Environmental Impact Audit and Assessment of Desalination Plants in Meradhoo Island, Gaafu Alifu Atoll

Proposed by:
Xanadu Holdings Pvt. Ltd.

Prepared by:
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Environmental impact audit and assessment of desalination plants in Meradhoo Island

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Executive Summary

The report documents the finding of the environmental impact assessment and audit of the desalination facilities at Meradhoo Island. Emphasis is given to the existing desalination plant at the main island, while the proposed desalination plant at the water villa area in the separate lagoon is also investigated and documented. When investigating the impacts and compliance of the plants, the existing environment is first investigated based on the field visit and previous studies undertaken on the island. Two previous studies have been undertaken assessing the environmental impacts of the resort development in Meradhoo Island and these have been referred to where appropriate.

The environmental compliance of the desalination plant is comparatively good, although there are some issues that need to be addressed as mentioned in detail in environmental compliance and in environmental mitigation. Also some impacts are predicted to be caused due to the implementation of the desalination plant in the water villa area. However, these impacts are small in magnitude and are reversible. Both desalination plants can be used sustainably if the necessary mitigation measures are taken. A monitoring plan is crucial to implementing effective mitigation measures, and as such a monitoring plan is detailed while concluding the report.
1. Introduction

The Ministry of Housing and Environment requires all desalination plants in the Maldives to be registered. In order to carry out the registration process, environmental clearance from EPA is mandatory. This clearance is obtained through the formulation of an Environmental Audit/Assessment of the desalination plant under the Desalination Regulation of the Maldives and subsequently obtaining a decision statement from EPA.

This report is based on the audit of the existing and the assessment of the proposed desalination plants in Meradhoo Island Resort and an assessment of the impact they may have on the environment. The report also highlights some possible alternatives to the existing and proposed RO plants and in addition to that outlines mitigation measures and a monitoring plan for the sustainable use of the desalination plants.

1.1 Aims and Objectives
The objectives of the report are:
- To assess the performance of the desalination plant.
- To assess the environmental compliance of the desalination plant.
- To provide mitigation measures and outline a monitoring plan for the environmental impacts.
- To register the desalination plant according to the requirements of the Environmental Protection Agency.
- To fulfil the obligations of the proponent to undertake an EIA under Clause 5 of the Environmental Protection and Preservation Act of the Maldives and the requirements of the tourism Regulations.

1.2 Audit and Assessment team
This assessment has been undertaken by a team of engineers and consultants led by Mr. Ahmed Jameel. The team was chosen by the proponent as the environmental consultants for this project.

The team members were:
- Ahmed Jameel, Environmental Engineer (EIA Registration No: EIA 07/07)
- Amir Musthafa, BEng (Hons) in Environmental Engineering
- Abdullah Wahid, Electrical Engineer

1.3 Terms of Reference
The terms of reference have been attached in Annex 1. This report has been prepared based on these terms of reference. The scope for this assessment and audit focuses on the environmental compliance and performance of the existing and proposed desalination plants in Meradhoo Island.
2. Project Description

The main project of Meradhoo Island resort development is proposed by Xanadu Holdings Pvt. Ltd (Company Registration No.: C-507/2006). The company, established in 2006, is the owner of Meradhoo Island Resort. The main contractor for the construction phase of the development is EoN Resorts. Currently, the operation of the resort is to be undertaken by the internationally renowned, Jumeirah Group. Components of the resort development is given in great detail in the initial EIA of the development of Meradhoo Island in 2007 by CDE Pvt Ltd., and the modifications that have been brought to the project has been covered in the Addendum to the EIA formulated on November 2010 by Water Solutions Pvt. Ltd.

2.1 Facility locations and Study Area

This study only focuses on the existing and proposed desalination plants in Meradhoo Island. This is a component of the main development project that has been underway in the island and is now close to completion.

The main development project is undertaken on Meradhoo Island as shown on Figure 1. The island is located on the northwest rim of Huvadhoo Atoll. It is approximately 400 km away from Male’, and travelling to the island requires an hour journey by flight to GDh. Kaadedhoo, followed by a 20 minutes launch ride. The island is at longitude 73°06’ E and latitude 0°35’ N. The closest inhabited island is GDh. Thinadhoo, the capital of South Huvadhoo Atoll.

Figure 1 Meradhoo Island located in North Huvadhoo Atoll (GA), (Source: Water Solutions Pvt. Ltd.)
Environmental impact audit and assessment of desalination plants in Meradhoo Island

A detached water villa area is located on the South of the island, with its own back of the house facilities. A Separate desalination plant was proposed in order to make the water villas independent from the main island. Moreover, the area between the island and the water villas is heavily populated with corals and therefore this component will have some negative impacts on them. It was also important to have the facilities separate in order to reduce the logistical cost and to avoid operational difficulties.

Since this report focuses only on the environmental impact of the desalination plants, no other operations of the resort will be looked into in this report.

### 2.2 Facility Description

There are two main RO plants on Meradhoo Island. Two more are proposed for the water villa area that is to be separate from the main island. The capacity of the RO plants in the main island is 100m³/day each, while the capacity of the proposed plants for the water villas are 50m³/day each. There is also an additional 18m³/day RO plant for standby.

The product water is stored in two 100m³ tanks on the main island, while there are two 30m³ tanks storing the product water in the water villa. More details of the RO plants are given on Section 6.4.

### 2.3 Need for the facilities

Desalination plants are required for each tourist island in the Maldives in order to provide safe utility water for the guests and staff of the island. As mentioned in Section 5.3, in 6.1 of the Regulation on the protection and conservation of environment in tourism industry, it requires a desalination plant on each resort in the Maldives for the purpose of provision of clean and safe water sufficient for use in the resort.

### 2.4 Alternatives

Considering alternatives for each technology is imperative for development as the best available technology needs to be implemented for sustainability. As such, alternative methods to obtain quality water other than desalination of seawater are discussed.

The no project option is an important alternative to consider in most cases, as developments may not really be necessary from the point of sustainability. However, the option is not possible in this case, as the presence of a desalination plant is required by law as mentioned in Section 5. Furthermore, continuous supply of quality water is necessary for a high-class resort such as that being developed on Meradhoo Island. However, several other alternatives are discussed such as use of alternative sources like rainwater, desalination of ground water, and an alternative technology in thermal distillation.

#### 2.4.1 Rainwater collection

As the ecological impacts associated with an industrial process are often related to the size of the ‘footprint’ it generates, the land area required for the establishment and operation of a facility is an important factor. Comparing desalination with rainwater collection; the catchment area needed for the latter, in a region of moderate rainfall, would be around 200 times greater than a desalination plant of the same capacity (Morton et al, 1996). The large land area occupied by conventional rainwater collection schemes does not make it favourable for development in a small island resort environment.
2.4.2 Thermal Distillation
Thermal distillation involves using large amounts of heat to purify the water. Thermal distillation processes have a greater thermal impact than membrane processes such as that used in Meradhoo Island, in terms of both marine and atmospheric discharges. It is more energy intensive and cannot be regarded to be feasible to be implemented in a small resort environment. However, By contrast, membrane processes have a greater impact in terms of salt concentration increase in discharged water, although salt mass flow rates are the same for both types of processes (Morton et al, 1996).

2.4.3 Ground water desalination
Boreholes can be used to utilize groundwater, instead of sea water for desalination purposes. Brackish groundwater would have a lower salt concentration of the input water, which reduces the osmotic pressure, and therefore energy consumption, as well as the concentration of salts in the effluent discharged to the sea. Potential local impacts provoked by brine discharge are also found to be lower, due to a reduced content of salts. Use of groundwater is therefore favorable. However, it must be taken into account that groundwater, as opposed to sea water, is a limited resource. The groundwater resource is already quite poor in Meradhoo Island, and it is not recommended to harness the resource. Furthermore, if the groundwater is exploited above its recharge rate, it will lead to the intensification of saltwater intrusion, thereby increasing the energy demand of the desalination process, and thus having a greater environmental impact. (Munoz & Fernandez-Alba, 1998)

3. Consultation
A scoping meeting was held between the major stakeholders of the project at EPA on 3rd April 2010 to highlight the important issues that need to be covered in the environmental audit and assessment. Participants at the meeting included

- Mohamed Hamdhaan (Environment Protection Agency)
- Athifa Ali (Ministry of Tourism Arts and Culture)
- Dilip (Xanadu Holdings Pvt Ltd)

Furthermore, consultation was held with the responsible people for the operation and management of the desalination plants during the field visits to Meradhoo Island.

