1 Non Technical Summary

This report discusses the findings of an environmental impact assessment study undertaken by Water Solutions Pvt. Ltd. upon request from Male' Water and Sewerage Company Pvt. Ltd. (MWSC), hereafter referred to as 'client'.

The project involves the construction and implementation of an additional sewerage outfall and a pump station in Hulhumale' and is the first phase of a sewer network for the Industrial area in Hulhumale'. The only existing sewerage outfall currently available has reached its maximum capacity. After the location approval for the sewerage outfall, the rest of the sewerage network will be planned. This EIA has been prepared to assess the social and environmental impacts of the sewage outfall pipe and the pump station.

The major findings of this report are based on extensive literature review, experiences gained from similar field inspections and qualitative and quantitative assessments undertaken during site visits on 16th September, 6th October, 7th October and 17th October 2010. There, seawater and groundwater samples were taken, study sites were photographed and lagoon and reef studies were undertaken. Long term data were collected from available sources, such as long term data on meteorology and climate from global databases.

Potential positive and negative impacts on the environment have been considered. During the construction phase, impacts are likely to be felt most intensively localized on the marine benthos in the lagoon and on reef slope in the form of suspension of sediments and generation of coral rubble while positioning the pipe and its anchor blocks. During operation, on the other hand, the impact of raw sewerage is expected to be felt in the marine environment for as long as sewage is discharged raw; however, monitoring is important to determine to which extent the environment will be harmed.

The health of Hulhumale' citizens and visitors using the eastern beach is of great concern in relation to a sewage outfall. Studying previous reports, we found an inconsistency of seawater quality results indicating contamination of the shallow recreational waters. Due to the unavailability of tests for Enterococci in the Maldives at this time, we were unable to determine whether contamination originates from the existing outfall or from the shedding of bathers and garbage disposed on the beach. A large-scale study to determine the dispersion and impact of sewage is strongly recommended in order to ensure safe swimming conditions for the public.

Based on impacts identified, appropriate mitigation plan and measures have been outlined. These measures reflect all aspects of the construction and the operational phases. Important measures that will be undertaken to minimize the damage on the environment include better pre-planning during the construction phase and proper maintenance of the system during the operational phase among other measures. Alternative to the proposed project have also been discussed and examined, one of which is the implementation of sewage treatment for the future of Hulhumale'.

This EIA has been produced in accordance with the EIA Regulations 2007, issued by the (former) Ministry of Environment, Energy and Water (now: Ministry of Housing and Environment) on preparing Environmental Impact Assessment studies.

2 Introduction

Discharge of waste water to deep sea is a world-wide practice, but is receiving progressively more criticism for the scientific community and general public (NRDC et al. 2004). Given the important role the marine environment plays in the economy of the Maldives, this waste water discharge practice should be done with the necessary care.

Deep sea discharge in 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 'General Guidelines for domestic wastewater disposal' state that '*wherever a sea outfall is used, it should be placed away from areas such as commercial harbours or areas designated for recreational purposes. The sea outfall must be placed in such a way that the effluent will be flushed out into the deep sea, where it can be diluted and dispersed so that the impact on the marine environment is reduced. Untreated wastewater shall not be disposed into the near shore lagoon'.*

This project proposes a pump station and a deep sea sewage outfall that will receive sewage from the so-called "Industrial area" of Hulhumale' (see Figure 7). The contents of industrial waste waters will differ significantly, depending on the nature of the industry. Waste water from metal/mechanical industries tends to have much higher metal and inorganic salts than human waste. Food processing industries such as the tuna industry tend to have high bacterial content, very high nitrogen and phosphorous concentrations, as well as organic components that will deplete oxygen rapidly during the natural break-down process. Human waste, on the other hand, consists mainly of human excreta .The urine is referred to as 'yellow waste', faeces are referred to as 'black waste' and human wash water, laundry and kitchen water are referred to as 'grey water'. The domestic waste water is therefore higher in bacterial / virus / pathogen – concentrations and lower in metal concentration than industrial waste.

Human feces are the biggest concern, because anything which infects one human could infect another. There isn't currently a quantitative method for measuring specifically human fecal bacteria. Expensive genetic studies can only give a presence/absence result. Ingesting a human stranger's feces via contaminated water supply is a classic means for infections to spread rapidly. The more pathogens an individual carries, the more hazardous their feces. Infection rates are around 5% in the US, and approach 100% in areas with poor hygiene and contaminated water supplies.

In addition to the impact of faeces on human health, untreated sewerage carries nutrients, especially nitrogen and phosphorus, from land-fertilizers and laundry outlets that enable rapid algal growth, leading to a condition called eutrophication. Coral reefs are specialized to nutrient poor conditions. Too many nutrients promote fast growing algae, which overgrow the corals. Furthermore, sewage outlets increase the density of bacteria in the seawater; thus, the number of bacteria-feeding organisms, for example sponges, can increase. Where sponges cover large areas, re-colonization with corals is difficult or impossible. In addition, some sponges are bio-erosive. If erosion is dominating over reef-building processes, the reef will decline and in consequence the protective function for the island will decline as well.

3 Terms of Reference

The Terms of Reference for this EIA are attached in the *Appendix 1: Terms of Reference*. This EIA has been prepared based on the Term of Reference.

4 Project setting: Applicable Policies, Laws and Regulations

The project complies with the requirements of the Environmental Protection and Preservation Act of the Maldives, Law no. 4/93. The EIA has been undertaken in accordance with the EIA Regulation 2007 of the Maldives by registered and unregistered (CV attached in *Appendix 7: CV of unregistered individual*) consultants. Furthermore, it adheres to the principles underlined in the regulations, action plans, programmes and policies of Ministry of Housing and Environment (former: Ministry of Environment, Energy and Water MEEW).

4.1 Environmental Protection and Preservation Act

The Articles of the Environmental Protection and Preservation Act (Law No. 4/93) addresses the following aspects of environmental management:

- Guidelines and advice on environmental protection shall be provided by the concerned government authorities.
- 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 MEEW.
- Identifying and registering protected areas and natural reserves and drawing up of rules and regulations for their protection and preservation.
- An EIA shall be submitted to MEEW before implementing any developing project that may have a potential impact on the environment.
- Projects that have any undesirable impact on the environment can be terminated without compensation.
- 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.
- 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.
- The penalty for breaking the law and damaging the environment are specified.
- 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.

The proposed sewerage outfall project will fully abide to the Environmental Preservation and Protection Act. Disposal of oil, chemicals and other hazardous materials will be strictly controlled and managed. Such materials will not be disposed in to the local or the regional environment, but will be transported to designated waste disposal site. All mitigation measures will be fully implemented in the interest of the environment.

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4.2 Water and Wastewater Regulations

From 1973 until 2008, the Maldives Water and Sanitation Authority (MWSA) has been the government authority responsible for water and wastewater regulation in the Maldives. This has changed when the MWSA and the Environment Research Centre of the Maldives were merged by President Mohamed Nasheed on 18th December 2008 and formed the Environmental Protection Agency (EPA). The EPA is an independent legal regulatory entity, working under the supervision of a governing body under the Ministry of Housing and Environment. The EPA Governing Board is a statutory body, established under the Environment Protection Act, with expertise in environment protection, industry, environmental science, regional issues, environmental law and local government.

The MWSA was established in 1973 with the sole purpose of improving environmental health by providing improved water and sanitation services and reducing water-borne diseases which were prevalent at the time to epidemic proportions. Cholera was endemic in the 1970s and Shigellosis and Typhoid were endemic even in the 1980s. However, improvements in water, sanitation and hygiene have been successfully contributed to reduced mortality and morbidity, increased life expectancy and inception. However, MWSA has mainly focused on regulating the service provider, and environmental controls have not been given adequate emphasis. Several attempts have been made to introduce regulations and standards; consequently, upon increasing requests from donors under the Tsunami relief assistance, the MWSA drafted the “Guidelines for Domestic Wastewater Disposal” in 2006 (Ref: MWSA – WWG 2006: First Edition) and the “National Waste Water Quality Guidelines MALDIVES” (January 2007, Ref: MWSA-NWWQG 2006: First Edition). The parameters required for water analysis of the effluent of the existing seawater outfall are taken from the latter document, as given to the consultant by the EPA.

It should be mentioned that currently, sewerage treatment plants are not compulsory on local islands in the Maldives. However, storm water needs to be managed according to the “National Waste Water Quality Guidelines: Storm Water Management Guideline” (Ref: MWSA-SEQG 2006). Solid waste and sludge needs to be removed according to the “National Solids from Wastewater Treatment Guideline” (Ref: MWSA-SWWTG 2006). Health sector waste is not allowed to be discharged to deep sea or via domestic pipelines and has to be treated according to the “National guidelines for the treatment of health sector waste” (Ref: MWSA-HSWG 2006).

4.3 Environmental Impact Assessment Regulation 2007

The former Ministry of Environment, Energy and Water has issued new EIA regulations in May 2007, which guide the process of undertaking the Environmental Impact Assessment in the Republic of Maldives . This guideline also provides a comprehensive outline of the EIA process, including the roles and responsibilities of the consultants and the proponents. This regulation outlines every step of the IEE/EIA process, beginning from application to undertaking an EIA study, details on the contents, minimum requirements for consultants, the format of the EIA/IEE report and many more.

The EIA regulations ensure that:

- all environmental parameters are addressed and their consequences recognized and taken into account in the project design
- substantive and predictive information on the proposed activity is provided, as well as a realistic review of alternatives, measures proposed to mitigate all adverse impacts, as well as the opportunities for environmental, economic and social enhancement

The guidance provided in the EIA regulation was followed in the preparation of this EIA report.

4.4 Post EIA Monitoring, Auditing and Evaluation

The environmental monitoring programme given in EIA reports is an important aspect of the EIA process. The monitoring programme outlines the objectives of the monitoring; the specific information to be collected; the data collection program, and managing the monitoring program. Managing the monitoring programme requires assigning institutional responsibility, reporting requirements, enforcement capability, and ensuring that adequate resources are provided in terms of funds, skilled staff, etc.

The proponent will make every effort to undertake mitigation measures to avoid and to minimize environment effects arising from the project activities. The monitoring programme outlined in this report will comply with the EIA Regulations 2007.

5 Project Description

The proposed pump station and sewer outfall is part of an integrative plan to establish a sewer network in the industrial area of Hulhumale'. Sewerage flow from house connections will be connected to network lines (not part of this EIA) and will be collected in the here proposed pump station (PS9) via a gravity flow system. From there, untreated sewage will be pumped through a 280mm pipe to 350m length from the sea shore into the open ocean at around 15m depth.

5.1 Need and Justification for the project

Currently, there is one sewer outfall in Hulhumale' that handles the sewerage of an estimated 12,000 people (by the end of 2009, figure according to HDC). Its capacity has now reached its limits, discharging untreated sewer automatically into the sea once the pump stations are full. Taking the rapid development of Hulhumale' into account, with a proposed population of 60,000 people by the end of 2020, the existing outfall will not be able to handle the additional sewer flow. Therefore, the project if of high importance and a necessity for a proper working sewer network in Hulhumale'.

5.2 The Proponent

This project is proposed by Male' Water and Sewerage Company Pvt. Ltd. The company has been established in the year 1995 with the purpose of solving the growing water needs in Malé. The principle objective of the company was to design, develop, operate, manage and maintain the public water, wastewater collection and disposal system in Malé.
MWSC has attained achievements including International awards for its success in operations and sharing its knowledge and business practice with regional utility companies. MWSC became an ISO 9001 certified Company in July 2006 on the basis of its good management of business. The Company's record for limiting the amount of water wasted to less than 3% is far ahead of other countries in the region.
MWSC has gained significant amount of knowledge and experience in designing, constructing, managing and operating water and wastewater related facilities during the past 15 years of its existence. Today, the MWSC team serves approximately 150,000 people in Malé, Villingili, Hulhumalé, Thilafushi, and Maafushi.

5.3 Ownership of land

The project will take place on land owned by HDC. Housing Development Corporation Ltd (HDC) is a 100% Maldivian government-owned corporation with the task to cater for government assigned housing projects in various parts of the country. However, its main focus is on ensuring the successful development of Hulhumale'. Therefore, the client had to seek approval from HDC to construct a second sewer outfall, which is attached in *Appendix 2: Project approval by HDC*.

5.4 Intended duration of the project & life span

It will take maximum 8 months for the project to complete, starting from the approval of the EIA:

After the permission is given, the client will order material which is mainly imported from Europe. It is estimated that the material will arrive in the Maldives and is ready to use approximately 3 to 4 months after the order, which also depends on the time when the order is placed.

The construction of the pump station and sewage outfall itself will not take longer than 2 months during favorable weather conditions. Since there is always unpredictability in weather conditions, the construction stage may be extended to a maximum of 4 months.

The life span of the sewage outfall depends on the plans of the government to declare Sewage Treatment Plants (STPs) mandatory to the Maldives. Once they become mandatory and it is decided who will bear additional costs, MWSC will provide treatment of the raw sewage and construct a sewerage outfall on the southernmost point of the island close to the MWSC plot. In this event, the complete sewer network of Hulhumale' will be redirected there and the here proposed outfall and the existing outfall will be inactivated.

However, in case the alternative option (see 11.2 Alternative location) is chosen, the proposed outfall does not need to be inactivated at a later stage, but will instead be planned with a larger diameter and used for treated sewer discharge.

5.5 Project Location and Study Area

5.5.1 Project location

The project is planned to take place on the south-eastern side of the reclaimed island Hulhumale' in North Male' Atoll (Figure 1).

A proposed pump station (PS9) that would receive domestic sewage from the network (the network will be proposed in a separate EIA) would be located at 4°12'23.77"N/73°32'21.98"E. Eventually, the network is intended to be a gravity flow system, where sewage flows to the pump stations, from where a pipe connects them eastwards towards the shore (4°12'23.06"N/73°32'33.51"E). There, the proposed outfall begins, extending 350m seawards perpendicular to the shore. Please refer to *Appendix 3: Proposed sewer network* for a drawing of the proposed pump station and sea outfall in relation to the surroundings of the island. Please refer to *Appendix 4: Sump well drawings* for architectural details of the sump well of a typical pump station, and to *Appendix 5: Panel shed drawing* for panel shed details.

5.5.2 EIA study area

The study area for the EIA surveys extends from the above mentioned proposed sea outfall northwards up to the existing sea outfall, and southwards up to the alternative outfall location (Figure 1). Water samples were also taken in the area where a swimming track is being proposed. Groundwater samples were taken at four locations (Figure 3).

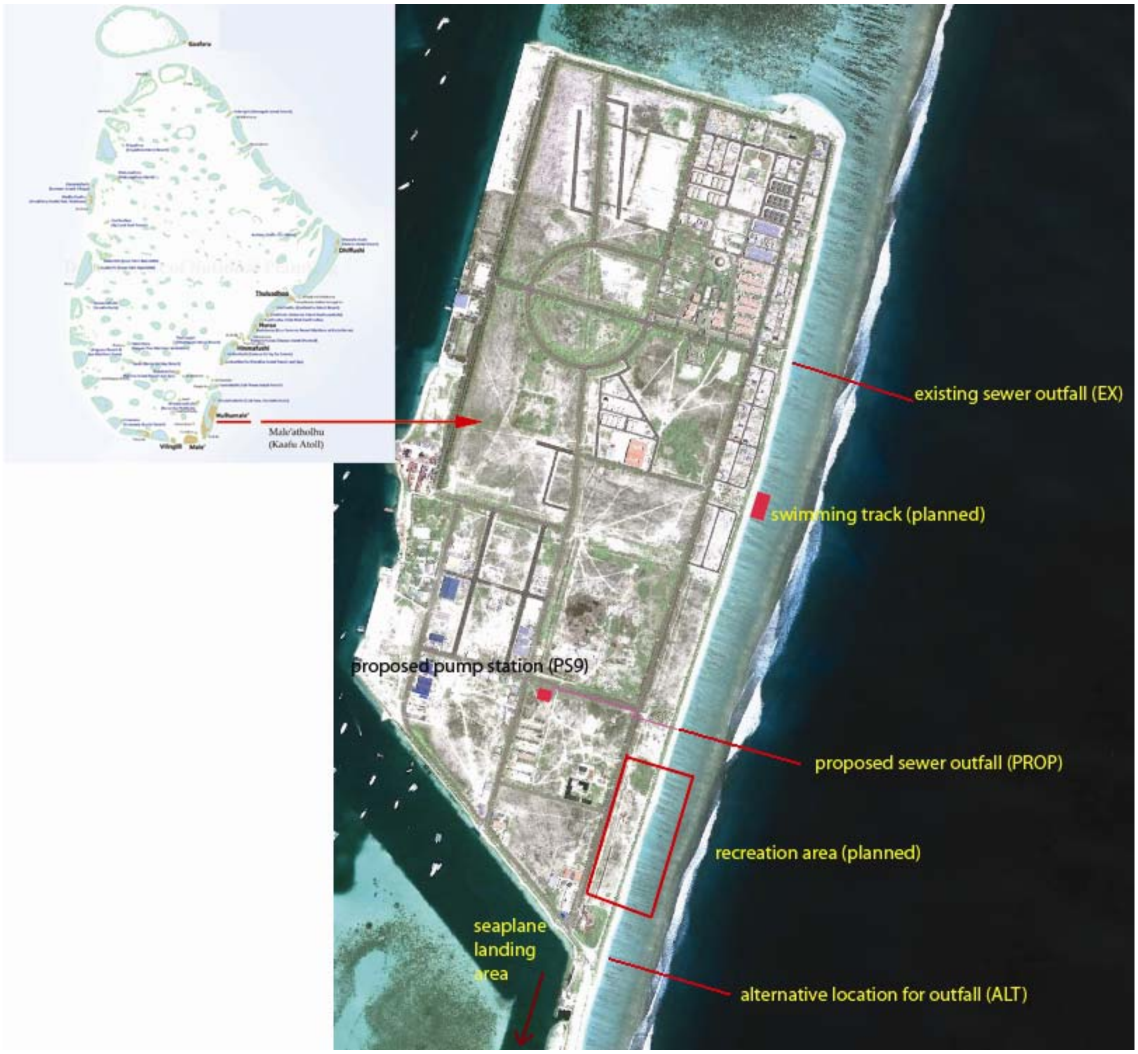

Figure 1. Project location in Hulhumale'
Top left: Position of Hulhumale' in the Kaafu Atoll (Graphic by Ministry of Planning).
Right: The artificial island Hulhumale'. The proposed and alternative sewer outfalls, as well as the pump station and its connection to the outfall are within the scope of this EIA. (Photo: Google Earth)

5.6 Project Activities and equipment used

- Before the commencement of work, the exact location of the outfall as per drawing and decision note from the EPA will be verified and approved by the engineer.

