7. TECHNICAL ASPECTS OF DESALINATION PLANT

7.1 DESALINATION TECHNOLOGIES

Desalination technologies can be classified according to the process involved, for example:

- Those involving phase change in water, as in distillation, freeze separation, and hydrate separation;
- Those utilizing surface properties of membranes, as in electrodialysis and reverse osmosis
- Those utilizing ion-selective properties of solids and liquids, as in ion exchange and solvent extraction.

Another common classification of desalination plant is the one which involves the various forms of energy required namely heat, mechanical, electrical or chemical.

A further classification is one which distinguishes between the withdrawal of water from solution, as is exemplified by the comparison of any distillation process with electrodialysis.

Within the scope of this project, the promoter intends to install a reverse osmosis process desalinator.

7.2 REVERSE OSMOSIS PROCESS

In the reverse osmosis process, water is made to pass from the more concentrated solution to a less concentrated one, which is the reverse of the principle of osmosis. The force necessary to accomplish this is the application of pressure greater than the osmotic pressure of the saline solution.

If a saline solution is in contact with a semi-permeable membrane which is placed under pressure being in excess of its osmotic pressure, water from the solution will flow through the membrane. Water flow will continue till the pressure created by the osmotic head equals the osmotic pressure of the salt solution.

Acetate membranes have proved most successful to be used for this purpose. Membranes are not perfectly semi-permeable as they allow certain quantities of ions to cross through the membranes. The salt content in the water produced can be controlled by reducing the pressure or increasing the number of filtrations.

7.2.1 Advantages of Reverse Osmosis Process

The main attraction of this process is its low energy consumption. The energy required for operating the process increases with feed water salinity. The technical difficulties include fabrication, degree of semi-permeability, fouling, membrane supports and energy recovery associated with the membranes.

7.2.2 Characteristics of Reverse Osmosis Process

The characteristics of the reverse osmosis desalination process are summarized in Table 7-1 below.

Table 7-1: Characteristics of Reverse Osmosis Process

Advantages	Disadvantages
▪ Suitable for both sea and brackish water	▪ Comparatively Low quality of permeate (250-500ppm)
▪ Flexibility in water quantity and quality	▪ Requires high quality feed water
▪ Low power requirements compared with other desalination processes	▪ Relatively high capital and operating costs
▪ Flexibility in site location	▪ High pressure requirements
▪ Flexibility in operation start-up and shut off	▪ Long construction time for large plants
▪ Simple operation	

Despite the disadvantages, the reverse osmosis process has been ranked as the best desalination technology when performance is evaluated in terms of economic, technical and environmental aspects.

7.3 COMPONENTS OF DESALINATION PLANT

The proposed desalination plant will have a nominal capacity of 125m^3/day to cater for the resort's daily domestic requirements and will include:

- 1 set of fine filters – to remove fine solid particles which would otherwise damage the membranes.
- 1 No reverse osmosis high pressure membrane desalinator
- 1No high pressure pump
- 1 No energy recovery unit with associated booster pump and accessories
- 1 No desalinated water neutralisation filter (outside of RO container)
- 2No pressure vessels
- 1 set of chemical dosing units
- 1 CIP system
- 1No beach intake well
- 1No dilution tank
- 1 No seawater buffer tank
- 1 No reject tank

The desalination plant room will be located within the desalination plant room area as shown on the Massing Plan enclosed at Annex 4A at the end of Section 4.

The basic simplified flowchart of the desalination plant is shown below in Figure 7-1.