The resort staff met during the consultation were

- Krishna Chalise (Project Manager, EON)
- Kannan (Resident Manager, Jumeirah)
- Prathab de Silva Vilharona (Mechanical/Electrical Engineer, EON)

4. Methodology
Several methods were employed in assessing the existing environmental conditions and also in identifying the environmental compliance and performance of the audited facility. Since there exists
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two substantial reports already formulated for Meradhoo island, which cover the existing environmental conditions and possible impacts from many factors in addition to the desalination plants; these reports have been used as a support to the onsite field visit to formulate this report. The field visit was undertaken on 26th March 2011, on the request of the proponent.

The consultations that were carried out during the scoping meeting and during the field visits were useful in identifying the problem areas and in the determination of standard of current facilities and possible impacts.

4.1 Location Identification
Location was identified using a handheld GPS receiver, running the application GeoRecorder 1.6 on Android 2.2 platform. The locations identified include the RO plant, water intake, brine discharge, proposed RO plant in water villa and associated proposed water intake and brine discharge locations.

4.2 Water Quality
All water quality measurements, including groundwater quality, marine water quality, desalinated water quality were undertaken in the National Health Laboratory in the capital Male’. The water samples were obtained on the field trip to Meradhoo Island on 26th March 2011.

4.3 Marine environment surveys
Previous studies, especially the Addendum to the Environmental Impact Assessment for the proposed concept modification in Meradhoo Island by Water Solutions Pvt. Ltd, Meradhoo Island EIA, had undertaken an extensive marine survey on the island in late 2010 and therefore an additional survey within such a small time period was deemed unnecessary. Therefore, most of the findings from this survey will be referred to when describing the existing marine environment of the island.

The methods carried out by Water Solutions Pvt. Ltd. are summarised below:

Marine environmental surveys were conducted to collect data on key environmental components that were impacted due to the new construction works. Three methods were primarily used to collect data, namely:

• Detailed LIT for sessile benthic community estimation, complimented by photo documentation
• Qualitative surveys through visual observations, particularly in the area where new development were to take place.

4.4 Noise
Since the RO plant was properly housed, noise pollution from the RO plant was negligible. Therefore use of a sound meter was deemed unnecessary for this audit and assessment.

4.5 Uncertainties in impact prediction
Quite a few uncertainties will be confronted during the identification of the environmental compliance of the facility and also while assessing the environmental impacts. In general, one can never be definite when predicting the possible impacts on the environment, as significant
differences are apparent with minor differences in ecological, geomorphological or social conditions in the given location.

Long-term data and information about the site under consideration are absent, making it rather difficult to predict impacts. However, the case of Meradhoo is better compared to other islands as there are two environmental impact assessments already done for the island in the space of 3 years. Furthermore, similar projects have been undertaken in the Maldives and therefore, the level of uncertainty, particularly in the case of the facilities under consideration for Meradhoo Island may be expected to be considerably low.

5. Legal and Policy Requirements

The legal and policy requirements that are relevant to the assessment or audit of desalination plants and their registration areas are as follows;

- Environmental Protection and Preservation Act,
- EIA Regulations,
- Regulation on the Protection and Conservation of the Environment in the Tourism Industry,
- Desalination Regulation of the Maldives,

These legal as well policy instruments and their relevance to the desalination infrastructure in Meradhoo are discussed below.

5.1 Environmental Protection and Preservation Act

The main legal Act that enforces the protection and preservation of the environment for sustainable development in the Maldives is the Environmental Protection and Preservation Act (Law No. 4/93) passed by the Citizen’s Majlis in April 1993. The following clauses of the Environmental Protection and Preservation Act (Law No. 4/93) are relevant to the project:

Clause 5a: An impact assessment study shall be submitted to the Ministry of Environment, Energy and Water (now Ministry of Housing and Environment - MHE) before implementing any development project that may have potentially negative effects on the environment.

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

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

Clause 10: The government of the Maldives reserves the right to claim compensation for all damages that are caused by activities that are detrimental to the environment. This includes all activities mentioned in Clause No. 7 of this law as well as those activities that take place outside the projects that are identified here as environmentally damaging.
5.2 EIA Regulations

The EIA Regulations, which came into force in May 2007, has been developed based on the Act as mentioned above. Since 2007, the EIA Regulations have been the basis for Environmental Impact Assessment in the Maldives. EIAs are required to be signed by registered consultants and reviewed by two independent reviewers and a final decision is made based on these reviews. As with all assessments, this audit would also be subject to these requirements and review criteria. The different environmental projects that require an EIA are listed under Section D of the EIA Regulations and desalination plants have been included in this list.

An assessment in the form of an Audit was needed for the registration of the facilities as no EIAs had been done specifically for the said developments in Meradhoo. The EIA Regulations do not directly indicate the requirements for environmental audits. However, the contents of environmental impact assessments have been defined in Schedule E and the format for monitoring reports can be found in Schedule M. These requirements and formats have consequently been taken into consideration in preparing this Audit Report.

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

The Regulation on the Protection and Conservation of the Environment in the Tourism Industry came into effect on 2006. Section 6 of the Regulation deals with the supply of water in tourist facilities. It requires every resort to have a desalination plant registered according to the Desalination Regulation and requires that water quality to be monitored properly by recording and maintaining daily logs of water quality. The regulation also gives a guideline for the provision of water storage sufficient for 5 days supply.

The regulation further states that groundwater shall not be used for drinking by guests or staff, and shall not be supplied to guest rooms or toilets or for use by staff. Furthermore, any type of oil or any other chemical which may damage the environment shall not be drained to the ground.

Clause 2.4 of the regulation requires an Environment Impact Assessment to be prepared before commencing any construction project or activity listed in clause 2.1 of the regulation, which covers coastal protection, dredging, reclamation, vegetation clearance, demolition of existing structures, import and export of living species, conducting research of land, sea and lagoon and anything that may adversely affect the vegetation and freshwater lens of the island.

5.4 Desalination Regulation of the Maldives

The Desalination Regulation of the Maldives came into effect on the year 2002. The Desalination Regulation states the requirements for plant capacity, intake and source water, storage capacity, plant operation and maintenance, brine discharge as well as water quality monitoring requirements.

The Environmental Protection Agency is currently in the process of reviewing the Desalination Regulation to incorporate the current regulatory requirements as well as an administrative framework. This regulation is the only regulation currently in force for the water and sanitation sector and has been established with their main goal being the safeguarding of public water supplies, the environment as well as the interest of service provider.
6. Water Supply Infrastructure

6.1 Water Demand
There are 200 staffs on the main island, while 12 staff would reside in the water villa area at any given time. There are 22 villas proposed for the main island, and 16 villas in the detached water villa area. It is anticipated that there will be 288 water consumers present in total. Based on resorts in the same category as Meradhoo Island, it is also anticipated that the per capita rate of water consumption can be over estimated to be 300 litres/person/day. This would lead to a water demand of approximately 86.4 m$^3$/day. The facilities in the island are well capable of meeting this demand for water consumption.

6.2 Water utilization
Desalinated water is mainly used for washing and laundry purposes, bathing, toilet flushing. In general it is used for the free distribution among the staff and guests at Meradhoo Island.

Currently groundwater has been used for landscaping and gardening within the island. However, this will be changed very soon as the resort owners regard using treated sewage water to be a better alternative and a more environmentally friendly option. This change would decrease the current impact on the islands groundwater system. Bottled water is used for drinking purposes.

6.3 Water circulation
Water is circulated to the kitchens, staff quarters, other back of the house facilities, guest areas, via underground distribution networks.

6.4 RO plant
The main RO plant was manufactured by Yonsan Engineering PTE LTD based in Singapore on November 2010. The main islands plant capacity is 100 m$^3$/day each. Energy rating is at 30kW. The plant was installed by Island Engineering Services Pvt Ltd.
The proposed RO plants at the water villa will be of similar design and function, however with less capacity. Two RO plants with a capacity of 30 m³/day each have been proposed. There is also a backup RO plant with a capacity of 18 m³/day.
Environmental impact audit and assessment of desalination plants in Meradhoo Island

The schematic flow diagram for the RO plant is shown in Figure 4.

![Figure 4 Schematic flow diagram for the RO plant](image)

### 6.5 Plant Site
The RO plant is located in a standard structure used for warehouses and storage of industrial equipment. However, the structure is made to be more sound proof to reduce noise pollution. The total land area of the plant is 80 m². Sedimentation tank is outside the main housing unit.

The proposed plant is housed in a dedicated overwater structure for the back of the house facilities approximately 60 m away from the tourist area. Sedimentation tank is inside the main housing unit.