- Wooden or metal moulds will be prepared for the casting of concrete blocks either in a workshop or in close vicinity of the proposed pump station. All the blocks required shall be precast and cured as per specifications and kept ready for installation.

- Information regarding variation of tide levels, currents, wind and other relevant information will be obtained for the respective working days from appropriate authorities before starting the work.

- The surrounding area of the work site of the sea will be marked using buoys.

- A dive boat, equipped with SCUBA tanks and a dive flag, will be used. Divers will use hammers, chisels, ropes and inflatable balloons for lowering the anchor blocks.

- A shore trench will be excavated with the use of an excavator after the exact location of the pump station is confirmed and marked. Excavation works shall commence from the ductile iron/polyethylene flange joint on the outside of the pump station.

- After completion of the trench work, a pipe will be laid and backfilled. This process will be continued until the shore is reached.

- Under water works will be started once the trench is backfilled. Some amount of bed preparation is required. Hammer and chisel will be used for minor adjustments. As far as possible, a profile will be chosen that will require least excavation/leveling. Pipes will be laid on the sea bed and anchored to the horizontal/or vertical sea bed, depending on the section.

- The sea outfall line shall be welded on dry ground of lengths 20 to 30 meters with attached flanges at both ends.

- Concrete blocks of required quantity will be transported to the work site by boat. The blocks will be lowered under water with extreme care and coupled, aligned to the proposed location and will be placed in position with required spacing.

- The connection pipes are transferred to the boat and lowered into the sea (flow-tow-sink operation). The flanged ends are bolted by the divers to complete the required length. Handling of pipes is done in a manner so as to avoid damage. The loading and unloading of loose pipes shall be carried out by hand, avoiding the use of skids. Metal slings, hooks and chains shall not come in direct contact with pipes and they shall not be dropped onto hard surfaces or dragged along rough ground. A diffuser will be fixed at the end of the pipe.

- A concrete thrust block will be anchored to the outfall pipe.

- The pipe will be observed for any leakages and the site will be cleaned after completion of works.

5.7 Project Inputs and Outputs

5.7.1 Project Inputs

Construction workers

The outfall project will not involve more than 15 -20 workers who will be engaged two to four months at the most. Labourers will be engaged from within the country.

Construction machinery and material

Usually, an excavator is used to excavate the trench from the pump station to the sewage outfall. Minor leveling of the sea floor will be undertaken; an excavator may be necessary for this, but most likely only hammer and chisel will be used.

Wooden or metal moulds will be prepared for the casting of concrete blocks. The major construction material will be concrete. Freshwater will be obtained from the MWSC RO water production plant in Hulhumale'.

Transport

The connection pipes and concrete blocks will be transported by boat and lowered down. Waste will be transported on land vehicles to the disposal site.

5.7.2 Project Outputs

Sewage

It is expected that about 120 litres of sewage will be produced per person per day.

Solid waste

Usually, the volume of work involved does not create a significant volume of waste if the contractor gives consideration to minimize the waste. Solid waste generated during construction (like moulds, concrete leftovers) will be transported to Thilafushi. Concrete waste is also accepted by Male' Municipality in their dumping depot in Male', therefore, this option might be used as well.

Solid waste is also generated in minimal quantities during the operational phase of the project. According to the client, solids from sewage (e.g. toothbrushes, bottle caps, etc.) used to be trapped in the pump station through a screen filter and were removed by the client about once in a week. This screen has been removed now, so occasional solids will be discharged into the sea.

Noise

Noise will be only localized during the construction of moulds for the anchor blocks, the building of the pump station and the placement of the sewage outfall pipe. Since the project will take place far away from the residential area of the island, this factor is negligible. Work will be conducted during day and night to make use of the tidal variations.

Odour

There may be minimal problems with H_2S odour during the operation of the sea outfall, but due to the gravity flow system, sewage is never kept in the system for a long time where it could produce bad smelling gases. The system will be filled every 10 to 15 minutes, depending on the load, and sewage is automatically pumped into the ocean. Therefore, odour is considered negligible in this project.

Air pollution

Limited quantities of dust in the construction area may be generated, but the amount is considered negligible. Mainly it will be arising as a result of dust emission from the construction work such as cement mixing or moving machinery.

Waste oil and grease

There will not be a separate grease/oil trap for the domestic sewer network as proposed in this project. Hotels and local tea houses discharge their sewage into the client's system through an oil filter.

Sea pollution

As for the construction phase, there may be limited quantities of concrete waste generated during the adjustment of the pipe in the water, using hammer and chisel. In addition, there will be a considerable amount of sediment stirred up. Sea pollution is a major concern during the operational phase of the project. Potential impacts and mitigation measures, as well as alternative methods to prevent sea pollution are described in the respective sections of this EIA report.

Disposal of excavated soil/coral rock

Soil that is generated during the excavation of the trench will be used for backfilling. Coral rock waste that is being generated while the pipe is positioned on the reef slope will remain on site.

6 Materials and Methods

The section covers methodologies used to collect data on the existing environment. The key components of the project that were considered were the physical environment, the groundwater quality as well as the marine environment that includes the lagoon and reef system. The following data collection methodologies were used during field visits undertaken in September and October 2010 to the island.

6.1 Mapping and Location identification

Several locations on and around the island such as groundwater and seawater sampling points were recorded using a Trimble Geo GPS. Water quality sampling sites and the location of the reef survey are outlined in Figure 3.

6.2 Water surface currents

Current directions from the eastern lagoon and outer reef were measured using a drogue (Figure 2). Drogues, which consist of a float and vane plates, were deployed and their movement tracked with a differential GPS instrument.

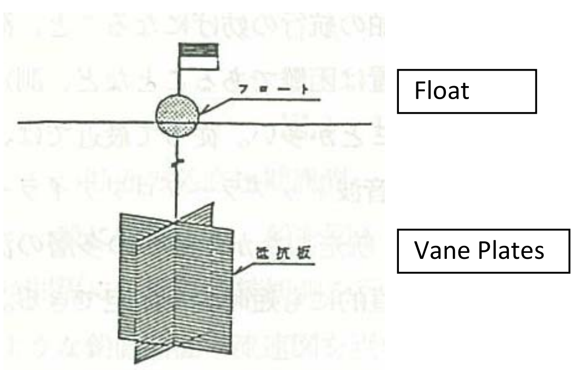

Figure 2. Equipment for drogue study

Figure 3. Survey locations for the present EIA study.
G1-G4 are groundwater quality sampling sites; ALT ... Alternative Site, PROP ... Proposed site for outfall, EX-N and EX-S ... North and South of the existing sewage outfall. Marine benthos survey sites are marked in blue quadrats.

6.3 Bathymetric survey

A rapid (spot) bathymetry using a hand echosounder and a Trimble GPS was performed in order to determine the depth at the proposed and alternative site for the sewer outfall.

6.4 Water quality

Water samples were taken at a depth of 1m from the mean sea level or at mid water depth for shallow areas such as the swimming track area. Ground water samples were taken from wells (G1, G2, G4) or taps (G3), respectively.

In-situ temperature and pH readings were recorded with a HANNA Combo pH&EC meter. Salinity and EC/TDS were recorded with the HACH SenSion 5 meter (EC/TDS conversion = 0.6). The instruments were calibrated before the measurements according to their instruction manuals. For pH calibration, a two-point calibration was performed with a pH 4.01 and pH 7.01 solution. For the TDS calibration, a 6.44ppt solution was used for both meters.

All other parameters were tested in the MWSC laboratory, since the National Health Laboratory (NHL) did not offer all our requested parameters. Enterococci could not be tested at any time in either laboratory (see *Appendix 6: NHL and MWSC lab statements*). The effluent water quality sampling was under the responsibility of MWSC.

6.4.1 Groundwater

Generally, the islands of the Maldives have superficial groundwater lenses below about a meter of coralline sandy soil with a very narrow humus layer on top. The groundwater lenses are formed due to density differences between percolated rainwater and saltwater beneath the island. The freshwater lens floats on top of the saltwater. This makes it extremely fragile and prone to saltwater intrusion due to over-abstraction.

This report assumes the reader to be familiar with the understanding of how freshwater exists within and beneath an atoll island. Falkland (2001) discusses this in detail.

Groundwater is still used in various islands of the Maldives for different domestic purposes like drinking (when water is healthy and aesthetic), for food preparation, bathing, gardening and laundry. Even though groundwater is not used for drinking in Hulhumale', it is used for food preparation, laundry and bathing and with this EIA it shall be ensured that all facilities that are included in this project shall be durable, leak proof and prevent any surface run-off to the aquifer.

In Annex B of the 'General Guideline for domestic wastewater disposal', the criteria for the use of groundwater in the Maldives were being set. The effects of different classes of water on the various domestic uses of water were grouped as in Table 1:

Table 1. Effects of the different classes of water on various domestic uses.
Source: General Guideline for Domestic Wastewater Disposal, MWSA – WWG 2006: First Edition

"Class A" (Ideal water quality):	No effects on drinking health, food preparation, bathing or laundry
"Class B" (Good water quality):	Suitable for lifetime drinking use with rare instances of sub-clinical effects, suitable for food preparation, with minor effects on bathing and bath fittings or laundry or on fixtures.
"Class C" (Marginal water quality):	May be used without health effects by the majority of individuals of all ages, but may cause effects in some individuals in sensitive groups. Some effects are possible after lifetime use. May be used without health or aesthetic effects by the majority of individuals for food preparation; will have slight effects on bathing, bath fittings, laundry and on fixtures.
"Class D" (Poor water quality):	Poses a risk of chronic health effects, especially in babies, children and the elderly; has got a bad taste, may pose a risk of chronic health effects if used in food preparation and will have significant effects on bathing, bath fittings, laundry and fixtures.
"Class E" (Unacceptable water quality):	Will have severe acute health effects even with short-term use, whether being drunk or used for food preparation, and will have serious effects on bathing, bath fittings, laundry and fixtures.

[Please refer to the 'General Guideline for Domestic Wastewater Disposal' for acceptable limits for Faecal coliforms, Electrical conductivity/TDS, pH, Nitrate, Nitrite and Turbidity criteria.]

Groundwater sampling for baseline data was conducted in 4 areas of the southern side of Hulhumale' (Table 2, Figure 3) as discussed in the scoping meeting on 12th August 2010.

Table 2. Groundwater sampling points

Code	Source	GPS coordinates
G1	Water Solutions plot (well)	4° 12' 26.1" N, 73° 32' 16.9" E
G2	Brick-production factory (well)	4° 12' 39.0" N, 73° 32' 18.3" E
G3	Nursery (tap)	4° 12' 19.0" N, 73° 32' 26.9" E
G4	Private land plot (well)	4° 12' 26.4" N, 73° 32' 22.0" E

As per the ToR, groundwater had to be tested for following parameters:

- Nitrates, phosphates, pH, suspended solids, ammonia, faecal and total coliforms.

(All parameters except pH were tested in the MWSC laboratory.)

- In addition to these parameters, we have taken in situ readings of (pH), temperature, salinity, conductivity and total dissolved solids.

6.4.2 Seawater

Seawater quality testing is particularly important considering not only the health of reef organisms, but also public health since a swimming track is going to be developed on the eastern side of Hulhumale', between the existing and the proposed sewage outfall. On the south-eastern side, a recreational area that will offer land-based and marine activities is in the planning stage.

Untreated sewage usually carries high levels of phosphorus and nitrogen, which can lead to eutrophication in the normally nutrient-low tropical environment. Eutrophication is a serious problem for the Maldivian environment because elevated levels of nutrients often result in exceeded plant (--> algal) growth. The slow growing scleractinian corals, on the other hand, are essential in reef-building processes and are not able to compete with the fast growing algae. Filamentous turf algae mats are visible in many islands of the Maldives and are directly related to an excess of nutrients discharged into the sea, often at distanced areas. Particularly island lagoons in warm months are vulnerable, because turf algae need good light conditions and nutrients to grow, converting them into biomass and sometimes changing reef communities.

Faecal pollution of recreational water can lead to health problems because of the presence of infectious microorganisms. Because it is so much more expensive and tedious to test for bacteria, viruses and parasites that make people sick, these actual pathogens are virtually never tested for, and indicators are used instead.

The best INDICATORS of health risk from water contact are *E.coli* and enterococci. Total coliforms are no longer recommended as an indicator by the US EPA, because total coliforms include genera that originate in faeces (faecal coliforms such as *Escherichia*) as well as genera not of faecal origin (non-faecal coliforms, such as *Enterobacter*, *Klebsiella*, *Citrobacter*). *E. coli* is an indicator microorganism for other pathogens that may be present in faeces.

Until recently, the faecal coliforms was the group of primary bacteria indicator, before the US EPA began recommending *E. coli* and enterococci as better indicators of health risk from water contact.

Enterococci indicate that there are faeces from warm blooded animals in the water. They are a type of faecal streptococci, and another valuable indicator for determining the amount of faecal contamination of water. According to studies conducted by the US EPA, enterococci have a greater correlation with swimming-associated gastrointestinal illness in both marine and fresh waters than other bacterial indicator organisms, and are less likely to “die off” in saltwater.

Nevertheless, after contacting both the National Health Laboratory and the MWSC laboratory, we were told that neither *E. coli**, nor enterococci could be tested at the time we required it for this EIA study. Thus, we were only able to test our samples for Faecal and Total Coliforms, but will recommend tests for enterococci as the best indicator of health risk in salt water in the monitoring programme.

**E.coli* was available in October, so one sample of the proposed Swimming Track was sent to the lab.

In general, increased levels of faecal coliforms provide a warning of POSSIBLE contamination with pathogens. Waterborne pathogenic diseases that may coincide with faecal coliform contamination include ear infections, dysentery, typhoid fever, viral and bacterial gastroenteritis, and hepatitis A. The presence of faecal coliform tends to affect humans more than it does aquatic creatures, though not exclusively. On the other hand, faeces of non-human origin are of less concern to humans.

Untreated organic matter that contains high levels of faecal coliform can be harmful to the environment. Aerobic decomposition of this material can reduce dissolved oxygen levels if discharged into the sea.

The current US EPA recommendation for body-contact with faecal coliforms during recreation is fewer than 100 colonies/100mL, and for drinking less than 1 colony/100mL (which could happen in case of ingestion during recreational use of seawater).

BACKGROUND INFORMATION

In addition to the parameters that we collected for this EIA, some information about the seawater quality at two more sites were available to us from the EIA of the proposed swimming track (LaMer 2010): from the shallow area where the swimming track has originally been proposed (Site “SW 1” at 4°12’55”N, 73°32’44”E), and at the alternative site, where the track is eventually planned (Site “SW 2”at 4°12’42”N, 73°32’41”E). The seawater sampling sites are indicated with a yellow dot in Figure 4:

Figure 4. Seawater quality sampling sites (SW1 and SW2, yellow dots) from the EIA for a swimming track (LaMer 2010)

In addition, the EPA (Environmental Protection Agency) has performed water quality tests in Hulhumale’ at locations shown in Figure 5. Site “6” is closest to the existing sewer outfall, whereas the swimming track will be made between Site “4” and “5”. The proposed outfall is closest to “3”, and the alternative location would be close to “1”.

Figure 5. Water quality sampling sites "1" to "8" along the eastern shore of Hulhumale'. Graphic: EPA

PRESENT STUDY

The quality of seawater was assessed in five areas on the eastern side of the island (Table 3, Figure 3): North and South of the existing sewage outfall (350 m from shore), at the proposed and alternative outfall site (350m from shore) and at the shallow area where the swimming track is planned.

The parameters to be tested were as follows:

- Temperature, pH, dissolved oxygen, salinity, suspended solids, turbidity, nitrates, nitrites, phosphates, chemical oxygen demand, biological oxygen demand, faecal coliforms and total coliforms.

Table 3. Seawater sampling sites

Code	Location	GPS coordinates
EX-N	north of the existing sewer outfall	4° 12' 55.8" N, 73° 32' 56.2" E
EX-S	south of the existing sewer outfall	4° 12' 50.1" N, 73° 32' 55.2" E
PROP	proposed site for sewer outfall	4° 12' 20.9" N, 73° 32' 44.6" E
ALT	alternative site for sewer outfall	4° 11' 26.1" N, 73° 32' 37.5" E
SWIM	approved location of a swimming track	4° 12' 42.2" N, 73° 32' 40.5" E

6.4.3 Effluent

As per the ToR, parameters to be tested are outlined in the National Wastewater Quality Guidelines issued by the EPA (Ref: MWSA-NWWQG 3006: First Edition). These guidelines have specified ‘Domestic Waste water Quality for discharge into Deep Sea’ (Chapter 6.2.), as well as ‘Combined Domestic and Industrial water requirements for Deep Sea Discharge’ (Chapter 7.).

For this EIA, MWSC has tested its effluent of the existing sea outfall in Hulhumale’ according to the ‘Domestic Waste water’ requirements, even though they may be receiving sewage from light industries and a poultry and fish processing farm (high in organic contents) from the industrial area as well.

The reason for testing according to domestic waste water guidelines only is that MWSC clearly stated that they will not accept any untreated sewage that does not comply with safe deep sea discharge guidelines. Hence, according to the “polluter pays” principle, MWSC will only accept sewage from industries/companies which perform on-site treatment (i.e. treatment that takes place within the boundary of the property generating wastewater.) until their sewage conforms to domestic waste water standards. This can be achieved by using e.g. septic tanks, biofilters or aerobic treatment systems.

