbour basin in Fiyoari is different because it has an open harbour basin with no engineered structures surrounding it. The harbour basin is naturally protected by the island's house reef and due to the situation of it on the eastern side, the island itself acts as a barrier against SW monsoonal winds and associated waves. Figure 1 shows the difference between two types of harbour basins found in the Maldives.

No protected marine environments were identified close to the island and project area.

Current population of the island is 677 according to the island Council. Much of the island remains vegetated and unutilised. Farming is the main form of work undertaken by the people. However, recently with the construction of a functioning harbour, the island has become a supply hub for fishing and safari vessels. Contribution to the local economy from tourism, is not significant. However there are signs that it's getting a foothold in the local economy. Fiyoari has a renowned surfing point on the SSW side of the island.

The island is not well connected to the capital island Malé or the neighbouring islands. A daily ferry stops at all islands in South Huvadho once a day, which is the only form of public transport that exist. Electricity is connected 24hrs and access to clean water is not an issue for the island. Projects to develop the local economy have been planned which include investment in tourism and the conversion of the harbour area into a port.



Figure 1: A- Open harbour and B- closed harbour

2.5 PROJECT JUSTIFICATION

Fiyoari is a significantly large island in the South Huvadhoo Atoll with a relatively low population. The main economic activity of the island is farming. Majority of the people belonging to Fiyoari have migrated to the capital Male' in pursuit of better education and health care. This has reduced the working population of the island. Nevertheless, there is a need for better health care, education, transportation and households. With the recent development of the island's harbour, dramatic improvements to the local economy is evident according to the locals. This is partly due to the fact that tuna fisheries improved in the Huvadhoo region compared to other regions of the country. As a result a lot of fishers from the region opted to station in Huvadhoo atoll. Approximately 25,314 mechanized vessels operate between North Huvadhoo atoll and Addu (Basic Fishery Statistics, 2013). Due to the strategic location of Fiyoari, it has become a supply hub for these fishing vessels creating additional economic opportunities in Fiyoari.

After long fishing journeys, most of the vessels would have exhausted all the ice, hence Fiyoari acts as the main station for refilling vessels with ice and water. Many vessels leaving for fishing ground past the South Huvadhoo atoll opt to get ice from Fiyoari since it is the last and closest stop to the fishing grounds. On average 20 fishing vessels stop for supplies daily at Fiyoari.

However, on numerous occasions many fishing vessels have encountered difficult circumstances when entering and berthing at Fiyoari harbour. This is mainly because of a shallow (*giri*) in the middle of the harbour and due to shallow areas at the entrance channel (*Neru*). The harbour becomes impossible to safely navigate through during bad weather and at night due to these features. This has not only lost valuable time for the fishers but also have resulted in physical damages to vessels amounting millions.

Local boat owners have encountered similar issues where veteran navigators have hit protruding rocks at the entrance channel. One of the major dangers for navigation has been the non-uniform nature of harbour basin.

Furthermore, safari boats occasionally berth carrying tourists who come to catch waves at the western renowned surf point of Fiyoari. As the demand for port rises many vessels are forced to queue up in the harbour basin as there are no available space left in the harbour to dock. This becomes an issue, because the large shallow area in front of the quay wall does not allow vessels to anchor without obstructing the entrance channel, which is the only access point to the island.

As the government authority mandated with implementing infrastructure development requirements on islands, the Ministry of Housing and Infrastructure has recognised the need to address the issue of safe access to Fiyoari island, and has formulated a project to enhance the condition of the harbour basin and entrance channel of the island that would result in safer access to the island and subsequently the overall improvement in the island's economy.

2.6 TERMS OF REFERENCE

This document has been developed based on the Terms of Reference (TOR) issued by the Environmental Protection Agency (EPA) on 26 November 2015 (See Annex 2 – Terms of Reference). This document is submitted to EPA by the proponent to fulfil the requirements of Environmental Protection and Preservation Act (EPPA) of the Maldives (4/93).

3 DESCRIPTION OF THE PROJECT

3.1 THE PROPONENT

The project proponent is the Ministry of Housing and Infrastructure (MHI). MHI is mandated with development and regulation of the infrastructure development activities of the country. In this regard, reclamation and dredging projects in islands fall under the management of MHI.

The contact details of the proponent are:

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3.2 PROJECT LOCATION AND SITE AREA

Fiyoari Island is located at 0°13'28.12"N and 73° 8'17.40"E in South Huvadhoon atoll. The proposed area to be dredged is located on the eastern coast of the island. Two areas within the harbour basin has been proposed for dredging. The entrance channel covering an area of 5,350 m² and the harbour basin covering an area of 25,699 m². (See Annex 3 – Site Plan for site plan)

3.3 PROJECT BOUNDARY AND IMPACT ZONE

The impacts of the proposed dredging project are almost exclusively concentrated to the moat of Fiyoari house reef. Two project impact boundaries were identified. These were zones, where direct and indirect impacts are perceived to occur. Impact area for the harbour was determined to be 95,400 m² and the impact area for entrance channel was determined to be 60,000 m² (Figure 2). These impact areas are justified based on:

- Project scale: The project scale was very small.
- Hydrographical conditions: Waves/currents were found to be stable.

3.4 PROJECT DURATION AND SCHEDULE

The proposed project is planned to be completed in 80 days. The dredging project will be carried out by Public Works (PW), under the direct supervision of MHI. The preparatory work including clearance and mobilisation is expected to take approximately a week and the dredging is to be completed in 44 days.

Table 1: Time schedule

	Month 1	Month 2	Month 3
Mobilization	5 Days		
Site setup works	14 Days		
In survey	7 Days		
Dredging		44 Days	
Out survey			5 Days
Demobilization			5 Days

3.5 THE PROJECT

The project involves dredging a total area of 31,049 m² (25,699 m² from the harbour basin and 5,350 m² from the entrance channel) of G DH. Fiyoari (See Annex 3 – Site Plan). The basin will be dredged to a depth of -3 from MSL. It is estimated through surveys that approximately 11,800 m³ of material will be dredged and accumulated as a result of the project. The material dredged is proposed by MHI to either be used as beach nourishment north of the quay wall or be stockpiled at designated locations.

*Note: From here in the **proposed project** refers to the description of project described in Section 3.2 and 3.5.*

3.6 EQUIPMENT AND WORK METHODOLOGY

3.6.1 Mobilization

Equipment

- Spud Barge

Method

- The machineries and equipment's will be loaded onto the barge and taken at tow;
- Existing facilities will be utilized for accommodation of workers.
- Best plan of logistics will be determined to manage harbour activities.
- Tool shed will be constructed for storage if there are no existing facilities.

3.6.2 Dredging

Equipment

- Excavator SK450
- Crane 35 TON
- Trucks 15 Ton x 1 Nos
- Site Equipment and tools

Method

- in order to adapt to the weather conditions at the time, dredging will be started based on hydrographical conditions at the time.
- The material excavated will be temporarily stockpiled at the harbour before being transported to the designated location.
- Excavators will be used to dredge the shallow areas.

Two methods are proposed to dredge and transport dredge material to the island, these are:

1. Using a single spud barge, onto which the excavator dumps dredge material. Once the barge has been completely filled it will be transported close to the quay wall where the dredge material from the barge will be transferred and temporarily stockpiled at the harbour area before being transported to final stockpile site. The barge and excavator are then mobilised to the dredge site. This process will be continued until all the shallow areas have been dredged.
2. Placing a bund connecting the shallow *giri* in the middle of the harbour basin to the island. 3,500 m³ of fill material would be required to make the bund to a width of 4.5 m. This amount of material can be obtained from the shallow area in front of the quay wall. Trucks can then be used to transport the dredge material to the island and transport them directly to stockpiling area.

Option 1 is the preferred method which was found to be environmentally more manageable and less costly.

- If hard strata is encountered, a drop hammer of 5 ton will be used from a height of 20m under free fall conditions from a 30 ton crawler to break the rocks and remove them with the excavators.
- If sections broken off are too large for the excavator an underwater demolition hammer will be used to break the section to manageable section and then removed by excavator.
- Rock removed from the drop hammer operation and rock recovered from dredging operation will be stock piled for later use.
- The level of dredging will be maintained at MSL-3.5 so that the bed settles at -3 m MSL after bedload transportation.

3.7 PROJECT INPUTS AND OUTPUTS

The main inputs into the project are human resources, machinery, fuel, water and facilities for the workers Table 2. The major outputs would be dredged material, dredged harbour basin and entrance channel, by products, solid waste and GHG emissions which are also considered as outputs Table 3.

Table 2: Project inputs

Inputs	Source	Method of Obtaining
Project staff	Skilled and semi-skilled labour: Manager(01) Supervisor(01) Excavator Operator (01) Truck operator (01) Welder (01) Labourer (04)	Work will be carried out by PW staff. The workers hired for the project will be capable and would possess necessary skills to undertake the tasks assigned. Foreign workers shall have the necessary documents and permits.
Machinery and Equipment	Excavator (01), dump truck (01) Barge (02) Survey equipment. Crane (1)	To be obtained and operated by contractor. Contractor will be required to bring the machines in good working conditions to avoid delays which may be caused by breakdown of machines, vehicles and equipment.
Fuel	Diesel, lubricants and Petrol (will be taken in bulk volume. (Approximately 45,000 L to operate the excavator for 44 days)	Purchased from Male' and taken to the island. These shall be obtained by contractor
Electricity (during construction period)	Power supplied by FENAKA. Electricity will be obtained from the island grid.	Contractor
Water	Desalinated water from Kooddoo ice plant. Mineral water from purchased from shops. Rain water.	Using existing facilities at the island and purchased from Male' and island.
Communication	Existing communication networks, Dhiraagu or Ooredoo.	Contractor
Accommodation	Existing guest house or rent rooms or vacated houses in the island for workers.	Contractor, facilitated by the council.
Food (during construction)	Purchased from local shops and cafes in the island	Contractor

Table 3: Project outputs

Outputs	Quantities	Method of Disposal/Outcome
Dredge Material	11,800 m ³	According to the proposed project, dredge material is to be stockpiled or used to nourish the beach north of quay wall.
Fuel	.	Unused, fuel should be safely transported and stored in designated area.
Solid waste	An average of 0.45 kg/person/day according to World Bank, (2012).	To be separated into waster type, stored and transported to Thilafushi waste site at the end of project
Noise	Noise is not expected to be a significant impact (See section 9)	-
Hazardous waste - Waste oil and grease by machinery/generator/vehicles, used batteries.	Used oils, batteries and wipe clothes are determined to be main hazardous waste due to the small scale of the project these wastes are going to be generated in very small quantities. (See section 9 for details)	Collected, separated, transported and disposed at Thilafushi by contractor.
Sedimentation	Sedimentation transportation is limited to only fine particles and the probability for sedimentation is low at the project. (See 6.5.1 and 9)	Managed as per the mitigation measures described in this report
Air pollution including GHG	Limited quantities of dust from machineries. Considering that approximately 45,000L is used for the project, approximately 120,000 kg of CO ₂ -e GHG's will be produced. (DECC and Defra, 2012)	Emitted to the atmosphere (See section 9.3 for mitigation)

3.8 PROJECT RISKS

Every project faces certain degree of risks due to physical or financial constraints. These risks must be identified in order to prevent them and manage them. There are a few identified risks associated with the proposed project. These include:

- Harsh weather events which could pose a risk to the project progress. Bad weather could delay completion of dredging works which would interfere with harbour activities and incur unexpected costs.
- Equipment failure could prolong the completion of project which could result in complaints from the locals.
- Unforeseen accidents such as fire incidents in vehicles, toppling of excavator and work related injuries could also delay the project progress.
- Financial security and delays could also interfere with the progress of the project.

Hence these project risks should be accounted for and the following mitigation measures should be considered before the project is initiated.

- Condition of equipment and machineries should be checked prior to deployment. Machines should be serviced and checked in this regard.
- Necessary spare parts, basic tools shall be available on site.
- Project date should be set based on meteorological data.
- Capable personnel should be hired.
- All workers must have undergone the basic training before commencing work.
- First aid kit shall be available on the site.
- Worksite should be sealed off for the public and necessary warning signs shall be on the site.
- Financial and technical capacity must have been assessed before commencement of work and reports of successful completion of projects and unsuccessful projects must be logged in order to build adaptive capacity.

4 ADMINISTRATIVE AND REGULATORY FRAMEWORK

4.1 INTRODUCTION

The proposed project in relative terms is considered to be a minor development project. Although the project does not involve a multitude of activities a number of laws, bi-laws and regulations that fall under the mandates of various government agencies comes into play. This section highlights on:

- The major stakeholders of the project and their role in the assimilation of the project within the administrative framework.
- Relevant national legislative framework applicable to the proposed project. The relevant national legislative framework provides guidance on several aspects related to planning and development in the Maldives. The legal framework pertaining to the proposed Project are also aimed at sustainable development, impact mitigation and conservation of the country's natural resources.
- The compliance of the proposed dredging project to relevant regulation, policies and laws pertaining to the Maldives.

4.2 ADMINISTRATIVE FRAMEWORK

A number of government agencies are determined to have a stake in the proposed dredging project. These include:

- Ministry of Housing and Infrastructure;
- Ministry of Finance;
- Ministry of Environment and Energy;
- Environmental Protection Agency (EPA);
- Island Council; and
- Atoll Council.

4.2.1 Ministry of Housing and Infrastructure

Ministry of Housing and Infrastructure is the primary government authority responsible for formulating and implementing policies related to housing, land, land use planning, construction industry development, and infrastructure development in the Maldives. In addition the Ministry is responsible for regulating dredging and land reclamation and planning and executing government projects of similar nature. Coastal protection and harbour development are also among the responsibilities of the Ministry. The proposed project is planned and executed by the Ministry of Housing and Infrastructure on behalf of the government of the Maldives. The project will also be implemented by the Public Works Section of the Ministry of Housing and Infrastructure.

4.2.2 Ministry of Environment and Energy

The Ministry of Environment and Energy (MEE) is the key Ministry for the government mandated protection of the environment. Environmental responsibilities assigned to MEE includes

- Formulating environmental policies, coordinating, preservation and management of the environment throughout the country, and enforcing Environmental Protection and Preservation Act (EPPA) (04/93). Under Article 5(a) of EPPA.

Environmental Impact Assessment (EIA) is mandatory for projects that may cause potential harm to the environment. The EIA report has to be submitted to the EPA for approval before commencement of a project. As per this legislation, any project that has any undesirable impact on the environment can be terminated without compensation by MEE.

4.2.3 Environmental Protection Agency (EPA)

EPA is given the broad responsibility to assess development projects that may have a significant impact to the natural environment. EPA is the key regulatory body on environment, which is a semi-autonomous body formed under the umbrella of MEE. It is mandated with implementing the EIA process in the Maldives, implementing the Environment Act and subsequent regulations on behalf of MEE, regulating water and sanitation, biodiversity conservation, waste management and coastal zone management. Also, it is responsible for developing environmental standards and guidelines in the country. EPA is also responsible for approving dredging permits which will be required for the proposed project.

4.2.4 Ministry of Finance

The Ministry of Finance is responsible for managing the financial resources of Government and to ensure that a proper legal framework and supporting systems are in place for that purpose. The Ministry in delivering its mandate seeks to promote government's fiscal policy framework; coordinate macroeconomic policy and intergovernmental and external financial relations; manage the budget preparation process; secure and allocate funding for approved public policies and programmes; and to monitor the implementation of departmental budgets.

Ministry of finance is a key stakeholder in the proposed dredging project as the ministry is mandated with disbursement of project funding for the project.

4.2.5 G DH. Fiyoari Island Council

The Decentralisation Act mandates Island Councils to provide primary health care and this was the first function to be decentralised to the Island Councils. The Act also mandates island councils to provide basic municipal services. The island council is also tasked with the development of economic activities, management of island resources and assimilation of projects relating to the island. The island council is a major stakeholder of the proposed project and is the main component which would facilitate the progress of the project once it has been approved by the EPA.

4.2.6 Atoll Council

Atoll Councils are established under the Act on Decentralisation of the Administrative Divisions of the Maldives (Law Number 7/2010). The main function of the Atoll Council is to coordinate functioning of the island councils. In addition, the Atoll Councils are responsible for overseeing the uninhabited islands in the atoll. Hence, the Atoll council of GDh. Thinadhoo is considered as a stakeholder.

4.3 POLICY FRAMEWORK

All development plans in the Maldives are pre-set to achieve certain predetermined goals which would enhance sustainable growth. This section of the report identifies and describes the major policies and plans to which the proposed project falls under.

4.3.1 Strategic Economic Plan

The Strategic Economic Plan highlights the need for further public sector investments into the development of support infrastructure such as harbours and jetties, and in doing so, strengthening linkages between the different sectors, as well as inter-island linkages required for economic growth.

4.3.2 Transport Master Plan

This document highlights the requirement for efficient maritime transport networks, including harbour facilities to sustain the country's economic growth. In addition the need to ensure efficient transport systems that systematically link Malé to the rest of the country has been identified as a crucial factor that will contribute to the socioeconomic development across the country.

4.3.3 National Environment Action Plan, 2009-2013 (NEAP III)

The third National Environment Action Plan (NEAP III) set forth the agenda for environment protection and management in the Maldives for the five year period 2009 – 2013. This instrument seeks to achieve the stipulated goals and targets.

- Through coordinated effort of the responsible government departments and
- Through the engagement of local level governance arrangements following the introduction of a decentralised system of governance.

The underpinning theme of the policy instrument is protection of the natural environment and making people and property resilient. NEAP III emphasised on promoting healthy communities by improving solid waste management, hazardous waste management, safe use and disposal of chemicals, clean air.

4.3.4 National Waste Management Policy (2015)

The first National Solid Waste Management Policy which was formulated in 2008 focused on the following aspects of solid waste management:

- Establishing and activating waste management governance;
- Creating waste producers' duties;
- Establishing waste management infrastructure;
- Activating waste management systems; and
- Influencing consumer choices and waste management practices.

The first National Solid Waste Management Policy framework underwent extensive review in 2015 leading to the formulation of the new National Solid Waste Management Policy framework which was launched on the 4th of November 2015.

The National Solid Waste Management Policy (2015) (NSWMP) was formulated taking cognizance of the changes in waste generation patterns resulting from the changing socio-economic conditions of the country.

The main objectives of the NSWMP is to instil a uniform vision in policies, regulations, standards and plans formulated for waste management and to create and identify the responsibility for waste management at individual, household, community, regional and national levels, establish a policy basis for introducing charges for waste management, identify the role of private partners in the waste management hierarchy and identify key stakeholders.

The NSWMP 2015 outlines the main policy goals targeted at addressing the solid waste management problem facing the nation. They are as follows:

- To reduce waste generation promote and inculcate 3R concept;
- Conduct sustained awareness building activities at all levels to create public awareness on safe waste management practices;
- Designate the MoE as the lead agency for the implementation of the national solid waste management policy and establish a mechanism to monitor island level waste management systems;
- Formulate solid waste management plans for each inhabited island and undertake waste management activities in accordance with such plans;
- Formulate the Waste Management Legislative framework and carry out waste management activities in accordance with the framework;
- Review medical waste management regulations and carry out waste management activities of the health sector in accordance with such regulations;
- Collect statistics on waste at island and national levels and disseminate such information;
- Establish a system to impose and collect fees/charges from waste producers/generators;
- In each inhabited island, establish a waste management system which is suitable for the needs of the island (to be determined based on the size of the island and the island population) and provide necessary tools and machinery and carry out waste management activities through the established system;
- In a sustained manner conduct training programmes on safe management of waste targeting stakeholders;
- Establish, maintain and update an inventory of waste management systems established in inhabited islands;
- Establish regional waste management facilities in all the designated regions of the Maldives;
- Transfer residual waste (after waste management at island level) to regional waste management facilities in accordance with the relevant regulations, and manage waste so transferred in the regional waste management facility;
- Conduct research on latest waste management technologies;
- Exhort preparation of waste management plans for islands designated and leased for industrial activities and conduct monitoring to ensure compliance with contents of such plans in the waste management activities; and
- Establish a “National Waste Management Trust Fund”

4.3.5 Saafu Raajje Initiative

The “Saafu Raajje Initiative”, which is a long term plan of action for management of waste, was launched by MoEE as a pre-event to the Sixth Regional 3R Forum in Asia and the Pacific held in the Maldives (16-19 August 2015). The initiative, which is a campaign, geared towards proper waste management and encouraging a significant reduction in waste generation was organised by the government of Maldives with the participation of more than 100 resorts operating in the Maldives. The initiative seeks to promote safe management of waste, increase awareness of safe waste management practices and to solicit atoll and island level support for such activities.

4.3.6 MARPOL Convention

The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention which covers pollution of the marine environment by ships due to operational and accidental causes. As a member party of the MARPOL convention, the convention applies to the Maldives and is expected to adhere by and maintain the standards specified by the convention with regard to maritime pollution and their control. These include pollution due to

- Oil spillage
- Noxious liquid substances in bulk
- Spillage of harmful substances carried by sea in packaged form
- Sewage and garbage from ships
- Air pollution from ships

Prevention measures should be taken into account with regard to these sources of pollution during the developmental and functioning stage of the project.

4.3.7 Basel Convention

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, usually known as the Basel Convention, is an international treaty that was designed to reduce the movements of hazardous waste between nations, and specifically to prevent transfer of hazardous waste from developed to less developed countries (LDCs). The convention identifies and proposes procedure to be followed with regard to hazardous waste transportation. It encompasses stringent requirements for notice, consent and tracking for movement of wastes. As a member party to the convention Maldives is obliged to practice these measures at both international and national levels.

4.4 LEGAL FRAMEWORK

All development projects identified by law must meet certain pre-set conditions for their approval. These legal frameworks are in place to protect the delicate natural environment of the Maldives, promote sustainable development, build resilience, and facilitate better decision making and management of the environment. This section of the report identifies the legal context to which the proposed dredging project falls under. Hence identifies and describes the relevant laws and regulations which applies to the proposed dredging project.

4.4.1 Environment Act

Environment Protection and Preservation Act of Maldives (Law No: 4/93) was enacted in April 1993 as an umbrella law to protect and preserve the environment of the country. The articles and clauses of the law are given below. The clause 5 is directly related to the proposed project in Fiyoari and this study. As the Government authority with a mandate for the protection and preservation of the environment, Ministry of Environment and Energy has the responsibility of formulating policies, laws and regulations on environmental protection and conservation.

Environment Protection and Preservation Act (Law No. 4/93) (EPPA) is the most important governing law as far as the environmental impact assessment is concerned.

EPPA mandates all development projects in the Maldives to undertake an Environmental Impact Assessment prior to undertaking any such project.

Introduction

1. The natural environment and its resources are a national heritage that needs to be protected and preserved for the benefit of future generations. The protection and preservation of the country's land and water resources, flora and fauna as well as the beaches, reefs and lagoons and all natural habitats are important for the sustainable development of the country.

Environmental guidance

2. The concerned government authority shall provide the necessary guidelines and advise on environmental protection in accordance with the prevailing conditions and needs of the country. All concerned parties shall take due consideration of the guidelines provided by the government authorities.

Environmental protection and conservation

3. The Ministry of Environment shall be responsible for formulating policies, as well as rules and regulations regarding the environment in areas that do not already have a designated government authority already carrying out such functions.

Protected areas and natural reserves

4. (a) The Ministry of Environment shall be responsible for identifying protected areas and natural reserves and for drawing up the necessary rules and regulations for their protection and preservation.

(b) Anyone wishing to establish any such area as mentioned in (a) of this clause, as a protected area or a reserve shall register as such at the ministry of Environment and abide by the rules and regulations laid by the Ministry.

Environmental Impact Assessment (EIA)

5. (a) An impact assessment study shall be submitted to the Ministry of Environment before implementing any development project that may have a potential impact on the environment.

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

The Termination of Projects

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

Waste disposal, oil and poisonous substances

7. (a) Any type of waste, oil, poisonous gases or any substance that may have harmful effect on the environment shall not be disposed within the territory of the Maldives.

(b) In case where the disposal of the substance stated in paragraph (a) of this clause becomes absolutely necessary, they shall be disposed only within the areas designated for the purpose by the government. If such waste is to be incinerated, appropriate precautions shall be taken to avoid any harm to the health of the population.

Hazardous/ Toxic or nuclear wastes

8. Hazardous/Toxic or Nuclear Wastes that is harmful to human health and the environment shall not be disposed anywhere within the territory of the country. Permission shall be obtained from the relevant government authority at least 3 months in advance for any transboundary movement of such wastes through the territory of the Maldives.

4.4.2 Environment Impact Assessment Regulations (2012)

Further the EPPA states an impact assessment study shall be submitted to the relevant Government authority before implementing any development project that may have a potential impact on the environment. It goes on to say that the relevant Authority of Government shall formulate the guidelines for environmental impact assessment and shall determine the projects that need such assessment as mentioned in above. The law also gives power to the relevant Government authority to terminate any project that has any undesirable impact on the environment. A project so terminated shall not receive any compensation. According to the EPPA waste disposal, oil and poisonous substances any type of waste, oil, poisonous gases or any substance that may have a harmful effect on the environment shall not be disposed within the territory of the Maldives.

Government of Maldives reserves right to claim compensation for all the damages that area caused by the activities that are detrimental to the environment.

Environment Impact Regulations, 2012 & other relevant regulations

Under the provisions of EPPA the Government of Maldives has formulated and gazetted Environmental Impact Assessment Regulations (2012) detailing the EIA process and the EIA preparation.

In addition to EIA regulations, other relevant regulation will be followed in development and implementation of the proposed project. These regulations include ban on coral mining. Coral mining from house reef and atoll rim reef has been banned since 1990. Sand mining from any island has also been banned since March 2000.

The EPPA, EIA Regulations and other relevant regulations will be duly taken into consideration in preparing the EIA report and in the implementation of the project.

4.4.3 Dredging and Reclamation Regulations

Regulation on Reclamation and Dredging of Islands Lagoons (Regulation 2013/R-15) came into effect in April 2013. The regulation requires having permission of EPA on projects requiring alternation of the island, either by reclamation or dredging. Specifically the regulation requires producing scaled-maps of the island before and after the proposed intervention. Special provisions have been made on protected and sensitive area restricting changes to the environment of the islands.

4.4.4 The Regulation on Environmental Liabilities (Regulation No. 2011/R-9)

The objective of this regulation is to prevent actions violating the Environmental Protection and Preservation Act 4/93 and to ensure compensations for all the damages that are caused by activities that are detrimental to the environment. The regulation sets mechanisms and standards for different types of environmental liabilities and equal standards that shall be followed by the implementing agency while implementing the regulation. According to this regulation the Government of Maldives reserves the right

to claim compensation for all the activities which have breached the Environmental Protection and Preservation Act 4/93.

4.4.5 Regulation on Sand and Aggregate Mining

This regulation addresses sand mining from islands and bird nesting sand bars. Sand and aggregate mining from beaches of any island whether inhabited or uninhabited is banned for protection of the islands. Permissions for sand and aggregate mining from other areas shall be obtained from the relevant authorities.

4.4.6 Regulation on Coral Mining

Coral mining from the house reef of islands and the atoll rim reefs is banned through a directive from the President's Office dated 26th September 1990. According to this policy coral mining shall not be carried out from house reefs of islands and atoll rim reefs and common bait fishing reefs. Coral and sand mining is only allowed for house construction from designated sites and approval from the concerned authorities is required prior to mining activities. Request for coral and sand mining from residents of inhabited islands are required to be submitted to the Atoll Offices through the respective island offices. The island office is required to estimate the quantities of coral or sand required for the applied construction work of houses to ensure that the permission is granted for minimum amounts required. Every island is required to maintain a log book of permissions granted and the amounts mined and the site where mining was carried out.

4.4.7 Regulation and Waste Management

Waste management Regulation (No. 2013/R-58) is more recent coming into effect on 6 February 2014. The regulation was gazetted on 05 August 2013. The regulation provides set of comprehensive guidelines on collecting, storing, transporting and managing waste. In the preamble it states the objective of the regulation is in line with the Article 22 of the Constitution which requires that development activities designed for achieving socioeconomic targets should ensure that environment and its constituent living component is not compromised and that resources are utilized effectively.

The regulation talks of the responsibilities of collection, transport, treating and storage of waste. It also talks of management centres and landfill sites and managing hazardous waste. Various sectors and entities (including tourist resorts) encouraged having their own waste management plans consistent with the Regulation.

4.4.8 Decentralization Act (7/2010)

In April 2010 the Decentralisation Act was passed by the parliament. This act formalised the roles and responsibilities of Atoll and Island Councils and required that they be democratically elected. Importantly the Decentralisation Act did not include any role for the provincial administrations. The Decentralisation Act provided for the establishment of a Local Government Authority to which Island and Atoll councils are accountable. The Local Government Authority was established in late 2010 and the first local council elections were held in February 2011. The Decentralisation Act mandates Island Councils to provide primary health care and this was the first function to be decentralised to the Island Councils. The Act also mandates island councils to provide basic municipal services

4.5 POLICY AND REGULATORY COMPLIANCE

The applicable administrative, policy and legal frameworks for the project has been identified and described in detail. It is important to ensure that the proposed project falls within the scope of these frameworks.

Table 4 below summarises the compliance of the project with regard to the identified legal and policy frameworks.

Table 4: Project compliance with the relevant legal and policy frameworks

Legal Framework	Measures to Comply
Environment Act (Law No. 4/93) Environment Impact Assessment Regulation 2012	All processes followed, EIA has been conducted and produced as per the guidance given in the Regulations
Dredging and Reclamation Regulation (2013/R-15)	The EIA has been submitted with the relevant scaled drawings of the dredge area, and the report defines the scope and context of the project setting with the perceived environmental impacts to the existing environment. The requirements under this regulation will be fulfilled when the EIA for the project is approved.
Regulation on Environmental Liabilities (2011/R-9)	Submission of the EIA report which had identified marine protected areas and proposed mitigation measures or alternatives for the identified negative impacts to the environment.
Regulation on Sand and Aggregate Mining (2000)	Although the project involves dredging it is not specified as sand mining. Mining for sand is not included in the scope of the project.
Regulation on Coral Mining	Although the project involves dredging it is not specific to coral mining. Coral mining is not included in the scope of the project. Hence this regulation is adhered.
Waste Management Regulation, (No. 2013/R-58)	Will be complied through the EIA report and its approval. The report specifies preventive and mitigation measures for all types of wastes that may result from the project (See section 9).
Decentralization Act (7/2010)	The report EIA report was shared with the island council and atoll council. See Annex 4 – Letter From Atoll Council and Island Council.
The Regulation on Environmental Liabilities (Regulation No. 2011/R-9)	The project is not expected to impact any environmentally protected areas or vulnerable species habitat. All environmental related impacts have been identified in the report with quantitative measures of coral loss and impact scales (See sections 6.7.3 and 9). The requirements under this regulation will be fulfilled when the EIA for the project is approved.
Policy Framework	
Strategic Economic Plan	The proposed project aims at strengthening harbour infrastructure, which will facilitate economic growth. This is elaborated in section 2 of the report.
Transport Master Plan	The proposed project is set to make harbour area easier to navigate hence strengthen maritime transport networks.
National Environment Action Plan 2009-2013	The administrative framework identified in the report illustrates compliance with National Environment Action Plan through division of management and involvement of local level government in the management of project.
National Waste Management Policy (2015)	Submission of the EIA report in which the proposed mitigation measures complies with the policy.
Saafu Raajje Initiative	In line with the initiative the EIA report proposes waste management and awareness measures to which the proponent has agreed to comply.
MARPOL Convention	In line with the convention, the EIA report proposes waste mitigation measures which applies to the numerous vessels that are expected to birth at Fiyoari. These include proposed locations for placing waste bins to collect solid organic waste and plastic wastes.
BASEL Convention	Hazardous waste disposal and mitigation measures are explained in section 9 of the report. Approval of EIA is an indication that the project will be carried out in line with the procedures proposed in the convention.