### 6.6 Desalination Process
Desalination is carried out by a regular Reverse Osmosis plant.

Liquid chlorine is used at 2ppm dosage for the disinfection of the water. Caustic soda is used at 3.3mg/l dosage during operation of the plant for cleaning and maintenance purposes.

The seawater flows through a sand filter with filter capacity of 15 microns by the filtration pump after being stored in the sedimentation tank. The two sand filters have a capacity of 1840 Litres, 182.72 kgs.

The filtered water is then passed through the reverse osmosis system. The reverse osmosis membrane reduces the salt content producing freshwater. Freshwater is pumped into the storage tank which is located outside the plant house. Water pumped into the storage tank is disinfected using chlorine solution for distribution via underground distribution network to all guest rooms and public areas.
6.7 Water intake and outfall
Source water is taken from the sea just outside the house reef. Water intake is located at the head of the spa jetty. The brine is discharges into the lagoon approximately 100m from the shoreline. The outfall is located on the east of the island. The proposed water intake for the water villas is located towards north, while the outfall is located towards east. Both are in closer proximity than in the island. The locations are shown on Figure 5. More details on the intake and outfall (the brine discharge) are given in Section 8.

Figure 5 Water intake and outfall locations for the main island (left) and the water villa (right). (The locations are highlighted in red circles)
7. Exiting Environment

Existing environment was determined by the conditions that have existed in the island prior to undertaking the current field study and during the field study. The existing conditions are based on previous environmental assessment studies and water quality monitoring conducted for the island. The areas of significance are the existing conditions of ground water, marine water and the marine environment.

7.1 Ground water

There is currently only one location on the island from which ground water can be obtained from without any further deterioration to the environment. Therefore ground water sample from this area, which is located near the gardening facilities, was tested and the results are shown on Table 1. The well that was used to obtain ground water is shown in Figure 6. This test was undertaken during the most recent field visit.

Table 1 Ground water quality parameters (National Health Laboratory)

<table>
<thead>
<tr>
<th>Location of Sample</th>
<th>Ground water from location (0°35'12.52&quot;N, 73°05'38.02&quot;E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Appearance</td>
<td>Clear</td>
</tr>
<tr>
<td>Total Dissolved Solids (mg/L)</td>
<td>2160</td>
</tr>
<tr>
<td>Electrical Conductivity (µs/cm)</td>
<td>4150</td>
</tr>
<tr>
<td>Total Hydrocarbon (mg/L)</td>
<td>2.48</td>
</tr>
</tbody>
</table>

Figure 6 Groundwater well
7.2 Marine Water

Table 2 Marine water quality tests done by Water Solutions Pvt. Ltd. in 2010

<table>
<thead>
<tr>
<th></th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salinity (mg/l)</td>
<td>33500</td>
<td>33900</td>
<td>33800</td>
</tr>
<tr>
<td>DO (mg/l)</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>0</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>pH</td>
<td>8</td>
<td>7.9</td>
<td>8</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>29</td>
<td>29</td>
<td>28</td>
</tr>
</tbody>
</table>

Table 3 Marine water quality tests done for monitoring purposes in February 2011

<table>
<thead>
<tr>
<th>Location of Sample</th>
<th>Sea Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Appearance</td>
<td>Clear with suspended particles</td>
</tr>
<tr>
<td>Total Dissolved Solids (mg/l)</td>
<td>34100</td>
</tr>
<tr>
<td>Suspended Solids (mg/l)</td>
<td>2</td>
</tr>
<tr>
<td>Electrical Conductivity (µs/cm)</td>
<td>53700</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>0</td>
</tr>
<tr>
<td>pH</td>
<td>6.1</td>
</tr>
<tr>
<td>Iron (mg/l)</td>
<td>0</td>
</tr>
<tr>
<td>Magnesium (mg/l)</td>
<td>1426</td>
</tr>
<tr>
<td>Calcium (mg/l)</td>
<td>412.8</td>
</tr>
</tbody>
</table>

7.3 Marine environment

As mentioned in Section 4.3, an extensive marine survey was conducted by Water Solution Pvt. Ltd. in Meradhoo Island in late 2010. Results of this survey are presented below.

Since the island has been under construction for a long period, most of the coral damage has already taken place from the ongoing construction. Four marine survey sites were investigated in that study which included:

- Site 1, the ‘impact Site’, was the location of the new service jetty
- Site 2 is the new spa area. It also covers the entire length of the area with the water intake and brine discharge
- Site 3 is the new arrival pavilion
- Site 4 is the area where the overwater back of house is located. It is also the area to which brine will be discharge from the proposed RO plant.
- Site 5 is a control site

The sites are marked on Figure 7 and the results of the survey are shown in Figure 8 and Table 4.
Table 4 Results of Marine survey undertaken by Water Solutions Pvt. Ltd.

<table>
<thead>
<tr>
<th></th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 3</th>
<th>Site 4</th>
<th>Site 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table corals</td>
<td>4</td>
<td>0</td>
<td>8</td>
<td>0</td>
<td>90.8</td>
</tr>
<tr>
<td>Digitate corals</td>
<td>2</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Coral branching</td>
<td>0</td>
<td>0</td>
<td>19</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Coral massive</td>
<td>0</td>
<td>2</td>
<td>12</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sand</td>
<td>75</td>
<td>10</td>
<td>23</td>
<td>75</td>
<td>0</td>
</tr>
<tr>
<td>Coral rubble</td>
<td>5</td>
<td>23</td>
<td>26</td>
<td>10</td>
<td>0.2</td>
</tr>
<tr>
<td>Dead rock</td>
<td>4</td>
<td>15</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Dead corals</td>
<td>10</td>
<td>50</td>
<td>3</td>
<td>10</td>
<td>0</td>
</tr>
</tbody>
</table>

Site 2 is the most important location. It is within the region from which water is taken in and water is discharged. As shown from the survey results, most of the corals present at this site is already dead corals and rock, and therefore any additional potential impact from brine discharge on the marine life here would be low. Site 4 is the region in which water will be discharged from the proposed plant. Here also, not much life is found. Additionally the currents in these areas are high and would lead to effective dispersion and dilution of the brine.
8. Environmental Compliance and Performance

The following are identified as to having an impact on the environment due to the operation of the desalination plants. These impacts are identified based on literature and from the past studies that have been undertaken on impacts of desalination plants in other similar islands in the Maldives.

- Impact on coral cover in the reef
Environmental impact audit and assessment of desalination plants in Meradhoo Island

- Impact on marine life in the lagoon
- Impact on ground water quality
- Impact on marine water quality
- Visual impacts
- Impact due to noise pollution

It should be ensured that all the components of the desalination plants including the water intake and outfall does not have a significant impact on the environment and that the existing plant is in compliance with the expected standards of a standard desalination plant.

### 8.1 Water Intake

Water intake is taken from the South East side of the island with GPS coordinates 0°35’06.89”N, 73°05’37.96”E. The pipe is located at about 3m deep. The location of the intake is shown in Figure 5.

Proposed water intake for the water villa area is taken from the Northern side of the villa area with similar depth and with GPS coordinates 0°34’46.81”N, 73°05’40.01”E.

The water quality at the intake locations have been tested in the National Health Laboratory and the results are shown in Table 5. The water was collected at 1m depth at the intake locations. The water quality at the proposed intake of the water villa RO plant is also given in Table 5.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Proposed seawater intake</th>
<th>Main island sea water intake</th>
<th>Main island Sea water intake from sedimentation tank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>Clear</td>
<td>Clear</td>
<td>Clear</td>
</tr>
<tr>
<td>pH</td>
<td>8.2</td>
<td>8.3</td>
<td>8.2</td>
</tr>
<tr>
<td>TDS (mg/L)</td>
<td>14350</td>
<td>5990</td>
<td>10530</td>
</tr>
<tr>
<td>EC (µs/cm)</td>
<td>24600</td>
<td>10910</td>
<td>17010</td>
</tr>
<tr>
<td>BOD (mg/L)</td>
<td>16</td>
<td>22</td>
<td>14</td>
</tr>
</tbody>
</table>

### 8.2 Sedimentation tank

The sedimentation tank is currently located outside the plant house. Water from the intake flows direct to the sedimentation tank where the particulates are separated from the water. Upon observation, the water from the intake is clear with very few sediments and does not possess any foul odour. It is expected that the membranes and filters will be more durable due to the clearness of the intake water. The tank is of good size and is well capable of handling the input of water. However, the tank is not inside the dedicated site allocated to the desalination plant. Therefore, it does have a detrimental impact in terms of loss of visual amenity. Also, there is a risk of airborne substances getting in the sedimentation tank and causing pollution to some extent.