Following tests were to be performed from a sample taken from n existing pump station according to the guidelines:

- Faecal coliforms, E. coli, pH, suspended solids, residual chlorine, nitrates, ammonia, phosphates, surfactants, conductivity, soap, oils and grease (food-related); oils, grease and waxes; chemical oxygen demand, biological oxygen demand, phenolic compounds as phenol, sum of metals (Cadmium, Chromium, Copper, Mercury and Lead), and acute toxicity.

6.5 Biotic marine environment

6.5.1 Lagoon system

The lagoon was assessed at both the proposed and the alternative location. A visual study of the seabed up to the wave breaking zone was undertaken. The status of the proposed swimming track area was documented with a photo, and photos of the lagoon at the existing outfall are available through the client.

6.5.2 Reef system

The purpose of the marine survey was to define and establish marine environmental baseline conditions in areas where sewage is planned to be discharged. Surveys are based on standard marine environmental surveys so that they can be repeatedly carried out to monitor and record changes and assess possible impacts on the marine environment from the proposed work activities.

Two methods were primarily used to collect data, namely:

- Quantitative assessment of the benthic composition with a 60x60cm photo frames
- Qualitative surveys through visual observations and photos taken

A quantitative study was undertaken at the proposed outfall site (PROP) and the alternative site (ALT). Since the client panned to discharge sewage approximately 350m from shore, this distance was calculated and the survey was conducted in 21m (ALT) and 15m (PROP) depth (Figure 3).

At each site, photo quadrats of 60x60cm length were positioned on the seafloor along a 20m transect line and photos were taken with a digital camera in an underwater housing. These photos were then evaluated on the PC using CPCe software (Kohler and Gill 2006). Additionally, photos were taken at various depths within the distance from shore to document coral coverage at the future sewage outfall site.

7 Existing Environment

7.1 The island Hulhumale'

The proposed project will take place on the island of Hulhumale', a reclaimed island located in the south of North Male Atoll, Maldives. The artificial island was built to relieve the urban congestion in the capital region of Maldives by providing housing from Hulhumale' in a socially responsible, commercially viable manner. Reclamation of the 188 hectares of land that comprises Hulhumale' commenced in 1997 and was completed in 2002. Primary developments in terms of the required physical and social infrastructure and residential developments were completed in 2004 and the very first settlement of Hulhumale' began in mid 2004 with a resident population of just over 1000 people.

Hulhumale' is being developed by Housing Development Corporation (HDC). Established in 2005, the corporation was initially named "Hulhumale' Development Corporation Ltd" (HDC) with the development of Hulhumale' as the main focus. In 2009, the corporation was renamed "Housing Development Corporation Ltd" and the mandate was broadened to cater to government assigned housing projects in various parts of the country. However, the main focus still remains in ensuring the successful development of Hulhumale'. Housing Development Corporation Ltd is a 100% Maldivian government-owned corporation.

By the target completion date for the development, the year 2020, Hulhumale' should have been transformed into a world class city where 60,000 people would live, work and raise their families. As well as providing a superb living environment for its residents, Hulhumale' will also serve as a catalyst for broad based investments in the fields of commerce, education, health, recreation, tourism, fisheries and a number of other related areas by both foreign and national parties (Figure 6).

Figure 6. Land use plan of Hulhumale'.
The master plan accommodates for a wide range of land uses in Hulhumale'. From commercial and residential to industrial and institutional uses and so on, land on Hulhumale' is being used for - and is planned to be further used in the future for a diverse set of activities. Graphic from www.hdc.com.mv.

Currently, all water-related recreational activities take place on the eastern beach of Hulhumale'. A swimming track has already been approved, and a recreational center is in the planning stage on the south-eastern side of Hulhumale' (see Figure 1). Therefore, the EIA study area represents the side of the island which will be extensively used by its residents and visitors.

The southern half of Hulhumale' accommodates an Industrial Zone, Municipal Services (such as water supply MWSC and electric supply by State Electric Company STELCO) and a Waste Yard. Drinking water is currently being generated by the client and minimally by large factories which are not connected to the public system yet and discharge brine through two seawater outfalls on the west side of Hulhumale.

As per information from HDC, the Industrial Zone, for which a sewer network is planned and for which the proposed outfall will be constructed, will consist of 4 Zones (Figure 7):

Zone 1 – Fish, Food and related services
Zone 2 – Warehouse and other light industries
Zone 3 – Workshop, Carpentry and similar activities
Zone 4 – Nuisance Industrial activities

The proposed project involves the construction of a pump station and sewage outfall on the eastern side of Hulhumale', which will be eventually connected to a sewage network in the Industrial Area.

Figure 7. Plan for the industrial zone in Hulhumale'. Graphic by HDC.

7.2 Existing sanitation system

MWSC has already provided a sewage network with seven pump stations for around 12000 residents in Hulhumale', which is connected to one sewer outfall at the north-eastern side of Hulhumale'.

The state of wastewater management in the island is similar to most of the local islands in the Maldives. Sewerage flows from house connections through network lines and is then collected at pump stations (gravity flow system). Once the pump stations are full, untreated sewage is automatically being pumped through a 280 mm pipe to approximately 350m length from sea shore to the ocean. Solids in sewage are currently not intercepted through screens, neither in the houses,

nor at the sump. Previously, solids were screened in the sump, dried and disposed at a waste disposal site. Discharge occurs in 15m depth. According to information from the client, a diffuser will be fixed at the end of the pipe to increase the dilution factor by the beginning of November 2010.
Septic tanks are in use in areas were the sewer network is not laid and where construction is ongoing. The septic tank effluent is soaked into the ground until a network is provided. The septic tanks will be terminated as soon as the sewer network is completed.

Storm water does not enter the sewer network and is also not in future within the client's mandate. It currently soaks into the ground, diluting the freshwater lens underground.

The fish factories currently connected to the sewage system intercept solids (like chunks of fish waste) in-house, but do not treat their waste, which mostly comprises of a water-blood mixture from fish and toilet sewerage (personal communication with staff at Ensis fish factory, Hulhumale').

The local hospital in Hulhumale does not treat sewage in particular. Hydrochloride acid is used on body excretions before they are being cleaned; however, blood from the operation theatre or excretions from the toilets enter the main sewer network directly (personal communication with Ms. Najmal, Hulhumale' hospital).

7.3 Ecological setting of the island

The totally reclaimed island of Hulhumale' is situated at approximately 4°12'43.40"N and 73°32'24.82"E on the south-eastern atoll rim of the North Male' Atoll (Kaafu Atoll). It is between 1.7 and 2.4km long, 900m wide and lays within the same reef system as Farukolhufushi ('Club Faru' Resort) to its North, and Hulhule Island (Male' International Airport) to its South, together stretching over 7.7km. Reclamation of the 188 hectares of land that comprises Hulhumale' (Figure 8) commenced in 1997 and was completed in 2002 (see Figure 1 for the fully reclaimed island in 2010).

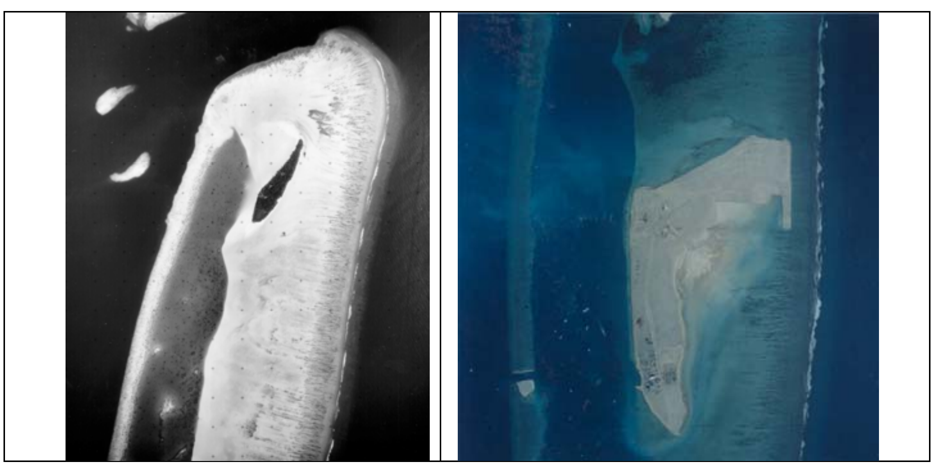

Figure 8. Aerial photo of the Farukolhufushi Faru.
Left: Farukolhufushi in 1969, when Hulhumale' did not exist. Right: Hulhumale' during the reclamation process 1999 (southern tip of Farukolhufushi on top of photo)

Hulhumale' is connected to Hulhule' Island by an artificial land bridge. Its eastern side faces the outer reef edge of the North Male' Atoll, its western side faces a lagoon. On the south of Hulhumale', sea planes use this lagoon to take off and land, for which part of the reef flat has been dredged. A coral reef stretches along the island's eastern and northern side.

7.4 Physical Environment

7.4.1 Meteorology and Climate

The Maldives has a warm and humid tropical climate. The weather is dominated by two monsoon periods: the South-West (SW) monsoon from May to November (rainy period) and the north-east (NE) monsoon from December to March (dry period), when winds blow predominantly from either of these two directions.

The relative humidity ranges from 73% to 85%. Daily temperatures in the country vary very little throughout the year with a mean annual temperature of 28°C.

7.4.2 Wind conditions

Winds affect sedimentation process both during the formation and development of islands. Winds help regenerate waves that are weakened by travelling over reefs and also cause locally generated waves over lagoons. Figure 9 shows the wind direction pattern for Malé International Airport from the National Meteorological Centre. Winds from the north-east and the east-north-east are predominant during December to February. During March to April the direction varies with the general direction being westerly. Strong winds are associated with the southwest monsoon season. Gales are uncommon, and cyclones very rare in the Maldives. The stormiest months are typically May, June and July. Storms and squalls producing wind gusts of 50-60 knots have been recorded at Malé.

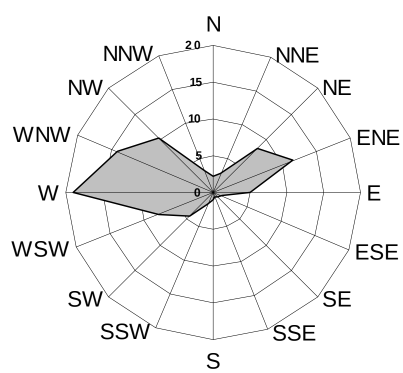

Figure 9. Percentage of average wind direction for Malé (1980-2006)

7.4.3 Sea level

Regional mean sea level is affected by a seasonal fluctuation of 0.2 m:

- increase of about 0.1 m from February to April,
- decrease of 0.1 m from September to November.

7.4.4 Tide levels

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

Tides in the Maldives are mixed semi-diurnal / diurnal. A permanent tidal record station has been established at Malé International Airport by Maldives Meteorological Services. Tide data is important information in any costal development project as it determines the elevation of the structures relative to a datum. Figure 10 provides the monthly tidal average that had been measured at Maldives International Airport.

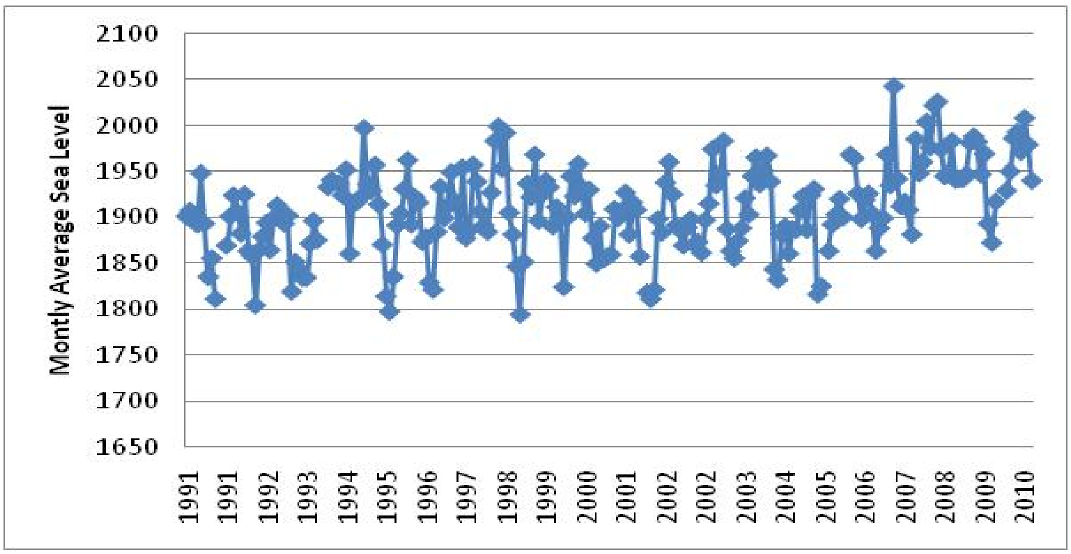

Figure 10. Tide level measured at Malé International Airport

Tidal levels given by the Admiralty Tables (2007) are presented in the following table.

Table 4. Maldives tidal levels in meters above Chart Datum (Admiralty tide tables, 2007).
LAT: Lowest Astronomical Tide, MLLW: Mean Lower Low Water, MHLW: Mean Higher Low Water, MLHW: Mean Lower High Water, MHHW: Mean Higher High Water, HAT: Highest Astronomical Tide

	GEO. COORDINATES		LAT	MLLW	MHLW	MSL (ML)	MLHW	MHHW	HAT
	LAT. (°N)	LONG. (°E)							
STANDARD PORT: COCHIN (WEST COAST OF INDIA)	9° 58'	76° 16'	-0.2	0.3	0.6	0.6	0.8	0.9	1.2
MALDIVE ISLANDS									
IHAVANDHOO	6° 57'	72° 55'		0.3	0.6	0.68	0.9	1.0	
GOIDHOO ATOLL	4° 51'	72° 55'		0.3	0.5	0.6	0.8	0.9	
GIRIFUSHI	4° 19'	73° 55'		0.3	0.4	0.58	0.7	0.9	
MALE	4° 11'	73° 31'		0.3	0.5	0.65	0.8	0.9	
VATTARU	3° 15'	73° 24'		-	-	0.7	0.9	1.0	

7.4.5 Storm surge

Storm surge may increase the water level due to the effect of atmospheric pressure variations. A water level variation of 10 cm occurs with a pressure variation of 10 HPa, and due to wind effects, especially in shallow water areas.

7.4.6 Wave setup

In the wave breaking zone, the water level is locally increased. As a first rough assessment, an increase corresponding to 10% of the deep water wave height can usually be considered.

7.4.7 Sea level rise

Analysis of data from tide gauges measuring sea levels at Malé and Gan meteorological stations shows that the Maldives coastal sea level is rising in the range between 3.9 (Gan) and 4.1 (Malé) mm/year.

According to the Intergovernmental Panel on Climate Change (IPCC) in its 4th report (2007), the global sea level rose by 1.8 mm/year between 1961 and 2003 and 3.1 mm/year between 1993 and 2003.

The latest predictions for the global sea level rise in the next century, provided by IPCC (2007), are in the range between 0.18 m and 0.59 m depending on the scenario modeled.

7.4.8 Currents

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

Hulhumale is located at the south-eastern side of North Male Atoll, south of Hulhule.

The proposed area for a sewer outfall is facing the outer atoll side. The main wave type received at the area is the oceanic swell received from the south eastern direction, while wind wave during NE monsoon will be coupled with swell waves. During SW-monsoon, the eastern quadrant of Hulhumale is sheltered.

The current regime therefore is strongly dictated by the wave condition. Analyzing the satellite image (Figure 1), the dominant current direction is east to west. At the proposed sewer outfall, the water current during SW-monsoon would be flowing east to west and northwards, which our drogue studies confirm, and southwards during NE-monsoon.

7.5 Bathymetric results

A spot bathymetry was performed at the proposed and alternative outfall site which revealed depth at 350m from shore as 21.6m (ALT) and at 15.0m (PROP), respectively. The reef further from the shore drops down to 50 meters and more. Being located at the atoll edge of the North Male' Atoll, the carbonate platform on which the Maldivian islands are formed drops down to more than 2000m below sea level.

7.6 Water quality

7.6.1 Groundwater

The groundwater was sampled and analyzed (Table 5) from four different locations as discussed in the scoping meeting of the project. Sampling method details and locations are outlined in Chapter Materials and Method.

Table 5. Groundwater results from four areas of southern Hulhumale', October 2010.
Temp...Temperature, EC...Electrical Conductivity, TSS...Total Suspended Solids, NO_3^-...Nitrates, PO_4^- ...Phosphates, N-NH_3...Nitrogen Ammonia, Total C...Total Coliforms, Faecal C...Faecal Coliforms

	G1	G2	G3	G4
Colour	clear	clear	clear	clear
TEMP [°C]	29.8	32.6	28.1	29.1
pH	9.03	8.72	8.02	7.73
EC [µS/cm]*	665	889	749	689
TSS [mg/L]	1	2	4	7
NO_3^- [mg/L]	1.70	0.30	0.30	0.60
PO_4^- [mg/L]	0.18	0.05	0.09	0.15
N-NH_3[mg/L]	0.18	0.17	0.20	2.70
Total C / 100mL	>100	>100	>100	>100
Faecal C/100mL	0	0	4	3

*approximated results due to inaccuracy of probe

According to the Criteria for the use of Groundwater in the General Guideline for Domestic Wastewater Disposal (Ref: MWSA-WWG 2006), water from the wells G3 and G4 contain water of "marginal water quality" due to the presence of faecal coliforms. Wells G1 and G2 did not contain faecal coliforms on the day of sampling, but their salinity is at the limit of "Ideal" drinking water quality. However, without a test for *E.coli* or Enterococci, we would not give recommendations on the drinking water suitability of groundwater.

7.6.2 Seawater

BACKGROUND INFORMATION

Seawater quality tests have been performed by the EPA, who has overtaken the responsibilities of the former MWSA (Maldives Water and Sanitation Authority), as well as within a recent EIA study undertaken by LaMer (March 2010):

RESULTS OF EIA STUDT BY LAMER (2010)

Results of the EIA study from March 2010 are shown in Table 6. Sites "SW1" and "SW2" are described in the Methodology section. Chemical parameters have only been tested for Site "SW1" during peak usage of the beach; microbiological analysis has been performed on both sites during peak, mid and low usage times.