In summary, the proposed project is in line with relevant government policies, initiatives, all applicable environmental legislation, and regulatory statutes. The proponent will ensure that the mitigation measures stipulated in the report is effectively implemented and that the monitoring program is conducted to ensure perceived impacts of the project is kept within acceptable levels.

5 METHODOLOGIES

5.1 INTRODUCTION

This section provides a brief description of methods utilized in acquiring the relevant geological, geographical, physio-chemical, hydrological, ecological, social and climatic data relevant to assess the current condition of the existing environment based on baseline studies, which can be used to:

- Determine the feasibility of the project with regard to economic equity, social and environmental justice.
- Develop an adaptable monitoring plan based on participatory management in order to maintain the baseline environment within the variability of dynamic equilibrium.

In addition, relevant literature was reviewed and previous studies utilised where appropriate. Data on the existing environment was collected during the field visit on 23rd-24th November 2015 to G DH. Fiyoari. The survey lasted for two days and was conducted in fine weather.

5.2 COAST AND SHORELINE

A GNSS RTK System relative to MSL, was used to determine the coast, shore line, current beach profile, vegetation, and building structures within the project boundary to a confidence interval of 3 mm. Interviews, previous surveys and photographs were also used to determine the previous conditions of the coast.

The bathymetric survey was conducted using the RTK method as spot heights of the shoreline. The accuracy of the horizontal measurements were always less than 0.002 m and the vertical measurements were less than 0.005 m.

5.3 MARINE SURVEY

Line transect method was utilised to assess the benthic cover of project area. Four 20 m geo-referenced line transects were placed in the project area. Overhead photographs were taken along the length of the line transect. Photographs were later analysed to determine the types of corals and develop a count graph of coral species which was used to determine the coral cover. Fish surveying was done by taking timed photographs and videos at the transect location. The photographs and videos were later analysed to identify the type of fish species using two sources:

1. Anderson and Hafiz, 1987 and
2. Kuiter, 2014.

Fish abundance was assigned through count, and comparing the count to a selected range which was specific for the area. The count and range band are as follows:

Table 5: Fish count range

Fish Abundance	Count Range
Rare	0 - 10
Common	10 - 35
Abundant	35+

5.4 COASTAL VEGETATION

Although vegetated area of the coastline is beyond the project boundary vegetation was analysed by first determining the coastal vegetation line. Next, photographs of trees within this boundary were taken and georeferenced. The photographs were then analysed by comparing with tree databases to identify the species and develop a count graph, which was used to determine the tree type and abundance.

5.5 NEARSHORE CURRENTS

A Garmin foretrex301 GPS tracker was submerged on the surface of water and position data was logged every second to determine the current direction and its speed. Four trials were logged, from which direction and speed of currents were calculated. The tracker was launched into the water, and the drift progress was timed between the tracker entering the water and coming out. Using tracker software these times were filtered out to calculate the velocity and current direction. Normal distribution based standard deviation was also calculated for the average current velocity.

5.6 CLIMATE, WAVES AND TIDES

Climate and oceanographic regime requires long-term data on climate and oceanographic conditions. Climate data collected at Kaadehdhoo local airport was considered for this study. Rainfall was analysed after compiling rainfall data obtained for the past six years, from Maldivian Yearly Statistics Book. The average monthly rainfall was calculated based on six years of monthly data. Variance monthly rainfall was determined through standard deviation calculations. The individual monthly averages were then compared with mean annual rainfall calculated based on six years of data and these patterns were used to assess the rainfall conditions at Fiyoari. Similar approach was used to determine the mean high temperature at Fiyoari.

Literature was reviewed to determine the wave and tide conditions at the project area. Hence historical data on climate and oceanography was used to predict and extrapolate climate and oceanographic conditions.

5.7 SEAWATER

Water samples were analysed using HORIBA U-52 Multi-water Quality Checker that had been span calibrated using standard grade reagents. All the parameters were measured and logged in real time on field which preserves the chemical constituents in equilibrium with their natural physiochemical environment, thus giving a more accurate picture of the quality and status of water samples. The instrument uses voltammetry methods to analyse conductivity, Dissolved Oxygen (DO) and Total suspended Solids (Turbidity) of water samples. This technique is more reliable than wet laboratory chemical analyses which would require numerous pre-processing steps to alleviate the effect of reduced and oxidized material.

5.8 BATHYMETRIC SURVEY

The bathymetric survey was conducted using a SonarMite MILSpec™ which has an accuracy of 0.01 m. The boundaries of dredge area was determined after referring to scaled drawings. The boundaries of alternate dredge areas were selected based on community and council consultations. The echo sounder was connected to a 50 hp 25ft dingy. The vessel was driven in consecutive adjacent 20 m wide transects in consecutive north south direction and east west direction within the reclamation boundary and burrow area.

The survey determined the volumes of sand that will be obtained from the maintenance dredging. Dynamic heights of area below sea level was incorporated in the volume calculation of area below MSL.

Volumes were calculated using the surface comparison method in Civil3D. Both the average end method and conic approximation method were utilized to calculate the volumes. Existing surface is generated using the field survey data with functions in the software.

5.9 GEOGRAPHIC LOCATION OF SAMPLING SITES

Geographic location was determined based on Garmin GPSmap 64 and the GNSS RTK system. Geographic locations for water samples and transects were marked as way points using the hand held GPS.

5.10 SOCIAL CONDITION

Social conditions were determined based on information provided by the island council and through interviews conducted with locals.

5.11 ISLAND RISKS AND VULNERABILITY

The risks and vulnerability of Fiyoari was determined through literature review, mainly Development of Disaster Risk Management Profile Maldives (DDRMP) Project done by RMSI (2005) and DIRAM (2009), which thoroughly identified the exposure to natural hazards Maldives islands faced based on location and probability of natural disasters.

6 EXISTING ENVIRONMENT

6.1 INTRODUCTION

The existing environment was assessed and analysed based on surveys, field work and research data collected from relevant similar studies and institutions. The analysis of existing environment is fundamental to determine the feasibility and impacts of the project and to develop an EMP. In this report seven core parameters were analysed. They were geological, geographical, physiochemical, hydrological, ecological, social and climatic aspects. These assessments were used to:

- Determine existing conditions which can then be contrasted with, in the future to understand and determine the shift in equilibrium from base conditions.
- Propose alternatives to the project.
- Do an impact analysis and prepare an EMP

Hence, this section of the report provides:

- The main findings of the key parameters used to define the existing environment including a discussion on the results obtained.

6.2 CLIMATE

6.2.1 Temperature

The daily mean high temperature throughout the six year period was found to be very consistent. Temperature analysis of GDH. Kaadehdhoo for the past six years showed that:

- Temperature gradually increases at the start of northeast monsoon and reaches a peak at April. (See Figure 3)
- The onset of southwest monsoon gradually decreases the mean high temperature where, temperature reaches its lowest in December.
- Temperature fluctuated from the mean in accordance with the monsoons, where highest and lowest registered temperatures were observed during the end of each monsoon.
- The mean yearly high temperature for the past six years was calculated to be 31.1 °C. (See Table 6)
- Yearly temperature variance for the past six years was extremely consistent with a standard deviation of 0.2 °C.

Table 6: Mean high temperature analysis of GDH.Kaadehdhoo for the past six years. Source: (Planning.gov.mv, 2016)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average Yearly Rainfall/ (mm)
2014	30.6	31	31.1	31.9	31.3	31.7	31.2	31.1	30.3	30.8	30.4	30.5	31.0
2013	31.1	31.0	31.5	31.7	31.0	30.9	30.9	30.4	30.9	30.5	30.5	30.1	30.9
2012	30.9	30.8	31.7	31.7	31.4	31.9	31.5	31.3	31.0	30.4	30.7	30.9	31.2
2011	30.7	30.3	31.4	31.6	31.3	31.2	31.2	30.9	31.2	31.1	31.2	30.6	31.1
2010	30.8	31.3	32.3	32.6	31.9	32	31.2	31.5	31.2	31.4	31.3	30.9	31.5
2009	30.8	31	31.8	31.6	31.9	31.4	31.5	31.2	30.9	30.9	30.7	30.6	31.1
Monthly Average 6 yr. Period	30.8	30.9	31.6	31.9	31.4	31.5	31.2	30.9	30.9	30.9	30.7	30.6	31.1
Standard Deviation	0.2	0.3	0.4	0.4	0.3	0.5	0.2	0.5	0.3	0.4	0.4	0.3	0.2

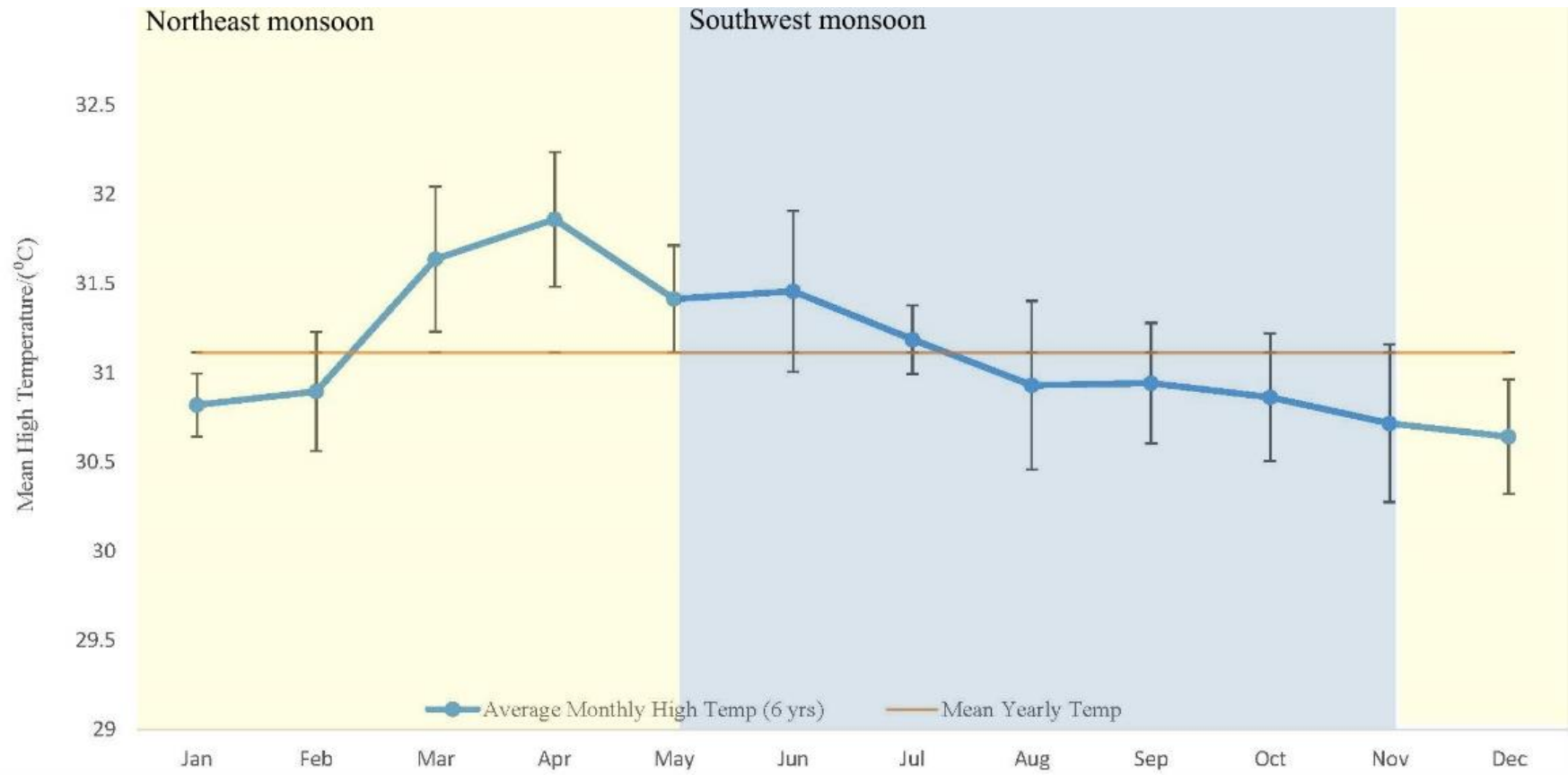


Figure 3: Mean monthly temperature (2009-2014) compared with average yearly temperature (2009-2014)

6.2.2 Rainfall

Rainfall was analysed after compiling rainfall data obtained for G DH. Kaadehdhoo for the past six years from Yearly Statistic provided by the DNP. The average of six year monthly rainfall was calculated from the compiled data. Variance of six year monthly rainfall was determined through standard deviation calculations. The six year individual monthly averages were then compared with the six year mean annual rainfall and these patterns were used to assess the rainfall conditions at Fiyoari.

It was found through historical rainfall data analysis that:

- The average yearly rainfall from data available for the past six years was 1936 mm. A minor variance 32 mm was observed annually, hence within the six year period, annual rainfall was fairly consistent (See Table 7).
- Rain fall was lowest during the northeast monsoon (127 mm), where rainfall was lower than the annual average 165 mm. (See Figure 4)
- The highest incidence and most variance in rainfall was observed in September where the six year average rainfall was 245 mm and the variance was 180 mm.
- January and December were found to have the highest rainfall variance during the northeast monsoon.
- Rainfall was highly variable during the southwest monsoon, where rainfall gradually increased from June onwards.
- June was found to be the month that received the least amount of rain based on six years of rainfall data (59 mm) with the least variance (26.9 mm). It was also the month with the least variance in rainfall.

Table 7: Mean Rainfall analysis of GDH.Kaadehdhoo for the past six years. Source: (Planning.gov.mv, 2016)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average Yearly Rainfall/ (mm)
2014	37.8	61.8	142.4	147.9	367.3	41.7	118.2	131.3	545.4	121.9	340.5	172.4	2228.6	185.7
2013	36.7	73.3	160.2	183.7	375.9	100.2	249.2	225.5	62.4	252.7	376.4	508.5	2604.7	217.1
2012	7.7	165.4	41.8	51.6	181.5	73.0	150.3	121.4	313.9	336.5	250.2	122.2	1815.5	151.3
2011	21.7	5.1	54	120.1	219.2	36.8	40.2	140.2	78.5	275.1	303.5	268.8	1563.2	130.3
2010	150.3	35.9	80.5	179.7	129.6	74.1	257.7	264.6	293.2	70.7	114.3	24	1674.6	139.6
2009	242.7	50	60.5	124.3	307.3	32.5	83.2	318.1	180.8	188	155.2	280.6	2023.2	168.6
Monthly Average 6 yr. Period	82.8	65.3	89.9	134.6	263.5	59.7	149.8	200.2	245.7	207.5	256.7	229.4	1936.2	165.4
Standard Deviation	93.4	54.4	49.5	48.6	101.9	26.9	88.3	81.5	180.3	99.7	104.1	166.7	386.7	32.2

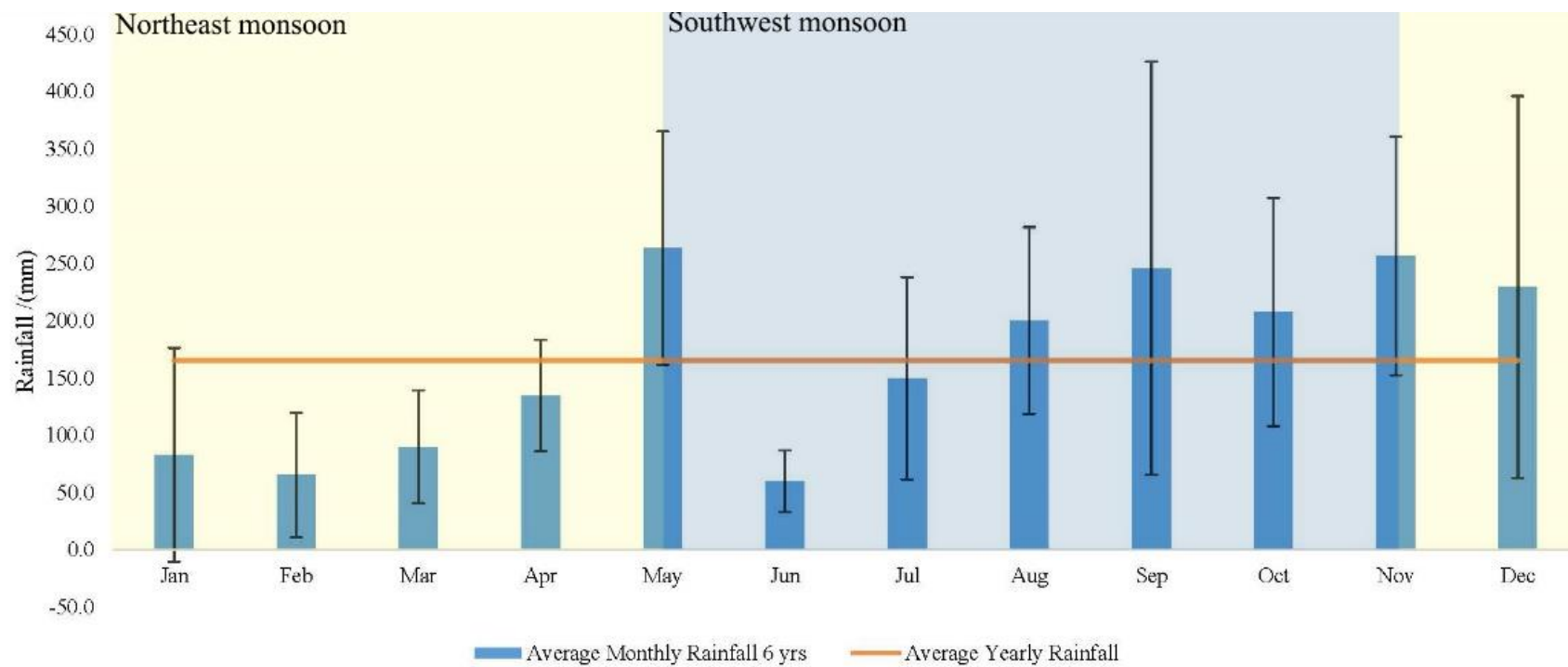


Figure 4: Annual monthly rainfall (2009-2014) compared with average yearly rainfall (2009-2014)

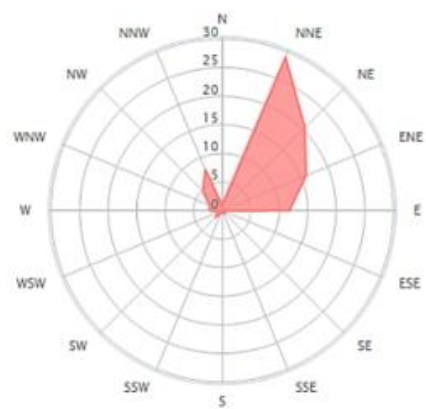
6.2.3 Wind

The wind conditions for the Maldivian islands are dominated by two monsoons. These winds approach with great constancy, primarily from the northeast and southwest directions. Some seasonal changes occur within this pattern, as a result of the relative position of the sun and the earth's surface. Strong winds and gales are infrequent although storms and line squalls can occur, usually in the period from May to October. During stormy conditions gusts of up to 60 knots have been recorded at Kaadhehdhoo (data from Maldives Meteorological Services). Wind has been shown to be an important indirect process affecting formation development and seasonal dynamics of the islands in the Maldives. Annual averages shows that wind directions are mostly in W (32%) and E (11%) and NW (10%). Figure 5 shows wind properties logged yearly at Kaadehdhoo international airport. The average wind speed logged for the whole year was 6 knots.

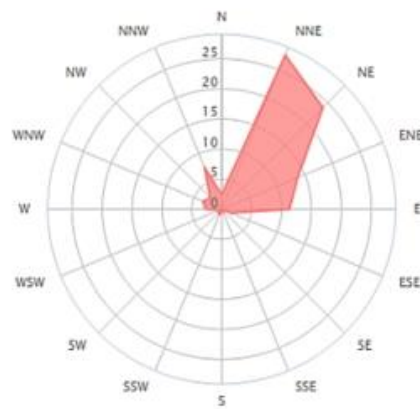
Month of year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
	01	02	03	04	05	06	07	08	09	10	11	12	1-12
Dominant wind direction	➤	➤	➤	➤	➤	➤	➤	➤	➤	➤	➤	➤	➤
Wind probability >= 4 Beaufort (%)	2	1	4	11	13	5	8	6	10	19	17	13	9
Average Wind speed (km/h)	11	11	11	13	13	11	11	11	11	15	13	13	11
Average air temp. (°C)	29	29	30	30	30	30	30	29	29	29	29	28	29

Figure 5: Wind properties at Kaadehdhoo source: wind finder

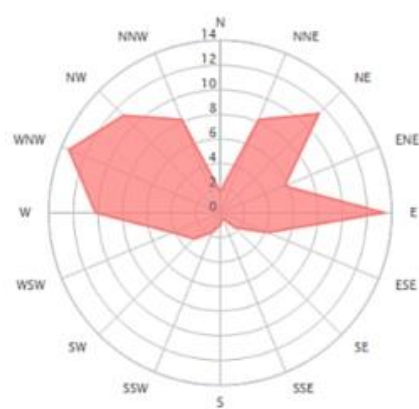
Figure 8 provides the average wind direction and magnitude at Kaadehdhoo for 2015. Monthly analysis of wind properties from Kaadehdhoo suggested that wind direction was primarily from W, WNW, WSW, NNE and E as evident from Figure 6 and Figure 7.



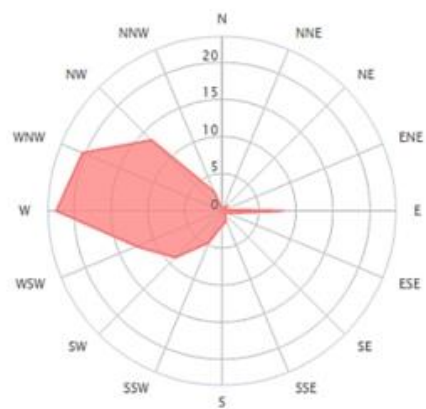
January



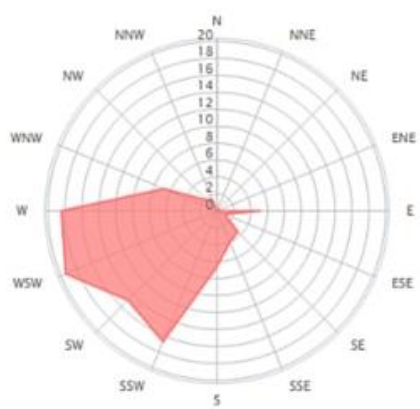
February



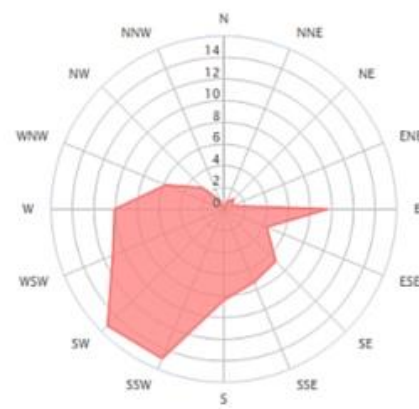
March



April

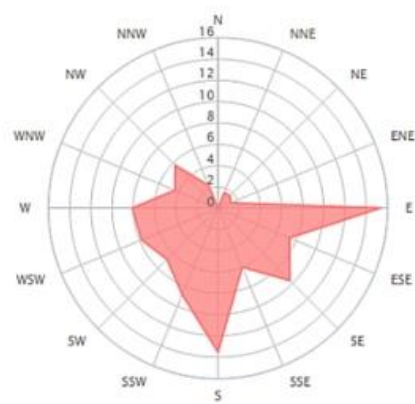


May

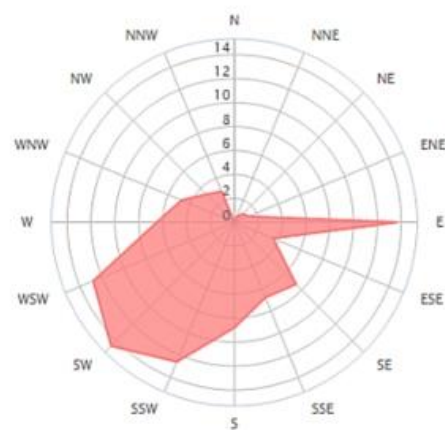


June

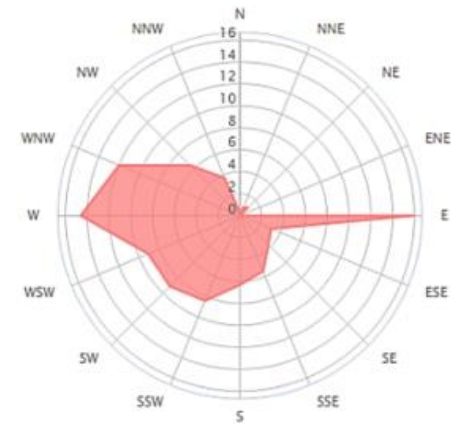
Figure 6: Wind rose for months January –December at Kaadehdhoo. source:windfinder



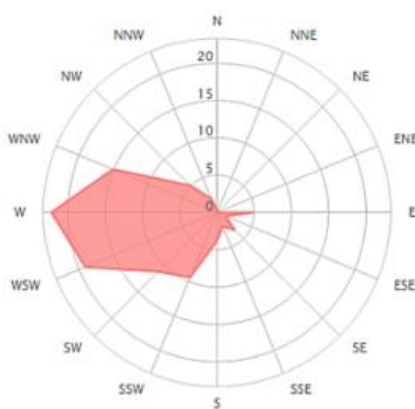
July



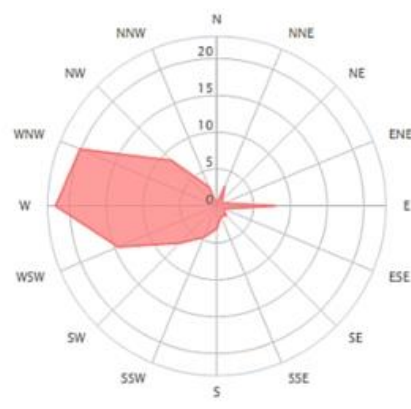
August



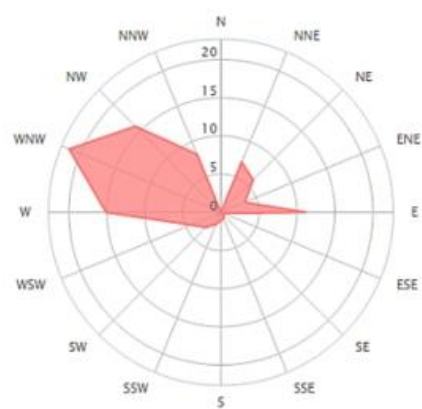
September



October



November



December

Figure 7: Wind rose for months July –December at Kaadehdhoo. source:windfinder

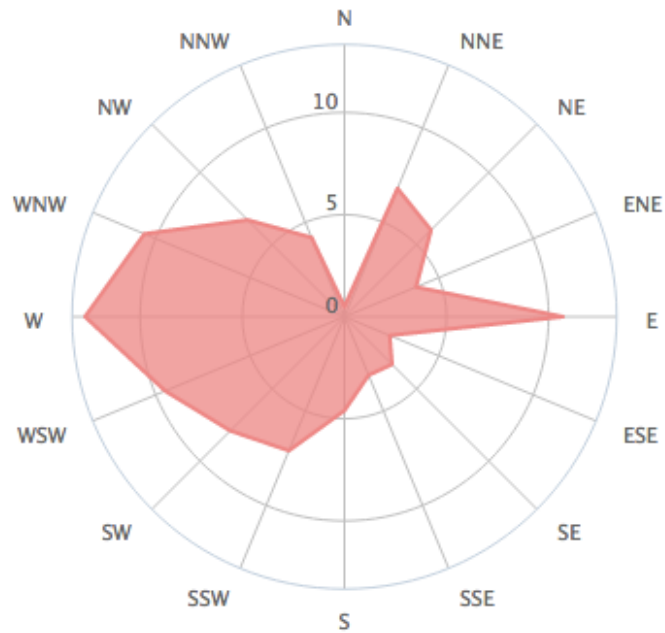


Figure 8: Average wind pattern for the year 2015 at Kaadehdhoo source: windfinder

Hence based on these findings it is concluded that

- The average yearly wind speed of Fiyoari was predicted to be approximately 3 ms^{-1} (6 knots) and
- The mean wind direction is westerly however a prominent North-eastern wind is observed during January and February during the northeast monsoon.
- Winds were strongest during March, June, May and August.

6.2.4 Summary Weather Analysis

- Northeast monsoon brought winds from the northeast direction for the months of January-March. The wind was dominant from the southwest direction for most of the year (April – January). The project area is expected to be calmer during the southwest monsoon as wind induced waves are expected on the west coast of the island.
- Rainfall analysis suggested that, rainfall was extremely variable but was largely concentrated during the south west monsoon. The initial stages of southwest monsoon between June and July was found to be the most stable in terms of rainfall events.
- Mean high temperature was found to consistent throughout the years however, peaks are projected to be observed during the latter stages of each monsoon, where end of southwest monsoon would yield the lowest temperatures and vice versa.
- In terms of weather related project risk mitigations, the period between June-July has been determined to be the calmest and most stable. If the project is conducted during this period, delays due to weather could be mitigated.

6.3 GEOLOGICAL

6.3.1 Land form and Soil

Fiyoari is a naturally formed island which has not been reclaimed. The island has an area of 768,044 m². The length of its widest section is approximately 1,653 m. Two types of beaches were observed in Fiyoari, Rocky beaches and sandy beaches. The islands geology can be considered as mature, based on the level of gradation in the soil profile of the island. The basis of soil for Fiyoari was calcareous material similar to other Maldivian islands. Soil comprised of very coarse sand to medium silt (0.03- 1 mm in diameter). Soil featured within the project boundary had a B horizon, hence it contained organic material. Soil close to the shore was observed to be porous although a thin layer of humus, clay and organic material were present at the soil found near the shore. Soil was structured in a gradational layer with no sharp changes observed between layers suggesting occurrence of bioturbation in the soil.

Soil properties found within the project area suggested that:

- The capacity of soil formation from mineral rocks situated in the C horizon through bioturbation was high;
- Soil was porous although the rich humus layer, roots of plants and the gradational structure of soil had made it compact; and
- Soil supported growth of vegetation at the coast.



Figure 9: Soil profile

Based on the soil structure and compaction, it was observed that the coast of Fiyoari had natural resilience towards inland erosion. However, erosion was observed to an extent at the project site. This is further discussed in the next section.

6.4 PHYSICAL

6.4.1 Coast and Shoreline

The harbour area was found to be a significant provider for the local economy as it contained the Kooddoo operated ice- plant which was situated north of the quay wall.

The western coast of Fiyoari had the only access point to the island through a dredged harbour basin. The open harbour basin encompassed an area of approximately 127,008 m². A quay wall spanning 154.16 m was the main berthing location for vessels entering into Fiyoari. The average width of the quay wall was measured to be 0.8 m (See Figure 10: Coastal features).

Analysis of the quay wall base suggested gradual scouring along the length of the quay wall (See Figure 11: Photo profile of coast). The current height of scouring was observed to be approximately 0 to 0.4 m at the base of the quay wall. Severe scouring could possibly lead to structure failure of the quay wall. However the current scouring observed at the base was minor.

Flanks of the quay wall were reinforced with revetment to prevent flank erosion. The length of revetment north of the quay wall was 25.8 m while the length of revetment south of quay wall was 23 m. The quay wall was installed after backfilling an area of 3,525 m², hence the quay wall extends 54 m from the actual island shoreline. Growths that extend out of the island have a tendency to cause flank erosion and depending on the current condition, the erosion may be prominent downstream or upstream (Kench, 2010). The extension was observed to have contributed to erosion of the coasts up and down the quay wall. The vegetation line north of the quay wall was located at an average distance of 3.48 m away from the shoreline, while the vegetation line south of the quay wall was observed to be located at an average distance of 13 m away from the shoreline.

Hence coast located north of the quay wall, was observed to have suffered moderate erosion when compared to the coast at the south. Cross section beach profiles of the coast north of quay wall suggested that the steep gradient between beach toe and erosion scarp were moderate. Profiles 2 and 3 just next to the revetment were observed to have suffered more erosion as a significant gradient was observed between erosion scarp and beach toe (See Annex 5 – Beach profiles North of Quay Wall).

Coast located south of the quay wall, past the revetment was also effected by minor erosion. Cross sectional beach profiles of the coast south of the quay wall suggested a minor gradient between beach toe and scarp. However just next to the revetment at the flanks, profiles 6 and 7 were observed to have suffered moderate erosion as the gradient between erosion scarp and beach toe was high. (See Annex 6 - beach profile south of quay wall).

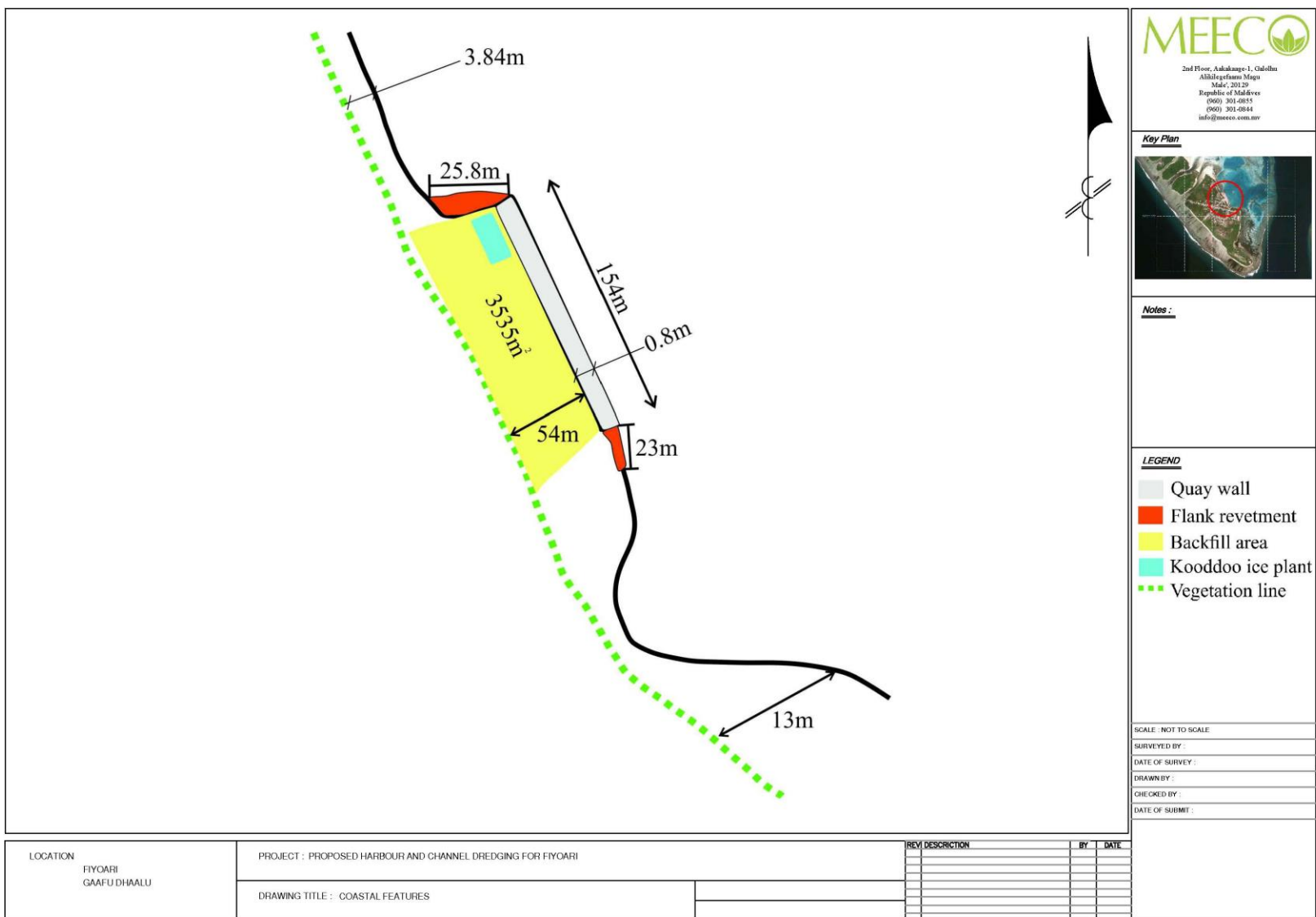


Figure 10: Coastal features of Fiyoari.

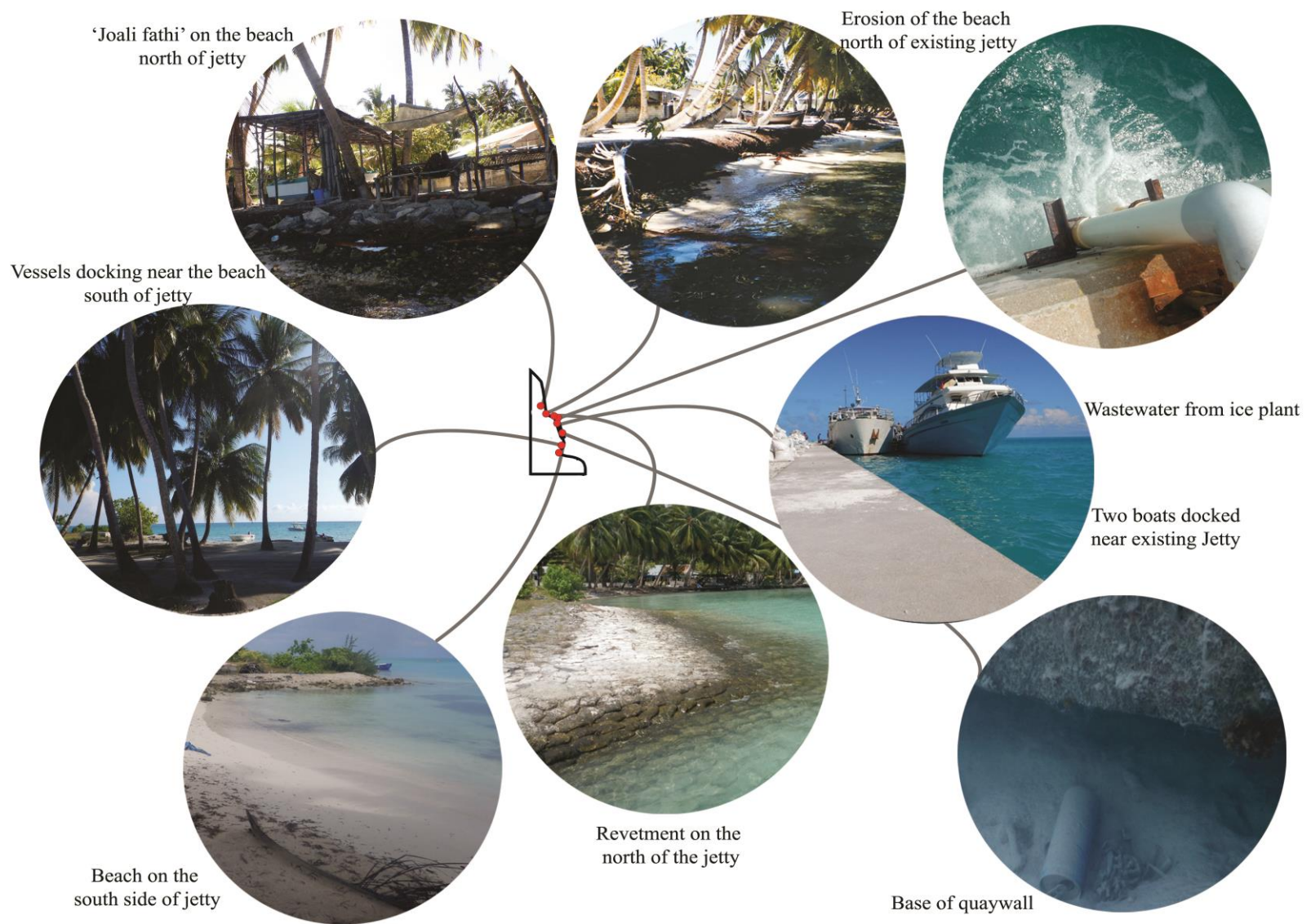
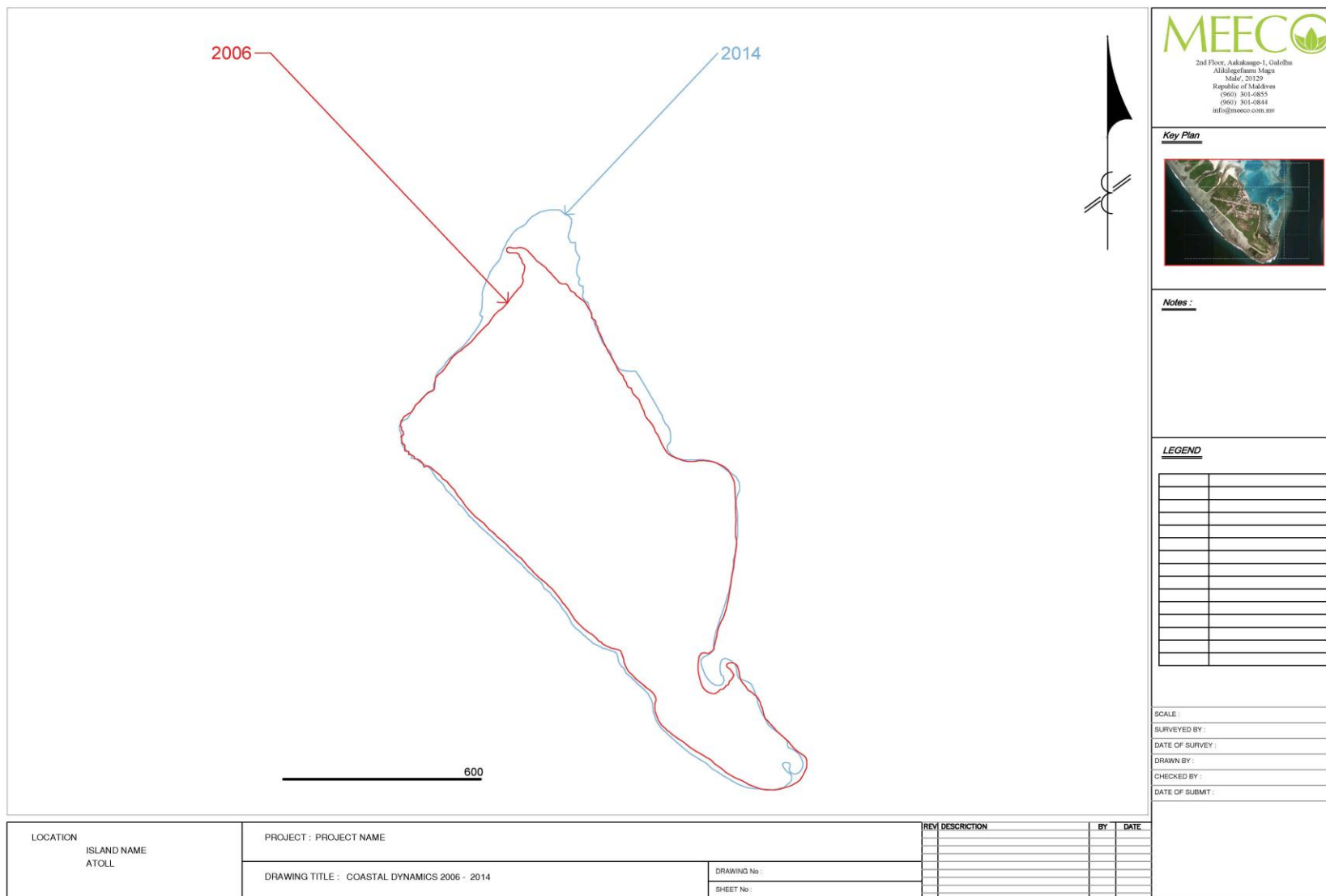


Figure 11: Photo profile of coast

Comparison of historical satellite images (See Figure 12) taken in 2006 and 2014 showed that:

- Significant coastal changes had been brought to the eastern coast of Fiyoari. The main coastal change observed was the development of a backfilled quay wall.
- Evidence of monsoonal sediment transport reversal was observed. Sediments accumulated at the northern coast was observed to move in accordance with the monsoonal wind. The image taken in 2006 was captured in the northeast monsoon while the image taken in 2014 was captured in the southwest monsoon. A reversal in sediment direction can be seen from the figure.
- A significant increase in accretion of sediments was observed at the northern tip of Fiyoari in 2014 compared to 2006. However, this accretion was not specific to only Fiyoari as the adjacent uninhabited islands were also found to have accumulated sediments.



6.5 HYDROGRAPHICAL

6.5.1 Currents

Wave breaking at an angle to the shoreline dissipates some of its energy along the shoreline, resulting in longshore currents. These currents move parallel to the shore carrying sedimentation, forming and eroding the beach through a natural process. Wave energy also gives rise to rip current that move away from the coast carrying sediments with it.

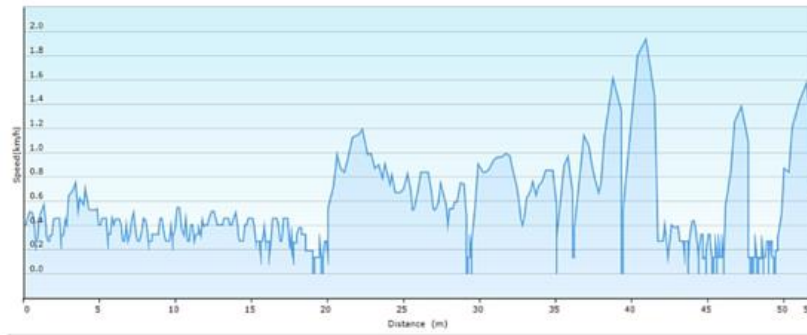
Four current measurements revealed that longshore currents propagated easterly with an average velocity of 0.06 ms^{-1} with a standard deviation of 0.06 ms^{-1} . Figure 14 shows where the current trials were taken and how they propagated.

Table 8 shows the current velocity and uncertainty in current measurements. Velocity distance graphs obtained for the current measurements are illustrated in Figure 13

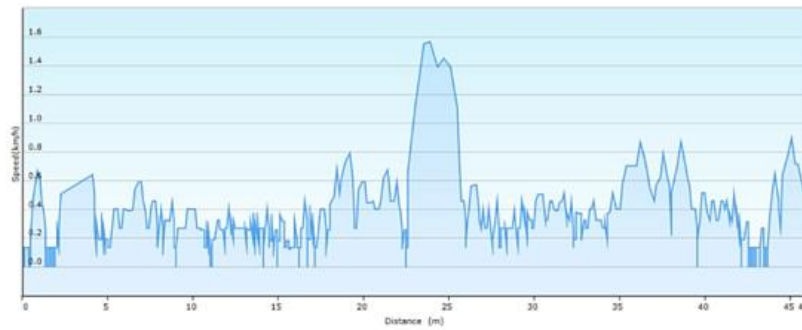
Table 8: Current data table

Measurement	GPS Coordinates	Current Speed / (ms^{-1})	Standard Deviation/(ms^{-1})
1	N0° 13.524' E73° 08.308'	0.09	0.10
2	N0° 13.547' E73° 08.245'	0.06	0.08
3	N0° 13.521' E73° 08.279'	0.02	0.05
4	N0° 13.497' E73° 08.608'	0.01	0.03

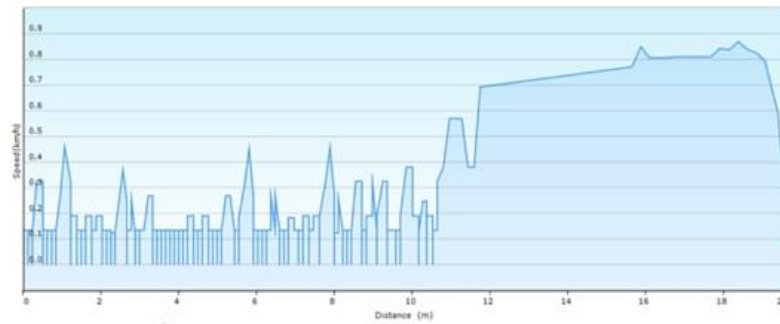
Measurement 1



Measurement 2



Measurement 3



Measurement 4

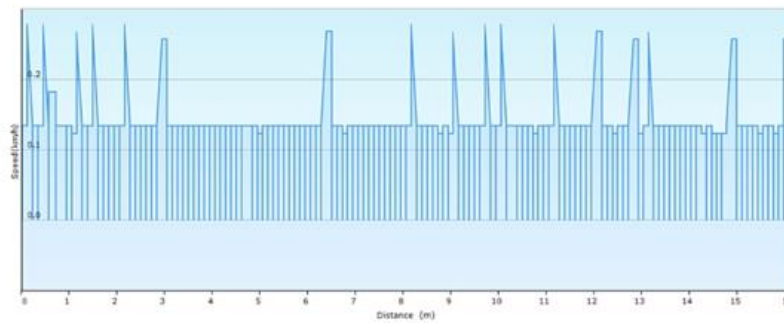


Figure 13: velocity distance graphs of the tracker

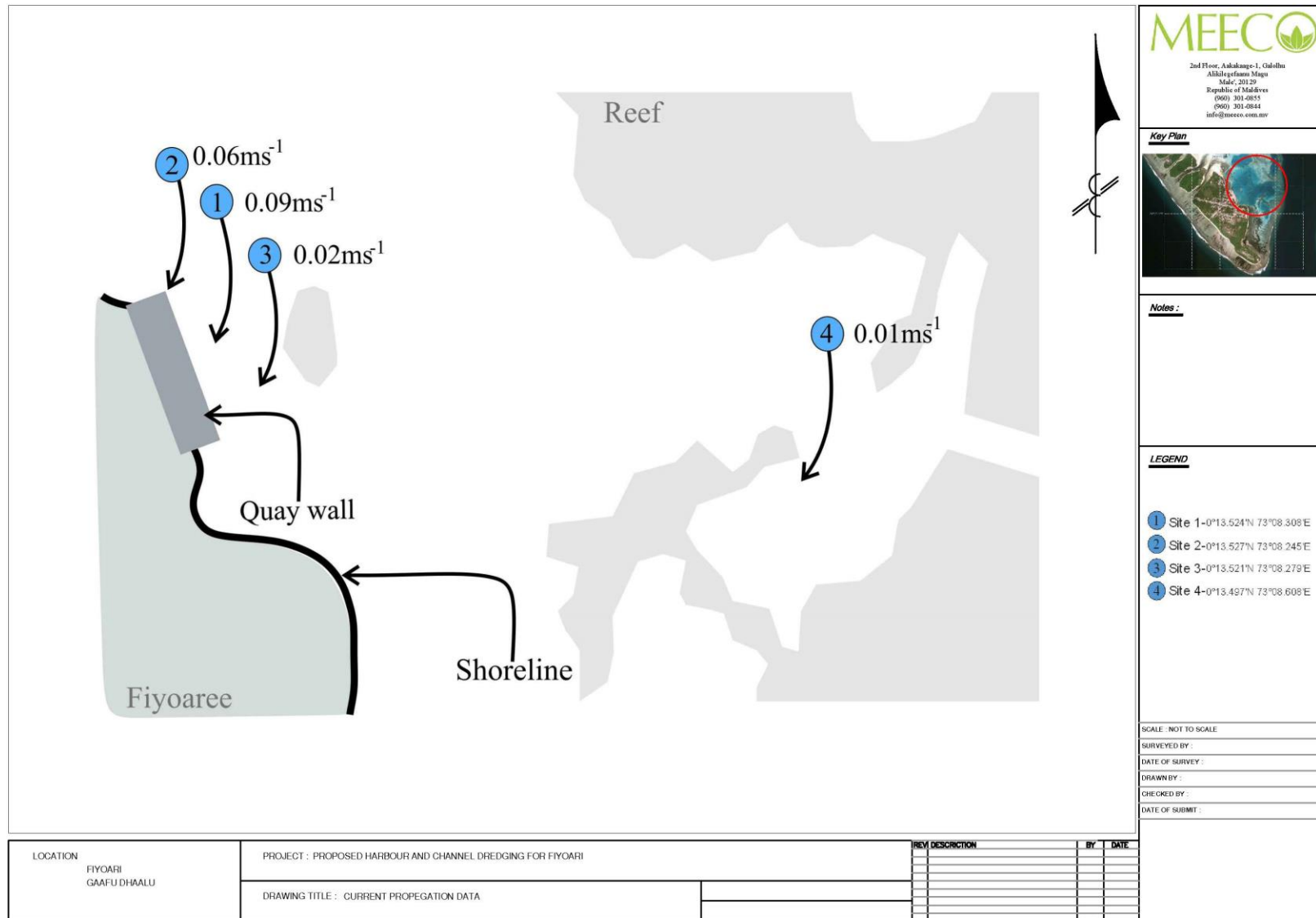


Figure 14: Current propagation data

From current measurement data:

- It was observed that the currents propagated towards the south.
- The average current velocity was extremely low. The four current measurements had an average velocity of 0.06 ms^{-1} .
- Velocity against distance graphs revealed that during the duration of data log time the tracker covered a fairly short distance and it was observed to remain stationary suggesting that surface currents measured at site were extremely low and the open harbour basin was calm and stable.

In order to determine whether the current velocity would influence sediment transportation, current measurement were compared with the Hjulström curve to predict fate of sediment particles based on particle diameter and critical shear stress.(See Figure 15).

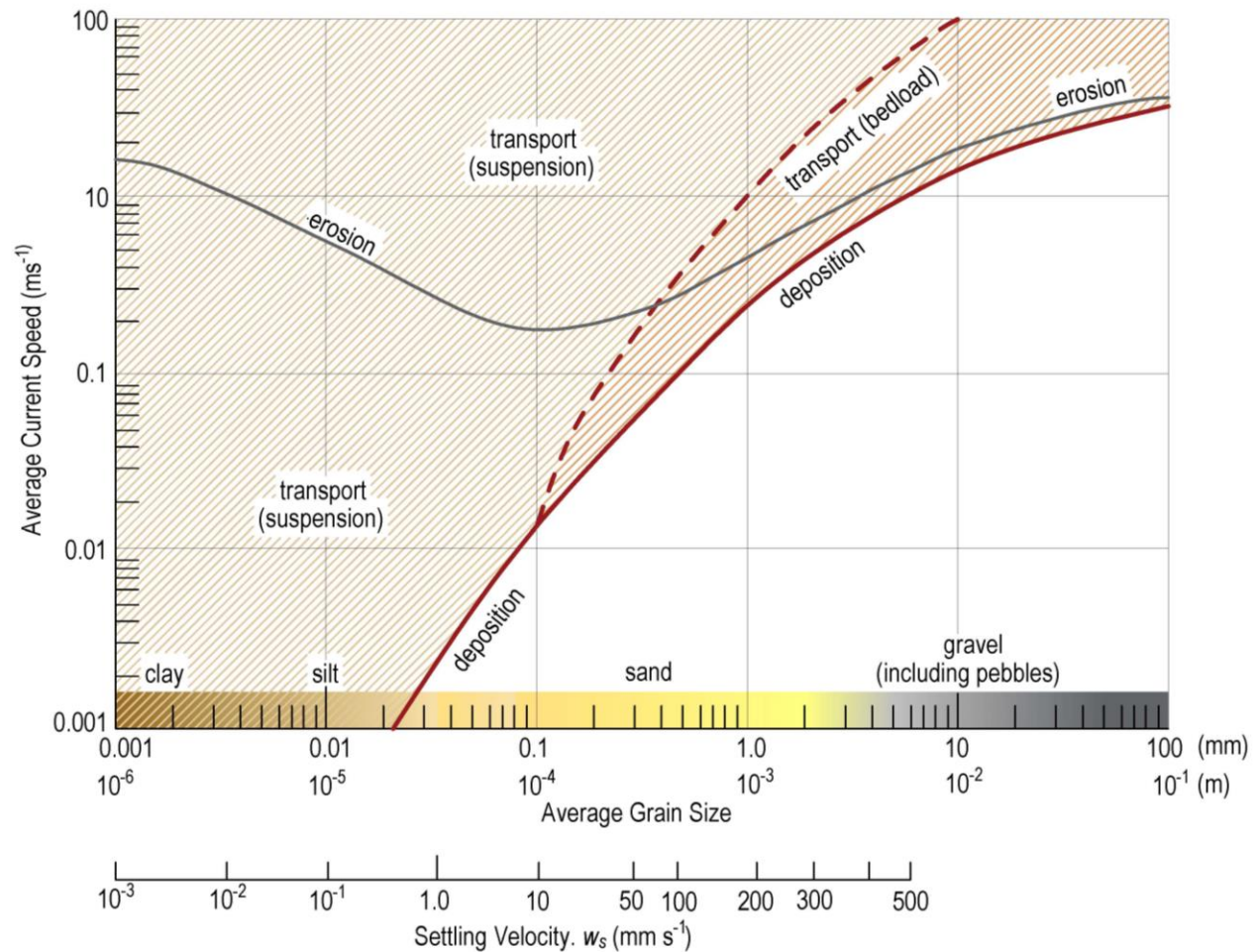


Figure 15: Hjulstrom curve (source: Goud and Aubry, 1985)

The average current speed observed for the project boundary was 0.06 ms^{-1} . A range of sand types were observed for the area. The project areas consisted of sand ranging from fine to fine gravel (average particle diameter between 0.5-4 mm).

Extrapolation of both current speed and average grain size suggested that sediments were likely to deposit onto the sea bed. The critical current speed required for particles of coarse sand to overcome the critical shear stress was approximately 0.25 ms^{-1} . The current speeds measured at project boundary would however, carry and actively transport very fine silt and clay particles. Shear stress forces for silt and clay particles are overcome at 0.01 ms^{-1} hence the observed current speeds would transport these fine particles as TSS. Hence, the method applied to predict the fate of sediment particles suggested that sediments with grain sizes less than 0.06 mm were likely:

- To be transported in a net southerly direction due to bed load disturbance arising from dredging and particles with diameters greater than 0.06 mm were likely to deposit.

However, the prediction method should be regarded as a simplified model because the methods applied encompass uncertainty as:

- Calculations were based on laminar flow only.
- Particles were assumed to be complete spheres.
- The effect of a single component of velocity acting upon the particle was utilised.
- Settling velocities and vertical velocities of sediments in still water was used in drawing the graph

The validity of these models should be concluded based on field monitoring, to better manage and understand the relationship, the project is going to have on the environment. Moreover, currents observed during field surveys were limited to a specific time and monsoon. It is important to measure current data over a longer period of time to better understand the current pattern in the harbor basin.

6.5.2 Waves

Waves and swells were predicted based on data accumulated by Kench and Brander, (2006), Zahir (2014) and through comparisons of wind data logged at Kaadehdhoo airport for 2015.

In general the southern regions of the Maldives are not known to experience waves greater than 2.5 m frequently. Wave heights exceeds 1 m in less than about one percent of the time from N, NW, NE and E. See Figure 16 below.

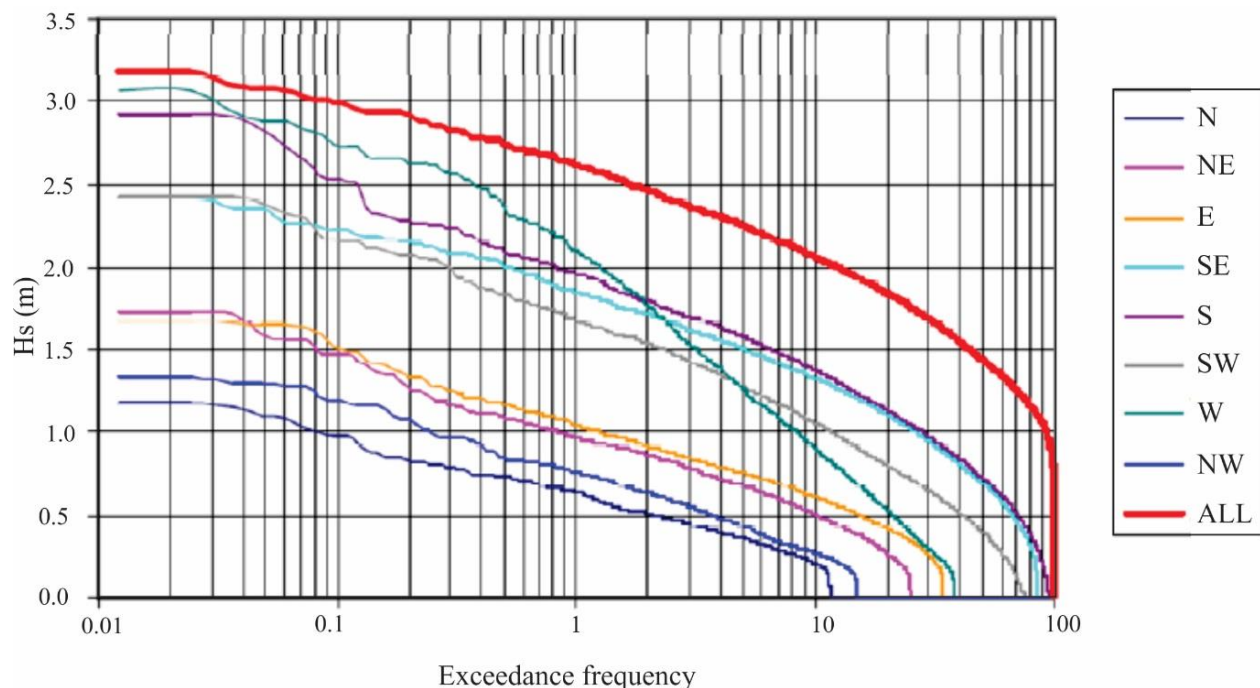


Figure 16: Wave Hs, exceedance curve for the southern region of the Maldives (source Kench and Brander, (2006)).

According to Kench and Brander, (2006) the dominant swell approached from a southerly and westerly directions, with some seasonal variations. Overall wave energy was greatest on all southern islands during the southwest monsoon (Kench and Brander, 2006).

Swells were predominantly from the south-southwest, between April to November, with a significant peak in wave height (H_s) of 1.8 m observed in June. Wind data logged at Kaadehdhoo airport suggested a fairly strong wind in June from SW, SWW direction which confirms that waves observed were mainly wind generated.

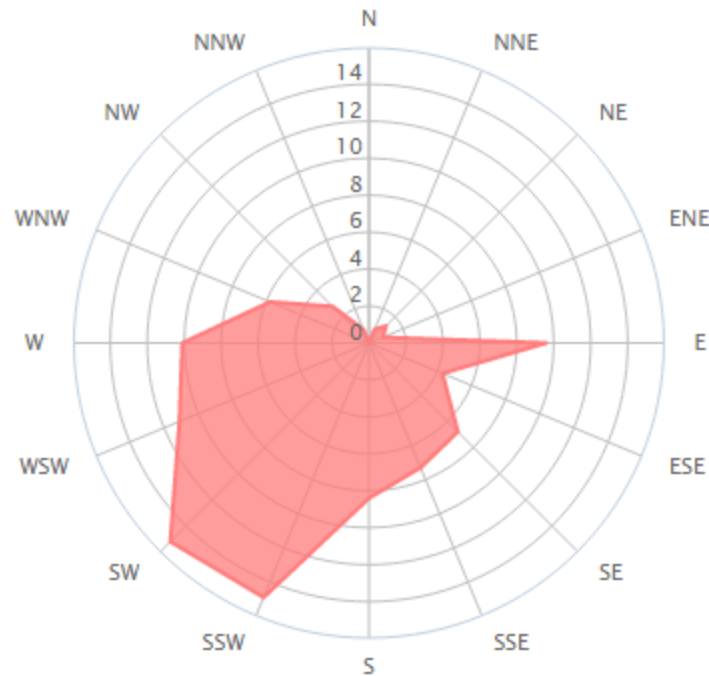


Figure 17: windrose for the month of June at Kaadehdhoo. Source: windfinder,(2016)

Furthermore, wave analysis done by Zahir (2014) for Thinadhoo west coast suggested that a correlation coefficient of 0.43 was observed between wind direction and wave height. It was also discovered through the analysis that peak, wave heights were observed as a result of wind generated from the west. In general the westerly waves were between 0.8 – 0.9 m in height and exceeded 1 m only 19% of the time. The percentage of wind generated waves were calculated to be 66%.

Based on these two studies a fairly conclusive wave pattern was identified for Fiyoari. It can be concluded that:

- Westerly monsoon would generate the strongest waves in Fiyoari. Most of the waves would be wind generated and propagate in the direction of the wind.
- Waves would propagate from W, SW, and SSW direction mostly. The harbour area would be shielded from wind generated waves as a result for much of the year.
- It is highly unlikely to encounter waves exceeding 1 m frequently, at the eastern coast of Fiyoari where the open harbour basin is situated.

6.5.3 Tides

Tide in the Maldives are characterized by sinusoidal oscillation containing two main cycles per day (semidiurnal tide) combined with a one cycle per day (diurnal tide). The combination of these two tides are referred to as mixed tide. Analyses of tides involve the study of harmonics which represents the period of oscillation of the celestial forcing that give rise to that harmonic.

There are no permanent tide stations established in Huvadhoo Atoll. The closest tide station is in Addu Atoll. This report inferred to tide analysis done on the island of Havoddaa by LaMer Pvt Ltd, (2013) which is located in South Huvadhoo atoll approximately 35 km North of Fiyoari. This is because of the close proximity of Havoddaa to Fiyoari and because the results obtained for tide analysis at Havoddaa closely correlated with tide data from Addu monitoring station.

Harmonic analysis of the measured tide data at Havoddaa indicated that tide observed had a principle lunar semi-diurnal (M2) tide with a period of 12.42 hours, luni solar diurnal (K1) with a period of 23.9210 hours. Tide observed at Havoddaa was seen to have an F ratio of 0.3001 which indicates that the tide observed at Havoddaa was, mixed dominantly semi-diurnal tides, where the range of water level calculated was 0.93 m (LaMer, 2013).

Hence, extrapolation of these results suggested that Fiyoari would experience a mixed semi-diurnal tide where two high tides and two low tides cycles repeats daily where the peaks of two cycles are non-identical. Based on the inferred study the change in water table at Fiyoari is approximated to be about 1 m.

6.6 PHYSIOCHEMICAL

6.6.1 Seawater Quality

In general the seawater quality of the project site was satisfactory. The water was slightly alkaline with an average of 8.3 pH. The average salinity and conductivity were 34.3 ppt 52.4 mScm⁻¹, respectively, characteristic of normal sea water. No sudden changes in conductivity was observed between sites that could suggest pollution. The average Dissolved Oxygen level was 13.2 mgL⁻¹ which is ideal for marine sea life to flourish. The DO readings also suggested sufficient air water oxygen saturation through circulation of water within the project boundary (See Table 9).

Total dissolved solids (TDS) combine the sum of all ion particles that are smaller than 2 microns (0.0002 cm). This includes all of the disassociated electrolytes that make up salinity concentrations, as well as other compounds such as dissolved organic matter. The TDS readings were normal with an average of 31.3 gL⁻¹. The TDS reading were close to the salinity of water body, which suggested that sea water hadn't been polluted by non-ionic hydrocarbons such as oils, lubricants and waste water.

The ORP, a measurement that indicates the degree to which a substance is capable of oxidizing or reducing another substance was observed to be normal. The average reading of ORP for the project boundary was 236 mV which suggested an oxidation potential. Most seawater bodies are oxidizing, with a positive potential. A significant negative potential would indicate an influx of reducing agent in the water.

Turbidity suggested suspension of sediments in water to some extent. Readings from the project site suggested a significant difference in turbidity between sampling sites. The average turbidity of all the sites were 0.3 NTU. TSS was also, measured at the project and was found to be below LOQ of the instrument. (See Annex 7 for test result)

However samples measured near the quay wall had significantly high turbidity readings. Notable readings were obtained for site F3 (1.3 NTU) and F4 (2.4 NTU) (See Figure 18). The increase in turbidity at these sites were due to:

- Release of waste water from the Kooddoo ice plant located north of the quay wall.
- Sediment disturbances from vessels and waves.

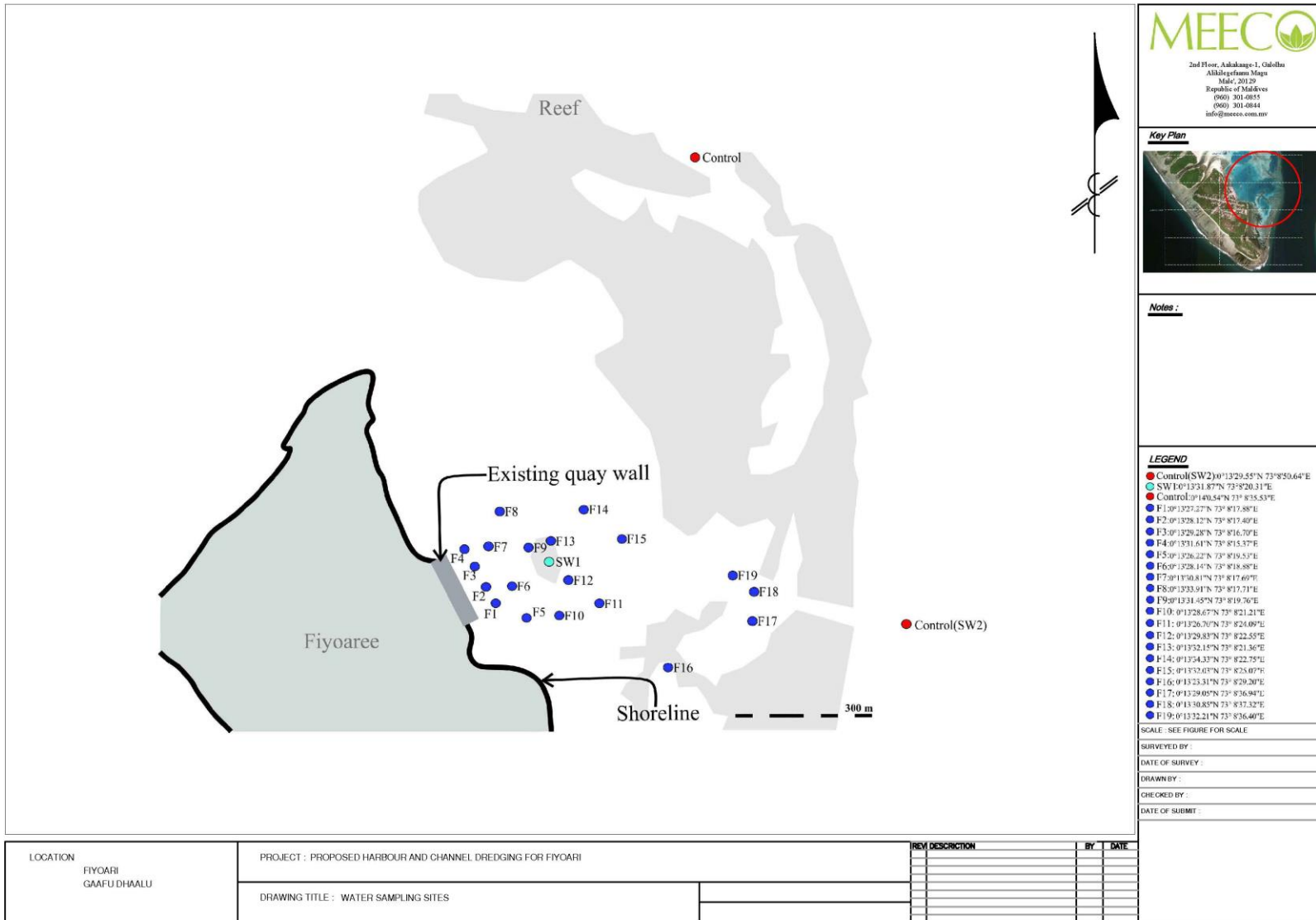


Figure 18: Water sample locations.

Table 9: Water sample data

Name	Location	Salinity/ (ppt)	pH	Turbidity/ (NTU)	DO/(mgL-1)	Conductivity (mScm-1)	Temp/(0C)	Specific gravity	TDS/(g/L-1)	ORP/(mV)	TSS/(mgL ⁻¹)
F1	0°13'27.27"N 73° 8'17.88"E	34.2	8.07	1.4	16.85	52	29.98	21.3	31.2	285	
F2	0°13'28.12"N 73° 8'17.40"E	34.4	8.13	0	15.53	52.3	29.8	21.5	31.4	252	
F3	0°13'29.28"N 73° 8'16.70"E	34.6	8.15	1.3	14.81	52.4	29.66	21.7	31.5	247	
F4	0°13'31.61"N 73° 8'15.37"E	34.5	8.17	2.4	14.15	52.4	29.67	21.6	31.4	236	
F5	0°13'26.22"N 73° 8'19.53"E	34.3	8.31	0	13.78	52.1	29.79	21.4	31.3	224	
F6	0°13'28.14"N 73° 8'18.88"E	34.5	8.29	0.3	13.52	52.4	29.69	21.6	31.4	226	
F7	0°13'30.81"N 73° 8'17.69"E	34.6	8.29	0.2	13.4	52.5	29.81	21.6	31.5	232	
F8	0°13'33.91"N 73° 8'17.71"E	34.4	8.29	0	12.7	52.3	29.63	21.6	31.4	236	
F9	0°13'31.45"N 73° 8'19.76"E	34.4	8.33	0	13.13	52.2	29.64	21.6	31.3	223	
F10	0°13'28.67"N 73° 8'21.21"E	34.4	8.35	0	13.33	52.2	29.75	21.5	31.3	226	
F11	0°13'26.70"N 73° 8'24.09"E	34.6	8.36	0	12.79	52.5	29.89	21.6	31.5	212	
F12	0°13'29.83"N 73° 8'22.55"E	34.5	8.37	0	12.94	52.4	29.66	21.6	31.4	218	
F13	0°13'32.15"N 73° 8'21.36"E	34.7	8.34	0	12.43	52.7	29.6	21.8	34.6	225	
F14	0°13'34.33"N 73° 8'22.75"E	34	8.35	0	12.86	51.7	29.61	21.6	30.9	230	
F15	0°13'32.03"N 73° 8'25.07"E	34.7	8.34	0	11.97	52.6	29.61	20	31.6	234	
F16	0°13'23.31"N 73° 8'29.20"E	34.6	8.38	0	12.31	52.6	29.92	21.2	31.5	249	
F17	0°13'29.05"N 73° 8'36.94"E	34.5	8.17	0	12.13	52.3	29.73	21.2	31.4	270	
F18	0°13'30.85"N 73° 8'37.32"E	32.4	8.25	0	11.77	49.6	29.76	21.8	30.2	241	
F19	0°13'32.21"N 73° 8'36.40"E	34	8.26	0	11.39	51.7	29.75	21.6	31.1	240	
SW1	0°13'31.74"N 73° 8'20.34"	-	-	-	-	-	-	-	-	-	<LOQ
control	0°13'41.64"N 73° 8'29.19"E	34.2	8.3	0	13.07	52	30.28	21.6	31.2	226	
Control (SW2)	0°13'41.64"N 73° 8'29.19"E	-	-	-	-	-	-	-	-	-	<LOQ
Average		34.3	8.3	0.3	13.2	52.1	29.8	21.5	31.3	236.6	

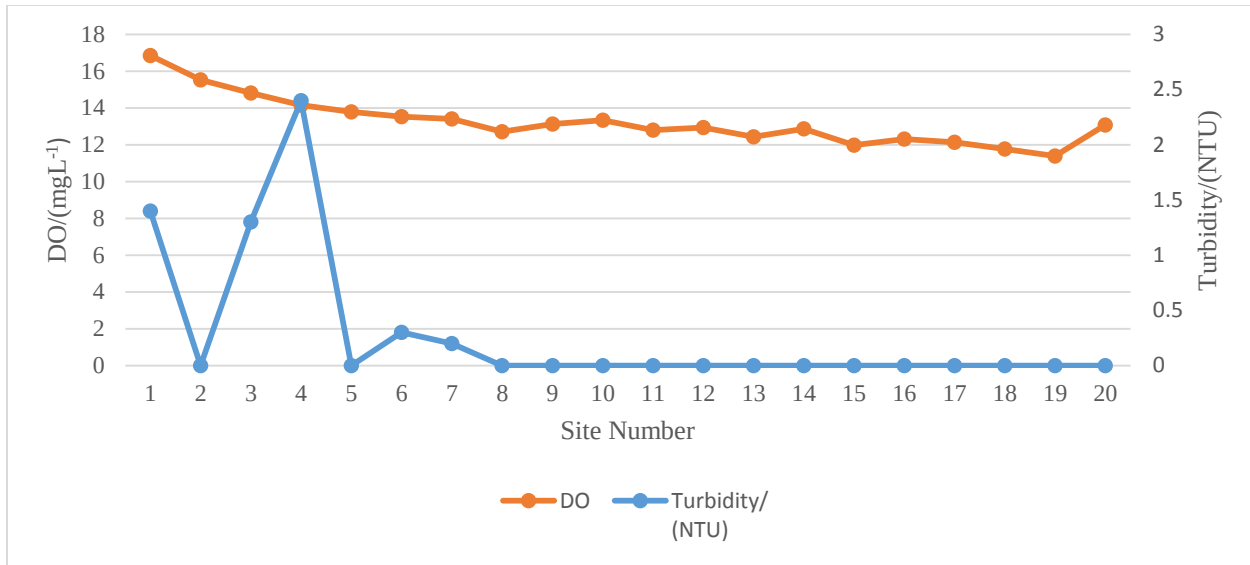


Figure 19: Changes in turbidity and DO across sample sites

Figure 19, DO levels were observed to be consistent throughout the project boundary. However turbidity spikes were observed between sites. High turbidity readings were noted for samples measured close to the quay wall. As the distance from the shore increases turbidity was observed to decrease. Turbidity readings were highest for sites F1, F3 and F4 which were closest to the quay wall. (See Figure 18. In order to determine whether

- The turbidity was significantly high close to the shore and a linear regression analysis (See Annex 8 – Linear regression Analysis) was performed which compared the turbidity readings against distance from the quay wall.

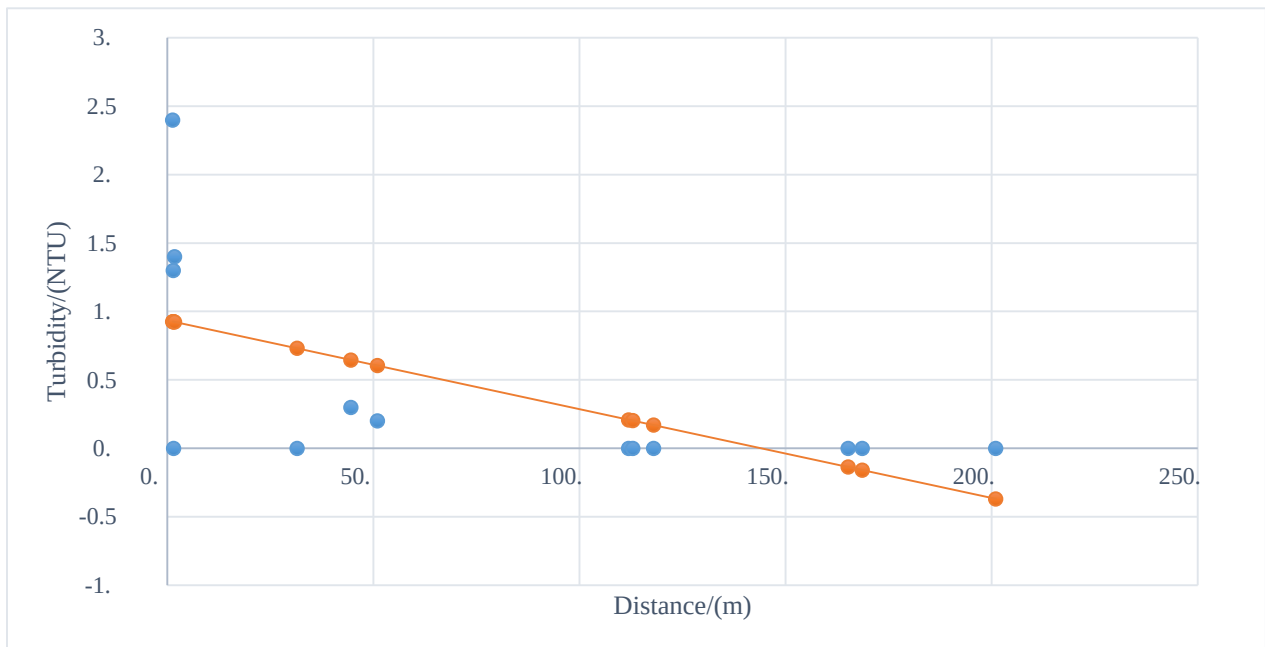


Figure 20: Linear regression turbidity against distance from quay

The analysis yielded Figure 20, where the correlation coefficient was 0.61 with a residual standard deviation of 2.6.

- The linear regression suggested a significant link between turbidity and distance from the quay wall.

The experimental values were clustered close to the linearity equation up to a distance of 200 m. Based on the correlation coefficient of 0.61, it can be concluded that turbidity decreases moving away from the shore where it normalizes further away from the shore (See Figure 21). The linear regression suggested that:

- Sediments were suspended in water column close to the quay wall. This may be due to the waste water pipe and scouring at the base of quay wall due to wave impacts and vessels disturbing bed load.

Turbidity was negligible 200m away from the quay wall close to outer house reef. No signs of sediment transportation towards the house reef was observed.

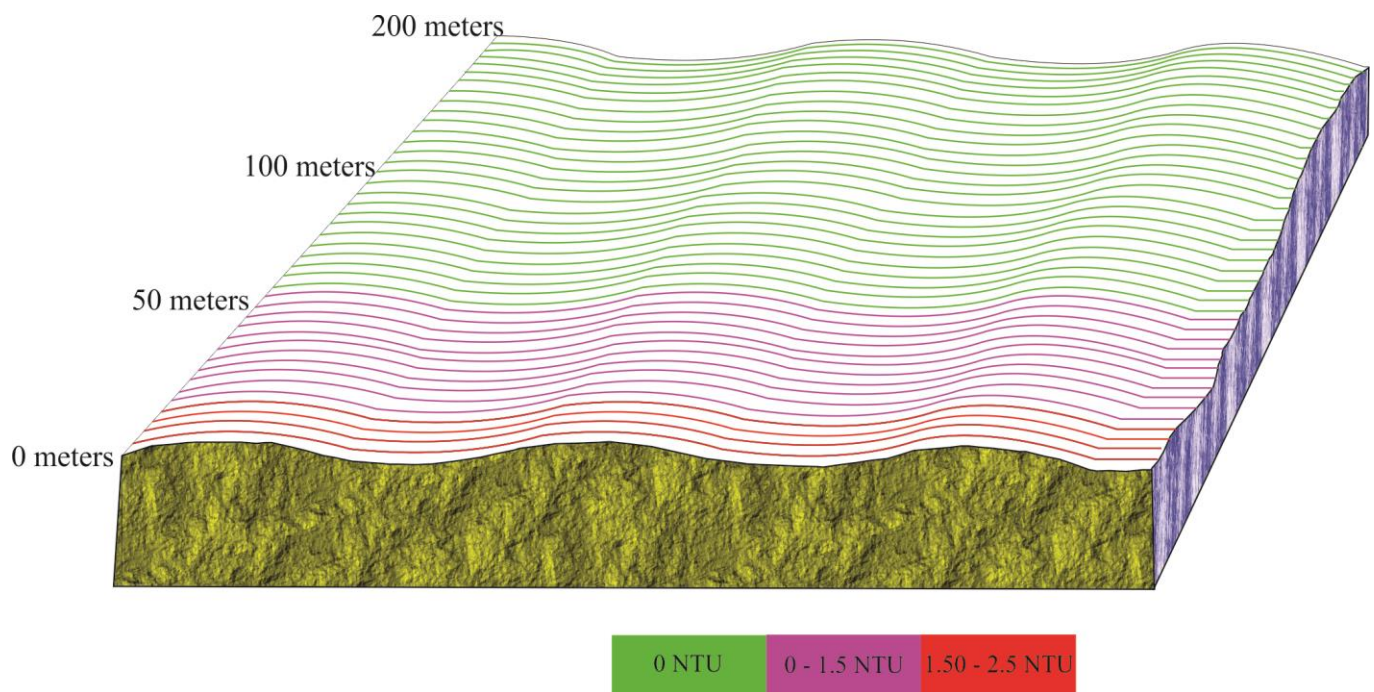


Figure 21: Turbidity changes with distance from harbour

6.7 MARINE ENVIRONMENT

6.7.1 Bathymetry

Proposed Dredge Area

Total proposed dredge area for the harbour basin by the proponent was 31,049 m². Table 10 summarises proposed dredge areas for the harbour and entrance channel and calculated dredge materials which will be obtained.

Table 10: Proposed project areas and fill material accrued

Name	Project area	Volume of fill material
Harbour Area	25,699 m ²	10,200 m ³
Entrance Channel	5,350 m ²	1,600 m ³
Total		11,800 m ³

Bathymetry Analysis

Bathymetry of the proposed area showed that:

- The average depth of harbour basin area was -4 m from MSL
- The shallowest area in the harbour was -0.83 m from MSL and was due to the shallow *giri* measuring 90 m in length and 28.34 m in width, situated 114 m from the quay wall, covering an area of 2,642 m². This was the only area shallower than – 3 m MSL.
- The average depth of entrance channel was – 4.25 m from MSL.
- Depth less than – 3m MSL was observed at the southern edge of the entrance channel. The average depth of this area was -2.5 m from MSL and covered an area of 1,650 m²
- These were the only two significant shallow areas observed at the entrance channel and harbour basin area.
- Bathymetry of study area (see Annex 12 –Changed Boundaries).
- The average depth of these areas were – 1.2 m from MSL and covers a total area of 6,380 m². Volume of dredge material from these two areas were calculated to be 6,700 m³
- The total dredge area when only shallow areas were included was 10,672 m²

Figure 22, summarises these findings and illustrates the locations of shallow areas.

The depth profiles of the proposed harbour area is attached in Annex 9 - Bathymetry of Harbour Area. The closer contours in Annex 9 adjacent to the quay wall represent a very steep slope. The depth profile of entrance channel and shallow areas close to the entrance channel is attached in Annex 10 – Bathymetry of Entrance Channel

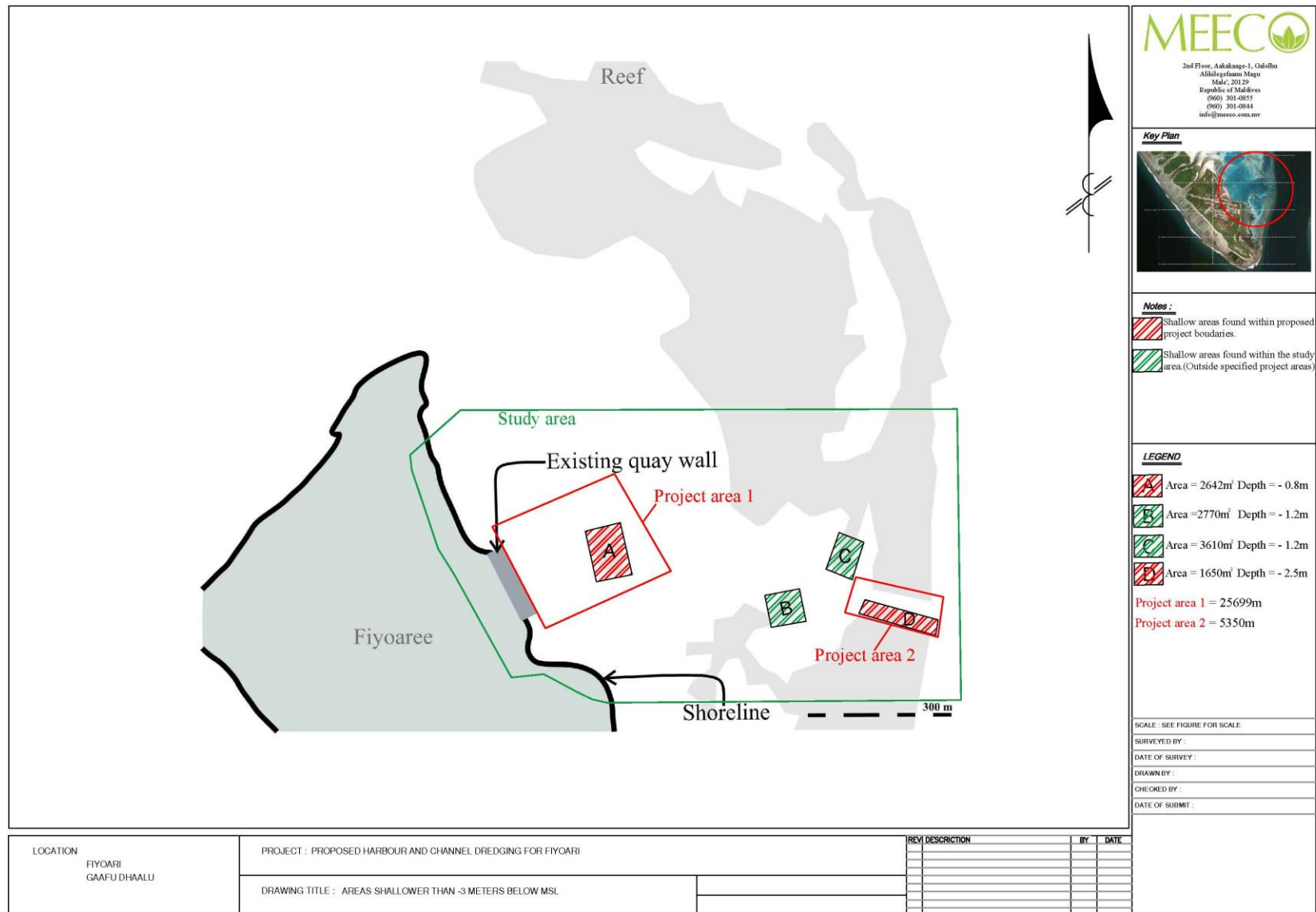


Figure 22: Significant shallow areas within the basin. The total dredge area when only shallow areas are included was found to be 10,672 m²

6.7.2 Benthic Cover

Observations of the marine environment to determine coral cover, diversity and abundance was carried out in areas within the project boundary that were expected to be impacted by the proposed harbour and channel development project. The areas surveyed for the study include the '*Giri*' (Shallow area in the middle of the harbour) and the area of the reef surrounding the existing channel Figure 23, shows the locations of all transect sites.

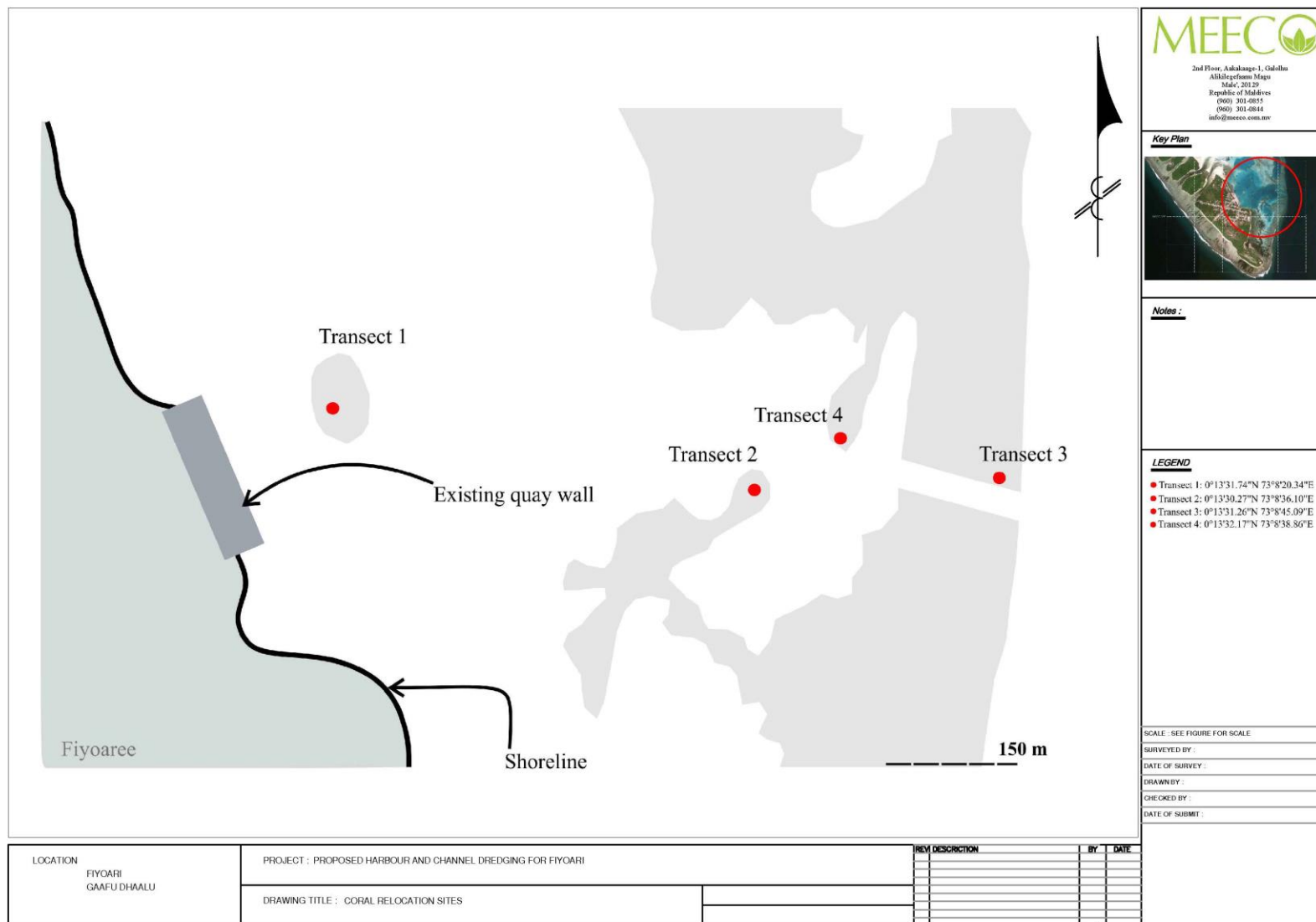


Figure 23: GPS location and map of transects

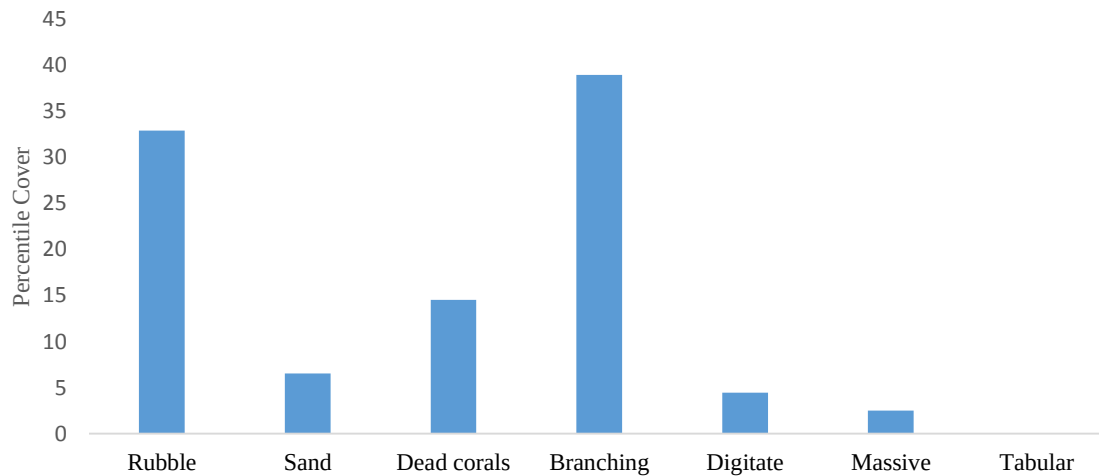


Figure 24: Benthic cover transect 1

Transect 1: Shallow area within the harbour basin; Dead corals, Sand and Rubble accounted for 54% of the transect length surveyed, while the remaining 46% was live coral cover consisting of Massive (2.5%), Digitate (4.45%) and branching corals (39%). Small coral colonies providing cover for various species of juvenile fish was also observed in this area. Coral bleaching was observed in 55% of the coral cover. See Figure 29 for photo profile of transect 1.

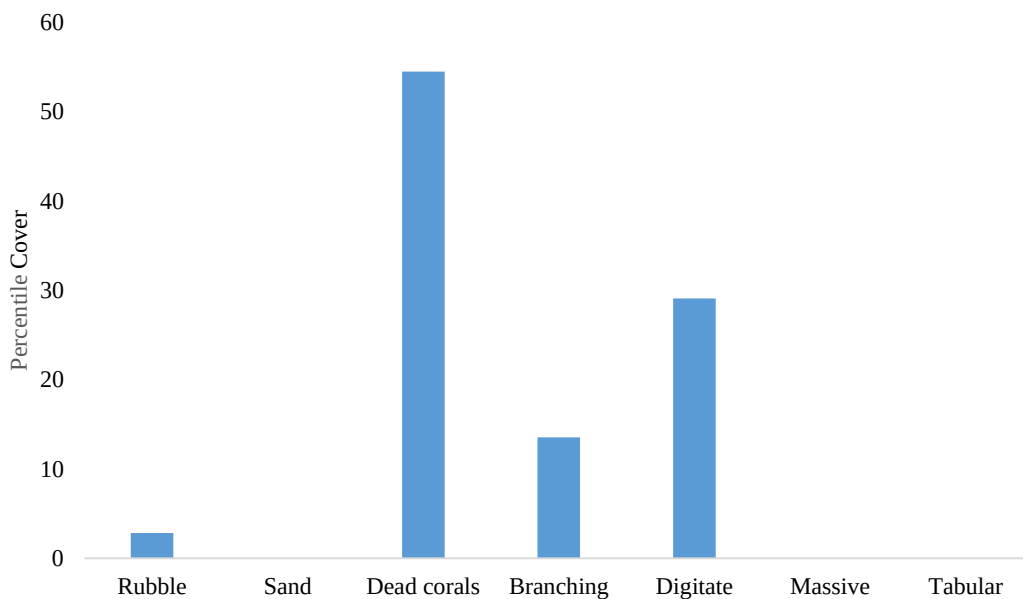


Figure 25: Benthic cover transect 2

Transect 2: A shallow and rocky patch of reef to the south of the existing channel; where 57.35 % of the corals observed were dead corals and rubble. The percentage of live coral cover amounted to 42.65% and consisted of branching (13.55%) and digitate corals (29.1%). See Figure 29 for photo profile of transect 2.

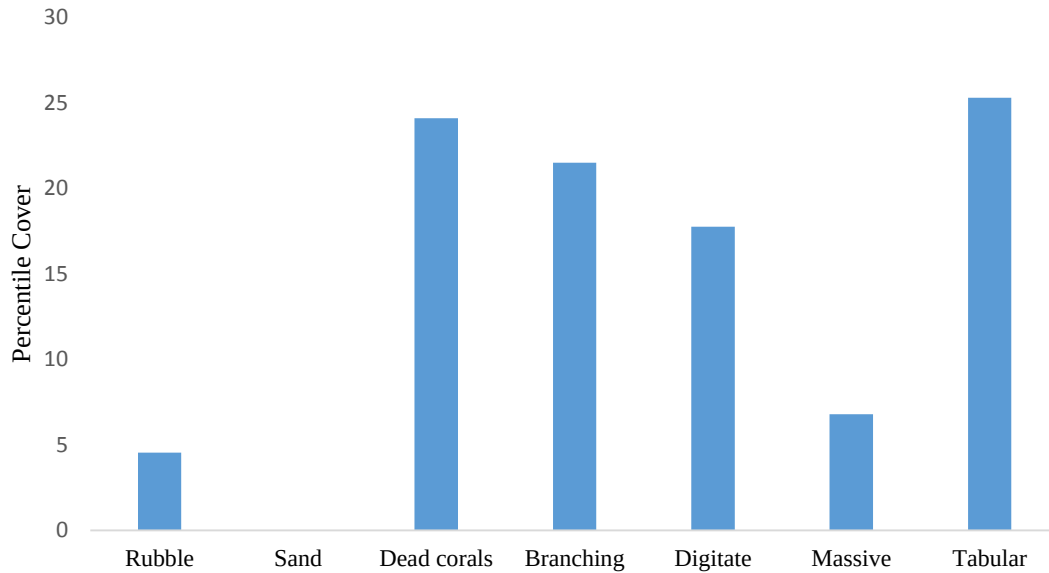


Figure 26: Benthic cover transect 3

Transect 3: Transect line was taken along the northern edge of the existing channel; this area included the highest percentage of live coral cover (71.35%). While branching (21.5%), massive (6.8%) and digitate corals (17.75%) were observed, this area also consisted of a considerable amount of tabular corals (25.3%). Rubble and dead corals amounted to 28.65% of transect 3. See Figure 29 for photo profile of transect 3.

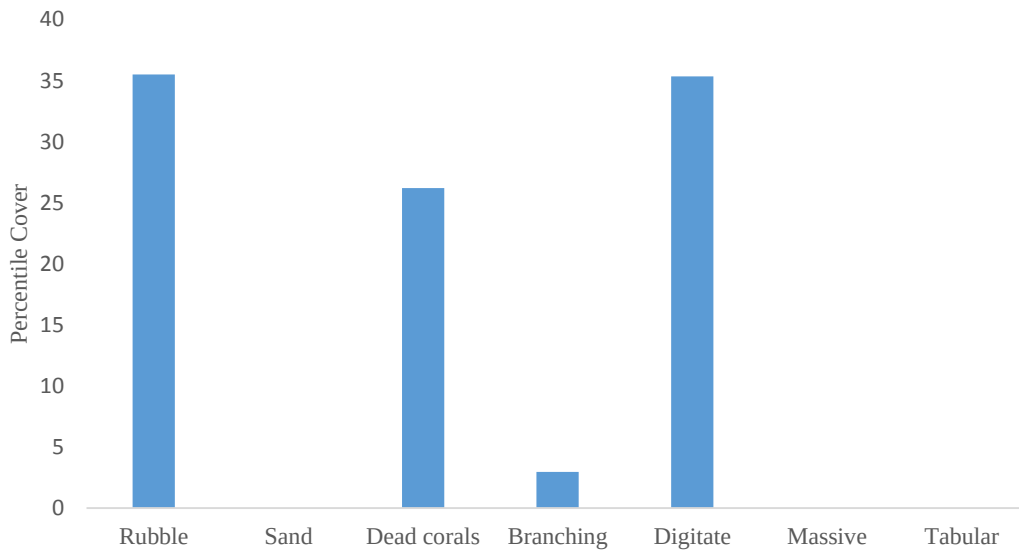


Figure 27: Benthic cover transect 4

Transect 4: Area of the reef north of the existing channel; Live coral cover was observed to be 38.3% in this area, diversity of live coral cover was limited to Branching (2.95%) and Digitate corals (35.35%) The percentage of Rubble and dead corals observed summed up to 61.7%. See Figure 29 for photo profile of transect 3.

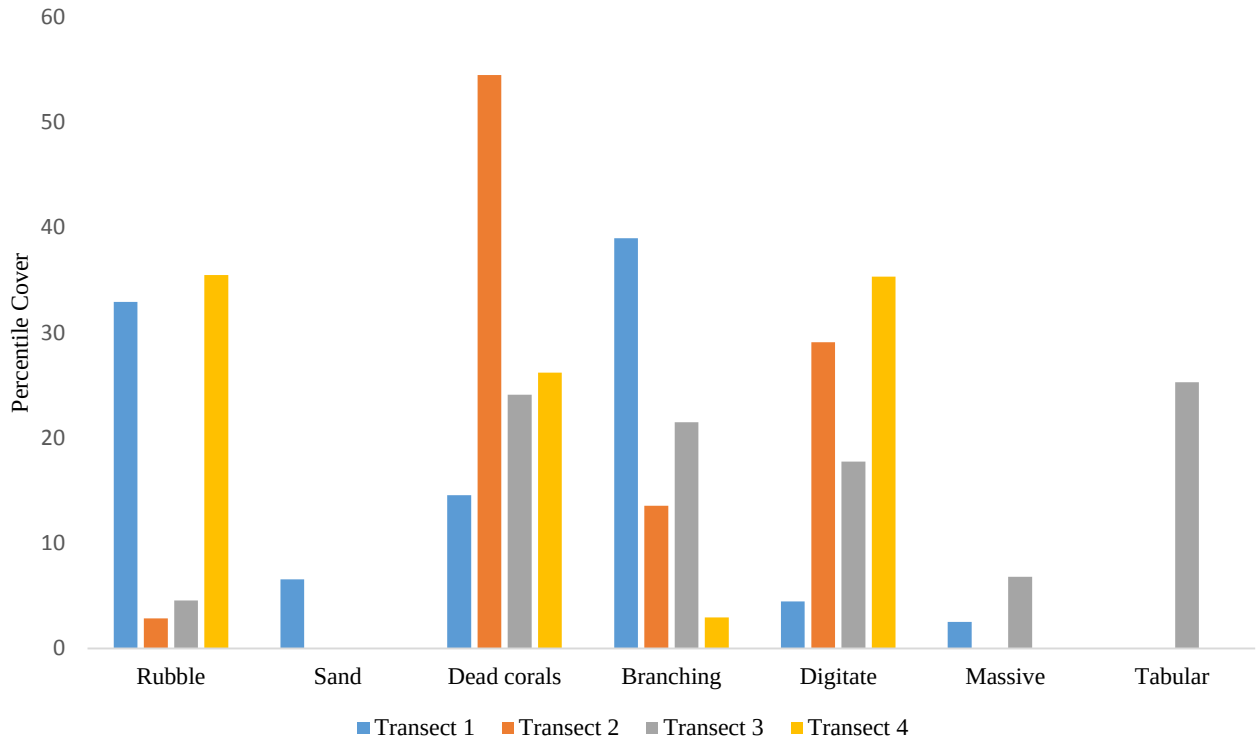
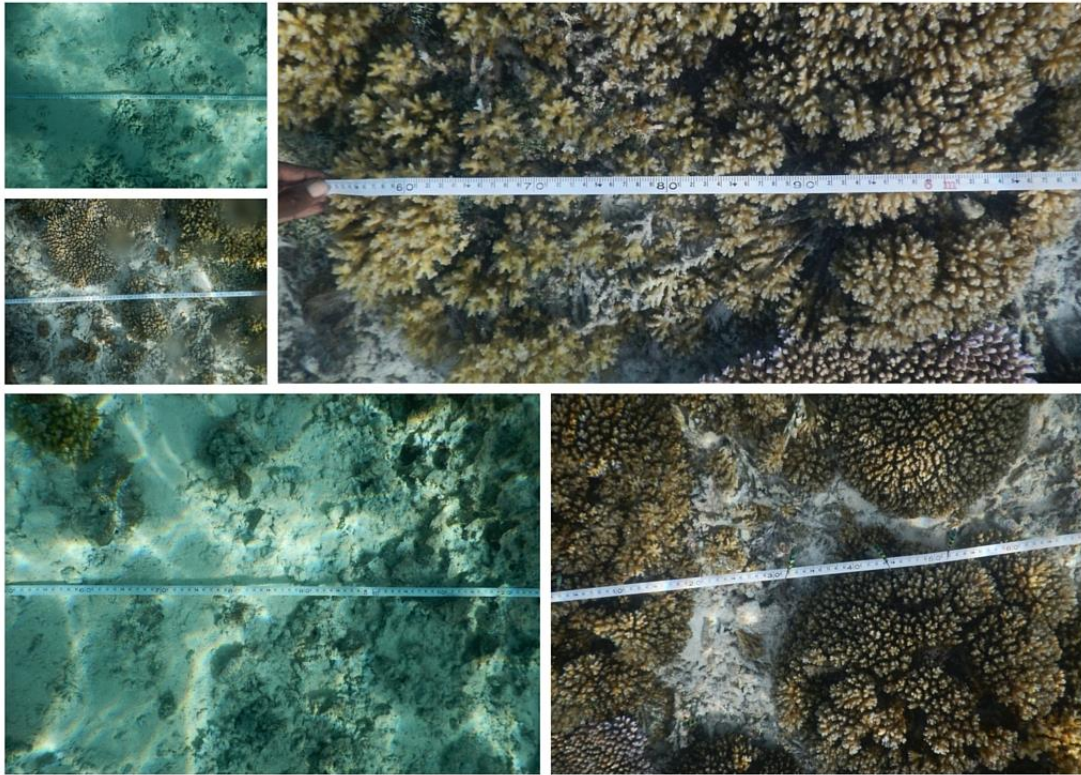


Figure 28: Benthic cover (all transects)

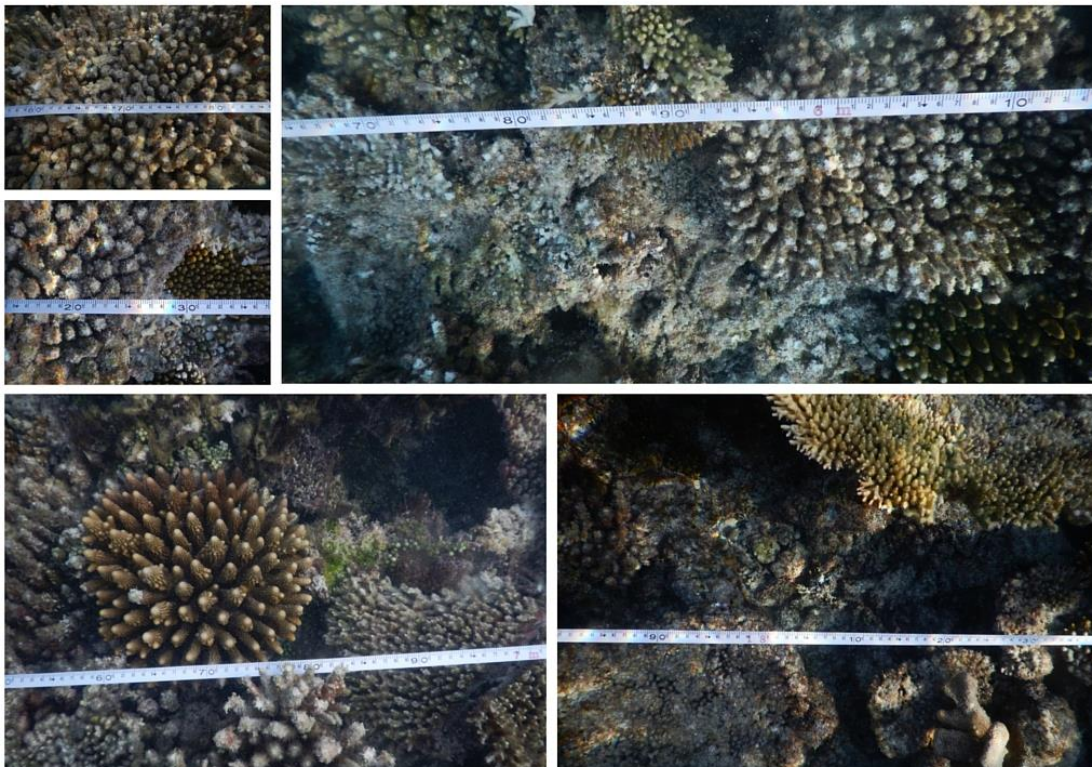
The field study of three transects taken from the assumed impact zone around the existing channel and one transect of the shallow area within the harbour basin concludes that there is a considerable percentage of live coral formations in all the surveyed areas. Coral bleaching was observed throughout the study area. More than 70% of the benthic cover was partially bleached. And over 10% of the colonies observed were completely bleached and accounted as dead corals.

Transect Photo Profiles

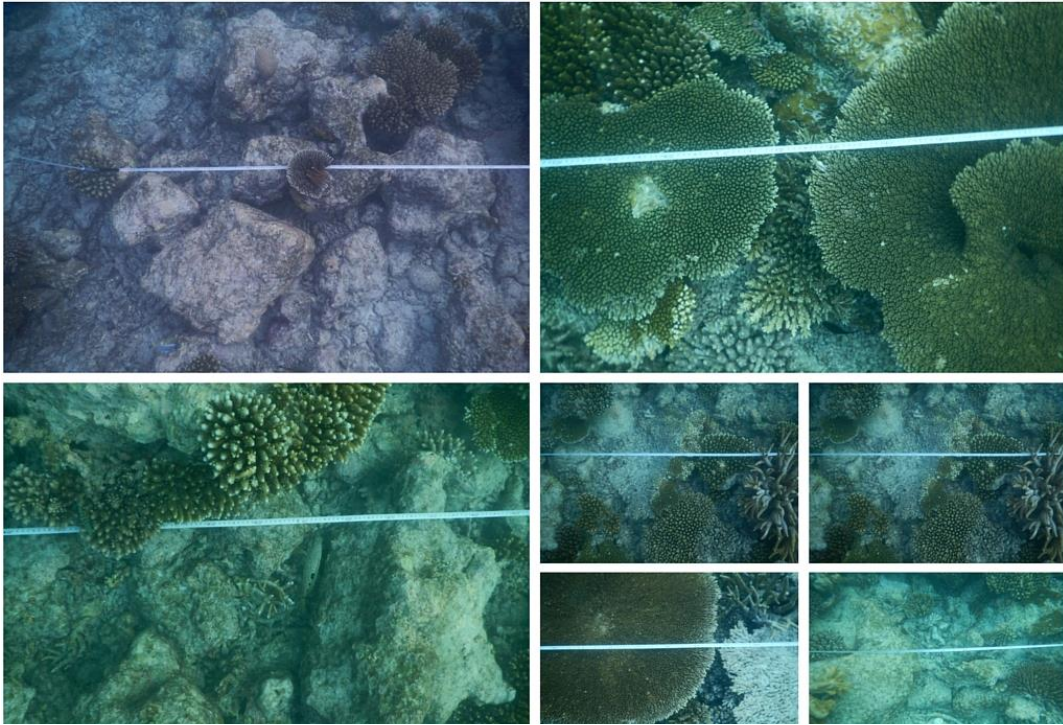
Transect 1



Transect 2



Transect 3



Transect 4



Figure 29: Photo profile of transect 1, 2, 3 and 4

6.7.3 Calculation of Live Coral Loss

The following method was used to estimate the loss of live coral cover as a result of the proposed project. Table 11 summarises size of reef, coral incidence and size of project areas.

Table 11: Reef area and live coral incidence

Reef Area	2560,000 m ²
Total Project Area	31,049 m ²
Size of <i>giri</i>	2,642 m ²
Size of shallow area entrance channel	1,650 m ²
Live Coral Incidence	18.14 %

$$\text{Total live coral cover in reef} = \text{Reef area} \times \text{Live coral incidence}$$

$$= 2,560,000 \times 0.1814$$

$$= 464,000 \text{ m}^2$$

$$\text{Total live coral cover in project area}$$

$$= \text{Project area (giri + entrance channel shallow area)} \times \text{Live coral incidence}$$

$$= 4,112 \times 0.1814$$

$$= 746 \text{ m}^2$$

$$\text{Loss of coral cover} = \frac{\text{Total live coral cover project area}}{\text{Total live coral cover in reef}} \times 100$$

$$\text{Loss of coral cover} = \frac{746}{464,000} \times 100$$

$$\text{Loss of coral cover} = 0.16\%$$

6.7.4 Fish Count

During the survey, 10 families of fish were discovered at the project site. These were classified into their respective families. Table 12 summaries the scientific and common names of all fish species that were identified at the project area and their count. 14.11 Annex 11 – Fish Species and Abundance for an illustration of the different types of fish that were identified and their relative abundance based on table 12.

Table 12: Common and scientific names of fish species identified

Common name	Scientific Name	Giri	Entrance Channel	Count
Acanthuridae				
Convict surgeon fish	<i>Acanthurus triostegus</i>		15	15
Lined Surgeon fish	<i>Acanthurus lineatus</i> <i>Acanthurus</i>		35	35
Powder blue surgeon fish	<i>Acanthurus leucosternon</i>		45	45
Lined Bristol tooth	<i>Ctenochaetus striatus</i>	4	36	40
Chaetodontidae				
Chevron butterfly fish	<i>Chaetodon trifascialis</i>	-	4	4
Traingular butterfly fish	<i>Chaetodon triangulum</i>	-	3	3
Citron butterfly fish	<i>Chaetodon citrinellus</i>	-	3	3
Oval Butterfly fish	<i>Chaetodon trifasciatus</i>	3	7	10
Holocentridae				
Yellow fin soldier fish	<i>Myripristis berndti</i>	-	3	3
Pomacentridae				
Two spot damsel fish	<i>Chrysiptera biocellata</i>	3	-	3
Sergeant Major	<i>Abudefduf vaigiensis</i>	4	3	7
Humbug dascyllus	<i>Dascyllus aruanus</i>	15	18	33
Green puller	<i>Chromis atripectoralis</i>	>10	>20	>30
Indian Gregory	<i>Stegastes fasciolatus</i>	1	1	2
Labridae				
Checkerboard Wrasse	<i>Halichoeres hortulanus</i>	-	3	3
Bicolour cleaner wrasse	<i>Labroides bicolour</i>	-	2	2
Bird wrasse	<i>Gomphosus caeruleus</i>	-	2	2
Six bar wrasse	<i>Thalassoma hardwickle</i>	-	6	6
Carcharinidae				
Blacktip reef shark	<i>Carcharhinus melanopterus</i>	-	1	1
Nempiteridae				
Two lined monocle bream	<i>Scolopsis bilineatus</i>	-	1	1
Scaridae				
Five saddle parrot fish	<i>Scarus scaber</i>	-	5	5
Eretmochelys				
Hawksbill turtle	<i>Eretmochelys imbricata</i>	-	1	1

From the fish count analysis it was concluded that:

- The most abundant fish at the site was the lined Bristol tooth
- The families' laridae, pomacentridae, chaetodontidae and acanthuridae were observed to be frequent at the site.
- The area was frequented by hawksbill sea turtles.
- Juvenile blacktip reef sharks sheltered in the coral cover provided

How the method encompasses certain degree of uncertainty. These include:

- Some species may be cryptic in the presence of surveyors, hence these species would not be accounted for in the survey.
- Fast moving fishes may not be captured during the timed swim hence these species would also be under estimated.
- Time of swim may impact observation of certain species as some species are more active at night.

Hence the results obtained for the marine diversity through in the report should be considered as an underestimate of the actual marine biodiversity when all these uncertainties are factored in.

6.8 VEGETATION

Vegetation within the proximity of project area were mostly dominated by coconut palms (Dhivehi ruh/ *Cocos nucifera*). They accounted for more than 80% of the plants that were studied during the survey. The shoreline had eroded completely up to the vegetation line on both sides of the jetty, exposing root systems and causing some of the trees at the edge of the vegetation line to collapse. Species of trees observed around the project area are given in the Table 13 below.

Table 13: Tree species

Dhivehi Name	Scientific name	Common Name	Genus	Tag
Dhivehi ruh	<i>Cocos nucifera</i>	Coconut palm	Arecacea / Palmae	D
Dhiggaa	<i>Hibiscus tiliaceus</i>	Sea hibiscus	Malvaceae	C
Jeymu	<i>Muntingia Calabura</i>	Japanese cherry tree	Tiliaceae	A
Kaani	<i>Cordia subcordata</i>	Sea trumpet	Ehretiaceae	G
Magoo	<i>Scaevola taccada</i>	Sea lettuce tree	Goodeniaceae	F
Hirundhu	<i>Guettarda speciosa</i>	Nit pitcha (s)	Rubiaceae	E
Kuredhi	<i>Pemphis acidula</i>	Iron wood	Lythraceae	H
Boashi	<i>Tournefortia argentea</i>	Tree heliotrope	Boraginaceae	B



Figure 30: Vegetation around the project area A-Jeymu, B-Boashi,C-Digga,D-Ruh,E-Hirundhu,F-Magoo,G-Kaani

6.9 HAZARDS AND VULNERABILITY

The DIRAM Project by UNDP (2009), modelled the islands and atolls risk to potential hazards. This was done to quantify the risk probability Maldives faced based on geographic location. The disaster risk scenario for Maldives can be described as moderate in general. Despite this, Maldives is among the most severely affected countries hit by the Asian tsunami on December 2004. The report identified the existing vulnerabilities and identified mitigation measures with costing. The report had identified the social groups of children, women and low income households as the most vulnerable.

Natural hazards that may occur at the project location can be broadly classified into geological and meteorological hazards. Based on the different types of hazards identified in DIRAM, the following hazards have been predicted to be particularly relevant to the project site in relation to the project components:

- Wind storms;
- Swell waves and wind waves;
- Flooding due to heavy rainfall/storms;
- Gravity waves (*udha*); and
- Tsunami.

DIRAM report has stated that major natural hazards in the Maldives are strictly controlled by the geophysical and climatic settings and shows quite different patterns in their distribution, as shown in Figure 31.

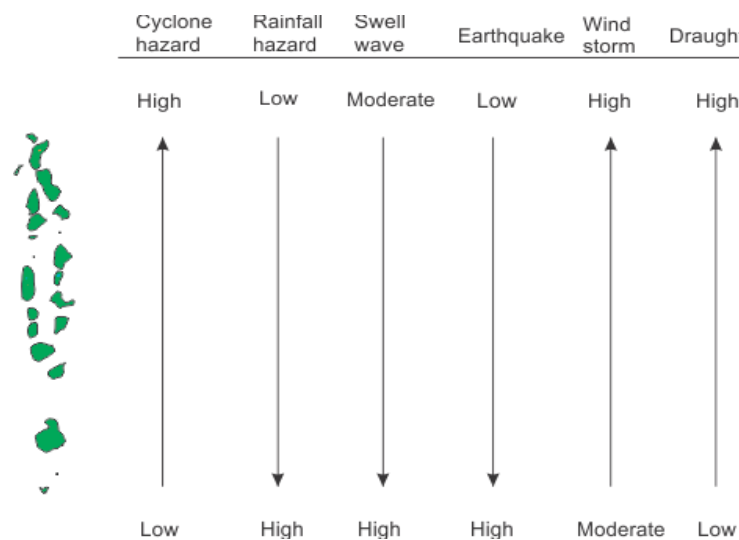


Figure 31: Exposure to hazards based on geographic location of atolls (source: adapted from DIRAM,(2009)

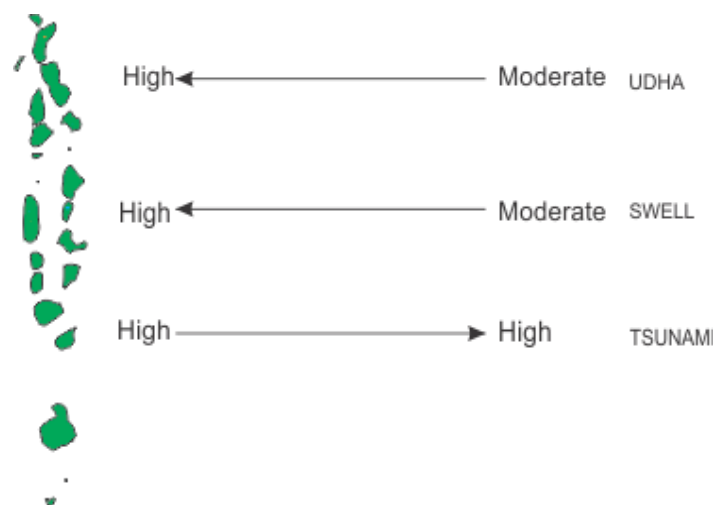


Figure 32: Major natural hazards distribution pattern in the Maldives. (A) Latitudinal variations of major natural hazards. (B) Longitudinal variations of major natural hazards across the Maldives (Adapted from UNDP, 2009)

The damage potential based on frequency of natural hazard to the Maldives is summarized in Table 14.

Table 14: Damage potential based on frequency of hazard

Hazard	Tsunami	Swell waves or storm surges	Rainfall flooding	Strong winds
frequency	Once in 200 years	Occasionally every year	Once every year	Several times a year
Potential damage	Very high	high	moderate	low

6.9.1 Wind Storms and Cyclones

Maldives being located within the equatorial region of the Indian Ocean is generally shielded from cyclonic activity (RMSI, 2005). There have only been a few cyclonic strength depressions that have tracked through the Maldives, all which occurred in the northern and north central regions. According RMSI, 2005, hazard risk assessment reports have not been intensively studied for the southern region, although a number of gale force winds have been recorded due to low depressions in the region. Winds exceeding 35 knots (gale to strong gale winds) were reported as individual events in Kadhdhoo annually between 2002 and 2006, all caused by known low pressure systems near Maldives rather than the monsoon. The maximum wind speed in Kadhdhoo during this period was approximately 46 kts.

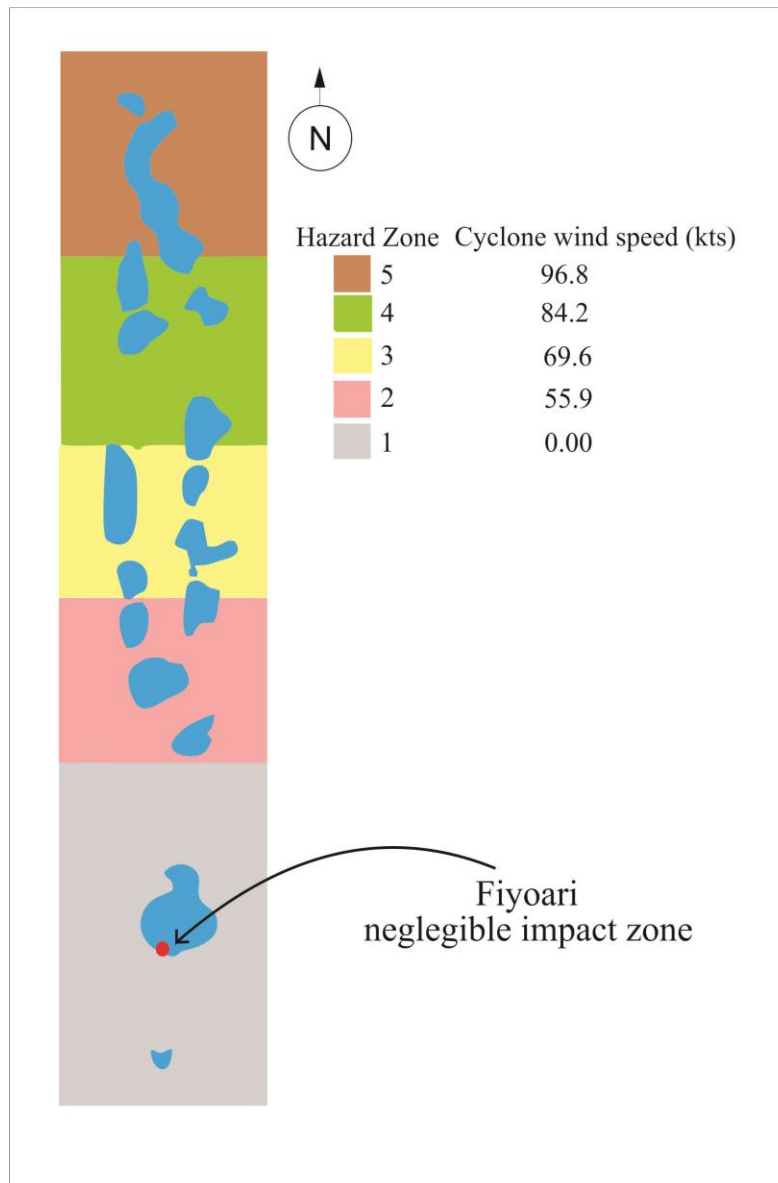


Figure 33: Cyclone risk assessment. Reference: RMSI, 2005

Historic records for Kahdhoo have indicated that near gale force winds have caused minor damage to property and trees on the island. Hence during the high winds between 2002 and 2005, a number of minor to moderate damages were reported to vegetation and backyard crops (RMSI, 2005). These finding imply that strong winds and cyclones are not considered a major hazard for the project location.

6.9.2 Potential for Flooding

Strong winds can cause higher incident waves to break on the reef and the sea-level can rise locally due to sheer force of wind on the water surface. The rise in water level due the sheer force of winds and the wave setup created as a result of breaking waves on the reef edge can produce high water level set up on the reef flat. Similarly surges or swell waves beyond significant wave heights of 9 m can cause water levels to rise 3.0 m on the reef flat. When such water level rises are combined with high tides there could be strong surges of water flow across the coast.

- The elevation of Fiyoari was found to be 0.7 m at the eastern coast. The quay wall had an elevation of 0.87 m. Since these are low elevation there is a significant chance for inland flooding due to waves and swells generated by very strong winds.

Incidences of coastal inundation was reported by the island council during the field visits which had caused inland erosion in the past.

7 SOCIOECONOMIC ENVIRONMENT

7.1 BACKGROUND

The registered population of the Atoll in the year 2012 was 20,206, out of which 10,360 were male and 9,846 were female (DIRAM, 2009). According to report by MPND (2006), the majority of the population within the atoll was employed in the agricultural industry. Other major sources of income were fisheries and agriculture, education and public administration as well as trade.

7.1.1 Accessibility and transport

Fiyoari is located at a distance of approximately 35 km south of Kaadehdhoo domestic airport. Air transport is the fastest means of travel to the island from the capital. The island hosts a number of small to medium passenger carrying speed boats which can travel to nearby island and the airport. The island has a single boat that transfer passengers and goods from Male' to Fiyoari weekly.

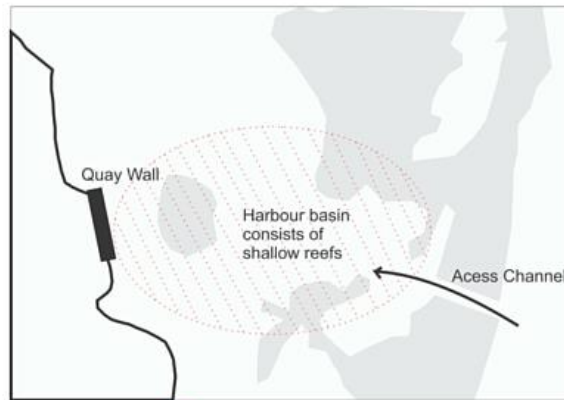
7.1.2 Quality of Services and accessibility

The info-graph (Figure 34) below illustrates the island specific conditions of:

1. Accessibility
2. Population distribution
3. Trade
4. Waste management
5. Power generation
6. Education
7. Fishing vessels
8. Healthcare system

G Dh. FIYORY ISLAND

Socio-economic Inforgraph



Island Accessibility

Accessible only through NE harbor.

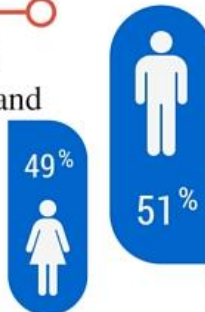
Harbor basin contains shallow reefs which makes navigation hazardous

Population Distribution

Majority of people had migrated to Male',



Total population of the island is 677 of which majority are males



Trade



The island has 17 shops
Goods are transported from Male' weekly
Fiyory produces coir rope products, sold to resorts



Waste Management

Currently there are no waste management schemes in place.

Power Generation



Provides power 24/7 to the island

Education

Island has 1 school.
Taught to grades from 1-10.



Fishing Vessels



Fiyory has 2 fishing vessels with hull lengths greater than 50 ft

Health Care System



Single health center is present.
Provides only basic services

Figure 34: Socioeconomic condition of Fiyori which identifies condition of healthcare, education and main forms of economic activity of the island. Source: Island Council

7.1.3 Community Needs

Overall, the island of Fiyoari hosts a large land area with a fairly small population. Navigation difficulties and island accessibility has been an issue that hampers the economic growth of the island. This issue has been resonated by the community of the island represented by the council. The concerns regarding the harbour are not only limited to the basin being unevenly dredged. The issue of congestion and availability of limited space in the harbour for foreign fishing vessels is also an issue which has been raised by the community. The island community understands the value of developing the harbour, which has created the need for not only dredging the shallow areas but a need to expand the harbour area to accommodate a greater number of vessels.

8 STAKEHOLDER CONSULTATIONS

8.1 INTRODUCTION

The key stakeholders of the project are the Fiyoari community, island council, Ministry of Housing and Infrastructure, Environmental Protection Agency and the contractor PWC. The stakeholders that participated in the Scoping Meeting held at EPA, had discussed about the various aspects and issues relating to the project.

8.2 METHODOLOGY

The stakeholders were explained briefly about the project. A set of standard questions were put to the stakeholders. The questions were framed so as to get their opinion on social, economic and environmental aspects in relation to the proposed development. In addition they were asked about the concept of the project and how the proposed project would solve the accessibility and navigation issues.

8.3 SCOPING MEETING

The Scoping meeting was held on 26 November 2015 at EPA. The meeting was attended by the following institutions:

- Ministry of Housing and Infrastructure
- Maldives Environment and Energy Company (MEECO)
- Environment Protection Agency (EPA)
- Atoll Council
- Fiyoari Community Member

Highlights of the Meeting:

- A brief overview of the project was given by MHI.
- The representatives of the island council suggested that it was difficult to navigate in the harbour due to the *giri* located in the middle of the harbour.
- Island council representative also highlighted that the entrance channel gets rough during some months in which accidents have happened.
- It was concluded that a suitable use of dredge material will be decided after field surveys based on EIA findings.
- The Atoll council representatives supported any development/changes which would increase the island accessibility.

8.4 MEETING WITH THE ISLAND COUNCIL

Date: 22 November 2015

Venue: Island Council

Time: 8:30 pm

Table 15: Island council meeting participants

Participants:	
Ahmed Shareef	Vice president
Saeed Mohamed	Council member
Adunan Ahmed	Council member
Siman	Council member
Ali Hammadh	MEECO
Hashika Gunaratna	MEECO
Muslih Mujtaba	MEECO

Highlights of the Meeting:

- Council highlighted that the existing harbour and entrance channel was dredged and constructed to improve access to the island.
- The council informed that the island is not invested in fishing however through the supply of ice and water to foreign fishing vessels, the harbour provides for the local economy.
- The council members expressed great concern over the inability to properly accommodate fishing vessels in the existing harbour due to the shallow *giri* present in the middle of the harbour and due to shallow areas present next to the entrance channel which makes navigation and berthing in the harbour basin difficult.
- The council highlighted that these shallow areas have caused numerous accidents during bad weather conditions and at night as unsuspecting vessels beach onto these areas.
- They informed that most of the accidents occurred during the northeast monsoon, when waves are dominant from the east.
- It was also highlighted that the entrance channel gets very rough and large waves pass through the channel opening creating rough conditions within the harbour basin.
- The council informed that the demand for ice/water supply has risen as Fiyoari is conveniently located close to an ocean channel which is used by fishing vessels. Hence due to the increased demand they are now faced with the issue of congestion at the harbour.
- The council informed that they were in need of dredge material for the ongoing sports arena construction project and would recommend stockpiling the dredge material at the construction site or use it to replenish the beach north of the quay wall.

To solve the issues highlighted the council proposed:

- Dredging all the significant shallow areas within the harbour basin.
- Widening the existing entrance channel.
- Construction of a second alternative channel north of the existing channel (See Section 8.6, Annex 12 –Changed Boundaries and Annex 13 – Bathymetry Of Alternate Entrance Channel.
- To extend the current quay wall to the North (See Section 8.6.3).

8.5 MEETING WITH LOCAL BOAT OWNERS

During the field visit a meeting with the boat owners of the island was also organised with the help of the island council.

Date: 24 November 2015

Venue: Island Council

Participants:

Table 16: Local boat owner meeting

Name	Post	Contact Number
Mohamed Rasheed Ibrahim	Fisherman; Dhoni Captain	7543045
Moosa Mohamed	Launch Captain	7891983
Hussain Khalid	Business Man	7501249
Ahmed Shareef	Vice president	-
Adunan Ahmed	Council member	7630637
Saeed Mohamed	Council member	9630979
Fahumy	‘Zinmadhaaru Veriya’	7773515
Ali Hammadh	MEECO	-
Muslih Mujtaba	MEECO	-
Hashika Gunaratna	MEECO	-

Major points highlighted by harbour users:

- ‘Fashan’ dhoni owned by Mohamed Rasheed Ibrahim reported damages worth MVR 50,000 to the hull after hitting a shallow ‘Giri’ at the entrance channel;
- The boat owners suggested that they had noticed four significant shallow areas within the harbour basin;
- They also informed that entrance to the harbour is extremely difficult in bad weather conditions, as it gets difficult to manoeuvre vessels around the shallow areas during rough seas.
- The local boat owners informed that a minimum of 6 vessels crash on to the ‘Giri’ in the middle of the harbour annually;
- They also highlighted that the reefs next to the entrance channel were very shallow as well.
- The boat owners also identified that Fiyoari is not renowned for fishing however, supply of ice and water to fishing vessels have boosted local businesses and it is necessary to develop the harbour area in order to fast track the local economic growth.

To solve the issues described the local boat owners proposed:

- Dredging all the shallow areas within the harbour basin.
- Widening the existing channel;
- Construction of a second alternative channel north of the existing channel (See Annex 12 –Changed Boundaries and Annex 13 – Bathymetry Of Alternate Entrance Channel).



Meeting with Council

Date: 22 November 2015

Venue: G DH. Fiyaori Island Council

Meeting with Community Stakeholders

Date: 24 November 2015

Venue: G DH. Fiyoari Island Council



Figure 35: Stakeholder consultation at Fiyoari

8.6 ASSESSMENT OF STAKEHOLDER VIEWS

8.6.1 Changing Project Boundary and Widening the Existing Entrance Channel

The proposed project aims to solve the navigational issues encountered at the Fiyoari harbour due to shallow areas. It was found through depth profiles that the proposed project area does not contain all the significant shallow areas identified by the island council and locals. These areas were profiled during the surveys and are described in section 6.7.1 and Annex 10 – Bathymetry of Entrance Channel, Hence in order to:

1. Facilitate ease of navigation
2. Minimise excessive dredging in areas which are already deep and
3. Mitigate environmental impacts

The changed project boundary which includes only the areas that require dredging are attached in Annex 12 –Changed Boundaries.

Complaints of entrance channel getting rough was noted after consultations with the island council and locals. The proposed solution has been to widen the entrance channel further. However the current width of the Fiyoari entrance channel was found to be 40 m which was greater than common entrance channel widths (approximately 20-25 m). Hence it was determined that physical hydrodynamic changes at the entrance channel was causing these observations which had led to accidents in the past.

Based on conventional diffraction theory:

- There would be no reduction in wave heights inside a harbour with a large entrance channel for waves running in line with the channel axis. However a difference in wave celerity between the waves travelling in the channel would be observed. (Zwamborn and Grieve, 1974)
- Due to the difference in depth the part of the wave travelling in the channel will move faster than that in the shallower surrounding areas of the channel.

Application of wave diffraction theory and existing hydrographical and climatic environmental conditions (See sections 6.5 and 6.2) to the current situation indicated that:

1. Wind generated waves, during the southwest monsoon, and northeast monsoon approach the entrance channel at oblique angles, significantly different from channel axis. These waves would be more prominent during the northeast monsoon. The waves approaching the channel at an angle refract the initial wave away from the normal as a result of increased wave velocity in the deepened channel. These refractions make the entrance channel unstable.
2. Waves which are in line with entrance channel axis under goes an increase in propagation at the entrance channels before abruptly decreasing in velocity where successive waves cumulate to create a transition wave break zone at the entrance channel.

Hence these two mechanisms are determined to be the main hydrodynamic changes at the entrance channel which makes it unstable at times.

The analysis showed that the current entrance channel is not located at the most convenient location in terms of wave energy impacts and hydrodynamic modifications. Moreover, the entrance channel is at the mouth of an ocean channel which may make it even more vulnerable to hydrodynamic changes.

Zwamborn and Grieve, (1974) proposes decreasing entrance channel bed slope to mitigate impacts of wave concentration due to refraction.

Widening the channel is not recommended to solve the issue and is likely to worsen the condition.

8.6.2 Proposed Second Entrance Channel.

Figure 36 below shows the proposed alternative entrance channel. The alternative entrance channel at the north will be 700 m in length, and would cover an area of 28,000 m². If dredged to – 3.5 m, the area would generate 50,700 m³ of fill material. (See Annex 13 – Bathymetry Of Alternate Entrance Channel). In terms of entrance channel stability as a result of wave energy changes, the location of the second entrance channel proposed by the council is in a more ideal location compared to the current entrance channel. It is situated in the same axis as wind driven waves and away from the ocean channel.

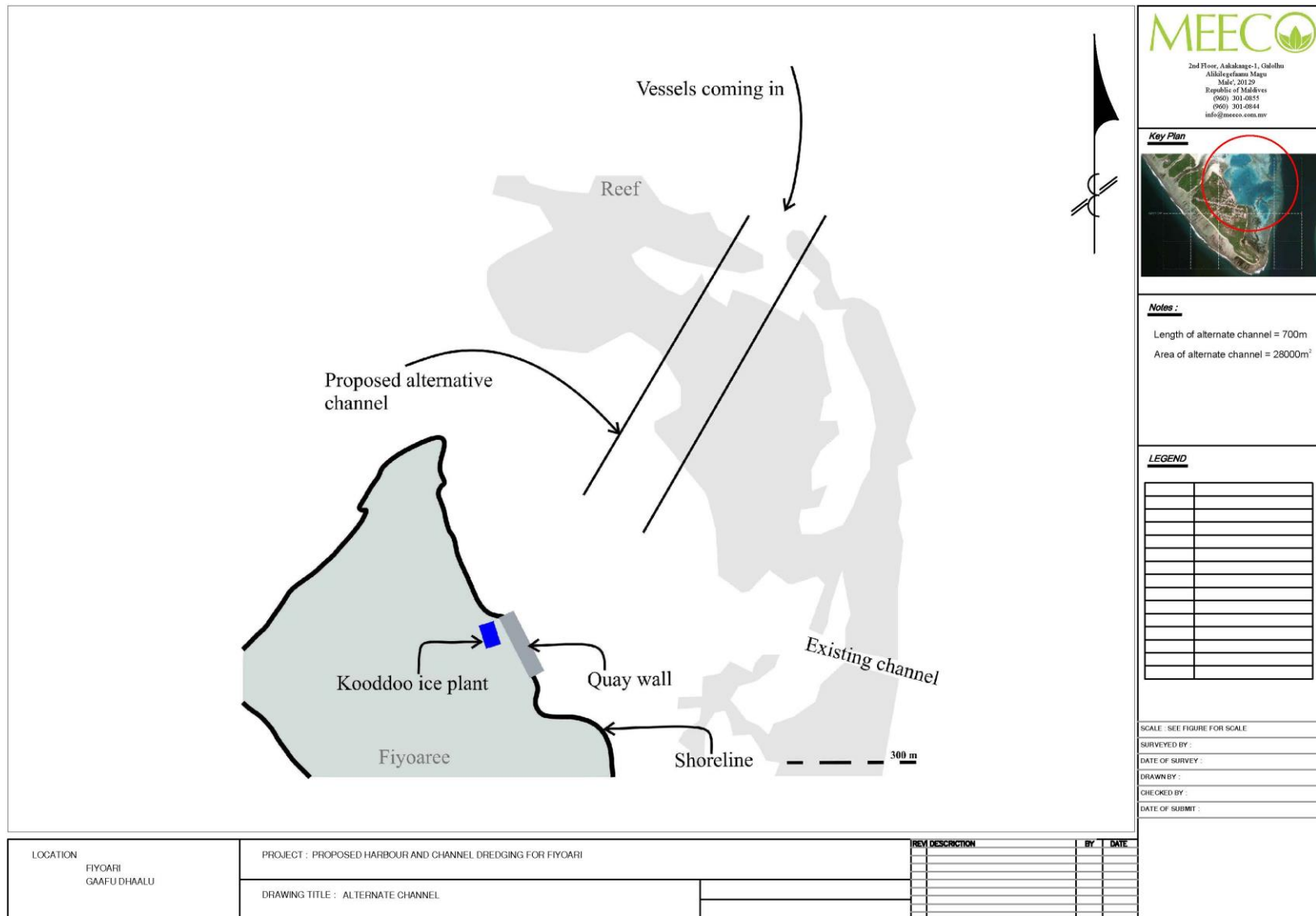


Figure 36: Second entrance channel

Even though the area for the alternative channel is quite large, transect analysis of the area suggested that for the most part the area comprised of sand bottom and patch corals. Figure 37 shows coral cover at the alternate channel site graphed using the transect method.

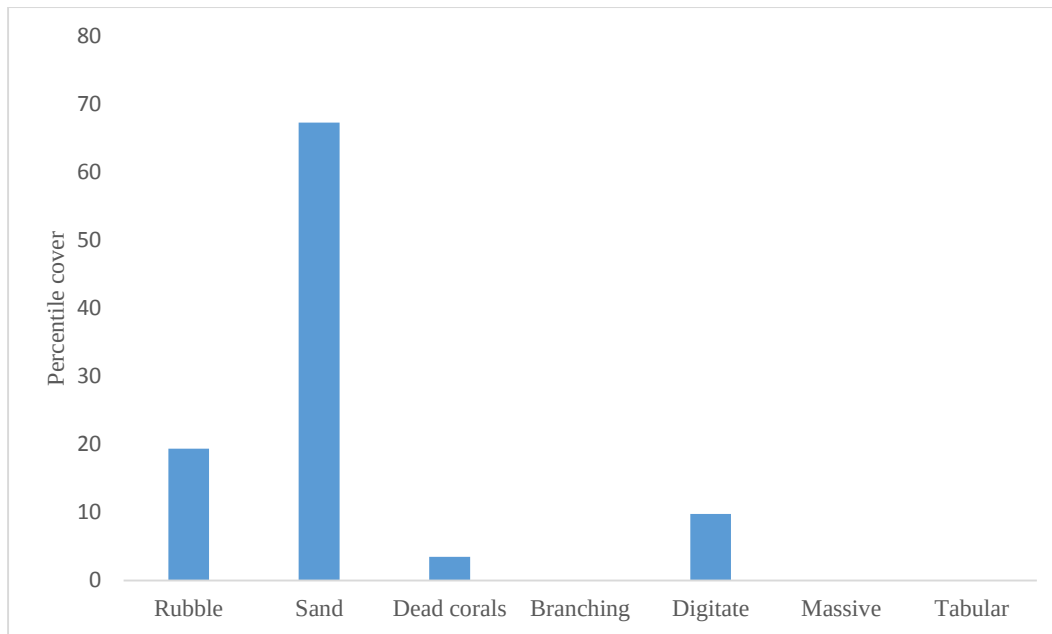


Figure 37: Coral cover at alternate site

The transect analysis was done for the area highlighted in Figure 38. However, the reef edge was observed to be diverse. Dredging this area would result in loss of diverse coral cover. Moreover, analysis of a single transect do not account for the actual coral cover of the area hence should be regarded as a guide.

Table 17 shows the advantages and disadvantages associated with the proposed alternative.

Table 17: Feasibility of the proposed alternative entrance channel

Advantages	Disadvantages
Easy access for vessels coming in from the north. The entrance channel on the south can be used as an exit.	Cost of project greatly increased
Convenient access if the quay wall is to be extended in the future	Loss of high density coral cover at the reef edge
Volume of fill material acquired can be used for other projects, or sold which will yield economic benefits to the island.	Increase in project duration, length and cost
Proposed area was found to have less live corals	Greater negative environmental impact
Entrance channel axis aligns with wind generated waves during the northeast monsoon.	

Based on these findings the proposed second alternative channel construction is not environmentally feasible.

8.6.3 Extension of Quay Wall

The existing quay wall spans 154 m in length. It is the only access point to the island, and is used for all the port activities. One of the major activities which influences the socio-economic environment of the island is carried out at the harbour area. The number of vessels stopping for supplies has gradually increased over time and currently the harbour services approximately 20 fishing vessels daily. Figure 39 below illustrates the proposed extension of quay wall to the north.

Table 18 below summaries the advantages and disadvantages of the proposed alternative.

Table 18 : Feasibility of extending quay wall

Advantages	Disadvantages
More vessels can simultaneously load and unload.	Dredge area is increased.
Space for local vessels to dock.	Project cost increased significantly.
Fishing vessels do not have to queue up in the harbour basin	Involves expansion of project scope and magnitude.
Positive economic growth as more vessels can stop for supplies without hindrance.	Magnitude of Environmental impacts will be increased.
Possibility to develop further port services. Eg: Fuel pump stations.	
Fill material dredged can be used as backfill and in other projects.	
Easier access to the area being developed for tourism.	

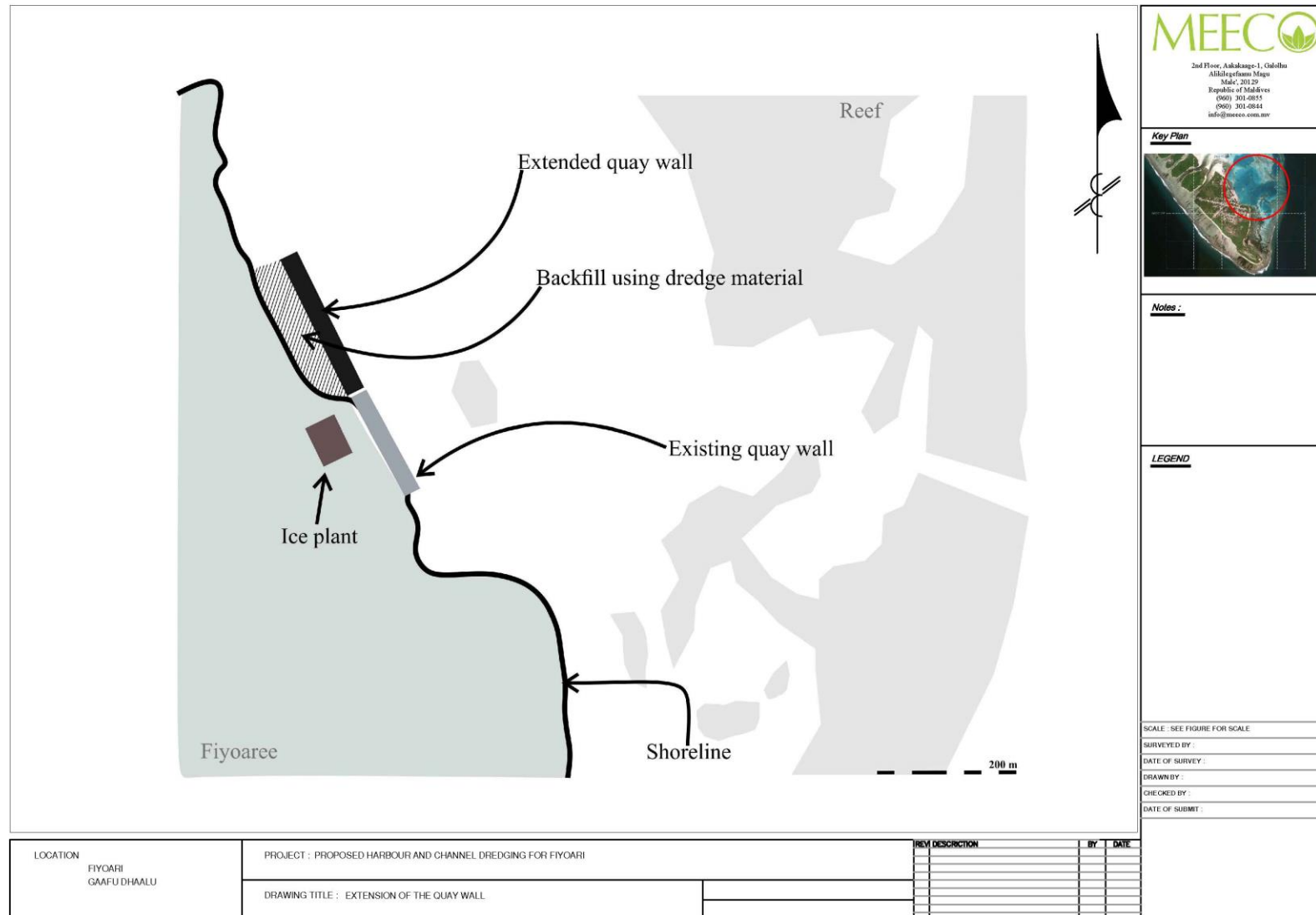


Figure 39: Extension of existing quay wall

9 ENVIRONMENTAL IMPACTS AND MITIGATION

9.1 INTRODUCTION

Developmental projects involving coastal development and coastal modification in island environments are considered to generate various levels of environmental impacts, some of which can be felt on the immediate environment and some impacts can be cumulative. Marine environment is directly affected from changes in hydrodynamics due to coastal modification from dredging and reclamation projects as coral reefs are very vulnerable to immediate changes that will be sustained from most of the development activities. Therefore, during the scoping, designing of the project activities and field surveys, consideration must be given to minimize the impacts felt on the environment. This Chapter describes in detail the potential environmental impacts and measures proposed to mitigate the impacts arising from harbour and channel dredging at G DH. Fiyoari, both during construction and operation phases of the proposed project.

9.2 IMPACT ASSESSMENT METHODOLOGY

Impact characteristics of the activities related to the project have been determined through information and data gathered from field work, surveys, stakeholder meetings and experience gained from projects of similar nature. Information obtained from these sources were analyzed to predict the extent and significance of the impacts that may arise from the proposed project. Impact analysis was based on Rapid Impact Assessment Matrix (RIAM) (Pastakia and Jensen, 1998).

In order to identify, predict, evaluate and analyse impacts:

1. Possible impact areas which could either have a positive or a negative impact were first identified based on their ecosystem services, ecosystem significance, potential for environmental degradation, and economic development.
2. Separate impact assessments were done for the construction phase and operational phase of the dredging project to get a better understanding of the overall impact of the project.
3. Where possible causal links of the project were identified, to explain the relationship to the impact areas identified
4. Significance of impact areas were described while providing a brief overview, discussion on possible positive or negative effects that may arise and the context to which they fall into.
5. Impact areas were then scoped based on RIAM classifications. These were physical/chemical (P/C), biological/ecological (B/E), Social/Cultural (S/C) and Economic/Operational (E/O). Impact areas were classified based on these categories.
6. An understanding of the properties of impacts were determined. Since these were dependent on future outcomes, the condition at a specific time and due to the holistic nature of impact areas, situational impact criteria's were assigned to impact areas after examination and consultation. Impact areas Criteria that are of value to any situation are defined as permanence, reversibility and cumulative properties. Any situation would inherently encompass these three criteria. Permanence defines whether a condition is temporary or permanent. Reversibility defines whether the condition can be changed and is a measure of the control over the effect of the condition. Cumulative property is a measure of whether the effect will have a single direct impact or whether there will be an accumulated effect over time, or a synergistic effect with other conditions.
7. Significance of the impact on impact area was assigned after calculating an environmental score (ES) for each impact area identified.
8. The significance of ES numbers was assessed based on alphanumeric range bands (RS).

Following is an example impact assessment calculation for one of the impact areas based on the methodology utilized in this report.

Application of methodology:

Impact area: Navigation

Phase of project: Construction

Cause: Harbour area busy or closed for construction

Description: Only a single entry point to the island, which will be closed or be very busy during the construction phase causing difficulties in navigating through the harbour.

Situational impact criteria: Permanence (temporary)

Duration: Specific only to the constructional phase

Significance of outcome:

$$ES = I \times M \times (P + R + C)$$

Equation: 1

Where:

I = 1 (Importance of condition).

Importance of condition scale:

4 = important to national/international interests

3 = important to regional/national interests

2 = important to areas immediately outside the local condition

1 = important only to the local condition

0 = no importance

M = -2 (disruption in navigataion and use of harbour)

Magnitude scale:

+3 = major positive benefit

+2 = significant improvement in status quo

+1 = improvement in status quo

0 = no change/status quo

-1 = negative change to status quo

-2 = significant negative dis-benefit or change

-3 = major dis-benefit or change

P = 2 (harbour closed or under renovation temporarily)

C = 2 (Cumulative because the progress of construction depends on factors)

R = 1 (No change in reversibility)

The Situational criteria scale:

Table 19: Situational scale

SCORE	PERMANENT (P)	REVERSIBLE (R)	CUMULATIVE (C)
1	No change/not applicable		
2	Temporary	reversible	Non-cumulative/single
3	Permanent	irreversible	Cumulative/synergistic

Hence:

$$ES = I \times M \times (P + R + C)$$

$$ES = 1 \times (-2) \times (2 + 2 + 1)$$

$$ES = -10$$

ES value was then compared to the range band:

Table 20: Range bands for ES

ENVIRONMENTAL SCORE (ES)	RANGE VALUES ALPHABETIC (RS)	Description of Range band
72 to 109	E	Major positive impact
36 to 71	D	Significant positive impact
19 to 35	C	Moderate positive impact
10 to 18	B	Positive impact
1 to 9	A	Slight positive impact
0	N	Negligible/No change
-1 to -9	-A	Slight negative change/impact
-10 to -18	-B	Negative impact
-19 to -35	-C	Moderate negative impact
-36 to -71	-D	Significant negative impact
-72 to -108	-E	Major negative impact

Hence navigation had a negative impact during the construction phase of the project. However, the same impact area was observed to have an ES value of 16 (positive impact) during the operational phase of the project (See Table 22). This was because, once the harbour has been dredged it will be much easier and faster for ships to navigate without the risk of beaching onto a shallow area.

9.3 IMPACT ASSESSMENT AND MITIGATION

Impact assessments were done for both the construction and operational phase of the project. Table 21 and Table 22 are impact assessment calculation tables where environmental scores (ES) for impact areas are calculated and described using alphabetic RS values for construction and operational phases of the project. The impact analysis and differences between extent of negative and positive impacts are illustrated in Figure 40. The illustration shows a graphic representation of differences in impacts between two phases of the project and the extent of how positive or negative the impact was as a result of the proposed maintenance dredging. Table 23 summaries, causal link of impacts and provides mitigation measures for the negative impacts.

Table 21: Constructional phase impacts

MOBILISATION & CONSTRUCTIONAL PHASE IMPACTS

		Permanence	Reversibility	Cumulative	Condition	Magnitude	Environmental Score(ES)	Range Value (RS)
Physical/Chemical (P/C)								
Coastal morphology	(P/C)-1	1	2	1	1	-1	-4	-A
Sediment transportation	(P/C)-2	3	1	1	1	-3	-15	-B
Seawater quality	(P/C)-3	2	1	2	1	-2	-10	-B
Current pattern	(P/C)-4	1	1	2	1	-1	-4	-A
Wave pattern	(P/C)-5	3	1	1	1	-2	-10	-B
Hazardous waste	(P/C)-6	2	1	1	1	-1	-20	-C
Solid waste	(P/C)-7	2	2	1	2	-1	-10	-B
Ambient air quality & GHG	(P/C)-8	1	2	3	2	-1	-24	-C
Ambient Noise	(P/C)-9	1	1	1	1	-1	-3	-A
Biological/Ecological (B/E)								
Terrestrial environment	(B/E)-1	1	1	1	1	0	0	N
Protected species	(B/E)-2	1	1	1	1	0	0	N
Mangroves	(B/E)-3	1	1	1	1	0	0	N
Sea grass beds	(B/E)-4	1	1	1	0	0	0	N
Eutrophication	(B/E)-5	1	1	1	1	0	0	N
Coral reef	(B/E)-6	3	1	1	3	-1	-15	-B
Social/Cultural (S/C)								
Health and safety of workers	(S/C)- 1	2	1	3	1	-1	-6	-A
Aesthetic and cultural value	(S/C)- 2	3	1	1	1	1	5	A
Public health and well being	(S/C)- 3	3	1	2	1	0	0	N
Recreational value	(S/C)- 4	1	1	1	0	0	0	N
Economic/Operational (E/O)								
Infra structure	(E/O)- 1	1	1	1	1	0	0	N
Regional economy	(E/O)- 2	2	1	1	1	-1	-4	-A
Employment	(E/O)- 3	2	1	1	1	1	4	A
Individual income	(E/O)- 4	1	1	1	1	1	3	A
Fisheries	(E/O)- 5	1	1	1	4	-1	-12	-B
Agriculture	(E/O)- 6	1	1	1	1	-1	-3	-A
Navigation	(E/O)- 7	2	1	2	1	-3	-15	-B

Table 22: Operational phase impacts

OPERATIONAL PHASE IMPACTS								
		Permanence	Reversibility	Cumulative	Condition	Magnitude	Environmental Score(ES)	Range Value (RS)
Physical/Chemical (P/C)								
Coastal morphology	(P/C)-1	1	2	1	1	1	-4	-A
Sediment transportation	(P/C)-2	1	1	1	0	0	0	N
Seawater quality	(P/C)-3	1	1	3	1	-1	-5	-A
Current pattern	(P/C)-8	1	1	1	1	1	3	A
Wave pattern	(P/C)-6	3	1	1	1	-2	-10	-B
Hazardous waste	(P/C)-5	2	1	1	1	-1	-4	-A
Solid waste	(P/C)-4	2	2	1	2	-1	-10	-B
Ambient air quality & GHG	(P/C)-7	1	1	3	1	-1	-5	-A
Ambient Noise	(P/C)-8	1	1	1	1	0	0	N
Biological/Ecological (B/E)								
Terrestrial environment	(B/E)-1	1	1	1	3	0	0	N
Protected species	(B/E)-2	1	1	1	1	0	0	N
Mangroves	(B/E)-3	1	1	1	0	0	0	N
Sea grass beds	(B/E)-4	1	1	1	0	0	0	N
Eutrophication	(B/E)-5	1	1	1	0	0	0	N
Coral reef	(B/E)-6	1	1	1	1	1	3	A
Social/Cultural								
Health and safety of workers	(S/C)- 1	1	1	1	1	-1	-3	-A
Aesthetic and cultural value	(S/C)- 2	3	2	1	1	1	12	B
Public health and well being	(S/C)- 3	3	1	1	1	0	0	N
Recreational value	(S/C)- 4	1	1	1	0	0	0	N
Economic/Operational (E/O)								
Infra structure	(E/O)- 1	1	2	3	2	0	0	N
Regional economy	(E/O)- 2	2	2	2	2	2	24	C
Employment	(E/O)- 3	2	2	2	1	1	0	N
Individual income	(E/O)- 4	2	1	2	1	1	5	A
Fisheries	(E/O)- 5	2	2	3	2	2	42	D
Agriculture	(E/O)- 6	1	1	1	2	1	6	A
Navigation	(E/O)- 7	2	1	1	2	3	24	C

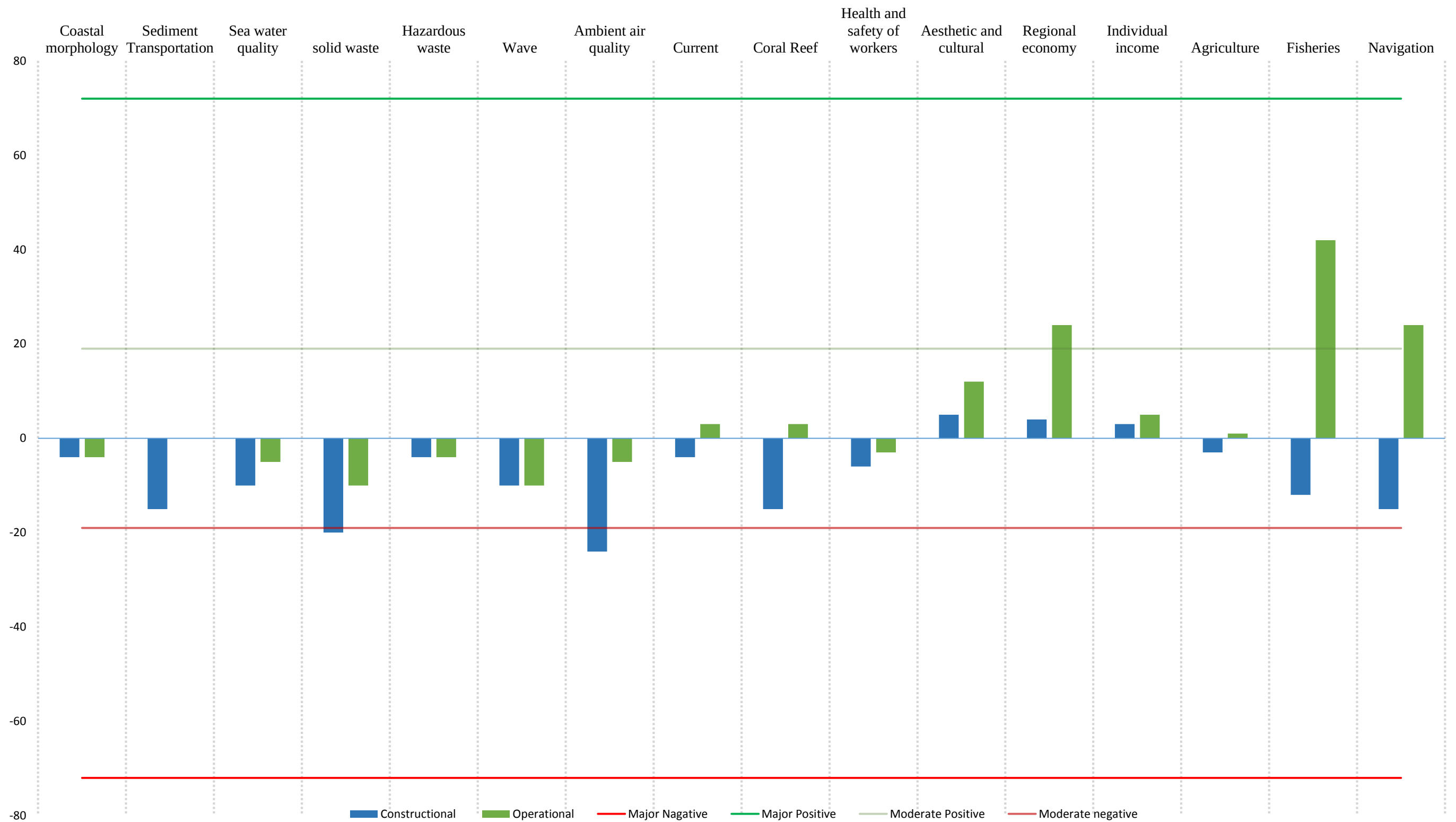


Figure 40: Impact assessment graph contrasting extent of constructional and operational phase impact

Table 23: Relationship of impact area to the project and their relevance to the environment

Impact Area	Significance & General Description of Impact Area	Cause	Duration	Impact Classification	Mitigation
Physical/Chemical (P/C)					
Coastal morphology (P/C-1) a- Beach Erosion	Integrity of coasts are important because they prevent inland erosion and flooding. In addition they provide a habitat for wild life and with the help of coastline vegetation, controls runoff to the sea. Beach gradient helps facilitate drainage of runoff and acts as a barrier against coastal inundation.	<u>Construction phase</u> Minor erosion was observed north and south of quay wall. It is highly unlikely that minor degrading of the shallow area could contribute to further erosion. Beach dynamics in the area may be altered if dredged material is dumped to “replenish” the eroded area hence it is not recommended without extending the existing quay wall or installing soft coastal measures to contain the sediments. The impact of minor dredging on the beach dynamics is expected to be negligible because: • Based on 6.2.3 and 6.5.2 it was found that the major wind direction was westerly and waves would frequent on the western coast of Fiyoari. Hence eastern coast will be more stable in terms of wave impacts. • Current velocities measured at the project site (See section 6.5.1) were very low. For these reasons the harbour basin is considered to be stable with regard to hydrographical conditions.	N/A	Slightly negative impact (RS –A)	Due to certain degree of uncertainties (see section 9.5 for details) involved in impact predictions, it is advisable to carry out a monitoring program to assess any unforeseen changes to the beach as a result of the dredging Further mitigation measures may be taken such as protecting the coast based on the monitoring of the shoreline and comparing it with baseline assessments provided in the report (see section 11.3 for monitoring plan).

		The proposed dredge area is very small (See 6.7.1) relative to the harbour basin, hence any energy changes due to the change in bathymetry is likely to be dissipated through a cushioning effect of the large undisclosed open harbour basin. The impact is not envisaged to change the current condition.			
		<u>Operational phase</u> Similar to the construction phase, operational phase of the project is not perceived to have a significant negative impact on beach profile.	Long term	Slightly negative impact	
Sediment transportation (P/C-2)	Sediment disturbances as a result of dredging has the potential to carry bedload as suspension in water. The increase in particles in water column directly results in the increase of water turbidity and TSS. Currents transport these suspended sediments before deposition. Increase in turbidity affects ecosystem as it restricts penetration of light which is compulsory for photosynthesis. Furthermore it decreases the oxygen partition factor in water which effects respiration of	<u>Construction phase</u> of the project is expected to have a short term negative impact because: - Surveys (See section 6.5.1), found that the current velocities measured were relatively low and propagated in a net southerly direction. Shear stress comparisons suggested that only very fine sediments were likely to be transported. - Recent sediment monitoring conducted at L. Baresdhoo for entrance channel dredging suggested that sediment	Short term	Negative impact (RS –B)	- When dredging the entrance channel placing silt screens and/or sand bunds. If the currents propagate in a net southerly direction, it is advised to place the sand bund on the southern side of the entrance channel to avoid any sediment dispersion on to the southern reef. - When dredging the harbour (<i>giri</i> in front of quay wall), if currents propagate in a southerly direction as observed during field surveys, there is no need to place silt screens as there is no risk of sedimentation onto the fore reef. However if currents are observed

	organisms. Physically when sediments deposit on top of live corals, it blocks light which is required by zooxanthella in corals to photosynthesise. Since the actual living material of a coral is present in a very thin superficial layer of the coral exterior, corals die easily due to sediment deposition. The transport of sediments in the water column is governed by cohesion and angle of internal friction between particles. When the force component of the water body exceeds the critical shear stress of particles they are transported as suspension.	transportation had a cut off distance of approximately 15 m with measured currents much higher than that observed at Fiyoari (Saleem et al. (2015)). These observations further suggest that the impact is going to be very minor.			to move north it is advised to place a silt screen north of the <i>giri</i>. It is recommended to observe current direction before dredging, using simple drogue techniques • Similarly if the currents propagate northward it is recommended to place bunds north of the entrance channel. • Avoid blasting techniques which would disperse sediments uncontrollably and cause more damage to the coral reef. Stop the dredging works if a drop hammer cannot accomplish the task.
		<u>Operational phase</u> This phase of the project is not considered to cause sediment transportation in the harbour basin.	-	-	-
Seawater quality (P/C-3)	Water quality is an important parameter that sustains the health and wellbeing of the ecosystem. The quality of sea water is maintained between an optimum level which facilitates respiration and photosynthesis in the photic zone of the ocean.	<u>Construction phase</u> of the project is considered to have a short term negative impact on sea water quality mainly because: • Proposed bucket dredging would temporarily increase the turbidity of water body which is expected to be highly localised due to the low current measurements and low energy properties of the basin (See 6.5.1).	Short term	Negative impact (RS-B)	• Daily water quality monitoring during the dredge period. • Place bunds and silt screens as described for (P/C-2). • Avoid construction waste run off into the sea. • Deposit dredged materials in designated stockpile areas only;

		Construction workers will use the harbour basin to discard solid waste, waste oil, and other wastes which may pollute marine environment.			- Place signs which illustrates that the harbour area cannot be used to discard human waste and litter. - If dredge material is to be transported in barges make sure the materials are contained in the barge.
		<u>Operational phase</u> is considered to have a long term slight negative impact on sea water quality mainly due to: - Increase in vessels birthing which will increase amount of waste discarded. - Harbour basin being used to discard human wastes. Since the harbour in Fiyoari is open in design, the water circulation would be quite high which would naturally compensate for the decrease in water quality.	Long term	Slightly negative (RS-A)	- Place signs to prevent discarding waste. - Provide easy access to bathroom facilities at the harbour.

Current Pattern (P/C-4)	Longshore currents play a crucial role in coastal morphology as they carry sediments and bedload.	<u>Construction phase</u> Widening and deepening of the entrance channel and harbour area would increase the energy of harbour basin. Hence currents are also expected to increase as a result of the project. However, the proposed project is not expected to have a significant impact on current pattern mainly because: • The scope and scale of the proposed project is very small, and alterations brought about by the project could be compensated for by the natural environment. The changes are not identified to bring a shift from the current state of the environmental conditions. • Current velocity at the project site was very low (See 6.5.1). <u>Operational phase</u> N/A	Long term	Slightly negative impact (RS-A)	Reef entrance widening not recommended. Limiting dredging and deepening to bare minimum required as described sections 6.7.1 and 8.6.1.
Wave pattern (P/C-5)	Waves loose energy and transform at the surf zone (Alvarez-Ellacuria et al, 2010). As waves move toward the shore, the shallower water causes the wave speed to decrease, hence the wavelength becomes shorter and	<u>Construction phase</u> Wave patterns are expected to be altered as a result of the proposed project. Deepening the harbour area would increase the wave length of the shore bound waves. However, this effect is considered to be very minor because:	Long term	Slight negative (RS-A)	Same as (P/C-1 and P/C-4). Widening the entrance channel is not recommended, as it would un-stabilise the entrance channel (see section 8.6.1). Even though impacts on the wave patterns are considered to be minor due to

	waves refracts towards the normal whilst losing energy.	- Through field surveys it was discovered that the eastern coast of Fiyoari was more stable. Wind generated waves were more prominent at the western coast. (See section 0 and 6.5.2). Hence incidence waves would be minor and less frequent. - Any wave alteration which occurs as a result of dredging the specified area would be dampened due to the (Open nature of the size of harbour basin when compared to project area. - The areas proposed to be dredged are very small and most of the harbour basin and entrance channel is already deeper than – 3 m. - No significant changes to wave patterns have been envisaged.			uncertainties, monitoring has been suggested.
		<u>Operational phase</u> Similar to the construction phase of the project the operational phase is expected to result in a slight negative impact.	N/A	Slight negative impact (RS-A)	

Solid waste (P/C-6) Include: a. Construction waste b.Human Waste	Solid non organic wastes takes a long time to disintegrate naturally. These pose a danger to the living organisms as these wastes could suffocate living organisms. Solid waste also makes the area aesthetically displeasing.	<u>Construction phase</u> <u>a. Construction Waste</u> These include clothes used for wiping machineries, batteries and hydraulic lubricants. - The construction waste produced is considered to be very small as the project involves only dredging and duration of project would be approximately 80 days. <u>b. Human waste</u> Plastics and organic materials will be the main, human solid waste. The amount of waste produced is perceived to be moderate because: - Less than 10 workers will be deployed - Considering that each worker in their day to day activities produces 0.45 kg/per day of waste as referenced from World Bank (2012) for the expected duration of project (80 days), the total solid waste produced by workers are $Total\ solid\ waste = 0.45 \times 10 \times 80$ $Total\ solid\ waste \approx 360\ kg$ Hence, solid waste production during the construction phase would have a moderate short term negative impact.	Short term	Moderate negative impact (RS –C)	Proposed mitigation measures for the operational phase and constructional phase include:
					- Placing waste bins at project location and installing signs that prohibit littering. - Arranging routine clean-up of the harbour area after works is completed for the day. - Waste should only be discarded in designated bins. - Waste shall be stockpiled and removed from island after completion of the project. - Construction waste should not be burned. - Plastic, organic and construction waste should be separated and transported to Thilafushi. - Quantity of waste produced at Fiyoari and discarded at Thilafushi should be recorded. Waste auditing shall be included in monitoring

		<u>Operational phase</u> Vessels berthing are determined to be the main source of solid waste. These waste include plastics, organic wastes and metals. Since Fiyoari harbour is an open basin harbour, waste discarded are not likely to aggregate. They will move towards the reef. Solid waste is considered to have a long term slight negative impact mainly because, berthing vessels are not expected to stay for a long period of time.	Long term	Slight negative impact	- Placing signs in the area indicating not to discard waste - Placing waste bins close to the quaywall.
Hazardous Waste (P/C-7)	In regulatory terms, a hazardous waste is a waste that appears on one of the four RCRA1 hazardous wastes lists (the F-list, K-list, P-list, or U-list) or that exhibits one of the four characteristics of a hazardous waste - ignitability, corrosivity, reactivity, or toxicity.	<u>Construction phase</u> The project is not expected to yield significant amounts of hazardous waste. The main hazardous waste expected are used oils, batteries, electronics from machines and lubricants. Quantities produced will be quite small as the number of machineries utilised for the project are low (See Table 2). Hence, the construction phase of the project is considered to have a short term slight negative impact.	Short term	Slight negative impact	Proposed mitigation measures for both the construction and operational phase are: - Oils, lubricants, batteries and electronic parts should be separated and disposed of in appropriate containers at Thilafushi. - The equipment used should be in good working condition to mitigate waste generated from maintenance. - Hazardous waste containers should be sealed labelled carefully - If hazardous wastes are spilled, make sure to wear PPG and use a sponge to soak the spill before
		<u>Operational phase</u> is not expected to yield a significant amount of hazardous waste. Oils lubricants and used batteries, from berthing vessels were identified to be the only hazardous waste which could be produced. However since the Fiyoari harbour is not used as a maintenance station by fishing vessels and since vessels do not stay for long periods of time the amount of waste	Long term	Slightly negative impact (RS-A)	

		generated during this phase is considered to be very minor.			discarding them in appropriate containers. - Disposal containers shall not be overfilled with oils and sufficient containers must be used. - Signs and boards should be placed throughout the harbour explaining harbour rules.
Noise (P/C-9)	Elevated workplace or other noise can cause hearing impairment, hypertension, ischemic heart disease, annoyance, and sleep disturbance. Changes in the immune system and birth defects have also been attributed to noise exposure.	<u>Construction phase</u> : noise is expected to be a minor negative impact mainly because: - Dredging works are set to take place in the open away from residents. . Based on wind analysis (See Section 6.2.3), wind was generated from the westerly direction, hence noise will be shielded by the wind which would diffuse it to the east Noise is expected to diffuse away in the open.	Short-term	Slight negative impact (RS-A)	Generic management level mitigation measure should be sufficient to mitigate the minor negative impact. These include: - Ensuring that the project does not get delayed due to equipment failure or financial constraints. - Carrying out work involving machineries during daytime. - Regular servicing of the equipment's and vehicles. - Providing workers noise cancellation headphones.
		<u>Operational phase</u> : noise is expected to have a minor negative impact and is not expected to be different from the current levels. This impact is considered minor because: The harbour is located away from resident properties.	Long Term	Slight negative/Negligible impact	-

		Vessels stopping for supplies would switch of their engines and remain at the harbour for a short amount of time.			
Ambient air quality & GHG Emission (P/C-8)	Air pollutants include benzene, CO₂, CO due to incomplete combustion and NO_x derivatives from exhaust pipes, which are both warming and toxic gases (WHO, 1999). Maldives is extremely vulnerable to climate change. The current CO₂ concentration is 398 ppm. The increase in GHG concentration is related to the new epoch which has been termed as the Anthropocene. One of the significant changes have been a rise in global mean temperature and its link to permafrost and polar ice caps melting. This has resulted in sea level rising and various changes to the climate. Maldives comprises of low lying islands where the highest peak above sea level is estimated to be 2 m. Sea level has been rising by 0.07 inch (1.7 millimeters) per year since 1950, on a globally averaged basis. An increase in sea level is likely to worsen existing	<u>Construction phase</u> of the project is expected to result in a moderate negative mainly because: - Even though the number of input machineries are low the duration of its use is increased. The construction phase duration of the project is estimated to be approximately 80 days hence amount of emission within this time is considered to be moderate. Based on approximations considering that 800 l of diesel is consumed each day by the excavator GHG emissions for 44 days was approximately 120,000 kg of CO₂-e (DECC and Defra, 2012) <i>The calculation is based on estimates of fuel required to operate the excavator for 44 days, hence it is an underestimation of GHG emission.</i> - The dredging work will be carried out in the open where wind would quickly carry particulate matter	Short term	Moderate negative impact (RS-C)	- Streamlining the project design based on bathymetry surveys, to only dredge the shallow areas. This would significantly decrease the duration of dredging and its associated environmental impacts. See section 8.6.1 for detailed justification of changed design and section 6.7.1 for bathymetry analysis of existing harbour basin. Other mitigation measures proposed for ambient air quality and GHG emissions for the construction and operation phase of the project are generic management level prevention measures which would be sufficient. These include: - Ensure the vehicles and marine vessels brought by the contractors complies with road worthiness and maritime worthiness requirements of the Transport Authority and all vehicles in use display compliance stickers on the windscreen. - If possible position the exhausts so that fumes are blown, away from the island.

	environmental stresses in the Maldives. Moreover, dust fall, particularly PM₁₀ and PM_{2.5} particulates contain carcinogens and neurotoxins such as atmospheric cadmium, lead and asbestos (Breuer, 2015).	away from the island and dissipate them into the atmosphere.			Improve fuel efficiency by: - Minimize idling time either by shutting equipment off when not in use or reducing the time of idling. - Provide clear signage that posts this requirement for workers at the entrances to the site. - Maintain all construction equipment in proper working condition according to manufacturer's specifications. - The equipment must be checked by a certified mechanic and determined to be running in proper condition before it is operated. - Train equipment operators in proper use of equipment. - Use the proper size of equipment for the job. - Use equipment with new technologies (repowered engines, electric drive trains). - Encourage and provide transportation pooling.
		<u>Operational phase</u> The operational phase of the project is expected to result in a slight negative impact in ambient air quality mainly because: - Birthing fishing vessels are expected to emit minor quantities atmospheric pollutants. - The effect of pollutants are mitigated because the fishing vessels will remain idle during loading and unloading of supplies and any pollutants emitted are likely to be dissipated as a result of wind towards the east away from the island.	Long term	Slight negative impact (RS-A)	

Biological Ecological Impacts					
Coral reefs (B/C-6)	Coral reefs: - Protect coastlines from the damaging effects of wave action and tropical storms - Provide habitats and shelter for many marine organisms - Are the source of nitrogen and other essential nutrients for marine food chains - Assist in carbon and nitrogen fixing - Help with nutrient recycling. It is also one the most readily available natural resource of the Maldives, which provide food and medicine for the local population. Coral reefs also, indirectly help the fishing industry by assisting in the spawning of pelagic and other species of economic value.	<u>Construction phase:</u> From field surveys it was observed that the project area harboured diverse marine life forms. However, the impact on coral reefs due to the proposed project is considered to be a minor negative impact. This is mainly because: - The area did not harbour any rare, endangered or protected species. - Mobile species could move away from the site during the dredge period when they sense disturbance in the environment. - The scale of the project is minor and the loss of live coral cover relative to the reef was calculated to be only 0.16%. Furthermore, the last dredge event at Fiyoari was on 2010. Since then coral reclamation at the entrance channel was observed during swim surveys. Hence the potential for coral regrowth is high after the construction phase.	Long term	Negative impact (RS-B)	- Corals that can be manually removed from dredging and reclamation areas shall be removed and re-planted in unaffected and suitable areas. (See Figure 41) - The contractor should monitor a radius of at least 15 m during dredging works of the entrance channel to determine sediment deposition, and as explained in (P/C-2) bunds and silt screens should be placed based on hydrographical conditions. - Complete the project within the shortest time possible. - There should be daily supervision by the contractor of the work progress and the work force should be properly trained on environmental awareness and best practices. - Avoid blasting techniques, to remove material.
		Operational phase	Long term	Negligible	-

		The operational phase of the project is considered to have a negligible impact on coral reefs. Propeller action could result in sedimentation disturbance at the entrance channel but these are considered to be negligible			
Social Cultural Impacts					
Health & safety of workers (B/C-6)	Health hazards are associated with skin contact, eye contact, and/or inhalation of fumes and vapours. Health effects from exposure to fumes include headache, skin rash, sensitization, fatigue, reduced appetite, throat and eye irritation and cough.	<u>Construction phase</u> Accidents have been reported to be rare for projects of similar nature in the past. But cannot be completely ruled out especially projects involving handling of heavy machineries and flammable liquids such as fuel and chemicals. • Incidences of fire have been reported in the past. • Toppling of machines during dredging have been reported. • Minor injuries to workers during operation and maintenance of vehicles • Workers will be exposed to fumes from machineries.	Short term	Slight negative impact	Mitigation measures include: • Personal protection equipment's (PPE) are necessary to protect workers from burns and irritation when handling lubricants/ fuels. • Flammable liquids shall be kept in an enclosed area with clear warning signs such as "No Smoking", "No Naked Flames" etc. • Work site shall have signs for the public indicating construction work ahead. • PPE shall be worn by all workers. These include helmets and gloves and ear mufflers during dredging. • Workers safety instructions shall be clearly made visible at the project site;

		- Workers will also be exposed to heat, salt and unexpected weather conditions. - Risk of unforeseen health hazards and accidents are more common during this phase of the project. Hence this phase of the project is considered to have a slight negative impact.			- Site accessibility shall be carefully controlled to avoid unauthorised access to the site. - First aid kit shall be available at the workers camp; - Only certified workers shall be allowed to operate machineries and vehicles. - All marine based machineries such as excavators shall have fire extinguishers. - Workers able to swim should be deployed to the sea. - All machineries should be stored at the designated storage camp.
		Operational phase N/A	N/A	N/A	-

Aesthetic and cultural value (S/C-2)	Aesthetic and cultural values are important to preserve the national identity of the Maldives.	<u>Construction phase</u> It has to be noted that aesthetic values are highly subjective. The proposed project is set to remove the shallow <i>giri</i> in front of the harbour area which is considered to be a slight positive impact when the harbour is observed superficially. Culturally the project, during its construction phase is considered to have an insignificant impact as the number of foreign workers mobilised to the island will be very small. However it is important that the foreign workers are accustomed to the customs of Maldives. <u>Operational phase</u> This phase of the project will have a slight positive impact aesthetically as the shallow areas will be removed and the observable harbour basin will be clear without patches.	Long term	Slight positive impact RS A	• Provide necessary information to the locals on the project to alert and inform the public of the planned work to avoid unnecessary accidents and conflicts; • Records of any public complaints related to project shall be kept and resolved as soon as possible. • Make sure foreign workers are briefed on the local customs and they do not behave in socially unacceptable ways. • Make sure all foreign workers have the required permits and health assurances before mobilising to the field.
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Economic and Operational Impacts					
Regional economy (E/O-2)	The regional economy is important in order to become financially viable, to fast track development projects and built development capacity. When economic activities are low within a region, accessibility to basic needs tend to be poor.	<u>Construction phase</u> of the project is perceived to cause a slight negative impact to the regional economy mainly because: It could become difficult for vessels to enter when the channel is being dredged. This could result in ice and water supply shortages.	Short term	Slight negative impact (RS –A)	- Proper timing and planning could avoid hindrance to accessibility of vessels. - Dredging works should be planned at a time which coincides with the least amount of harbour traffic.
		<u>Operational phase</u> the project is expected to increase the regional economy significantly mainly because: Boats can come in for supplies irrespective of weather conditions. It is expected that more than 20 vessels can be serviced daily once navigation through the harbour has been eased.	Long term	Significant positive impact (RS C)	-
Individual income (E/O-4)	Individual income is important as it serves as a mean for people to access better health care, education and transportation.	<u>Construction phase:</u> of the project is expected to slightly increase the individual income mainly because: Workers would use the facilities of the island and if they needed extra hands, people from Fiyoari would be hired	Short term	Slight positive impact	-
		<u>Operational phase:</u> is expected to increase individual income of islanders mainly because: More fishing vessels docking at the harbour would create more customers who would require	Long term	Moderate positive impact	

		goods and facilities provided by the island.			
Fisheries (E/O-5)	In recent times most of the fishing has been localized to the south of Maldives. Approximately 25,314 mechanized vessels operate between North Huvadhoo atoll and Addu. A total catch of 31,200 MT were logged in the year 2013 alone for the region. Fiyoari being located close to the tip of South Huvadhoo Atoll act as an easy supply station and as the entrance channel and exit channel for vessels leaving from North and South Huvadhoo Atoll and vessels coming in from Addu Atoll. Fisheries is one of the nation's main sources of income hence it is significant on a national level.	<u>Construction phase</u> of the project is perceived to have a slight negative impact on fisheries as harbour activities would be slowed down as a result of maintenance dredging.	Short term	Slight negative impact (RS-A)	Same as above (E/O-2)
		<u>Operational phase</u> of the project is expected to facilitate fisheries by providing: Safer access to the harbour during the day and night without risk delaying departure time. This would also save the catch from going bad and maintain the catch at a higher quality so the value of product is not diminished. This phase of the project is expected to have a significant positive impact.	Long term	Significant positive impact (RS D)	-
Agriculture (E/O-6)	Agriculture is an important sector which is developing quickly. Major obstacle to this sector include scarcity of land and nutrient rich soils.	<u>Construction phase</u> will have a slight negative impact on agriculture. This is mainly because: Supply vessel may face difficulty in accessing the harbour during the dredge time, which may cause delays.	Short term	Slight negative impact (RS –A)	Same as above (E/O-2)

		<u>Operational phase</u> of the project is expected to facilitate agriculture by providing: • Safer access to the harbour during the day and night without risk of delays. Hence this phase will have slight positive impact.	Long term	Slight positive impact	N/A
Navigation (E/O-7)	Navigation is important to ease accessibility to islands and safe transport of good from one place to another. Difficulty in navigation would strain the economy too as, delays in transport of goods could damage or spoil goods that are carried. Islands in the Maldives do not produce organic material to sustain itself and depends on transport of goods from Male'. Furthermore, the main commodity exported from the Maldives needs to be transported to the consumer, hence navigation is an important aspect connected to the national economy.	<u>Construction phase</u> is not expected to ease navigation within the harbour basin. Dredging vessels is expected to make navigation more difficult and reduce space available in the harbour basin. This would result in a slight negative impact.	Short term	Moderate negative impact	Mitigation measures include • Planning work beforehand so that dredging works are carried out when the harbour is least busy. Early morning was found to be less hectic. Vessels entering harbour increased during the evening.
		<u>Operational phase</u> The operation phase of the project is expected to ease safer navigation within the harbour basin. It is expected to improve navigation during night time as well, and reduce damages to vessels which has been reported See section 8.	Long term	Moderate positive impact.	-

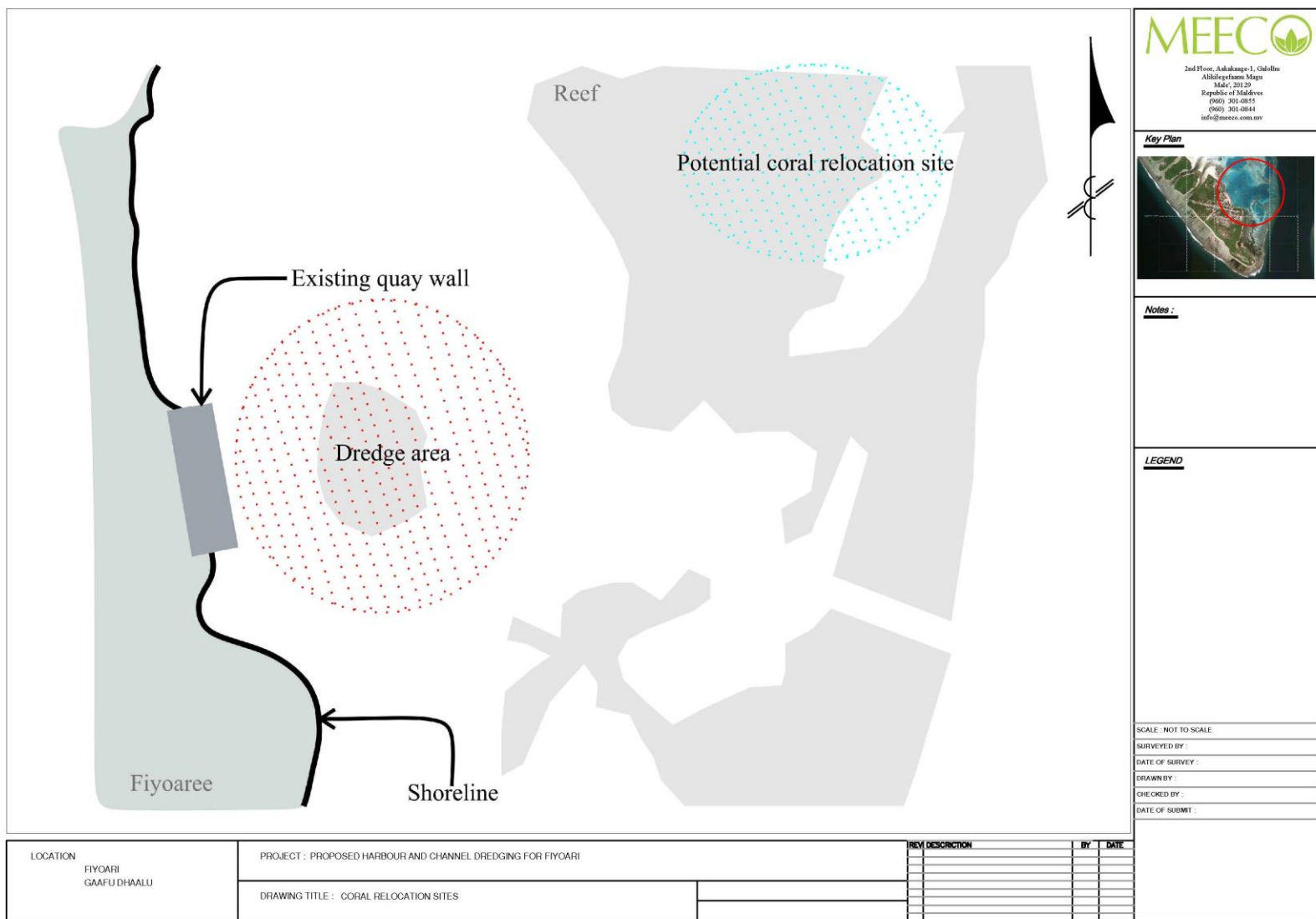


Figure 41: Potential coral relocation site

9.4 SUMMARY OF IMPACT ASSESSMENT

- No major negative impacts were identified for the project based on its current scope.
- Two moderate short term negative impacts were identified for the constructional phase of the project.
- These were solid waste production and GHG emissions where corresponding RS values and ES scores were:
Solid Waste: RS-C, ES-20
GHG: RS-C, ES-24
- Both of these impact areas were high due to the duration of project period. Hence mitigation measures are proposed to decrease these moderate negative impacts which includes reducing the duration of construction phase. This can be achieved by only dredging the shallow areas which have been identified in the report and by adopting fuel economising strategies which have been discussed. Duration of construction phase would significantly reduce the moderate negative impacts.
- The rest of negative impacts were identified to be minor. All negative RS values were between –A and –B. (corresponding ES values were 0 to – 18) for rest of impact areas.
- Majority of negative impacts were short term, localised to physical/chemical environment and specific to construction phase only.
- Minor negative impacts were mainly due to, loss of approximately 0.16% of live corals, disturbance to benthic organisms, sediment transportation during dredging, solid waste produced during both phases of the project, hazardous waste produced during construction and minor changes to wave pattern.
- The operational phase of the project was found to comprise of minor negative and moderate to major positive impacts.
- Areas found to have the most positive impact during the operational phase of the project was found to be the economic/operational (E/O) aspect of the environment.
- Regional economy, fisheries, individual income and navigation were determined to have a significant positive impact.

9.5 UNCERTAINTIES

Environmental impact prediction itself involves a certain degree of uncertainty, as the predicted impacts may vary according to weather, ecological conditions and social conditions in the atoll or island. Furthermore, limited time available to collect primary data on the existing environment of the project may not yield the most accurate long term patterns. Data on environmental aspects such as currents, waves, and sediment transport regimes may require at least one full year of data collection to make accurate informed judgments. Given the time and budgetary constraints, the impact predictions to a large extent had to be based on short term primary data and secondary information obtained from literature review and conducting interviews with the locals. Uncertainties of the impact assessment include:

- Lack of long term data. Current measurements were taken only during the southwest monsoon. If the project is mobilised in the northeast monsoon baseline current data should be measured at the site.
- Lack of confirmed amounts of resources and inputs which that will be utilised. Hence calculations were based on estimates.
- The impact assessments and mitigations measures provided in the report would only be applicable to the current scale and scope of project.

Although measures will be taken to mitigate known impacts, there is always the probability that an unforeseen impact may arise. It is also important to note that some of the impacts may turn out to be far greater or less than predicted. This is mainly because:

- Although the impact assessment method accounted for the holistic nature of environmental systems gaps exist in identifying the cumulative links between impact areas. These can be addressed through environmental monitoring.

Such limitations have been taken into account during the compilation of the report and proposed adaptability measures include

- Taking baseline data at the time of project based on limitations identified in the report.

However the level of uncertainty, in the proposed project is considered to be low, daily observations by the site supervisor is important to ensure deviations of impacts from what is being predicted and timely corrective actions are taken.

10 ALTERNATIVES

According to the EIA regulations, alternatives of the options for the proposed project must be considered. The first alternative is the option of “no project option”. Other alternatives that have been proposed in this report are:

- Alternative use of dredge material
- Alternative dredging methodology

10.1 NO PROJECT SCENARIO

If the “no project scenario” was considered, environmental impacts associated with the project could be avoided completely. No project would also mean no financial implications to the government. The advantages and disadvantages of the no project option are discussed below in Table 24

Table 24: Advantages and disadvantages of no project option

Advantages	Disadvantages
Environmental issues related to project can be avoided.	Navigation issues would not be solved
No development costs to the government.	The development of the island would be impeded.
	No unique or exceptional environment preserved.
	Public pressure on the government would persist.
	Risk of losing the funds if not utilised for allocated purpose before the end of the fiscal year
	Vessels at risk of facing damages
	Main source of local economic growth would be left undeveloped.

The disadvantages of not undertaking the project outweighs the advantages, hence the no project option cannot be considered as viable and as a preferred option that will satisfy all the stakeholders involved.

10.2 ALTERNATE FILL MATERIAL USAGE

The current dredging scheme is projected to yield approximately 11,800 m³ of material which in the current design is proposed to:

- a) Be used to nourish the beach north of quay wall covering an area of 7,167 m²
- b) Be stock piled in two bundles near the harbour area each holding 1,200 m² (See Annex 3 – Site Plan)

There are advantages and disadvantages associated with both of these options. Option a, to nourish the beach north of the quay wall is in line with the council's future plan to develop this area for tourism. If the fill material is used to nourish the beach, it is highly likely that the fill material could be eroded away and lost without barriers to contain the material.

Option b, which involves stock piling the dredge material in the harbour area could disturb the port activities. The harbour area is already facing issues of congestion and through field surveys it was observed that the harbour area was extremely hectic and placement of sand piles in the area could disturb harbour activities. Hence the proposed alternatives with regard to fill material are:

1. Move and stock pile the fill material at the sport arena construction site and use the fill material in the sports arena construction project. Through consultations and surveys it was determined that there was a need for fill material at the project. or:
2. Sieve the fill material and use fine grained sand to nourish the beach north of the quay wall and create a pocket beach through installations of artificial headlands (groynes) which would prevent loss of material from the beach.

Out of the proposed two options, option 2 was determined to be the most feasible in this case. Since it does not require the use of trammel screen to sieve the dredged material and there is no possibility for it to be lost and it is requested by the island council.

10.3 ALTERNATE DREDGE METHODS AND EQUIPMENT

10.3.1 Clam Shell Dredger

The grab dredger is the most common used dredger in the world, especially in North America and the Far East. It is a rather simple and easy to understand stationary dredger with and without propulsion. In the latter the ship has a hold (hopper) in which it can store the dredge material, otherwise the material is transported by barges. The dredgers can be moored by anchors or by poles (spuds). The capacity of a grab dredger is expressed in the volume of the grab. Grab sizes varies between less than 1 m³ up to 200 m³.

The opening of the grab is controlled by the closing and hoisting wire or by hydraulic cylinders.

The dredging process is discontinuously and cyclic and includes:

1. Lowering of the grab to the bottom
2. Closing of the grab by pulling the hoisting wire
3. Hoisting starts when the bucket is complete closed
4. Swinging to the barge or hopper
5. Lowering the filled bucket into the barge or hopper
6. Opening the bucket by releasing the closing wire.

The area's most suitable for use of clam dredgers are bulk dredging. While the smaller ones are mostly used for special jobs, such as:

- Difficult accessible places in harbours
- Small quantities with strongly varying depth.
- Along quay walls where the soil is spoiled by wires and debris
- Borrowing sand and gravel in deep pits

The production of a grab depends strongly on the soil. Suitable materials are soft clay, sand and gravel. Though, boulder clay is dredged as well by this type of dredger. In soft soils light big grabs are used while in more cohesive soils heavy small grabs are favourable.

The dredging depth depends only on the length of the wire on the winches. However the accuracy decreases with depth.

One of the main advantages of clam dredgers over backhoe excavator dredging as proposed to be used in the project is the accuracy it provides. Furthermore if used properly and combined with propulsion it could be used to accurately select and dredge on the required areas without having a significant impact on adjacent reefs.

10.3.2 Cutter Suction Dredger

The cutter suction dredger is a stationary dredger equipped with a cutter device (cutter head) which excavate the soil before it is sucked up by the flow of the dredge pump(s).

During operation the dredger moves around a spud pole by pulling and slacking on the two fore sideline wires. This type of dredger is capable to dredge all kind of material and is accurate due to their movement around the spud. The spoil is mostly hydraulically transported via pipeline, but some dredgers do have barge-loading facilities as well.

Cutter suction dredgers are applied for dredging harbors, channels, reclamation areas and so on. The transport distance of the mixture is limited to maximum 10 km. She is very useful when the accuracy of the works is important. Cutter suction dredgers are very suitable to dredge harbours.

One of the main environmental mitigations which could be achieved through the use of cutter suction dredgers are prevention and reduction of sedimentation loss. The workings of the cutter suction dredgers suggest that it aims to suck in all the sediments which are suspended as a result of the cutting process which is how it accumulates fill material. This vacuuming effect of sediments mean that dispersal of sediments are minimized through the process. Hence, this is a positive aspect of cutter suction dredgers when compared to the crane bucket method if, volumes greater than the bucket are hauled, sediments seep through the bucket into the harbour basin making the area highly turbid and facilitate sediment transportation towards the coral reef beside the entrance channel of Fiyoari.

10.4 SUMMARY OF ALTERNATIVES

Alternate Use of Dredge Material

Alternatives were proposed for the utilisation of dredge material and the best option was found to be utilisation of dredge material in the ongoing sports arena construction project as:

- It would save space in the harbour area.
- There is no risk of dredge material getting lost as a result of waves and currents.

Alternate Dredge Methods

Finally two alternative dredge methods were proposed of which the suction cutter dredger was found to be environmentally friendly. However after consideration of the scale of project and the feasibility of navigating a cutter suction dredger within the harbour basin, the backhoe dredger is considered to be the most effective method.

11 ENVIRONMENTAL MONITORING

11.1 INTRODUCTION

This Chapter outlines the monitoring plan for the project. Adoption of appropriate mitigation measures as described in Table 25 can significantly reduce the environmental damage caused by a development project. However, occurrence of unforeseen impacts is still possible, even with proper implementation of mitigation measures. Moreover, some of the predicted impacts may turn out to be greater than predicted, necessitating different or more rigorous mitigation measures. Therefore, monitoring of the environment is vital, in order to avoid or reduce the chances of such events, and to minimize the impact and cost of unforeseen events by taking prompt remedial action if such events occur.

The monitoring plan is based on impact analysis outlined in Section 9 of the report and the existing environmental conditions determined in Section 6 of the report.

The main scope or objectives of the environmental management plan are to:

- a) Monitor and manage any unforeseen impact on the project environment
- b) Produce a framework for anticipated impacts, including practicable and achievable performance requirements and systems for monitoring, reporting and implementing corrective actions during dredging.
- c) Manage environmental matters in a synchronized manner and to collect information that can be used for verification of environmental impacts;
- d) Collect information that can be used for evaluating the effectiveness of implemented mitigation measures.
- e) Provide evidence of compliance laws, regulations and requirements of enforcement agencies.
- f) Embrace the variability and uncertainty in environmental system to distinguish between change and variability.
- g) Broaden the adaptability of the management plan, as some of the decision during dredging have to be made based on physical environmental conditions at the time.
- h) Assess the magnitude of the impacts resulting from dredging
- i) Validate the fate of sedimentation which has been modelled through the report.

The measures and parameters that are most relevant for monitoring and managing the impacts that may arise from the proposed project are included in the monitoring plan. These include:

- Sediment transportation to the reef;
- water quality;
- Current and wave
- beach profile changes and
- bathymetry changes after dredging
- Waste quantity

11.2 ENVIRONMENTAL MONITORING SYSTEM

The environmental monitoring framework for the proposed project is based on the standards and policies set out by the Environmental Protection Agency under EIA Regulation 2012.

Environmental monitoring planning and establishment of key performance indicators:

- a) Use the field data for the EIA development as the baseline for monitoring conditions;
- b) *Monitoring and corrective action:* The implementation of the monitoring measures will be monitored during operational stage and will be reported. Any inconsistencies between the monitoring plan and its on-site implementation will be identified and addressed through corrective actions; and
- c) *Auditing, reviews and enhancement:* The Monitoring Plan will be reviewed. Improvements to the monitoring plan will be made as necessary to achieve desired environmental outcomes.

11.3 ENVIRONMENTAL MONITORING PLAN

Monitoring would begin from the EIA preparation phase to record any possible changes to the environment due to dredging and would continue into the operational phase until the end of the monitoring plan.

Figure 42 below, shows a plan for monitoring, where data collection points have been planned as a guide to assess the condition of the environment during the two stages of the project and to compare it with baseline existing environment.

This program would commence from the beginning of the project. The proponent is committed to continue the monitoring program for a year after the construction phase. See

11.4 REPORTING

Reporting will be carried out by the environmental consultant assigned for the purpose by the proponent. The report will include;

- Details of the site;
- Methodology of data collection and data analysis;
- Major findings; and
- Section contrasting findings with the baseline
- Mitigation measures that would be implemented based on the monitoring.

A detailed environmental monitoring report is required to be compiled and submitted to the EPA at the end of the one-year monitoring period as summarised in Table 26.

11.5 PROJECT MONITORING COST & TIMEFRAME

This monitoring should be commenced during the preparation stage and continued at least one year after the completion of the project. The monitoring frequency, costs and details of various monitoring aspects are explained in Table 25 and a summary of environmental monitoring is presented in Table 26.

Table 25: Environmental monitoring plan

Environmental aspect	Parameters and Methods of Monitoring	Monitoring Frequency	Cost (USD)	Baseline Study
Waste	Measurement of solid waste and hazardous waste quantities. Quantification of each type of waste as described in section 9.3. This can be determined through weight or volume measurements. These shall then be compared with the quantity disposed at Thilafushi.	<u>Construction phase</u> At the end of construction when all the waste have been separated and stored in appropriate containers. <u>Operational phase</u> Waste audit is not required.	Approx. USD 1000	N/A
Beach Profile	Changes to the Fiyoari coastline is not considered to be a significant impact area. However simple beach profiling is recommended to ensure that no significant unexpected changes had occurred during the easterly and westerly monsoons. Visual observation of beach profiles, shoreline monitoring and simple beach profiling methods can be used to observe accretion and erosion patterns and compare it with the baseline profiles.	<u>Construction phase</u> Beach profiling is not required during this phase. <u>Operational phase</u> Every 6 months for one year	- Approx. USD 1000 for all surveys	See Annex 5 – Beach profiles North of Quay Wall and Annex 6 - beach profile south of quay wall and Annex 9 for shoreline
Bathymetry	Bathymetry of the dredge areas using sonar and GPS after dredging work is complete. This shall be compared with the baseline bathymetry which has been attached in the EIA.	<u>Construction phase</u> A3 Bathymetry drawings attached with the EIA <u>Operational phase</u> Once after dredging is complete. An A3 scaled bathymetry drawing	- Approx. USD 2000 for all surveys	See Annex 9 - Bathymetry of Harbour Area and Annex 6 - beach profile south of quay wall
Current and Waves	Current speed and direction should be measured at the entrance channel and harbour basin after dredging. Drogue techniques can be used to obtain these two parameters. Wave period, direction and height should be monitored after dredging at the same locations as the current.	<u>Construction phase</u> Current measurements taken in southwest monsoon can be used as baseline if the project is mobilised during this season. <u>Operational phase</u> Currents and waves shall be monitored once every six months. This would address the monsoonal variations.		See section 6.5

Water quality	Water quality should be measured to check the turbidity or TSS, DO, temperature and conductivity. A multi parameter probe could be used to check these parameters or samples can be collected on site and transported to a lab within 24 hrs. It is important to measure the current direction during dredge time using simple drogue techniques to determine sample locations.	<u>Construction phase</u> Water quality should be conducted daily for the duration of dredge period.	Approx. USD 2000	See section 6.6.1
		<u>Operational phase</u> Water quality should be monitored every 6 months for one year.		
Coral reef	The following parameters of the reef shall be assessed: Fish abundance, Sediment deposition and coral cover. These parameters can be monitored through: • Timed swim surveys. • Visual inspection, photography of sediment deposition on the reef. Conducted up to 10-20 m away from immediate dredge site. • Transect or quadrat analysis. Note: Make sure to note down current direction at the time of dredging and monitoring. Simple drogue techniques could be used for this.	<u>Construction phase</u> Coral reef monitoring shall be carried out twice during the dredge period. <u>Operational phase</u> Should be monitored every 6 months for one year.	Approx. USD 3000	See section 6.7

11.6 SUMMARY OF ENVIRONMENTAL MONITORING

Four parameters have been identified to be monitored these include:

1. Changes to beach profile
2. Bathymetry
3. Water Quality
4. Coral Reef

A single monitoring report is to be submitted at the end of one year to EPA and shall have the following data included in the report:

Table 26: Summary of environmental monitoring

Parameter	Number of Assessments	Detail
Beach profiles	2	Measured every six months for one year after project.
Bathymetry	1	Right after dredging
Water quality	7	Daily during dredging Once every six months for one year after project.
Coral reef	4	Two transect analysis during dredging within a boundary of 15 m of the dredge area Once every six months for one year after project

12 CONCLUSION AND RECOMMENDATION

12.1 CONCLUSION

The report identified that the proposed dredging at G. Dh. Fiyoari would ease the navigation issues currently faced by the harbour users and improve the local economy of the island as more vessels can use the harbour basin.

The existing environment at the project area was found to be stable. Minor to moderate beach erosion was observed north and south of quay wall.

Currents at the project site were significantly low and propagated southerly. Sediment transport was found to be limited to particles with diameters less than 0.5 mm. Water quality was satisfactory. However, a linear relationship between turbidity and distance was observed.

The bathymetry of project area suggested that the depth of the harbour basin and entrance channel was deeper than – 3 m from MSL, apart from a *giri* in front of the harbour. Bathymetry also showed that not all the shallow area within the harbour basin had been included in the proposed project area. The marine environment at the project location was found to be diverse. Different classes of fish were found from herbivores to carnivores at the site suggestive of a healthy eco-system.

The socioeconomic environment of the island was found to be greatly linked to the development of the harbour. Fiyoari had a fairly small population with average social services available to the locals. The community and council identified development of the harbour as an effective means through which they could improve the social condition of the island. Hence the report has proposed alternatives through considerations of social and environmental aspects of the project.

The impact assessment was classified into two phases of the project. The construction phase of the project was found to comprise of only minor negative and moderate short term negative impacts to the physical environment. This was mainly due to the small scale of the project. The operational phase of the project was found to mainly comprise of positive impacts. Areas that would have a significant positive impact during the operational phase of the project are, the fisheries sector, navigation and the local economy of the island.

The impact assessment and prediction had inherent uncertainties associated with them. In reality the most effective way to validate how the environmental system work is to monitor the area. The EMP devised in the report requires water quality testing, marine environment surveying, beach profiling and bottom morphology testing which is to be monitored during construction and operational phase of the project.

The EIA did not find any significant negative impacts to the environment. Minor negative impact was found to be within the natural dynamic equilibrium zone of the environment or localised only to the construction phase. Furthermore the assessment did not find the project causing damage to a protected environment or loss of critical habitat and species. No impact arising out of the project is found to be a concern at a regional or national significance. The predicted impacts can be effectively mitigated, controlled maintained at an acceptable level if the proposed recommendations and mitigation measures described in the report are followed. Therefore, the proposed project is reasonable and feasible from the view of environment protection.

12.2 RECOMMENDATIONS

The following recommendations are compiled after analysis of the impact assessment and existing environmental conditions.

1. Silt screens/sand bunds should be placed based on current and wind direction at the time of dredging to avoid sediment deposition onto the reef. Simple drogue techniques could be used to determine the current direction.
2. Movable corals if feasible should be relocated to the rehabilitation location proposed in the report, to balance out the damage caused to the reef as a result of the project.
3. The calmest months were identified to be June-July in terms of weather conditions hence, if feasible it is recommended to carry out dredging works during this time of the year to avoid weather related risks, if feasible.
4. It is recommended to record the current conditions during dredging and monitoring, and to make decisions based on physical parameters at the time of dredging and monitoring as discussed in the report
5. Minor scouring at the quay wall base was observed during field surveys, it is unlikely that the proposed dredging would exacerbate or have any affect on scouring through synergistic impacts, however it is recommended to monitor base of quay wall.
6. Dredging the four shallow areas identified in the report is strongly recommended. It would avoid excessive dredging of deep areas and shorten the duration of project which will reduce environmental impacts
7. Further widening of the entrance channel is not recommended. Although removal of existing strip of shallow area as maintenance dredging is recommended. Additional hydrodynamic surveys should be carried out to understand the wave changes that occur at the entrance channel.

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