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Consultant's Declaration

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

Name:

Simad Saeed (EIA 06/2007)

Signature

Summary

This Environmental Impact Assessment (EIA) is an evaluation of the potential environmental, socio-economic and natural impacts of the proposed sewerage system development project, planned for Miladhoo Island, Noonu Atoll. The project is being undertaken by Works Corporation Limited.

1.1 Introduction and key feature of the project

Project Background

This project is undertaken as part of an initiative by Government of Maldives to develop water supply and sewerage facilities in the atolls.

Project Objectives

The main objective of the project is to improve the sanitation system and overall health of inhabitants of N. Miladhoo.

Project Features

The key features of this project are:

1. Conventional gravity system, including two pump stations and an outfall pump station
2. Household connections with inspection chambers inside boundary wall of each house
3. Ocean outfall

1.2 Conformance to laws and regulations of Maldives and international conventions

The proposed developments require it to conform to a number of laws and regulations in the Maldives and other international protocols and conventions.

1.3 The existing environment

This project is being undertaken in an inhabited island. The following are notable features on the island.

- The island is fairly small only 700 m long and 365 m wide with an area of 22 hectares.
- Natural environment of the island has been considerable modified; main alterations are on the beach where reclamation harbour dredging project.
- The island is low lying with an average elevation of +1.3 m MSL.
- Present sanitation system in the island is septic tanks
- The reef is not in pristine condition and large part of the reef system contains dead coral and sand.
- The economy of the Miladhoo is relatively small and is mainly dominated by fishing, thatch weaving, sewing masonry and carpentry.
- The population of N. Miladhoo is looking forward to the project and there are no major conflicts. However, there is high level of scepticism on whether this project will actually take place.

1.4 Environmental impacts

The potential significant impacts from the project are summarized below:

Potential Adverse Impacts during the Construction Stage

- Air and noise pollution
- Pollution due to waste
- Loss of flora and fauna species.
- Groundwater salinisation and depletion
- Smothering of corals, siltation of lagoon benthos and affects of fish population
- Water contamination (marine water and/or ground water)

Potential Adverse Impacts during the Operations Stage

- Release of effluent to surrounding area
- Eutrophication, accumulation of toxins in marine species, changes to species composition and changes to sensitive marine habitats
- Waste from sewage sludge

1.5 Alternatives

Alternate Location

The alternate location of the sewage outfall at the southern side of the island

Alternate sanitation options

1. No project option
2. Sanitation Technology Options
    a. Continue with the existing individual septic tanks
    b. Individual septic tanks improved quality with ocean outfall
    c. Sewage treatment plant

1.6 Conclusion

The project does not involve major significant and irreversible adverse environmental, social or economic impacts that may affect the community of Miladhoo. Replacement of the current sanitation system with a proper sewerage system will help improve the health of the population of the island and help improve the groundwater quality of the island. Therefore, with proper mitigation measures in place the project is deemed favourable to the community of Miladhoo.

1 Introduction

This Environmental Impact Assessment (EIA) is an evaluation of the potential environmental, socio-economic and natural impacts of the proposed sewerage system development project, planned for Miladhoo Island, Noonu Atoll. The project is being undertaken by Works Corporation Ltd.

The proposed project includes constructing and operating a sewerage network. The main components of the project include, construction of gravity mains and pressure mains, pump stations and an ocean outfall.

The construction of the sewerage network system is expected to begin as soon as the EIA is approved and will be completed within 12 months. The estimated cost of the project is 36.6 million Rufiyaa.

This EIA has been developed based on the Term of Reference (ToR) issued by the Ministry of Housing and Environment (MHE) of the Maldives on 18 August 2010. This document is submitted by the proponent to the Ministry of Tourism and Civil Aviation and MHE to fulfil the requirements for an EIA under Article 5 of the Environment Protection and Preservation Act (4/93). The *EIA Regulations 2007* have been used as the basis for developing this document.

Works Corporation Limited (WCL) is a company developed specifically for the purpose of implementing Public Infrastructure Project (PISP) in the Maldives. Recently, Government had announced several PISP projects to be carried out though out the Maldives. These included more than 150 harbor projects, 65 resorts, 11 airports and hundreds of other smaller projects including reclamation, shore protection, electrification, schools, hospitals-etc. WCL will raise finance for the projects and subcontract the projects to private parties. As a return, WCL will be earning a management fee for overlooking the projects all through.

Works Corporation is one of the leading constructors in the country. WCL has successfully completed several projects throughout the nation.

1.1 Report Outline

This EIA is organised into nine sections. They are:

Chapter	Brief Description
Chapter 1	Introduction
Chapter 2	A description of the project including the project location, need for the project, information on the proponent, detailed description of project components including site conditions, site plans, implementation schedules, work methods, waste management and summary of inputs and outputs.
Chapter 3	A summary of the policy, planning and legal framework applicable to the project and a demonstration of how the project conforms to these aspects.
Chapter 4	Detailed description of the existing baseline environmental conditions on the island and areas of project influence. These include coastal, terrestrial and marine environment of the island, socio-economic environment and natural hazard vulnerability of the site.
Chapter 5	Information on the potential impacts and mitigation measures of the project.
Chapter 6	Assessment of best alternatives for the project or for certain project component.
Chapter 7	Details of the environmental monitoring program
Chapter 8	Information regarding stakeholder consultations

1.2 Project Background

The government of Maldives decided to design and establish a sewerage system in Miladhoo and handed over the project to Works Corporation Ltd (WCL), as contractor finance basis.

Miladhoo has an area of 22 Ha and has a population of 1375. The island is very congested and has no area left for future developments and for housing. The island is experiencing severe groundwater contamination due to poorly built onsite sanitation systems. In addition to this, the house plots are being sub-divided due to unavailability of land for new plots, resulting the distance between the groundwater wells and septic tanks/soak-aways becoming closer.

The economic activities on the island are limited: more that 30% of the work force is employed outside the island while the main economic activities on the island are fishing, thatch weaving and small businesses.

1.3 Project Objectives

Works Corporation has the objective of constructing and operating a sewerage network system in N. Miladhoo to improve the sanitation system and health of the inhabitants of the island. The specific objectives of the project are as follows:

- Develop the infrastructure and facilities necessary to operate a sewerage system in Miladhoo;
- Locate, design and operate all project facilities in a manner that results in minimal impact to the natural and socioeconomic environment of the island; and
- Comply with all Maldivian regulations, including constructing and operating the project to Guidelines.

1.4 Project Scope

The proposed project involves the construction and operation of a sewerage network in Miladhoo Island. Details of the project description are discussed in Chapter Two.

1.5 Terms of Reference

This EIA has been prepared to the requirements established by the Term of Reference (ToR) issued for this project on 18 August 2010 (See Appendix 1 for the ToR).

1.6 EIA Methodology

The process followed in the preparation of this environmental impact statement consists of five components: scoping consultations; literature review; field surveys; analysis of results; and output.

The first step of the process covered consultations with client and government agencies to determine the scope of the impact assessment. The scope was decided and the ToR was finalised on 18 August 2010 based on the information contained in the *EIA Regulations 2007*. During this stage the client clearly outlined their development needs and assessment was geared to match the development plan and environmental assessment needs.

During the second stage, a literature review was conducted to acquire background information on the site and its environment as well as to identify possible environmental impacts of the proposed developments in similar island settings. In this context, the *EIA Regulations 2007* and best practices from sewerage network development activities from other islands was considered. The timeframe for assessment was small given the geophysical setting of Maldivian coral islands. Hence, a reliance on scientific studies undertaken in similar settings around Maldives and historical publications are a necessity during assessments in Maldives.

The third stage involved field assessment on the island and in neighbouring areas covered by the EIA scope. Conditions of the existing environment were analysed using established appropriate scientific methods. Coastal topographic and hydrographical conditions were studied through field surveys which involved using DGPS, echo-sound meters and remote sensing applications. Elevation of the island was measured using standard levelling equipment. Aspects of the marine environment were assessed using established surveying and recording procedures such as Manta tows, and line transects. In addition, data from regional studies, particularly climate and wave data were used to assess environmental impacts.

Water quality was assessed by laboratory analysis from the National Health Laboratory after collecting samples from various locations. Samples were collected in clean 500ml PET bottles after washing them with water to be sampled. Also to test for faecal coliform, samples were collected in sterilized 100ml glass bottles provided by the National Health Laboratory. Parameters tested for sea water quality assessment were Biological Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Total Suspended Solids (TDS), pH, and temperature. For ground water quality assessment parameters tested were Total Coliform, Electrical Conductivity, Nitrates, Phosphates, pH and Ammonia.

In addition, field assessments were undertaken in the Miladhoo community to determine the socio-economic impacts on them using established social assessment methods such as random interviews and form-based surveying.

The fourth stage involved in-house analysis using scientific analysis methods. These methods will be explained in detail in later sections.

The final stage involved compilation of individual consultant findings and consultations with the developer to adjust certain elements of the designs which were deemed to have significant affects on the operation of the islands and the resorts.

Field surveys were undertaken during 3rd to 6th September 2010. The assessment and compilation of the EIA took 3 weeks.

1.7 Review of Similar Projects

For the purposes of assessing the environmental impacts of this project the following EIAs of similar projects has been reviewed.

Al-Habshi Consultants Office & Riyan Pte Ltd, 2009. *Environmental Impact Assessment Report: HA.Utheemu Water Supply and Sewerage Facilities*. [Online] Environmental Protection Agency, Male', Maldives. Accessed: 19 September 2010.

Zahid, A. 2010. *Environmental Impact Assessment: For the Proposed Development of Sewerage System, Naifaru, Lhaviyani Atoll, Maldives*. [Online] Environmental Protection Agency, Male', Maldives. Accessed: 19 September 2010.

1.8 The EIA Study Team

The team members of environment consultant team and their areas of contributions are listed in Table 1.1 below. Their CV's of are attached in Appendix 2.

Table 1-1 EIA study team and their areas of contribution

Consultant	Areas of Contribution
Dr Simad Saeed	Team Leader, Social Scientist and Environmental Management and Planning
Dr Ahmed Shaig	Terrestrial Environment, Atmospheric Environment and Risk Assessment
Hafeeza Abdulla	Environmental assessment and planning
Lubna Moosa	Environmental Management and Development
Mohamed Faizan	Marine Biologist
Mohamed Shinaz Saeed	Diver
Ali Moosa Didi	Surveyor
Ali Zayaan	Field Assistant (Community consultation)

2 Project Description

2.1 Project Location

Miladhoo is located on the eastern side of Noonu atoll at approximately 05° 47' 27" N latitude and 73° 21' 45" E longitude shown in Figure 2.1. With a width of about 0.36km and 0.71km in length, Miladhoo is a relatively small island with a total land area of approximately 22ha. The island is in close proximity to most inhabited islands of Noonu atoll with Magoodhoo on the south of Maafaru being the closest. Miladhoo is also not far away from the recently established tourist resorts in Noonu atoll namely, Irufushi Beach and Spa and Zitahli Resorts and Spa.

Similar to other islands of the Maldives, Miladhoo experiences a warm and humid monsoonal climate with two distinct seasons; dry season (northeast monsoon) and wet season (southwest monsoon). The dry season usually occurs from December to February and the wet season usually lasts from May to September. The transition period of southwest monsoon occurs between March and April while that of northeast monsoon occurs from October to November. The annual average rainfall recorded at Hanimaadhoo, the nearest weather station is 1786.4mm. Temperature remains almost same throughout the year although daily temperature ranges from around 31 degrees Celsius (^{o}C) in daytime to 23 degrees Celsius in night-time. The relative humidity ranges from 73 per cent to 85 per cent. Winds are generally mild although, storms and line squalls can occur, usually in the period May to July.

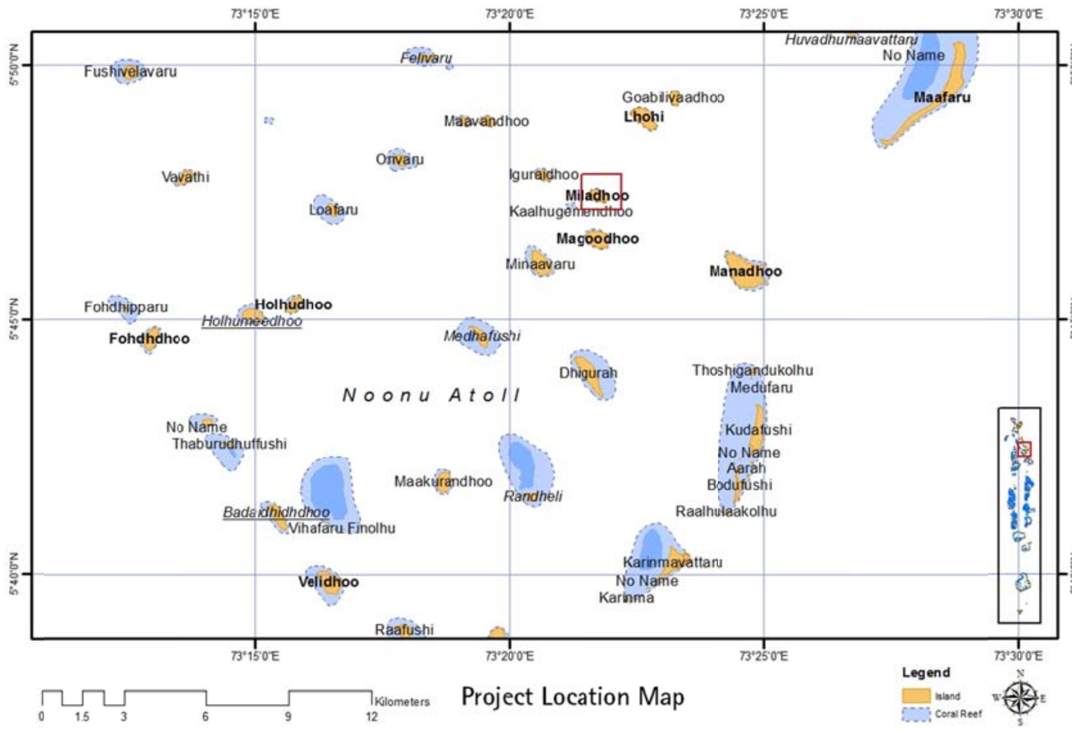

Figure 2-1 Location of Miladhoo (Circled in Red)

As stated previously, the population of Miladhoo according to latest statistics provided by the island office is 1322 persons with a population density of sixty persons per hectare. Accordingly, Miladhoo has a relatively high population density.

The infrastructure of the island includes a powerhouse with two publicly owned generators of engine capacity 55KW and 39 KW serving 24 hours of electricity, four mosques, a government school teaching up to Grade 10 and a publicly owned four preschool. The island also has a health post established by the government with two nurses, a community health assistant, two family health assistants and a midwife working there. However due to the limited capacity and service that can be provided from the health post, people from Miladhoo has to travel to the nearest hospital at Manadhoo or travel to Male' in case of emergency or a serious medical condition.

The main economic activities on the island are fishing, thatch weaving, carpentry and small businesses. Due to the limited economic opportunities, more than 30% of the force is currently employed outside the island.

2.2 Project Need and Justification

The island of N. Miladhoo has an area of 22 Ha and has a population of 1375. The island is very congested and has no area left for future developments and for housing. The island is experiencing severe groundwater contamination due to poorly built onsite sanitation systems. In addition to this, the house plots are being sub-divided due to unavailability of land for new plots, resulting the distance between the groundwater wells and septic tanks/soak-aways becoming closer.

Safe water and its availability are vital from human health perspective as well as maintaining the general environmental quality to improve the quality of life of citizens of Maldives as stipulated by the Constitution of Maldives. Accordingly, Government of the Maldives have initiated projects to develop water supply and sewerage facilities in the atolls with an overall objective of improving the sanitation system and health of the inhabitants of the island communities. This project is being undertaken as part of this initiative.

2.3 Project Boundary

The project boundary is within Miladhoo including the lagoon and within the vicinity of the reef edge on the northern side of the island.

2.4 Project Outline

Appendix 3 portrays the site plan for the proposed project. The proposed project thus involves the construction and operation of a gravity sewerage reticulation network, two reticulation pumping stations and pressure main systems along with an ocean outfall. Accordingly, the proposed project components are detailed below.

2.4.1 Site Conditions

Miladhoo is an inhabited island with a relatively high population density of sixty persons per hectare.

Due to the high population density vegetation cover in the island is low and localised to areas such as within backyards and coastline. Therefore, removal of any vegetation is not expected as most of the project work will be undertaken on existing roads.

2.4.1.1 Timing and Coordination

The work plan proposed for the project is presented in Figure 2-2 below. In general, the works are expected to be completed within 12 months. The preparatory works are expected to take 2 months.

Figure 2-2 Work plan of the construction activities

No.	*Activity*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
1	*Mobilization*												
1.1	• *Site preparation*	■	■										
1.2	• *Preliminary works*	■	■										
2	*Construction*												
2.1	• *Gravity mains*			■	■	■	■	■					
2.2	• *Pressure mains*			■	■								
2.3	• *Pump stations*								■	■			
2.4	• *Ocean outfall*							■	■	■	■	■	
3	*Demobilization*												■

2.5 Design Considerations

2.5.1 Ground Conditions

Islands from the Maldivian context typically display soil conditions with a 2m to 3m thick coral sand or coral rubble layer over a porous coral stone base with some limestone or coral stone outcrops. The ground water is generally located between 0.5m and 1.2m below surface level. It is proposed to carry out additional geotechnical surveys for establishing conditions within and around the proposed site for the pump station. Additionally trial pits for the location of existing services are also proposed to identify electricity, existing sewer lines, water mains as well as T.V. and telecommunication services.

2.5.2 Design Population

The most recent population figures for the Island of Miladhoo over the past 10 years are extremely varied ranging from 737 to 1337 individuals identified in separate census data. Given the variability of these figures and topographical surveys, a total of 259 separate plots have been identified as either existing or for future construction. As the Island is extremely small and not a candidate for further reclamation, the number of plots is unlikely to increase. Considering this figure as maximum design criteria, and utilizing census data indicating an average of five (5) residents per household, the maximum design population has been calculated. In addition, current Government data reflects that Miladhoo is experiencing a negative growth rate and therefore the selected design criteria are deemed justified. The figures below illustrate the population numbers for design of the Wastewater Collection and Treatment System on Miladhoo.

Table 2-1 Population considered in the design of the wastewater collection system

Design Population-Miladhoo		
Total Plots	E.P./HH	Design Population
259	5	1295

2.5.3 Wastewater Flow Estimation

2.5.3.1 Average Dry Weather flow (ADWF)

Given the small size of Miladhoo and the limited access to fresh drinking water, an average of 120L/E.p/day has been assumed for the purpose of wastewater estimation. Of this figure, 80% is considered to be wastewater however this figure is still considered conservative. As current wastewater guidelines do not permit the disposal of grey water to the ground surface without treatment the combination of black and grey water will be considered as the total load for wastewater. The estimated ADWF is calculated in Table 2-2.

Table 2-2 Average Dry Weather Flow estimation

Average Dry Weather Flow		
Design L/C/d	l/day	120
Design Pop.	No	1295
WW%	%	80%
ADWF	m^3/d	124.3

2.5.4 Peak Flows

2.5.4.1 Peak Dry Weather Flow (PDWF)

Peak Dry Weather Flow is calculated using the figure for ADWF multiplied by the peak factor and is calculated to represent the peak daily flow which may occur. Utilising Babbitt's formula, a value of 4.78 was calculated. As the Babbitt formula is designed for populations in multiples of 100,000 the peak factor has been compared with values used elsewhere. In Australia (as used by Hunter Water), a figure of 3 is considered more acceptable and methodology recommended in the *Guideline of Sewerage Concept Design and Review (Draft, 2010)* prepared by the Japan International Cooperation Agency (JICA), a figure of 2.4 is achieved. In light of the numerous methods for determination of peak factor, **an average of all three methods has been used for the Miladhoo design to give a peak factor value of 3.3.**

Table 2-3 Peak Dry Weather Flow estimation

Peak Dry Weather Flow (D_{max}), PDWF = ADWF x D_{max} (4)		
ADWF	m^3	124
P.factor	NA	3.3
PDWF	m^3	410

2.5.4.2 Peak Wet Weather Flow (PWWF)

Infiltration may occur where pipelines are laid below ground water level or where rainfall percolates through the soil profile and enters pipes through crack, leaks or joints. In addition rainwater can infiltrate into the sewer system through manholes and cleanout structures**. For the purpose of the Miladhoo design, and as per guidelines commonly used in Australia for the design of wastewater systems, a value of 0.1 L/s/Ha will be applied as calculated in Table 2-4.**

Table 2-4 Peak Wet Weather Flow estimation

PDWF= PDWF + Infiltration		
Area Serviced	Ha	18
Infiltration	L/s	0.1
Infiltration	m^3/d	155
PWWF	m^3/d	565

Table 2-5 shows a summary of wastewater flow estimated for the proposed system in Miladhoo and Table 2-6 shows a summary of the design criteria applied to the proposed conventional gravity system.