The sedimentation tank to be present at the water villas are of the same design but with smaller dimensions. It is to be located within the same structure as the RO plants and is positioned at the North East wall.
8.3 Processed Water

Water quality of the processed water by the RO plant has been tested in the National Health laboratory and the results are shown in Table 6. The water quality at the proposed plant, where the backup RO plant was undergoing a test run during the field visit was also used. Microbial tests were given the emphasis during the quality testing of the processed water.

Table 6 Microbiological test results for process water

<table>
<thead>
<tr>
<th>Sample</th>
<th>Proposed RO plant</th>
<th>Main RO plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total coliform count /100ml</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Faecal Coliform Count (E.coli)/100ml</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Tests were also carried out for many other parameters other than microbial to ensure the quality of the water. The results are shown on Table 7.

Table 7 Water quality tests for other parameters for process water

<table>
<thead>
<tr>
<th>Sample</th>
<th>Main RO plant</th>
<th>Main RO plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>Clear with suspended particles</td>
<td>Clear</td>
</tr>
<tr>
<td>ph</td>
<td>6.7</td>
<td>6.8</td>
</tr>
<tr>
<td>TDS (mg/L)</td>
<td>363</td>
<td>657</td>
</tr>
<tr>
<td>EC (µS/cm)</td>
<td>744</td>
<td>1328</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Iron (total, mg/L)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Magnesium (mg/L)</td>
<td>9.3</td>
<td>6.5</td>
</tr>
<tr>
<td>Calcium (mg/L)</td>
<td>2.1</td>
<td>2.1</td>
</tr>
<tr>
<td>Calcium Hardness (mg/L)</td>
<td>5.4</td>
<td>5.4</td>
</tr>
<tr>
<td>Apparent colour (TCU)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The processed water does not have any microbial content and the quality of water is general quite good. The issue with few suspended particles will be dealt with by sedimentation effect in the storage tanks before distribution through the water network.

Figure 10 Sedimentation tank in main island
8.4 Storage tanks

Water is stored in Zincalum steel Tank with concrete foundation. Two such tanks exist on the main island with a capacity of 100 cm\(^3\) each. In case of maintenance or damage to the plant, the stored water can be used for 2.5 days.

![Figure 11 Storage tanks in main island](image)

Storage tanks for the proposed plants are smaller with a capacity of 30m\(^3\).

8.5 Brine Discharge

Brine discharge is located on the East side of the island with GPS coordinates 0°35’15.80”N, 73°05’42.40”E. The brine is discharged into the lagoon approximately 100m away from the shoreline. Upon observation of the currents near the island, this location would ensure maximum dispersal of the salty water leading to dilution. There is some amount of coral cover at this location. However, most of the corals found are dead corals as observed in the marine survey.

The proposed brine discharge for the water villas is located near the arrival jetty, where maximum dispersion of the brine can be achieved due to current action. The location has GPS coordinates of 0°34’40.55”N, 73°05’44.20”E.

The main brine discharge pipe is at a depth of approximately 5m deep, while the proposed discharge pipe for the water villas will also be at a similar depth. The water quality test results are shown in Table 8.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Proposed seawater discharge condition</th>
<th>Main island seawater discharge</th>
<th>Main island Sea water discharge from temporary tank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>Clear</td>
<td>Clear</td>
<td>Clear</td>
</tr>
<tr>
<td>pH</td>
<td>8.4</td>
<td>8.0</td>
<td>8.2</td>
</tr>
<tr>
<td>TDS (mg/L)</td>
<td>9640</td>
<td>14700</td>
<td>11180</td>
</tr>
<tr>
<td>EC (µs/cm)</td>
<td>17010</td>
<td>25100</td>
<td>19510</td>
</tr>
<tr>
<td>BOD (mg/L)</td>
<td>14</td>
<td>18</td>
<td>18</td>
</tr>
</tbody>
</table>

Despite the high salinity of the brine discharge, this factor in compliance, as the discharge is far away from the main island and would be dispersed and diluted by the currents present in the area.
8.6 Noise
Noise was barely audible/observable from within 5m of the RO plant house. Therefore it will have minimum impact on the staff, while no impact on the tourists, since it is located within the back of the house facilities.

The situation is same for the RO plant to be present in the water villas. However, here the staff will have to endure some noise pollution as the staff area is located in close proximity to the RO plant. Enforcing a larger distance between the plan and the staff area would lead to the water villas having a greater footprint and greater impact, thus the current set up is recommended. However the staff should be enforced to wear safety ear plugs or ear muffs near the plant and their accommodation should be made sound proof. Noise levels are in compliance.

8.7 Visual Impact
The plant will have minimum impact on the aesthetics of the island as it is located almost at the centre of the back of the house facilities and well beyond the guest area. Since Meradhoo is a small island, the plant is located close to staff quarters. However, it is housed in a properly built structure and would not cause any visual obstruction to the staff. However, the sedimentation tank is located outside the structure and does have a detrimental impact as mentioned in Section 8.2.

8.8 Operation and Maintenance
There are no major temperature variances during the flow of water through the RO plant.

Regular testing of water is not been carried out currently. However, the regular water quality monitoring will be undertaken by dedicated staff by the time the operation phase begins to ensure that the output water quality from the desalination process is safe and meet the WHO standards. Recently there had been a water quality test undertaken for the purpose of monitoring. The results of these tests are given in Section 7. Water quality will eventually be monitored on daily, weekly and monthly basis. The water samples will be taken from the RO plants as processed water, brine discharge, water intake, guest area and staff quarters.

8.9 Safety
Fire protection and prevention measures had been taken at the RO plant and the surrounding areas. In order to protect the RO Plant from the fire accidents the proponent has installed fire fighting equipment at the plant as shown in Figure 12. Since the plant is located on the ground, there is no need for a dedicated fire escape. The staff located on the first floor with the monitoring equipment can use the standard staircase in case of an emergency.
## 8.10 Environmental audit summary for existing plant

<table>
<thead>
<tr>
<th>Environmental and Social Aspects</th>
<th>Compliance</th>
<th>Performance</th>
<th>Comments</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water quality monitoring</td>
<td>X</td>
<td></td>
<td>Regular monitoring has not commenced yet</td>
<td>To undertake monitoring on a set regular basis</td>
</tr>
<tr>
<td>Noise</td>
<td>X</td>
<td>X</td>
<td>Housing well insulated from noise pollution</td>
<td>Use of ear muffins for the staff at the RO plant.</td>
</tr>
<tr>
<td>Visual impact</td>
<td>X</td>
<td></td>
<td>Standard structure which houses the plant, away from tourist area in the heart of the back of the house facilities, however close to staff quarters due to lack of space</td>
<td>To include sedimentation tank within the plant housing.</td>
</tr>
<tr>
<td>Storage</td>
<td>X</td>
<td></td>
<td>Is able to store water for 2.5 days for regular usage</td>
<td>Can increase the storage to be able to cater for 5 days and can include a backup storage tank.</td>
</tr>
</tbody>
</table>

Figure 12 Fire extinguishers
### Environmental impact audit and assessment of desalination plants in Meradhoo Island

<table>
<thead>
<tr>
<th>Category</th>
<th>Action</th>
<th>Impact</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water intake</strong></td>
<td>X</td>
<td>X</td>
<td>Any pollution at intake area should be prevented.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Include marine water quality testing as part of the monitoring program.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Use a finer mesh to prevent any possible intake of marine organism.</td>
</tr>
<tr>
<td><strong>Brine discharge</strong></td>
<td>X</td>
<td></td>
<td>Some amount of live corals observed in discharge area. But mostly dead corals and rock.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Include marine water quality testing as part of the monitoring program. Ensure water is discharged further out to ensure minimum impact on any flourishing marine life.</td>
</tr>
<tr>
<td><strong>Groundwater impact</strong></td>
<td>X</td>
<td></td>
<td>No impact on groundwater as no leakage currently.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Periodically check for leakage along the water distribution network.</td>
</tr>
<tr>
<td><strong>Energy usage/ Emissions</strong></td>
<td>X</td>
<td></td>
<td>Plants should be run only at required times.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Can implement innovative technology to reduce energy. Can implement best available technology for heat recovery.</td>
</tr>
<tr>
<td><strong>Water conservation</strong></td>
<td>X</td>
<td></td>
<td>Good ideas in place for water conservation. Some amount of groundwater is used for irrigation purposes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>More methods need to be employed for water conservation and use of groundwater has to be stopped.</td>
</tr>
<tr>
<td><strong>Safety</strong></td>
<td>X</td>
<td></td>
<td>Fire fighting equipment visible and easily accessible.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Need to also include a fire warning system.</td>
</tr>
</tbody>
</table>
8.11 Environmental impacts summary for proposed plant