The study suggests that total coliform count varies from one site to the other and from low usage of the beach to peak usage. There is no clear pattern; one could vaguely say that the total coliform count at both sites is higher during peak usage of the beach, than at low usage.

While the faecal coliform count is at 0 at both sites during all times, Enterococci levels are extremely high during high and medium usage at "SW 1", elevated at low usage at "SW 1" and absent at low usage at "SW2".

BOD is rather high at peak usage at "SW1" and unfortunately no data are available from the other site and at low usage time. As a consequence, DO levels are rather at the lower limit. Fish growth and activity require a minimum DO of about 5-6 mg/L. The temperature at time of sampling is not mentioned in the EIA.

Nitrite and Nitrate levels are of no concern for the marine environment in this study.

Table 6. Seawater quality results from Hulhumale' by LaMer, early 2010
SAL...Salinity, NO_3^-...Nitrates, NO_2^-...Nitrites, DO...Dissolved Oxygen, BOD...Biological Oxygen Demand, COD...Chemical Oxygen Demand, Total C...Total Coliforms, Faecal C...Faecal Coliforms

	Site "SW 1"			Site "SW 2"	
	Peak	**Mid**	**Low**	**Peak**	**Low**
Physical appearance	**clear**				
pH	**8.5**	**n.a.**	**n.a.**	**n.a.**	**n.a.**
SAL [%o]	**35.4**	**n.a.**	**n.a.**	**n.a.**	**n.a.**
NO_2^- [mg/L]	**0**	**n.a.**	**n.a.**	**n.a.**	**n.a.**
NO_3^- [mg/L]	**0**	**n.a.**	**n.a.**	**n.a.**	**n.a.**
DO [mg/L]	**5.8**	**n.a.**	**n.a.**	**n.a.**	**n.a.**
BOD [mg/L]	**26**	**n.a.**	**n.a.**	**n.a.**	**n.a.**
COD [mg/L]	**412**	**n.a.**	**n.a.**	**n.a.**	**n.a.**
Total C / 100mL	**1664**	**6**	**62**	**200**	**38**
Faecal C / 100mL	**0**	**0**	**0**	**0**	**0**
Enterococci / 100mL	**1340**	**1800**	**32**	**152**	**0**

RESULTS OF REGULAR EPA WATER QUALITY TESTS

Results that we received from the EPA are shown in Table 7. Sites "1" to "8" are shown on a satellite photo in Figure 5 in the Methodology section.

We regret that water quality tested for Enterococci has ceased by 31st December 2009. Enterococci levels were extremely high at Site 1 and Site 6, which are located at the southernmost end of Hulhumale and next to the existing sewage outfall, respectively. The number of faecal coliforms has never climbed to an alarming level. However, not much can be said because it is clear that neither the total, nor the faecal coliform count give an indication of the health risk to bathers.

Table 7. Seawater quality tests performed by EPA in 2009/2010.

Total C...Total coliform. Faecal C...Faecal coliform. Sites "1" to "8" are located at the eastern side of the island in equal distances from each other, starting on the southern end with "1" and ending on the northern end with "8". Site "6" is located next to the existing sewage outfall. Samples were taken in knee-deep water.

Location	1	2	3	4	5	6	7	8
Date	31Dec09	31Dec09	31Dec09	31Dec09	31Dec09	31Dec09	31Dec09	31Dec09
Total C	20	16	68	60	16	176	360	x
Faecal C	0	0	0	0	2	12	2	x
Enterococci	960	0	0	0	0	544	0	x
Date	10Jan1010	10Jan10	10Jan10	10Jan10	10Jan10	10Jan10	10Jan10	10Jan10
Total C	0	0	0	0	0	2	4	0
Faecal C	0	0	0	0	0	0	0	0
Date	19Jan10	19Jan10	19Jan10	19Jan10	19Jan10	19Jan10	19Jan10	19Jan10
Total C	4	0	0	0	0	48	0	2
Faecal C	0	0	0	0	0	0	0	0
Date	31Jan10	31Jan10	31Jan10	31Jan10	31Jan10	31Jan10	31Jan10	31Jan10
Total C	32	6	10	4	4	3	16	10
Faecal C	0	0	0	0	0	0	0	0
Date	23Feb10	23Feb10	23Feb10	23Feb10	23Feb10	23Feb10	23Feb10	23Feb10
Total C	8	4	0	2	8	4	0	16
Faecal C	0	0	0	0	0	0	0	0
Date	25Feb10	25Feb10	25Feb10	25Feb10	25Feb10	25Feb10	25Feb10	25Feb10
Total C	14	2	14	6	8	8	6	2
Faecal C	12	0	3	2	3	3	0	0
Date	28Feb10	28Feb10	28Feb10	28Feb10	28Feb10	28Feb10	28Feb10	28Feb10
Total C	16	2	24	0	0	2	0	0
Faecal C	0	0	0	0	0	0	0	0

RESULTS OF THE PRESENT EIA STUDY

Table 8. Results of the marine water quality in Hulhumale', September/October 2010

Temp...Temperature, SAL...Salinity, TSS...Total Suspended Solids, DO...Dissolved Oxygen, NO_2^-...Nitrites, NO_3^-...Nitrates, PO_4^-...Phosphates, N-NH_3...Ammonia, TURB...Turbidity, BOD...Biological Oxygen Demand, COD...Chemical Oxygen Demand (test not available at this time), Total C...Total Coliforms, Faecal C...Faecal Coliforms; not perf.... test requested but not performed; n.a.... test not available

	EX-N	EX-S	PROP	ALT	SWIM
Temp [°C]	29.2	29.0	30.2	29.8	30.8
pH	8.22	8.16	8.19	8.23	8.30
SAL [%o]*	35.0	35.8	35.1	35.0	34.9
TSS [mg/L]	0	0	0	0	22
DO [mg/L]	7.02	6.79	6.83	6.94	8.25
NO_2^- [mg/L]	0.004	0.006	0.004	0.005	0.003
NO_3^- [mg/L]	0.4	0.5	0.5	0.6	0.5
PO_4^- [m/L]	0.07	0.14	0.04	0.06	0.24
TURB [NTU]	0.23	0.141	0.182	0.154	4.32
COD [mg/L]	n.a.	n.a.	n.a.	n.a.	n.a.
BOD [mg/L]	3.2	2.9	not perf.	not perf.	4.02

Total C / 100mL	>100	50	>100	>100	>100
Faecal C / 100mL	>100	0	0	0	0
Separate sample taken on 13th October:					
Total C	-	-	-	-	72
Escherichia coli	-	-	-	-	0

* Approximated results due to inaccuracy of probe. Salinity was unusually low at 29%o, compared to expected 35%o. We suspect a damaged probe, since we got low results from all areas.

Baseline data collected for the present EIA study show that BOD levels are relatively low (< 5mg/L for unpolluted waters) and DO levels allow fish growth and activity (> 6mg/L). BOD at the proposed and alternative site were not analysed by the laboratory. However, the existing outfall is located between EX-N and EX-S and BOD levels at both sites are of no major concern. We assume that effluent that is discharged there in about 15m depth is either properly diluted once it reaches the surface, or it takes another route and was not assessed here. BOD levels at the proposed swimming track area are low too.

Phosphate levels > 0.20mg/L are considered favourable for green and blue algae growth, if nitrates are not the limiting factor, and are exceeded at the proposed swimming area site at 0.24mg/L. The Nitrate and Nitrite levels are of no concern for fish life.

Faecal coliforms were only present in considerably high numbers at EX-N downstream of the existing sewage outfall. *E. coli* was tested for but not found at the proposed swimming track area. There, however, turbidity levels were much higher than out on the reef, as expected.

7.6.3 Effluent

BACKGROUND INFORMATION

No tests have been performed on the effluent discharge quality to date, according to information to MWSC. Therefore, there are no baseline data available for this study.

RESULTS OF EIA STUDY

Parameters of the effluent discharged from the existing sewer outfall have been tested by the client, since this was considered as an obligatory monitoring by the service provider to ensure that national guidelines are being followed. Parameters that could not be tested in their in-house laboratory were sent to the National Health Lab (Maldives Food and Drug Authority).

COD tests were not available in either laboratory at the time of sampling, so were tests for the sum of metals. Only tests for Chromium and Copper were available at the NHL in October 2010. MWSA laboratory has performed the tests for Copper and Chromium.

The other available results show that Faecal coliforms, *E. Coli*, TSS, Ammonia and Oils (in PS-6), as well as BOD levels in two analyzed pump stations are exceeding the maximum allowable limits in Domestic Waste Water for discharge into deep sea, set by the National Waste Water Quality Guidelines. This means that one more of the users of the marine environment will be affected.

Table 9. Results of the effluent discharge quality of the existing sewage outfall
14th – 24th October 2010, by MWSC & MFDA laboratory. Results that exceed the maximum allowable concentrations are marked with an asterisk.

Domestic waste water component	PS-2	PS-3	PS-4	PS-6	Maximum allowable concentration as per NWWQG 2006
Total Coliforms / 100mL	>100	>100	>100	>100	
Faecal C / 100mL	>100*	>100*	>100*	>100*	100 org / 100mL for less than 95% of samples taken
E. coli [CFU, Coliform forming unit]	50,000	56 million	50milli on	23 million	1 org / 100mL
pH	7.43	6.76	6.68	6.78	5 – 9.5
TSS [mg/L]	6	382*	325*	331*	150 mg/L, to prevent sludge formation on corals
Residual chlorine [mg/L]	0	0	0	0	0.1 mg/L
Nitrates [mg/L]	0.2	3	2	2	15 mg/L
Nitrogen Ammonia [mg/L]	2.5	25*	31.1*	22.0*	10 mg/L
Phosphate [mg/L]	2.1	9.1	7.0	5.9	10 mg/L
Surfactants (Anionic, detergents) [mg/L]	0.00	0.04	0.00	0.00	10 mg/L
Electric conductivity [μS/cm]	682	3130	3080	1080	less or equal compared to the surrounding seawater
Oil (Hydrocarbons) [mg/L]	0.0	1.6	0.0	12.9*	5 mg/L
COD [mg/L]	not available in both laboratories				50 mg/L
BOD_5 [mg/L]	18	104.2*	88.0*	144.6*	40 mg/L
Phenols [mg/L]	0	0	0	0	1 mg/L
Sum of metals	not available in both laboratories				5 mg/L
Copper [mg/L]	0.01	0.03	0.01	0.22	
Chromium [mg/L]	0.001	0.155	0.142	0.133	

7.7 Biotic Marine environment

7.7.1 Background information

On the search for reef benthos data available from Hulhumale' before the reclamation works began, we tried to obtain the EIA for Hulhumale and were informed that "Stage 1" was undertaken by Binnie Black and Veatch (2000) from Singapore. Although not undertaken before the reclamation, we tried to obtain the EIA from both the Ministry of Housing and Environment (MHE) and from HDC, but did not receive it until the end of this EIA report.

There are records of the marine environment after the construction of the one and only sewage outfall available (Multi Marine Services 2010). Our client sends divers along the pipeline to inspect for leakages and the condition of marine life around the discharge point. Two leather corals (*Sarcophyton sp.*) and one sea fan have been regularly monitored and observed to survive without any significant changes. There are no growth records or surveys on live coral cover available. Neither has the status of hard corals around the sewage outfall, nor the water quality been monitored. The fish status has been described as "*attractive species of reef fishes are found common surrounding the reef*." The report also states that "[...] *direct sewer flow on to the reef seems to affect the coral growth especially near the discharging end of the pipeline*".

In March 2010, a marine survey was performed within the scope of an EIA for a proposed swimming area on the eastern side of Hulhumale (LaMer 2010). The coral reef flat has been assessed north of the existing outfall ("RF1" at 4°13'03"N, 73°32'48"E) and between the existing outfall and the future swimming track ("RF2" at 4°12'47"N, 73°32'44"E). It shall be noted that the "future swimming track" in this report corresponds to the "alternative location" in the original EIA, since the proposed location has not been approved.

Live coral cover at site RF1 was 5.2%, while abiotic categories such as rock, sand and rubble contributed to 88% of total cover (rock 23%, rubble 12% and sand 53%). Among the dominant and common live corals were: *Acropora* sp., which includes mainly branching and encrusting forms (48%), *Porites* sp.(23%) and *Pocillopora* sp. (12%), while *Pavona* sp. contributed to the remaining cover.

Coral cover at site RF2 was lower than site RF1 with 3.4%. Rubble, sand and rock cover was approximately 87%. Few recently dead coral colonies were also observed the area, these included mostly *Pocillopora* colonies. Unlike site RF1, *Acropora* cover at RF2 was higher (59%), followed by *Pocillopora* (24%) and *Porites* (12.1%), while other genera were in low abundance.

7.7.2 Results of EIA study

LAGOON SYSTEM

The shallow lagoon (Figure 11) at both the proposed and the alternative location shows similar features. It drops to about one meter depth and rises again in front of the wave breaking zone. The seabed consists almost entirely of sand and dead coral rubble (Figure 12). Scattered are live coral heads of Poritidae, Faviidae and Agariciidae, composing less than an estimated one percent live coral coverage. Sedimentation particularly in the first twenty meters from the shore was extremely high. Fish (Pomacentridae like *Chrysiptera biocella* and *Dascyllus aruanus,* Balistidae like *Rhinecanthus aculeatus*) were encountered occasionally. Generally, the lagoon system in Hulhumale' can be considered of very low ecological value without outlook on coral settlement. A pipe laid through the lagoon is not expected to have any significant negative impact on the lagoon.

Figure 11. Proposed site, view from beach over the lagoon towards the wave breaking zone

Figure 12. Lagoon sea floor, consisting mainly of dead coral rubble and sand

REEF SYSTEM

Proposed outfall site

The proposed site for the sewage outfall consists of dead coral rock and rubble up to approximately 12 meters depth, with scattered young coral colonies attached. Figure 13 and Figure 14 show benthos at 9-11m depth, consisting of either loose coral rubble overgrown with coralline algae, or large coral remains where young corals attached themselves to.

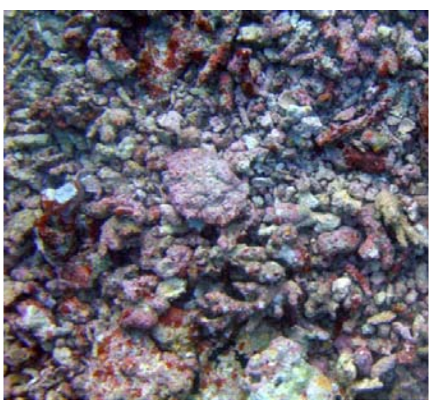

Figure 13. Coral rubble covered in coralline algae. 11m depth (PROP)

Figure 14. Large Porites partly alive, with Pocillopora colonies attached. 9m depth (PROP)

The proposed sewage pipe would be laid vertically across down to about 15m depth (350m from shore), where live coral coverage increases and the quantitative survey was conducted.

There, live coral cover was found to be 20.4 ± 4.2% (mean ± SE), with encrusting forms of various species dominating the transect (9.8%), followed by young tabular or digitate Acroporidae (6.4%), massive Poritidae (2.4%) and prostrate Pocilloporidae (1.8%) (see Figure 15). Corals were generally small and are estimated to be less than three years old. Coral rock and rubble dominated the transect with 73.1 ± 4.6% and was mainly composed of rock and rubble covered in coralline algae (35% and 25%, respectively, see Figure 13 for illustration). No bleached corals were found, and sand as well as other live forms (such as the Ascidian *Didemnum molle* and sponges at this site) constituted only to a minimal fraction of the transect.

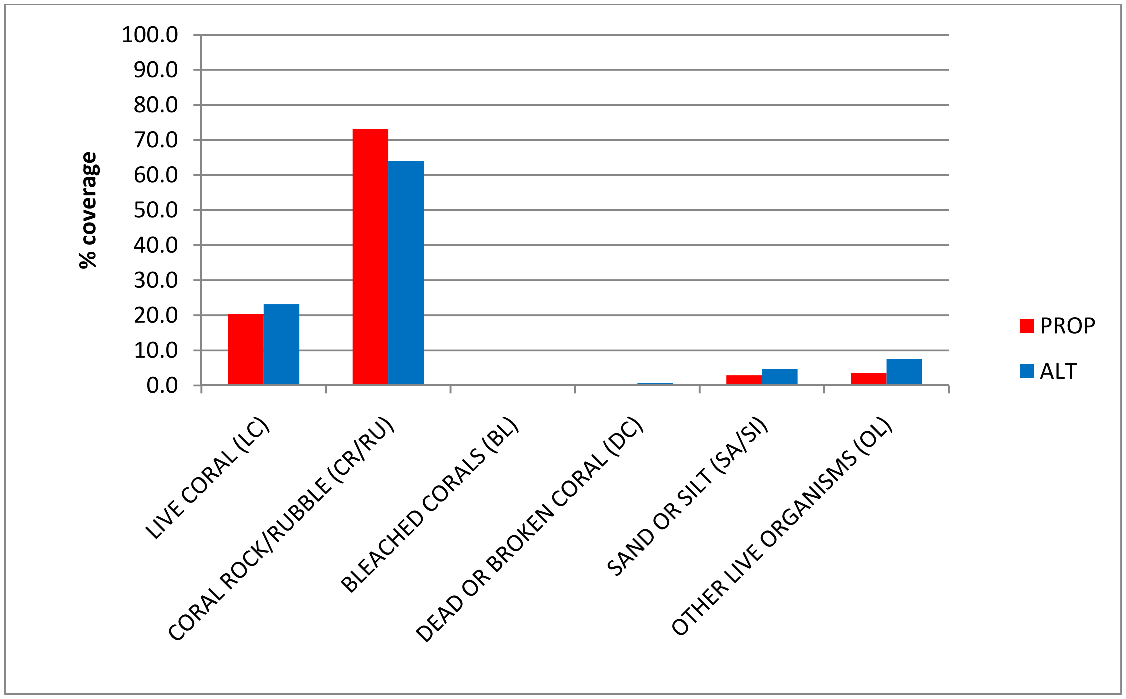

Figure 15. Results from the benthic reef community survey at the proposed (PROP) and alternative (ALT) site

Fish life was rich in diversity at this site; snapper schools of *Lutjanus kasmira* and *L. biguttatus*, surrounded by the Butterflyfish *Hemitaurichthys zoster* were observed around the proposed outfall. Occasionally, Spotfin Squirrelfish (*Neoniphon sammara*), Angelfish (*Pygloplites diacanthus*) and Groupers (*Cephalopholis argus, Anyperodon leucogrammicus*) were encountered. Coming shallow, at 9m depth, wrasses are more dominant, with schools of *Thalassoma amblycephalus* and occasional *T. janseni* and *Haliochaeres hortulanus*. Under a large *Porites* head, which was about 20% alive, one *Forcipiger flavissimus*, two *Chaetodon lunula*, various Squirrelfish (*Sargocentron sp.*), a Spotfin Firefish (*Pterois antennata*) and an unidentified Grouper was found.