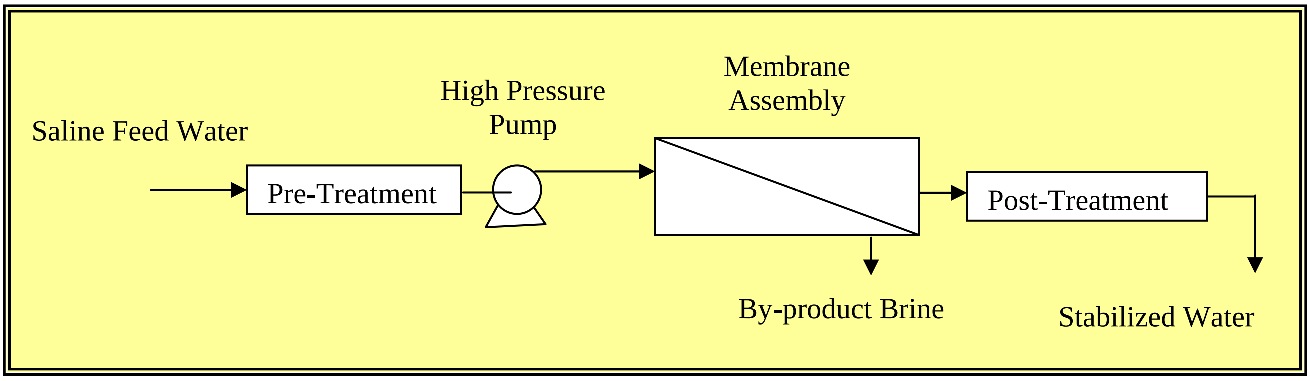

Figure 7-1: Basic Process Flow Diagram

7.4 PRODUCTION CAPACITY OF DESALINATION PLANT

The plant will be rated to produce a treated water volume of the order of $50m^3$/day, say $2.1m^3$/hr based on a 24-hour basis operation. This production is roughly equivalent to one-day demand of the hotel.

The water produced will feed the $50m^3$ service storage reservoir which is located close to the desalination plant, towards the western boundary.

Disinfection of the stored water will be given consideration as part of the pipework exiting the tank. UV disinfection is a clean and safe alternative to chlorine, and is being explored.

The RO plant will be demand-based. The service reservoir will be fitted with float switches. When the level in the service reservoir drops to a pre-determined level, the RO unit will start automatically and begin producing potable water. It will keep running until the reservoir upper level switch is reached, when it will automatically switch off again. The tank will be equipped with an outlet valve and associated piping for draining and cleaning the reservoir, as required.

7.5 SEAWATER QUALITY

Seawater samples taken in Rodrigues in October 2009 in Saint Francois lagoon and investigated for physico-chemical qualities of the water have served as baseline data have for the preliminary design of the desalination plant. The parameters have been reproduced at Table 7-1 below.

Note: Such baseline data is considered adequate for the preliminary design of the desalination plant system for the purpose of the EIA. For the actual dimensioning of the final plant to be actually installed at the hotel, the M&E Engineer will obtain finer design details from the manufacturer of the desalination plant.

Table 7-1: Physic-Chemical Quality Testing Result

Parameters	*Sample No 1*	*Sample No 2*
▪ pH	8.3	8.2
▪ Salinity	40.9	41.2
▪ Total Suspended Solids	<2.0	<2.0
▪ Dissolved Oxygen	8.7	8.3
▪ Chemical Oxygen Demand	8	6

7.6 FEATURES OF THE DESALINATION PLANT

As already mentioned, the desalinator will be of the reverse osmosis type and will be equipped with the energy recovery technology.

The proposed desalination plant will be made up of high quality materials and all the components used will be anti-corrosive thus preventing damages due to saline water.

The proposed system will be equipped with a pressure transmitter/exchanger which will act as an energy recovery device. This device enables the re-use of the high pressure of the concentrate (brine) coming out of the RO membrane and re-injecting same into the system. This allows the decrease in the capacity of the pressure pumps which will be used and will also decrease energy consumption, resulting in lesser operation costs, and savings in electricity consumption.

The typical desalination kit from the manufacturers, which will be installed at Cotton Bay Hotel is reproduced in Figure 7.2 below.

Figure 7-2: Reverse Osmosis Desalinator

The different components comprising the desalination network system are as follows:

- 1 No seawater intake borehole
- 1 No seawater storage tank
- 1 No desalination equipment of capacity 125m^3/day including filtration, reverse osmosis membrane assembly, safety instruments, pressurisation system
- Dosing Pumps for Pre-treatment and Post Treatment

- 1 No underground potable water storage tank
- 1 No brine dilution tank
- 1 No reject tank

7.7 SELECTED DESALINATION PROCESS

Seawater having an average salinity level of the order of 41, 000ppm at 25°C will be pumped by stainless steel submersible pumps, from a borehole at the rate of 23.0m^3/hour (i.e. 550m^3/day) and transferred to a buffer tank of 30m^3. Seawater stored within the buffer tank of 30m^3 will be used for the RO process as well as for dilution of brine before same is rejected at sea. This storage tank will provide a buffer of 1.3 hours - which is adequate for the whole system to operate.

The desalinator will draw seawater from the storage tank for treatment and discharge the desalinated water to the concrete reservoir located close to the desalination plant area. This potable water reservoir acts as central buffer potable water storage and feeding source to all the hotel's water consuming components.