<table>
<thead>
<tr>
<th>Environmental and Social Aspects</th>
<th>Magnitude of Impact</th>
<th>Significance of Impact</th>
<th>Duration of Impact</th>
<th>Nature of Impact</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Conservation</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Short to long term</td>
<td>Reversible</td>
<td>Water conservation measures to be implemented</td>
</tr>
<tr>
<td>Groundwater impact*</td>
<td>Negligible</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Marine water impact</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Long term</td>
<td>Cumulative</td>
<td>Water currents should be observed to ensure water dispersion and dilution</td>
</tr>
<tr>
<td>Disinfection</td>
<td>Minor</td>
<td>Moderate</td>
<td>Short term</td>
<td>Reversible</td>
<td>Alternative methods of disinfection should be considered</td>
</tr>
<tr>
<td>Noise pollution</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Short to Long term</td>
<td>Cumulative</td>
<td>Safety ear muffs should be used</td>
</tr>
<tr>
<td>Visual impact</td>
<td>Minor</td>
<td>Low</td>
<td>Short term</td>
<td>Temporary</td>
<td>No impacts as separately housed</td>
</tr>
<tr>
<td>Safety</td>
<td>Minor</td>
<td>Low</td>
<td>Short to long term</td>
<td>Irreversible</td>
<td>Proper fire fighting equipment and fire warning system to be implemented</td>
</tr>
<tr>
<td>Energy usage /Emissions</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Long term</td>
<td>Cumulative</td>
<td>Suitable heat recovery methods to be investigated</td>
</tr>
<tr>
<td>Sufficient storage</td>
<td>Minor</td>
<td>Moderate</td>
<td>Short term</td>
<td>Unavoidable</td>
<td>Back up storage to be implemented</td>
</tr>
</tbody>
</table>

Note: the magnitude of impacts progresses from better to worse in the following order; Positive, Negligible, Minor, Moderate, Major.

*There wont be any ground water impacts as the plant is located on an over water structure and is used solely for the water villa area.

9. Impact Mitigation

This section would outline how some of the impacts mentioned in Section 8 can be mitigated and how the desalination plant can be sustainably used. Since an operations manual was not observed during the site visits, it is highly recommended such a manual be maintained to mitigate many of the potential impacts.

9.1 Energy Conservation

Desalination is generally an energy intensive process. Alternative methods of desalination can be employed to reduce energy consumption. Use of energy recovery equipment can be employed. The
Environmental impact audit and assessment of desalination plants in Meradhoo Island

possibility of using a renewable energy source, at least to partially power the plant should be investigated to reduce energy usage and also to reduce emissions from the plant.

9.2 Water Conservation
Several methods for water conservation have already been proposed by the proponent and will be implemented when the resort operation commences. Water consumption can be decreased to lower than 250 L/person/day. As such, the following steps have been proposed

- treated sewage is to be used for gardening purposes on the island
- dual flushing tanks are to be used for both staff quarter and tourist accommodation
- Water meter is to be connected to all the systems in locations such as the kitchen and guest area to monitor and minimize the amount of water usage
- Water used for the swimming pools in both the staff quarter and guest area is to be recycled continuously.
- Linen will not be washed daily, and will be left without washing upon request by the guests.

Water conservation can be further improved upon by implementing an efficient monitoring program as given in Section 10. It should be noted that currently, water usage meters are already in place to monitor the amounts of water used from main locations such as the kitchen, laundry etc. These can be used as baseline data to decrease the water usage amounts.

Alternative water resources such as collection and use of rainwater can be employed. However there are specific that arise due to the use of each method as discussed in Section 2.4.

9.3 Brine outfall
Although the brine contains materials originated from sea (source water), its high salinity per volume and the potential presence of chemicals introduced in disinfection may harm the marine environment in the area in which the water is discharged. However, this would be a significant issue if only the discharge was close to the shoreline or is close to the reef. The water discharge at Meradhoo island is considerably far away from the shoreline, although it is close to the reef. The discharge is targeted towards area of high current leading to dispersion and dilution of the salty water, thereby minimizing impacts.

The Brine outfall can be further extended as to not be directed to any corals, which may possess marine life among them. However, this should only be implemented after ensuring no damage would be carried out on the current cover near the area. Also the reject water from the desalination plant can be pre-diluted using cooling water from the power plant. Impact from chemicals can be avoided by employing a procedure to remove chemicals such as chlorine from the reject water before disposal. Use of alternative pretreatment methods can also be considered, such as use of Ultraviolet. However, economic feasibility of such an option for such a small island needs to be considered before being implemented. Furthermore, quality of brine discharge can be regularly monitored as given in section 10

9.4 Source water intake
The trapping of marine organisms against the intake screens by the velocity and force of water flowing to it (impingement) and smaller marine organisms passing through the intake screens and getting into process equipment (entrainment) are two key impacts of desalination. Also the source
water should not be subject to any anthropogenic pollution, which would later decrease the quality of the desalinated water.

For mitigation, smaller mesh size filters can be used on the intake end to prevent marine organisms from getting trapped and being taken in by the intake pipe. Also, low intake velocity should be considered. The total intake water can also be reduced by utilizing cooling water from the power plant. Furthermore, quality of water at intake can be regularly monitored as given in section 10, to observe whether any significant pollution is occurring at the water intake area.

9.5 Impact on ground water

Although currently there is minimum impact on the ground water, there is the possibility of leakage of the brine discharge pipe contaminating the groundwater system of the island. Leak detectors can be used throughout the water distribution network. However this is not recommended as the feasibility of implementing this for such a small island is low, and the impact of small leakages on the ground water will also be minimum.

The small impact on the ground water currently due to use for irrigation can be mitigated by using an alternative water source for irrigation purposes. Usage of treated waste water has already been proposed for this purpose and is due to be implemented.

10. Environmental Management and Monitoring

This section deals with the Environmental Management and Monitoring plan for Meradhoo Island. The data collected for this assessment and previous assessments will be used as baseline data while undertaking the monitoring plan. Monitoring will only be targeted towards changes in quality of desalinated water, groundwater and marine water, especially at intake and outfall locations. Monitoring should be undertaken quarterly, while summary monitoring reports should be submitted to the EPA annually. In house water quality monitoring of processed water should take place on a more frequent basis.

It is highly recommended that the monitoring program outlined in this report is regarded as complementary to the programs already mentioned in the previous EIA studies for the island and the monitoring programs be carried out jointly. This is essential in saving time and money for the management and monitoring purposes.

The proponent is fully committed to carry out the monitoring program outlined in this report. The proponent’s declaration of commitment is given on Annex 2.

10.1 Monitoring Methodology and Costs

The methodology used for monitoring will be similar if not the same as those used in this environmental assessment. Additionally, the following costs are calculated for monitoring to be undertaken quarterly throughout the year.
## Table 9 Summary of information required for environmental monitoring

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Indicator</th>
<th>Location</th>
<th>Frequency</th>
<th>Estimated Cost*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intake water quality (marine)</td>
<td>DO, COD, BOD, pH, EC/Salinity,</td>
<td>Both water intake locations, 1 m below sea level.</td>
<td>Quarterly</td>
<td>$250 per quarter</td>
</tr>
<tr>
<td>Discharged water quality (marine)</td>
<td>DO, BOD, COD, pH, EC/Salinity,</td>
<td>Both water outfalls, 1 m below sea level.</td>
<td>Quarterly</td>
<td>$250 per quarter</td>
</tr>
<tr>
<td>Ground water quality</td>
<td>DO, TDS, COD, BOD, EC/Salinity, THC, nitrate, phosphate.</td>
<td>From the well that already exists in the island</td>
<td>Quarterly</td>
<td>$250 per quarter</td>
</tr>
<tr>
<td>RO processed water quality</td>
<td>pH, EC, DO, free and residual chlorine, coliform bacteria</td>
<td>From both RO plants, guest area, and staff quarters.</td>
<td>Weekly and Quarterly</td>
<td>$250 per quarter</td>
</tr>
<tr>
<td>Water Demand</td>
<td>Daily production of water</td>
<td>Using the water quality meters that are setup.</td>
<td>Quarterly</td>
<td>$200 per quarter</td>
</tr>
<tr>
<td>Marine Environment</td>
<td>Percentage of coral cover identified locations</td>
<td>Locations given in Section 7.3</td>
<td>Quarterly</td>
<td>$300 per quarter</td>
</tr>
</tbody>
</table>

*Note: the costs are approximations made at the time of making this report and are subject to change.