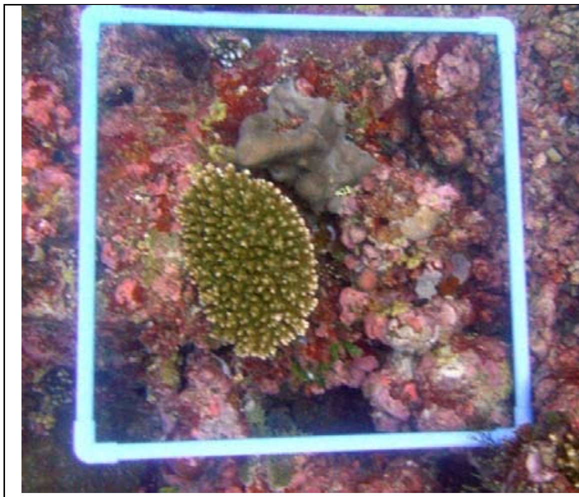

Figure 16. Photo quadrat at PROP site, 15m depth

Figure 17. View down the reef slope (PROP) from 15m depth down at a school of blue-striped and two-spot Snappers

<u>Alternative outfall site (ALT)</u>

The alternative site is similarly low in coral cover for the first 15m from the surface. The survey was conducted in 21m depth, from which the sandy seafloor can be seen in about 25m depth (Figure 18).

Similarly to the proposed site, although a few meters deeper, the alternative site, i.e. where sewage is estimated to be discharged if the proposed site is rejected, is dominated by coral rock and rubble (64 ± 4.4%; see Figure 15 and Figure 19). 63% of this is rock covered in coralline algae, and 20% is loose rubble overgrown by coralline algae. Live coral cover is 23.1 ± 4.2% with again various encrusting forms of different families dominating the composition (15.6%), followed by young (< 3 years old) digitate Acroporidae (6.7%) and prostrate Pocilloporidae (0.9%). “Other Live Organisms” at the alternative site (7.6%) were sponges, ascidians, foraminifera and zoanthids. The amount of sand at this site (4.7%) was slightly higher than at the proposed site, probably due to its depth and proximity to a sandy sea floor.

Figure 18. Survey site in 21m depth, looking eastwards towards the sandy seafloor

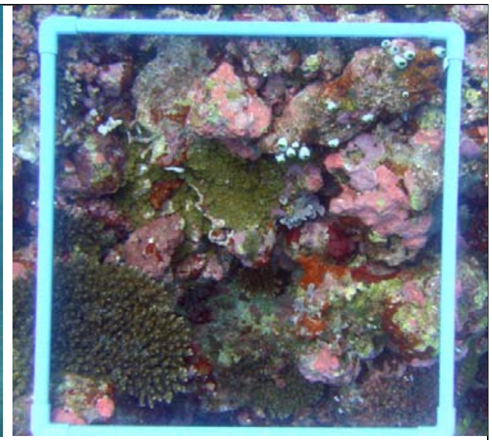

Figure 19. Benthos in 21m depth (ALT), with coral rock covered in coral, coralline algae and ascidians

The alternative site houses a variety of fishes with schools of *Odonus niger*, *Caranx melampygus*, *Pterocaesio tile* and *Caesio xanthonota*, as well as Pomacentridae (*Pomacentrus indicus, Dascyllus trimaculatus*), Mullidae, *Zanclus cornutus*, juvenile and adult Scaridae and Acanthuridae (predominantly *Acanthurus leucosternon*). One anemone *Stichodactyla gigantea* housing five *Amphiprion clarkii* was found during the ascent towards the surface.

8 Discussion of results

The presupposition for a discussion of water quality results is that they are correct. This should not be automatically assumed since observational errors can occur during the collection of data or during analysing in the laboratory. We have tried to rule out major errors resulting from quality meters by calibrating them as described in the methodology section. Most of our parameters, as well as the ones found in the LaMer (2010) EIA report and in the EPA surveys, have been analysed in a laboratory. Unfortunately, we do not have any possibilities to verify data we receive from a laboratory. Therefore, the following discussion is based on the assumption that results are the true reflection of the subsample taken from the total population, i.e. the environment at the time of sampling. It has to be borne in mind that results may vary daily, monthly or annually, and that a large set of external circumstances (time of sampling, weather and currents, number of bathers, time of sewage discharge, level of treatment and many more) influence results. This EIA can only represent a small fraction of the true conditions and was therefore complemented with results from the above mentioned studies.

8.1 Bathymetry

A spot bathymetry allowed us to dive at the proposed and alternative site of the sewage outfall. As expected, the sea bottom 350m from shore is around 15 to 20 meters deep. At the alternative site, a sandy seafloor is reached at about 25m depth before the reef drops further down to 50m and more. To avoid major damage to corals in 20m depth, the outfall could be extended up to the sand bottom and sewage could be discharged through a diffuser above it. A detailed bathymetry, which was not scope within this EIA study, will reveal the exact positioning of the sewage pipe. In any way, the end of the pipe should be lifted up from the ground and equipped with a diffuser.

8.2 Water quality

8.2.1 Groundwater

We have come to the conclusion that the parameters to test groundwater for in the National Guidelines are not sufficient to determine whether groundwater is suitable for drinking purpose, or not. While faecal coliforms give a rough indication for the contamination of water, a test for *E. coli* (freshwater) or Enterococci (saltwater) would be a better indicator. To be on the safe side, water should never be considered for drinking purpose, if faecal coliforms are above 1/100mL. From seawater tests we learned that Enterococci can still be high, even if faecal coliforms are 0 because of the different growth media used in the laboratory. Since raw EC results from seawater are unusually low, we expect similar measuring errors in groundwater as well. Therefore, EC results could be higher than measured in this study (data are corrected in the table). However, compared with measurements with a different instrument, results should not vary more than ± 250 µS/cm, which means that groundwater in all wells is still within the range of “Class A” (Ideal) for bathing and laundry purpose (< 1500 µS/cm EC).

As per information from the land owner who has provided housing units in Hulhumale’, the new apartments were equipped with two separate water systems: purified tapwater (generated from seawater by the reverse osmosis process) and groundwater. Groundwater is currently not used for drinking purpose, but for laundry and flushing toilets. Based on the results of this EIA study (4 groundwater samples), the use for flush tanks and laundry should be harmless. However, we want to highlight the importance of a regular monitoring programme to ensure groundwater is safe to use in future as well.

8.2.2 Seawater

Sewage generated from the existing and the proposed sewer outfall will ultimately change the quality of seawater. The major concerns in this project are:

- the impact of raw (untreated) sewage on the seawater quality and its effects on marine life and
- the impact of untreated sewage on the health of swimmers on the eastern side of the island.

IMPACTS ON MARINE LIFE

As for the lagoon habitat, the low live coral coverage near the reef crest as reported in LaMer 2010 (5.2% at RF1 close to the existing outfall, 3.4% at RF2 500m further south) can not directly be related to the discharge of sewage. The composition of benthic substrate with 54-50% coral rubble and sand, together with a high-energy environment make it hard for corals to settle and grow.

It is a hurdle to estimate the impacts of raw sewage on marine life without adequate baseline data in the same environment. Monitored corals (Reference MWSC/S/2008/43, 2010 report) around the existing sewage outfall are non-scleractinian and therefore unsuitable to determine how much raw sewage could influence reef growth, since it is the scleractinian corals that are crucial to reef formation. The reef at the estimated discharge point does not contain large and old corals at this time. Raw sewage with a high amount of phosphorus and nitrogen generally promotes algal growth and is expected to weaken corals around the discharge point. The high amount of turbidity may act as a light filter on reef-building corals which heavily depend on sunlight for their growth. In the 2010 report of marine inspections undertaken at the existing outfall it is stated that "*Direct sewer flow on the reef appears to be affecting the coral formation near the pipe end.*" (without a percentage of live coral cover given in the report). This gives us an indication that raw sewage could indeed be detrimental to the reef near the pipe.

However, raw effluent discharge on the other hand could attract more fish species that feed on the effluent. Photos analyzed from the marine inspection reports of the existing outfall reveal that schools of *Lutjanus biguttatus, Lutjanus kasmira* and *Hemitaurichthys zoster*, as well as *Abudefduf vaigiensis* gather around the outfall. The first three (Two-spot and Blue-stripe Snapper and the "Black Pyramid" Butterflyfish) have been observed at the proposed outfall site as well and are expected to welcome discharge in their habitat.

IMPACTS ON BATHERS

Recreational waters generally contain a mixture of pathogenic and non-pathogenic microorganisms. These microorganisms may be derived from sewage effluents, the recreational population using the water (from defecation and/or shedding), livestock (cattle, sheep, etc.), industrial processes, farming activities, domestic animals and wildlife. In addition, recreational waters may also contain free-living pathogenic microorganisms. These sources can include pathogenic organisms that cause gastrointestinal infections following ingestion or infections of the upper respiratory tract, ears, eyes, nasal cavity and skin.

As described in the Methodology section, health risks to bathers/swimmers are commonly assessed by looking for INDICATORS that could reveal the presence or absence of bacteria, viruses and parasites harmful to humans. Since these pathogens cannot directly be assessed, it was a common practice to analyze total and faecal coliforms in the water. However, recent studies by the US EPA have revealed that *E.coli* (belonging to the faecal coliform group) and Enterococci (subgroup of the faecal streptococcus group) are far better indicators of health risk from recreational water contact (*E.coli* best for freshwater, Enterococci best for salt water).

Enterococci results are available from the EIA study of the swimming track (around March 2010) and from the EPA survey on 31st December 2009. Assuming that the test results are correct, it is clear that neither the total, nor the faecal coliform count give an indication for the contamination with Enterococci. This is due to different growth media used when counted for faecal coliforms and for Enterococci, respectively (pers. communication with microbiologist at National Health Laboratory Male'). If Enterococci had not been tested for, there would not have been any indication for a possible contamination of the water. Interestingly, the number of Enterococci during low usage of the beach is lower than during high usage (n=1 at two sites, LaMer 2010, this could also be coincidence). A large amount of samples taken at different times would be interesting to find out whether results are significantly different during low/peak usage times, or whether the results were coincidental. An Enterococci count > 50/100mL is usually enough for a beach closure. The question arises whether the high number of Enterococci could actually result from shedding of bathers?

It is known that bathers themselves can influence water quality directly (Eisenberg et al, 1996). For example, Papadakis et al. (1997) collected water and sand samples from two beaches, counted the swimmers present on the beaches and conducted microbiological tests for counts of coliforms, thermotolerant coliforms, enterococci, *Staphylococcus aureus*, yeasts and moulds. There was a significant correlation between the number of swimmers present on the beach and *S. aureus* counts in water samples, the correlation being more pronounced on the more popular of the two beaches. Yeasts of human origin in water samples also were correlated with the number of swimmers on the more popular beach.

In Maldives, people are not requested to take showers before they enter the sea. There is possible contamination from defecation in the sea. In addition, it is a common practice in Maldives to change baby's nappies on the beach and leave the dirty nappy behind. Faeces from nappies, in addition to defecation and bather shedding during the use of the swimming area could have resulted to a peak in Enterococci. Unfortunately, it is not sure how many people were in the water when the EPA collected high numbers of Enterococci on Thursday, 31st December 2009 at Site 1 and Site 6.

Once the analysis for *E.coli* was available, we tested water from the swimming track area for this indicator and as expected from our previous results (Faecal coliforms = 0), no *E.coli* were found in the water at the time of sampling (no beach users). However, at the moment (during SW-monsoon), surface currents are flowing south to north, and the proposed swimming track and recreational area are located upstream of the existing sea outfall. During the NE-monsoon, the swimming area and recreational area would be located downstream of the existing outfall, and upstream of the proposed and alternative site (as for the swimming track).

Therefore, it is highly recommended to repeat water quality tests during NE-monsoon to see whether the existing outfall influences the swimming area and during the next SW-monsoon when the proposed outfall is under operation. The recommendation of a maximum 100 Total Coliforms/100mL at recreational areas was only exceeded at Site EX-N, the currently downstream oceanic side of the existing sewer outfall which is not used for recreational purpose. Unfortunately, the laboratory doesn't give more accurate results for faecal coliforms – every number above 100/100mL is reported at >100/100mL.

We conclude that the existing sewage outfall cannot solely be made responsible for the contamination found by LaMer and occasionally by the EPA. Further investigations with larger samples both at low and peak usage times, and during both monsoon seasons, are necessary to determine the source of local contamination. It is strongly recommended that laboratories in the Maldives test for Enterococci and that this test is included in the regular monitoring programme of the EPA.

8.2.3 Effluent

Naturally, the effluent collected in pump stations have a high amount of faecal coliforms per 100mL, although we regret that no more accurate amount than >100 can be given by the laboratories. Extremely high levels of *E.coli* counts suggest that the number of Faecal coliforms must be similar, since *E.coli* is a faecal coliform bacteria.

The BOD from three out of four pump stations is higher than the allowable concentration of 40mg/L; however, it has to be noted that untreated sewage in Europe reaches 600mg/L and in the US around 200mg/L, and Hulhumale' effluent is therefore, compared to other countries, rather "weak" or "medium" sewage than "strong" (> 400mg/L). However, to come down to the maximum allowable limits, secondary sewage treatment is required which is generally expected to remove 85 percent of the BOD measured in sewage and produce effluent BOD concentrations with a 30-day average of less than 30 mg/L and a 7-day average of less than 45 mg/L (US EPA, see references).

Ammonia, which is known to damage fish gills, is elevated in three of the four tested pump stations. Since fish are seen around the existing sewage outfall, it is expected that ammonia levels, once mixed with seawater, do not have a large negative impact on fish.

Nitrates and phosphates, which in high amounts usually favour algal growth, are within the allowable limits, and are therefore considered of no direct harm to the surrounding benthic environment. On the other hand, suspended solids (TSS) which are tiny particles of material such as mud, sand and organic debris that are suspended in water, can settle down over time and are known to cause sludge on corals are too abundant in the effluent and can only be considered of no direct harm on the surrounding corals if they get dispersed rapidly. To compare, maximum allowable limits in the US are 30 mg/L in effluent (NSF certification standard). Sewerage treatment is expected to be able to reduce TSS levels below the recommended maximum.

Hydrocarbon oils are present in an amount that exceeds the maximum allowable concentrations in PS-6. Crude oils contain hydrocarbons, which are molecules that contain hydrogen and carbon and come in various lengths and structures, from straight chains to branching chains to rings. They contain a lot of energy, so that many of the things derived from crude oil like gasoline, diesel fuel, paraffin wax and so on take advantage of this energy.

It is possible that effluent contains high amounts of hydrocarbons only at certain times and that the high concentrations in PS-6 results from petroleum discharged into the sewer system. Regular monitoring of the effluent would help the client to keep track about harmful substances that are discharged into their system.

8.2.4 Biotic marine environment

In contrast to the below surveys undertaken, an estimation of live coral coverage was made in order to predict the influence of raw sewage on the marine environment. Studies from the "untouched" Hulhumale' reef before the reclamation process are not available. Further, studies of the marine benthos after the reclamation process are lacking as well, which do not allow us to compare baseline data with data collected from the existing sewer outfall. Therefore, we are unable to predict the effect of the proposed outfall on the surrounding reef, assuming that sewage would spread in a similar way. Hence, here we can only present baseline data of the Hulhumale' reef at two sites (ALT and PROP), nine years after the completion of the reclamation process. The impact on the reef can then be compared to these baseline data once the system is operating and data are collected again. The monitoring process is therefore crucial to estimate an impact on the environment.

The benthic reef composition at both sites is similar with a high amount of coral rock and rubble covered in coralline algae as typical for outer atoll environments. The scarcity of marine life from the reef flat ends in about 8 to 12 meters, where corals and other benthic communities take hold at the underlying rock and flourish in from about 12-15 meters below. Corals found at both sites are generally young, with the exception of a few large *Porites* boulders (example in Figure 14) in the shallow area, which are only partly alive. Generally, the chances for coral recruitment are high in both areas since there is enough proper hard substrate to settle. Apparently, a concrete block was disposed at the proposed site at 12m depth which can now be seen completely covered in young corals as shown in Figure 20.

Figure 20. Concrete block covered in at least ten species of coral and coralline algae (PROP), 12m depth

Therefore, a similar amount of disturbance from construction is estimated at both the proposed and the alternative site. During anchoring the pipe, loose coral rubble will be mobilized and will fall down the reef, breaking off or smothering young settlers. A considerable amount of live coral will be covered by the pipe and its anchoring blocks. Due to the high settlement rate, it is expected that the pipe itself will attract coralline algae, coral larvae and other organisms such as sponges and ascidians after a short time. Due to the lack of background information, an estimation on the destructive effects and severity of eutrophication on the coral reef cannot be made at this time. We recommend conducting a survey within five meters radius around the outfall site once the pipe and the diffuser are in place and compare findings with results gathered 6 months after effluent is discharged.

9 Stakeholder consultation

This project involves various stakeholders at different levels. From the initial project planning stage, stakeholder consultations have taken place at various levels. For this EIA, stakeholder consultations were undertaken with the client (MWSC) and representatives of various government ministries. During the consultations with the client, their plans and expectations were noted.