Table 2-5 A summary of flow estimates

Summary-Estimated Waste Water Flow		
ADWF	m^3	124.3
PDWF	m^3/d	410
PWWF	m^3/d	565

Table 2-6 Summary of the conventional gravity system design criteria

Summary of Conventional Gravity System Design Criteria	
Pipe Material	uPVC with rubber ring joints
Location/Depth	Located in roadways - minimum depth of 0.5m
Pipe Size	150mm throughout
Pipe Slope	0.5% throughout
Maximum Depth of pipe	1.5 m
Maximum Depth of Excavation	3 to 3.5m
PWWF	565 m^3/d

2.5.5 System Selection

Table 2-7 summarizes the outcome of community feed back with respect to the type of collection system preferred by the community. The complete Community Discussion Report is attached in the Appendix.

Table 2-7 Outcome of community feedback on the preferred type of collection system

Community Consultation			
System Description	**Disadvantages**	**Advantages**	**Community Response**
Small Bore System	Existing system would have to be removed and replaced with new septic tanks. As the Island is very small and already congested, this operation would cause significant disruption to HH. Desludgeing of septic tanks required	The Pipe diameters required could be smaller and laid to flatter grades reducing the number of pump station s required. Pollutant load reduced before discharge.	Community members are reluctant to have construction carried out on the properties and congestion may limit the installation of septic tank on many properties
Vacuum System	Associated costs for construction operation and maintenance are vey high and requires trained technical staff to operate	Construction is easier as pipes do not have to be laid at grade removing the need for construction in high water tables	Cost was the prime concern and requirement for trained technical staff for operation
Conventional Gravity System	Regulations do not permit the use of pipes less than D150mm. Flow estimations do not reach minimum requirement for self cleansing therefore regular flushing will be required. Pipes must be laid at minimum grade of 0.5% increasing the number of pump stations required.	System is very simple to operate and requires minimal training	Community members are familiar with the concept and technology and offered CGS as the preferred option

Conventional Gravity System + Communal Septic Tanks	four large septic tanks would need to be constructed within public spaces. Desludgeing of septic tanks required.	Pollutant load reduced before discharge.	While the community did not disagree with this option, the planning department refused the proposal based on insufficient public land available for the construction of the septic tanks.

The overriding outcome of the meeting was that community members did not want septic tanks installed within their property boundaries due to limited space requirements or be subject to a system which will cause excessive financial burden. While the concept of communal septic tanks was not dismissed by the community, the Planning Department in Male' rejected the proposal on grounds of insufficient public space to accommodate tanks of the required size. Based on these findings, the proposal for the construction of Conventional gravity system was considered the most suitable option for the Miladhoo community.

2.6 Major Development Activities

The proposed sewerage system for Miladhoo is the conventional gravity system. It is based on constructing a system of sewers, which allows the sewage to flow downhill under gravity to a central point. This point could be a sewage pumping station or a treatment plant. The proposed sewerage system consists of the following main components:

- Conventional gravity system
- Access chambers
- Pump stations
- Household connections
- Wastewater treatment

It must be noted that the wastewater treatment component except the ocean outfall is not included in the development activities. Wastewater treatment component has been omitted following consultations with the EPA based on the small size of Miladhoo population and costs of establishing a treatment plant. However, it is deemed necessary by the EPA to place infrastructure in place which would make it possible for the installation of a treatment plant should it become necessary and/or financially more viable. Therefore, the inclusion of a pre-treatment facility has been considered for the design of the Miladhoo system.

2.6.1 Conventional Gravity System

2.6.1.1 Excavation and Dewatering

The Maldives is a unique environment with respect to construction of wastewater systems due to the extremely high water tables which on average are between 0.5 and 1.5m below ground level. Because of this, extensive dewatering is required during construction and installation of pipe networks which increases in intensity as depth increases. In addition, the instability of the prevailing sand/soil conditions of coral atoll islands makes excessive dewatering extremely hazardous as increased dewatering with depth removes significant quantities of sand/soil further exacerbating the unstable soil conditions. Previous experience of sewer construction in the Maldives has indicated that excavation depths in excess of 3.5m are not recommended for conventional dewatering methods to avoid the risk of undermining and trench collapses. These recommendations are reiterated by JICA in the Standard Checklist for Outsourced Design (Draft, 2010) which recommends a maximum depth of 3 m as well as contractors with experience in the construction of sewer networks in the Maldives.

For the purpose of the Miladhoo design, a maximum depth of excavation of 3.0 to 3.5 m is proposed. Strict adherence to these criteria is considered necessary for Miladhoo as the streets are very narrow and congested leaving limited space for excavation and installation of pipelines between buildings. **Given the instability of the sand/soil conditions, trench shoring is to be used to maintain the vertical integrity of the sidewalls.** All water removed during excavation for trenching and construction will be disposed of inland from the excavation for re-percolation back into the water table as outlined in the EPA guidelines.

2.6.1.2 Minimum Cover

Considering the limitations with respect to depth of excavation a maximum depth for pipeline excavation should be within the range of 1.5m. This will allow for the installation of pump stations to a depth of not more than 3.0m to 3.5m. With a view to minimizing the number of pump stations required, the minimum depth of cover should allow for maximum fall of the pipeline over a specified distance. The standard minimum cover for areas experiencing light traffic is 60 cm however these specifications are designed for western/developed countries where light traffic is considered to be small cars and trucks. **As the light traffic in the Maldives is more likely to be motorcycles and pedestrians with an occasional light truck, a value of 50 cm for minimum cover is proposed for pipelines in public roadways.**

2.6.1.3 Pipe Size

The minimum pipe size specified for the construction of conventional gravity sewers is 150mm. As the system is designed for a small community, wastewater flow does not exceed the rate requiring the upsizing of the pipe and therefore **150mm is the proposed pipe size throughout the Miladhoo system**.

2.6.1.4 Slope

In an effort to minimize the number of pump stations required for the Miladhoo system a maximum slope of 0.5% has been adopted for use uniformly throughout. As the system is relatively small compared to most a greater slope would have been more desirable to ensure minimal cleansing velocity however this would have increased the number of pump stations required. **With respect to Manning's Formula and as demonstrated in Table 2-8, a 0.5% slope is adequate to provide minimum cleansing velocity with the pipe at 40% to 50% of full flowing capacity.**

Table 2-8 Pipe Velocity for 150mm, uPVC Pipe

% Full	0.30%	0.50%	1.00%	1.50%	2.00%
100	0.804098	1.038086	1.468075	1.798018	2.076172
90	0.749556	0.967672	1.368495	1.676058	1.935345
80	0.692951	0.894595	1.265149	1.549485	1.789191
70	0.63393	0.8184	1.157392	1.41751	1.636799
60	0.572018	0.738472	1.044357	1.279071	1.476945
50	0.50655	0.653953	0.92483	1.13268	1.307906
40	0.436532	0.56356	0.796994	0.976114	1.12712
30	0.360349	0.465208	0.657904	0.805765	0.930417
20	0.274998	0.35502	0.502075	0.614913	0.710041
10	0.173238	0.223649	0.316287	0.387371	0.447298
0	0	0	0	0	0

Despite this however it is anticipated that the low flow rates for the Miladhoo system may require additional maintenance with respect to flushing of lines to minimize the occurrence of blockages.

2.6.1.5 Pipe materials

Given the availability of **u-PVC pipes and fittings** in the Maldives and wide spread experience of using such materials it **is recommended for all gravity sewers for the Miladhoo project. All gravity sewer mains are to be rated SN8 solid wall and rubber ring jointed**.

Table 2-9 provides a summary of the conventional gravity system that is proposed for Miladhoo.

Table 2-9 Summary of Conventional Gravity System

Summary of Conventional Gravity System	
Pipe Material	uPVC with rubber ring joints
Location/Depth	Located in roadways - minimum depth of 0.5m
Pipe Size	150mm throughout
Pipe Slope	0.5% throughout
Maximum Depth for Excavation of pipe	1.5 m

2.6.2 Access Chambers

2.6.2.1 Maintenance Shafts

Maintenance shafts are to be used in place of manholes and located at pipe junctions or where the lengths of gravity sewer runs exceed 75m. **A minimum size of DN315 is to be used for minor junction of 2 pipes or where gravity sewer lengths are exceeded. For all other pipe junctions Maintenance Shafts of DN 600mm are required.** Due to the small nature of the project it is not deemed necessary to have traditional manhole structures for which workers can gain access. **All of the Maintenance Shafts are at a depth which is readably accessible from the surface and any blockages could be cleared from the surface. Pre cast PVC fittings have been selected as the preferred material for Access Chambers.** Experience indicates that in-situ concreting is not recommended for the following reason;

- Logistics of transporting and associated costs of raw materials to remote Islands
- Requires the use of fresh water which due to scarcity may require the provision of onsite RO production.
- Extensive de-watering is required during construction and curing period.
- Potential for ingress of brackish/saline water into the excavation during dewatering

Alternatively, access chambers could be precast and located on site however there still remains the associated logistical issue of transport as well as scarcity of fresh water and the associated costs for transport and production respectively. **The materials for maintenance shafts will be:**

- **Maintenance shaft bases will be pre-cast PVC, multiple entries to suit DN 100/150 uPVC rubber ring jointed sewer mains.**
- **Maintenance shaft risers will be double walled or corrugated PVC with "O" ring seals at all joints.**

- **Plastic screw on cover**

Maintenance shafts will be installed with a concrete collar surround and trafficable cast iron cover. In addition a concrete base, or collar, will be located over the maintenance shaft at the base of the installation for the purpose of buoyancy control. Previous experience has indicated that PVC Maintenance shafts installed at depths up to 1m below water tables without concrete ballast do not experience adverse effects due to buoyancy and the collar is provided as added security.

2.6.2.2 Clean-outs

Clean-outs or, rodding points, will be located at the beginning of all sewer mains and comprised of a DN 110mm PVC bend of 45 deg, with threaded end cap and rubber gasket for the purpose of up-stream flushing of sewer mains.

2.6.3 Pump Stations

Following design of the Miladhoo system, **it is determined that a total of two (2) catchments will be required to adequately service all areas** given the design specifications as outlined in the design criteria. **Depths have been limited to a maximum of 3.5m** which is effectively 1.5m below the water table. This is deemed necessary to avoid the issues as outlined in Section 4.1. Excavation and Dewatering.

Pump stations will be located on the road based on the community consultations held by the proponent and based on what is technically feasible. Houses, Island Office, schools are avoided in locating the pump stations. The community agreed on areas such as near cemetery and within the power house area. However, for technical reasons pump stations will be located on the roads.

2.6.3.1 Wet Wells

Fiber/Glass Reinforced Plastic (F/G/RP) package pump Stations will be used and installed inside a reinforced concrete caisson. A concrete base plug will be located at the base of the caisson and the annulus between the caisson and the FRP wet well will be grouted with concrete.

2.6.3.2 Valve Chambers

A separate valve chamber (dry well) will service each of the package pump stations. A stop and non-return valve will be located on the discharge line on each pump and be serviceable from the dry well.

2.6.3.3 Pumps

The pumps utilized for the catchments pump stations will be single phase submersible type with dual pumps in each wet well. Discharge pipe velocities shall have a minimum velocity of 2.0 m/s to aid in the scouring of valves and fittings and a maximum of 4.0 m/s to prevent scouring of the pipe walls. Dual pumps will alternate between duty and stand-by after each pumping event and controlled by float switches in the following configuration.

- All Pumps Stop
- Duty Pump Start
- Stand By Pump Start
- High level Alarm

2.6.3.4 Control Panels

Pump Station Control panels will incorporate mechanical switching control and not utilize microprocessors. The cabinets will be lockable stainless steel with an IP68 rating. An outlet for connection of an alternative power supply will be located at the panel in the event of an Island wide power outage.

2.6.3.5 Rising Mains

Rising mains, or pressure mains, will be of Class PE80B PN10 due to its increased wall thickness, as opposed to PVC, and greater resistance to abrasion and ease of jointing utilising fusion butt welding. Velocities in the rising mains are to be maintained at a minimum of 2.0 m/s to facilitate removal of sedimentation from valves and a maximum of 4.0 m/s to avoid scouring of pipe walls. Thrust blocks are to be placed at all changes in direction for all pipe networks under pressure.

2.6.3.6 Isolation/Control Valves

An isolation valve is to be placed immediately upstream of the rising-main junction in order to isolate the junction in the event of pipe failure. Where required, gravity scouring valves will be located at the low end of long rising-mains to facilitate drainage of effluent from the main in the event of pipe failure necessitating repair. The scouring the down-stream end of the scouring valve will be connected via maintenance shaft to the gravity sewer network.

2.6.3.7 Additional Items

Catchment Overflow Link

A DN150mm emergency overflow pipe will be located between the two adjunct catchments at minimum cover to provide relief in the event that the pump station in one catchment fails. After failure of a pump station, and subsequent build up of effluent in the sewer network, effluent will begin to flow into the adjacent catchment for pumping until such time as repairs on the failing pump station can be carried out.

Vent Stacks

A vent stack is to be located at each pump station providing for the release of gasses from inside the wet well. The vent stack will be constructed of hot dip galvanized steel with tapered finish to a height of 7.0m.

2.6.4 Household Connections

Residential connections to the sewer main will include a 100mm gravity sewer laid at minimum grade of 2.5% to facilitate the flow of solids. Where domestic fixtures do not include a water trap an "S" bend will be installed on the external side at the point of exit. A vent line will be installed in the upstream side of the residential connection, generally at the point of exit. **A precast inspection chamber will be placed at the boundary of each residential connection prior to downstream connection with a precast "Y" fixture, lateral connection.**

2.6.5 Wastewater Treatment

2.6.5.1 Pollutant Loads

The figures indicated in Table 2-2 for ADWF (124 m3/d) are used for the evaluation of the average daily pollutant load for Miladhoo. Adopted values for the characteristics of typical residential wastewater provided by the EPA have been used to determine the daily pollutant load from the Miladhoo community shown in Table 2-10.

Table 2-10 Expected daily pollutant loadings- Miladhoo

Parameter	Estimated Loading	TOTAL
BOD_5	Kg/d	37.2
COD	Kg/d	62
TSS	Kg/d	40.92
TN	Kg/d	7.44
TP	Kg/d	1.24
Oil & Grease	Kg/d	9.92
TC Concentration	No	10^9
FC Concentration	No	10^6

Previous consultation with the EPA have indicated that given the small size of the community and the minimal expected daily pollutant loads, the need for a wastewater treatment plant post collection was not required. In addition to the minimal pollutant loads generated, the associated costs for establishing a treatment plant were not considered viable and likely to create an unsustainable economic burden for the Miladhoo community.

Despite this however it is deemed necessary by the EPA to place infrastructure in place which would make it possible for the installation of a treatment plant in the future should it become necessary and/or more financially viable and therefore the inclusion of a pre-treatment facility has been considered for the design of the Miladhoo System.

2.6.5.2 Pre-Treatment

The purpose of pre-treatment is to provide equalization of incoming wastewater and remove heavier particulate matter and suspended solids prior to treatment as they may cause damage to a treatment facility or inhibit the treatment process. The Pre-Treatment Tank (PTT) is sectioned into two portions each receiving equal flow from the pump stations. For maintenance purposes, one side of the tank can be isolated. A screen at the inlet of the tank removes any rags and gross solids before effluent enters the first chamber of the tank. The floor of the tank is sloped towards the inlet to facilitate the flow of solids/sludge into the sludge collection basin during operation and maintenance periods. Effluent flows though the PTT and under gravity flows out to the ocean outfall pumping station. The pumping station can be bypassed with an isolation valve allowing for effluent to flow through to the ocean outfall under gravity. Isolating valves at the sludge collection basin can be opened to divert accumulated sludge and solids to a sludge drying basin or alternatively bypassed into the ocean outfall pumping station.

A vent structure is located on the PPT in the freeboard zone to reduce the buildup of gasses and odors. The vent structure will also act as an overflow in the event of a blockage in the tank diverting effluent to the ocean outfall pump station.

2.6.5.3 Ocean Outfall

The Ocean Outfall (OOF) pump station is designed with the same parameters as the catchment pump stations. Effluent flows under gravity to a common maintenance shaft after the PTT and into the OOF pump station. An emergency relief valve is located at the OOF pump station in the event of malfunction or power outage.

As per MWSA guidelines, the Ocean outfall pipeline will be constructed of HDPE OD 150mm. The pipeline will be buried to a depth of 1.25m through the Island lagoon to the point at which it reaches an average depth of 1.5m below MSL. The pipeline is to be backfilled with coarse gravel to 150mm above the pipeline after which the remainder will be filled with gabion baskets. Following the emergence of the pipeline at depth, it will be secured with concrete ballast blocks of a mass sufficient to prevent the movement of the pipeline during heavy wave activity. The pipeline will be fixed to the ballast blocks with stainless steel straps and secured with bolts of similar material cast into the blocks. Ballast blocks will be placed at intervals of 6m to center to a depth of not less than 7.5m. **A "T" head diffuser will be fixed to the discharge end of the OOF pipeline to increase dilution performance and dispersion of effluent.**

The length of the ocean outfall is 119m ensuring that the outfall extends beyond the reef edge into the deep ocean.

2.6.5.4 Catchment 1

Utilising the design criteria defined in Table 2-5, Catchment 1 has been designed with the characteristics defined in Table 2-11 below. The maximum depth of invert is determined as 1.67m. As the system has been designed from the lowest reference to MSL of 0.88m, and considering the reference of the pump station to MSL of 1.06, the depth to of excavation is given as 1.85m. This figure is outside of the maximum recommended depth to excavation for pipelines which is set to limit the depth of total excavation to 3.5m. As the depth of pump station 1 below the invert is a further 1.5m (defined below) the maximum depth to excavation is 3.35m which is within the recommended limits. **The flow rate for Catchment 1 under peak flow conditions is 3.1 L/s which is 50.7% of the total peak flow value for Miladhoo.** The flow rate figures are representative of the flow within the upstream and downstream locations only and do not represent cumulative flow rates.

Table 2-11 Design Summary of Catchment 1

Catchment 1 - Design Summary		
Total Length of Pipe	m	1753
Minimum MSL Ref	m	0.88
PS Ref MSL	m	+1.06
Invert at PS	m	1.67
Maximum Depth of Exc. Pipeline	m	1.85
Peak FR	l/s	3.41
Maintenance Shafts	No	23
Clean-Outs	No	17

2.6.5.5 Catchment 2

Utilising the design criteria defined in Table 2-5, Catchment 2 has been designed with the characteristics defined in Table 2-12 below. The maximum depth of invert is determined as 1.66m. As the system has been designed from the lowest reference to MSL of 0.994m, and considering the reference of the pump station to MSL of 1.132, the depth of excavation is given as 1.84m. This figure is outside of the maximum recommended depth to excavation for pipelines which is set to limit the depth of total excavation to 3.5m. As the depth of pump station 2 below the invert is a further 1.5m (defined below) the maximum depth to excavation is 3.34m which is within the recommended limits. **The flow rate for Catchment 2 under peak flow conditions is 3.0 L/s which is 49% of the total peak flow value for Miladhoo.** The flow rate figures are representative of the flow within the upstream and downstream locations only and do not represent cumulative flow rates.

Table 2-12 Design summary of Catchment 2

Catchment 1 - Design Summary		
Total Length of Pipe	m	1498
Minimum MSL Ref	m	0.944
PS Ref MSL	m	1.132
Invert at PS	m	1.66
Maximum Depth of Exc. Pipeline	m	1.85
Peak FR	l/s	3.41
Maintenance Shafts	No	18
Clean-Outs	No	20

2.6.6 Pressure Mains

2.6.6.1 Head Loss Calculations

The Cumulative head losses for PS1 and PS2 from pump station to point of discharge at the pre-treatment tank are defined in Table 2-13 below and give total head losses of 5.56 and 5.76 respectively.

Table 2-13 Cumulative head losses for PS1 and PS2

PS-1 Cumulative Head Loss					PS-2 Cumulative Head Loss				
Req. FR	3.5 L/s				Req. FR	3.5 L/s			
Pipe D.	80mm				Pipe D.	80mm			
Description	Unit	No	Mult. Factor	HL	Description	Unit	No	Mult. Factor	HL
Static head	m	2.1	1	2.1	Static head	m	2.85	1	2.13
90 deg Elb.	No	3	0.05	0.15	90 deg Elb.	No	3	0.05	0.15
Reflux Valve	No	2	0.2	0.4	Reflux Valve	No	2	0.2	0.4
T Junction	No	1	0.1	0.1	T Junction	No	1	0.1	0.1
Pipe Run to "T"	m	74	0.004	0.296	Pipe Run to "T"	m	116	0.004	0.464
Req. FR			7 L/s		Req. FR			7 L/s	
Pipe Run After "T"	m	161	0.015	2.415	Pipe Run After "T"	m	161	0.015	2.415
90 deg Elb.	No	2	0.05	0.1	90 deg Elb.	No	2	0.05	0.1
TOTAL				5.561	TOTAL				5.759

2.6.6.2 Pump Selection

Grundfos SE1.50.65.09.2.1.502 has been selected as the most suitable pump for both Miladhoo pump stations. The selected pump can deliver a flow rate of 7.3 L/s with a head loss of 5.5m and velocity of 2.22 m/s which is within the allowable minimum and lees than maximum for system pressure mains. Given the conservative approach adopted throughout the design with respect to both peak flow rates and head losses, the SE1.50.65.09.2.1.502 is considered to be suitable for use in the Miladhoo system. Table 2-14 below illustrates the pump curve for the Grundfos SE1.50.65.09.2.1.502.