### 10.2 Monitoring Report

Monitoring report should be compiled based on the baseline data collected. This report should be submitted to the EPA or any other relevant government agencies for compliance, if requested. The report will include details of the site, data collection and analysis, quality control measures, sampling frequency and monitoring analysis and details of methodologies and protocols followed.

It is recommended that the monitoring report be submitted after undertaking the monitoring program outlined in the previous EIAs for the island.
11. References


Water Solutions Pvt. Ltd., 2010, Addendum to the Environmental Impact Assessment for the proposed development in Meradhoo, Gaaf Alifu Atoll, Maldives.
12. Declaration of the consultants

This Environment Audit has been prepared according to the EIA Regulations 2007, issued by the Ministry of Environment, Energy and Water. The EIA was carried out by a multidisciplinary consulting team.

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

Name: Ahmed Jameel (EIA 07/07)

Signature:
Environmental impact audit and assessment of desalination plants in Meradhoo Island

ANNEX
203- Admin/68/2011/79

1432 01
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Website: www.ere.gov.mv
Environmental Protection Agency

Terms of Reference for the Environmental Audit on existing Desalination plant and related infrastructure at Meradhoo, Gaafu Alif Atoll

The following is the Terms of Reference for preparing an Environmental Audit report for the existing desalination plant and related infrastructure in Meradhoo, Gaafu Alif Atoll, Maldives. This Environmental Audit is carried out for the purpose of registering the desalination plant on the island. While every attempt has been made to ensure that this TOR addresses all of the major issues associated with development proposal, they are not necessarily exhaustive. They should not be interpreted as excluding from consideration matters deemed to be significant but not incorporated in them, or matters currently unforeseen, that emerge as important or significant from environmental studies, or otherwise, during the course of preparation of the audit report.

1. Introduction - The Ministry of Housing and Environment requires that desalination plants in the Maldives to be registered. In order to carry out the registration process, environmental clearance is required from the EPA, i.e. a Decision Statement regarding the environmental impact assessment of the water infrastructure. In order to provide such clearance the EPA requires that an Environmental Impact Assessment be done for proposed new or upgrading projects and an Environmental Audit be done for existing facilities. Since there are no upgrading or additional components at Meradhoo, Maldives it was decided that an Environmental Audit will be done for the purpose of registering the desalination infrastructure.

2. Study Area - The study will be focused on desalination infrastructure existing on the island. The specific areas include immediate vicinity affected by noise, the seawater intake, plant housing, storage facilities and brine discharge locations.

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

Task 1. Description of the Project Components - Provide a brief description of the proponent, full description of the relevant parts of the project, using clearly labeled maps, scaled site plan including location of existing desalination plant, outfalls and saltwater intake. In addition provide a process flow diagram of the desalination plant.

Provide details of area of the plant room, number and capacity of desalination plants, method of saltwater intake and, location and length of brine discharge outfall and its reject arrangements, and disinfection and reticulation mechanism and existing safety measures in place in case of an emergency.

Task 2. Description of the Environment - Assemble, evaluate and present baseline data on the relevant environmental characteristics of the audit area, including the following:

a) Physical environment: Water quality at the location of intake and brine discharge locations. Intake water quality parameters shall include dissolved oxygen, COD, BOD, pH, EC/salinity. Water quality at brine discharge location should include dissolved oxygen, BOD, COD, pH, E-
Conductivity/salinity. Groundwater quality shall include dissolved oxygen, TDS or E-Conductivity, THC, COD, BOD, nitrate and phosphate. Quality of the product water from desalination plant shall also be assessed for pH, E-Conductivity, and coliform bacteria.

b) Biological environment: Assessment of coral cover along the pipe if the brine discharge or intake pipe or part of the pipe runs on reef areas where live corals can be found.

c) Human environment: Identify the noise levels in the vicinity and how they affect recreational quality and public and occupational health.

Characterize the extent and quality of the available data, indicating significant information deficiencies and any uncertainties associated with the prediction of impacts. All available data from previous studies of the island, if available, should be presented. Geographical coordinates of all sampling locations should be provided. All water samples shall be taken at a depth of 1m from the mean sea level or mid water depth for shallow areas. Absence of facilities in the country to carry out the water quality tests will not exempt the proponent from the obligation to provide necessary data. The report should outline the detailed methodology of data collection utilized to describe the existing environment. Baseline conditions should be presented for the marine environment. An average of at least 5 measurements must be given for each parameter tested and analyzed from a certified laboratory. Provide details of calibration for any onsite data analysis.

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

Task 4. Determine the Environmental Performance, compliance, mitigation and recommendations - Identify impacts related to operation and maintenance desalination plants. Distinguish between significant impacts that are positive and negative, direct and indirect, and short and long term. Identify impacts that are cumulative, unavoidable or irreversible. Identify any information gaps and evaluate their importance for decision-making. Identify any information gaps and evaluate their importance for decision-making. Determine how well the existing infrastructure complies with existing environmental policies and regulations.

Give details of all mitigation measures currently implemented to minimize any adverse impacts. Are these mitigation measures sufficient, provide recommendations to improve the existing operations. Commitment of the proponent to implement any required additional mitigation measures and cost, equipment, resources required to implement these measures shall also be given.

Task 6. Environmental Management Plan and Monitoring - Identify the critical issues requiring monitoring to ensure compliance to mitigation measures and present impact management and monitoring plan. Details of the monitoring programme including the physical and biological parameters for monitoring, frequency, duration and cost commitment from responsible person, detailed reporting time table and ways and means of undertaking the monitoring programme must be provided. A general guideline for monitoring is provided in appendix 1. Relevant components of this guideline must be followed when preparing the audit report.
Task 7. Methodology - Explain clearly the methodologies used for data collections, making predictions and data gaps and also the information on the uncertainties and assumptions involved in interpreting the data.

4. Appendix - Operational manuals (if not maintained shall be recommended), layout of the desalination plant, process flow diagrams, an A-3 site plan showing location of desalination plant.

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

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

5th April 2011
Appendix 1

PHYSICAL MONITORING

SEA WATER QUALITY TESTING FOR BASELINE DATA COLLECTION

These parameter guideline triggers have been adopted from the Great Barrier Reef Marine Park Authority (GBRMPA, 2009). The marine ecology in the Maldives is so vulnerable that it should be compared to that in the GBRMP. This will help maintain healthy ecosystems to preserve valuable natural resources that are directly or indirectly part of all people's livelihoods.

Take 3 control water samples away from the project site, 3 water samples from the project site and a representative number of water samples from different locations around the project site. All water samples shall be taken at a depth of 1m from the mean sea level or mid water depth for shallow areas. Record the GPS coordinates of each water sample taken. Analyze the following parameters and check the water quality standards to evaluate the status of the sample.

Table 1. Water quality parameter optimum conditions.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>OPTIMAL RANGE</th>
<th>REFERENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEMPERATURE</td>
<td>18°C and 32°C * Changes should not surpass 1°C above the average long term maximum</td>
<td>GBRMPA, 2009</td>
</tr>
<tr>
<td>SALINITY</td>
<td>3.2% - 4.2%*--------------------</td>
<td>GBRMPA, 2009</td>
</tr>
<tr>
<td>PH</td>
<td>8.0-8.3 * Levels below 7.4 pH cause stress</td>
<td></td>
</tr>
<tr>
<td>TURBIDITY</td>
<td>3-5 NTU &gt; 5 NTU causes stress</td>
<td>Cooper et al. 2008</td>
</tr>
<tr>
<td>SEDIMENTATION</td>
<td>Maximum mean annual rate 3mg/cm²/day Daily maximum of 15mg/cm²/day</td>
<td></td>
</tr>
<tr>
<td>NITRATES</td>
<td>&lt;5 mg l⁻¹ NO₃⁻N</td>
<td>UNESCO/WHO/UNEP, 1996</td>
</tr>
<tr>
<td>AMMONIA</td>
<td>Max. 2-3 mg l⁻¹ N</td>
<td>UNESCO/WHO/UNEP, 1996</td>
</tr>
<tr>
<td>PHOSPHATE</td>
<td>0.005 - 0.020 mg l⁻¹ PO₄⁻P</td>
<td>UNESCO/WHO/UNEP, 1996</td>
</tr>
<tr>
<td>SULPHATE</td>
<td>2 mg l⁻¹ and 80 mg l⁻¹</td>
<td>UNESCO/WHO/UNEP, 1996</td>
</tr>
<tr>
<td>BOD</td>
<td>&lt;2 mg l⁻¹ O₃</td>
<td>UNESCO/WHO/UNEP, 1996</td>
</tr>
<tr>
<td>COD</td>
<td>&lt;20 mg l⁻¹ O₂</td>
<td>UNESCO/WHO/UNEP, 1996</td>
</tr>
</tbody>
</table>

* * * * * * * This could be higher at the brine outfall location. Assess biological impacts, if any.
ACCEPTABLE DRINKING GROUND WATER QUALITY RANGES

The Water & Sanitation Authority require that ground water quality meets specific standards. Table 1, 2 & 3 indicate the ranges for drinking water quality. If the water is not used for such purposes, quality ranges may not be within the limit but quality will not decrease after construction. All survey locations shall be referenced with Geographic Positioning System (GPS). All parameters shall be tested and analysed at a certified laboratory.