Stakeholder consultations were held with the following agencies and groups:

9.1 Consultation with the proponent

The proponent for this project is Maldives Water and Sewerage Company Pvt. Ltd. (MWSC). Initial consultations were conducted with the client before the surveys for the EIA have been performed at the beginning of September 2010.

For the first meeting, the Engineering Manager Mr. Mohamed Rasheed, the Water Quality Assurance Officer Mr. Adam Rasheed, the Assistant Environmental Engineer Mr. Midhaath Gafoor and the Assistant Manager P&D Mr. Mohamed Imran Adnan were present. The purpose of this meeting was to inform the client about the upcoming water quality tests and to clarify their viewpoint of a treatment plant. The client stated that the proposed as well as the existing sewage outfall would be used only until a sewage treatment plant (STP) would be installed; then, a third sewage outfall would be planned close to the site of the MWSC plot in the South of Hulhumale'. The installation of the STP would depend on the commitment of either the consumer to bear the costs, or on the government to provide subsidies for the additional costs for the sewage treatment. MWSC showed a very positive attitude towards an STP, as long as the costs would be covered. Further, MWSC confirmed that their existing sewage outfalls are regularly inspected for leakages. However, until then, the proposed sewage outfall is considered very urgent by the client since the existing one has already reached its capacity limits. MWSC is currently installing a diffuser at the end of the existing pipe and noted that a diffuser would be fixed on the proposed pipe as well.

During a second meeting with the client, the duration of the project, monitoring responsibility, details about the sewage system and the contingency plan were discussed. Several emails were exchanged between the consultant and the client to clarify details for this EIA report. Response from the client was always fast and professional.

Our contact person at MWSC throughout the project was Mr. Midhath Gafoor, Assistant Environmental Engineer. His CV is attached in *Appendix 8: CV of MWSC contact person*. Engineering Manager Mr. Mohamed Rasheed provided assistance in technical details for this report.

9.2 Consultations with the Environment Protection Agency (EPA)

Mr. Isaac Naseer, Admin officer from the Water and Sewerage Section of the EPA, was consulted after water quality and marine benthos results were available. He told that the reason why the EPA has stopped testing for Enterococci was because sampling bottles were not available anymore and the test itself was not offered by the National Health Laboratory. However, he agreed on the importance of Enterococci as a crucial indicator for seawater contamination and is planning to make tests for Enterococci available in the in-house laboratory of the EPA. He said that sooner or later, a sewage treatment plant should be installed in Hulhumale', as it is the case in some even smaller inhabited islands of the Maldives. He stressed that the real cause of contamination in the lagoon needs to be found, and noted that the client should identify the disperse rate of sewerage and the radius in which sewerage effects the environment. A yearlong current study needs to be performed to investigate how sewage gets dispersed in the sea.

9.3 Consultations with Housing Development Corporation

Mr. Suhail and Mr. Azleem from HDC were consulted after results from our surveys were present. I informed them about the proposed and alternative outfall location and discussed issues such as inconsistency of seawater contamination with them. Their biggest concern was that not only the swimming track area would be used for recreational purpose, but also that a separate recreational area is planned on the south-eastern side of the island where Hulhumale' residents and especially also visitors from Male' will use the shallow lagoon extensively on weekends. It was concluded that a large survey is required in order to determine the definite source of seawater contamination, especially during high usage of the beach. The contamination might have resulted from bather shedding or garbage rather than from sewerage travelling back to the shore, thus, Water Soutions team recommended that dustbins are installed in the recreational area so that waste does not end up in the sea, and that people are advised to take showers before entering the sea. As for sewerage treatment, HDC recognizes the importance of a treatment plant but foresees problems when additional costs are charged to the customers. Mr. Suhail anticipates that Hulhumale' residents will compare water prices with those in Male' and won't accept to pay more for treatment, pointing at Male' where raw sewerage is discharged as well. He noted that awareness programmes by MWSC are necessary to make residents understand the importance of sewerage treatment.

9.4 Consultations with the Ministry of Housing and Environment

A meeting with Mr. Afzal (Environmental Analyst), Mr. Sararanan (Consultant), Mr. Leigh Burgess (Technical advisor at Sewage section) from the Ministry of Housing and Environment, and Mr. Imran Adnan from MWSC was held on November 8th 2010. MHE did not prefer any of the alternative locations, but noted that the EPA should comment to the EIA report and, based on their review, if our client can justify that a sewerage treatment plant is appropriate, the MHE will prepare a cost breakdown and will try to take the matter to policy level.

10 Potential Impacts and Mitigation Measures of the proposed project

10.1 General

This chapter discusses the environmental and socio-economic impacts both during the construction of the sewage outfall and the pump station, and after construction has finished.

Mitigation measures to minimize these impacts are being proposed.

10.2 Environmental Impacts and Mitigation during construction

The major environmental impacts during the construction stage in Hulhumale' are related to:

- Leveling of the seabed to lay the outfall pipe and its impact on benthic communities:

  Leveling of the seabed is required for the positioning of the sewage pipe and is not expected to have any major negative impact on the lagoonal seabed since it currently consists of dead coral rubble and sand, with few exceptions of live coral colonies, which are barely surviving on the sand. Sedimentation in the lagoon is naturally high, thus, suspension of sediments during the construction should not lead to the degradation of the lagoon. As a mitigation measure to preserve the last remaining corals on the reef flat, live corals should be avoided or moved (if attached to a mobile rock). All activities should be properly supervised to ensure that construction is according to the required specification or standards and that no threat or damage to the environment other than the specific location is done.

- Impact on the coral reef:

  The planned discharge distance from shore is around 350m which corresponds to a depth of 12-15 meters. Our benthic marine study has revealed that corals start growing consistently from about 10 meters onwards and are covering around 20% of the substrate in 15m depth. Therefore, there will be a localized impact on the coral reef during the positioning of the pipe along the reef slope. The pipe and anchoring blocks will permanently damage corals, and during leveling, a great amount of coral rubble is expected to roll down the slope, potentially smothering and even breaking other corals beneath. On the other hand, concrete anchoring blocks will act as a new settling ground for coral larvae and could eventually have a positive effect on the reef after some years. As a mitigation measure, divers who position the pipe and the anchoring blocks need to take utmost care not to damage the coral reef unnecessarily. A large amount of coral rubble generated needs to be avoided.

- Waste handling and pollution control by the contractor:

Usually, the volume of work involved does not create any significant volume of wastes if the contractor gives consideration to minimize the waste. Solid wastes generated during construction stage (moulds, concrete left-overs) will be transported to Thilafushi.

- Noise, light and air:

  This impact is considered negligible, since the project takes place in an area far from residents.

10.3 Environmental impacts and Mitigation after construction

The major environmental impacts after the construction stage are related to:

- Wear and tear of the pipe leading to environmental pollution:

  During normal operation of the sewage system, the pipe itself does not pose any environmental hazard to the surrounding reef; instead it may act as a settling ground for new coral larvae, just like the existing sewage outfall (see Figure 21).

  Environmental and social problems will arise if the pipe is damaged due to wear and tear or anchor damage. To avoid this, the pipe will be embedded by two anchor blocks and covered with rubberized material to avoid ware and tare. Where anchoring is likely, buoy markers will be permanently fixed at the location to warn not to use anchors.

  Regular visual inspections of the pipe will be carried out by divers to detect leakages as it is being done for the existing pipe.

Figure 21. Existing sewage outfall in Hulhumale' with young corals using it as a settling ground

- Marine environment:

  The major environmental impact will be occurring during the operation of the sewage pipe, which is obviously the scope of this project and cannot be avoided therefore.

  To avoid degradation to the marine environment, a deep sea discharge system was chosen for Hulhumale' where waste water will be discharged beyond the shallow reef and at a depth which will ensure proper dispersion and rapid dilution. Discharges of untreated wastewater to the marine environment have the potential to cause eutrophication. Waste water discharge practice has to be done with the necessary care by adhering to guidelines that set maximum allowable concentrations for discharge (MWSA-NWWQG 2006).

Solids in sewage are currently discharged into the ocean. While toilet paper is automatically liquefied and has passed previously installed screen filters, solids were trapped in a screen filter at the sump wells. However, this filter has been removed due to the minimal discharge of solids deriving from Maldivian households, according to the client.

We recommend that solids continue to be removed through screen filters in the sump wells, since solids can negatively affect the environment into which they are dumped. This would prevent particularly plastic objects to enter the marine environment through the sewage system. The client is familiar with the practice to remove, dry and dispose solids from the incoming sewer. An aid to the proper disposal of solids in waste water is given in the National Solids from Waste Water Treatment Guideline (Ref: MWSA-SWWTG 2006).

Oils in sewage is currently not removed from domestic sewage, but restaurants/tea house/hotels need functioning oil traps in place, according to the client, that will hold back waste oil from the kitchens. Such traps should be inspected regularly to ensure proper use.

Health sector waste shall not be allowed to be discharged to deep sea or via domestic pipelines if it has not been treated according to the National guidelines for the treatment of health sector waste (Ref: MWSA-HSWG 2006). We recommend that health sector sewage that is being discharged into the client's system is tested for pathogens and other parameters to ensure that it complies with guidelines for the discharge of domestic sewage.

A diffuser shall be installed at the end of the pipe to disperse the out flowing sewage as much as possible. According to the client, a diffuser is already planned to be installed. The direction of the outfall shall not face the reef directly. If possible, the outfall shall end on a natural steep gradient, or shall be positioned in a 45 degree angle upwards from the reef.

To reduce the long-term impacts on the reef and possible impacts on the health of bathers, the EPA recommended a study with the scope to identify the disperse rate and the affected area of sewerage. Only with year-long current studies it can be identified where sewage travels and how far from the source it gets diluted to a point where it has no or minimal negative impact on the environment and on the health of bathers.

For the near future, it is strongly recommended that wastewater is being treated in a sewerage treatment plant (STP) before discharge. Tourist resorts in the Maldives have to treat their sewage; similarly, the impact on the environment would be greatly reduced if this regulation was applied to local islands as well. An option for sewerage treatment is given in Chapter 11. Refer to *9 Consultation with the proponent* for the client's opinion on sewerage treatment.

10.4 Social impacts and Mitigation during construction

The project is not expected to have any social impacts during the construction, since it is located far from the nearest residential area.

10.5 Social impacts and Mitigation after construction

The major social impacts after the construction stage are related to:

- Service provided to residents by the client

  Social impacts from the proposed project are positive, since it allows sewerage to be transported off the households into the sea through a second pipeline.

- View of the sewage outflow:

  During the operation of the pipeline, some residents could be disturbed by the view of the concrete blocks that keep the pipe in place, especially on the reef flat. This impact is considered minor adverse, but unavoidable due to the shallowness of the reef flat.

- Marine water quality:

  If sewage is not being treated and being washed up with upwelling waves into the beach area, especially during NE-monsoon into the swimming track area, there could be a major social impact in the form of health risk to bathers.

  There have been reports from the swimming track and artificial beach area in Male', where people, especially children, sometimes suffer from eye and ear infections and skin rashes after bathing. As to our knowledge, it was never confirmed that sewage from the outfall was the cause for the infections, or whether the polluted lagoon (boats anchoring and discharging waste/sewage) would be the culprit. However, whenever contamination with faecal coliforms exceeded allowable limits, the swimming track/artificial reef area had to be closed for swimming at some times. It has to be noted that the swimming areas in Male' (Artificial beach and Swimming Track) are somewhat different from Hulhumale' as that there are more possibilities for seawater exchange in Hulhumale' due to its undisturbed connection to the ocean.

  However, according to the State of the Environment Report 2004, the "*current system of sewage disposal constitutes a serious threat to prospects for sustainable development and, in many densely populated islands, it has become a critical problem*". To avoid such problems in Hulhumale' and for the safety of its residents, it is of utmost importance that the effluent discharge is tested regularly and complies with standards outlined in the National waste Water Quality Guidelines. If the effluent does not meet these requirements and threatens residents (for example if human parasites, harmful bacteria or viruses are found from hospital sewage), sewage needs to be treated until it does. Solids in wastewater have to be intercepted through screens at the sump and disposed at a waste disposal site (minimum requirements). It is strongly recommended that the construction and implementation of a sewerage treatment plant begins, once the pressure on the existing outfall is relieved by the proposed outfall.

10.6 Emergency response plan

Emergencies in the context of a sewer network are restricted to following major categories:

1) Fire outbreak
2) Sewer spillage
3) Severe contamination of seawater and health risks for recreational areas

Fires can origin at any place wherever electricity is used. Therefore, it is possible that fire is generated in one of the pump stations. Standard MNDF-approved fire extinguishers have to be provided in close vicinity to places where fire could break out. Staff at MWSC who work with electrical devices in the sewer system have conducted a fire fighting course.

Sewer spillage is caused by a blockage of the system or leakage of the pipes. Incidents of sewer spills have to be addressed immediately by the client. The EPA has to be informed about sewer spills or damages to pipes with outflowing sewage. The repairing works have to be conducted immediately to avoid contamination of the groundwater and health risks to citizens.

If there is an increased number of reports from bathers complaining about eyes and ears infections or intestinal disorders, the public needs to be informed and microbiological water quality tests need to be performed as soon as possible and the outfall needs to be inspected. If water quality tests show high levels of Enterococci, they indicate that pathogens are threatening bathers and swimmers. Government authorities need to be informed and the beach has to be closed for swimming until the hazards are found and removed. Potential hazards should be searched for in infected health sector waste that has passed the treatment process (bacteria, viruses and pathogens), but also in the shedding of bathers, disposed baby nappies, sanitary napkins and defecation into the sea. If such cases shall occur, the client shall cooperate with the EPA and the Health Ministry.

Our client informed us that MWSC staff will participate in a training course in sewer maintenance and safety of sewers in 2011.

11 Analysis of Alternatives to the proposed project

For this EIA, there are two main options, which are (1) no-construction at all and (2) the construction of a second sewage outfall. Regarding the overall design of the island and its location within the atoll, different locations for the outfall can be considered, but are limited to the eastern side of the island, since sewage must not be discharged within the atoll. Two alternatives are suggested in addition to the no project alternative.

11.1 No Project Option

The No Project Option means that the proposed sewage outfall will not be constructed which could have detrimental effects to both the environment and the health of citizens. A no-project option will eventually cause the existing system to collapse; sewage would leave the system uncontrolled and the island would be uninhabitable.

Sewer overflows have major detrimental effects on both the environment and on human health, and are not restricted to third world countries, as one may think. In Hamilton County (Ohio, USA), for example (NRDC 2004), raw sewage spilled from sanitary sewer overflows (SSO) seven times in 2000 and nine times in 2001. The result was thick, odiferous, and infectious raw sewage from toilets flowing into the county's residential basements, playgrounds, streets, and nearby waterways. The fundamental problem with Hamilton County's sewer system is that it is overloaded. New connections have been added in areas with insufficient capacity, even while the system is badly in need of upgrades.

Since the existing outfall in Hulhumale' has already reached its maximum capacity and is connected to seven pump stations, the construction of another pump station and sewage outfall is considered of utmost importance to avoid environmental hazards resulting from overflows and guarantee proper sewage disposal for the residents of Hulhumale'.

11.2 Alternative location

An alternative location (Figure 22 and Figure 23) for the sewage outfall is proposed on the south-eastern end of Hulhumale' in close vicinity to the MWSC plot (Figure 24). This site has been chosen for two reasons: firstly, it is located further away from the swimming track that is going to be built (see Figure 1 for an aerial view of the alternative location and the swimming track area). Secondly, if a STP is planned for the future, this outfall can be directly connected to the treatment plant, and no third outfall has to be created at a later stage. In this case, a pipe with a larger diameter than the proposed 280mm would be chosen.

The disadvantage of this location is that the construction time will be longer than for the proposed area (2 – max. 4 months for the proposed project) and that more material is required; more than one pump stations may even be needed.

In terms of impact on the lagoon, the alternative location is considered just as good as the proposed. The lagoon that needs to be crossed with the sewer outfall consists of sand and dead coral rubble only. Adjacent to the alternative location is a link road that connects Hulhumale' to the airport island Hulhule. This road prevents seawater exchange between the outer atoll and the lagoon between Hulhumale' and the Airport. Seaplanes fly shallow over the MWSC plot and land in the lagoon southwards of Hulhumale'.

Figure 22. View across the shallow lagoon at the alternative site.

Figure 23. View from the shallow lagoon at the alternative site towards the restricted area eastwards of the link road to Hulhule' airport.

Figure 24. MWSC plot on the southernmost part of Hulhumale

Figure 25. Sea planes land in the lagoon between Hulhumale' and Hulhule airport, flying closely over the MWSC plot

11.3 Technology Alternatives

The most self-evident, although costly, alternative to the proposed project is the treatment of sewage before its discharge into the sea.

The higher in the levels of treatment, e.g. from primary to secondary to tertiary or advanced levels, the costlier would be the operation. Secondary level treatment is expected to attain the effluent standards that are set by MWSA in its General Guideline for Domestic Wastewater Disposal. According to the client, sewage treatment would be feasible if the additional costs were either born by the community, or by the government in form of subsidies. However, the sewage system in Hulhumale' has currently reached its maximum capacity and needs an upgrade as soon as possible, therefore, this technology alternative should not be considered as an immediate alternative; instead, a time frame should be given to implement a new system.

Conventional sewage treatment may involve three stages, called primary, secondary and tertiary treatment.

1. *Primary treatment* consists of temporarily holding the sewage in a quiescent basin where heavy solids can settle to the bottom while oil, grease and lighter solids float to the surface. The settled and floating materials are removed and the remaining liquid may be discharged or subjected to secondary treatment.
2. *Secondary treatment* removes dissolved and suspended biological matter. Secondary treatment is typically performed by indigenous, water-borne micro-organisms in a managed habitat. Secondary treatment may require a separation process to remove the micro-organisms from the treated water prior to discharge or tertiary treatment.
3. *Tertiary treatment* is sometimes defined as anything more than primary and secondary treatment. Treated water is sometimes disinfected chemically or physically prior to discharge, or it can be used for irrigation. If it is sufficiently clean, it can also be used for groundwater recharge or agricultural purposes.

For the Maldives, sewage treatment up to secondary level is feasible due to the high amount of salty water in the sewage that makes tertiary treatment too expensive, since the removal of salt from waste water would be as expensive as the production of water from seawater.

According to MWSC, the existing and the proposed outfall would be used only until sewage treatment becomes mandatory in the Maldives. Once it becomes a requirement and a STP is installed, the sewage from the complete island would be rerouted via network pipes to a municipal sewage treatment plant, from where it would be discharged through an outfall close to the plant.

The alternative 'sewage treatment' would only have a positive effect on the environment, since contaminants are being removed, thus reducing the impact on the fragile Maldivian environment and protecting bathers on the eastern side of Hulhumale' from health risks. Both packaged and customized plants can be readily adapted for nutrients (nitrogen or phosphorus) removal. Materials of construction for tanks are chosen from GRP, concrete or fused glass coated steel panels. Installation is quick and simple and operation has been designed for low maintenance and consistency of performance. Packaged plants are normally designed to produce high quality effluent with BOD_5 < 20 mg/liter, suspended solids < 30 mg/liter and NH4 - N < 5 mg/l and can be further improved as necessary.

Properly treated sewage can then be pumped safely into the sea. Specialists will be engaged to help designing a water treatment system for Hulhumale' as soon as the Government makes it mandatory and tariffs are approved. Two treatment systems and two case studies are being described in the following section.

11.3.1 The Sewage Treatment System – Extended Aeration process (EA)

In this process, the whole screened wastewater is aerated in a reactor sized for large retention time followed by settlement of the biomass in a separate tank (final clarifier). This variation of

Activated Sludge Process (ASP) readily lends itself to modular design and construction to produce effluent of high quality.

EA is an aerobic process for treating biodegradable wastewater to a high quality and plants can be designed for simple operation and reduced attendance. Screened wastewater is treated in an aeration tank designed to provide a retention time of between 24 and 30 hours. The process is continuous with incoming flow displacing an equivalent volume of mixed liquor from the tank.

The displaced mixed liquor passes through to a separate settlement tank where the biomass is settled out and returned to the aeration tank to provide the acclimatized activated sludge for continuing treatment. Clarified treated effluent is discharged to a watercourse (subject to approval from Regulating Authorities) or re-used for other non-human consumption e.g. irrigation or recycle for toilet flushing after disinfection.

Extended Aeration plants (Figure 26) feature the unique tapered aeration concept where the process air distribution is managed to take account of the higher BOD and COD strength of wastewater at the inlet to the reactor where a higher proportion of process air is introduced.

The proportion of air is gradually reduced or tapered as the wastewater is treated through the reactor.

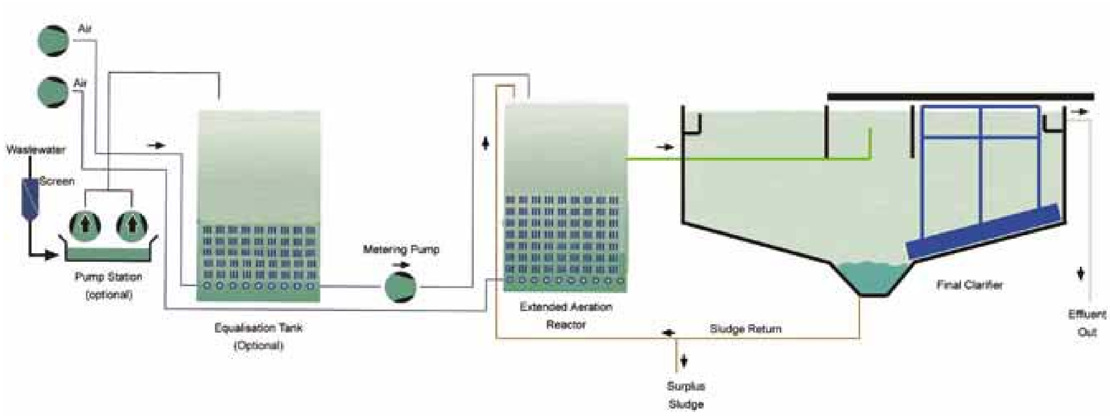

Figure 26. Schematic of Extended Aeration

This controlled and managed air distribution in the reactor creates an apparent plug flow condition and affects the staging of the reactor internally, thereby increasing the process efficiency of the treatment plant and providing the necessary environment for sustained nitrification of the wastewater. The extended aeration plant is engineered and operated such that the mixed liquor is held at a near constant concentration by a self-regulating process known as endogenous respiration. This minimizes production of surplus sludge and reduces the desludging frequency. For small plants, maintenance free, linear blowers are used to provide the process air. Rotary vane blowers are used or larger plants. The whole aeration system is completed using fine bubble diffusers to enable the efficient transfer of oxygen to the wastewater. Other methods of providing oxygen such as surface aerators or venturi aerators can be substituted for blowers and diffusers. The aeration methods are common for both SBRs and Extended Aeration Systems.

11.3.2 The sewage treatment system – Sequencing Batch Reactor (SBR)

Here, the incoming wastewater is screened to remove gross solids followed by aeration of the whole liquid waste, including suspended solids. Separation of the biomass takes place in the same reactor tank. For larger flows, two or more reactors may be used in sequence. Higher quality effluents including nutrient removal can be accomplished where necessary.

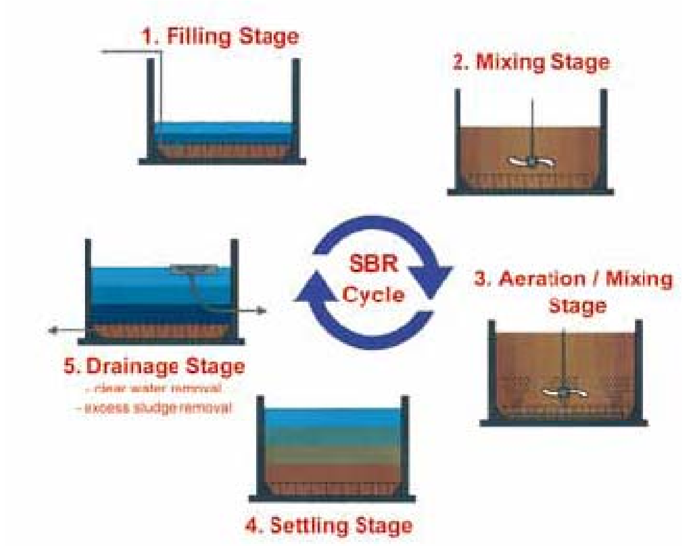

Figure 27. The SBR cycle

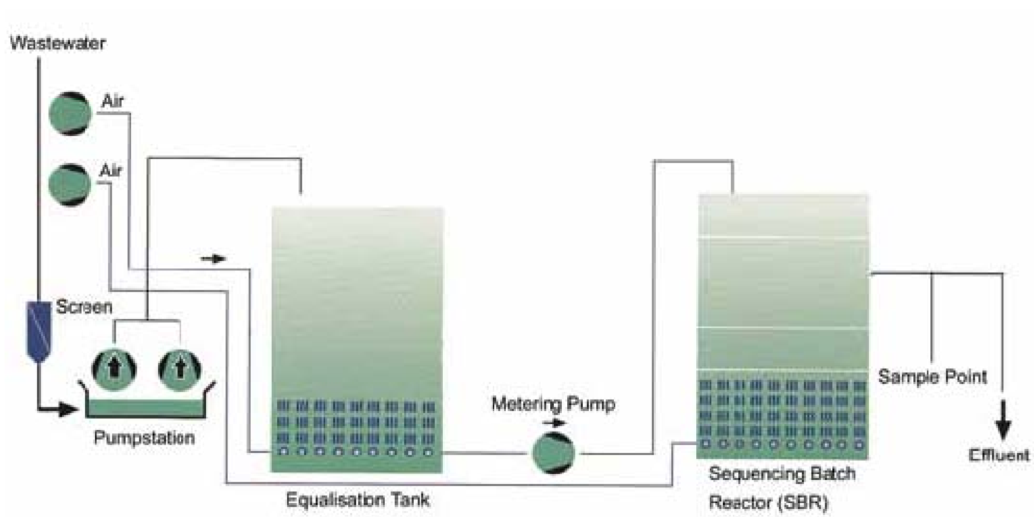

Figure 28. Typical layout of single reactor

1. The operational cycle of an SBR (Figure 27) will vary from one application to another. However, a typical cycle would commence with partial fill of new wastewater into the reactor containing activated sludge. Nutrient removal can occur at this stage if required.

2. Aeration and mixing are commenced approximately 40 minutes into the fill stage, while filling is continuing. Fill and aeration duration of an SBR largely depends on the BOD and COD strength of the wastewater and typically varies between 8 - 12 hours for BOD values

of up to 500 mg/liter, in excess of 12 hours for BOD values 500-800mg/liter and increases with higher BOD .For industrial wastewater pilot plant testing for treatability and wastewater characterization is recommended.

3. Settling and decanting (drainage) are achieved by turning off the air supply. After about one hour, discharge takes place. This is achieved in a number of ways, but one method is to use a floating decanter that follows the water level. Packaged plants are decanted through electrically operated solenoid valves. Up to two floating decanters can be used in each reactor tank to achieve the desired rate of discharge. The depth of decant liquor is predetermined. Decant time can also coincide with settling time.

It is always wise to look into systems that have been applied in similar environments like the Maldives. Following are two case studies from St. Philips (Barbados) and Deer Island (Boston, Massachusetts) that show how treated sewage and sludge could even be reused.

11.3.3 Case study 1: Treated Wastewater Reuse Scheme

This system is being practiced on the island of St. Philips, Barbados, and could be modified for the Maldivian environment. Similar to the Maldives, groundwater cannot be used due to overpumping of the aquifer, but the island requires a lot of expensive freshwater for irrigation:

Effluent, consisting of kitchen, laundry, and domestic sewage from the hotel, is sent to a collection chamber from which it is pumped through a comminutor to an aeration chamber (Figure 29). No primary sedimentation is provided. The aerated, mixed liquid then flows out of the aeration chamber through a rectangular opening at one end of the aeration chamber into a clarifier chamber for gravity separation. The effluent from the clarifier chamber is passed through a 5 m deep chlorine disinfection chamber, and, after disinfection, is pumped into an automatic sprinkler irrigation system. The irrigated areas are subdivided into sixteen zones, with each zone having twelve sprinklers. Some areas are also provided with a drip-irrigation system. The sludge, which has high water content, is pumped from the sludge chamber into boreholes without thickening.

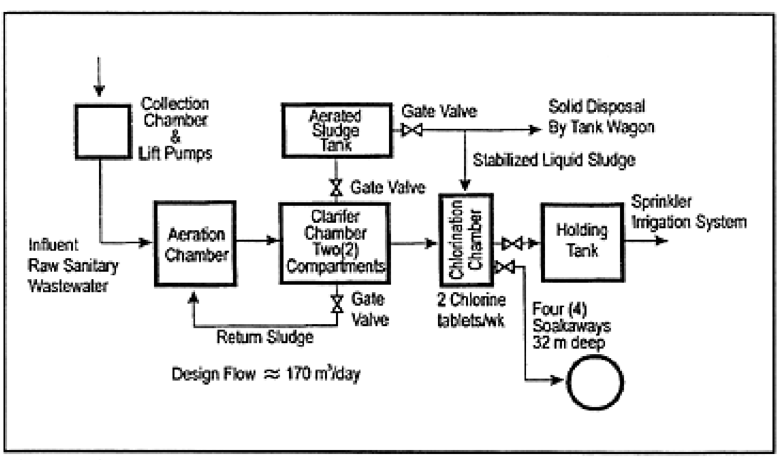

Figure 29. Wastewater treatment process for St. Philips, Barbados

The wastewater treatment plant was designed abroad, but constructed using local contractors. The drip and sprinkler irrigation system was designed and installed, in part, by a local systems consulting company and, in part, by Sam Lord's Castle Hotel maintenance personnel. The Environmental Engineering Division (EED) of the Ministry of Health and Environment approved and monitors packaged treatment plants, and issues permits for irrigation reuse, although there is currently no controlling legislation governing reuse of wastewater in Barbados. The approval process also generally involves consultations with the Town and Country Planning Office and the Barbados Water Authority.

11.3.4 Case Study 2: Fertilizer pellets made from Sludge

Sludge removed from the waste in a sewage treatment plant (after primary and secondary treatment) could be sent to an array of a number of 150-foot-high (46 m) egg-shaped sludge digesters, commonly known as "egg digesters". Each digester has a capacity of three million gallons of sludge. Methane from the digesters is captured and helps power the plant. Digested sludge could be barged to another plant that converts it to fertilizer pellets. Such a system (Figure 30) is being practiced on Deer Island in the Boston Harbour, Massachusetts (see References for operation details).

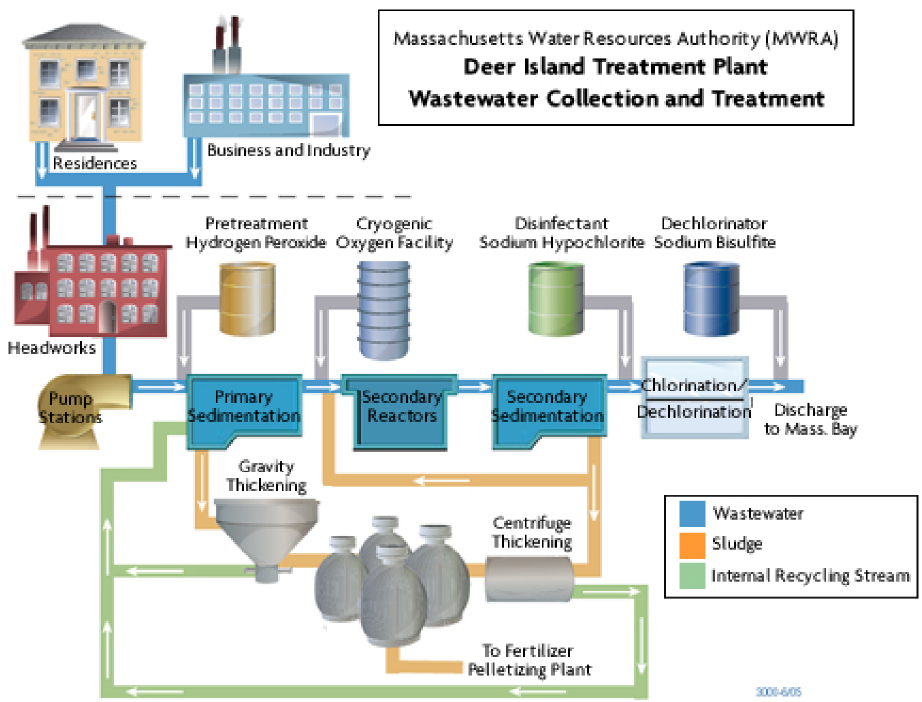

Figure 30. Deer Island Treatment Plant - Wastewater Collection and Treatment scheme

11.4 Preferred alternative

From an environmental point of view, the proposed and alternative locations are similar in benthic composition and topography. Viewing at the project on a long-term scale with an outlook on a sewerage treatment plant on the southern side of the island, the alternative location is preferred because no third outfall has to be created once sewage treatment becomes mandatory in Maldives, thus reducing the impact on the environment. At the alternative site, there is also the option to extend the sewage pipe a few meters deeper up to a sandy seafloor (Figure 18) where it could rest, if an extension is required.

Due to the urgency of the project, a sewerage treatment plant as an alternative to the proposed outfall at this point of time cannot be considered; however, according to HDC, sewage treatment will be considered for Hulhumale and we recommend the idea to be developed so that treatment can be implemented soon. Especially since the impact radius of the existing sewage outfall is unknown and the proposed outfall will have a similar distribution as the existing one, the only environmentally friendly method is to discharge sewage after its treatment.

12 Environmental Monitoring Plan

An environmental monitoring plan should be applied for the proposed 'pump station and sewer outfall project' in Hulhumale' during its construction and operational phases.

Possible impacts of the project are identified in this EIA report as well as their mitigation measures addressed (see Chapter 0). These mitigation measures should be applied in all the phases of the project.

Records of technical failures or complaints or any problems that occur during construction or operation shall be addressed (see 10.6 *Emergency response plan*).

The monitoring for this sewerage project focuses on the adverse impact of sewerage on the marine environment and on human health. Due to the short construction time (between two to maximum four months), a monitoring of the marine environment is limited to water quality control, but shall commence immediately as soon as the operational phase of the sewer outfall begins (i.e. as soon as effluent is being discharged into the sea). Baseline data on the marine benthos and marine and groundwater quality have been collected during this EIA study and shall be used to compare to data collected during the operational phase.

The inspection of the sewer main is of utmost importance to detect any leaks in the system. Inspections of the existing outfall pipe and the surrounding marine benthos are currently being undertaken by a contracted marine service provider. Such inspections have to be continued for both the existing and the new outfall.

All components of the network, including the pump station, have to be durable and leak-proof. Sewage must be prevented to leak from the connection pipe into the soil or aquifer. As per the 'General Guideline for Domestic Wastewater Disposal" (Ref: MWSA-WWG2006), Chapter 5.5. "*All public sewerage systems must be monitored and must comply with the standards and other requirements that the Authority may specify*." In this context, an 'Analysis Schedule for Groundwater Sampling' is provided in Annex A of these guidelines. Groundwater quality tests shall be continued according to this schedule.

Seawater quality tests for total and faecal coliforms are currently being performed by the EPA from 8 locations in the shallow water on the eastern side of Hulhumale' to ensure safe swimming conditions for users of the recreational area. As mentioned earlier, it would be more useful to test for faecal coliforms and Enterococci.

Further shall be monitored the amount of sewerage produced per day, taking into account the increasing population of Hulhumale'. The effluent water quality has to be monitored in order to compare whether it complies with the National Waster Water Quality guidelines. Focus shall be on parameters that currently exceed the maximum allowable limits.

If other than domestic houses are being connected to the sewer network (e.g. animal husbandry farms, fish processing farms, light or heavy industries, hospitals etc.), their effluents have to be tested prior to connection and it has to be ensured that they meet the requirements for safe discharge of <u>domestic</u> sewage. Test reports have to be made available to the EPA. In addition, it has to be monitored whether places that serve food from industrial kitchens (such as local tea houses or hotels) use an oil trap before their sewage is discharged into the public sewer network. The effluent from hospitals is of particular importance since it may contain pathogens that are discharged directly into the sea if not treated.

12.1 Monitoring Requirements, Frequency and Costs

The monitoring requirements are separated into a construction phase and operational phase. The operational phase begins as soon as sewage is being discharged into the sea from the new outfall pipe that is being proposed in this EIA.

Monitoring during the construction phase is limited to a water quality test since it will take a short time to construct the outfall (working time between two and four months).

12.1.1 Monitoring during the construction phase

Subject and location	Parameter to be monitored	Cost	Frequency and duration	Purpose
Recreational swimming area around the construction site	Temperature, Turbidity, TSS, DO, Toxins	undertaken by client	Monthly during construction	To determine the effects of construction (sedimentation and toxic waste) on the marine environment.

12.1.2 Monitoring during the operational phase

Subject and location	Parameter to be monitored	Cost	Frequency and duration	Purpose
GROUNDWATER				
Groundwater quality to be monitored from future sewer network area. Baseline data from four sites are given in this report.	Basic: Temperature, pH, Electric conductivity, nitrates, phosphates, TSS, turbidity, ammonia, faecal coliforms, *E.coli*.	undertaken by client	every three months; as long as sewage is being discharged by client	Monitoring and surveillance of groundwater so as to ensure public health and environmental protection from sewage leaks
	Extended: Cadmium, Chromium, Copper, Iron, Manganese, Mercury, Sodium, Potassium, Calcium hardness, Total hardness, Arsenic, Bromide, Boron, Chloride, Cyanide, Fluoride, Sulfide, Sulfate, Phenolic compounds, Total petroleum , Hydrocarbon, Anionic detergent, COD	undertaken by client	Annually; as long as sewage is being discharged by client	

SEAWATER				
At various sites from the recreational area, depending on the development of the island and usage of beach. Baseline data from the future swimming track area are given in this report.	Temperature, pH, DO, BOD, EC, TSS & TDS, turbidity, nitrates, phosphates, faecal coliforms, Enterococci	undertaken by client, or in cooperation with the EPA	At the beginning of operational stage, monthly for three months; later every three months if previous results do not show contamination; In case of contamination: monthly, for as long as sewage is being discharged by client.	Monitoring and surveillance of the seawater so as to ensure public health for users of the marine recreational areas in Hulhumale
Sewage movement from the existing and proposed outfall; surface currents from SW-monsoon are given in this report.	Sewage dispersion and dilution using dyes/current meters/water samples at various distances from origin	n.a.	yearlong study for both monsoons, until the radius of dispersion is found	To determine the direction of sewage flow and impact radius in order to protect users of the recreational areas in Hulhumale' to come in contact with pathogens
EFFLUENT				
Effluent water quality of sewer outfall; current status data are given in this report	Faecal coliforms, *E. coli*, pH, suspended solids, residual chlorine, nitrates, ammonia, phosphates, surfactants, conductivity, soap, oils and grease (food-related); oils, grease	undertaken by client;	At the beginning of operational stage; followed by bi-annual intervals. Effluent of hazardous sewage (e.g. toxic industrial waste, health sector waste	to comply with maximum concentrations as listed in the National Waste Water Quality guidelines so that no user of the marine environment will be affected negatively

	and waxes; chemical oxygen demand, biological oxygen demand, phenolic compounds as phenol, sum of metals (Cadmium, Chromium, Copper, Mercury and Lead), and acute toxicity.		etc.) to be tested prior to connection and later in annual intervals. Oil traps to be regularly checked whether in use at hotels/tea houses/industrial kitchens etc. Check if contaminated health sector waste undergoes treatment before discharge into MWSC system.	
CORAL REEF MONITORING				
Quantitative marine benthos survey and fish census around the proposed outfall; baseline data are given in this report	Live coral cover (%) and fish species present as per Chapter 6.5.2 Reef system (Marine benthos)	starting from approx. USD 500.00 per survey, undertaken by marine biologists	At the beginning of the operational stage. Later: bi-annually for two years	To determine the impact of sewage on the marine benthos
SYSTEM PERFORMANCE				
Sewage discharge	Amount of sewage discharged	Undertaken	Daily records; currently	To monitor the amount of sewage in

	per day	by client	calculated from the number of running hours per month. [The client is looking into the option of installing flow meters at a later stage.]	relation to the growing population of Hulhumale’
Visual inspection of the sewage outfall	Inspection for leaks	Undertaken by client / contracted specialists	To be continued as being practiced for the existing outfall in “Underwater Inspection of Seaoutfalls”	to ensure environmental health and public health for users of the recreational area
System performance	Maintenance of the complete sewage system connected to the outfall, including condition of material used	Undertaken by client	Daily readings on system performance, number of pump running hours, the electrical consumption etc. to be taken as being performed. The client is currently using a telemetry system that automatically informs a technician about a system failure. Client is looking into the option of extending this system for Hulhumale’ as well.	To ensure that the system is correctly functioning in order to avoid environmental or public hazards

Table 10. Monitoring timetable for construction and operation phase.
The table presented here ends at 12 months after the beginning of operation, but in reality is extended for as long as the client discharges sewerage.

		Construction stage					Operational stage (for as long as sewage is being discharged)											
Months after beginning (= 0)	0	1	2	(3)	(4)	0	1	2	3	4	5	6	7	8	9	10	11	12
Construction site Water quality[1]		x	x	(x)	(x)													
Ground water (basic)	✔								x			x			x			x
Groundwater (extended)																		x
Recreational areas, lagoon[2]	✔					x	x	x	x	(x)	(x)	x	(x)	(x)	x	(x)	(x)	x
Dispersion of sewage		yearlong study during both monsoons																
Effluent	✔					x						x						x
Marine study	✔					x						x						x

[1] (x) ... depending on the duration of operational stage
[2] (x) ... monthly monitoring if previous results show contamination, otherwise every three months

12.1.3 Monitoring report and responsibility

Reporting should be done annually, with summary reports at 2-monthly intervals according to the EIA regulations 2007. These reports are to be submitted to the Environment Protection Agency (EPA) of the Ministry of Housing and Environment.

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.

It is important that the information and experience gained through the monitoring activities are fed back into the EIA evaluation and analysis system to improve the quality of future assessment studies.

The monitoring responsibility will be with the client.

13 Conclusion

We conclude that the sporadic contamination of the recreational waters in Hulhumale' could, but does not necessarily result from the discharge of raw sewage, while on the other hand the impact area of sewage has actually never been determined. There is a possibility of contamination of the water resulting from the shedding of bathers themselves. Testing for *Staphylococcus aureus* during low, mid and heavy beach usage and at control sites could give an indication for that.

As per information given to us during research for this EIA report, neither the sewage from the hospital, nor from fish processing factories is treated before discharge into the domestic sewer network provided by the client. Seawater quality parameters currently tested for by the EPA do not give a proper indication of contaminated seawater. Continuous and reliable tests for Enterococci and other indicators are necessary instead. There is a possibility that infected sewage from the hospital could enter the shallow lagoon and when water is ingested, infections could occur.

Further, as recommended by the EPA, a large study that determines the dispersion of sewage and its influence on nearshore recreational areas is important with outlook on the activities that will be performed on the eastern side of Hulhumale'. At no time should any user of the sea be in risk of being negatively affected by the sewage. We consider a close monitoring of recreational waters, as well as of the effluent water and its dispersal of high importance.

How the fragile marine life will be affected by the discharge of raw sewerage can only be concluded after the monitoring programme has begun. Baseline data for both the proposed and the alternative site have been collected during this study to which data six months after the beginning of discharge can be compared. If it turns out that the coral reef gets negatively impacted by raw sewage, an extension of the pipe into greater depths and further away from corals need to be considered.

Eventually, a sewerage treatment plant is strongly recommended as the population of Hulhumale' grows towards 60,000 by the end of 2020. Treatment would improve parameters currently exceeding the maximum allowable limits in effluent, such as *E.coli*, suspended solids, BOD, Ammonia, faecal coliforms and hydrocarbon oils.

14 Declaration of the consultants

This EIA has been prepared according to the EIA Regulations 2007, issued by the (former) Ministry of Environment, Energy and Water of the Republic of the Maldives. The EIA was carried out by a multidisciplinary consulting team representing Water Solutions Private Ltd.

We certify that the statements in this Environmental Impact Assessment study are true, complete and correct to best of our knowledge and our abilities.

Name: Abdul Aleem (EIA 09/07)

Signature:

Date:

Name: Ahmed Jameel (EIA 07/07)

Signature:

Date:

Name: Verena Wiesbauer Ali (unregistered consultant, CV in Appendix 7)

Signature:

Date:

15 References

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Appendix 1: Terms of Reference

Appendix 2: Project approval by HDC

Appendix 3: Proposed sewer network

Appendix 4: Sump well drawings

Appendix 5: Panel shed drawing

Appendix 6: NHL and MWSC lab statements

Appendix 7: CV of unregistered individual

who participated in the preparation of the EIA report

NAME	Mag. Verena Wiesbauer Ali
CONTACT DETAILS	Farimaahiya 216, Villingili, Kaafu Atoll, Rep. of Maldives (960)7869666, verena@water-solutions.biz
NATIONALITY	Austrian
EDUCATION	Mag. rer. nat. = M.Sc. (Zoology / Marine Biology) University of Vienna, Austria (2003 - 2008)
OTHER TRAINING	PADI Open Water Diver (April 2004, Austria) PADI Advanced Open Water Diver (May 2004, Austria) Nitrox Enriched Air Diver (July 2005, Maldives) Dangers and Protection for Coral Reefs (July 2005, Austria) Marine Laboratory Training (January and June 2006, Austria) Marine Pollution and Utilization of the Seas (June 2006, Austria) Field Work – Fauna and flora of Marine habitats (July 2006, Croatia) Participation in the 1st National Workshop on Resort Reef Management (September 2006, Maldives) Biodiversity of Maldivian Coral reefs (November 2006, Austria) Biology of recent reefs (January 2007, Austria) Practical training in kanaeozoic Scleractinia (January 2007, Austria) Coral Reef practical training (September 2007, Egypt) Biology of the Marine Plankton (November 2007, Austria) Management of endangered species (January 2008, Austria)

PROFESSIONAL EXPERIENCE

Project Name : Establishment of an Artificial Reef around the World's first underwater Spa
Location : Huvafen Fushi (Nakatchafushi), Maldives
Period : Feb – Aug 2007
Position Held : Project Coordinator
Tasks : Design and establishment of an artificial reef, scientific monitoring, diving.

Project Name : Establishment of a Coral Nursery at Huvafen Fushi
Location : Huvafen Fushi (Nakatchafushi), Maldives
Period : August 2007
Position Held : Project Coordinator
Tasks : Coordinate the establishment of a processing table and underwater grow-out table, coordinate staff to work together, coral propagation, diving, monitoring of coral nubbins.

Project Name : Environmental Impact Assessment for the proposed Upgrade and Redevelopment in Athuruga Resort
Location : Maldives
Period : May 2009
Position Held : Marine Biologist

Tasks : Scientific marine survey and analysis, Marine section in EIA report

Project Name : Environmental Impact Assessment for the proposed modification for the original development concept in Hadahaa island
Location : Maldives
Period : June 2009
Position Held : Marine Biologist
Tasks : Scientific marine survey and analysis, Marine section in EIA report

Project Name : Environmental Impact Assessment for the proposed redevelopment at Moofushi Island Resort
Location : Maldives
Year : June 2009
Position Held : Marine Biologist
Tasks : Scientific marine survey and analysis, Marine section in EIA report

Project Name : SAARC Coral Reef CD-Rom
Location : Maldives
Period : September 2009 – April 2010
Position Held : Marine Biologist, Consultant
Tasks : Providing material (text, photos and videos) for an educational coral reef CD-Rom for youth in SAARC countries. Coordination with the SAARC Coastal Zone Management Centre, Male'.

Project Name : Environmental Impact Assessment for the Reef Rehabilitation and Coral Nursery Project in Bodu Hithi
Location : Maldives
Period : October 2009 – April 2010
Position Held : Project Coordinator
Tasks : Marine surveys, coordination of staff, EIA Report.

Project Name : Coral transplantation as part of the mitigation measures for the proposed redevelopment at Moofushi Island Resort
Location : Maldives
Year : December 2009
Position Held : Marine Biologist
Tasks : Training of resort staff in coral transplantation, creation of artificial coral gardens

Project Name : Dangerous Marine Animals. Biology, Injuries & Medical Treatment"
Location : Maldives
Year : December 2009
Position Held : Co-Author
Tasks : Co-authoring the book, reviewing, design.

Project Name : Schools Go Green – Environmental Workshop for school children
Location : Maldives
Year : February 2010
Position Held : Project manager
Tasks : Lecturing a workshop for Thaajuddeen school, Nature care students Grades 3 - 7

Project Name : Discover Maldives 2011
Location : Maldives
Period : March – October 2010

Position Held : Chairwoman of the board
Tasks : Writing and collecting articles for the WS Magazine, reviewing articles and combining all articles and photos. Organizing meetings.

Project Name : Launching event for the Coral project in Coco Palm Bodu Hithi
Location : Maldives
Year : April 2010
Position Held : Coordinator from Water Solutions for the inauguration ceremony
Tasks : Setting up a temporary coral nursery station; teaching coral transplantation to resort guests and staff; transplantation of coral nubbins

Project Name : Environmental Impact Assessment on the proposed upgrade and redevelopment of Olhahali
Location : Maldives
Period : April 2010
Position Held : Marine Biologist
Tasks : Scientific marine survey and analysis, Marine section in EIA report

Project Name : Reef Rehabilitation and Coral Nursery Project in Coco Palm Bodu Hithi
Location : Maldives
Period : April 2010 (ongoing)
Position Held : Project Coordinator
Tasks : Marine surveys, choice of location and methods for transplantation, coordination with staff. Setting up artificial reefs and a coral nursery on Bodu Hithi, North Male' Atoll. Monitoring. Scientific work.

Project Name : Environmental Impact Assessment for the proposed redevelopment of Kuda Hithi Island Resort
Location : Maldives
Period : June 2010
Position Held : Marine Biologist
Tasks : Scientific marine survey and analysis, Marine section in EIA report

Project Name : Monitoring of Redevelopment in Moofushi island resort
Location : Maldives
Period : June 2010
Position Held : Marine Biologist
Tasks : Scientific marine survey and analysis for monitoring report

Project Name : Environmental Impact Assessment for a pump station and sewerage outfall in Hulhumale'
Location : Maldives
Period : August 2010 (ongoing)
Position Held : Project coordinator, Marine Biologist
Tasks : Organizing surveying team; scientific marine survey and analysis, EIA report.

Project Name : Environmental Impact Assessment for the redevelopment of the Male' International Airport, Hulhule
Location : Maldives
Period : October 2010 (ongoing)
Position Held : Marine Biologist
Tasks : Scientific marine survey and analysis, Marine section in EIA report

Appendix 8: CV of MWSC contact person

Position: Assistant Engineer, Environmental		
Personnel information	Name : Midhath Abdul Gafoor	Date of birth: 25th July 1980
	Professional qualifications Bachelor of Engineering (Hons) in Environmental Engineering Nanyang Technological University Singapore	
Present employment	Name of employer Malé Water & Sewerage Company Pvt. Ltd.	
	Address of employer 5th Floor , Fen Building, Ameenee Magu, P.O. Box 2148, Malé, Republic of Maldives	
	Telephone: +960 332 3209	Contact (manager / personnel officer) Mohamed Sameer
	Fax: +960 332 4306	E-mail: midhath.gafoor@mwsc.com.mv
	Job title: Assistant Engineer, Environmental	Years with present employer: 04

Professional Experience

From	To	Company / Project / Position / Relevant technical and management experience
June 2006	Present	Assistant Engineer, Environmental - Malé Water & Sewerage Company Pvt. Ltd., Maldives EIA for the Sewer outfall at Hulhumale and new Brine reject outfall at Male'. Project officer of Sewer and water network projects. Assisted in new water and sewer connections. Updated water and sewer connection records
2009	2010	Final Year Project (Nanyang Technological University- Singapore) Completed Final Year Project on rejection of trace organic compounds by membrane adsorption in RO/NF membranes. Completed Experiments with NF90, NF270, and BW30 Membranes and samples were analyzed by using SPE (solid phase extraction) followed by LC/MS/MS method of analysis.

2009	2009	Projects Assistant (Industrial Attachment) - Great Earth Construction Pvt. Ltd (Singapore) Assisted in Implementing Environmental Management System (EMS) at Construction project which comprises of mixed development of 28 storey Hotel and 38 storey Condominium Apartments at Rochester Park, Singapore Coordinated Site Surveying using Total Station, EDM, Theodilite, and Auto Level. Assisted Project Engineer in coordinating structural works liaison with Resident Engineer. Handled site safety and safety awareness in compliance with NEA and ISO standards.
2004	2006	Senior Admin & HR Officer – Jausa Holdings Pvt. Ltd. Updated Tender and Bidding documents for construction projects and maintained bidding preparation with accordance to the Tender Board. Prepared Tender and Bidding document of Government Office Buildings. Handled admin and HR correspondences and coordinated Employees Training and Development. Maintained correspondences with the government authorities and private sector. Supervised staff welfare, external welfare, donation, sponsorships. Updated Legal correspondences, prepared Sub-Contractor Agreements.

ENVIRONMENTAL IMPACT ASSESSMENT

for the construction and implementation of a pump station and sewerage outfall in Hulhumale’

Proposed by

Male’ Water & Sewerage Company Pvt. Ltd.

Signature:

____

Prepared by

Ahmed Jameel (EIA 07/07)

Abdul Aleem (EIA 09/07)

Verena Wiesbauer Ali

Water Solutions Pvt. Ltd., Maldives

November 2010

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