The desalinator will produce potable water at a rate of 2.1m^3/hour. The desalinated water will thereafter be:

(i) Neutralised by the addition of sodium hypochlorite in order to increase the pH and alkalinity;

(ii) Remineralised by addition of calcium chloride to balance the hardness of the treated water;

The post treatments mentioned above will be carried out prior to storage in the underground concrete reservoir for potable water. As a standard policy of the hotel, the incoming water from the CWA system and from the desalination plant will be stored in the potable water reservoir, prior to utilisation of the potable water within the hotel's consuming points; this potable water will further undergo a re-chlorination process.

The seawater salinity will be reduced from 41, 000ppm at intake to not more than 300ppm after the R.O. treatment

The alignment of the piping layout from the intake borehole to the raw water tank and from the dilution tank to the reject tank is highlighted in yellow on the Massing Plan showing Desalination Plant Components, enclosed at Annex 7A at the end of Section 7.

7.8 WATER QUALITY ASPECTS OF DESALINATED WATER

The RO product water called "*permeate*" will be chlorinated to ensure the persistence of a residential chlorine dosage which will ensure the quality of the water for human consumption; the water will then be stored in the water storage tank of the hotel.

If so required, prior to its release to the distribution network of the hotel, the water will be further disinfected with ultra-violet rays to ensure quality and safety of the product.

A low-pressure mercury arc lamp will be used as the principal means of generating UV energy for disinfection. A mercury lamp has been favoured because 85% of light output is monochromatic at a wavelength of 253.7nm, which is within the optimum range for germicidal effects. The lamps are typically about 0.75-1.5m in length and bout 15-20mm in diameter.

7.9 DESCRIPTION OF PRE-TREATMENT PROCESS

The proposed prefiltration units will consist of two components:

(a) Fine filters, followed by

(b) Absolute Filters

7.10 HIGH PRESSURE PUMP UNIT

The plant will be fitted with a highest-efficiency high-pressure pump unit operating in parallel with a small booster pump. The high-pressure pump will be a piston-type positive displacement unit to increase the pressure from approx. 3 to approx. 60 bars. The pump will be made of homogenous materials to avoid galvanic corrosion, which would have otherwise rendered it unsuitable for working with seawater. The head, the internal parts, the valve sealing rings, plugs etc. of the pump being in contact with seawater will be made of stainless steel. All wear surfaces are lubricated/cooled by the pump medium (water) thus oil and grease are not required.

All the materials will be fully compatible to avoid any possibility of electrolysis effect between the different components.

7.11 REVERSE OSMOSIS MEMBRANE ASSEMBLY

The membrane assembly will be composed of a range of 12 spiral wound polyamide elements contained inside of 2 pressure vessels rated to operate at a pressure of approx 69 bars, depending on the feed water analysis results (assuming 27^0C and 41, 000 ppm). The membrane assembly will be efficiently designed to provide the required flow rate at optimal flow velocity through the membrane units for long lasting life expectancy. At such an operating pressure and flow conditions, the yield will be almost immediate and pure drinking water will be available after a few seconds only.

During normal operation, the membrane units will be working simultaneously but in case of damage or failure of one unit, this broken membrane unit will be by-passed with the plant continuing to operate safely with the remaining ones.

7.12 HIGH PRESSURE INSTRUMENTS

The following minimum control and safety instruments will be provided in association with the high pressure aspect of the plant:

- 1No electrical contact pressure gauge to monitor membrane inlet pressure
- 1No pressure gauge to monitor membrane discharge pressure
- Emergency pressure switch for membrane inlet pressure
- Flow meter for control of pressure exchanger flow
- 1 No Air relief valve
- 1 No security valve for excess pressure

7.13 LOW PRESSURE INSTRUMENTS

The following minimum instruments and control components will be provided for monitoring and controlling the lower pressure sections of the plant:

- 1 No pressure control and gauge (manometer) to monitor inlet pressure
- 1 No pH indicator prior to feed filters
- 1 Redox prior to fine filters
- 1 No pressure control to monitor high-pressure pump inlet
- Pressure gauges on all fine filter housing
- Pressure gauges to monitor brine outlet pressure
- Conductivity meter of permeate
- 1 No level control in CIP tank
- 3 No dry-run protection for CIP tank and dosing tanks
- Re-hardening station including media
- Flow meter for monitoring outgoing permeate
- pH meter for drinking water, following the neutralisation media
- Conductivity meter for drinking water, following the neutralisation media
- 2 No pressure gauge to monitor feed into and out of neutralisation filter
- SDI meter on inlet piping

7.14 ELECTRICAL PANEL

A control panel will be delivered with the plant so as to control and monitor all the operating and security functions of the plant. The central switchboard is designed according to IEC/VDE/OVE-standards and it includes:

- PLC-system (programmable logic controller) for data processing
- Process control system
- Main interruptor
- Central visual alarm
- All necessary contactors, fuses, status lights/displays
- A busbar for power cable connection

The alarm panel will be designed to indicate the following important parameters:

(i) Overload relay of pump motors

(ii) Mini/maxi abnormal – pressure conditions

(iii) High salinity pre-alarm/pH/Redox

(iv) Operating hour recording

7.15 CLEANING IN PLACE UNIT

The CIP-system (“cleaning-in-place”) is integrated in the RO-container and permits flushing with fresh water at any plant stop. This ensures removal of brine solution from the membranes and also avoids any standstill corrosion of piping material, high pressure pump and other components. In case of necessity of cleaning the membranes with chemicals, the respective solution is prepared in this tank and re-circulated through the membranes to restore their desalination capacity.

The cleaning in place unit will comprise of:

- 1No pump with $14m^3$/hr capacity, working at 5 bar pressure
- 1No 2,000 Litre plastic holding tank to contain water and chemical products for membrane cleaning. A mixer is installed in the tank to optimally dilute and prepare the solution prior to beginning the cleaning process.

7.16 SKID FRAME AND ASSEMBLY MATERIALS

The skid frame will be entirely made-up in high quality ST37 alloy, sand-blasted and coated, suitable for working in saline environment.

Manifolds and clamps will all be in ST37 sand-blasted and coated for extended life span. Screws, nuts, bolts and high pressure piping will be 1.4571 staninless steel. Connections between stainless steel pipes and ST37 steel will feature galvanic insulated separators.

7.17 BEACH INTAKE BOREHOLES

The feeding seawater will be pumped from 1No beach intake borehole situated within the hotel premises, at 15metres from the High Water Mark, as shown on the Massing Plan showing Desalination Plant Components enclosed at Annex 7A at the end of Section 7.

A total volume of $23.0m^3$/hour will be pumped for the purpose of operating the whole desalination plant, and ensure the complete desalination, dilution and final rejection processes. The borehole will provide sea water at ambient salinity firstly to enable the desalination process and secondly to provide feed water for the brine dilution process. The borehole will be fitted with a meter which will enable the monitoring of the volume of water being pumped.

The borehole will be drilled by an experienced contractor. The boreholes will be drilled to a depth of 20-25 metres in 250 mm diameter. They will be lined with a PVC lining of diameter 200mm, which will be wrapped with a geotextile fabric grade U24. After drilling, an air lift will be carried out during 4 hours in order to clean and develop the borehole, following which a pumping test will be carried out for at least 12 hours to determine the maximum aquifer recharge rate and the associated draw-down. Finally, chemical and physical analysis of the seawater will be undertaken.

The borehole will be equipped with a submersible pump placed at the bottom. The submersible pump will feed the seawater storage tank – which will be installed upstream of the RO desalinator via a 160 mm HDPE pipeline connected to it. The seawater storage tank will be of $30m^3$ capacity and will be located within the desalination plant area close to the R.O plant

7.18 BRINE PRODUCTION

The output of the desalinator which can also be referred to as the by-product of the desalination plant process will be a concentrated salt solution having a salinity level of the order of 68, 300ppm. This concentrated brine solution which will be discharged from the desalination plant at a rate of 3.12m^3/hour during the operation of the plant will be pumped at the required pressure and flow rate to the dilution tank where it will be mixed with in-coming seawater of ambient salinity resulting in a mixture/effluent of lesser salinity conducive to life support of the receiving flora and fauna media in the lagoon. After dilution, the final effluent will be sent to the reject tank (located as indicated on the site plan enclosed at Annex 7A at the end of Section 7) from where it will percolate into the sandy formation into the lagoon.

7.18.1 Brine salinity

The feed seawater to the desalinator of nominal capacity 125m^3/day (based on a 24-hour operation) will be discharged at a rate of 5.21m^3/hr to the desalinator, with salinity 41,000 ppm.

The permeate production for the desalinator will be 2.10m^3/hr at a salinity concentration of 300 ppm.

The brine production will be 3.12m^3/hr from the desalinator with a salinity of 68, 300ppm as shown in the following calculations for the mass balance at the desalinators.

7.18.2 Desalination Process Mass Balance Diagram

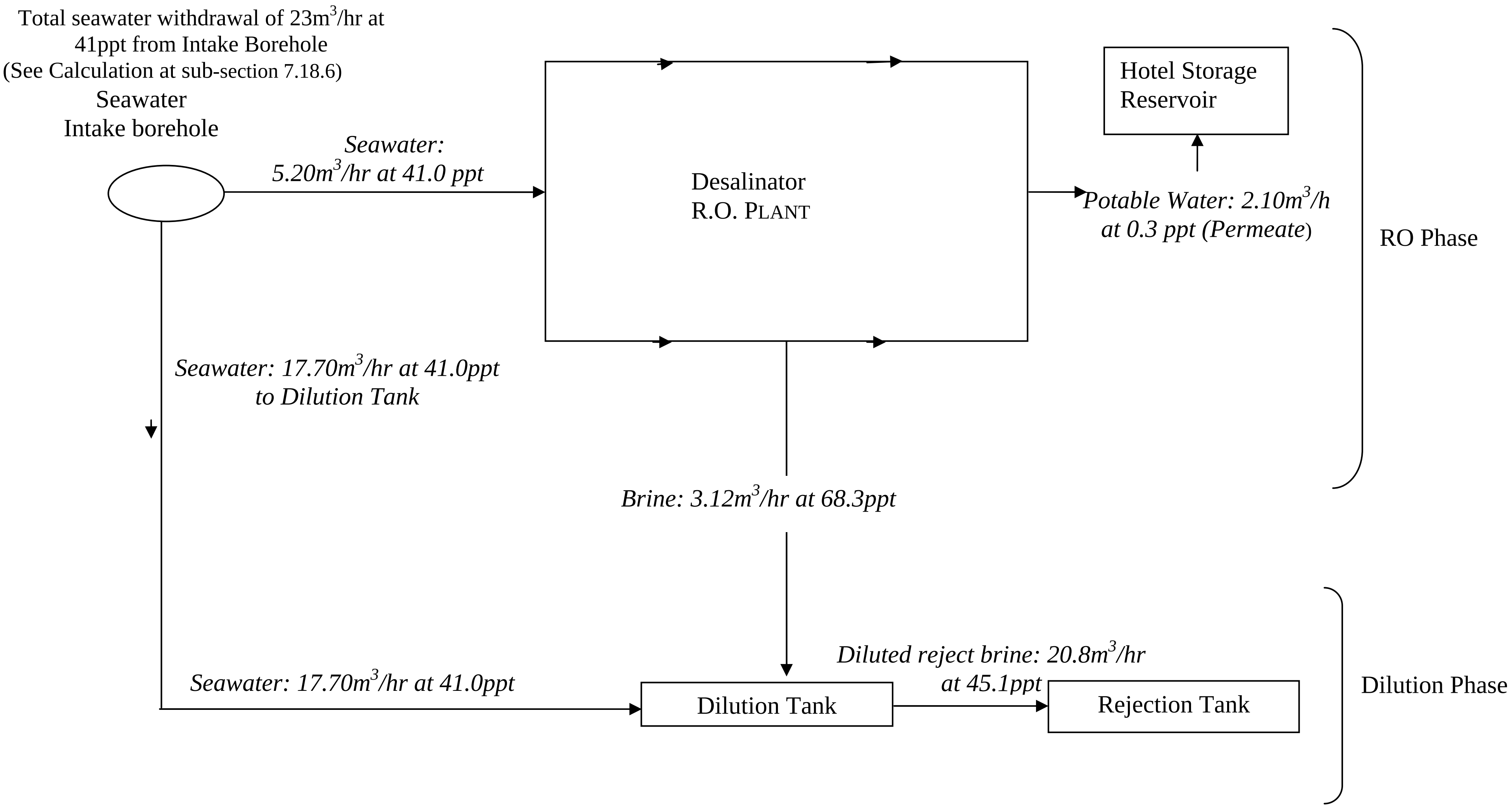

Figure 7-3: Entire Desalination Process Mass Balance Diagram

7.18.3 Mass Balance Calculation

$$5.21 m^3/hr \times 41 ppt = 2.10 m^3/hr \times 0.3 ppt + 3.12 m^3/hr \times S_2 (ppt)$$

$$213.6 = 0.63 + 3.12 S_2$$

$$S_2 = 68.3 \text{ ppt i.e. } 68,300 ppm$$

Hence from above calculation, it can be seen that the brine salinity will be 68, 300 ppm.

7.18.4 Function of Brine Dilution Tank

Prior to disposal of brine into the rejection well, the brine of salinity of level 68, 300ppm coming as effluent from the desalination plant at a rate of 3.12m^3/hr will be diluted in the dilution tank with seawater of salinity level 41, 000ppm being pumped from the beach intake borehole.

The dilution tank has 2 entry points:

- Seawater from beach seawater tank
- Brine from RO desalinator and backwash water from sand-filter

If the brine at a concentration of 68, 300ppm is discharged into the lagoon without any upstream induced dilution treatment, it will adversely affect the marine ecosystem i.e. the marine flora and fauna. It is therefore imperative that the salinity of the brine should be reduced to an acceptable level (not exceeding 45,000ppm) prior to discharge into the lagoon. This will be carried out by incorporating a dilution tank into the design of the desalination plant system.

The purpose of the brine dilution tank is to re-dilute the brine by-product of the RO desalinator to within 10% of the ambient salinity of the seawater – which will enable its discharge into the lagoon without impairing the water quality.

The dilution tank will be made of fibre-glass of thickness 10mm. The dilution tank arrangement showing the in-coming pipes, the out-flow pipe and the purge outlet is shown in the drawing enclosed at Annex 7B at the end of Section 7.

7.18.5 Computation of Required Flow Rate from Beach Intake Borehole for Brine Dilution

- Pumping rate of seawater for desalination 5.21m^3/hr
- Rate of production of desalinated water (40% efficiency) 2.10m^3/hr
- Hence rate of production of brine 3.12m^3/hr
- Salinity of feed seawater 41,000ppm
- Salinity of outflow from dilution tank 45, 100ppm
- Salinity of brine from desalinator 68, 300ppm

Assume pumping rate from Intake Well (IW) for dilution to be Vm^3/hr

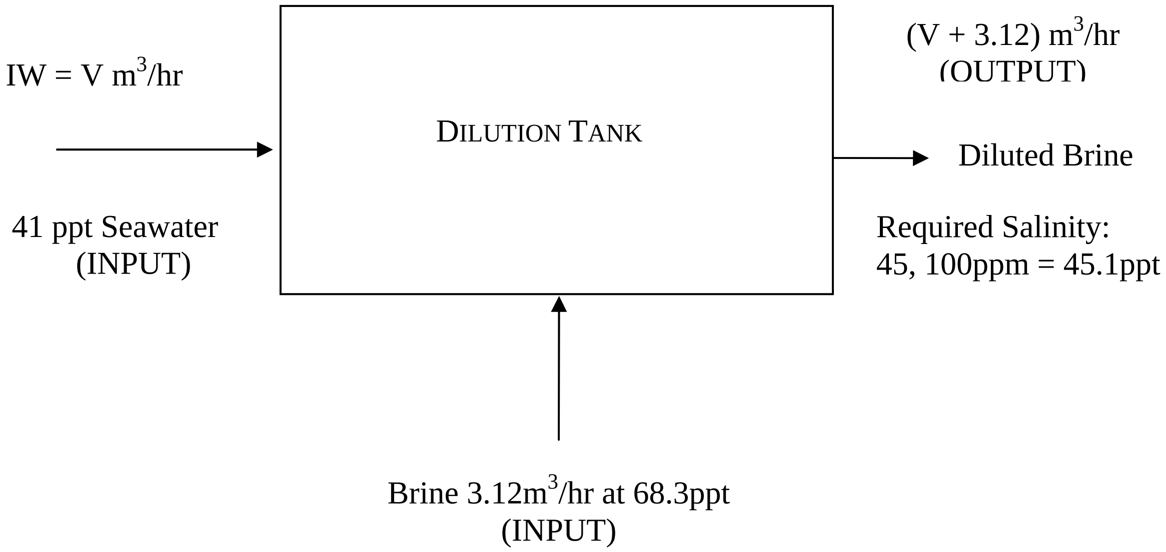

Figure 7-4: Computation of Required Flowrate from Beach Intake Borehole for Brine Dilution

7.18.6 Mass Balance Calculation

(Vm^3/hr x 41ppt) + (3.12m^3/hr x 68.3pt)	=	(V + 3.12)m^3/hr x 45.1ppt
41V + 213.10	=	45.1V + 140.71
72.39	=	4.1V
17.7m^3/hr say 18m^3/hr	=	V

Hence from above calculation, it can be seen that the required flow rate from the beach intake borehole for brine dilution will be 17.7m^3/hr.

Hence total pumping capacity of borehole pump will be (17.7 + 5.2) = 22.9 say 23.0m^3/hr

7.18.7 Brine Dilution Tank

Prior to disposal of brine into the reject tank, the brine of salinity level 68, 300ppm coming from the desalination plant at a rate of 3.12m^3/hour will be diluted in the dilution tank with seawater of nominal salinity level 41, 000ppm being pumped from the intake beach borehole at a rate of 23.0m^3/hour to the sea water tank and from the seawater tank to the dilution tank at a rate of 17.7m^3/hour.

Within the dilution tank, receiving 17.7m^3/hour of seawater at 41, 000ppm from the seawater tank, the brine will be pre-diluted with the seawater to reach a salinity of ±45, 100ppm before being injected into the reject tank at an average rate of 20.8m^3/hour.

The dilution tank will be an underground tank designed to induce optimum mixing of the concentrated brine with seawater of ambient salinity to produce the diluted effluent.

It will be designed for a 20-minute retention period. Thus, allowing for a retention time of 20 minutes for optional mixing to achieve a uniform concentration prior to discharge to the reject tank, the dilution tank will have a capacity of about $7m^{3.}$

A typical design and details of the dilution tank are reproduced on the drawing enclosed at Annex 7B at the end of Section 7.

7.19 BRINE DISPOSAL SITE

After dilution and return of salinity to a level of ±45, 100ppm, the diluted brine will be discharged/injected into the reject tank situated at a minimum of 10metres (referring to Option 1) from the High Water Mark as shown on the Massing Plan showing Desalination Plant Components enclosed at Annex 7A at the end of Section 7.

At this preliminary stage, 2No options have been selected for the sitting of the reject tank, as shown on the drawing enclosed at Annex 7A at the end of this section, as described below:

- Option 1: At the mouth of the existing drain at about 23metres from HWM
- Option 2: Within the beach area, at about 10metres from HWM

N.B: Please note that for either option, the reject tank will be completely below ground and will therefore not be visible at surface. It will therefore not impact on beach occupation, on the aesthetic value of the beach and will not cause any obstruction to people walking along the beach.

The reject tank, as shown on the plan, is situated at a minimum of 76metres (referring to Option 1) from the raw water intake borehole so that the radius of influence of the intake borehole does not interfere with that of the reject tank.

7.20 BRINE REJECT TANK

The brine after having been diluted to a salinity level of $\pm$ 45, 100ppm will be rejected from the dilution tank at a rate of approximately $20.8m^3$/hour pumped and made to discharge to the reject tank which is 2m deep located at, a minimum of 10m for Option 1 and 23m for Option 2, from the HWM (Refer to site plan). Alternatively, the connection piping can be made to flow under gravity depending on the topographical slope available at the site and within the system. This will be decided at the design and installation stage by the Contractor.

The proposed method of disposal of the diluted brine by-product of the desalination plant process will ensure a controlled and/or constant release of the diluted brine effluent to the sandy soil through which it will percolate before reaching the lagoon.

Drawing giving details about the brine reject tank is enclosed at Annex 7D at the end of Section 7.

7.21 WASTE STREAM FROM DESALINATION PLANT

The proposed desalination facility will produce 4 waste streams as shown in Figure 7-3 below:

(a) Effluent water from the sand coarse and fine filtration process

(b) Backwash water from the sand filtration membrane cleaning process

(c) By-product water from the reverse osmosis process (brine solution)

(d) Spent membrane cleaning solution (MCS)

7.21.1 Volume of Brine

It is estimated that at full capacity, the brine effluent will be of the order of 3.12m^3/hour average arising out of the daily activities of the hotel set up, as calculated below:

- Seawater pumped from beach intake borehole for desalination process: 5.21m^3/hour
- Daily production of desalinated water: 50m^3/day i.e. 2.10m^3/hr
- Volume of brine produced hourly: 3.12m^3/hour

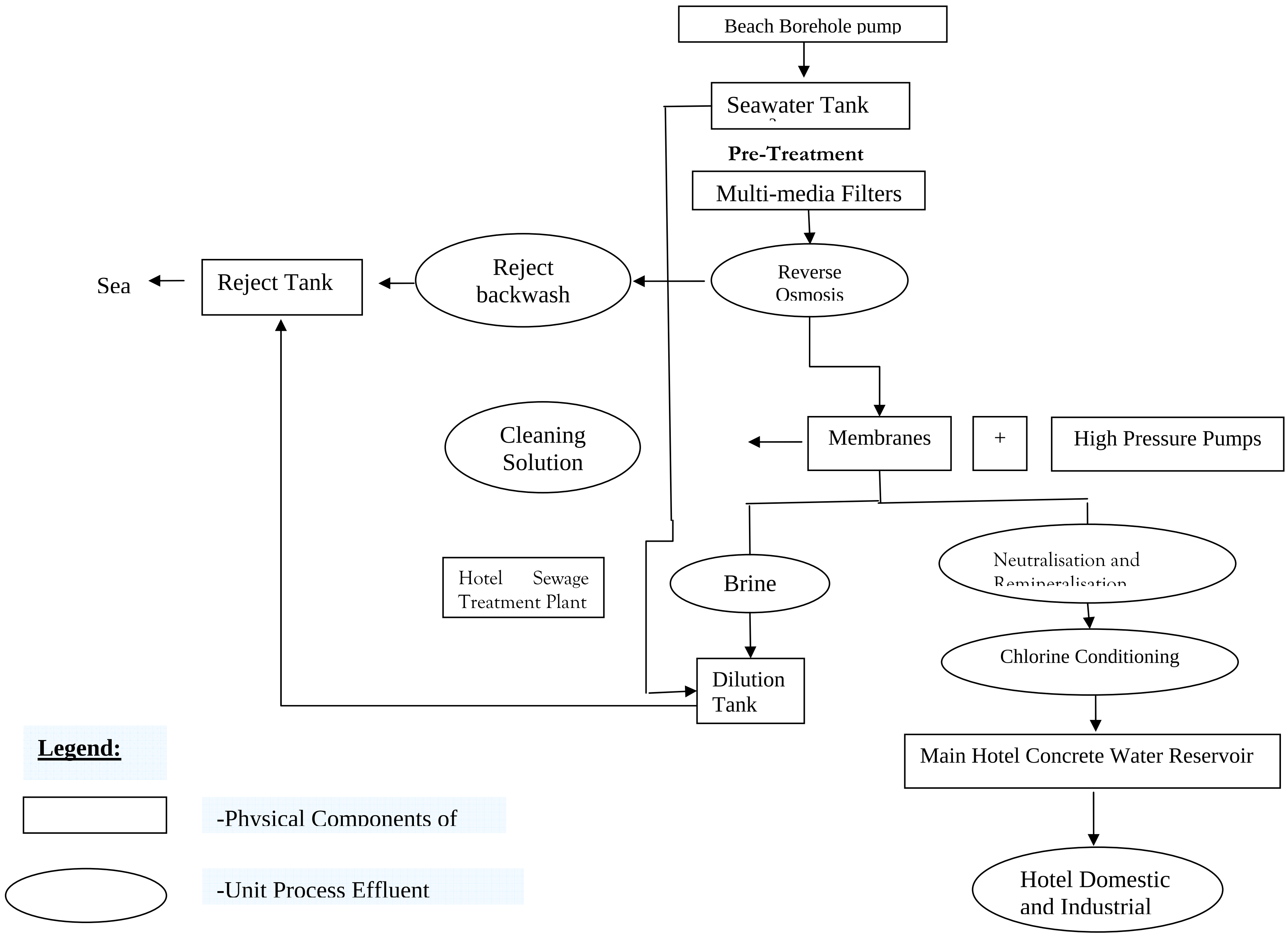

Figure 7-5: Detailed Flowchart of Proposed Seawater Desalination Facility

7.22 SOLID WASTES

As mentioned at sub-section 7.10, seawater pumped from the beach intake borehole will be pre-filtered through the geo-textile cloth provided around the 200mm PVC lining in the intake borehole; consequently the majority of solid particles will be stopped at the borehole level while only fine silt or sludge particles are expected to reach the multimedia filters.

Backwashing to clean the sand filters will then be done for not more that 10 minutes per each day of operation. The backwash water will afterwards be discharged into a lifting station in the vicinity of the plant room from which it will be transferred to the piping arrangement downstream of the desalinator plant room, which discharges to the dilution tank and eventually to the reject well and finally back to the lagoon. This backwash water will contain essentially fine sand whose origin was the seawater itself. Hence they can be rejected in the sea via the reject wells without any ecological risks.

7.23 DOCUMENTATION, TESTING AND COMMISIONING

All the technical documentation including installation drawings and wiring diagrams will be provided by the plant supplier.

The desalination equipment skid will be delivered entirely assembled, ready to operate. For shipping purposes the desalinator equipment skid will be fitted with silent-blocks. The supplier will be responsible for the final testing and commissioning of the entire desalination plant.

7.24 SUMMARY OF TECHNICAL FEATURES

The technical features of the desalination plant are summarized as below:

Feeding seawater temperature..	25°C
Feeding seawater salinity..	41,000ppm
Feeding seawater pH..	8.2
Feeding seawater Total Dissolved Solids (TDS)......................................	41, 000mg/L
Borehole pumping capacity...	23m^3/hour
Hourly production of desalinated water..	2.10m^3/hour
Daily production of desalinated water...	50m^3/day
Expected salinity of desalinated water..	300ppm
Expected TDS of desalinated water..	273mg/L
Rate of brine effluent discharge..	3.12m^3/hour
Power required for the unit..	220V
Expected salinity level of final effluent	±45100ppm