Table 1. Weekly tests (Source: WHO).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Reference Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free chlorine</td>
<td>0.2-0.5 mg/l</td>
</tr>
<tr>
<td>pH</td>
<td>6.5-8.5</td>
</tr>
<tr>
<td>Physical Appearance</td>
<td>Clear &amp; Colorless</td>
</tr>
<tr>
<td>Temperature</td>
<td></td>
</tr>
<tr>
<td>Electrical Conductivity</td>
<td>&lt;1500 µS/cm</td>
</tr>
<tr>
<td>Total Coliforms</td>
<td>0/100 ml</td>
</tr>
<tr>
<td>Faecal Coliforms</td>
<td>0/100 ml</td>
</tr>
</tbody>
</table>

Table 2. Six monthly tests should be performed along with those given in table 2 (Source: WHO).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Reference Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbidity</td>
<td>&lt;5 NTU</td>
</tr>
<tr>
<td>Total Dissolved Solids</td>
<td>&lt;1000 mg/l</td>
</tr>
<tr>
<td>Chloride</td>
<td>&lt;250 mg/l</td>
</tr>
<tr>
<td>Nitrate</td>
<td>&lt;50 mg/l</td>
</tr>
<tr>
<td>Ammonia</td>
<td>1.5 mg/l</td>
</tr>
<tr>
<td>Iron</td>
<td>0.3 mg/l</td>
</tr>
<tr>
<td>Total Coliforms (MF)</td>
<td>0/100 ml</td>
</tr>
<tr>
<td>Faecal Coliforms (MF)</td>
<td>0/100 ml</td>
</tr>
</tbody>
</table>

Table 3. Annual tests should be performed along with those given in table 2 & 3 (Source: WHO).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Reference Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphate</td>
<td>&lt;250 mg/l</td>
</tr>
<tr>
<td>Manganese</td>
<td>&lt;0.1 mg/l</td>
</tr>
<tr>
<td>Total Petroleum Hydro Carbon</td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td>&lt;200 mg/l</td>
</tr>
<tr>
<td>Potassium</td>
<td></td>
</tr>
<tr>
<td>Calcium Hardness</td>
<td></td>
</tr>
<tr>
<td>Bromine</td>
<td></td>
</tr>
<tr>
<td>Total Residual Chlorine</td>
<td></td>
</tr>
<tr>
<td>Hydrogen Sulphide</td>
<td>&lt;0.05 mg/l</td>
</tr>
<tr>
<td>Substance</td>
<td>Concentration (mg/l)</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Mercury</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Lead</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Copper</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Boron</td>
<td>&lt;0.3</td>
</tr>
<tr>
<td>Arsenic</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Fluoride</td>
<td>&lt;1.5</td>
</tr>
<tr>
<td>Phenolic compounds</td>
<td></td>
</tr>
<tr>
<td>Anionic detergents</td>
<td></td>
</tr>
<tr>
<td>Cadmium</td>
<td>&lt;0.003</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.05</td>
</tr>
<tr>
<td>Cyanide</td>
<td>&lt;0.07</td>
</tr>
</tbody>
</table>

**BATHYMETRY AND HYDROLOGY**

Waves, currents, tides: These parameters are important for understanding sediment transportation and the rate of effluent water dispersion. Ideally, presented a map illustrating the extent of sediment plumes and highlight the sites which will be affected by high sedimentation and turbidity rates. This study will complement coastal erosion monitoring.

Present bathymetric data on an A3 map. Identify the sites which have high water dispersion and dilution rates as well as intense erosion performances. State the tidal ranges in the area including neap and spring tides throughout the year. Mark the areas where wave action is more intense (e.g. where waves break).

This data is key for sewage projects, desalination plants, dredging activities, aquaculture ventures, agriculture and all those which involve water dispersion and sediment transport activities. Sewage outfall pipes shall be located where currents quickly disperse effluent. Brine water from desalination plants ought to be placed in high energy waters too, however, the impacts from this are still relatively unknown.

**2. BIOLOGICAL MONITORING**

The first action in developing a long-term monitoring program is establishing the key questions about the study. This will guide the selection of methods, sites and times of sampling (English et al., 1994). It is important to select sites for monitoring that are representative of the system as a whole, and not necessarily the closest or most pristine areas. Such "pristine" sites may be essential as "controls", if the aim of monitoring is to determine impacts at test sites (English et al., 1994). All site selection should be made following a "pilot study" of the area, if the project is localized. The number of sites chosen for monitoring will necessarily be a balance between trying to achieve the maximum amount of information and the amount of resources and time available (English et al., 1994). The monitoring program should be designed around a series of sites that can be visited on
a regular basis, e.g. every year. Recording the GPS coordinates of the sites are really important for survey repetition. The first step is to establish a sound baseline description of the system before construction occurs.

2.1. CORAL REEF, FISH & INVERTEBRATES MONITORING

2.1.1. Pilot study: Manta tow: The manta tow technique is used to assess broad changes in the benthic communities or coral reefs where the unit of interest is often an entire reef or large portion thereof (English et al. 1994). Therefore this technique can be used to perform preliminary assessments to design a comprehensive monitoring study.

- Tow an observer, using a rope and manta board, behind a small boat powered by an outboard motor. Tows are carried out at a constant speed around the perimeter of a reef and are broken into units of 2 minutes duration (English et al. 1994).
- During each 2 minute tow, observations are made on several variables (e.g. percent cover of live coral, dead coral and soft coral). Additional information may be collected, dependent on the survey objectives, e.g. percent cover of sand and rubble.
- This technique is not recommended for fish counts. A pilot study for fish is not necessary since reef fish will inhabit the healthiest available reef. Exclusive fish and invertebrates surveys will be carried out in the main study.

2.1.2. Line Intercept Transects (LIT): It is the standard method recommended by the Global Coral Reef Monitoring Network (GCRMN) to determine percentage cover and colony size for management level monitoring, and obtains information on percentage cover of benthic communities e.g. hard coral, soft coral, sponges, algae, rock, dead coral. The community is characterized using lifeform categories which provide a morphological description of the reef community.

- These categories are recorded on data sheets by divers who swim along lines which are placed roughly parallel to the reef crest at depths of 3 metres and 10 metres at each site (English et al., 1994).
- Place 5 x 20m long replicate transects at each of the two depths (shallow: 3 m and deep: 9-10 m depths). If permanent transects are used, place metal stakes, hammered deep into the substratum (at least 0.5m). If a typical reef flat, crest and slope is present, the shallow transects will be located on the reef slope, approximately 3 metres below the crest. The deeper transects will be located approximately 9-10 metres below the crest. If the site is on a reef without a well defined crest, then transect depth should be approximated to a depth below mean water mark. If there is little or no coral at 10m then transects should be laid at 6-8m and not difference.
- A representative number of sites around the island should be surveyed including those that are directly and indirectly affected by construction. A “control” site shall be selected and test sites thereafter. These shall be sufficient to make a quantitative assessment of the impacts caused by construction all around the island.
- Observers must be as consistent as possible when recording benthic lifeforms. The same observers should collect data at all sites and, where possible, during repeat surveys.

2.1.3. Coral Recruitment Plates: The larval supply of coral species is examined by estimating the number of new corals settling on replicated units of substratum (terracota tiles). The tiles are deployed at 5 metres depth on a regular basis (e.g. monthly) and are collected after exposure for equal amounts of time, 3 months is recommended. After collection they are examined microscopically to count the new corals. Year round
sampling should be undertaken to determine the period, or periods, of recruitment. When they are known, sampling effort can be concentrated in these periods.

It is ideal for EIA monitoring because it will evaluate whether the system is recovering after it has been damaged and at what rate. This will help understand the impact significance in later projects in the Maldives.

2.1.4. Settlement Quadrats: This is used to measure the growth, mortality and recruitment of corals in a permanently marked (fixed) quadrat located at metres depth on the reef slope (English et al., 1994). It complements the LIT method by providing changes in individual corals and recruitment to a mapped area. This provides abundance estimates of recruits that have survived the first year, thus giving a more reliable estimate of future coral species composition than recruitment tiles that look at newly settled recruits.

