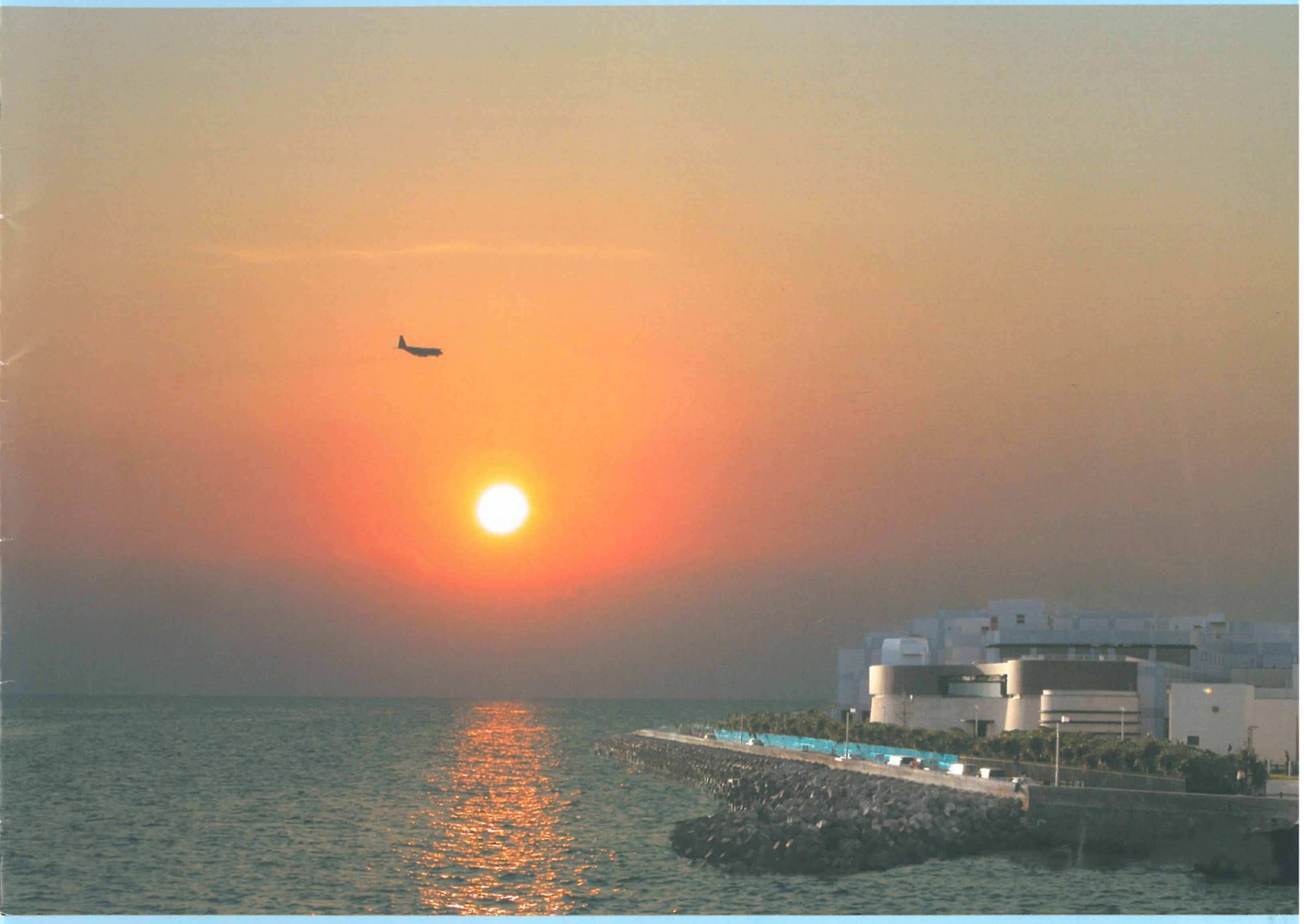
Seawater Desalination Plant

Abundant Water From The Beautiful Ocean



Enterprise Bureau
Okinawa Prefecture

■Need for Desalination Facilities in Okinawa

The water demand on mainland Okinawa has been increasing due to rapid population growth, economic development, the climbing number of tourists, and so on. The daily average water consumption in Okinawa was about 200,000m³/day in 1972, and reached approximately 420,000m³/day in 2003, when water demand became twice as much as it was 32 years ago. The water demand in Okinawa is expected to increase in the future.

In order to meet the ever-increasing demand for water in Okinawa, the governments of Japan and Okinawa Prefecture have implemented countermeasures, including the development of new dams and water resources (rivers) in the west coast of Okinawa to provide needed water supplies. However, demand still exceeds supply.

Water rationing has occurred repeatedly in Okinawa. Since Okinawa was returned to Japanese administration in 1972, there has been water rationing in 14 of the past years. The prolonged drought in 1981 and 1982 resulted in 326 days of water rationing. The most recent water rationing was observed for 64 days from June to September in 1991 when the rainy season brought little rain. In worse cases, the water supply was shut off for 24 hours at a time during this period.

Based on the increasing water demand and limited water sources, Okinawa is anticipated to face difficulties in meeting demand for water based solely on the development of dams and rivers on Okinawa. Therefore, the Enterprise Bureau of Okinawa Prefecture has decided to promote the desalination project.

It has been a long-cherished dream for the people of Okinawa Prefecture to establish a necessary fresh water production method that functions regardless of the weather condition, using the clear and clean seawater surrounding the islands of Okinawa. The construction of a desalination facility on mainland Okinawa is expected to ease Okinawa's water shortage problem to a large extent.

Outline of Seawater Desalination Facility

1. Outline of Seawater Desalination Facility

- Location: Chatan-cho, Okinawa Prefecture
- Land Area: Approximately 12,000m²
- Building Area: Approximately 9,000m²(Floor Area:Approx. 17,600m²)
- Structure: RC & PC Structure (underground and 4 story building)
- Water Production Capacity: 40,000m³/ Day
- Desalination Method: Reverse Osmosis Method (RO Method)
- Recovery Rate: Approximately 40%
- Membrane Used: Aromatic Polyamide Compound Membrane, Spiral Type (Reverse osmosis membrane)
- Intake System: Seabed Water Intake Pipeline System
- Discharge System: Rapid Water Dispersion Discharge
- Total Construction Cost: Approximately 34.7 billion yen (85% is government subsidy)
- Main water supply zones: Chatan, Okinawa City, Kitanakagusuku, Nakagusuku, Ginowan, Urasoe, Naha

Chronology of Project

Year	Description
1977	Water Re-Use Promotion Center (foundation) was consigned by Ministry of Health & Welfare to conduct "Mainland Okinawa Desalination Project: Survey(I)."
1978	Ministry of Health & Welfare conducted "Mainland Okinawa Desalination Project: Survey (Integrated Water Source Project)".
1978	Japan Water Works Association was consigned by the Ministry of Health & Welfare to conduct "Mainland Okinawa Desalination Project: Survey (Facility Planning)"
1980	Under "Mainland Okinawa Desalination Plant Basic Planning", reverse osmosis plant was reviewed by Water Re-Use Promotion Center who was consigned by the Ministry of Health and Welfare.
1988	The 5th change order request of the entire project was approved and reverse osmosis technique was introduced into the suggested desalination plant construction.
1989	"Feasibility Survey on Chatan Desalination Plant Construction" was conducted and basic planning was made.
1990	Desalination Facility Construction Committee consisting of scholars and experienced experts was established.
1990	Preliminary survey No.1 to construct a desalination plant was conducted; facility adjustment planning and environmental assessment surveys (fall & winter seasons) were made.
1991	Preliminary survey No.2 to construct a desalination plant was conducted; basic planning and environmental assessment surveys (spring & summer seasons) were made.
1992	Water Works Law Enforcement Ordinance and Okinawa Promotion and Development Special Treatment Law Enforcement Ordinance were partially amended, a desalination facility was regarded as water resource facility, and also a government subsidy was approved for the desalination facility construction.
1992	Construction Design of Okinawa Prefectural Desalination Plant was prepared.
1993	Construction of the building of Okinawa Prefectural Desalination Plant was started.
1995	Partial operation of the desalination plant was started. (10,000m³/day)
1996	Operation of the desalination was increased. (25,000m³/day)
1997	Whole desalination plant was completed. (40,000m³/day)

Merits of Desalination Method

(1) Potable water will be obtained from seawater, an unlimited natural resource, which is unaffected by season or weather conditions.
(2) The construction of a desalination facility mainly involves plant construction. Thus the construction period is shorter than dam construction.
(3) A desalination plant is relatively compact, requiring a relatively small land area.
(4) Since the plant can be established near a consumption area, a shorter distance of the water pipes are required.

Probable Effects of Desalination Facility on Nearby Sea Environment

Okinawa Prefecture Desalination Plant produces 40,000m³ of fresh water per day, which requires 100,000m³ of seawater, out of which approximately 60,000m³ of concentrated seawater is sent back to the ocean.

Normally, seawater contains approximately 3.5% salt, but the discharged water from the desalination plant may contain as much as 5.8% salt.

Special care is taken to ensure that the water discharged from the desalination plant is well mixed with the surrounding seawater. The discharged water will be released through the outlet nozzle in a manner to provide an efficient mixing with the nearby seawater. Studies using simulation models showed that salt concentration in the discharged water goes down from 5.8% to 3.6% when the water reaches 8 meters away and 3.54% when it reaches 12 meters away from the outlet nozzle end.

Furthermore,the Black Current, which flows almost parallel to the coast line of mainland Okinawa, minimizes an influence by the desalination plant. The study concluded that marine life in the nearby sea will not be affected to any considerable extent by the discharged water from he desalination plant.

Desalination Cost at the Plant

The operation cost at the Okinawa Prefectural Desalination Plant for each 1m³ of water produced is approximately ¥170 based on ① total construction cost of ¥34.7 billion, ② water production capacity of 40,000m³/ day, ③ the rate of operation of 90%, ④ recovery rate of 40%, ⑤ calculation period of 20years, and ⑥ government subsidy ratio of 85%.
Electric power is the largest operational expense and accounts for 33% of the total cost. Others include: 28% for capital expense, 12% for chemicals and 11% for semipermeable membranes respectively.

The water production cost of seawater desalination plants is higher than utilizing river or dam reservoir water.

Mixing fresh water produced at the desalination plant with inland water-treated water

Fresh water produced at a desalination plant is soft and corrosive, and it often causes rust-colored water inside pipes and water facilities. So post-treatment processing,in which a hardness agent such as calcium is added to the fresh water, is usually necessary to prevent corrosion. But next to the desalination plant we have the Chatan water purification plant which produces potable water from inland water. The water from this plant is rather hard. By mixing these two plants' water, we can get delicious water with moderate hardness and alkalinity. So we don't think post-treatment of the desalinated water is necessary.

Reverse Osmosis Membrane Units

Water quality comparison

~ Comparison of sea water quality and desalinated water quality as of 2003 ~

	Sea Water (RO Feedwater)	Desalinated Water
Evaporation Residue (mg/ℓ)	36,000	276
Chloride Ion (mg/ℓ)	19,400	158
Sulfate Ion (mg/ℓ)	2,270	3.0
Sodium (mg/ℓ)	11,500	105
Total Hardness (mg/ℓ)	6,353	7.5
Alkalinity (mg/ℓ)	83	5
Conductivity (µs/cm)	51,300	534

Desalination Techniques

Seawater contains approximately 96.5% water and approximately 3.5% salt.
Desalination technique is a method of producing fresh water by removing salt from seawater. The major desalination techniques in extensive and practical use are: Evaporation Method, Reverse Osmosis Technique, and Electrodialysis.

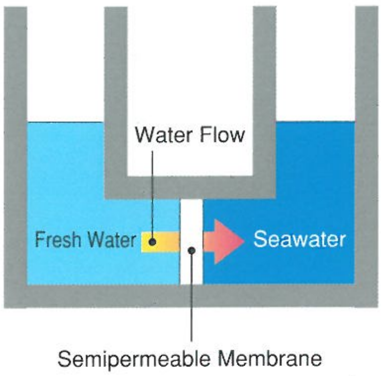
Okinawa Prefecture decided to employ the Reverse Osmosis Method for the desalination plant. The Plant has drawn people's attention, enjoying popularity in and outside of Japan due to its energy saving features.

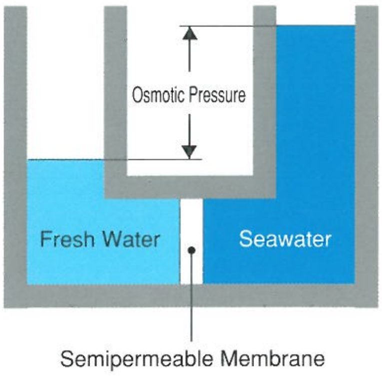
The basic theory of fresh water production from seawater is derived from a semipermeable membrane which allows the passage of water but not salt. If a semipermeable membrane is placed between fresh water and seawater in a tank, fresh water moves toward seawater through the membrane. This phenomenon is called, "osmosis" and fresh water stops moving when it creates a specific pressure difference between fresh water and seawater. This difference is called osmotic pressure.

If any pressure greater than osmotic pressure is added to seawater, water moves from seawater to fresh water. This phenomenon is called, "reverse osmosis." Reverse Osmosis Method is based on the reverse theory of the adove mentioned osmosis.

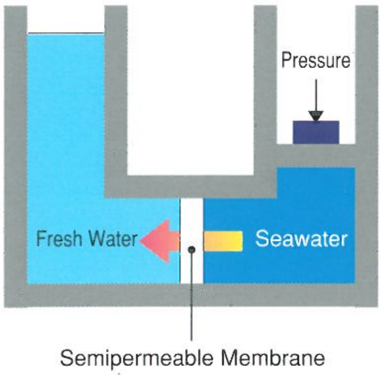
Osmotic Pressure Story

Osmosis





Reverse Osmosis



If cellophane paper is placed between fresh water and seawater in a tank as shown above, fresh water moves toward seawater so that the salt concentrantion of both liquids become equal. This phenomenon is called "osmosis." Then, the water level on the seawater side rises and reaches a specific height to maintain a balance with the fresh water. The difference between the two water levels is called "osmotic pressure." The osmotic pressure of seawater which contains 3.5% salt is approximately 2.5MPa.

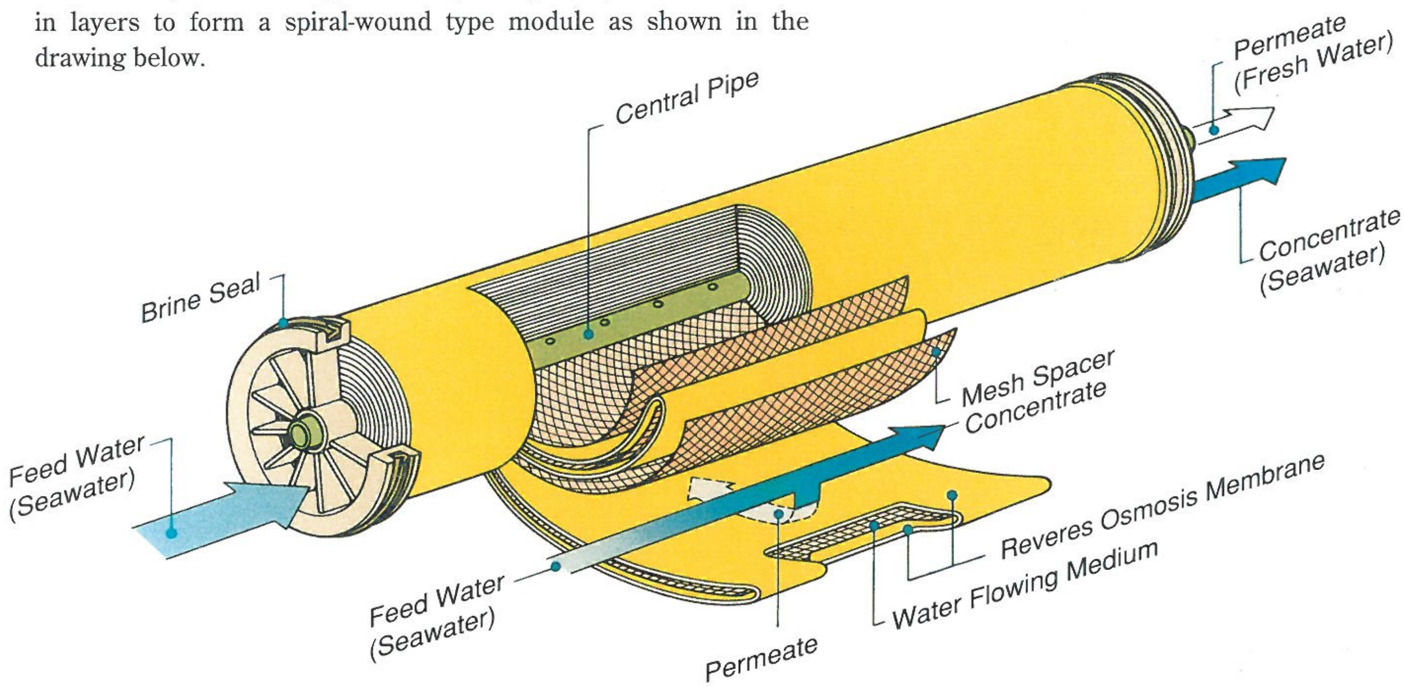
On the contrary, if a pressure that is greater than osmotic pressure is added to seawater using the same model, water solely is pushed through the membrane toward the fresh water from the seawater. This phenomenon is called "reverse osmosis." This is what happens inside the reverse osmosis modules where desalination of seawater takes place based on the theory of reverse osmosis.

■ Reverse Osmosis Membrane Unit

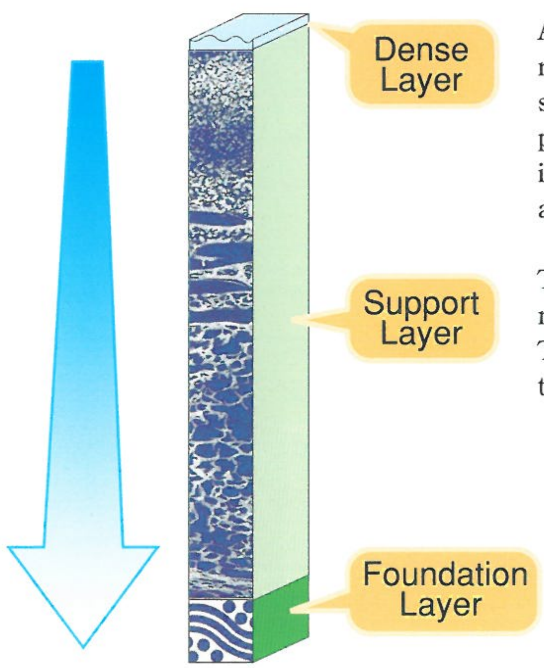
The reverse osmosis unit is installed as the core of the desalination facility, and it enables production of fresh water from seawater. A reverse osmosis membrane consists of reverse osmosis membrane modules with six reverse osmosis membrane elements per module. One unit consists of 63 reverse osmosis membrane modules and can produce approximately 5,000 m^3 of fresh water per day.

■ Structure of Reverse Osmosis Membrane Element

A reverse osmosis membrane element consists of reverse osmosis membranes, water flowing mediums, and spacers, which are rolled in layers to form a spiral-wound type module as shown in the drawing below.



■ Structure of Reverse Osmosis Membrane



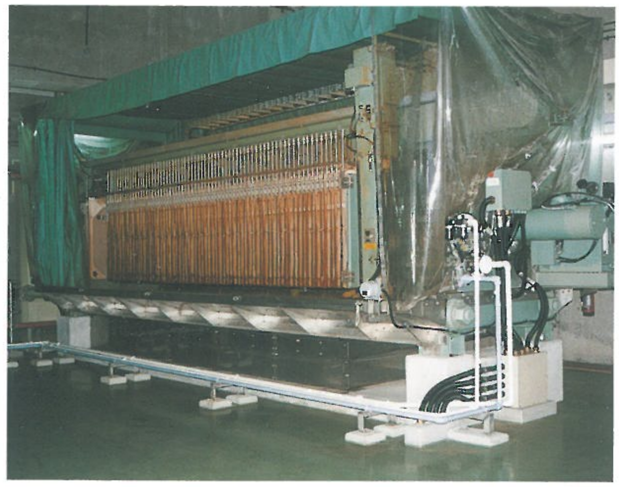
As indicated in the section drawing, a reverse osmosis membrane is a synthetic composite membrane made of polyamide compounds that are arranged in layers of semipermeable membranes as foundation, support, and dense layers.

This type of membrane can remove more than 99% of salt from seawater. Thus one-time-desalination is sufficient to produce fresh water.

Sand Settling Basin

Central Control Room

Chemical Feeding Room



Dehydrator Room

Intake Tower

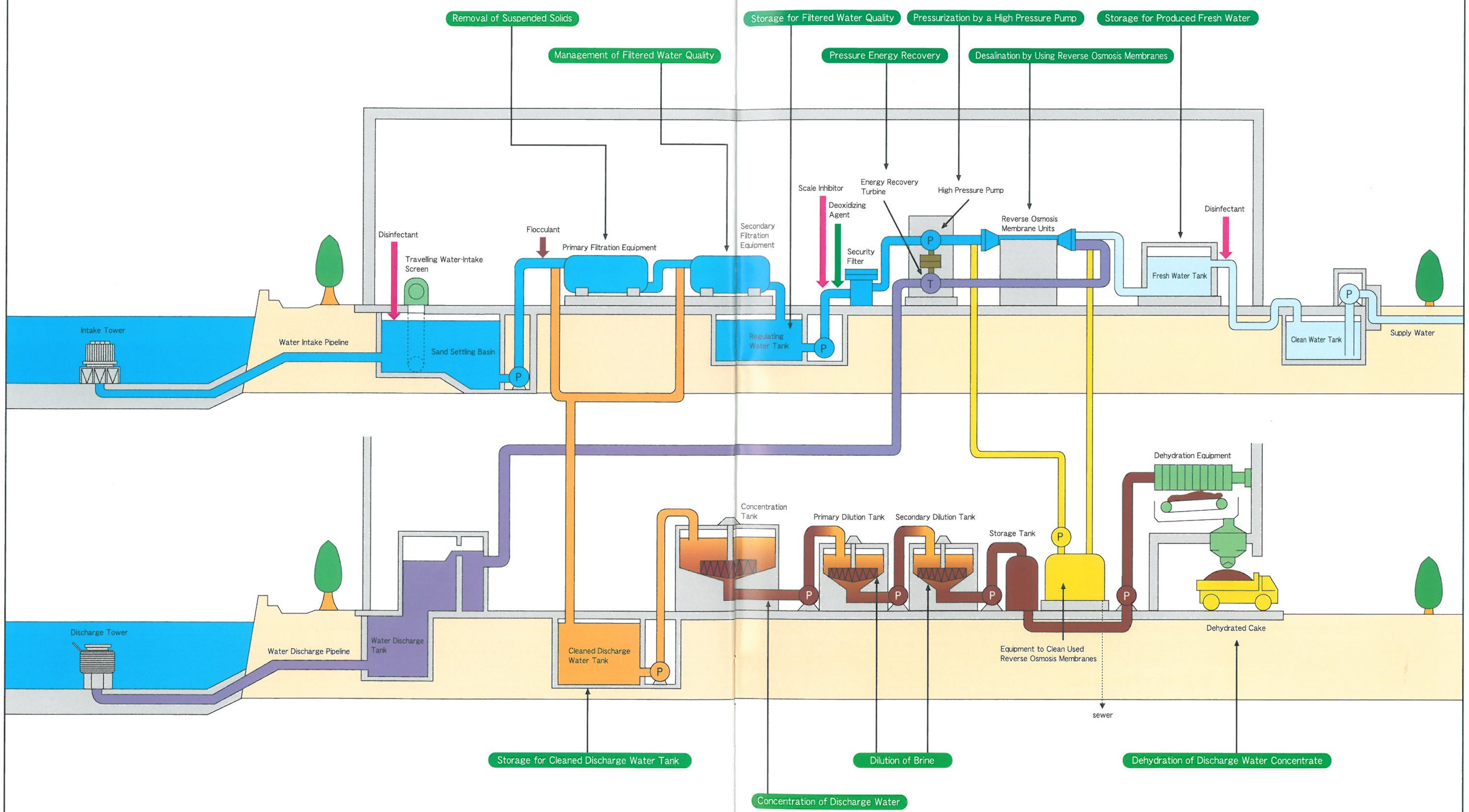
Discharge Tower

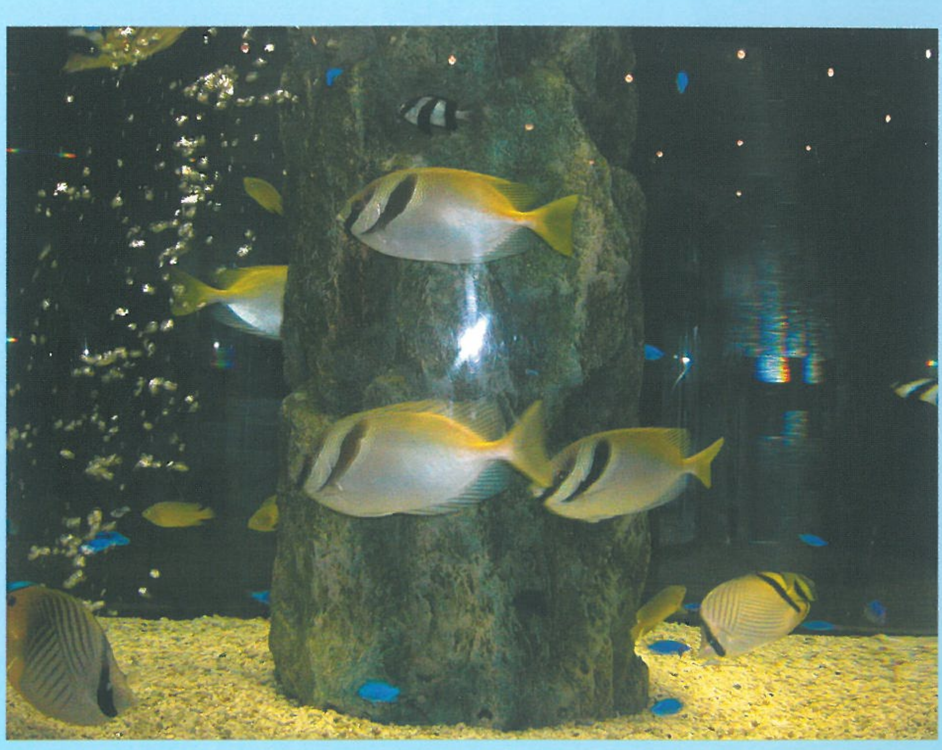
Outline of the Desalination Plant Facility

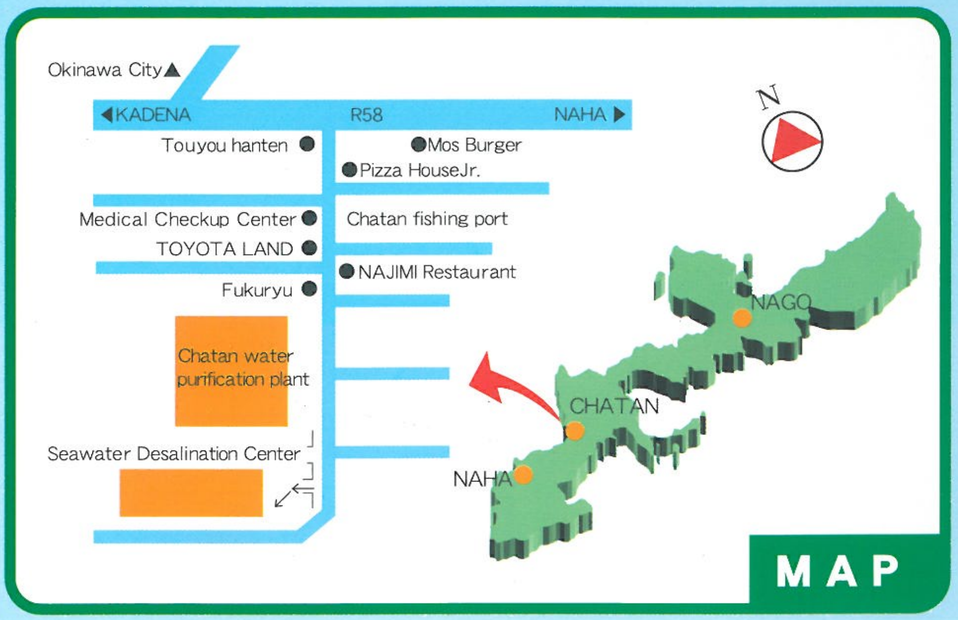
(40,000 m³/day)

Facility		Remarks
1) Raw Water Facilities	Intake Pipeline	ϕ 1,200mm × 220m (an Offshore Intake Pipeline located on seafloor)
	Intake Pits (Sand Settling Basin)	W 4.5m × L 10.5m × H 5.3m(effective height) × 2 pits (Travelling Water-Intake Screen)
	Intake Pumps	Q = 19.4 m³/min × H 48m × 5 pumps (one pump is for reserve)
2) Ajustment Facilities	Filtration Equipment	Direct Coagulation and Filtration (Direct Two Stage Filtration) Primary Filtration Equipment 32 m²/unit × 13 units (one unit is for reserve) Secondary Filtration Equipment 33.6 m²/unit × 9 units (one unit is for reserve)
	Regulating Tanks	V = 1,000 m³ × 2 tanks
3) Revers Osmosis Facilities	Feeder Pumps	Q = 8.94 m³/min × H 45m × 9 pumps (one pump is for reserve)
	Security Filter	Q = 537 m³/hour × 9 units (one unit is for reserve)
	High Pressure Pumps	Q = 8.91 m³/min × H 650m × 8 pumps (no reserve pumps)
	Membrane Assembly	5,131 m³/day × 8 units (no reserve units) (6 elements /vessel × 63 vessels/unit × 8 units = 3,024elements)
	Attached Equipment	Chemical Cleaning Equipment, Energy Recovery Turbine
	Facility Supply Pumps	Q = 4 m³/min × H 40m × 3 units (one pump is for reserve)
	Fresh Water Tanks	V = 200 m³ × 2 tanks
4) Discharge Facilities	Discharge Pipeline	ϕ 700mm × 230m (an Offshore Discharge Pipeline located on seafloor)
	Discharge Tank	V = 210 m³ × 1 tank
(Wastewater Treatment Facilities)	Cleaned Discharge Water Tanks	V = 330 m³ × 2 tanks
	Discharge Pumps	Q = 1.63 m³/min × H 20m × 4 pumps (one pump is for reserve)
(Dehydration Facilities)	Concentration Tanks	Separation Area = 94 m², V = 380 m³/3 tanks
	Dilution Tanks	Separation Area = 64 m², V = 260 m³/2 tanks
	Dehydrators	Operation :4～5hours/day Area = 100 m² × 2 units Dehydrated Cake : about 2.5 m³/day (moisture Content : less than 65%)
5) Chemical Feeding Facilities		Ferric Chloride Feeding Facility Sodium Hypochlorite Feeding Facility Sulfuric Acid Feeding Facility Sodium Bisulfite Feeding Facility Sodium Hydroxide Feeding Facility
6) Power Receiving Equipment		Lead-in Equipment, Power Receiving Equipment, Transformer, Distribution Equipment
7) Power and Instrumentation Equipment		Power Equipment, Emergency Generator, Controlled Source, Supervisory and Control Equipment, Instrumetation Equipment

Flow Chart of Desalination Process







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