Table 2-14 Pump requirements

Pump Requirements		
Cumulative Head Losses	m	5.76
Minimum Flow rate	L/s	6.0
Voltage Requirement	Single Phase	

2.6.6.3 Pump Station Data

Given the design criteria and data for selected pumps, the Pump station characteristics for Catchments 1 and 2 are defined in Table 2-15 below. At peak flow, the average time for pump out is estimated at 234 (3.9 minutes) seconds for PS1 and 252 (4.2 minutes) for PS2.

Table 2-15 Pump station characteristics for Catchments 1 and 2

PS-1			PS-2		
Ref to MSL	m	1.06	Ref to MSL	m	1.13
Min Ref to MSL	m	0.88	Min Ref to MSL	m	0.94
Fall to Invert	m	1.6715	Fall to Invert	m	1.656
Depth to Invert	m	1.8515	Depth to Invert	m	1.846
Depth Below Invert to pumped Volume	m	0.15	Depth Below Invert to pumped Volume	m	0.15
Pumped Volume	m^3	1	Pumped Volume	m^3	1
Depth from Pump Start to Base	m	0.4	Depth from Pump Start to Base	m	0.4
Total depth	m	3.4015	Total depth	m	3.396
Diameter	m	1.2	Diameter	m	1.2
Total Volume	m^3	3.85	Total Volume	m^3	3.84
Flow rate at PWWF	L/s	3.1	Flow rate at PWWF	L/s	3.0
Pump Capacity	L/s	7.37	Pump Capacity	L/s	7.37
Time to Pump	s	234	Time to Pump	s	252

2.6.7 Ocean Outfall (OOF) Pump Station

Grundfos SE1.50.65.09.2.1.502 has been selected as the most suitable pump for the OOF pump station on Miladhoo. The selected pump can deliver a flow rate of 11.6L/s with a head loss of 3.33m at a velocity of 3.33 m/s which is within the allowable minimum and less than maximum for system pressure mains. Table 2-16 below illustrates the pump curve for the Grundfos SE1.50.65.09.2.1.50.

Table 2-16 OOF cumulative head loss

OOF Cumulative Head Loss				
Req. FR	3.5 L/s			
Pipe D.	150 mm			
Description	Unit	No	Mul. Factor	HL
Static head	m	2.85	1	2.13
90 deg Elb.	No	3	0.05	0.15
Reflux Valve	No	2	0.2	0.4
T Junction	No	1	0.1	0.1
Run to Diffuser	m	250	0.002	0.5
Density Factor	m	7.5	0.03	0.225
	TOTAL			3.505

2.7 General Construction Activities

2.7.1 Mobilisation of Equipment and Materials

Site mobilisation involves the mobilisation of construction equipment, materials and workforce to Miladhoo and providing necessary storage for materials and site access and services for the workforce. All site mobilisation and construction related activities will be undertaken in a planned manner.

A temporary site office and the necessary facilities for formworks and other preparatory works will be constructed at the initial phase of the project.

2.7.2 Labour Requirements and Availability

There will be about 50 - 70 workers in total during the construction stage. These workers will be accommodated on Miladhoo Island. Labour will be sought from local atoll population and from neighbouring countries.

2.7.3 Waste Management

Waste will be generated from construction activities and from material consumption by construction workforce. Both the construction waste and the general domestic waste will be managed according to Environment Ministry Regulations and it would be the Contractor's responsibility to dispose of all construction-related waste during demobilisation along with any other waste. The Contractor will be required to clear all areas of work.

2.7.4 Pollution Control Measures

The following measures will be taken to ensure minimal pollution during construction stage.

- Machinery will be properly tuned and maintained to reduce emissions and minimize risk of spills/leaks.
- Fuel storage will be bunded.
- Spill kits will be maintained around island to handle any liquid spills.
- All paints, lubricants, and other chemicals used on site will be stored in secure and bunded location to minimize risk of spill.

2.7.5 Health and Safety Measures

- The contractor would ensure that Health and Safety procedures are complied with at all times.
- Construction activities would be carried out under the supervision of a suitably experienced person.
- All reasonable precautions will be taken for the safety of employees, and equipment will be operated by competent persons.
- Warning signs, barricades or warning devices will be provided and used. Necessary safety gear will be worn at all times.

2.7.6 Utilities

Water and electricity will be provided for construction activities from the existing facilities of the island.

2.7.7 Sewage and Water Disposal

Sanitation facilities for the workforce will be provided using existing toilets on the island.

2.8 Summary of inputs and outputs

The types of materials that will go into the development and from where and how this will be obtained are given in Table 2.17 and the type of outputs (products and waste streams) and what is expected to happen to the outputs are given in Table 2.18. A more detailed list of equipment and materials is provided in Appendix 11.

Table 2-17 Major inputs to the project activities during construction and operation

Input resource(s)	Source/Type	Method of obtaining materials
Construction		
Construction workers	Local and foreign, mainly foreign	**Recruiting agencies, etc.**
Engineers and Site supervisors	Local and foreign	**Advertise in local papers, social networks, etc.**
Construction material	Timber; electrical cables and wires, DBs and MCBs, PVC pipes, light weight concrete blocks, reinforcement steel bars, sand, cement, aggregates, telephone cable CAT 5, PVC conduits, floor and wall tiles, gypsum boards, calcium silicate boards, zinc coated corrugated metal roof, paint, varnish, lacquer, thinner...etc	**Import and purchase where locally available at competitive prices – Main Contractor's responsibility.**
Water supply (during construction)	Groundwater and/or rainwater	**Wells and/or rainwater tanks as designated by island office**
Electricity/Energy (during construction)	Diesel	**Existing 55 kVA generator + 39 kVA generator**
Machinery	Excavators, concrete mixers	**Import or hire locally where available**
Food and Beverage	Mainly imported sources except a few locally available products.	**Import and purchase locally**
Fuel, Kerosene and LPG	Light Diesel, LPG Gas, Petrol, Lubricants	**Local suppliers**
Operation		
Electricity supply	Diesel	**Existing 55 kVA generator + 39 kVA generator**
Operational staff	Works Corporation Limited	**Recruiting agencies**
Sewage	Households	**PDWF 410 m^3/d PWWF 565 m^3/d**

Table 2-18 Major outputs from the project activities during construction and operation

Products and waste materials	Anticipated quantities	Method of disposal
Construction		
Green waste from site clearance	Small quantity	**Burnt or mulched on site**
Construction waste (general)	Small quantities	**Combustibles: Burnt/incinerated** **Others: Sent to designated landfill**
Waste oil	Small quantities	**Transferred to designated waste management**
Hazardous waste (diesel)	Small quantities	**Barrelled and sent to designated waste management site**
Operation		
Wastewater	PDWF 410 m^3/d PWWF 565 m^3/d	**Discharged through the ocean outfall**

2.8.1 Vegetation Clearance

- No large vegetation clearance is expected for this project.

3 Policy, Planning and Legal Framework

3.1 Introduction

This Chapter will provide a summary of the legal instruments applicable to the project and demonstrate how the project conforms to these aspects.

The main legal instruments of concern are the Environmental Protection and Preservation Act (EPPA) 1993 and the Environmental Impact Assessment Regulations 2007.

3.2 The Environmental Protection and Preservation Act (EPPA) 1993

The Environmental Protection and Preservation Act (EPPA) of the Maldives (Law No. 4/93) is an umbrella law that provides wide statutory powers to the Environment Ministry regarding environmental regulation and enforcement.

The EPP Act 1993 states that the natural environment and its resources are a national heritage that needs to be protected and preserved for the benefit of future generations and that the protection and preservation of the country's land and water resources, flora and fauna as well as the beaches, reefs, lagoons and all natural habitats are important for the sustainable development of the country.

The primary components of the EPP Act 1993 are:

3.2.1 Environmental Guidance

Guidelines and advice on environmental protection shall be provided by the concerned government authorities in accordance with the prevailing conditions and needs of the country. Hence, all concerned parties shall take due consideration of the guidelines provided by the government authorities.

3.2.2 Environmental Protection and Conservation

Formulating policies, rules and regulations for protection and conservation of the environment in areas that do not already have a designated government authority already carrying out such functions shall be carried out by the Environment Ministry.

3.2.3 Protected Areas and Natural Reserves

The Environment Ministry shall be responsible for identifying and registering protected areas and natural reserves and drawing up of rules and regulations for their protection and preservation.

3.2.4 Environmental Impact Assessment

An EIA shall be submitted to the Environment Ministry before implementing any developing project that may have a potential impact on the environment.

3.2.5 Termination of Projects

Projects that have any undesirable impact on the environment can be terminated without compensation.

3.2.6 Waste Disposal Oil and Poisonous Substances

Disposal of waste, oil, poisonous substances and other harmful substances within the territory of the Maldives is prohibited. Waste shall be disposed only in the areas designated for the purpose by the government. If such waste is to be incinerated, appropriate precaution should be undertaken to avoid any harm to the health of the population.

3.2.7 Hazardous/Toxic or Nuclear Waste

Hazardous / Toxic or Nuclear Wastes shall not be disposed anywhere within the territory of the country. Permission should be obtained for any trans-boundary movement of such wastes through the territory of Maldives.

3.2.8 The Penalty for Breaking the Law and Damaging the Environment

The penalty for minor offenses in breach of the EPP Act 1993 or any regulations made under this Act, shall be a fine ranging between Rf. 5.00 (Five Rufiyaa) and Rf. 500.00 (Five Hundred Rufiyaa) and for all major offences a fine not exceeding Rf. 100,000,000.00 (One Hundred Million Rufiyaa). The fine shall be levied by the Environment Ministry or by any other government authority designated by that ministry and shall depend on the seriousness of the offence.

3.2.9 Compensation

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

This EIA report will comply with the EPP Act 1993.

3.2.10 Solid Waste Management

Article 7 of the Environment Protection Act (4/93) prohibits the disposal of wastes, oil and gases in a manner that will damage the environment. Wastes, oil and gases has to be disposed off in areas designated by the Government.

Article 8 of the Environment Protection Act (4/93) prohibits the disposal of hazardous wastes within the territory of Maldives.

Any waste generated during the construction and operation of the proposed project will be disposed according to the laws and regulations of Maldives. Waste will be taken to a disposal site designated by the Government.

3.3 Environmental Impact Assessment Regulation 2007

The Environment Ministry issued the EIA Regulation in May 2007, which guides the process of undertaking the Environmental Impact Assessment in the Maldives. This Regulation provides a comprehensive outline of the EIA process, including the application to undertake an EIA, details on the contents, format of the IEE/EIA report, the roles and responsibilities of the consultants and the proponents as well as minimum requirements for consultants undertaking the EIA.

This EIA has been undertaken in accordance with the EIA Regulations 2007 of the Maldives.

3.3.1 Post EIA Monitoring, Auditing and Evaluation

The EIA Regulations 2007 provides a guideline of the environmental monitoring programme that should be included in EIA reports as monitoring is a crucial aspect of the EIA process.

Accordingly, the monitoring programme shall outline the objectives of monitoring, the specific information to be collected, the data collection program and managing the monitoring programme. Managing the monitoring programme requires assigning institutional responsibility, enforcement capability, requirements for reporting and ensuring that adequate resources are provided in terms of funds, skilled staff and the like.

The monitoring programme outlined in this report will comply with the EIA Regulations 2007.

3.4 Maldives Building Code

The building code hand book of Maldives details the guidelines and standards that should be used for designing building in Maldives. All construction projects are required to meet the standards specified in the building code.

All construction activities of the project will follow the Building code.

3.5 Waste Management Policy

MHTE has published a National Solid Waste Management Policy for the Maldives. The aim of the waste management policy is to formulate and implement guidelines and means for solid waste management in order to maintain a healthy environment. The developer shall follow any guidelines regulations on waste management that the government may introduce.

Waste management during construction and operation of the proposed project will be guided by the relevant laws, regulations and policies related to waste in Maldives.

The key elements of the policy include:

- Ensure safe disposal of solid waste and encourage recycling and reduction of waste generated;
- Develop guidelines on waste management and disposal and advocate to enforce such guidelines through inter-sectoral collaboration;
- Ensure safe disposal of chemical, hazardous and industrial waste.

3.6 General Guidelines for Domestic Wastewater Disposal

General Guidelines on Wastewater Disposal have been drawn up by the EPA former MWSA in 2006, to assist those providing public sewerage networks and private house owners constructing on-site sanitation systems, whose activities may pose a pollution risk. These guidelines have been mainly targeted at provisions in local inhabited islands. The Guidelines requires wastewater disposal to be undertaken with written consent of the Authority. A copy of the guidelines can be obtained from the EPA.

3.7 By Law on Cutting Down, Uprooting, Digging Out and Export of Trees and Palms from One Island to Another

In pursuant to the Environment Protection and Preservation Act of Maldives 1993, the Environment Ministry made a bylaw with the purpose of educating developers about the importance of trees including best management practices for maintaining trees and provide standards for preservation of trees in the Maldives and set down rules and regulations to be adhered to prior to commencing felling, uprooting, digging out and exporting of trees and palms from one island to another in Maldives.

The by law states that the cutting down, uprooting, digging out and export of trees and palms from one island to another can only be done if it is absolutely necessary and there is no other alternative. It further states that for every tree or palm removed in the Maldives two more should be planted and grown in the island.

The by law prohibits the removal of the following tree types;

- The coastal vegetation growing around the islands extending to about 15 meters into the island
- All the trees and palms growing in mangrove and wetlands spreading to 15 meters of land area;
- All the trees that are in a Government protected areas;
- Trees that are being protected by the Government in order to protect species of animal/organisms that live in such trees; and
- Trees/palms that are abnormal in structure.

3.8 Law on Inhabited Islands (Law No. 21/98)

This law deals with vegetation on all inhabited islands except Malé. The law states that except housing plots owned by the public and land leased for certain activities, vegetation in all other areas shall be dealt with in consultation with the arrangements made by the Ministry of Atolls Administration, after permission from the Island Office and in areas approved by the Island Office.

According to clause 8 of this law, those vegetated areas or trees that has been leased to or owned by the public shall only be removed after advice from the Ministry of Fisheries, Agriculture and Marine Resources (MFAMR) and in accordance with the arrangement of the Ministry of Atolls Administration. Clause 10 of this law gives MFAMR the authority to protect vegetation in inhabited islands including those that are above 50 years old and those that may be threatened or those that need special attention. However, no such areas have been declared on any island. However, the Ministry of Home Affairs, Housing and Environment has proposed to protect the area on the northern end of S. Hithadhoo, and is under consideration as a pilot area in Hithadhoo (Pers. Comm., Hussain Naeem, Environment Research Center).

Clause 11 defines activities that relate to vegetation of inhabited islands that are banned and clause 12 states the penalties for those actions that are banned under clause 11.

3.9 Ban on Coral Mining

Coral mining from the house reef and the atoll rim has been banned from 26th September 1990 through a directive from the President’s Office.

3.10 National Waste Water Quality Guidelines

3.10.1 Domestic Waste Water Quality for Discharge into Deep Sea

Deep sea discharge in the context of the Maldives means discharge of waste water beyond the shallow reef and at a depth which will ensure proper dispersion and rapid dilution. Deep sea discharge does not imply discharge of waste water inside the atoll.

The values presented in the National Waste Water Quality Guidelines Maldives provide the maximum allowable concentration of listed components that has to be complied with at all times. If these maximum values are exceeded, one or more of the users of the marine environment will be affected. The values presented assumed proper dispersion as well as thorough and instant mixing at the point of discharge to limit impact at the point of discharge.

3.10.2 Monitoring

Monthly compliance reports have to be submitted to MWSA indicating at least the minimum and maximum value for each guideline requirement, as well as other aspects detailed in the National Waste Water Quality Guidelines Maldives.

In cases of non-compliance to any guideline in this document, MWSA has to be informed immediately, indicating the components concerned and concentrations. A plan of action has to be submitted indicating responsibility for specific actions and an expected date of compliance.

A maintenance plan also has to be submitted annually. Results of maintenance inspections have to be submitted to MWSA within 30 days of inspection - to indicate results and plan of action in cases where the infrastructure has to be replaced.

Sample analysis can only be carried out by a laboratory approved by MWSA. The method of analysis should comply with requirements of AWWA/APHA or Public Health Laboratory of Maldives and the results reported as requested in guidelines.

3.11 Land Act

The Land Act provides for allocation and releasing of land for different needs as well as releasing of public land for housing. The Act also states the conditions that govern the using of, owning, selling, renting and transferring of ownership of public and private land.

3.12 Relevant International Conventions, Treaties and Protocols

3.12.1 United Nations Convention on Climate Change (UNFCCC) and the Kyoto Protocol

The UNFCCC is an "overall framework for the intergovernmental efforts to achieve stabilization of greenhouse gas concentrations in the atmosphere at a low level enough to prevent dangerous anthropogenic interference with the climate system, recognizing that the climate system is a shared resource whose stability can be affected by industrial and other emissions of carbon dioxide and other greenhouse gases."

The Clean Development Mechanism (CDM) of the Kyoto Protocol allows implementing project activities that reduce emissions in non-Annex I Parties, in return for certified emission reductions (CERs). Accordingly, the CERs generated by such project activities can be used by Annex I Parties to help meet their emission targets under the Kyoto Protocol.

3.12.2 United Nations Convention on Biological Diversity (UNCBD)

The objective of the UNCBD is "the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies and by appropriate funding."

Maldives was one of the first nations to ratify the UNCBD. In 2002, Maldives developed the National Biodiversity Strategy and Action Plan (NBSAP) through wide consultation and extensive stakeholder participation.

3.12.3 Male' Declaration on Control and Prevention of Air Pollution and its Likely Transboundary Effects for South Asia

The objectives of Male' Declaration includes:

- Assessing and analyzing the origin and causes, nature, extent and effects of local and regional air pollution,
- Developing and/or adopting strategies to prevent and minimize air pollution
- Setting up monitoring arrangements beginning with the study of sulphur and nitrogen and volatile organic compounds emissions, concentrations and deposition.

3.12.4 1994 Barbados Programme of Action for Small Island Developing States – Waste Management Section

This Programme of Action makes the suggestions that:

- Sewage disposal in small island states should look for ways to convert wastes, such as sewage, into a resource such as compost or sewage
- Sewage disposal companies should work to change community attitudes to the disposal and use of sewage
- Implement appropriate regulatory measures for the reduction, prevention, control and monitoring of pollution and for safe and efficient management of solid wastes
- Develop information systems and baseline data for waste management and pollution control, monitoring the types and quantities of wastes, for both sea- and land-based sources of pollution
- Facilitate the formulation and implementation of public awareness and education campaigns designed to gain local recognition of the need to control wastes at the source; the value of reuse, recycling and appropriate packaging; and of the possibilities for converting wastes to resources in culturally appropriate ways

4 Existing Baseline Conditions

4.1 Introduction

This section assembles, evaluates and presents baseline data on the relevant environmental characteristics of the study area and includes the following subsections:

1. Study Methodologies
2. Physical Environment
    a) Climate

       General climatic patterns, wind, rainfall

    b) Coastal Environment

       Waves, currents, tides, bathymetry, coastal geomorphology

    c) Lagoon and reef flat

       Lagoon bottom conditions and marine water quality

3. Natural and Biological Environment

a) Terrestrial Environment

Groundwater aquifer

b) Coral Reefs

Marine life including coral reef and other marine organisms

4. Socio-economic Environment

a) Social setup of Miladhoo and Noonu Atoll

b) Economic setup

4.2 Methodologies

Baseline environment of the study area were analysed by using standard scientific methods. The environmental components of the study area were divided into marine, terrestrial, coastal and aquatic resources. The marine environment of the island covered the lagoon habitats including coral patches and marine water quality. The coastal environment covered the coastal processes including longshore sediment transport, nearshore currents, tides and wave climate. The terrestrial environment covered groundwater quality.

Particular attention was placed in detailed surveys on the marine environment life, as these components are likely to involve the most significant environmental Impacts. The different methods used in assessing and presenting the conditions of the existing environment of the island are given in the following subsections.

4.2.1 Study area and Survey Locations

The study area covers much of the surrounding lagoon area of Miladhoo. Figure 4.1 below shows the specific study area.

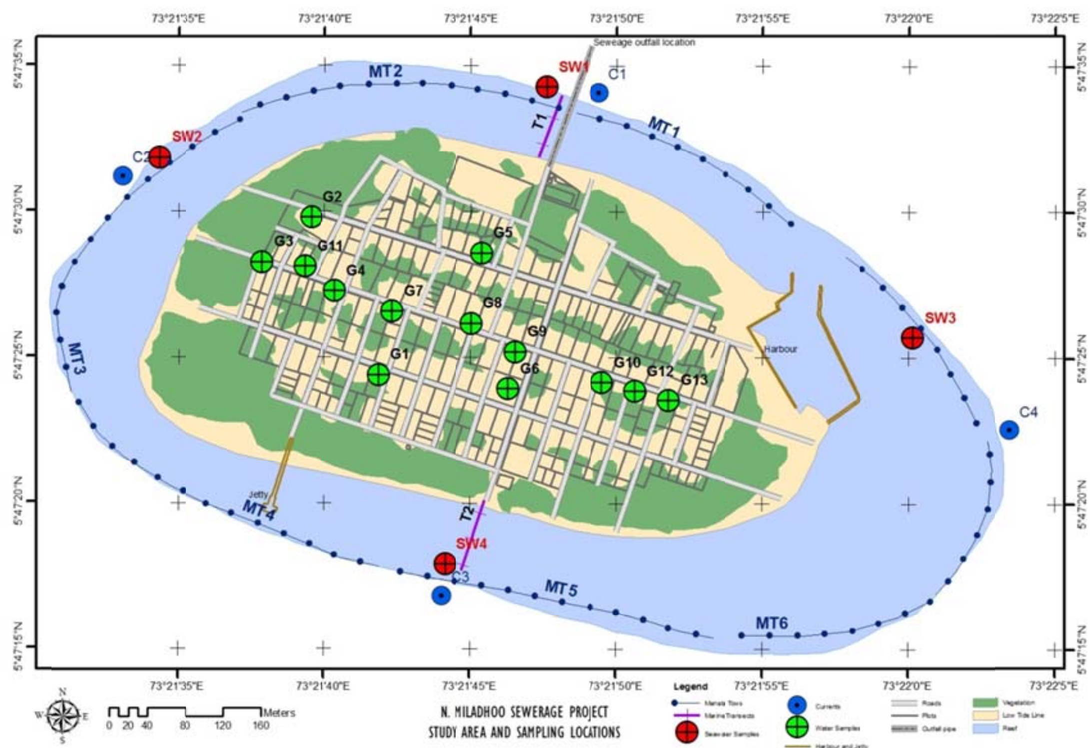

Figure 4-1 Survey locations.

The location of data collection sites have been identified using GPS. The details of the locations are presented in Appendix 8.

4.2.2 Aquatic Resources

One of the main environmental components that would be affected by implementing the project would be the aquatic resources and water quality. Water quality was assessed at four different locations during the field visit to Miladhoo from 3rd to 6th September 2010. Samples were collected in clean 500ml PET bottles after washing them with water to be sampled. Also to test for biological content (faecal coliform), samples were collected in sterilized 250ml glass bottles provided by the National Health Laboratory. Parameters tested for sea water quality assessment were Biological Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Total Suspended Solids (TTS), pH, temperature, and Enterococci. For ground water quality assessment parameters tested were Total Coliform, Electrical Conductivity, Nitrates, Phosphates, pH and Ammonia. All samples were analysed at the Maldives Food and Drug Authority (MFDA) Laboratory. Some of the parameters could not be tested at the Laboratory and a letter from MFDA is provided in Appendix 5 stating the reasons for this.

4.3 Physical environment

4.3.1 Geologic setting

Miladhoo is a slightly elongated island of about 700 m long and 365 m wide with an area of 22 hectares lying on the central-eastern area of Noonu Atoll. The island is situated in the middle of an oval-shaped house reef and occupies about 70% of the total reef area. The distance between the shoreline and the reef flat edge ranges between 30-50 m. The island and the reef system is oriented in an east-west direction.

The natural environment of this island has been considerably modified. From a geomorphological perspective the main alterations are on the beach where reclamation activities have been undertaken in the past during the harbour dredging project.

Its shape, location and proximity to reef edge does not favour the formation of wide sandy beaches all around the island. The island is low lying with an average elevation of +1.3 m MSL. Miladhoo should be considered moderately mature island with reef system large saturated with the island and without room for further growth. The high seasonal mobility of beach sediments keeps the shore line periodically shifting although the harbour dredging activity has considerably altered this process.

The influence of Indian Ocean oceanographic and climatic factors on the geologic setting and environment is likely to be less pronounced in Miladhoo than the islands on the rim of the atoll. Being located inside the atoll lagoon, the environmental forcing is mainly dominated by monsoonal currents. However, the wide channel between Maafaru and Manadhoo causes swell waves to penetrate through the channel and influence the local hydrodynamics around Miladhoo.

4.3.2 Climatic setting

The Maldives, in general, has a warm and humid tropical climate with average temperatures ranging between 25°C to 30°C (MHAHE, 2001) and relative humidity ranging from 73 per cent to 85 per cent. The country receives an annual average rainfall of 1,948.4mm. There is considerable variation of climate between northern and southern atolls. Table 4.1 provides a summary of key meteorological findings for Maldives. General studies on climatic conditions of Maldives were taken into account during study as local level time-series data are limited for longer periods at the nearest meteorological station in Hanimaadhoo.

Table 4-1 Key Meteorological Information

Parameter	Data
Average Rainfall	9.1mm/day in May, November 1.1mm/day in February
Maximum Rainfall	184.5 mm/day in October 1994
Average air temperature	30.0 C in November 1973 31.7 C in April
Extreme Air Temperature	34.1 C in April 1973 17.2 C in April 1978
Average wind speed	3.7 m/s in March 5.7 m/s in January, June
Maximum wind speed	W 31.9 m/s in November 1978
Average air pressure	1012 mb in December 1010 mb in April

4.3.2.1 Monsoons

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

4.3.2.2 Wind

The two monsoon seasons have a dominant influence on winds experienced across Maldives. These monsoons are relatively mild due to the country's location close to the equator and strong winds and gales are infrequent. However, storms and line squalls can occur, usually in the period May to July; gusts of up to 60 knots have been recorded at Male' during such storms.

Wind was uniform in speed and direction over the past twenty-plus monsoon seasons in the Maldives (Naseer, 2003). Wind speed is usually higher in central region of Maldives during both monsoons, with a maximum wind speed recorded at 18 m.s-1 for the period 1975 to 2001. The highest wind speed recorded in the northern region for the period 1992 to 2001 was 12.3 $m.s^{-1}$. Mean wind speed was highest during the months May and October in the central region. Wind analysis indicated that the monsoon was considerably stronger in the central and northern region of Maldives compared to the south (Naseer, 2003). During the peak months of the SW monsoon, Miladhoo may experience strong wind and associate rise in water level.

Table 4.2 summarises the wind conditions in Miladhoo throughout a year. Medium-term meteorological data from Hanimaadhoo Airport weather station (see figures 4.2 to 4.4) and findings from long-term Comprehensive Ocean-Atmosphere Data Set (COADS) were used in this analysis.

Table 4-2 Summary of predicted wind conditions in Miladhoo

season	Month	Wind
NE - Monsoon	December	Predominantly from NW-E. High Speeds from N & NE
	January	
	February	
Transition Period 1	March	From all directions. Mainly NW and E. High Speeds from N & NW
	April	
SW - Monsoon	May	Mainly from W and NW. High Speeds from W & WNW
	June	
	July	
	August	
	September	
Transition Period 2	October	Mainly from W. High Speeds from W
	November	

Figure 4-2 Monthly frequencies of wind direction in Northern Maldives based on Hanimaadhoo Stations 10 year Data (adapted from Naseer, 2003).

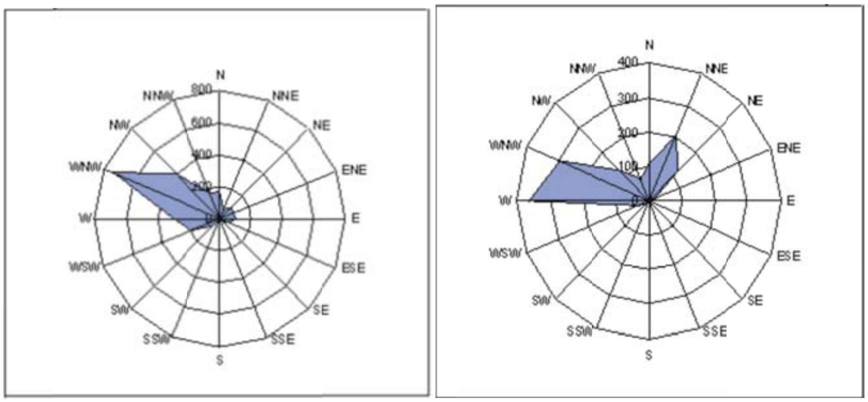

Figure 4-3 10 year wind frequency for Hanimaadhoo weather station (in Days) and long term COADS data (adapted from Naseer, 2003).

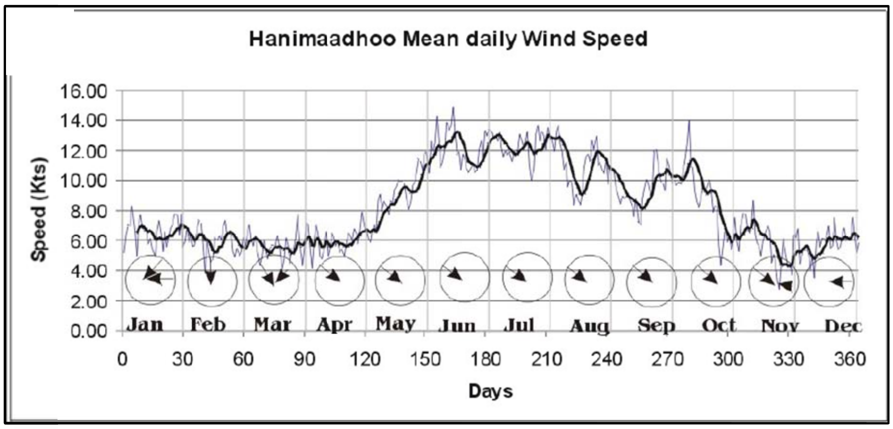

Figure 4-4 Mean daily wind speed and direction Hanimaadhoo Airport. Arrows indicate dominant wind direction (adapted from Naseer, 2003).

4.3.2.3 Waves

Long-term site specific data on wave conditions in Miladhoo were not available. Due to the limitations in data, studies conducted in similar settings of Maldives have been considered as a general guide to wave conditions in Miladhoo.

Generally, two major types of waves have been reported on the coasts of the Maldives: wave generated by local monsoon wind and swells generated by distance storms. The local monsoon predominantly generates wind waves which are typically strongest during April-July in the south-west monsoon period. During this season, swells generated north of the equator with heights of 2-3 m with periods of 18-20 seconds have been reported in the region. Local wave periods are generally in the range 2-4 seconds and are easily distinguished from the swell waves. The location of Miladhoo reduces its exposure to swell waves and monsoon generated wind waves as it is protected by rim reefs.

Distant cyclones and low pressure systems originating from the intense South Indian Ocean storms are reported to generate long distance swells that occasionally cause flooding in Maldives (Goda, 1988). The swell waves that reached Malé and Hulhule in 1987, thought to have originated from a low pressure system of west coast of Australia, had significant wave heights in the order of 3 metres. Medhafushi could experience the effects of such waves reaching Maldives.

In addition, Maldives have recently been subject to earthquake generated tsunami reaching heights of 4.0m on land (UNEP, 2005). Historical wave data from Indian Ocean countries show that tsunamis have occurred in more than 1 occasion, most notable been the 1883 tsunami resulting from the volcanic explosion of Karakatoa (Choi et al., 2003). Miladhoo is vulnerable to such waves but to a lesser extent than the islands on the rim.

In summary, wave conditions in project site are expected to be moderate to low in general and moderate to high during SW monsoon and peak NE monsoon. The peak periods of SW and NE monsoon may cause waters around Miladhoo to be rough but is unlikely to experience major swells. This aspect of climate will therefore have an effect on the design of coastal protection.

Table 4-3Summary of estimated wave condition in Miladhoo

Season	Short Period Waves
NE - Monsoon	Mainly E-NE. Moderate to high waves from E
Transition Period 1	Mainly from NE-SE
SW - Monsoon	Mainly from SE-S. High waves from E
Transition Period 2	From SE-W. Moderate to Higher waves from E

4.3.2.4 Currents

Currents which affect the sea areas around Miladhoo reef system can be the result of one or more of tidal currents, wind-induced currents and wave-induced currents.

It is presumed that dominating two-monsoon season winds have a greater effect on both oceanic currents and lagoonal currents around Maldives. Westwardly flowing currents are dominated from January to March and eastwardly from May to November.

Studies on current flow within a reef flat in Male' Atoll suggests that wave over wash and tides generate currents across the reef platforms, which are also capable of transporting sediments (Binnie Black & Veatch, 2000).

In general terms, the tidal component of current is eastward during flood tide and westward during ebb tide.

Currents were measured during the field survey to determine the general trends. These figures only provide a snapshot of the situation at the time of survey. Measurement of currents requires longer periods of measurement to get any meaningful picture of the localised patterns. However, the time available for this EIA is not suitable for such measurements.

The currents speeds at the time of the survey were negligible and are summarised Table 4-4. Location of current surveys are shown in the survey location map in Figure 4.1.

Table 4-4 Current speeds at Miladhoo

Site ID	Speed m/sec	Direction (deg)	Time of Survey
C1	<0.05	105	10:00 – 10:15
C2	0.1	110	10:30 – 10:45
C3	<0.05	95	11:00 – 11:15
C4	0.03	150	11:15 – 11:30

4.3.2.5 Tides

Tides experienced in Maldives are mixed and semi-diurnal/diurnal. Typical spring and neap tidal ranges are approximately 1.0m and 0.3m, respectively (MEC, 2004). Maximum spring tidal range in the central and southern atolls is approximately 1.1m. There is also a 0.2m seasonal fluctuation in regional mean sea level, with an increase of about 0.1m during February to April and a decrease of 0.1m during September to November. Tidal variations in Maldives are presented in Table 4.5. Tidal measurements were carried out during the field surveys in Miladhoo but were insufficient to discern any major trends due to the short duration (3 days) of observation.

Table 4-5 Tidal Variations at Male' International Airport

Tide Level	Referred to Mean Sea level
Highest Astronomical Tide (HAT)	+0.64
Mean Higher High Water (MHHW)	+0.34
Mean Lower High Water (MLHW)	+0.14
Mean Sea Level (MSL)	0.00
Mean Higher Low Water (MHLW)	-0.16
Mean Lower Low Water (MHLW)	-0.36
Lowest Astronomical Tide (LAT)	-0.56

Source: MEC, 2004

The predicted astronomical tides provided above may vary at any given time and location based on a number of meteorological and other factors including:

- Wind set-up or set-down, due to onshore or offshore winds;
- Atmospheric pressure deficiency or excess, due to areas of low or high pressure, leading to a positive or negative surge component respectively.
- Wave set-up or set-down due to 'groupiness' of waves reaching the shore, due to 'surf beats', or due to ponding of broken waves.
- Seasonal variation in Mean Sea Level; and
- Tsunamis

4.3.2.6 Rainfall

Annual average rainfall in Maldives is about 1900 mm. There is a marked variation in rainfall across Maldives with an increasing trend towards south. The annual average rainfall in north is 1977 mm and for south is 2470 mm.

The southwest monsoon is known as the wet season with monthly average rainfall ranging from 125-250 mm. The northeast monsoon is known as the dry season with average monthly rainfall of 50-75 mm.

Long term data for Miladhoo area are not available. Medium term records in Hanimaadhoo indicate an average annual rainfall of 1977 mm.

The possibility of lack of rainfall during dry periods may be a concern for shortage of drinking water, aquifer recharge and terrestrial environment in general.

4.3.2.7 Temperature

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

32.7°C, the next highest being 32.6°C in April 1998. The lowest minimum average temperature of 23.7°C was recorded in July 1992.

Average daily temperatures for Hanimaadhoo Meteorological Station vary between 26°C and 31°C and hence Miladhoo is expected to have a similar variation.

4.3.3 Groundwater

4.3.3.1 Groundwater Quantity

Methodology

Based on numerous studies carried out in the Maldives over the past years and comparative studies in the Pacific, it has been determined that approximately 25 to 50% of recharge to the freshwater lens can be sustainably extracted. This value increases with consistency in rainfall events. In studies carried out by Falkland (2001) in the Northern areas of the Maldives a figure for sustainable extraction of 30% of recharge was adopted due to the variability of rainfall in this region. Given the location of Miladhoo, the more conservative figure of 30% of recharge has been adopted.

Water Storage Capacity-Fresh Water Lens

Based on numerous studies carried out in the Maldives over the past years, it has been determined that Maldivian Islands, as with other atoll Islands studied in the Pacific, typically display two distinct sediment layers between depths of 10 to 15 m (Woodrofe and Falkland, 1997). Extensive study of such Islands has identified that the freshwater lens typically lies within the upper sediments which are of low permeability compared to the lower sediments. In addition to these criteria it is generally assumed that for the purposes of estimation, there is direct correlation between the thickness of the fresh water lens and the height of the fresh water lens above MSL. As a general rule the thickness of the fresh water lens can be determined as the height above MSL multiplied by a factor of 12. The average height of the fresh water lens above MSL for Miladhoo is approximately 0.4m. Applying a porosity factor of coarse gravel sand of 0.4, Table 4-6 below gives the estimated volume of the freshwater lens.

Table 4-6 Estimated volume of freshwater in Miladhoo

Area of lens	Unit	TOTAL
Island Area	m^2	18,000.00
Fresh Water lens	m^2	140,000.00
Average height above MSL	m	0.3

Multiplication Ratio	m	12
Estimated thickness	m	3.6
Available Volume	m^3	504,000.00
Porosity/ Coarse Sand	No	0.40
Total Volume	m^3	201,600.00

In addition to the above assumptions it is generally assumed that a 50 m mixing zone exists between the freshwater lens and area of salinity around the edge of the Island. This buffer zone is allowed for when estimating the capacity of the freshwater lens. Allowing for the fresh to saline mixing zone, Figure 1 below illustrates the fresh to saline mixing zone.

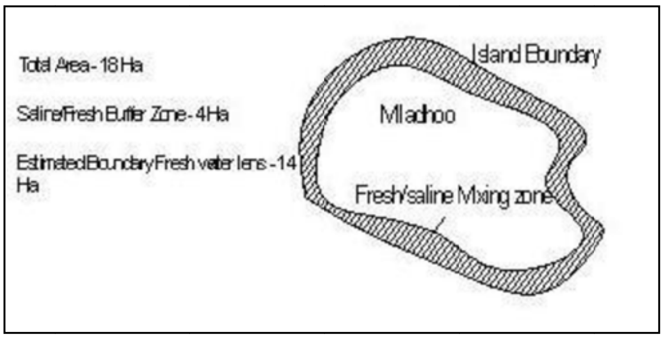

Figure 4-5 An illustration of the fresh to saline mixing zone

Estimated Recharge

The estimated recharge back to the freshwater lens is assumed to be all water not consumed for drinking and cooking purposes. This approach is adopted as the freshwater lens in Miladhoo is considered to be highly contaminated owing to the practice of discharge of blackwater to the water table through malfunctioning septic tanks. The poor quality of the water table is confirmed by the presence of "rotten egg" gas smell present in water drawn from the fresh water lens. The unpleasant odor is largely due to the liberation of sulfur gas during denitrification indicating high levels of nitrogen, and subsequently blackwater contamination, in the water table. Table 4-7 indicates the total wastewater recharged back into the water table from wastewater sources.

Table 4-7 Total wastewater recharged back into the water table from wastewater resources

Total Water Extracted	l/day	142,450.00
Evapotranspiration	%	0.50%
Total Recharge (WW)	l/day	141,737.75

Using rainfall data for the Northern Atolls the total annual recharge due to rainfall is given in Table 4-8.

Table 4-8 Total annual recharge due to rainfall

Total Extracted	m^3/Y	51,994.25
Recharge Wastewater	m^3/Y	51,734.28
Recharge Rainfall	m^3/Y	138,600.00
Sustainable Extraction	%	30%
Sustainable Extraction	m^3/Y	57,100.28
Deficit	m^3/Y	5,106.03

The data indicates that present extraction practices are only just maintaining the fresh water lens with a limited surplus. Assuming the total removal of all recharge from the fresh water lens the model used for evaluating the sustainability of present consumption rates in simulating the collection and discharge of both black and grey water is given in Table 4-9.

Table 4-9 Model used for evaluating the sustainability of present consumption rates

Total Extracted	m^3/Y	51,994.25
Recharge Rainfall	m^3/Y	138,600.00
Sustainable Extraction	%	30%
Sustainable Extraction	m^3/Y	41,580.00
Deficit	m^3/Y	(10,414.25)

Table 4-9 indicates that with the installation of the new system combined with current extraction rates will ultimately result in over extraction of water from the freshwater lens. Given the sustainable extraction rate, to maintain the sustainable yield for Miladhoo, island residents would have to reduce consumption rates to approximately 85L/p/day. Assuming this is not an option, the removal of greywater from the collection system could potentially improve the daily sustainable yield from the fresh water lens to 108 L/p/day.

4.3.3.2 Groundwater Quality

Ground water quality was assessed by taking samples from 13 different locations during the field visit to Miladhoo from 3rd to 4th September 2010. At each location, samples were collected in a 100 ml sterilized glass bottle to test for biological content and 1.5 l clean PET bottles to test for all other parameters. Samples in the PET bottles were collected after washing the bottle with the sample to be collected. Time and date of sampling was also recorded. All samples were to the

National Health Laboratory to be analysed. Details of the location are included in the sampling survey map.

There are no national groundwater quality standards or guidelines; therefore the results were compared to WHO drinking water standards. Values exceeding the WHO drinking water standards are highlighted in the table. However it must be noted here that groundwater not used for drinking in the island, but used mainly for washing and bathing. Results of the tests are given in the Table 4-10.

Table 4-10 Results for water quality testing for ground water.

Parameter	Sample ID						WHO Standards for Drinking Water
	GI	G2	G3	G4	G5	G6	
Total Coliform	0	32	0	0	0	0	0
Physical appearance	Clear with suspended particles	Clear with suspended particles	Clear with suspended particles	Clear with suspended particles	Clear with suspended particles	Clear with suspended particles	Clear and colorless
pH	7.4	7.5	7.4	7.5	7.8	7.2	6.5 – 8.5
Electrical Conductivity	634 µs/cm	794 µs/cm	785 µs/cm	805 µs/cm	575 µs/cm	478 µs/cm	<1500 mg/L
Reactive Phosphate	0.17 mg/L	0.20 mg/L	0.11 mg/L	0.22 mg/L	3.51 mg/L	0.19 mg/L	-
Ammonia, Nitrogen	0.30 mg/L	3.30 mg/L	0.37 mg/L	1.07 mg/L	0.00 mg/L	0.52 mg/L	<1.5 mg/L

Parameter	Sample ID							WHO Standards for Drinking Water
	G7	G8	G9	G10	G11	G12	G13	
Total Coliform	32	0	0	150	0	0	0	0
Physical appearance	Clear with suspended particles	Clear with suspended particles	Clear with suspended particles	Clear with suspended particles	Clear with suspended particles	Clear with suspended particles	Clear with suspended particles	Clear and colorless
pH	7.5	7.5	7.7	7.5	7.7	7.7	7.6	6.5 – 8.5
Electrical Conductivity	522 µs/cm	1354 µs/cm	607 µs/cm	997 µs/cm	828 µs/cm	664 µs/cm	1809 µs/cm	<1500 mg/L
Reactive	0.16	0.12	0.59	0.14	0.21	0.16	0.30	-

Phosphate	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
Ammonia, Nitrogen	3.25 mg/L	8.35 mg/L	0.06 mg/L	0.06 mg/L	3.45 mg/L	0.03 mg/L	0.02 mg/L	<1.5 mg/L

4.3.4 Rainwater Quantity

According to the latest Island Information form, provided by the island office the island has 107 rainwater tanks (5000 L), which means the island has a capacity to store 535,000 L of rainwater.

4.3.4.1 Bathymetry

A detailed bathymetric survey of the island and its reef system was undertaken during September 2010. Survey results have been summarised in bathy charts presented in Appendix 5. The depth figures presented are in meters below MSL.

The reef flat areas around the island are fairly narrow and have a fairly flat depth ranging from -1.0 to -1.5m MSL as shown in Figure 4-6. Areas west of the island gently slope into the atoll lagoon. Around the rest of the island the reef slope is steep. The beach line is closest to the reefline on the northern and south eastern side.

The water depths within the main entrance channel and harbor are around 3 m MSL. There is a portion of the harbour with sand deposits reaching to within 1.0 m MSL. This area is shallowing rapidly. These sediments have moved in by the due to the natural processes of sediment movement, particularly during the SW monsoon

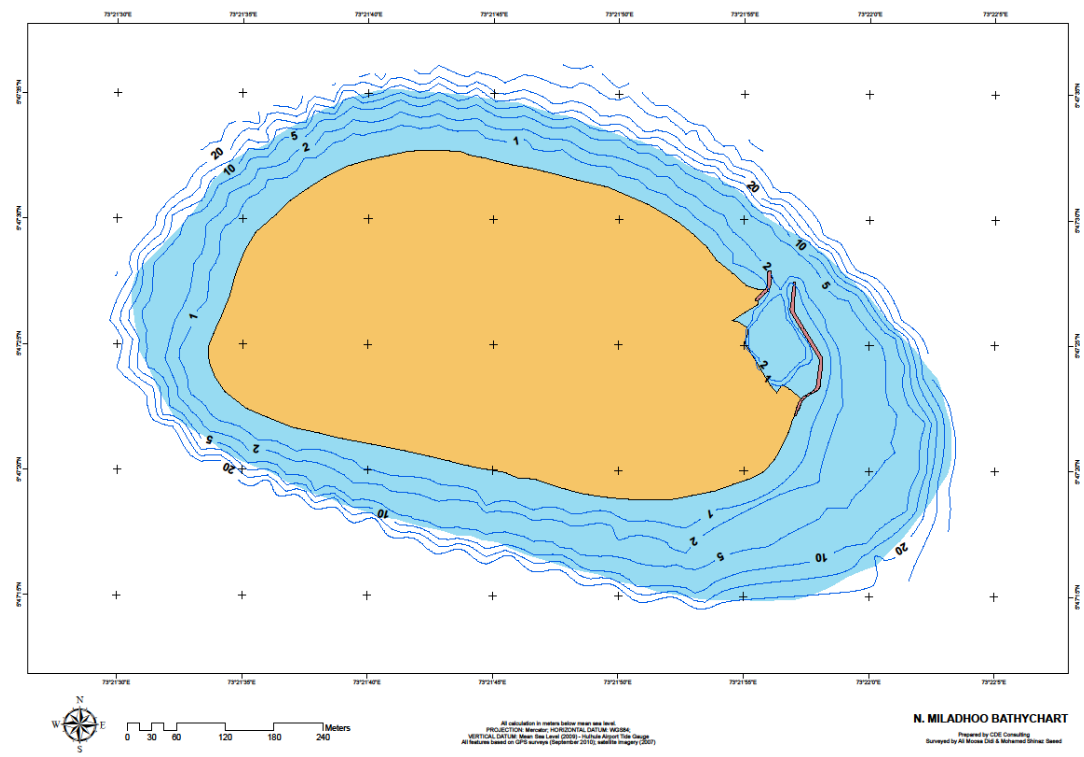

Figure 4-6 Bathymetry of Miladhoo

4.3.5 Geomorphology and Coastal dynamics

4.3.5.1 Beach and Beach rock

Miladhoo Island has a well established but a heavily modified beach system as shown in Figure 4-7. During the development of the harbour beach areas on the north and eastern side of the island replenished due to erosion.

The impact of the harbour construction on the beach environment appears to be significant. At present, the movement of sediment around the island has been stopped due to the dredged basin. Movement of sediment eastward during the SW monsoon is now causing the harbour to become shallow. There is an area on the northwestern corner of the island (see map below) which has shallowed by over 2.5 m, making the area inaccessible for boats.

In general, the beast beach area of the island is the western side. However, the beach is retreats significantly during the peak SW monsoon and returns back in NE monsoon. There is constant erosion on the south eastern side with exposed beach rock.

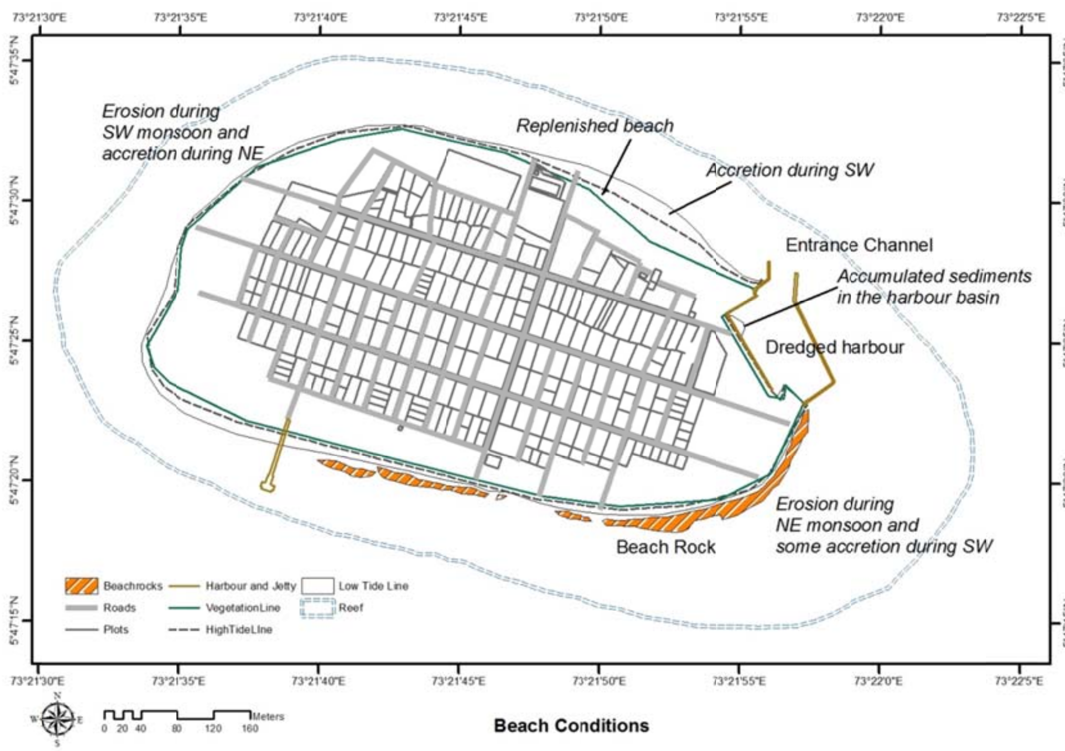

Figure 4-7 Beach conditions at Miladhoo

4.3.6 Lagoon Water Quality

The primary objective of the lagoon water quality sampling was to determine the baseline conditions of the marine water surrounding Miladhoo. Quality of coastal water is not only important for the ecological functioning of organisms living in the habitat but also important for aesthetic and health reasons such as swimming in unpolluted waters. As the proposed project involves disposal of significant amounts of sewerage into the water, marine water quality should be treated as an important indicator of environmental impacts. Four sampling locations were identified on the island and are shown in Figure 4-1.

Water quality tests were done at MFDA. Tests covered both biological and ambient conditions as shown in Table 4-11.

Table 4-11 Sea Water Quality Results

Parameter	SWI	SW2	SW3	SW4
Physical appearance	Clear with suspended particles	Clear with suspended particles	Clear with suspended particles	Clear with suspended particles

Temperature	24.3 °C	24.3 °C	24.3 °C	24.3 °C
Biological Oxygen Demand	38mg/L	24mg/L	42mg/L	34mg/L
pH	8.0	8.3	8.4	8.3

4.4 Natural and biological environment

4.4.1 Marine environment

4.4.1.1 Introduction

This marine assessment was conducted on the 4th-5th of September 2010; the weather during the assessments was mostly sunny with few clouds. The main objectives of this assessment were to determine the overall condition of the marine environment of the island, and identify areas impacted by both natural and anthropological activities. In addition quantitative surveys were conducted on corals and fish populations in the locations shown in Figure 4-1.

4.4.1.2 Methodology

Firstly a manta tow survey was done around the reefs around the island. The tow was divided into 2 minute survey; with two snorkeler's simultaneously recording and photographing the reef area. Results of this survey are presented below.

Secondly, 20 m transects were laid perpendicular to the island on the reef area of the proposed location of the sewage disposal pipe and the alternative site. Benthic composition and fishes present at transect was recorded.

4.4.2 Manta tow results

For descriptive purposes the tow results have been divided into 7 zones as shown in Figure 4-8. Benthic composition at these zones is shown in chart below.

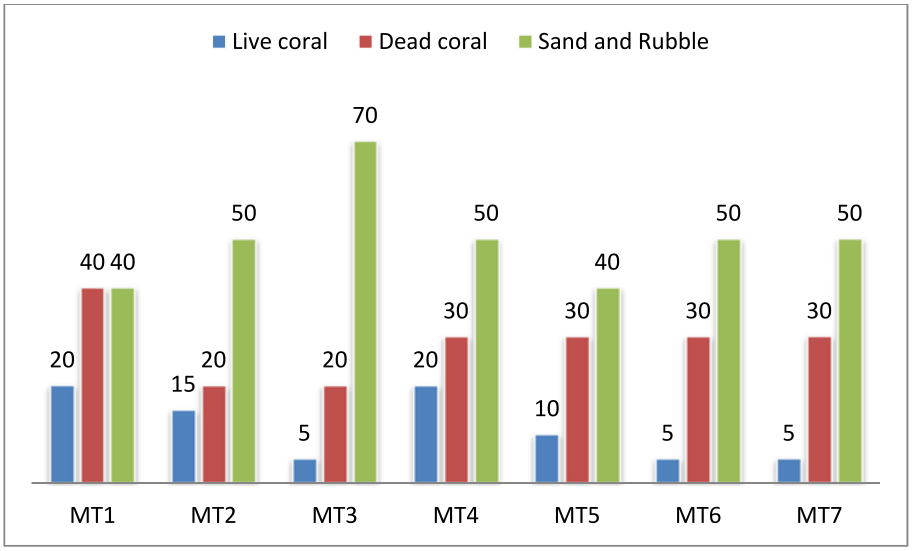

Figure 4-8 Benthic composition at Zone A to G

Most common type of coral that occur in the reefs of this island is small to medium sized boulder shaped massive corals (Figure 4-9). In addition corals of the genera Pocillopora, Acropora and solitary Fungia were observed. Two main types of soft corals that occur around the island are of the genera Sarcophyton (Figure 4-10) and Sinulari.

Figure 4-9 Small boulder shaped massive corals at zone MT1

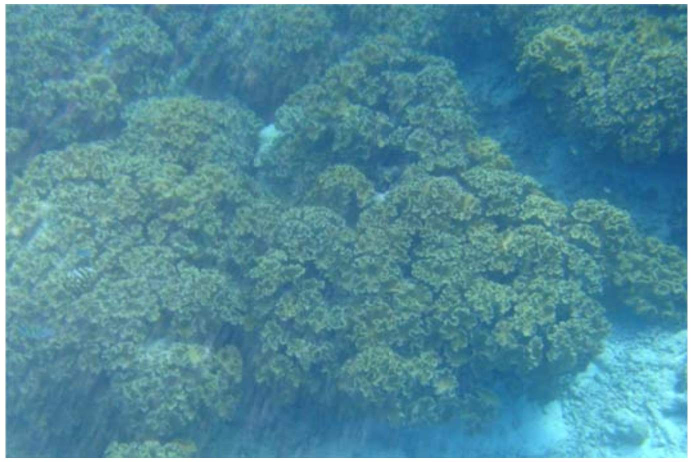

Figure 4-10 Large colonies of Sarcophyton species (soft coral)

Most commonly observed fishes during the manta tow were Powder Blue Surgeonfishes (Acanthurus leucosternon), Goldspot emperors (Ganthodentex aureolineatus), Blue-striped snapper (Lutjanus kasmira), and several species of Rabbitfishes, Unicornfishes, Butterflyfishes and Parrotfishes. Both Goldspot Emperor and Blue-striped Snapper were observed in large schools at several locations around the island (Figure 4-11). List of fish species observed during the manta tow is included Table 4-12.

Table 4-12 List of fish species observed at Miladhoo

Genus	Species	Common name
Abudefduf	vaigiensis	Sergeant major
Acanthurus	leucosternon	Powder blue surgeonfish
Balistoides	viridescens	Titan triggerfish
Carangoides	orthogranmus	Yellow spotted trevelly
Chaetodon	collare	Head-band butterflyfish
Chaetodon	meyeri	Meyers butterflyfish
Dascyllus	aruanus	Hambug damsel
Ephinephelus	longispinis	Longspine grouper
Forcipiger	longirostris	Very-long-nose butterflyfish
Ganthodentex	aureolineatus	Goldspot emperor
Halichoeres	hortulanus	Checkerboard wrasse
Hemigymnus	fasciatus	Barred thicklips
Hemitaurichthus	zoster	Black pyramid butterflyfish
Henioclaus	acutninatus	Reef bannerfish
Henioclaus	dipherutes	Schooling bannerfish
Lutjanus	kasmira	Blue-striped snapper
Lutjanus	madras	Indian snapper
Melichthys	indicus	Indian triggerfish

Myripristine	murdjan	Bloteye soliderfish
Naso	brachycentron	Humpback unicornfish
Naso	lituratus	Orange-spine unicornfish
Naso	hexacanthus	Sleek unicornfish
Paracirrhites	foresteri	Freakled hawkfish
Paracirrhites	foresteri	Blackside hawkfish
Pomacentru	indicus	Indian damsel
Scarus	rubroviolaceus	Ember parrotfish
Scarus	tricolor	Three color parrotfish
Scarus	sordides	Shabby parrotfish
Thalassonma	hardwicke	Six-bar wrasse

Figure 4-11 School of blue-striped snappers and goldspot emperors

Waste material such as plastic bags, diapers, old anchors, long metal rods, ropes and even large tree trunks were observed at several locations around reefs of the island (Figure 4-12). These materials are most probably washed off from the beaches of the island (residents of the island use beaches to dispose waste).

Figure 4-12 Waste material observed on the reefs

No significant signs of coral bleaching or populations of Crown-Of-Thorn Starfishes were observed during the manta tow. However the wave strength on the southern western side of the island was very strong and the area was mostly composed of sand and dead coral rubble.

Several large spur and groove formations perpendicular to the island with grooves in-between was observed on the south eastern side, shown in Figure 4-13. These types of formations are result of long term strong wave action.

Figure 4-13 Spur and Groove formations perpendicular to island observed at MT6

4.4.2.1 Transect 1

A 20 m transect perpendicular to the island was laid on the reef area on the proposed sewage outfall location. Large portion of this area was covered with coral rubble and sand. The most dominant corals were small boulder shaped submassive corals. Few fish species was observed at this site, these species are common all around the island as recorded in the manta tow survey. List of fishes observed at transect 1 is given in Table 4-13.

Table 4-13 List of fishes observed at transect 1

Genus	Species	Common Name	Fish count
Acanthurus	leucosternon	Powder-blue surgeonfish	2
Cephakopholis	argus	Peacock rock cod	2
Chaetodon	trifasciatus	Pinstriped butterflyfish	2
Forcipiger	longirostris	Very-long-nose butterflyfish	1
Melichthys	indicus	Indian triggerfish	1
Naso	lituratus	Orange-spine unicornfish	1
Pygoplites	diacanthus	Regal angelfish	1
Scarus	rubroviolaceus	Ember parrotfish	1

Besides the species of groupers observed and a few giant calms no other species of significant economic value such as sea turtles, sea cucumbers, lobsters or sharks were observed during the survey. As this survey was conducted during day time, it is possible some of the nocturnal species are missed out during this survey.

Predominant type of live coral at this transect location are small boulder shaped submassive coral. In addition few solitary mushroom corals and small Acropora branching corals were also observed. Young soft corals of the species Sinularia was present. However large portions of this transect was covered in sand and rubble.

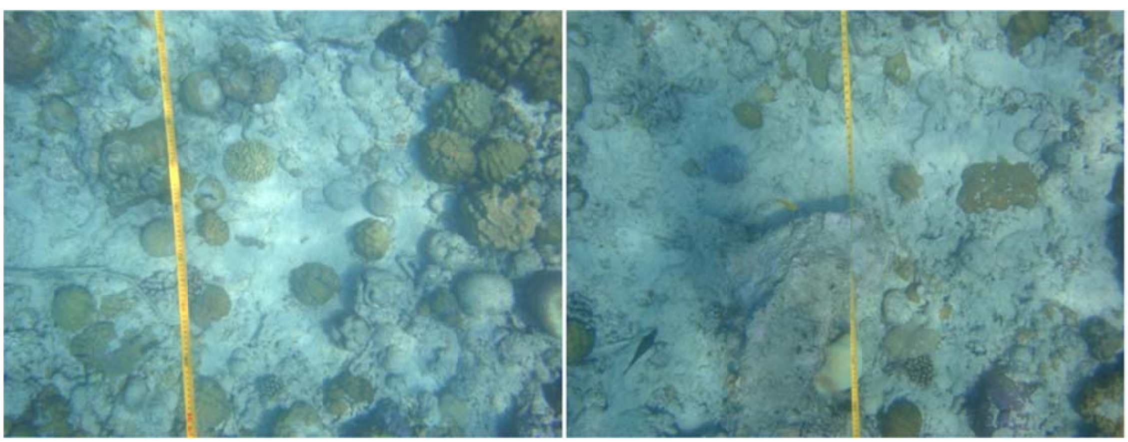

Figure 4-14 Selected photographs at transect 1

Total live coral cover estimated at this transect is 15%, dead corals 30% and sand and rubble at 60% as show in the Figure 4-15.

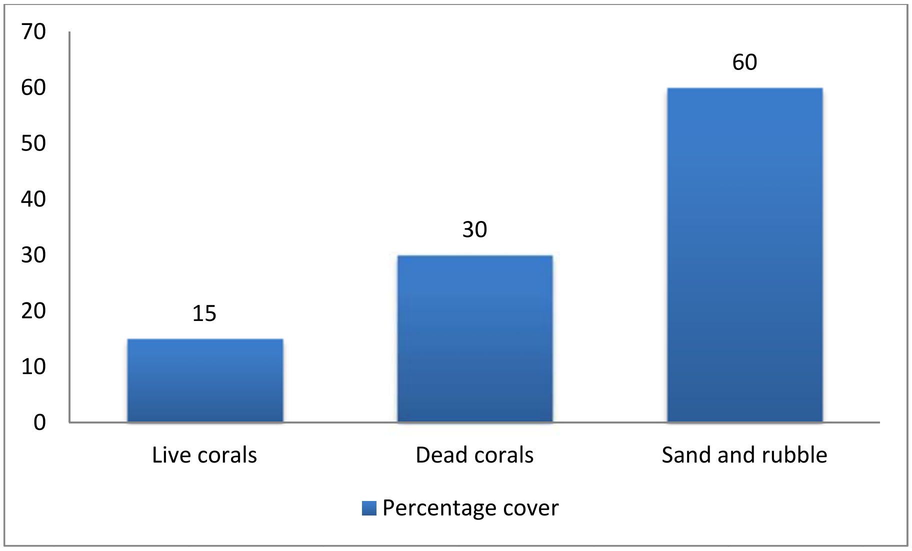

Figure 4-15 Benthic composition at transect 1

4.4.2.2 Transect 2

Transect 2 was planned to be conducted at the alternative sewage outfall location, however due to high wave action on the southern side of the island during the survey it was impossible to carry out a transect survey at this location.

Results generated from the manta tow, indicate this area has low live coral cover and is mainly composed of dead corals, sand and rubble.

4.5 Socio-economic Environment

4.5.1 Noonu Atoll Socio-Economic Setup

Noonu Atoll consists of 13 inhabited islands distributed over approximately 33km by 31 km area (see Figure 4-16 above). Population of the Atoll stands at around 10,080 (MPND 2006a). There are 4 major population centres in the Atoll; Velidhoo, Manadhoo the Capital Island, Holhudhoo and Kendhikulhudhoo. Together they account for more than 56% of the atoll population (see Table 4.14 below). Seven of the inhabited islands have a population below 600, often an indicator of poor economic conditions in these islands. The majority of the population of the atoll was below 15 years of age in 2000 and is expected to remain so today.

Figure 4-16 Socio-economic map of Noonu Atoll

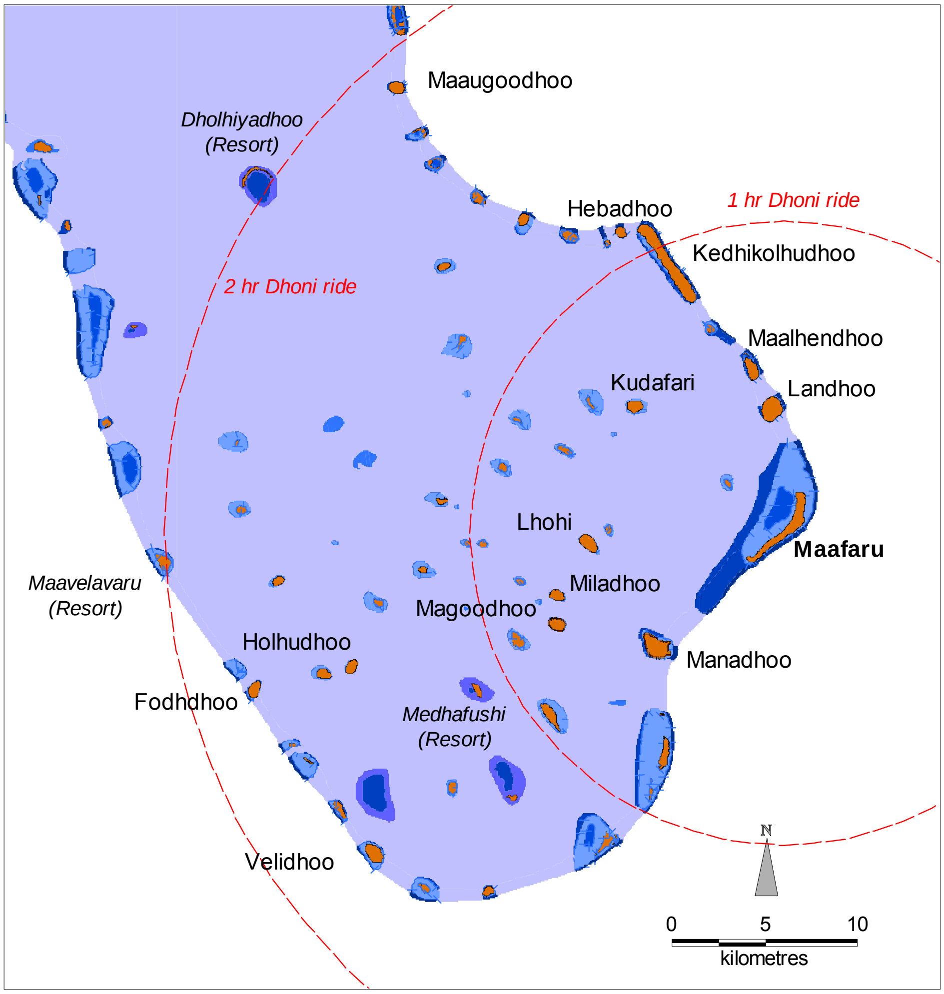

Table 4-14 Population of Noonu Atoll

Island Name	Population 2006	%	Population 2000	Children& School age	Working Age	Old
Hebadhoo	396	4%	417	60%	38%	2%
Kedhikolhudhoo	1209	12%	1114	58%	37%	5%
Maalhendhoo	561	6%	567	54%	41%	5%
Kudafari	381	4%	394	56%	38%	6%
Landhoo	582	6%	653	57%	39%	4%
Maafaru	**716**	**7%**	**758**	**61%**	**35%**	**4%**
Lhohi	557	6%	525	59%	38%	3%
Miladhoo	817	8%	808	57%	37%	6%
Magoodhoo	209	2%	242	55%	38%	6%
Manadhoo	1221	12%	1238	58%	37%	5%
Holhudhoo	1526	15%	1559	60%	35%	5%
Fodhdhoo	200	2%	275	47%	49%	4%
Velidhoo	1705	17%	1864	57%	40%	4%
TOTAL	***10,080***		***10,414***	***58%***	***38%***	***5%***

There are about 2124 households in the atoll with an average household size of 6 persons per household. Housing conditions are generally good throughout the atoll (MPND, 2006b). However, better housing conditions prevail in Velidhoo, Holhudhoo and Manadhoo, while below average housing conditions could be observed in lowly populated islands. The number of 10 or more rooms in a household is quite high in Noonu atoll compared to other parts of the country, while the amount of multi-story housing is almost negligible.

School enrolments are generally high in Baa atoll but the numbers of institutions providing education beyond grade 7 are limited to some islands. Islands with population below 500 often find it hard to get enough enrolments to sustain secondary education. However, secondary education facilities are available in the four highly populated settlements. It is noteworthy that enrolment in grade 10 is quite high in Noonu atoll. This suggests the availability of a fair number of job seekers with O'level standard.

Health care is generally good in Manadhoo, Velidhoo and Holhudhoo. The Atoll Hospital is located in Noonu atoll Capital Manadhoo and the nearest Regional Hospital in Raa Atoll Ugoofaaru. Smaller islands generally find themselves without any residential health facility and hence have to travel to nearby islands for treatment.

In the past the main economic activities in Noonu Atoll has been fishing. Over the years new activities such as boat building has become dominant in islands like Velidhoo. In terms of current employment, majority of the population is employed in manufacturing, tourism, public service and construction sector (see Table 4-15 below). The economies of most islands have been undergoing gradual restructuring with the decline of fishing industry and more people being employed in the tourism sector and the manufacturing sector with employment in fish canning factory in Felivaru and safari boat building.

Table 4-15 Employment by Economic Activities in Noonu Atoll (source: (MPND,2002))

Locality And Sex	Total	Agriculture, Forestry	Fishing	Quarrying	Manufacturing	Electricity, gas, water	Construction	Whole sale, retail trade	Hotels, restaurants	Transport, storage, communication	Finance, business services	Community, social services	Not stated
South Miladhunmadhulu (Noonu)	**2,704**	**143**	**341**	**30**	**666**	**41**	**177**	**104**	**105**	**143**	**78**	**474**	**402**
Hebadhoo	**118**	3	9	0	43	1	10	5	3	3	4	13	24
Kedhikolhudhoo	**373**	11	82	0	158	4	12	6	5	11	9	53	22
Maalhendhoo	**182**	6	13	0	51	3	11	4	16	21	3	23	31
Kudafari	**119**	16	11	5	19	2	17	3	10	8	1	21	6
Landhoo	**193**	15	18	1	59	2	11	9	11	16	7	29	15
Maafaru	**195**	10	40	3	75	1	5	7	6	5	8	20	15
Lhohi	**121**	0	38	0	39	0	3	3	0	3	5	14	16
Miladhoo	**179**	11	33	2	16	1	9	7	8	16	5	32	39
Magoodhoo	**76**	13	21	0	10	0	0	0	1	4	4	13	10
Manadhoo	**300**	13	15	2	21	5	22	11	10	15	10	93	83
Holhudhoo	**353**	21	35	5	79	6	28	23	5	7	11	74	59
Fodhdhoo	**83**	17	0	0	22	2	6	3	3	4	3	10	13
Velidhoo	**412**	7	26	12	74	14	43	23	27	30	8	79	69

4.5.2 Miladhoo Island Socio-Economic Setup

4.5.2.1 Population

The population of Miladhoo is 1322 persons of which 50.5% is men while 49.5% is women. The working age population of Miladhoo is approximately 66% of total population and the dependent population is 34%. More than 30% of the work force is employed outside the island, according to the recent statistics provided by the Island Office.

4.5.2.2 Economic Activities & Employment

The main economic activities on the island are fishing, thatch weaving, tailoring, masonry and carpentry.

A total of 273 people are working outside the island; of which 265 are men and 8 are women.

There are 11 shops on the island, 1 restaurant, 3 tailor shops and 1 carpentry workshop. (Source: Island information form, Ministry of Atolls development)

4.5.2.3 Land Use and , Social and Economic Infrastructure

Land use in Miladhoo at present is not planned and development activities have been implemented mainly by the Island Office. Land use plan of Miladhoo is at present under development according to the Housing Department of Ministry of Housing and Environment.

The key social infrastructures are school (1), power house (1), rainwater storage facilities (1) and a health post. School teaches up to grade-10, in addition this school there are 4 private nursery schools. The power house is run as a community facility. The health post has 1 male doctor and 2 nurses, 1 community health worker and 2 family health workers.

The key economic infrastructure on the island is the harbor.

4.5.2.4 Planned Development Activities

There are no planned development activities at Miladhoo according to Mr.Hassan Moosa, Island Councillor of Miladhoo.

4.5.2.5 Community Perception of the Development

Social consultations were carried out in the form interviews with individuals. The following is a summary of main points raised by the islanders regarding the project:

- Main concerns expressed by the interviewees regarding the current sanitation system are; groundwater pollution, blockage of toilets and junction pipes and difficulties they face clearing out blocked septic tanks.
- Interviewees expressed skepticism about the likelihood of a sewerage system project actually being carried out. Many of them told us that survey teams had come to the island previously but that nothing had ever been done, and expressed their view that this

was just a political exercise to appease the residents of the island without any intention of an actual project being carried out.

- There was also some concern that the project might be stalled or abandoned after it had been started.
- There were also some worries about problems that might be caused during the construction phase of installing a sewerage system, such as how digging up streets might make the ground unstable and possibly cause collapse of buildings. However, the general consensus was that the project would be a good idea and that, if it did end up being carried out and followed through to completion; its benefits far outweighed any potential problems it might bring.
- Many interviewees did not know what a sewerage system was and thus were not able to answer questions.

5 Potential Impacts and Mitigation Measures

5.1 Introduction

The proposed development of the sewerage system on Miladhoo is anticipated to cause some significant detrimental as well as beneficial impacts. Impact identification (environmental/social/economic impacts) and mitigation measures were primarily based on literature reviews, professional judgment and past experience from similar projects.

For the purpose of this EIA, the chain of events linking activities to specific impacts and knock-on effects are represented in flowcharts to allow for easier interpretation. This is because the cause-effect relationship between a specific activity and its potential impacts are rarely linear and in most cases, a series of casual factors linked to different activities create the conditions that cause an impact. Three separate flowcharts were developed and organized to display logically the following sequence of events:

Activity *Casual Factor* *Potential Impacts* *Short Term Effects* *Long Term Effects*

Accordingly, Figure 5.1 below illustrates the flowcharts. The first chart will show the potential negative impacts of the proposed development activities during the construction stage and the second chart will show the potential negative impacts of the proposed development activities during the operation stage. Finally the third chart will show the potential positive impacts expected to arise once the project is complete (operation stage). It should be noted that no potential positive impacts could be identified for the construction stage of the proposed development activities.

5.2 Uncertainties in Impact Prediction

In the EIA process of the Maldives, uncertainties in impact prediction generally arise due to the lack of long term data, limited timeframes to complete EIAs and lack of standard procedures to collect data leading to inconsistent methodologies used by the various EIA consultants. Such issues are mainly linked to the lack of importance given to the EIA process in strategic planning and initial stages of development projects. Typically in the Maldives, EIAs for major development projects are only done after development activities and project locations are finalised. This gives the EIA consultants limited time frames to conduct a comprehensive impact assessment.

Accordingly, the uncertainties in impact prediction for this particular EIA are due to the time constraints in data collection and due to the limited amount and type of data available for measuring or predicting impacts.

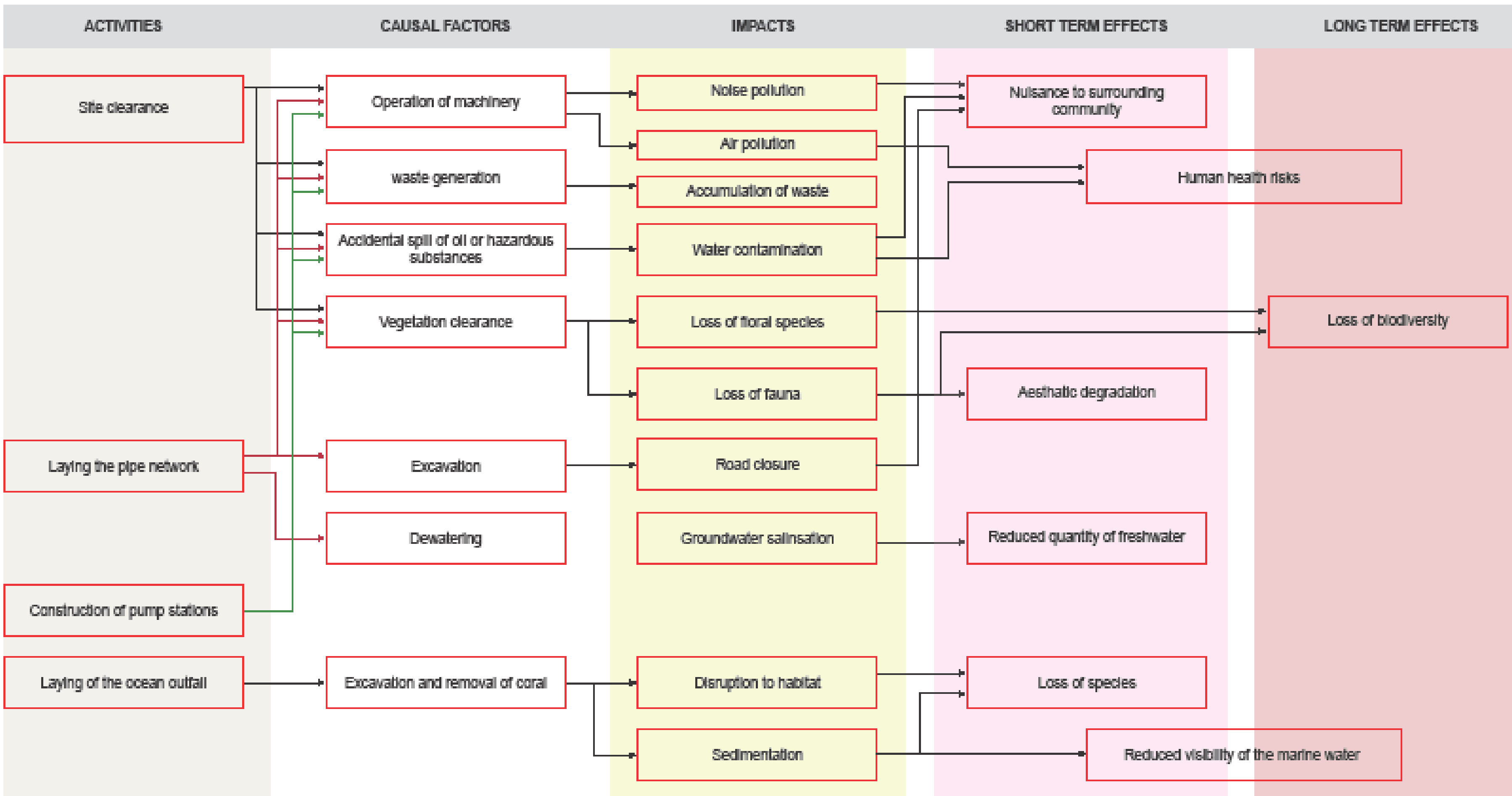

Figure 5-1 Potential negative impacts during construction stage of the project

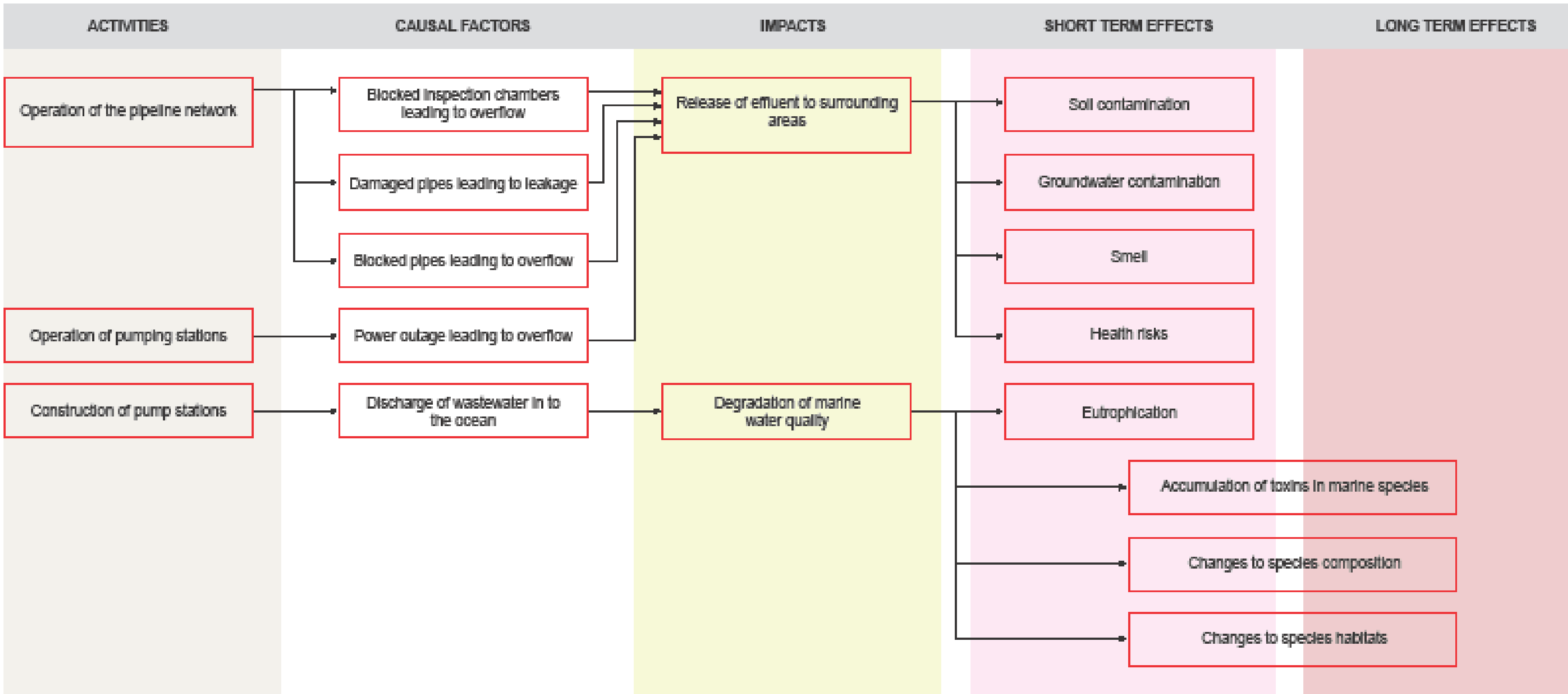

Figure 5-2 Potential negative impacts during operation stage of the project

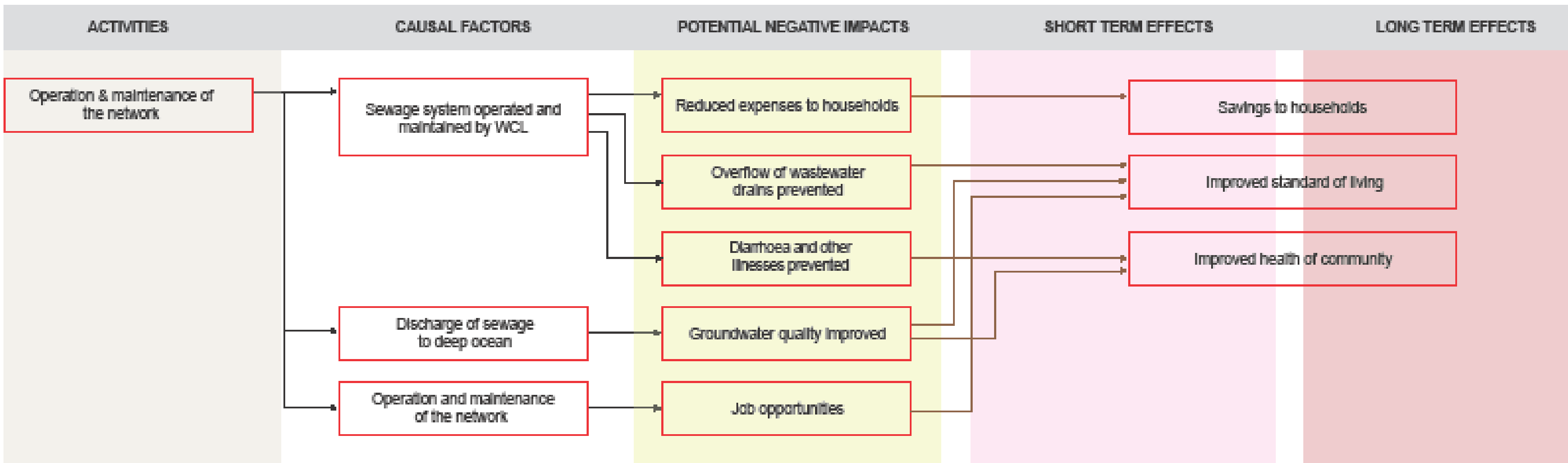

Figure 5-3 Potential negative impacts during operation stage of the project

5.3 Brief Description of Potential Impacts and Suggested Mitigation Measures for All Adverse Impacts

This section will provide a brief description of each of the potential impacts illustrated in the flowcharts of Figure 5-1 and Figure 5-2 and suggest appropriate mitigation measures for all potential adverse impacts. Similar to the flowcharts, firstly potential negative impacts and mitigation measures during the construction stage will be described. This will be followed by descriptions of the potential negative impacts during the operation stage. Finally all potential positive impacts will be discussed. Table 5-1 shows an analysis of all impacts.

As mentioned in the project description, the pre-treatment facility will not be part of the initial system. However, the impacts described here are applicable to the system with the treatment plant. Impacts specific to the plant are discussed in the respective sections.

Table 5-1 Analysis of impacts

Impact	Nature	Spatial Distribution	Duration	Reversibility	Magnitude	Significance
Air and noise pollution	Direct	20 m radius from project site	Short term	Yes	Minor	Significant during construction
Pollution from waste	Direct	Project site	Short term	Yes	Moderate	Insignificant
Loss of flora and fauna	Direct	Project site	Short term	Yes	Minor	Insignificant
Groundwater salinisation and depletion	Direct	Project site	Short term	Yes	Moderate	Insignificant
Smothering of corals	Direct	10m radius	Short term	Yes	Moderate	Significant
Water contamination	Direct	Project site	Short term	No	Minor	Insignificant
Release of effluent	Direct	Near pump stations mostly	Short term	Yes	Minor	Insignificant
Marine impacts	Direct	Near ocean outfall	Short term	Yes	Moderate	Insignificant
Waste from sewage sludge	Direct	Sewage treatment plant	Short term	Yes	Minor	Insignificant

5.3.1 Potential Adverse Impact during the Construction Stage and Suggested Mitigation Measures

5.3.1.1 Air and Noise Pollution

Site mobilisation and construction activities specifically site clearance, laying out of pipelines, construction of pump stations and laying out of the ocean outfall are expected to cause air and noise pollution. Specific activities that may cause air and noise pollution are operation of machinery, excavation and dewatering. Air and noise pollution will lead to nuisance to public during construction in the short term. Dust and emissions from vehicle and machinery exhausts will degrade the air quality leading to long term health risks to the community. These adverse impacts can be mitigated to avoid nuisance and risks to the community. With proper mitigation measures, it is unlikely that noise and air pollution impacts will cause long term effects such as human health risks leading to increased public and private health costs.

Mitigation Measures

- All construction works will be carried out during day time to minimise nuisance to the local community and disturbances caused to nocturnal fauna such as birds and fruit bats that uses auditory communication.
- All vehicles and machinery will be tuned and well maintained to minimise air pollution.
- To minimise dust from construction works, ground/soil will be kept damp.

5.3.1.2 Pollution due to Waste

Sources of waste during construction stage are mainly site clearance, construction activities and the workforce. Site clearance will involve removal of minor amounts of vegetation. Construction activities are likely to generate construction waste such as packaging, extra materials such as pipes etc. Waste types from the workforce will be general domestic waste and sewage. Waste generated during construction stage may affect the groundwater and general terrestrial environment of the island. In general waste quantities are expected to be minor and with proper mitigation measures impacts from waste will be insignificant. Waste management will be a responsibility of the contractor and the proponent will ensure that a clause on proper waste management is included in the contract.

Mitigation Measures

- All construction waste will be segregated and stored temporarily until transfer to a designated disposal site during demobilisation of the project.
- Non-biodegradable domestic waste will be sorted and stored in closed containers until transfer to a designated disposal site during demobilisation.
- No waste except biodegradable waste will be disposed at the island waste disposal site.

5.3.1.3 Loss of Flora and Fauna

Vegetation clearance is not anticipated from the project activities. If any clearance is required only minor amounts will be needed. All pipelines will be laid along the roads and no large trees will need to be removed for this purpose.

Loss of vegetation means, loss of fauna that depend on those vegetation. Such species include birds, rats, fruit bats and invertebrates.

Wastewater Treatment

As the project has made allowance as required by EPA for the development of a pre-treatment facility in the future, the location of the plant as shown in the site plan in Appendix 3 is not expected to require removal of large trees. The proposed location is an empty area which may have undergrowth that may need to be cleared in minor amounts. Mitigation measures are the same as those measures given below.

Mitigation Measures

- Vegetation clearing will be only done for the vegetation that will require clearing. Any trees that can be retained will be retained.
- All clearing works will be carried out during day time to minimise disturbances caused to nocturnal fauna such as birds and fruit bats that uses auditory communication and to the local community.

5.3.1.4 Groundwater Salinisation and Depletion

The project involves excavation and dewatering for the laying of the pipeline network and set up of pump stations. For the purpose of the Miladhoo design, a maximum depth of excavation of 3.0

m to 3.5 m is proposed. As water tables are on average between 0.5m and 1.5m below ground level pipes will be laid below groundwater level and hence, some dewatering will be required for the installation of the pipe networks. Impacts from dewatering will be felt on the groundwater aquifer mainly salinisation and reduction in volume of water in the aquifer. Salinisation and depletion of groundwater aquifer is expected to be short term. The aquifer is expected to be recharged during rainfall.

In addition, during excavation roads may have to be closed temporarily causing inconvenience to the public.

Mitigation Measures

- Dewatering will be carried out only if and where necessary after on-the-spot assessments by construction supervisor.
- Dewatering will be carried out during low tide in order to reduce the amount of dewatering required.
- All water extracted from ground during construction should be drained back into the system.
- All necessary permissions will be sought for road closure and access to pedestrians will be allowed as much as possible.

5.3.1.5 Smothering of Corals, Siltation of Lagoon Benthos and Affects on Fish Population

During anchoring of the ocean outfall excavation activities is expected to cause a significant amount of sedimentation of the lagoon waters and disruption to the coral reef habitat. Also increased turbidity of the lagoon water is expected. The outfall will be buried in the lagoon area at the appropriate depth in order to protect from vessel and anchor damage.

Sedimentation will cause adverse impacts such as smothering of corals and reduced light penetration to the coral and benthic communities. As corals have a self cleansing mechanism and can withstand a certain rate of sedimentation, detrimental impacts such as reduced coral growth and recruitment rate and decreased visibility can be short term effects. However if the sedimentation exceeds the rate at which corals can self clean, then it may lead to serious detrimental impacts such as coral mortality and alteration of habitat and species composition within the lagoon.

Lagoon bottom is a habitat for certain organisms such as worms, mollusks, amphipod etc. which are important food sources for bottom feeders such as certain species of fishes. Excavation activities will disturb habitats of these organisms. However, it has been found elsewhere that lagoon bottom dwelling organisms re-establish within few months after such disturbances.

Fish population is often affected when their gills are stuck by suspended sediments. There will be loss of habitat for a large portion of the juvenile species. Most species will stay out of the harm's way my moving to safer areas of the lagoon. However, the juveniles may lose their habitats and this may affect the fish population in the short term.

Direct removal of corals and hard bottom substrate for the set up of the ocean outfall can result in loss of habitats for fish, and reef benthos in addition to loss of coral colonies.

Wastewater Treatment

Pre-treatment facility is not expected to cause major impacts on the marine water and life as raw sewage will not be disposed into the marine environment. The wastewater discharged to the ocean will have solids and sludge removed thereby improving the quality of the effluent that is discharged.

Mitigation measures

- A temporary bundwall with multiple settlement basins should be placed around the excavation area to prevent suspended sediment outflow during excavation. Once excavation is completed, sufficient time could be given to settle the sediments. Once the sediment settles, the bundwall could be removed. Removal should occur preferably at low tide. However it has to be noted that the construction and removal of bundwall itself would cause some disturbance. An alternate option would be to use silt screen to prevent suspended sediments from escaping on to the reef. The cost and lack of sensitive areas around the excavation site may warrant the use of a cheaper option.

- The project should be completed in as short period as possible and the work should be carried out during outward drift of current so that sediment settling on the reef would be minimised. It is best to carry out the work during low tide and in calm weather conditions to minimise spread of any sediment plume. In addition, all construction works will be undertaken during NE monsoon when wave activity will be calmer.

- The project manager, and the work force involved during the operation of the work should be briefed of environment friendly practices.

- The work should be properly supervised and monitored to minimise any adverse effect on the environment.

- The marine environment should be monitored for sedimentation and siltation stress and possible impacts on the biological aspects such as bottom benthos. This is further outlined in the monitoring programme given in this EIA report.

- In case heavy equipment and vessels are to be mobilized closer to the reef care should be taken to avoid accidents and damage to the reef.

5.3.1.6 Water Contamination (Marine Water and/or Ground Water)

During construction any accidental spill of oil and toxic substances will contaminate the marine and/or groundwater. Likewise, during the construction significant quantities of waste will be generated where any mishandling of solid (non-biodegradable) waste and hazardous waste will also contaminate the marine and/or groundwater.

In the Maldives, groundwater contamination is an irreversible impact due to the absence of impermeable layers to separate the freshwater lens in independent reservoirs. Accordingly, any point sources of pollution would cause the contamination of the entire island groundwater resources. If human consume such contaminated groundwater, it may lead to serious health risks leading to increased public and private health costs. Furthermore, contamination of groundwater will force the local community to rely on rainwater or desalinated water that will also be costly (rainwater can be costly due to the need for increased storage capacity). Therefore, special care should be taken when handling oil, solid waste and hazardous waste to entirely avoid any accidental spills and leakage.

Mitigation measures

- All paints, lubricants, and other chemicals used on site will be stored in secure and bunded location.

- Oil, solid waste and hazardous waste will be handled carefully and transported in sealed containers in properly bunded vehicles/vessels

- Construction activities will be carried out under the supervision of a suitably experienced person.

- Vessels, equipment and machinery used for the work should be properly maintained at all times during the operation.

- Littering and accidental disposal of any construction wastes can be avoided by pre-planning modalities for waste disposal or re-use wherever possible. Careful planning of the work activities can also reduce the amount of waste generated.

5.3.2 Potential Adverse Impact during the Operation Stage and Suggested Mitigation Measures

5.3.2.1 Release of Effluent to Surrounding Area

During operation of the system effluent may be released to the surrounding environment due to blocked inspection chambers at household level, damaged/blocked pipes and overflow at pump stations. As the system will be operated on power supply from existing powerhouse any power cuts that may occur could lead to overflow at pump stations. Release of effluent will potentially cause soil and groundwater contamination and unpleasant odour. Health risks may be associated with contaminated groundwater.

The system is designed to have maintenance shafts located at pipe junctions or where the lengths of gravity sewer runs exceed 75m. All of the maintenance shafts will be at a depth which is readily accessible from the surface and any blockages could be cleared from the surface. Furthermore, clean outs will be located at the beginning of all sewer mains for the purpose of upstream flushing of sewer mains.

The catchment pump stations are designed to account for any failures. An isolation valve is to be placed immediately upstream of the rising-main junction in order to isolate the junction in the event of pipe failure. Where required, gravity scouring valves will be located at the low end of long rising-mains to facilitate drainage of effluent from the main in the event of pipe failure necessitating repair. The scouring the down-stream end of the scouring valve will be connected via maintenance shaft to the gravity sewer network.

A DN150mm emergency overflow pipe will be located between the two adjunct catchments at minimum cover to provide relief in the event that the pump station in one catchment fails. After failure of a pump station, and subsequent build up of effluent in the sewer network, effluent will begin to flow into the adjacent catchment for pumping until such time as repairs on the failing pump station can be carried out.

The Ocean Outfall (OOF) pump station is designed with the same parameters as the catchment pump stations. Effluent flows under gravity to a common maintenance shaft after the PTT and into the OOF pump station. An emergency relief valve is located at the OOF pump station in the event of malfunction or power outage.

Mitigation Measures

- Households will be informed on how to maintain the connections within their boundary walls and the inspection chamber to avoid blockages and overflow as much as possible.
- Regular maintenance of the system will be carried out to avoid failure of pump stations.

5.3.2.2 Eutrophication, Accummulation of Toxins in Marine Species, Changes to Species Composition and Changes to Sensitive Marine Habitats

During operation of the sewerage system raw sewage will be disposed through the ocean outfall. Discharge of effluent into the ocean have the potential to lead to eutrophication from continuous discharge of nutrients and organic matter, accumulation of toxins in marine species, changes to composition of species in the area that are tolerant to pollution and longterm deterioration of coral reefs. However, the project is unlikely to cause degradation of the marine water as the ocean outfall extends beyond the reef in to the deep ocean. The pipe will be buried to a depth of 1.25m through the island lagoon to the point at which it reaches an average depth of 1.5m below MSL. The purpose of placing the outfall beyond the reef is to ensure adequate dilution of the effluent by the current patterns at the selected location. Further, a “T” head diffuser will be fixed to the discharge end of the ocean outfall pipeline to increase dilution performance and dispersion of effluent.

Mitigation Measures

- Ensure that the outfall is located appropriately during construction.
- Carry out regular maintenance of the ocean outfall to detect any leakages early and address the damage in a timely manner.

5.3.2.3 Waste from Sewage Sludge

In the event that a pre-treatment plant is installed and operated the main impact will be the generation of waste due to sewage sludge. The purpose of the pre-treatment is to provide equalization of incoming wastewater and remove heavier particulate matter and suspended solids prior to treatment. The plant is designed to collect sludge in a sludge collection basin. Isolating valves at the sludge collection basin can be opened to divert accumulated sludge and solids to a sludge drying basin or alternatively bypassed into the ocean outfall pumping station.

The collected sludge if not treated properly may cause nuisance to the public in terms of odour. In addition, although the quantity of sludge is not expected to be high, if the sludge is not reused or disposed in a timely manner may accumulate within the island.

- Ensure proper treatment of sludge to control odour.
- Introduce ways to reuse sludge within the community such as a fertilizer at household level or to improve soil quality generally in the island.

5.3.3 Potential Positive Impacts from the Proposed Development Project

- At present households carry out cleaning and repair of septic tanks. This has a cost associated with it from the recruitment of workers to do the maintenance work. Installation of the proposed system will reduce costs of maintenance to households.
- The proposed system is likely to prevent further contamination of groundwater. The quality of groundwater could improve in time to providing groundwater of appropriate quality for household use. This will increase the water security of the community.
- Operation of the sewerage system will reduce health risks from illnesses such as diarrhea and therefore improve the quality of life in the island.
- The project is also expected to provide employment opportunities for operation and maintenance work.
- Installation of a pre-treatment system in the future will improve the quality of the effluent that is discharged into the deep ocean. This will reduce potential adverse impacts on the marine environment.

5.4 Cost of Mitigation Measures

Table 5-2 Cost of Mitigation Measures for Impacts during Construction Phase

Impact	Mitigation Measures	Costs
Air and noise pollution	• All construction works will be carried out during day time to minimise nuisance to the local community and disturbances caused to nocturnal fauna such as birds and fruit bats that uses auditory communication. • All vehicles and machinery will be tuned and well maintained to minimise air pollution. • To minimise dust from construction works, ground/soil will be kept damp.	NA US$5000 US$1000
Pollution from waste	• All construction waste will be segregated and stored temporarily until transfer to a designated disposal site during demobilisation of the project. • Non-biodegradable domestic waste will be sorted and stored in closed containers until transfer to a designated disposal site during demobilisation. • No waste except biodegradable waste will be disposed at the island waste disposal site.	US$5000 US$5000 NA
Loss of flora and fauna	• Vegetation clearing will be only done for the vegetation that will require clearing. Any trees that can be retained will be retained. • All clearing works will be carried out during day time to disturbances caused to nocturnal fauna such as birds bats that uses auditory communication and to t community.	NA NA
Groundwater salinisation and depletion	• Dewatering will be carried out only if and where necessary after on-the-spot assessments by construction supervisor. • Dewatering will be carried out during low tide in order	US$2000

	to reduce the amount of dewatering required. • All water extracted from ground during construction should be drained back into the system. • All necessary permissions will be sought for road closure and access to pedestrians will be allowed as much as possible.	NA US$5000 US$1000
Smothering of corals	• Silt-screens or bund-walls will be established at selected points around the project site to control sediment disbursing. • The project should be completed in as short period as possible. • The project manager, and the work force involved during the operation of the work should be briefed of environment friendly practices. • The work should be properly supervised and monitored to minimise any adverse effect on the environment. • The marine environment should be monitored for sedimentation and siltation stress and possible impacts on the biological aspects such as bottom benthos. • In case heavy equipment and vessels are to be mobilized closer to the reef care should be taken to avoid accidents and damage to the reef.	US$10000 NA US$2000 US$1000 US$5000 US$1000
Water contamination	• All machinery will be properly tuned and maintained • All paints, lubricants, and other chemicals used on site will be stored in secure and bunded location. • Oil, solid waste and hazardous waste will be handled carefully and transported in sealed containers in properly bunded vehicles/vessels • Construction activities will be carried out under the supervision of a suitably experienced person.	US$5000 US$10000 US$8000 US$2000

Table 5-3 Cost of Mitigation Measures for Impacts during Operation Phase

Impact	Mitigation Measures	Costs
Release of effluents	• Households will be informed on how to maintain the connections within their boundary walls and the inspection chamber to avoid blockages and overflow as much as possible.	US$2000
	• Regular maintenance of the system will be carried out to avoid failure of pump stations.	US$13000
Marine impacts	• Ensure that the outfall is located appropriately during construction.	US$2000
	• Carry out regular maintenance of the ocean outfall to detect any leakages early and address the damage in a timely manner.	Included in maintenance costs

6 Alternatives

6.1 Introduction

This section looks at alternative ways of undertaking the proposed project. Firstly, at the broad level there are two main options to undertake the project: (1) undertake the project or (2) not undertake the project. The environmental evaluation above has been conducted in view of the latter and this section will explore the no project option. This chapter will further consider alternative technologies and locations where applicable.

6.2 No Project Option

The no project option takes the following into account.

- The island continues with the existing sanitation system of household septic tanks.

The advantages and disadvantages of the no project option are discussed in Table 6-1 below.

Table 6-1 Advantages and Disadvantages of the No Project Option

Advantages	Disadvantages
• Environmental problems related to	• Environmental impacts and health

development can be avoided. Absence of the ocean outfall keeps the marine environment in good health; avoidance of any land clearing will keep the terrestrial environment intact.

- No development costs to the Proponent
- Potential short term groundwater salinisation that may exacerbate the problem and cause inconvenience to the community may be avoided.
- Air, noise and waste related pollution due to project activities may be prevented.

risks from improper sanitation will continue to deteriorate the quality of life in Miladhoo.

- Loss of public confidence in the Proponent.
- Loss of employment opportunities for the island population.
- More expensive alternative water source may need to be sought in future with long term final implications on the community.
- Political and social problems due to poor infrastructure.

Despite the environmental disadvantages of the no project option, the socio-economic benefits are too numerous for this project to not be undertaken. The modern day mitigation technologies if followed properly as prescribed in this document will ensure negative impacts are managed efficiently, when implemented properly.

6.3 Alternate Sanitation Technologies

There are several alternate sanitation technologies in terms of sewage collection, treatment and disposal. These alternates have been assessed extensively by the leading consultant in sanitation systems, Ahmed Zahid in Zahid (2010). Below is a summary of the main findings found in Zahid (2010). Alternate options presented in Table 6-2 are assessed based on the main findings of the evaluation of sanitation technologies in Zahid (2010).

6.3.1 Main Findings of an Evaluation of Sanitation Technologies

6.3.1.1 Sewage Collection

- There are three different options for the collection or conveyance of sewage in a sewer network. These are the gravity system, pressure system and the vacuum system.
- Gravity sewers convey the sewage with the help of gravity and therefore have the advantage of not requiring a power supply. Adequate gradients in sewer network have to be met with deep excavation and several outfalls will be needed.

- A pressure system is a gravity flow system up to a certain depth, after which lifting stations are used to pump the wastewater to a final pumping station that pumps the effluent directly to an offshore location at the proposed outfall. This system minimizes the number of outfalls.

- A vacuum system conveys sewage and wastewater by sucking the wastewater by creating a vacuum inside the system. In a vacuum system, five or six homes can be connected to one interface valve unit. The vacuum pipeline conveys the sewage to the ejector pump station that creates the vacuum and delivers the effluent to the pumping station or treatment works.

6.3.1.2 Sewage Treatment

- The existing system in Miladhoo is individual septic tanks. However, there are cleaning and maintenance costs as well as health risks associated with this system.

- Communal septic tanks is another option that works similar to an individual septic tanks except they require more space.

- Packaged treatment plants include secondary treatment and are already in place in resorts. In addition packaged treatment plants are also proposed in some of new inhabited island developments that are underway. These treatment plants are however costly.

- Reed beds have been tried in Maldives but are quite expensive and require space.

6.3.1.3 Disposal

- Wastewater disposal can be to the ground, lagoon or deep sea. Ground and lagoon disposal are suitable if secondary treatment is available.

- Ground disposal are known to have caused contamination of groundwater in islands.

- Lagoon disposal in some instances have been successful in Maldives, however they have not been favoured in some cases due to aesthetic reasons.

6.3.2 Sanitation Technology Options

Based on the field assessments and the main findings presented in section 6.3.1. there are three main technology options available for Miladhoo. These are:

1. Continue with the existing individual septic tanks systems
2. Individual septic tanks of improved quality with ocean outfall
3. Sewage treatment plant

Table 6-2 shows an evaluation of the alternative sanitation technology options in the context of Miladhoo based on the main findings given in section 6.3.1.

Table 6-2 An evaluation of options in terms of potential environmental, social and economic impacts

Technology Option	Potential environmental Impacts				Potential social Impacts		Potential economic Impacts		
	Groundwater	*Vegetation*	*Marine water*	*Marine life*	*Employment opportunities*	*Acceptance*	*Investment cost*	*Maintenance cost*	*Affordability*
Existing system of individual septic tanks	Negative. Groundwater contamination.	None. Vegetation clearance not required.	None. There is no disposal to the marine environment.	None. There is no disposal to the marine environment.	None. Does not create job opportunities.	Negative. Community is dissatisfied with the existing system due to health risks.	Low. No new investments are require except at household level in new plots.	High. Cost to households to clean and maintain regularly.	High. Affordable at household level.
Septic tanks of improved quality with disposal via ocean outfall	None. Risks of leakage to groundwater reduced and disposal is offshore via outfall.	None.	Negative. Sedimentation from construction. Discharge of untreated wastewater.	Negative. Smothering of marine life. Changes to habitat and species composition.	Positive. Job opportunities from operation and maintenance.	Positive. Prevent groundwater contamination due to high quality of septic tank reducing health risks.	Moderate. Better quality septic tanks and set up of ocean outfall.	High. Cleaning and maintenance costs.	High.
Sewage treatment plant	Positive. Groundwater can be protected from contamination.	None. Empty land already available.	None. No untreated wastewater discharged to marine environment.	None.	Positive. Jobs related to operation and maintenance.	Positive. Health risks from contaminated groundwater reduced.	High.	High.	Low.

6.3.2.1 Preferred Alternative

Based on the evaluation in Table 6-2 the preferred alternative sanitation technology option in terms of potential environmental, social and economic impacts is the septic tanks of improved design with an ocean outfall. Impacts on the marine environment and marine life can be mitigated with proper measures. In addition, the outfall when extended beyond the reef edge and into the deep ocean where currents are strong is unlikely to cause significant impacts to the marine environment.

6.4 Alternate Ocean Outfall Location

The proposed location of the ocean outfall is the northern side of the island approximately at mid- point of the island length perpendicular to the coastline as shown in Figure 6-1. Construction of the outfall in this location will not require any vegetation clearance. In addition, this location is proposed considering the development of a sewage treatment plant in future. Sufficient land can be allocated for this purpose on the northern side and the ocean outfall can be used as an emergency outfall when a tertiary sewage treatment plant is in place.

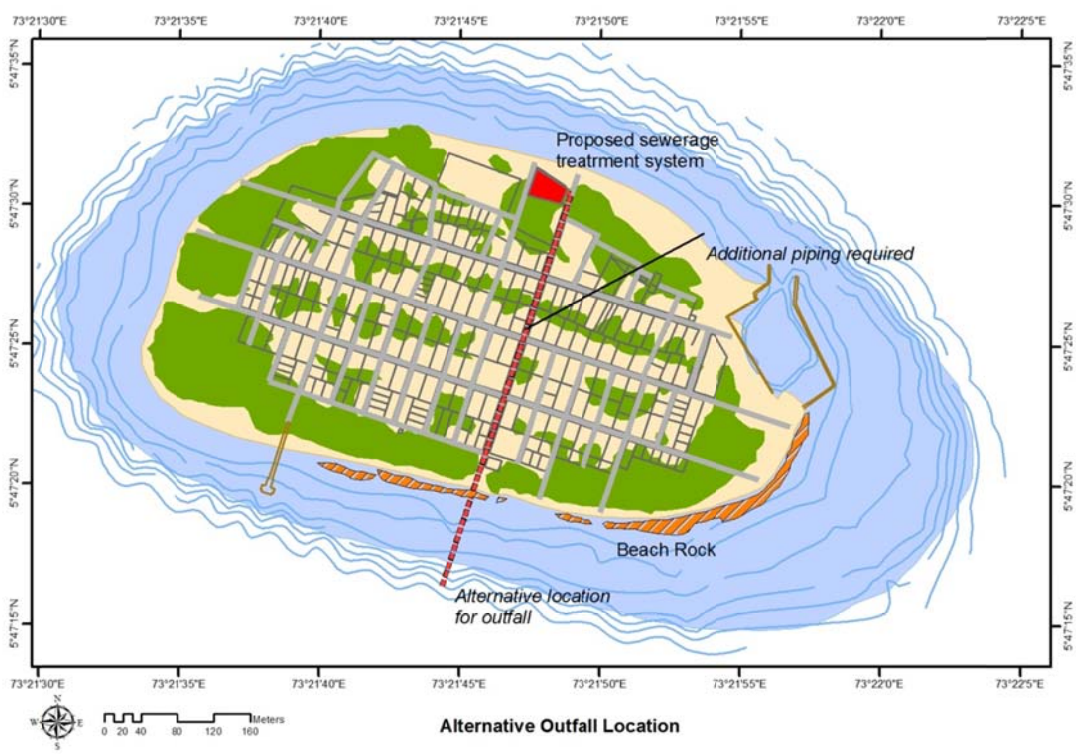

Figure 6-1 Alternative for ocean outfall location

The alternate location for the ocean outfall is on the opposite side of the island i.e. on the southern side of the island as shown in Figure 6-1. Similar to the proposed location the outfall can be placed perpendicular to the shore line and beyond the reef edge in to the deep ocean to ensure proper dilution of the discharged sewage. However, on the southern side there is coastal vegetation that may need to be cleared and a larger footprint may need to be excavated and dewatered to link with the sewerage treatment plant. Currents are perhaps more favourable on the southern side but this effect can be negated in the northern side by extending the pipeline a bit further.

Table 6-3 shows a comparison of the proposed location and the alternate location in terms of the different aspects.

Table 6-3 Summary of Impacts from Alternate Options

	Current option	**Alternate Option**
Practicality	High	High
Terrestrial impacts	Low	High
Marine & coastal impacts	High	High
Social impacts	Moderate	Moderate

Alternate option: In general, this option has similar impacts to the northern side option. The difference is in higher terrestrial impacts due to additional excavation, dewatering and vegetation removal. Perhaps this option has more favourable currents as it generally has an away movement form the island during both seasons. However, the cost of locating on the southern side purely on favourable currents involves a much higher cost that the northern side option. The issue of currents have been mitigated by extending the pipeline a bit further out, which costs a fraction of locating on the southern side. Hence in terms of environmental impacts and financial costs, this would be not be the preferred option when compared to the existing option.

Preferred option: Considering that the practicality and social impacts of both options are similar and the alternate option possibly has less terrestrial impacts, the preferred option is the proposed location.

7 Environmental Monitoring Program

7.1 Introduction

Environmental monitoring and auditing is an essential component of any project. Under the EIA regulations of Maldives, a detailed monitoring plan is a mandatory component of any EIA. Major areas that will impact the environment should be included in the monitoring programme. In this regard, the project components should specify the location of monitoring points, the parameters to be analysed, and the frequency of such analyses. An appropriate time interval can be planned for monitoring activities that will address the major areas of concern. For the purpose of this project, monitoring should be done for all components of the project that have the potential to influence the environment.

It is noted here that if a pre-treatment facility is installed in the future the monitoring parameters are same as those described in the following sections. Additional parameters that may be needed in relation to the pre-treatment facility are included in the respective sections.

7.2 Monitoring during Construction Phase

Outlined here are project specific monitoring requirements for the construction phase. This monitoring programme for the proposed project includes at least monthly monitoring and covers the three stages of the project implementation.

Information Requirements

- Water quality aspects including suspended sediments and sedimentation
- Ecological aspects related to coral: changes to coral cover, coral reef health, fish abundance, turbidity and sedimentation.
- Ecological aspects related to lagoon benthos: changes to coral health, fish abundance, turbidity and sedimentation.
- Groundwater salinity: salinity levels in the aquifer.

The following parameters will be setup and monitored:

- Ecological aspects - Percent live coral cover and overall health of the reef and lagoon benthos
- Sedimentation rate monitoring - Setup sediment traps on the lagoon and reef to measure sedimentation rate (kg/sqm/day): parameters will include, location, time and date, weather conditions, sea conditions, tidal mode and depth.
- Sea Water quality – Total Suspended Solids, Dissolved Oxygen (% saturation), Dissolved Oxygen (mg/l), turbidity (NTU), temperature and water depth.
- Groundwater quality – pH, conductivity, faecal coliform and TDS

7.2.1 Constructional Monitoring Timetable

The following Table 7-1 shows the frequency at which the different parameters may be monitored. Each bar represents one month. This monitoring programme may be continued during the operational phase.

7Monitoring Frequency of each Parameter

	Setup stage	Construction phase																	
Percent live coral cover	♦	♦						♦						♦					

Marine water Quality	♦	♦						♦						♦					
Groundwater quality	♦	♦						♦						♦					
Sedimentation rate	*	♦		♦	♦	♦	♦		♦		♦		♦			♦			

** Setup sediment traps*

7.2.2 Other Monitoring Needs

The following aspects will be monitored during the construction stage:

- Daily monitoring to ensure that the cleared areas and other construction processes are not creating any significant dust nuisance for the local environment.

- Daily monitoring of vehicle refuelling and repair to ensure that these exercises are carried out on hardstands and to ensure that they are done properly. This is to reduce the potential of soil contamination from spills. Spot checks will be conducted by the site supervisor.

- Daily inspection of site clearance activities to ensure that the proposed clearing plans are followed.

- Monthly water quality monitoring to ensure that the construction works are not negatively impacting on the marine environment. The parameters that should be monitored are temperature, pH, BOD, COD, dissolved oxygen, total suspended solids, turbidity and total coliforms.

- Monthly water quality monitoring to ensure that the construction works are not negatively impacting on the ground water. The parameters that should be monitored are pH, conductivity, total coliform, TDS, phosphates, nitrates and ammonia.

- Undertake daily assessment of the quantity of solid waste generated and provide verification of its ultimate disposal.

- Weekly assessment to determine that toilets are in proper working order. This will ensure that sewage disposal will be adequately treated.

- Regularly monitor bundwalls of silt screen lining to ensure they are intact.

7.3 Monitoring During Operational Phase

7.3.1.1 Water Quality

Monitoring and auditing of ground and marine water quality is vital for environmental protection of islands. Considering this as an important component, a baseline data set was gathered based on the existing data and field surveys conducted for the EIA. This monitoring programme would be required to ensure the implementation of the recommended water quality mitigation measures and to assess the effectiveness of these measures. If monitoring results indicate that the water quality is not improving after the implementation of the recommended mitigation measures, then appropriate alternatives need to be carefully considered.

Table 7.2 outlines the implementation schedule for water quality monitoring, both ground and marine water. Baseline data for groundwater was collected from one location. However, once the proposed developments go in to operation, additional monitoring locations will be identified and selected for continuous monitoring. These locations will be preserved and marked for monitoring purpose.

Table 7-1 Implementation schedule for the water quality monitoring programme

Type of water and location	Frequency of monitoring	Main Concerns to address	Parameters to monitor
Ground water from the well from which baseline data was collected	Every three months initially and then every six months	Assess the changes to groundwater quality	Electrical conductivity, pH, total coliforms, phosphates, nitrates, ammonia
Seawater quality of the lagoon from all the four locations from where baseline data was collected.	Every three months initially and then every six months	Assess changes to water quality in the lagoon	Temperature, pH, E-Conductivity, TSS, total coliforms, BOD, COD, nitrates, phosphates and ammonia
Seawater quality near the sewage outfall	Every three months initially and then every six months	Water quality of the lagoon around the outfall and ensure quality standards are within acceptable limits.	BOD_5, Nitrates, Phosphates, Faecal and total coliforms,
Effluent quality if a pre-treatment facility is installed	Every three months initially and then every six months	Water quality of the lagoon around the outfall and ensure quality standards are within acceptable limits.	Temperature, pH, BOD5, COD, TSS, faecal coliform and total coliform

7.3.2 Monitoring the Marine Environment

Ecological change often occurs gradually over time. Therefore, long term monitoring and research programs are necessary to accurately assess environmental change. This is particularly true when the change is due to small but chronic perturbations to the environment which have a cumulative effect. It should be kept in mind that (1) many ecological processes are slow occurring over a number of years, (2) inter-annual variability is often high, (3) short term studies miss rare but important events, and (4) monitoring only reveals recent historical events. It should be noted, however, that the proposed activities involve high level turbidity and sedimentation and therefore may have faster rate of environmental change.

The objectives of this monitoring programme are to detect and document the changes occurring to the reef system due to the proposed project. The purpose will be to 1) assess the magnitude of the impacts resulting from project activities 2) evaluate the success of a particular management action, 3) to quantify the change in abundances of certain marine organisms, e.g. indicator species near a sewage outfall and elsewhere to compare.

Table 7-3 gives the marine environment monitoring schedule recommended for the long-term evaluation ambient marine environment for impact assessment and mitigation of impacts. If monitoring of sea water quality shows degradation then a more comprehensive monitoring programme should be set up that includes impacts on coral reef system.

Table 7-2 Marine environment monitoring schedule

Parameter/Method	Frequency of Monitoring	Purpose
Ambient Environmental Parameters Turbidity/light penetration, Currents	Twice a month in construction Once every month in operation	Important to the 'health' of living marine resources, reefs and fish populations and other benthos
Sedimentation / Sediment traps deployment/collection	Twice a week in construction Once every 3 months in operation	Quantitative assessment of sediment loading on the reef benthos.

7.4 Socio-Economic Impact Monitoring

At present public perception of the project shows a lack of confidence towards the implementation of the project and lack of awareness regarding sustainable sanitation. In addition currently the community is experiencing health risks from deteriorated groundwater. Therefore the monitoring program should focus on these specific aspects of the project. The following indicators in Table 7-4 are proposed to measure the socio-economic impacts. While some of this data can be obtained from official sources other data has to be obtained through surveys using pre-designed questionnaires.

Table 7-3 Monitoring socio-economic conditions

Impact Area	Data sought	Min. Frequency	Purpose
Public perception	How does the present system compare with previous system. How satisfied are people with the new system on a given scale (Likert).	Before and after the project	To assess community confidence and satisfaction towards the system
Community health	Incidence of water borne diseases Diarrhoea Typhoid Cholera	Once a year	To assess improvement in community health due to the project
Employment	Percentage of employees from the atoll and island Number of female employees from the atoll and island	Once a year	To understand the impacts on employment from the project

7.5 Monitoring Report

A detailed environmental monitoring report is required to be compiled and submitted to the Environmental Protection Agency yearly based on the data collected for monitoring the parameters included in the monitoring programme given in this Chapter. This report may be submitted to the relevant Government agencies in order to demonstrate compliance. The report will include details of the site, strategy of data collection and analysis, quality control measures, sampling frequency and monitoring analysis and details of methodologies and protocols followed. In addition to this more frequent reporting of environmental monitoring will be communicated among the environmental consultant, project proponent, the contractors and supervisors to ensure possible negative impacts are mitigated appropriately during and after the project.

7.6 Cost of Monitoring

The cost of monitoring is estimated to be US$ 10,000 annually. Professional consultants will be hired to undertake the monitoring and the necessary equipment for monitoring will be procured.

7.7 Commitment to Monitoring

The proponent is fully committed to undertake the monitoring programme given in this Chapter. Letter of Commitment is provided in Appendix 7.

8 Stakeholder Consultations

8.1 Introduction

This Chapter reports on the relevant stakeholder consultation undertaken on the proposed sewerage project at Miladhoo. Public consultation for this EIA was undertaken during the field survey visit and is presented in Chapter 4 as outlined in the ToR.

8.1.1 Housing Department of MHE

Mohamed Azim, Assistant planner at Ministry of Housing and Environment was consulted:

- Land use plan for N. Miladhoo is under development; therefore no future plans for land use plan is available at the time of preparation of this EIA.

9 Potential Gaps in Existing Data and Limitations in the Assessment

9.1 Gaps in Information

The environment of Maldives is generally poorly understood. This may be due to the lack of detailed studies in the Maldives. Much of the literatures on coral islands are derived from studies done in the pacific which unfortunately has very different and climatic and geologic settings.

Detailed environmental analysis for an EIA is often required to be undertaken in a relatively short period of time. Give the seasonal climatic variations in Maldives and the differences in local geomorphologic and climate settings in individual islands such a short time frame is often too little to assess selected aspects of the environment. This problem is compounded by the absence of long-term studies in other parts of Maldives. Hence, most EIA's end up being based on an environmental snapshot of specific point in time. However, experienced EIA specialists can deliver a close match to reality based on a number of similar assessments.

In this regard, the following gaps could be identified in information.

1. Absence of long-term site specific or even regional data (at least 2 years). Most critical data include current, wave and sediment movement history.

2. Absence of historical and long-term records on reef and lagoon environment.
3. Lack of detailed data on geology and groundwater due to time limitation in EIA submission.

These gaps are seriously considered in the assessment and care has been taken to address the issue in designing mitigation measures and the monitoring programme.

9.1.1 Uncertainties in impact prediction

Environmental impact prediction involves a certain degree of uncertainty as the natural and anthropogenic impacts can vary from place to place due to even slight differences in ecological, geomorphological or social conditions in a particular place. As note earlier, there is also no long term data and information regarding the particular site under consideration, which makes it difficult to predict impacts. However, the level of uncertainty is partially minimised due to the experience of resort construction and operation, land reclamation activities and land clearing activites in similar settings in the Maldives. Nevertheless, it is important to consider that there will be uncertainties and voluntary monitoring of natural processes as described in the monitoring programme is absolutely essential.

10 References

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Appendix 1: Terms of Reference

Appendix 2: CVs of Consultants

Appendix 3: Site Plan

Appendix 4: Letter from Food and Drug Authority

Appendix 5: Water Testing Results

Appendix 6: Bathymetry Chart

Appendix 7: Letter of Commitment

Appendix 8: GPS Locations of Field Surveys