- Using a 2.5cm x 2.5cm quadrat, swim in a haphazard fashion around the reef and place the quadrat on the substratum in areas lacking large (>25 cm diameter) sessile invertebrates;
- Count all small (maximum diameter 2 cm) stony corals within the quadrat. Record to genus if possible;
- Repeat 80 times.

2.1.5. Sedimentation on the reef: This is to measure direct sedimentation on the reef resulting from land clearing activities, construction, dredging, mining and drilling activities. Sedimentation reduces light availability for photosynthesis, deplete dissolved oxygen and cause smothering of organisms. Sedimentation rates are measured using sediment traps.

- Attach sets of 3 PVC sediment traps to the reef. The base of the traps should be 20cm above the substratum. Place 4 sets on the reef slope at 3 metres, 2 on either side of the permanent quadrat at one metre intervals.
- Collect traps every month, replace traps immediately with new clean traps. Dry and weigh sediments to the nearest milligram.
- Monitor monthly for the first year and then every 3 months for the next 2 years.

2.1.6. Coral Reef Fish Census: Belt transect: The aim is to simultaneously estimate the abundance and size of fish along 50 metre transects. A visual census is conducted during daylight hours along 3 of the same transects as the line intercept but the fish census transects must be 50 m long at 2 depths (3-5 m and 8-10 m). Wait for 5 to 15 minutes after laying the line before counting to allow fishes to resume normal behaviour, then swim slowly along the transect recording fish encountered in a 5 m belt and 5 m tunnel above the transect. There are two techniques:

- Detect differences in assemblages of reef fishes at different sites using abundance categories (table 3). It provides baseline data for zoning, management and monitoring, or;
- Count individual fish and estimate their total lengths to determine the standing stock and population size structure of specific species (those that are favoured by fishermen e.g. Serranids, Siganids, Acanthurids, Lutjanids, Lethrinids, Haemulids, Balistids). This is to determine the standing stock and population size structure of specific species.
<table>
<thead>
<tr>
<th>Category</th>
<th>Number of fish</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2-4</td>
</tr>
<tr>
<td>3</td>
<td>5-16</td>
</tr>
<tr>
<td>4</td>
<td>17-64</td>
</tr>
<tr>
<td>5</td>
<td>65-256</td>
</tr>
<tr>
<td>6</td>
<td>257-1024</td>
</tr>
<tr>
<td>7</td>
<td>1025-4096</td>
</tr>
<tr>
<td>8</td>
<td>4097-16384</td>
</tr>
</tbody>
</table>

2.2. SEAGRASS MONITORING

Seagrass meadows occur in shallow, sheltered soft-bottomed marine coastlines (Kirkman, 1990). They physically help to reduce wave and current energy, help to filter suspended sediments from the water column and stabilise bottom sediments (Fonseca et al., 1982). The habitat complexity attracts high biodiversity and abundance of animals. They are also nutrient sinks, buffering or filtering nutrient and chemical rich waters (Short and Short, 1984). The high primary production rates are linked to high fishery production rates.

Monitoring seagrasses consists of mapping the distribution and density of existing meadows to determine the natural variability (e.g. seasonal dieback) before estimates of loss or gain due to perturbation can be made (English et al., 1994). Percentage cover are measured within replicate quadrats placed at regular intervals along the length of a transect.

- Place transects perpendicular to the shore and that extend to the outer limits of the beds (where seagrass disappears). Transects should be parallel and separated by reasonable distances from each other (50m to 100m). Take 3 replicate transects at each site. Swim along the transect along a compass bearing, perpendicular to the shore.
- Place 25cm x 25cm quadrats at regular intervals (5m-10m) and estimate the percent cover using similar categories to those used in coral reef surveying.
- Estimate the abundance and length of fish the same way as performed in the coral reef visual census.

2.3. TERRESTRIAL MONITORING

Terrestrial environments in the Maldives play an important role in sustaining island shapes and many indigenous species. Vegetation maintains the soil on the ground and hosts 70 bird species, many interesting reptiles and amphibians and mangrove communities. In Environmental Impact Assessments, terrestrial monitoring should include evaluating the damages caused by the project development on the following flora and fauna:
• Land clearance activities including removal of trees, shrubs, seedlings, forest litter;
• Mangroves survey including area, species, health;
• Reptiles and amphibians including species, population size, location;
• Birds including species, population size and location;
• Marine turtle tracks;
• Soil texture changes, and,
• Garbage description.

A general procedure for collecting island data is through focus group discussions where islanders can identify the major changes in flora and fauna. All stakeholders should attend this meeting.

Finally, the legislation states that:

• No trees shall be felled for tourism ventures (Regulation on the Protection and Conservation of the Environment in the Tourism Industry)
• The maximum area for construction allowed for tourism ventures is 20%.
• The buffer zone between the high water mark and the first construction is 20 metres minimum.

3. SOCIO-ECONOMIC MONITORING

Public consultation is an important part of the project assessment since stakeholders will influence the success or failure of the project. If stakeholders and members of the public fully support the development activities will process much easier and benefits by both parties will be apparent. The following is important in all consultations:

• List of stakeholders and key informants, describe chronological plan of interviews and meetings and key points of discussions;
• Apply for all the necessary permits for project development;
• Census of the economic activities in the area (project island and neighbouring islands);
• Employment and economic opportunities and diversification in the area;
• Impacts on ground water from construction and operational phase and water availability for locals;
• Increased demands for natural resources and services in the area, e.g. water supply, energy, waste water treatment, solid waste generation, health services, population pressure, space availability, food and nutrition security – fisheries, agriculture, other- etc.
• Impacts on tourism, and
• Social destabilization of the island community.

The key outcomes from each stakeholder and key informant consultation ought to be included in the EIA. Follow up consultation will validate the success of the project, failures and suggest improvements.
COMMON SET #1
COMMON SET #2
COMMON SET #3

1000mm CABLE TRAY INSTALLED 450mm BELOW FIRST FLOOR SLAB

450mm CABLE TRAY INSTALLED 450mm BELOW FIRST FLOOR SLAB

7M CABLE 1500mm INLET
ATTEN.

NO WINDOWS IN GENERATOR HALL

GROUND FLOOR
MAIN RO PLANT
MERADHOO ISLAND,
GAAF ALIFU ATOLL
<table>
<thead>
<tr>
<th>Time Tested</th>
<th>12 mdl</th>
<th>14 mdl</th>
<th>16 mdl</th>
<th>18 mdl</th>
<th>20 mdl</th>
<th>22 mdl</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:10</td>
<td>10:10</td>
<td>11:10</td>
<td>12:10</td>
<td>13:10</td>
<td>14:10</td>
<td></td>
</tr>
</tbody>
</table>

**TEST METHOD**

- Oxygen Demand Biological
- Total Dissolved Solids
- pH
- Physical Appearance

**PARAMETER TESTED**

- Sample No.
- Type of Water
- Time Sampled
- Date Sampled Processed
- National Reference No.

**LOCATION OF SAMPLE**

- Purpose of Testing: Quality Monitoring
- Name and Address of Client: Power System PVT LTD.
- Phone: (+966) 77 1143
- Accreditation No. 11456/01

**REPORT NUMBER: WATER CHEMISTRY ANALYTICAL RESULTS**

Telephone: #33437, FX #30490
South Service, Main, 02000, Republic of Maldives
Medicine Pool, Dhing Authority,
National Health Laboratory

**COMMENT**

- Oxygen Demand Biological
- Total Dissolved Solids
- pH
- Physical Appearance

**Parameter Tested**

- Sample No.
- Type of Water
- Time Sampled
- Date Sampled Processed
- National Reference No.

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Telephone: #33437, FX #30490
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Medicine Pool, Dhing Authority,
National Health Laboratory

**COMMENT**

- Oxygen Demand Biological
- Total Dissolved Solids
- pH
- Physical Appearance
<table>
<thead>
<tr>
<th>Parameter Measured</th>
<th>Method</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Chloride</td>
<td></td>
<td>mg/L</td>
</tr>
<tr>
<td>Physical Appearance</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Parameters tested:**
- Sample ID: 280313W026
- Date tested: 28/03/2011
- Place of test: Ground
- Time sampled: 14:30
- Date sampled: 28/03/2011
- Reference Form No.: NH:WMC-2011:R001
- Location of sample: GROUND WATER
- Purpose of testing: Quality Monitoring

**Report number:** NH:WMC:WOC-2013

**Water Chemistry Analytical Results**

Reported by: National Health Laboratory

Date: 30 April 2011

Authorized by: