FEASIBILITY STUDY REPORT
ON
SEA-WATER DESALINATION PROJECT
IN
THE REPUBLIC OF COLOMBIA

FEBRUARY 1980

JAPAN INTERNATIONAL COOPERATION AGENCY

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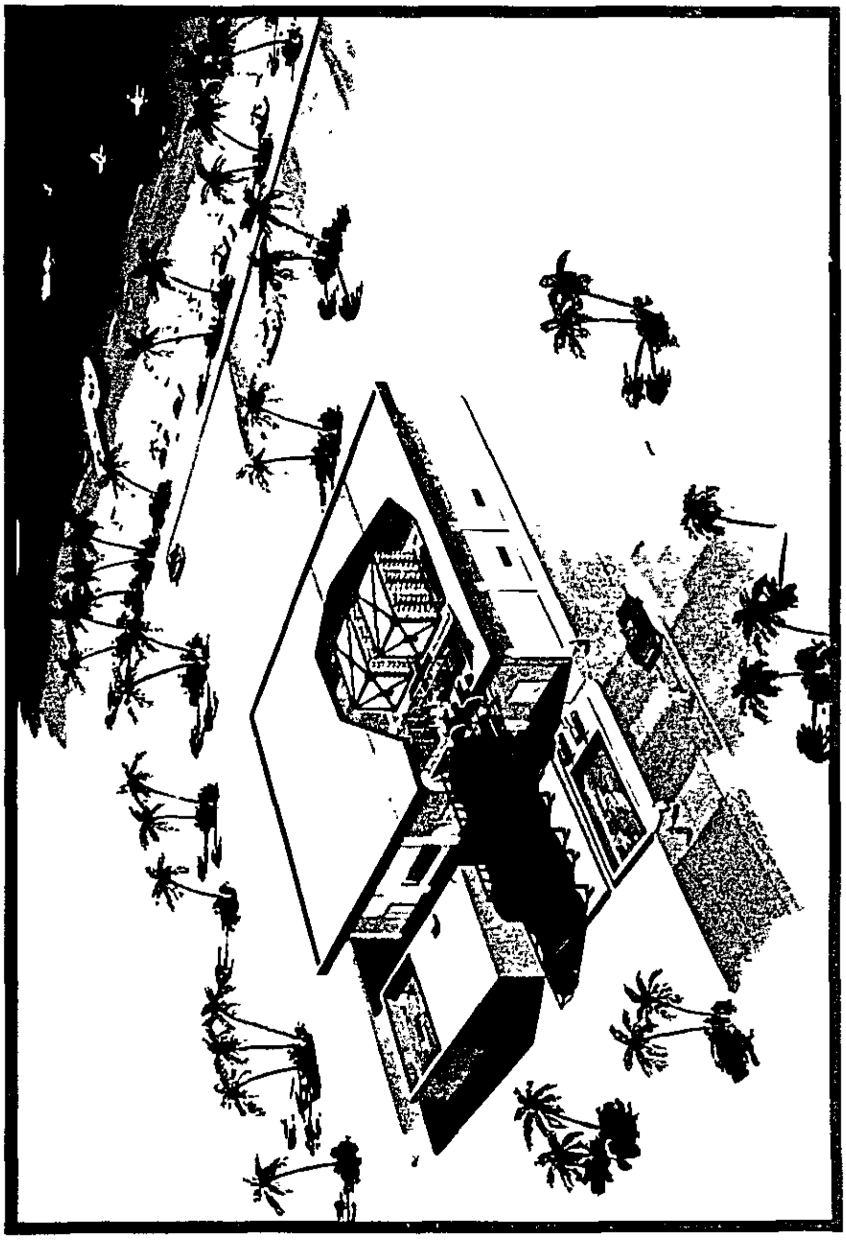


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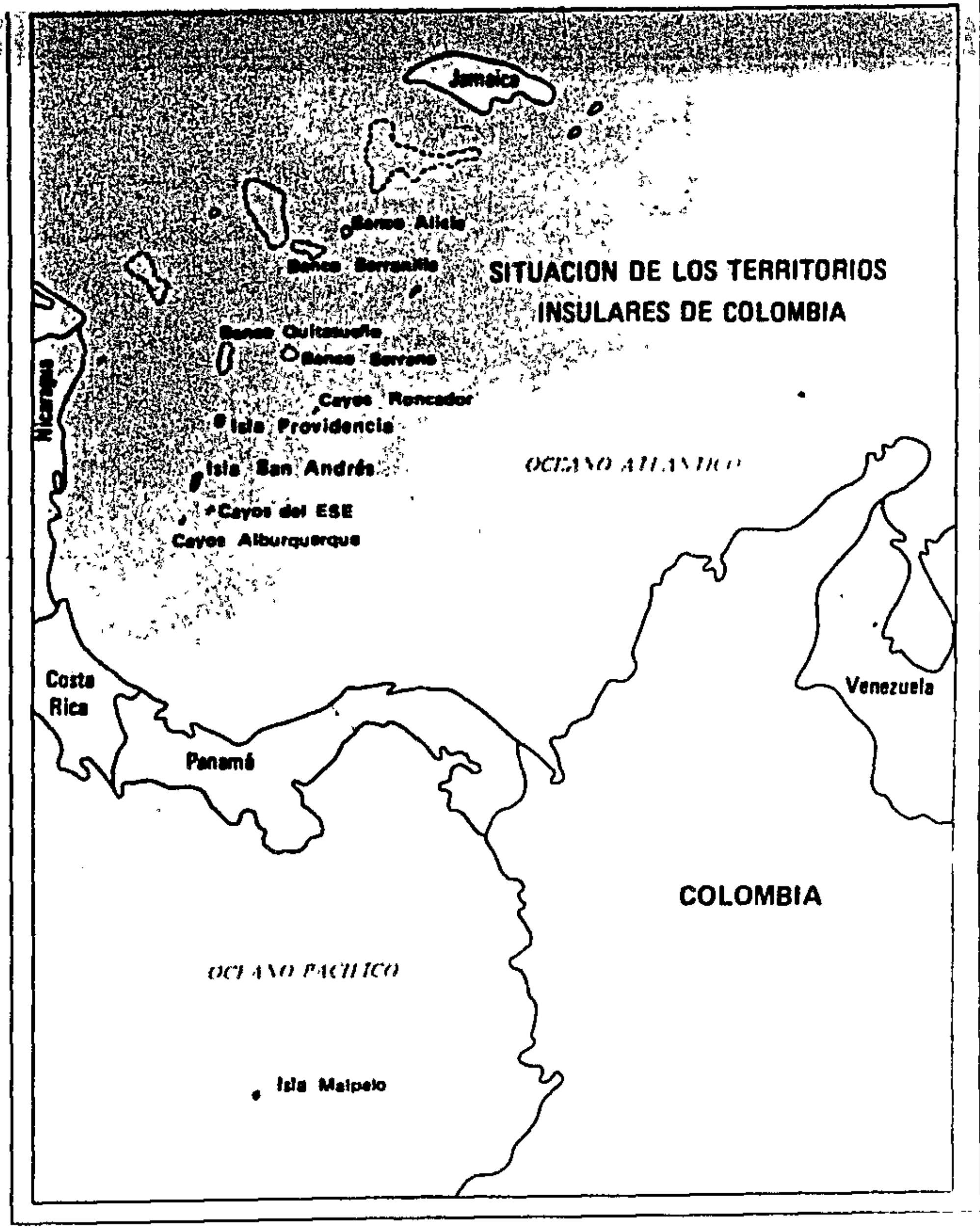
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PREFACE

In response to the request of the Government of the Republic of Colombia, the Government of Japan decided to conduct a feasibility study on the water desalination project in San Andres and Providencia areas on the Caribbean Sea, and entrusted the study to the Japan International Cooperation Agency (JICA).

The JICA sent to Colombia a feasibility study team headed by Mr. Naoto Hashimoto (Water Re-Use Promotion Center) for 27 days from July 3, 1982.

The team exchanged views with the officials concerned of the Government of Colombia, and conducted on-the-spot investigations of the area and data collection. After the team returned to Japan, further studies and analyses were made based on results of the survey, and the present report has been prepared.

I hope this report will serve for the development of the project and contribute to the promotion of friendly and cooperative relations between Japan and the Republic of Colombia.

I wish to express may deep appreciation to the officials concerned to the Government of the Republic of Colombia for their close cooperation extended to the team

February 1983

Keisuke Arita
President
Japan International Cooperation Agency

Introduction

1. Survey background

In October 1981, the government of the Republic of Colombia requested the Japanese government to provide technical cooperation in conducting a feasibility study on a seawater deasalination plant project on San Andres, an island under the direct jurisdiction of Intendencia de San Andres y Providencia. This request was made as the result of a meeting held between the Japanese seawater desalination technical survey team despatched in June, 1981 and the government of the Republic of Colombia.

In response to this request, the Japan International Cooperation Agency (JICA) sent a preliminary survey mission to the Republic of Colombia in February, 1982, in order to determine the basic conditions, such as the scope of the feasibility study and so forth.

For the purpose of studying the feasibility of establishing a seawater desalination plant on San Andres Island and the various related matters under the agreement made between the preliminary survey mission and the government of the Republic of Colombia, a team, consisting of Mr. Naoto Hashimoto (leader) and five other members, was formed with the title of "Study Team for Seawater Desalination Plant Project in the Republic of Colombia," and dispatched to the Republic of Colombia for the period from 3 July, 1982 to 29 July, 1982.

Meanwhile, in February 1982, the government of the Republic of Colombia had requested the preliminary survey mission to conduct a rough feasibility study concerning a seawater desalination plant project for Providencia Island as well. In July this year, an agreement was made between a second preliminary survey mission and the said government to study the latter project together with the San Andress project and the scope of work was revised.

Both the islands of San Andres and Providencia in the Republic of Colombia are isolated islands in the Caribbean Sea, neither having surface water as a water source and therefore, depending solely upon groundwater resulting from the infiltration of rain.

The rapidly increasing demand for potable water due to the increased number of tourists, as well as the recent increase in the permanent population, cannot be met by means of the above source alone Hence the installation of seawater desalination plants to alleviate this situation had been raised as a subject for study.

It is assumed that this is the reason underlying the request for technical cooperation made by the government of the Republic of Colombia.

Based on this background, the study team collected various information at the respective sites and, as a result of further work in Japan, has reached the conclusion that the establishment of seawater desalination plants on both the islands of San Andres and Providencia would be feasible around 1985. Means for the materialization of these projects have also been studied. A draft of the final report on the subject was submitted and explained to the government of the Republic of Colombia in December, 1982. For this purpose, the leader and two other members of the survey team was dispatched to the said country.

2. Purpose

The major objectives of the survey consisted of the following two points.

(1) To determine whether or not the seawater desalination plant project to cope with the anticipated future increase in domestic water demand would be feasible from the viewpoint of its effect on the water supply systems for both islands and the profitability of such system by studying and planning it based on the required volume of water supply, selection of optimal sites and the technical aspects of seawater desalination.

(2) Together with the above, economic and technical information would be furnished to the government of the Republic of Colombia for reference in implementing the project. However, the feasibility study for Provincia Island would be of an approximate nature.

3. Formation of study team

The study team was formed as follows:

(1) Site survey

Naoto Hashimoto:	Water Re-USE Promotion Center Team leader
Yasuo Ohtaka:	JGC Corp. (Nikki)
Harutoshi Nagano:	Same
Shintaro Takahashi:	Water Re-Use Promotion Center
Masaaki Awamoto:	Same
Norio Tsuji:	Same

(2) Reporting, presenting and discussion

Naoto Hashimoto:	Water Re-Use Promotion Center
Harutoshi Nagano:	JGC Corp. (Nikki)
Shintaro Takahashi:	Water Re-Use Promotion Center

and explained the purpose and nature of the survey.

Then the team visited the Departamento Nacional de Planeacion, accompanied by the residential staff of the embassy and the JICA office, explained the purpose, nature, procedure, and so forth of the survey to obtain governmental permission thereon and then visited all the agencies and public bodies concerned to collect various information and data.

On San Andres, the team visited both the Intendencia de San Andres y Providencia and the Empresa de Obras Sanitarias de San Andres y Providencia Ltda. (EMPOISLAS), and explained the purpose of the survey. With the cooperation of the staff of EMPOISLAS, a survey was conducted on the conditions of the existing water supply system on San Andres and three candidate sites were inspected. Further, the team conducted the same sort of surveys on Providencia as well. The Interim report contair ing the results of the above field survey and outline of the findings, which was submitted to the government of the Republic of Colombia prior to the return of the survey team to Japan, is attached to this final report.

Step	Date	Day	Stayed at	Time	Place Visited or Surveyed
1	July 3rd	Sat.	Travell-ing	10:00 A.M.	Departure from Tokyo
2	4th	San.	Travell-ing	2:45 P.M.	Arrival at Bogota
3	5th	Mon.	Bogota	9:30 A.M.	Japanese Embassy and JICA - Mr. Nagasaki Hiroshi, Ambassador - Mr. Tateyama Michisuke, Counselor - Mr. Ogasawara Kenichi, 2nd Secretary - Mr. Takahashi Fusakazu, 2nd Secretary - Mr. Ishii Kazuo, Resident Representative, JICA-Bogota
				2:30 P.M.	Department Nacional de Planeacion-DNP - Dra. Nohra Bateman D., Gerente, Division Tecnica de Cooperacion International - Dr. Luis Mario Barrera H., Gerente, Division de Ingenieria Sanitaria - Dra. Ligia Rodriguez, Division Tecnica de Cooperacion
4	6th	Tue.	Bogota	10:30 A.M.	Instituto Colombiano de Hidrologia, Meteorologia y Adecuacion de Tierras - Dr. Eufrasio Bernal Duffo, Subdirector
				2:00 P.M.	Instituto Nacional de Fomento Municipal-INSFOPAL - Dr. Luis Alberto Leal F., Subdirector Técnico
5	7th	Wed.	Bogota	9:00 A.M.	Divisions Maritima y Porturia de la Armada Nacional - Captain Efrain Angel
			Travell-ing	3:45 P.M. 6:35 P.M.	Departure from Bogota Arrival at San Andres
6	8th	Thu.	San Andres	9:00 A.M.	Empresa De Obras Sanitarias De San Andres y Providencia Ltda, - EMPOISLAS - Dr. Carlos Jose Villate S., Engineer - Dr. Rodrigo I. Andrade S., Engineer - Miss Carogeen Watson A., Secretary

Step	Date	Day	Stayed at	Time	Place Visited or Surveyed
7	July 9th	Fri.	San Andres	9:00 A.M.	EMPOISLAS - Dr. Alvaro Forbes J., Manager - Dr. Carlos Jose Villate S. - Dr. Rodrigo I. Andrade S. - Miss Carogeen Watson A.
				4:00 P.M.	Plant Sites - Taller, Plaza de Mercado and Campamento - Dr. Carlos Jose Villate S. - Dr. Marco Quimbay C., Engineer - Miss Carogeen Watson A.
8	10th	Sat.	San Andres	10:00 A.M.	Water Supply Facilities Same Members as 9th
9	11th	Sun.	San Andres		Holiday
10	12th	Mon.	San Andres	9:00 A.M.	EMPOISLAS Same Members as 9th
				2:30 P.M.	Sewage Facilities Same Members as A.M.
11	13th	Tue.	San Andres	9:00 A.M.	EMPOISLAS - Dr. Alvaro Forbes J.
				2:30 P.M.	ELECTROSAN - Dr. Antonio Manuel Stephens, Manager, and other staffs.
12	14th	Wed.	San Andres	9:30 A.M.	Constructors in the Island - Systemas Hidraulicos y Sanitarios, and Pyne Corpus & CIA. Ltda.
				3:00 P.M.	INTENDENCIA - Dra. Berardo Howard N., Secretary - Dr. Guillermo Luna F., Chief of Urban Development Division
				4:00 P.M.	Transporters in the Island - Agencia Maritima and Importaciones Ramirez
13	15th	Thu.	San Andres	Fore-noon	Review of Materials
				2:00 P.M.	EMPOISLAS - Dr. Carlos Jose Villate S. - Miss Carogeen Watson A.

Step	Date	Day	Stayed at	Time	Place Visited or Surveyed
14	July 16th	Fri.	San Andres	Fore-noon	Review of Materials
				3:00 P.M.	EMPOISLAS - Dr. Alvaro Forbes J. - Dr. Carlos Jose Villate S. - Miss Carogeen Watson A.
15	17th	Sat.	Travell-ing	10:00 A.M.	Departure from San Andres
				10:30 A.M.	Arrival at Providencia
			San Andres	Fore-noon	Review of Materials
			Travell-ing	5:50 P.M.	Departure from San Andres
				7:50 P.M.	Arrival at Bogota
16	18th	Sun.	Provi-dencia	9:00 A.M.	Site Survey - Dr. Alvaro Forbes J. - Dr. Carlos Jose Villate S. - Dr. Marco Quimbay C. - Miss Carogeen Watson A. - Dr. Efrain Rojas I., Administrator at Providencia
				4:00 P.M.	ELECTROSAN at Providencia - Dr. Edburn Newball, Manager at Providencia
			Bogota		Holiday
17	19th	Mon.	Provi-dencia	9:00 A.M.	EMPOISLAS at Providencia Same Member as Yesterday
				After-noon	Review of Materials
			Bogota	9:00 A.M.	DNP - Dra. Ligia Rodriguez
				After-noon	Preparing Interim Report
18	20th	Tue.	Travell-ing	11:00 A.M.	Departure from Providencia
				11:30 A.M.	Arrival at San Andres
			San Andres	After-noon	Review of Materials
			Bogota		Preparing Interim Report

Step	Date	Day	Stayed at	Time	Place Visited or Surveyed
19	July 21st	Wed.	San Andres	9:30 A.M.	EMPOISLAS - Dr. Carlos Jose Villate S. - Miss Carogeen Watson A.
			Bogota	10:00 A.M.	DNP - Dra. Nohra Bateman D. - Dra. Ligia Rodrigues
				After-noon	Preparing Interim Report
20	22nd	Thu.	San Andres	10:00 A.M.	EMPOISLAS - Dr. Alvaro Forbes J. - Dr. Carlos Jose Villate S. - Miss Carogeen Watson A.
			Travell-ing	5:50 P.M. 7:50 P.M.	Departure from San Andres Arrival at Bogota
			Bogota		Preparing Interim Report
21	23rd	Fri.	Bogota	Fore-noon	Preparing Interim Report
				2:30 P.M.	DNP - Dra. Nohra Bateman D. - Dr. Luis Mario Barrera H. - Dra. Ligia Rodriguez
22	24th	Sat.	Bogota		Preparing Interim Report
23	25th	Sun.	Bogota		Holiday
24	26th	Mon.	Bogota	11:00 A.M.	DNP - Dra. Nohra Bateman D. - Dr. Luis Mario Barrera H. - Dra. Ligia Rodriguez
				After-noon	Preparation for Home-Coming
25	27th	Tue.	Travell-ing	10:30 A.M.	Departure from Bogota
27	29th	Thu.	Travell-ing	5:15 P.M.	Arrival at Tokyo

VOLUME I

SAN ANDRES ISLAND

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Summary

(Seawater Desalination Plan for San Andres Island)

Summary of proposed project:

1. Name of project:	Seawater desalination plant
2. Production capacity:	3,000 m^3/day
3. Applicable process:	Reverse osmosis process
4. Construction site:	Campamento in San Andres Island
5. Expected date of commercial operation:	At the beginning of 1985
6. Major facility:	
1) Seawater intake unit:	
Method:	3 wells
Intake pumps:	3.2 m^3/min./unit x 3 pumps
2) Pretreatment unit:	Dual media filter x 3 units
3) Reverse osmosis unit:	Cellulose-triacetate hollow fiber module for single stage desalination
4) Product water transfer unit:	Conveying pump of 2.5 m^3/min./unit x 2 units
5) Waste water discharge unit:	Discharge pump x 0.6 m^3/min./unit x 2 units
7. Product water quality:	
Chloride ion (Cl):	250 mg/l or less
Calcium (Ca):	75 mg/l or less
Magesium (Mg):	125 mg/l or less
Total dissolved solids:	500 mg/l or less
pH:	6.5 – 8.5
8. Water balance:	
Seawater intake:	9,000 m^3/day
Production:	3,000 m^3/day
Waste water:	6,000 m^3/day
9. Utility consumption:	
Electricity:	21,200 KWH/day
10. Chemical consumption:	
Ferric chloride:	27.3 kg/day
Sulfuric acid (98%):	441.0 kg/day
Caustic soda (flake):	28.8 kg/day
11. No. of personnel required:	
Supervisor:	1
Operator:	7
Total:	8

12. Construction cost:	
Desalination facility:	US$4,888,000
Auxiliary facility:	US$1,979,000
Total:	US$6,867,000
13. Required construction period:	18 months
14. Project life:	16 years (1985 – 2000)
15. Criteria for profitability:	IRROI 15%
16. Product water sales price:	US$ 1.85/m^3
17. Payout time:	6 years

Chapter 1: Outline of San Andres Island

Natural Condition:

San Andres is a coral island situated on the west side of the Caribbean Sea with a total area of 27 km^2. Due to the calcic soil derived from coral, the only source of water is infiltrated rainwater existing in the form of groundwater. There is no surface water available. The average annual temperature is 27°C, and the average annual rainfall is 1,933 mm.

Social environment:

The total population of San Andres is 41,882 (1981), almost 80 per cent of which live in the urban area. Since this island is a free trade port, there are many tourists from mainland Colombia and, therefore, tourism is the biggest industry on the island. There are 27 hotels with a total of approximately 1,900 rooms. Some 300,000 travelers visit the island each year, with the estimated daily average being 3,000 persons per day.

As for public services, there is a public hospital in addition to the water supply and sewerage works. There are also about 60 elementary and middle schools, attended by approximately 7,600 pupils. Electric power generating capacity is 16,100 kW.

Chapter 2: Current status and supply-demand forecasts concerning water supply on San Andres

Water supply undertaking:

The total of 2,644 households, representing 15,864 persons' houses was supplied with water in 1980 at a daily rate of 2,776 m^3 or 32 ℓ/sec.

Water source and supply facility:

The wells which serve as the source of water are located in the El Cove district, at the center of the island. Water is being drawn at 12 locations out of a total of 15 locations. The total capacity of the submersible pumps for drawing water is 54 ℓ/sec. or 4,700 m^3/day. The water is supplied mainly to the urban area of San Andres in the northern part of the island. For this purpose, the water from the pumping station at El Cove is initially fed to a service reservoir (elevation, 60 m; capacity, 1,200 m^3) at El Cliff. From this reservoir water is distributed to the individual households via an undergrounded piping network, by gravity.

Future plan:

The planned total number of people to be supplied with water in 1985 is 42,300, at a daily supply rate of 7,600 m^3.

Chapter 3: Planning of seawater desalination plant

Plant capacity:

For the planned 1985 water supply rate of 7,600 m^3/day, groundwater supply capacity will be increased by 2,000 m^3/day, due to further development of that source which, when added to the present capacity of 2,800 m^3/day, will amount to 4,800 m^3/day. Therefore, it was decided to make up the remaining 2,800 m^3/day by means of seawater desalination plant with a 3,000 m^3/day capacity.

Water intake and discharge:

Considering the local conditions in San Andres Island, it was decided to adopt the following method.

1) Raw seawater intake: Well method
2) Waste water discharge:
   Waste water will be discharged to Punta Norte on the northwest side of the island where there is a large diffusion effect due to tidal current and wave action.

Chapter 4: Process selection

To select a suitable process for the seawater desalination plant, the following three processes were compared and studied, considering the relatively small capacity of 3,000 m^3/day.

1) Reverse osmosis process
2) Multi-effect evaporation process
3) Electro-dialysis process

As a result of studying each of the foregoing processes technically and economically, the conclusion was reached that the optimal process would be the reverse osmosis process, because of the following reasons.

1) Minimum energy consumption
   Energy consumption per cubic meter of product water is as follows:

Process	(1)	(2)	(3)
Electric power consumption (kWH)	7.0	4.3	10.0
Fuel oil (kg)	0	9.1	0

2) Low plant construction cost
3) Easy operation
   Starting and stopping is very simple, posing no problems whatever even when operation is suspended due to an emergency stopage.

Chapter 5: Site selection

For the purpose of selecting the plant site, a comparative study was made of the following three locations in close proximity to each other on the north side of the island.

1) Taller
2) Plaza de Mercado
3) Campamento

As a result of this comparative study, Campamento was selected as the plant site.

Advantages:

1) It has a large area and is located near the sea.
2) There are no houses around the site.
3) The estimated total cost of the facilities for waste water discharging, product water transfer and electric power receiving is the lowest and most economical.

Chapter 6: Outline of proposed plant

Outline of the plant:

The proposed seawater desalination plant using the reverse osmosis process consists of five major units, namely, the seawater intake unit, pretreatment unit, reverse osmosis unit, product water conveying unit and waste water discharge unit. The functions and performance of each of these units are as follows:

1) Seawater intake unit

   Three deep wells (60 m in depth) will be established. Seawater will be pumped up and sodium hypochlorite added thereto to prevent the growth of micro-organisms and algae in the seawater.

   The major equipment will consist of:

   a) Well: Three wells, each of 60 m in depth x 300 mm in diameter.
   b) Intake pump: 3.2 m^3/min x 55 kW x 3 pumps
   c) Chlorine generator: Seawater electrolysis, 0.73 kg/hr x 7.7 kW x 1 unit

2) Pretreatment unit

   Ferric chloride is added to the raw seawater to coagulate and filtrate all suspended solid by means of dual media filters. Pre-treated seawater with pH adjusted by adding sulfuric acid is sent to the reverse osmosis unit.

3) Reverse osmosis unit

   The reverse osmosis unit, which is the heart of this seawater desalination plant, is mainly consisted of hollow fiber type modules. The pH of the fresh water produced by means of the reverse osmosis module is adjusted by adding caustic soda and then sent to the subsequent process of product water transfer unit.

   The major items of equipment consist of:

a) Hollow fiber type modules with cellulose-triacetate membrane

b) High pressure pumps:
Multi-stage turbine pumps, 500 kW x 3 pumps

c) Power recovery turbines:
Multi-stage turbine, 111 kW (Recovered power) x 3 units

4) *Product water transfer unit*

The fresh water produced by the reverse osmosis unit is sent by this unit to the existing service reservoir at El Cliff.

The major items of equipment consist of:

a)	Product water transfer pumps:	2.5 m^3/day x 75 kW x 2 pumps
b)	Product water basin:	50 m^3 x 1 basin

5) Waste discharge unit

The concentrated brine from the reverse osmosis module is sent by self-pressure and discharged at Punta Norte via an underground piping. Other waste water is also discharged together with concentrated brine. The major equipment consists of:

a)	Drain discharge pumps:	Centrifugal type, 0.6 m^3/min. x 11 kW x 2 pumps
b)	Underground piping:	Material: FRP, 1,600 m in length

No. of personnel:

One supervisor and seven operators are required to operate this seawater desalination plant.

Construction period:

The estimated total construction period is 23 months, consisting of 5 months for the selection of a contractor after deciding on the implementation of the project and a further 18 months up to the completion of the test run.

Chapter 7: Total capital requirements and operating cost

Total capital requirements:

Total capital requirements (needed until the commercial operation of the projected plant is started) are as given in the following table.

(US$1,000)

Items	Foreign exchange	Local currency	Total
Plant construction cost	4,678	2,189	6,867
Preoperating cost	71	175	246
Initial working capital	–	272	272
Interest during construction	33	–	33
Total	4,782	2,636	7,418

Operating cost:

Operating cost includes variable (utility and chemical costs) and fixed (labor cost and general expenses, and maintenance cost) operating costs.

(US$1,000)

Item	Annual amount
Utility and chemical costs	782
Operation labor cost	62
Maintenance cost	206
General expenses	38
Total	1,088

Note: Variable operating costs are those corresponding to an on stream factor of 100%.

The above individual items have been calculated on the basis of the following assumptions.

- As utility, electric power alone is necessary. The unit purchase price is 5.66 Pesos/kWH.
- The maintenance cost has been assumed to be 3% of the plant construction cost.

Chapter 8: Financial analysis

Using computers, the following financial statements have been prepared.

- Income statements
- Cash flow statements
- Balance sheet

Premises for financial analysis:

- Commencement of commercial operation: from January 1985
- Projected period: 16 years after the commencement of commercial operation
- On stream factor: 100% from the first operating year
- The total capital requirements will be obtained in the following manner:
  - 30%: governmental subsidy
  - 70%: long-term loans
    - Interest rate: 7.5%/year
    - Repayment of principal:
      - repayment with straight line
      - 5 times for 5 years from the year (1986) subsequent to the year when commercial operation is started.
- Any shortage of cash, if it occurs after the commencement of commercial operation, will be made up by short-term loans.
  - Interest rate: 18.0%/year
  - Repayment of principal: The full amount will be repaid in the year subsequent to the year when the loans are made.
- IRROI: 15% (Basis)

Results of financial analysis:

The results of financial analysis are given in the following table.

(US$1,000)

Item	IRROI	IRROE
Sales price of product water (US$/m^3)	1.85	1.85
Annual sales revenues	1,942	1,942
Average annual operating cost	1,088	1,088
Average annual production cost	1,469	1,677
Unit production cost (US$/m^3)	1.40	1.60
Average annual net income	471	265
Average annual cash flow	612	265
IRR (%)	15.0 (Basis)	8.08
Payout period (year)	6.0	12.5

In this financial analysis, IRR has been calculated on the basis of the following assumptions, with due consideration to the specific features of the Project.

1) IRROI is calculated as the subsidy is deemed to be an earning.
2) In order to grasp the financial status of the Project, IRROE is calculated, for reference, by regarding the governmental subsidy as an owned fund (equity).

As a result, the sales price of product water in case where the above IRROI of 15% is satisfied has been calculated to be US$1.85/m^3.

Evaluation of financial analysis:

The results of financial analysis show that IRROE is 8.08% versus the assumed IRROI of 15%. This is because short-term loans (interest rate: 18% p.a.) are required to make up the shortage of cash resulting from the repayment of the principal of the long-term loans during the first half of the projected operating years. Consequently, the payout period of the investment in Case IRROE becomes 12.5 years. This will put the Project in a considerably unfavorable financial state.

The implementation of this Project, however, is considered to be financially feasible. In addition, when the specific features of the waterworks in San Andres Island are considered, the estimated sales price of US$1.85/m^3 is considered to be acceptable to the inhabitants.

Any increase of the amount of subsidies or extension of the repayment period of principal of long-term loans will greatly assist in improving the financial status of the Project, and assure a reduction of sales price of the product water.

Chapter 9: Effect on San Andres's economy

EIRR:

The EIRR of the Project has been calculated by defining the economic cost and benefits of the projected plant as follows.

- Economic cost: total investment cost plus operating cost minus insurance cost.
- Economic benefits: amount equivalent to the sales revenues of product water

As a result of the above calculations, EIRR is 9.08%.

Intangible benefits:

The implementation of this Project will serve to eliminate the problem of shortage of potable water in San Andres Island. This will further serve to reinforce the foundation of tourism which is the main industry on the Island, assuring the upgrading of the standard of living of the inhabitants.

Effect of project implementation:

It is considered that early implementation of the Project is vital in view of social welfare and the fact that the Project will have a considerably large effect on the stability of the regional community. In general, the profitability of infrastructure-related projects is low. This Project, however, is considered to be financially feasible in spite of its unfavorable financial status.

The project should be implemented as early as possible with due consideration to the immeasurable economic benefits.

Chapter 1: Outline of San Andres Island

1.1 Location

San Andres Island is located between longitudes 78° and 82° west and between latitudes 12° and 16° north, on the west side of the Caribbean Sea, and is the biggest island (total area: 27 km^2) of the San Andres and Providencia group. It lies at a distance of 760 km northwest from the city of Cartagena on the mainland of the Republic of Colombia and is situated 200 km east of the coastline of Nicaragua in Central America. It comes under the direct jurisdiction of the central government of San Andres where the administration offices are located.

1.2 Topography and geology

1.2.1 Topography

As shown in Fig. 1.1 below, San Andres is a coral island with a total length of 12.8 km in the north-south direction and a total width of 3.2 – 4.8 km in the east-west direction.

The north and south parts of the island have a flat topography, but a karst topography inherent to a limestone region exists in the central part of the island, formed by a gradual slope toward the center from the surrounding flat topography, with the existence of various hills and hollows called "doline" here and there, typical of karst topography.

The flat topography around the island is 2 m above sea level. The maximum elevation is 90 m at Cima Pussy (on a hill at San Wright).

The hollows existing here and there in the karst topography serve as recharge basins for the groundwater vein.

1.2.2 Surface geology

San Andres Island consists of calcareous deposits derived from anthonoa over a period extending from the initial and mid-term of the Miocene epoch to the current Quaternary epoch.

The rocks are porous and contain many hollows as a result of the dissolving action of water infiltrating into numerous existing cracks.

1.3 Climate and sea conditions

1.3.1 Meteorology

The meteorological data applicable to the San Andres airport located in the northern part of the island are summarized as follows:

a) Annual average temperature: 27°C

b) Annual average precipitation: 1,933 mm
(average over the period 1961 – 1975)

c) Annual average humidity: 80%

d) Monthly average wind velocity: 6.0 m/sec.

e) Maximum wind velocity: 20.6 m/sec.
(over a period of 20 years)

f) In addition, the monthly average precipitation (average over the period 1961 – 1975) applied to the study on water resource is as follows (in mm):

January:	110.2	July:	195.3
February:	42.0	August:	181.1
March:	23.7	September:	208.2
April:	32.6	October:	277.2
May:	110.4	November:	341.3
June:	214.6	December:	196.5

1.3.2 Sea conditions

The actions of waves, tidal current and sea current are subdued in the bays of both Sardinas and San Andres on the north side of the island due to the existence of a barrier reef, but are strong on the southeast side of the island due to direct wind force. The west coast of the island is influenced by wind direction, as there is no coral reef.

The tidal differential is 0.25 m on an average, with a maximum of 0.30 m. The main sea current flows from east to west at an average speed of one knot.

1.4 Water source

As there is no surface water on San Andres Island, the island depends on groundwater for its water supply. The groundwater now in use is obtained from the San Andres aquifer in the El Cove river basin in the El Cove district at the center of the island.

1.4.1 Outline of San Andres aquifer

1) Geological structure

The geological structure of San Andres Island is shown in Table 1.1. The water bearing stratum exists in the Tertiary Miocene San Andres stratum. Namely, both the breccia and sandstone facies in the San Andres stratum as in the above Table 1.1 form the water bearing stratum, containing the confined water in the clay facies of the upper stratum.

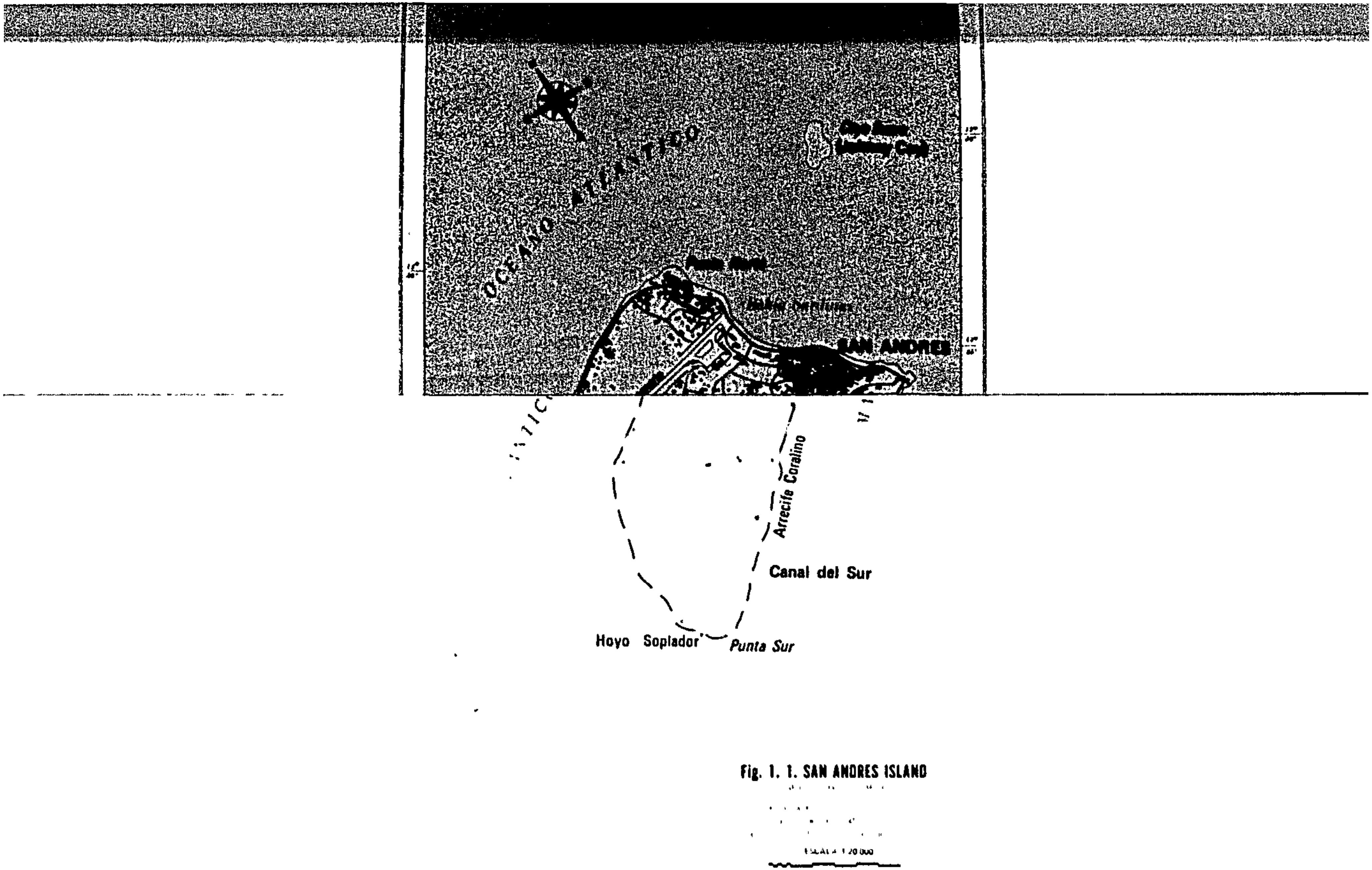


Fig. 1. 1. SAN ANDRES ISLAND

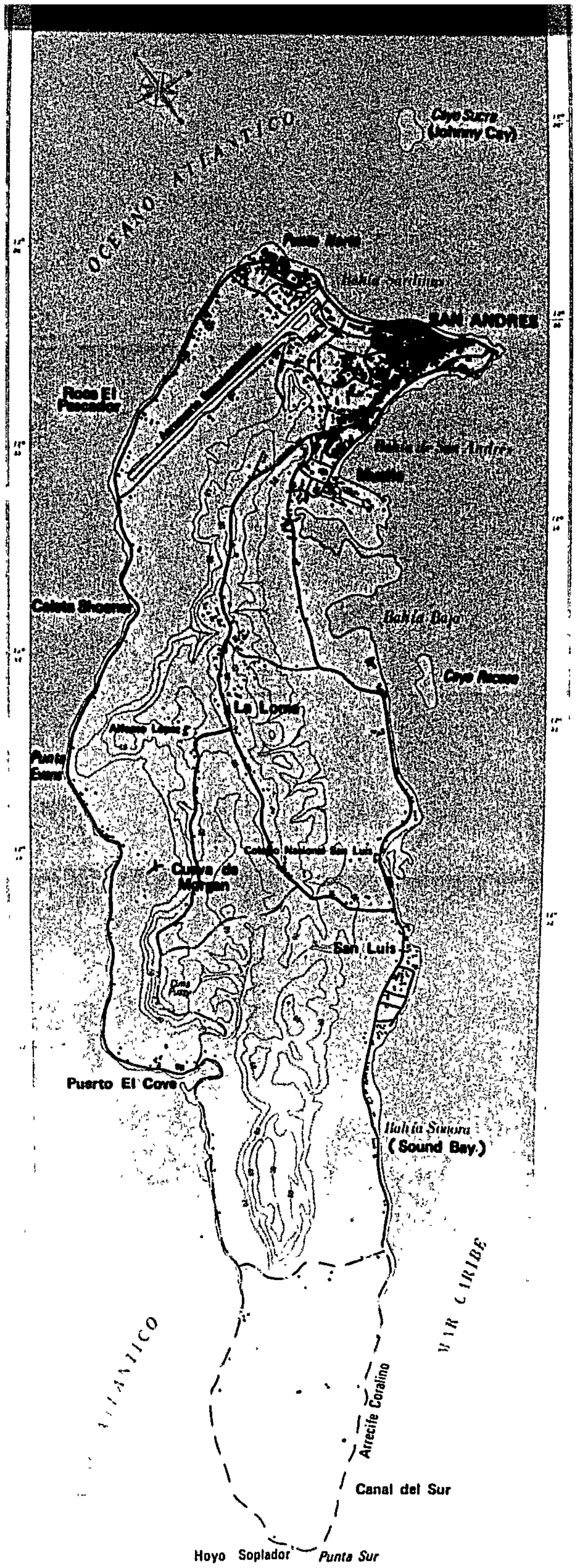


Fig. 1. 1. SAN ANDRES ISLAND

Table 1.1 Stratification of San Andres Island

Period		Stratum	Rock Facies	Thickness
Quaternary	Alluvial Epoch	Alluvium	Clay	
	Diluvium Epoch	Diluvium	Blocks & Pebbles of Sand	
	Peistocene Epoch		Gray Wacke	
Tertiary	Pliocene	San Luis	Fractured Limestone	~ 4m
	Miocene	San Andres	Clay	6 ~ 19m
			Breccia	
			Sandstone	

2) Scale of aquifer

The size of the San Andres aquifer is 14.9 km^3, seemed with the storage capacity of 100 mm in thickness.

1.5 Social and economic conditions

1.5.1 Population

The total population of the island was 41,882 in 1981, giving a population density of 943 persons per km^2. The majority of the population is concentrated in the San Andres district (urban area) in the northern part of the island, the remainder being distributed in the center and extending toward the south. The population distribution is as follows:

	Urban section	Rural section	Total
Population	31,830	10,052	41,881
Percentage (%)	76.0	24.0	100

Now, looking at the rate of population increase, the annual average rate of increase over the past 10 years is 4.4%, reaching 5.6% in the last three years. This rapid increase in population is deemed attributable to the fact that the island was designated a free port in 1954 and, as a result, many shoppers from mainland Colombia are visiting the island. The population trend of the island is shown in Table 1.2 below.

Table 1.2 Population of San Andres Island

Year	1970	1971	1972	1973	1974	1975
Population	26,219	27,138	28,088	29,071	30,230	31,440
Year	1976	1977	1978	1979	1980	1981
Population	32,540	33,678	35,565	37,558	39,661	41,882

1.5.2 Primary industry

1) Agriculture

There is very little agriculture on the island, with the major crop consisting only of palm trees. Other produce includes very small amounts of potatoes, yucas, bananas, water melons and sugar cane. Table 1.3 below shows the farming area per crop.

Table 1.3 Cultivated Acreage in the Island

(Unit: Hectare)

Year \ Crops	Coco	Sweet Potato	Yucca	Banana	Water-melon	Sugar-cane	Total
1974	2,200	20	40	10	10	40	2,320
1977	2,200	26	44	15	13	48	2,346
1978	2,200	28.6	48.4	16.5	14 3	52.8	2,360.6

2) Livestock industry

There is no livestock industry on the island, apart from the breeding of a few pigs and chickens.

3) Fishery

Although there is a fishing port on the north coast of the island, fishing is done only on a very small scale.

1.5.3 Industry and commerce

1) Industry

Industry on the island is of very small proportions, intended only to serve the needs of the island.

The main industries are these concerned with foodstuffs, beverages and minerals, and amount to 10 enterprises in all. Table 1.4 below shows the industrial production of the island.

Table 1.4 Output of Manufacturing Industries

Group \ Items	No. of Enterprises	Production 1,000 Pesos	
		1977	1978
Foods	3	6,018	20,607
Beverages	2	7,117	10,600
Minerals	5	19,554	14,047
Total	10	32,689	45,254

2) Commerce

Commerce on the island consists mainly of the sale of duty-free goods and the activities of the service industry (such as hotels, restaurants, etc.) directed toward the tourists coming from mainland Colombia.

1.5.4 Tourism

1) General

The economy of the island depends on tourists visiting the island for leisure and the purchasing of duty-free goods. Most of the tourists are domestic travelers coming from the highlands of mainland Colombia. The remainder are overseas tourists coming mainly from central America.

There are 27 hotels available to these travelers, with a total of 1,898 rooms and an estimated total number of approximately 6,000 beds. Table 1.5 below lists the hotels, showing the number of rooms in each.

Table 1.5 No. of Rooms of Hotels

Hotel Name	Rooms	Hotel Name	Rooms	Hotel Name	Rooms
Antillas	30	Casablanca	80	Gran Hotel International	200
Aquarium	200	Caliseo	30	Kingston Nuevo	30
Aurora	50	Dann International	200	Mediterraneo	40
Bahia Marina	30	Eden	30	Morgan	40
Casique Tone	150	El Dorado	70	Royal Abacoa	80
Capri	50	El Isleño	50	Tiuna	200
Calypso Beach	90	Europa	50	5 Other Hotels	98
Caribbean	70	Galaxia	30	Total	1,898

2) Number of travelers

There are no statistics on the total number of travelers, but estimating from the number of beds of the hotels and the approx. one million overnight stays per year, it is assumed that there are 3,000 travelers on the island every day, staying for an average of about 3 days, and the cumulative annual number of travellers is 300,000. With about 30,000 travelers per annum from overseas accounted for in the available statistics, it is assumed n that the remainder of the 300,000 travellers come from within Colombia.

1.5.5 Social service

1) Education

The total number of educational institutions (schools) is 60, consisting of 27 kindergartens, 26 elementary schools and 7 middle schools, the majority of which are public. The total number of pupils attending these schools is approximately 7,600. The educational diffusion rate is 66%, and considered to be rising further.

2) Medical service

There is a national general hospital (Hospital Santander) and three clinics. This hospital has a total of 52 beds, and is now being expanded. There are 31 medical doctors, including the two medical doctors residing on Providencia Island.

1.5.6 Public service

1) Water supply

The waterworks on this island, as well as the sanitary and sewerage works, are operated under the management of the Empresa de Obras Sanitarias de San Andres y Providencia Limitada (EMPOISLAS). This public corporation was established with funds from the government of the Republic of Colombia, the Intendencia de San Andres y Providencia and the Instituto Nacional de Fomento Municipal (INSFOPAL), and is thus a totally public corporation. The waterworks are described in detail in para. 2.1 but a summary is given hereunder.

a) Population served by waterworks: 15,864

b) Total number of subscribers: 2,544

c) Coverage: 40%

d) Quantity of water supplied: Approx. 2,800 m^3/day

e) Quantity of water supplied per person: 175 ℓ/day

f) Total number of water sources: 12 wells

2) Sewerage work

There is at present no sewerage system on the island, and therefore sewage is disposed of by each individual household. The EMPOISLAS is now constructing a sewerage system and is scheduled to commence the operation of a part of the system from September, 1982. For the time being, there is only the sewer piping, without treatment plant. The treatment plant legoon is scheduled to be put into operation upon completion in January, 1983.

3) Electricity

The electric power undertaking on the island is operated by the public corporation, ELECTROSAN, with 90% of the funds being supplied by the government. The power station is located in the northeast part of the island and is equipped with electro-diesel generators. The particulars of the electric power generating equipment is as shown in Table 1.6 below.

Table 1.6 Aspect of Electro-Diesel Generators

No.	Capacity kW	Current Capacity kW	Status for Service
1	1,500	–	Out of service
2	1,500	1,000	Regular
3	3,200	3,200	Good
4	3,200	3,200	Good
5	2,100	1,500	Regular
6	2,100	–	Out of service
7	2,500	2,500	Good
Total	16,100	11,400	

As can be seen the electric power generating capacity is 16,100 kW in total, but actual effective capacity is about 11,000 kW. Moreover, the 1,500 kW, 2,100 kW and 2,500 kW units are not in the best of condition and, therefore, new electric power generating equipment (3,200 kW x 3 units) are now on order.

The total number of households supplied with electricity is approximately 4,500, representing more than 90% of the total number of houses on the island.

4) Telephone

The telephone system, serving approximately 1,600 subscribers is operated by TELECOM (Telecommunications Nacionales E Internacionales), the same as main land Colombia.

1.5.7 Revenue of Intendencia

The revenue of Intendencia is listed in Table 1.7 below to indicate the state and scale of the administration on the island.

Table 1.7 Revenue of Intendencia

Items \ Year	1978		1979		1980		1985		1990	
	Thous. pesos	%	Thous. pesos	%	Thous. pesos	%	Thous. pesos	%	Thous. pesos	%
I. Tax Revenue	127,552	95.9	158,314	96.4	356,741	98.2	1,516,642	99.1	7,737,516	99 5
Direct Tax	5,749	4.3	7,805	4 8	11,101	3.1	74,693	4.9	564,406	7 3
Indirect Tax	121,803	91.6	150,509	91.6	345,640	95.1	1,441,949	92.2	7,171,110	92 2
II. Non-Tax Revenue	5,468	4.1	5,927	3 6	6,256	1.8	13,421	0.9	39,991	0 5
Total	133,020	100.0	164,241	100 0	363,267	100.0	1,530,063	100.0	7,777,507	100.0

As can be seen from this Table, the island's budget depends greatly upon indirect tax revenue, most of which comes from the 10% to 15% tax levied when visitors take duty-free goods outside the island. This constitutes more than 80% of the total revenue.

This is can be seen that the depends upon visitors who are attracted to the island by the free port system.

Chapter 2: Current Status and Supply-demand Forecasts Concerning Water Supply on San Andres

2.1 Current status of waterworks

2.1.1 Current status of water supply system

In 1980, the waterworks on the island supplied water to a total of 2,644 hauseholds (representing 15,864 people), as shown in Table 2.1 below, at a daily water supply rate of 2,776 m^3 or 32 ℓ/sec. Additionally, the water supply coverage was 40 per cent of the total population of the island. While the quantity of water supplied per person is 175 ℓ/day, water shortages are prone to occur during the dry season (January – May).

Table 2.1 Present Status of Water Supply

Items \ Year		1979	1980
Population		37,558	39,661
No. of Houses		6,260	6,610
Coverage of Water Supply %		40	40
Population Served Water Supply		15,023	15,864
Present Subscribers		2,504	2,644
Classification of Subscribers	Residential	2,253	2,374
	Industrial	25	26
	Business	175	185
	Official & Others	51	54
Actual Water Supply	ℓ/pop. day	174	175
	ℓ/sec.	30.3	32 1
	m^3/day	2,614	2,776

2.1.2 Water rates

EMPOISLAS, which operates the waterworks, is an independent public corporation, but the water rates are determined by the government of Colombia, from the public point of view.

The water rates differ according to use, and the system is such that it imposes a higher prices on large consumers and those located on high-priced land, thus imposing a higher burden on consumers who can afford it. The current rates became effective in June, 1981. The details are shown in Table 2.2 below.

Table 2.2 Tariff of Water Supply

Classification of Subscribers	Categories		Fixed Charge Peso/Month	Extra Consumption Peso/m^3	Fixed Charge without Metering Peso/Month
Officials & Special Services	1st. Category		130	20	770
	2nd Category		500	24	2,150
Residents	Land Evaluation Peso	0.01 ~ 150,000	170	9	400
		150,000.01 ~ 350,000	350	20	730
		350,000.01 Up	600	31	1,440
Businesses	Trade Subscribers		500	30	–
Hotels	No. of Rooms	1 ~ 20	800	35	2,200
		21 ~ 50	2,000	40	4,700
		51 ~ 100	3,000	42	5,750
		101 Up	3,200	43	5,900
Mixed Services	Areas Containing Residential Housings & Industrial or Trading Buildings		20% up of Corresponding Residential Tariff		

Further, though approval has been given to raise these water rates within the range of 25% after January 1982, this has not yet been effected.

Average unit price of portable water (total revenue of water works/total quantity of supply) in 1981 is approximately 18 pesos per cubic meter. It is estimated that the present average price is higher than the above as the water rates were revised in June, 1981 as mentioned before.

2.1.3 Facilities of waterworks

1) Water source and intake

The wells which serve as the water source are located in the El Cove district, at the center of the island. A total of 15 wells have been drilled, but only 12 wells are in use at present. Water is drawn by submersible pumps, with a total 12-well capacity of 4,700 m^3/day or approximately 54 ℓ/sec.

Water pumped from the 12 wells is collected in a receiving tank, located centrally among the wells, where it is sterized with chlorine (bleaching powder), and then sent to a service reservoir.

2) Water conveyance

Water sterilized in the receiving tank is sent to the service reservoir by means of conveying pumps. There are three conveying pumps (two for normal operation), each with a pumping capacity of 20 ℓ/sec., totaling 60 ℓ/sec. or approximately 5,200

m^3/day. There are two service reservoirs, the larger one being at El Cliff and the smaller one at La Loma. Further, there are other smaller water reservoirs at San Luis and El Cove, into which water is fed directly from wells without passing through a receiving tank. The flows are shown in Fig. 2.1, "Flow Diagram."

3) Water distribution

Underground distribution piping extends to each water supply area from each service reservoir, with the water flowing by gravity. The largest area supplied with water is the San Andres area (urban section) where water from the service reservoir at El Cliff is distributed. There is a small number of consumers in the rural sections (e.g. La Loma, San Luis, etc.).

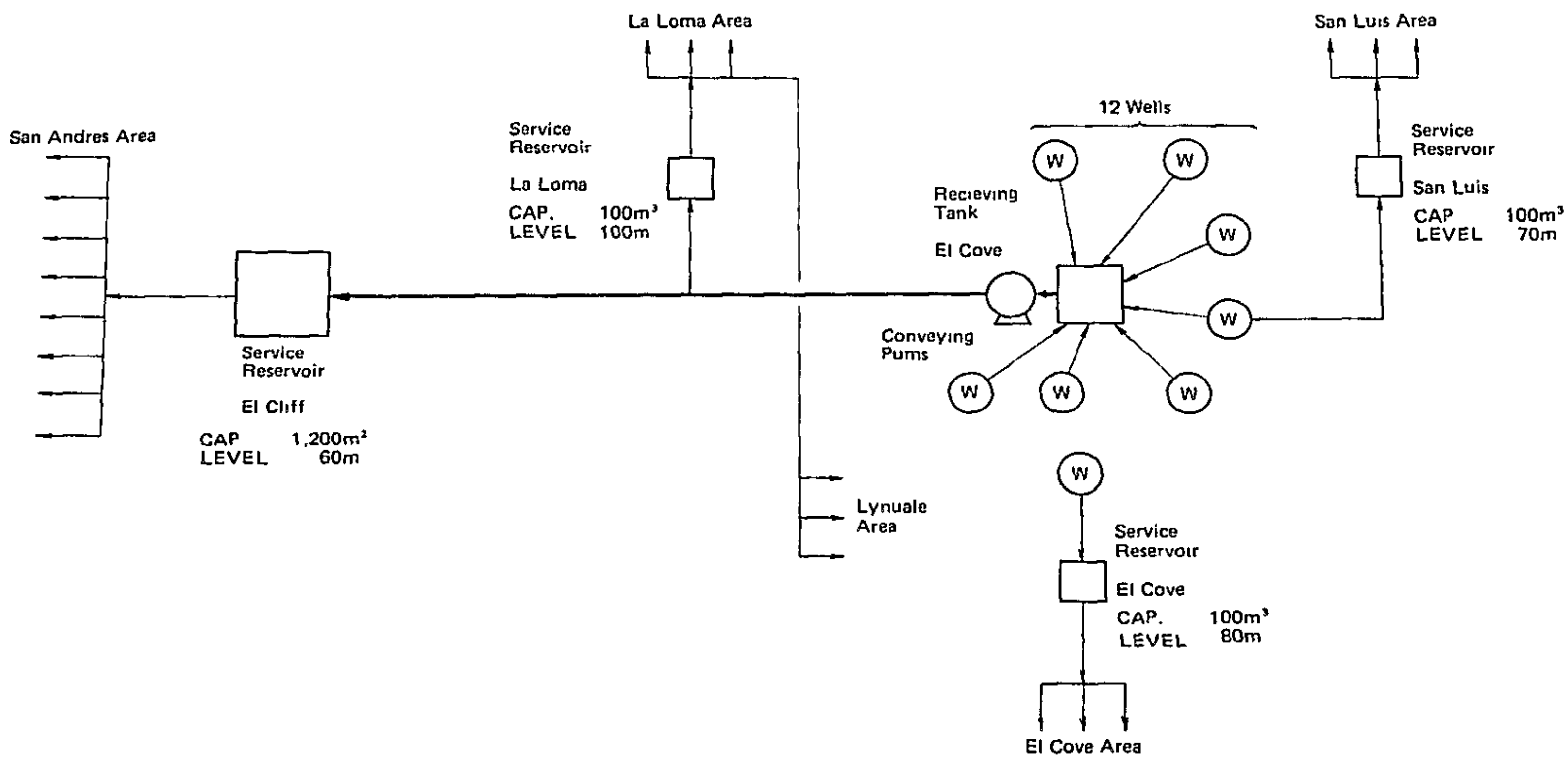


Fig. 2.1 Flow Diagram of Water Intake and Covnveying System

2.1.4 Management and administration

1) Organization and personnel

As previously mentioned, the waterworks are operated by EMPOISLAS, whose organization and personnel employment are shown in Figs. 2.2 and 2.3, respectively. The operation and maintenance of waterwork facilities are carried out by a relatively small number of personnel, as shown in Fig. 2.3.

2) Maintenance

The inspection and maintenance of waterwork facilities (such as wells, pumps, service reservoirs, etc.) are carried out once a year. The piping lines (such as water conveying and distribution lines, etc.) are inspected and maintained from time to time. The quantity and quality of water are checked monthly by measuring the intake volume, groundwater level, and chloride ion concentration.

2.1.5 Water quality

1) Water quality at source

The quality of water at the source is listed in Table 2.3 below. Although the data on the well water quality is old, it is still deemed to be applicable.

Table 2.3 Quality of Well Water

Items of Quality	Well No. / Date of Analysis	2	3	6	8	9	10	12
		Oct. 10, 1965	Dec. 10, 1965	Sep. 1, 1966	Jan. 25, 1967	Jan. 24, 1967	Mar. 2, 1967	Apr. 20, 1968
Turbidity	ppm	60	1.5	29	2.5	3 5	15	3.5
Color	ppm	10	4.0	14	10	8 0	13	6 0
PH		7.3	7.4	7.3	7.3	6 7	7 3	6.6
Total Hardness	ppm $CaCO_3$	230	260	260	300	300	300	340
Alkailinity	ppm $CaCO_3$	225	220	325	300	320	310	305
Chloride Ion	ppm $C\ell^-$	63.90	39.05	47.21	42.60	39	46 15	37 27
Sulfate Ion	ppm SO_4^{--}	7.7	8.34	–	12 82	13 14	9.30	–
Iron	ppm Fe	0.085	0.060	0.54	0.070	0 060	0.070	0 050

2) Quality of water supplied

The quality of the water distributed from the receiving tank by conveying pumps is listed in Table 2.4 below. The corresponding values as set forth in the standards for potable water applied in the Republic of Colombia are entered in this Table for reference purposes only. The analyzed water qualities all meet the standards.

Table 2.4 Quality of Supplied Water

Items of Quality \ Date of Analysis		July, 10 1982	cf: Standard for Potable water
PH		7.4	6.5 ~ 8.5
Electroconductivity	μS/cm	715	–
Alkalinity	mg/ℓ $CaCO_3$	277	–
Calcium Hardness	mg/ℓ $CaCO_3$	270	Ca 75.0 mg/ℓ
Magnesium Hardness	mg/ℓ $CaCO_3$	24.1	Mg 125.0 mg/ℓ
Total Dissolved Solid	mg/ℓ	445	1,000
Solid Chloride Ion	mg/ℓ $Cℓ^-$	44.1	250.0
Nitrogen as NH_4	mg/ℓ N	<0.15	–
Sulfate Ion	mg/ℓ $SO_4^{=}$	18.6	250.0
Total SiO_2	mg/ℓ	11.1	–
Sodium Ion	mg/ℓ Na	26.5	–

2.2 Supply-demand forecasts

2.2.1 Supply-demand forecasts developed by the Instituto Nacional de Fomento Municiapl (INSFOPAL)

The INSFOPAL has forecast the population increase for San Andres Island and the corresponding increase in the demand for water as follows:

Year	Population	Water demand (m^3/day)
1981	41,882	7,404
1985	52,876	9,539
1990	66,592	12,320

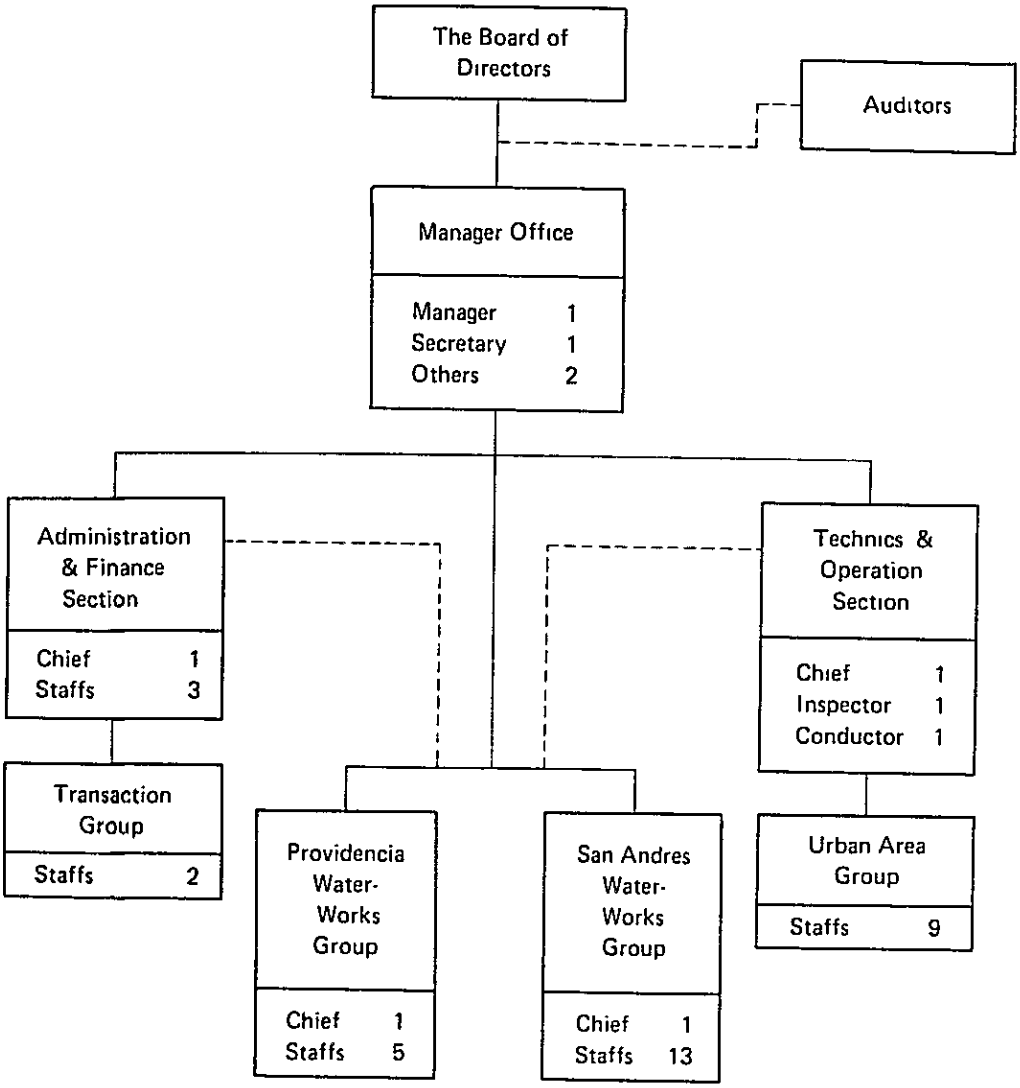


Fig. 2.2 Organization of EMPOISLAS

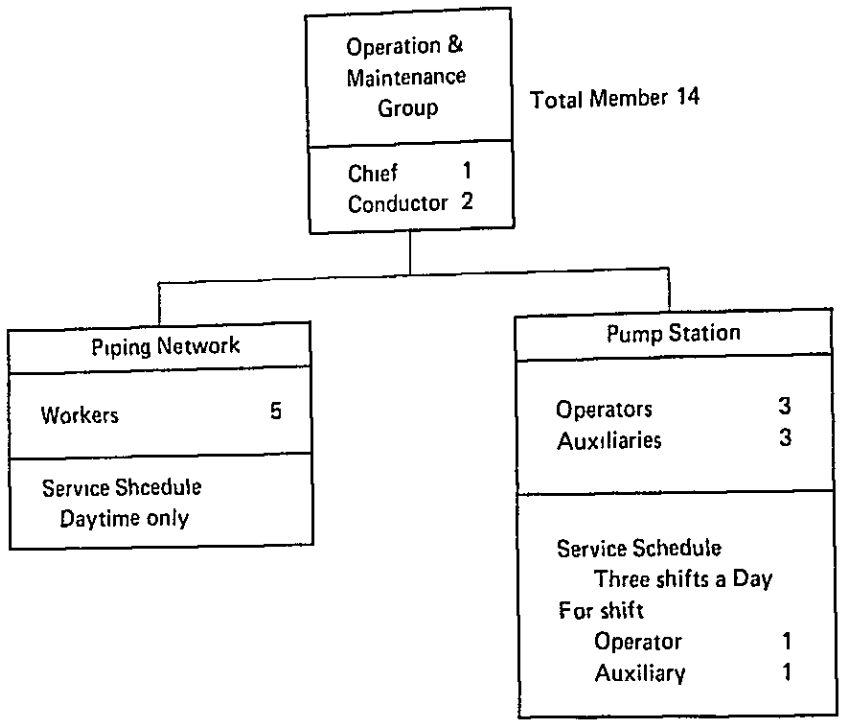


Fig. 2.3 Organization for Waterworks in San Andres Island

2.2.2 Future water supply expansion plan

Based on INSFOPAL's supply-demand forecast as above, EMPOISLAS is planning an expansion of the water supply system, as follows:

Year	Population supplied	Planned water supply (m^3/day)
1980 (persent)	15,864	2,776
1985	42,301	7,614
1990	53,273	9,908

The details are shown in Table 2.5 below.

Table 2.5 Water Supply Plan of Waterworks

Items \ Year		1981	1982	1983	1984	1985	1986	1987	1988	1990
Pupulation		41,882	44,839	47,372	50,047	52,876	55,224	58,455	61,050	66,592
No. of Houses		6,980	7,473	7,895	8,341	8,813	9,204	9,743	10,175	11,099
Coverage of Water Supply	%	45	55	70	80	80	80	80	80	80
Population Served Water Supply		18,847	24,661	33,160	40,038	42,301	44,179	46,764	48,810	53,273
Re-quired Water Supply	ℓ/pop. day	176	177	178	179	180	181	182	183	186
	ℓ/sec.	38.4	50.3	68.3	8.30	88.1	92.6	98.5	103.4	114.7
	m^3/day	3,317	4,365	5,902	7,166	7,614	7,996	8,511	8,938	9,909
Subscribers		3,141	4,165	5,526	6,673	7,050	7,363	7,794	8,140	8,879
Classification of Subscribers	Residential	2,827	3,748	4,973	6,005	6,345	6,627	7,015	7,326	7,991
	Industrial	27	28	29	30	31	32	33	34	36
	Business	232	333	467	580	615	644	685	718	788
	Official & others	55	56	57	58	59	60	61	62	64

Chapter 3: Planning of Seawater Desalination Plant

3.1 Plant capacity

The required capacity of the proposed seawater desalination plant can be determined by applying the following formula, viz:

$$\begin{pmatrix}\text{Seawater desalination}\\ \text{plant capacity}\end{pmatrix} = \begin{pmatrix}\text{Planned water}\\ \text{supply}\end{pmatrix} - \begin{pmatrix}\text{Available supply}\\ \text{of groundwater}\end{pmatrix}$$

Now, the period to be covered by the plan becomes a problem. Meanwhile, EMPOISLAS considers that approximately 4,800 m^3/day of groundwater will be available in 1985 due to the future increase in quantity of 23 ℓ/sec. or approximately 2,000 m^3/day plus the current water supply of 32 ℓ/sec. or approximately 2,800 m^3/day. From the above, the required capacity of the proposed seawater desalination plant will be as shown in Table 3.1 below.

Table 3.1 Required Capacity of Proposed Sea Water Desalination Plant

(in m^3/day)

Items / Year	Total Planned Water Supply	Avail. Total Ground Water	Desal. Water Supply
1985	7,600	4,800	2,800
1990	9,900	4,800	5,100

As a result of the foregoing study, a seawater desalination plant of 3,000 m^3/day capacity is required to satisfy the 1985 water demand, and 5,000 m^3/day for the 1990 water demand.

Meanwhile, we suggested to EMPOISLAS during the site survey that a capacity of 3,000 m^3/day would be desirable. As shown in Table 3.1 above, a plan based on the 5,000 m^3/day capacity assumes 100% full operation commencing in 1991 in the 7th year after starting commercial operation at the beginning of 1985. Therefore, the rise in the cost of product water to a low operating rate till then cannot be neglected. Meanwhile, a plan based on the 3,000 m^3/day capacity assumes an almost 100% full operation from the first year of commercial operation at the beginning of 1985, and is thus favorable economically.

With consideration to the additional future capacity to meet the shortage caused by increased demand after 1985, the required capacity of the proposed seawater desalination plant is considered to be 3,000 m^3/day.

3.2 Product water quality

The quality of the water produced by this plant is listed in Table 3.2 below. This fully conforms to the standards for potable water as set forth by the government of the Republic of Colombia.

Table 3.2 Standard for Potable Water

Item		Maximum Acceptable Concentration		
Coliforme		MPN 10/100 mℓ, Average in 90 samples		
Turbidity		10 Units (Turbidimetric)		
Color		20 Units (Platinum-Cobalt)		
Taste & Odor		Not Objectionable		
Lead	(Pb)	0.05	mg/ℓ	
Fluoride	(F)[1]	0.6 ~ 1.7	mg/ℓ	
Arsenic	(As)	0.05	mg/ℓ	
Selenium	(Sc)	0.01	mg/ℓ	
Chrome	(Cr^{6+})	0.05	mg/ℓ	
Cadmium	(Cd)	0.01	mg/ℓ	
Iron	(Fe)	0.3	mg/ℓ	0.3 mg/ℓ as Total
Manganese	(Mn)	0.05	mg/ℓ	
Zinc	(Zn)	5.0	mg/ℓ	
Calcium	(Ca)	75.0	mg/ℓ	
Magnesium	(Mg)[2]	125.0	mg/ℓ	
Chloride	(Cℓ)	250.0	mg/ℓ	
Sulfate	(SO_4)[2]	250.0	mg/ℓ	
Nitrate	(NO_3)	45.0	mg/ℓ	
Phenol		0.001	mg/ℓ	
Total Dissolved Solids		1.000	mg/ℓ	
PH		6.5 ~ 8.5		

Notes
1) Maximum permissible concentration of fluoride varies inversely with the annual average temperature.
2) When sulfate contents is 250 mg/ℓ, it is recommended that Mg content is not over 30 mg/ℓ.

Table 3.2 shows the total dissolved solids (TDS) to be less than 1,000 mg/ℓ which is higher than the standard of 500 mg/ℓ forth by the World Health Organization (WHO) but since the chloride ion concentration is 250 mg/ℓ, the TDS in the product water of this plant will be planned at a value below 500 mg/ℓ.

3.3 Characteristics of raw seawater

Raw seawater quality was analyzed using sample seawater collected from the sea near the coastline and from two offshore spots within the coral reef on the north side of San Andres Island. The results are shown in Table 3.3 below.

Table 3.3 Results of Sea Water Analysis

Item	Unit	North Shore	North Off Shore
PH	–	8.2	8.2
Total Dissolved Solids (TDS)	mg/ℓ	36,200	36,300
Chloride (Cℓ)	mg/ℓ	20,080	20,100
Electric-conductivity	μS/cm	57,000	57,000

Based on the results given in Table 3.3, the raw seawater characteristics are shown in Table 3.4 below as a basis for planning of this plant.

Table 3.4 Characteristics of Sea Water as Design Basis

Item	Unit	Design Basis
PH	–	8.2
Total Dissolved Slids (TDS)	mg/ℓ	37,000
Chloride (Cℓ)	mg/ℓ	21,000
Electric-conductivity	μS/cm	57,000
Temperature	°C	
Max.		40
Min.		25

Further, the minimum water temperature is assumed to be 25°C as the measurements of seawater temperature at several spots within the island waters fell within a range of 26° – 28°C. 40°C is taken as the maximum temperature, taking into account the temperature rise due to storing the seawater taken in the storage basin.

3.4 Method of taking raw seawater

The following three methods are generally adopted ror taking in raw seawater, each having the features as shown in Table 3.5 below.

(a) Pipe method

(b) Open pit method

(c) Well method

Table 3.5 Relative Features of Sea Water Intake Methods

Methods	Features
(1) Pipe Method Intake by piping installed on the bottom of sea	• Most prevailing method. • Requiring moderate sea depth at the intake point. (More than six meters of depth is preferable) • Requiring the construction in the sea with difficulty • Requiring rather long pipeline between the site and the intake point.
(2) Open Pit Method Intake from open pit at a coast	• Suitable for rather large sea water intake facility. (more than 100,000 m^3/day). • Preferring a rock beach and moderate sea depth. • Requiring mechanical equipment (pump & screens) at the sea side.
(3) Well Method Intake from wells at/near the site.	• Suitable for relatively small seawater intake facility. • Requiring well survey to aquire the well characteristics. • Requiring reserved wells to provide against decreases of well capacity.

For a relatively small-scale plant like this, the open pit method is unsuitable. The pipe method, considered as the conventional, also cannot be adopted because there are no locations possessing a suitable depth of water on the north side of the island, and a slow tidal current and waves at which marine work can be easily carried out.

The well method must be carried out after a thorough preliminary survey has been completed, such as test boring of wells, and so forth. However, threre are already many fresh water wells on the island, permanently equipped with construction machinery which is familiar to everybody. The well method is thus a preferable method, also from the standpoint of preserving the landscape of the island for tourism.

Considering all the above points, the well method was selected.

3.5 Waste water discharge method

Since the candidate plant construction sites are all in the vicinity of a swimming beach, it is not desirable to discharge the waste water directly into the waters of such a beach.

Discharging of the waste water must, therefore, be done at a selected location where the waste water will not affect tourism resources such as the swimming beach and others, and yet where the waste water would not flow back to the seawater intake point.

On the reasonable grounds that because the waste water, if discharged into Punta Norte, will be quickly diffused by the tidal current running in the direction from northeast to southwest, any effect upon the ecological system can be negligible, and Punta Norte has no houses in the vicinity and is located relatively close to all the candidate sites. Hence, Punta Norte is deemed appropriate for discharging the waste water.

Therefore, all waste water will be discharged into Punta Norte.

3.6 Utilities and chemicals

3.6.1 Electricity

The existinfg total capacity of ELECTROSAN, which supplies electricity throughout the island is 16,100 kW, as shown in Table 1.6 in foregoing para. 1.5 of Chapter 1.

The practical electric power generating capacity is 11,400 kW, which satisfactorily meets the existing total electricity demand of 9,600 kW, but the addition of three 3,200 kW units totaling 9,600 kW is now being planned. It is, threrefore, considered that there will be no problem in supplying electricity to this plant. Further, the main cable capacity is presently insufficient to transmit electricity from the electric power station to the candidate plant construction sites in the northern part of the island. It is, therefore, necessary for the plant to receive electricity via an indipendent cable laid separately from the exising supply conditions are shown in Table 3.6 below.

Table 3.6 Condition of Electric Power Supply

Item	Specification of Condition
Voltage	13.2 kV
Frequency	60 HZ
Phase	3 ϕ
Tariff	5.66 Peso/KWH

3.6.2 Fuel oil and chemicals

The fuel price complies with the unit fuel price now being purchased by ELECTRO-SAN. The unit price of chemicals required is set up based on the results of the site survey.

All the above results are tabulated in Table 3.7 below.

Table 3.7 Unit Price of Fuel and Chemicals

Items	Specification	Form	Price
Fuel Oil	–	Liquid	80 Peso/gal
Ferric Chloride	98 %	Powder	57 Peso/kg
Sulfuric Acid	98 %	Aqueous Solution	25 Peso/kg
Caustic Soda	99 %	Flake	80 Peso/kg
Sodium Hypochloride	13 %	Aqueous Solution	16.6 Peso/kg
Sodium Bisulfate	100 %	Powder	120 Peso/kg
Citric Acid	100 %	Powder	156 Peso/kg
Aqueous Ammonia	25 %	Aqueous Solution	102 Peso/kg

3.7 Measures for environmental protection

Waste water and noise resulting from the operation of this plant can be considered as factors adversely affecting the environment of San Andres Island.

Waste water consists mainly of concentrated seawater, and is considered to have a minimum effect upon the environment, if discharged into Punta Norte, as previously mentioned.

The major noise sources which come out during operation of this plant are the pumps and motors. It is considered that any adverse effect on the surrounding environment can be minimized by installing the pumps and motors inside a building.

Chapter 4: Process Selection

4.1 Seawater desalination technology

There are 14×10^{17} tons of seawater on the surface of this earth. This virtually unlimited amount of seawater contains 3.5 – 4.5% salt. Seawater desalination means the removal of this salt content, and method of effecting this can be classified as shown in Fig. 4.1. Among these methods, the freezing process is not adequate for usual applications, except where a cold source, such as LPG, is available. Accordingly, a comparative study was made of three processes, namely the evaporation process, reverse osmosis process and electrodialysis process to determine the most suitable process for this plant.

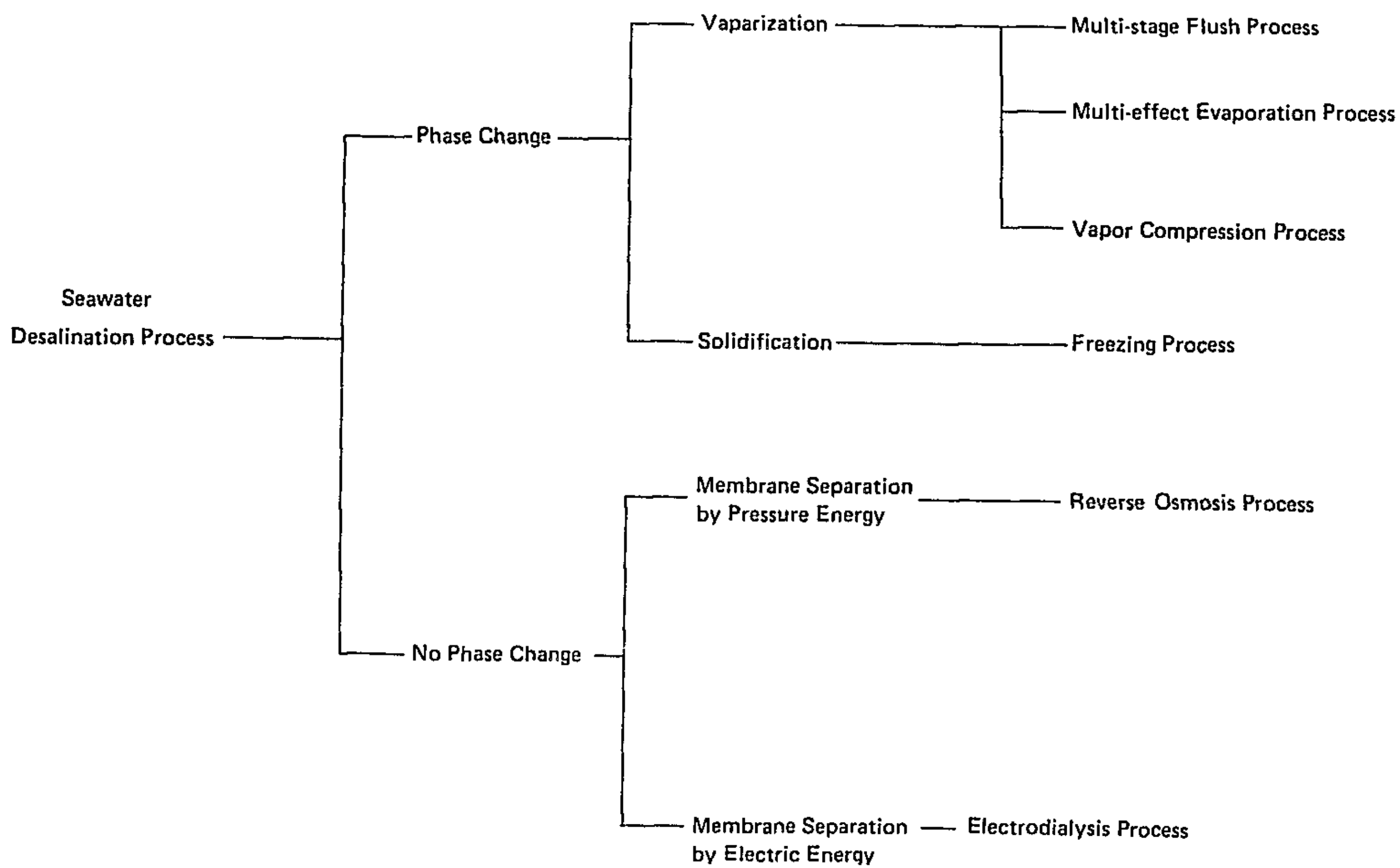


Fig. 4.1 Classification of Seawater Desalination Processes

4.2 Evaporation process

4.2.1 *Principle*

This is a process for obtaining freshwater by heating and evaporating seawater and condensing the generated steam. This process makes effective use of the heat of the generated steam utilizing the fact that the boiling point of seawater varies depending upon the applied pressure. Evaporation processes include the multi-stage flush process, multi-effect process and vapor compression process and they vary in respect to the way in which the generated steam heat is used.

In this survey, the multi-effect process, which is most suitable for the scale of this project, was adopted. The multi-stage flush process is suitable for larger-scale plants, and the vapor compression process for smaller-scale plants.

In the multi-effect process, a number of evaporators are installed to reduce the pressure in successive stages using the heat generated in the higher pressure evaporator as the heat source for the following evaporator.

4.2.2 Process description

The principle of the muti-effect process is shown in Fig. 4.2. The raw seawater sent by the conveying pumps passes through the pre-heater where its temperature is raised, and is then sprayed onto the heating tubes of 1st effect evaporator and partially evaporated by steam passing through the heating tubes. The raw seawater remaining in the 1st effect evaporator is then sprayed onto the heating tubes of the 2nd effect evaporator and partially vaporized by the steam passing through the heating tubes, which was generated in the 1st effect evaporator. The steam generated on the outside the heating tubes of the last effect evaporator is condensed in the condenser, thus ending the series of evaporating operations. The inside of each evaporator is maintained at a progressively higher vacuum going in the direction of the evaporation process by the dearation ejectors, so that the lower the vaporators, the lower the evaporation temperature. In addition the desalination plant with the multi-effect evaporation process has a steam boiler unit for heat supply and an acid dosing unit for preventing from scaling. The process flow is shown in Fig. 4.3. An outline of the plant is:

1) Intake seawater quantity: 27,000 m^3/day
2) Waste water discharge quantity: 24,000 m^3/day
3) Major equipment
    - 2 Multi-effect evaporators
    - 1 steam boiler
    - 2 ejectors
    - 1 ejector condenser
    - 3 tanks

- 14 pumps
- 2 reservoir pits
- 1 sterilization unit

4) Requred space	Approx. 750 m^2 (25 X 30 m)
Total building area:	Approx. 160 m^2
5) Utilities	
Fuel oil:	27,400 kg/day
Electricity:	13,000 kWH/day
6) Chemicals:	Sulfuric acid
	Sodium hypochlorite

4.3 Reverse osmosis process

4.3.1 Principle

There exists a semipermeable membrane to allow water to pass through and retard the passage of dissolved ions and molecules. A tank is divided into two parts with this semipermeable membrane and pure water and aqueous solution contained ions and molecules are fed into each side of the tank respectively. This produces a force to eliminate the concentration difference, thus allowing the pure water to permeate into the aqueous solution through the semipermeable membrane (osmosis phenomenon). This flow continues until the pressure difference between two sides developed by the above permeation reaches the pressure (force) produced by the concentration difference. This pressure difference is called "osmotic pressure." If a pressure higher than the osmotic pressure is applied to the aqueous solution side in the above system, the flow is from the aqueous solution to the pure water which is in the opposite direction to the osmosis phenomenon. This is called reverse osmosis. Its principle is illustrated in Fig. 4.4.

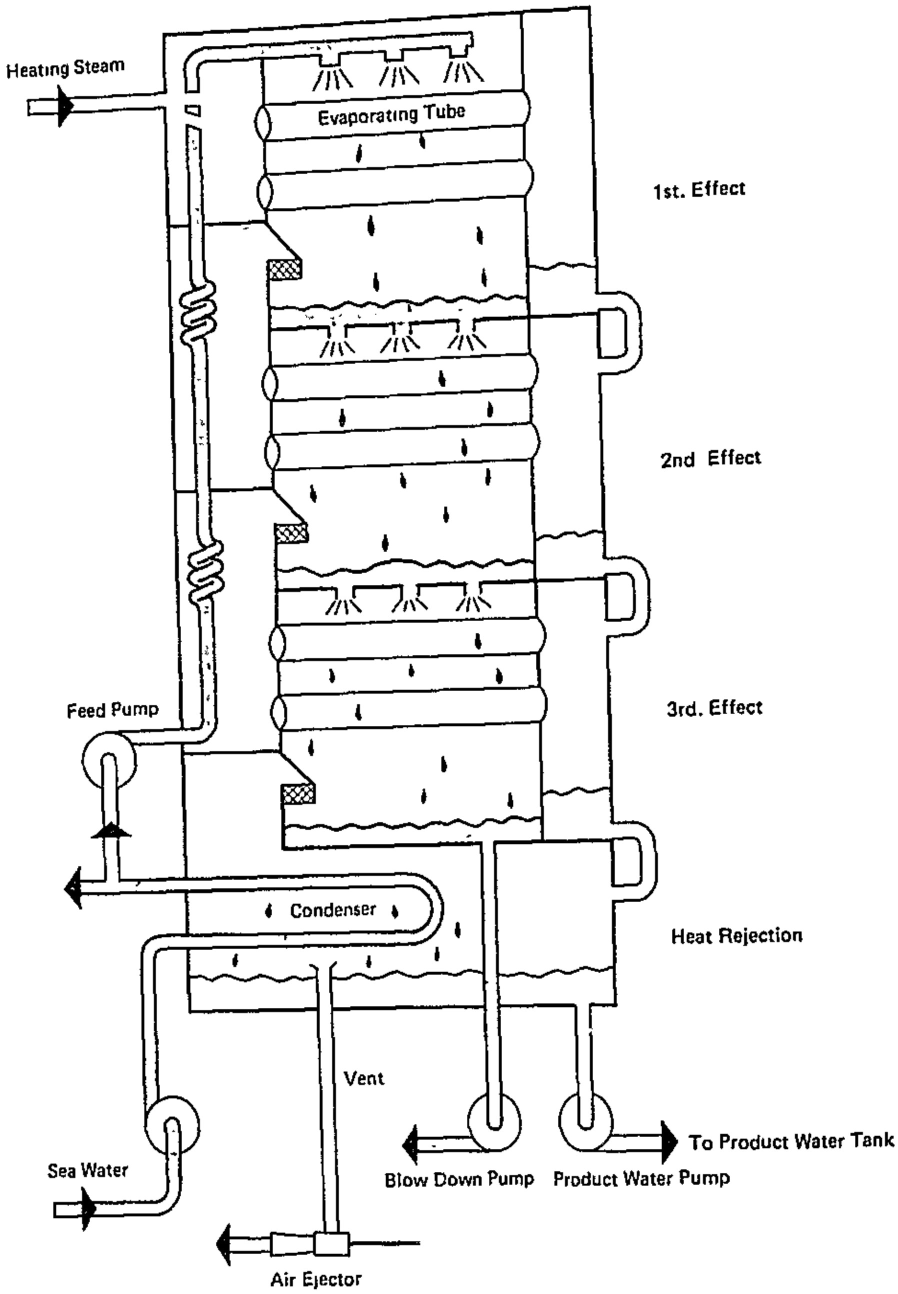


Fig. 4.2 Princple of Multi-Effect Evaporation

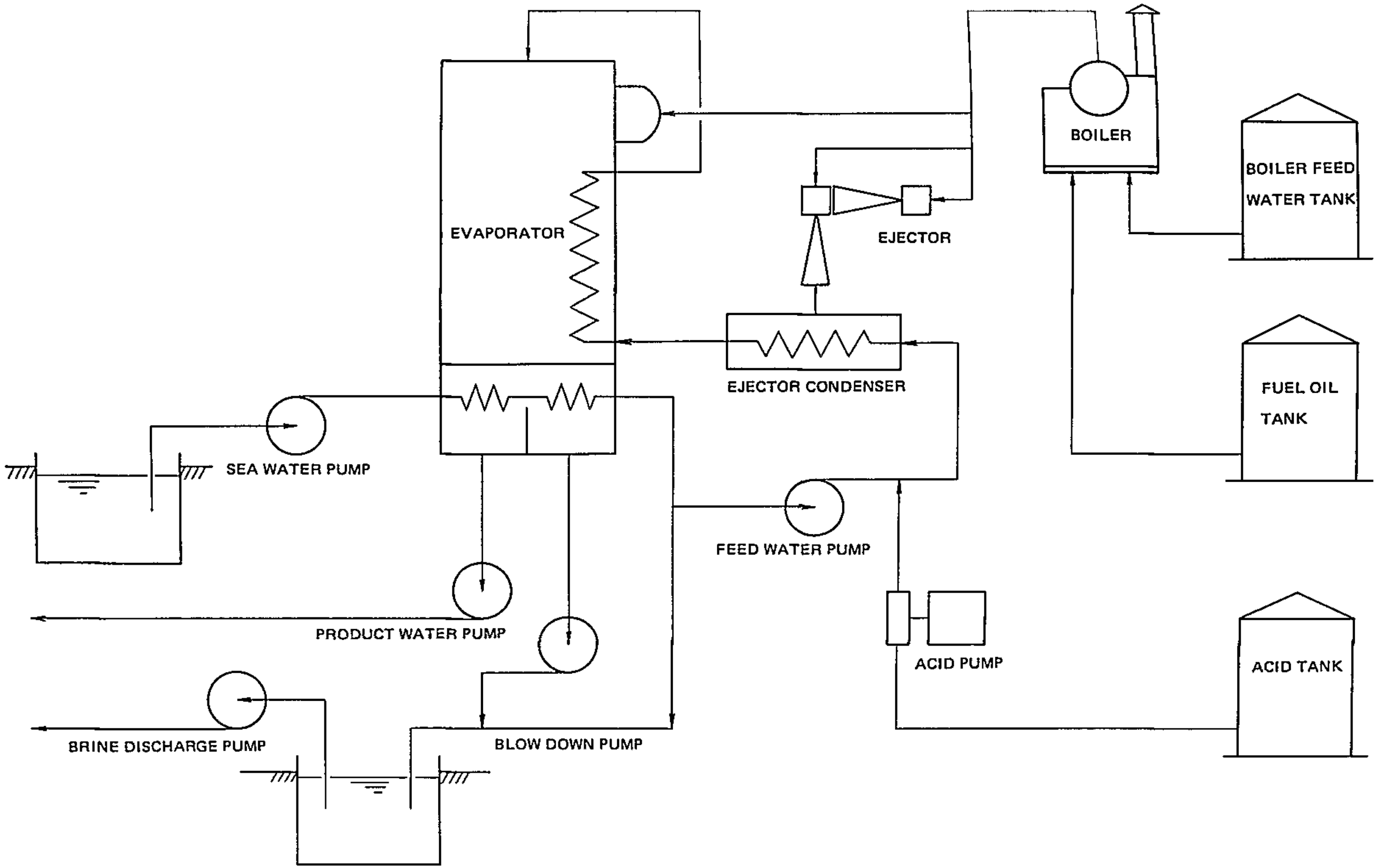


Fig. 4.3 Schematic Flow Diagram of Multi-Effect Evaporation Process

4.3.2 Process description

The desalination plant by the reverse osmosis process consists of a pretreatment unit and reverse osmosis unit. In the preteatment unit, after sterilization of raw seawater, turbid substances in raw seawater are coagulated by addition of coagulant and then removed from the seawater via dual media filter. The reverse osmosis unit consists of the power recovery turbine, alkali dosing unit for ajusting the product water pH, and reverse osmosis module cleaning unit, and reverse osmosis modules. Fig. 4.5 shows the flow of Reverse osmosis process. The outline of the plant is:

1) Intake seawater quantity: 9,000 m^3/day
2) Waste water discharge quantity: 6,000 m^3/day
3) Major equipment
   a) Pre-treatment unit
      - 3 dual-media filters
      - 3 cartridge filters
      - 1 chlorine generator
      - 4 tanks
      - 17 pumps
      - 2 blowers
      - 2 reservoir pits
   b) Reverse osmosis unit:
      - 2 reverse osmosis modules
      - 3 high-pressure pumps with power recovery turbine
      - 3 pumps
      - 1 tank
      - 1 reverse osmosis module cleaning unit
      - 3 reservoir pits
4) Required space: Approx. 800 m^2 (25 X 32 m)
   Total building area: Approx. 500 m^2
5) Utilities
   Energy: Electricity: Approx. 21,200 kWH/day
6) Chemicals: Ferric chloride
   Sulfuric acid
   Caustic soda

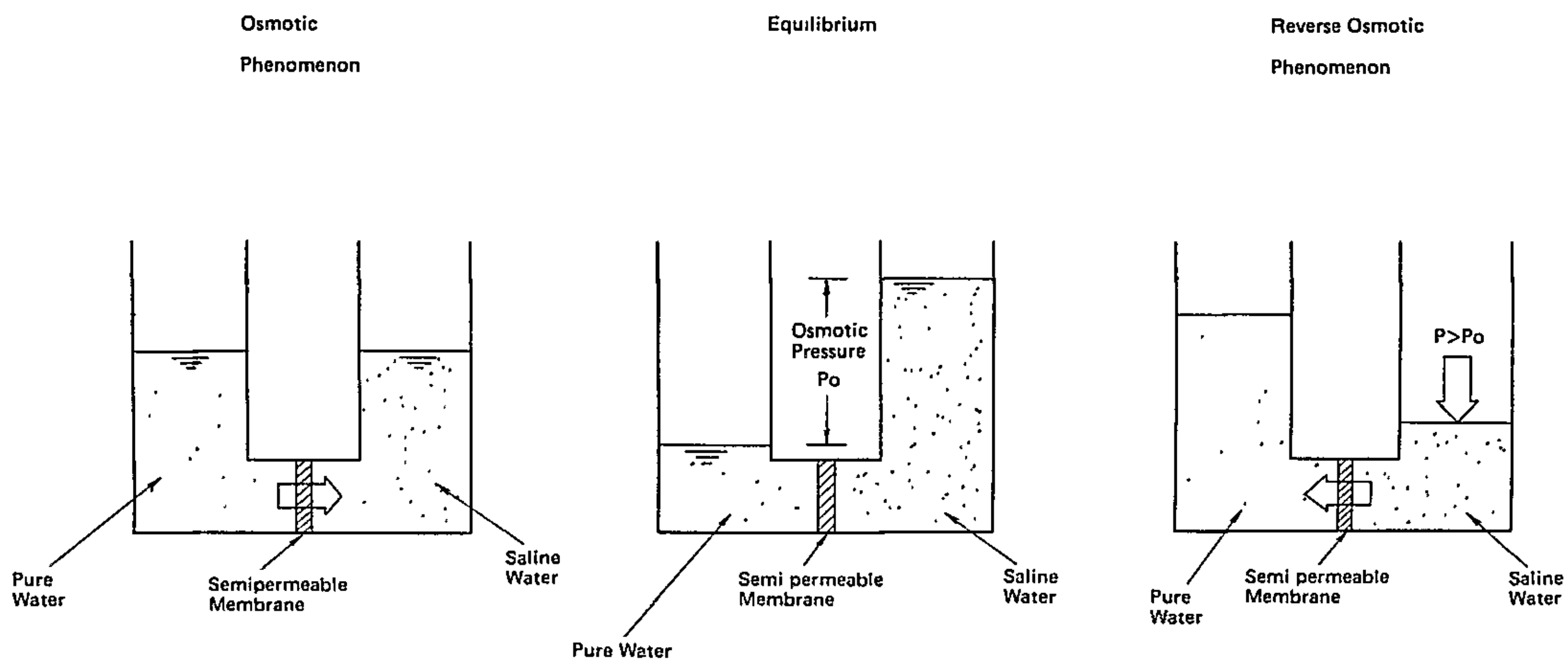


Fig. 4.4 Principle of Reverse Osmosis

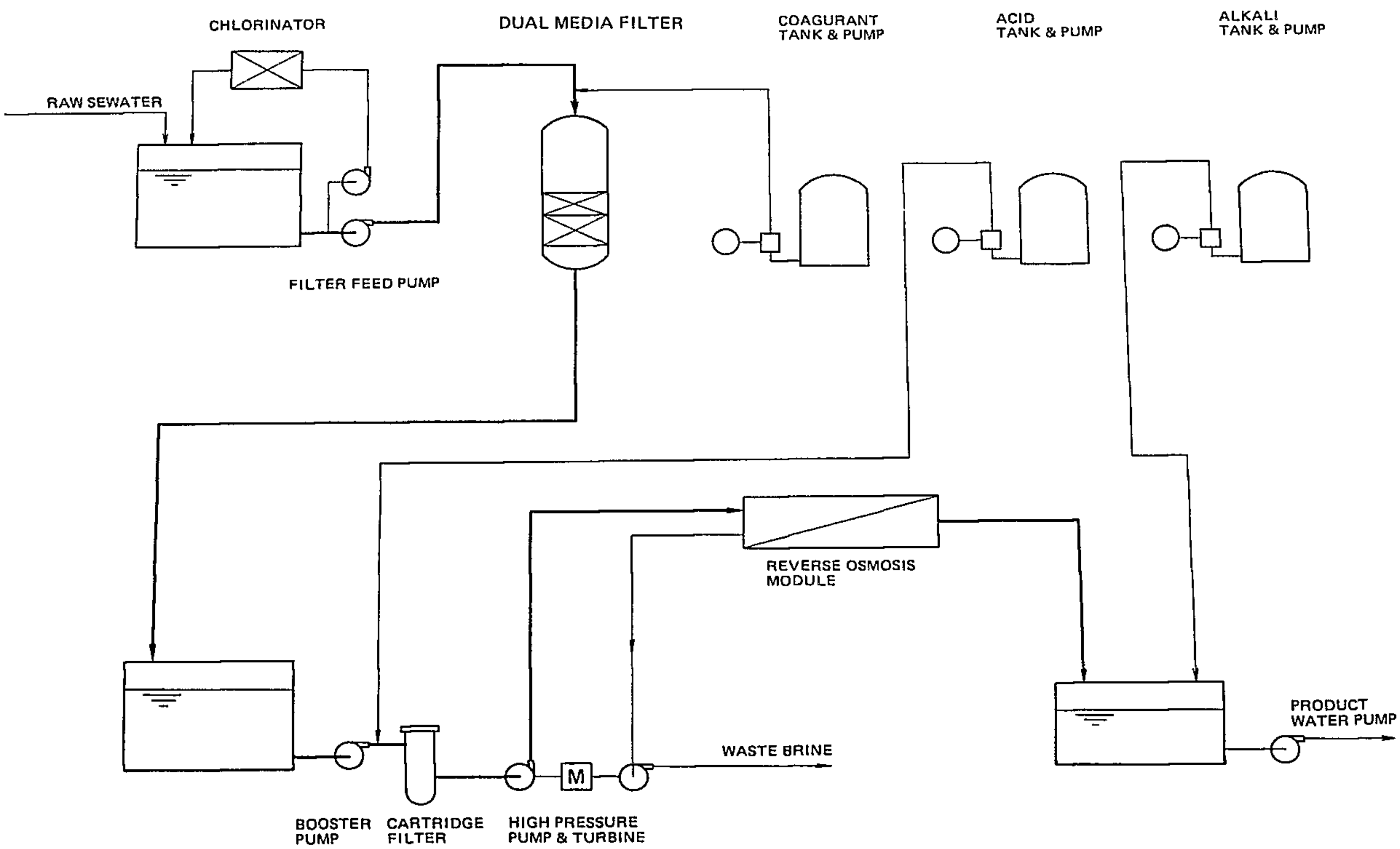


Fig. 4.6 Schematic Flow Diagram of Reverse Osmosis Process

4.4 Electrodialysis process

4.4.1 Principle

An outline of the electrodialysis process is as shown in Fig. 4.6. Namely, the cation and anion exchange membranes are placed alternatively – the former can permeate only the cation and the latter only the anion. Aqueous solution containing numerous ions, such as seawater, is fed into the compartments between these two membranes. Further, placing the electrodes at both ends of such aligned membranes, they are energized by direct current. Of the ions contained in the water inside the compartments between the two membranes, the cations flow in the direction of the current, while the anions flow in the opposite direction. The ions are then selectively permeated through the membranes, depending upon the kind of membrane. Consequently, the raw seawater in the compartments is alternatively separated into two groups, namely, desalinated water and concentrated seawater, thus giving fresh water.

4.4.2 Process description

The equipment under the electrodialysis process consists of a pre-treatment unit and electrodialysis unit. In the pre-treatment unit, turbid substances are removed from the seawater via the sand filter. The electrodialysis unit has an acid dosing unit to neutralize caustic soda generated in the cathode compartment, a chemical dosing unit to reduce chlorine generated in the anode compartment, and an electrodialyzer unit. Fig. 4.7 shows the process flow. The outline of the plant is:

1) Intake seawater quantity: 6,400 m^3/day
2) Waste water discharge quantity: 3,400 m^3/day
3) Major equipment:
   a) Pre-treatment unit:
      - 2 sand filters
      - 6 cartridge filters
      - 16 pumps
      - 2 reservoir pits
   b) Electrodialysis unit:
      - 10 electrodialyzer units
      - 10 rectifiers
      - 3 tanks
      - 10 pumps
      - 2 reservoir pits
      - 1 sterilization unit
4) Required space: Approx. 2,000 m^2 (50 X 40 m)
   Total building area: 1,100 m^2
5) Utilities:
   Electricity: Approx. 30,000 kWH/day

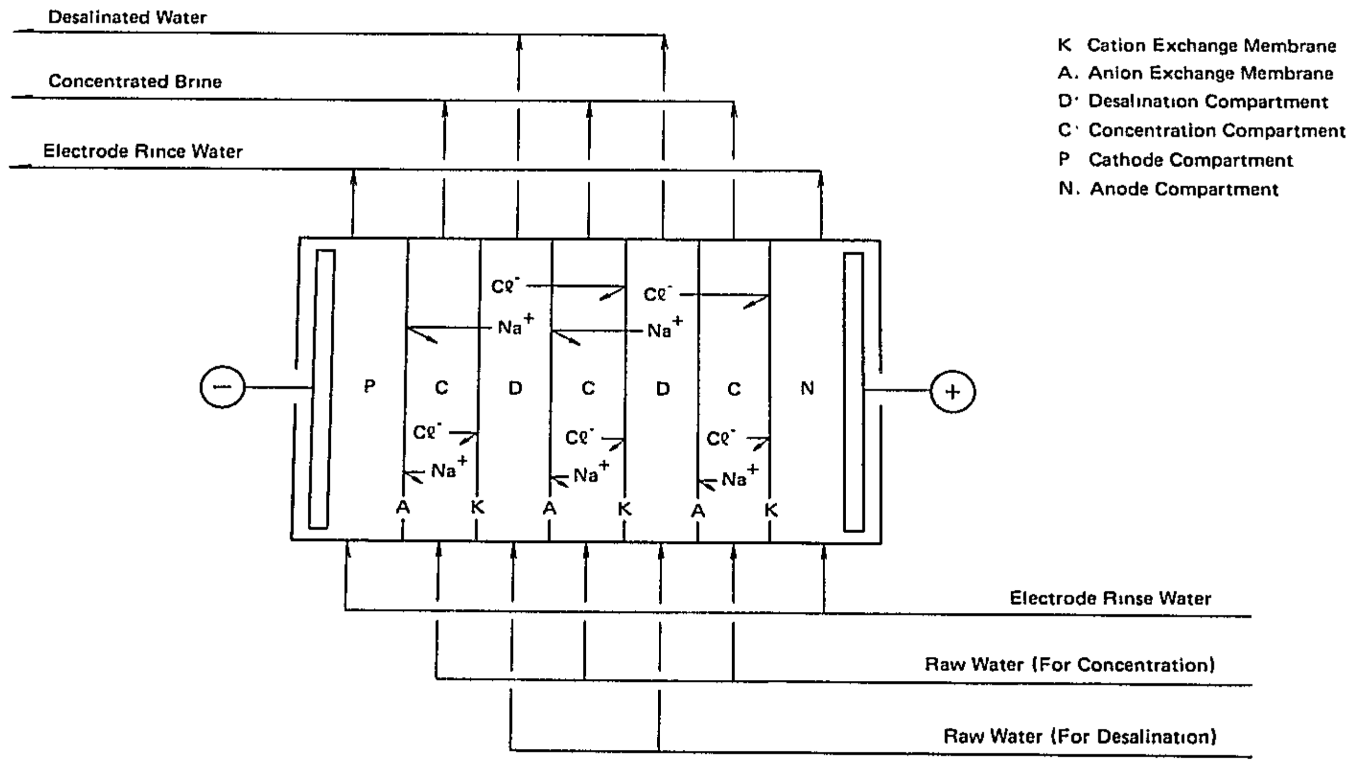


Fig. 4.6 Principle of Electrodialysis

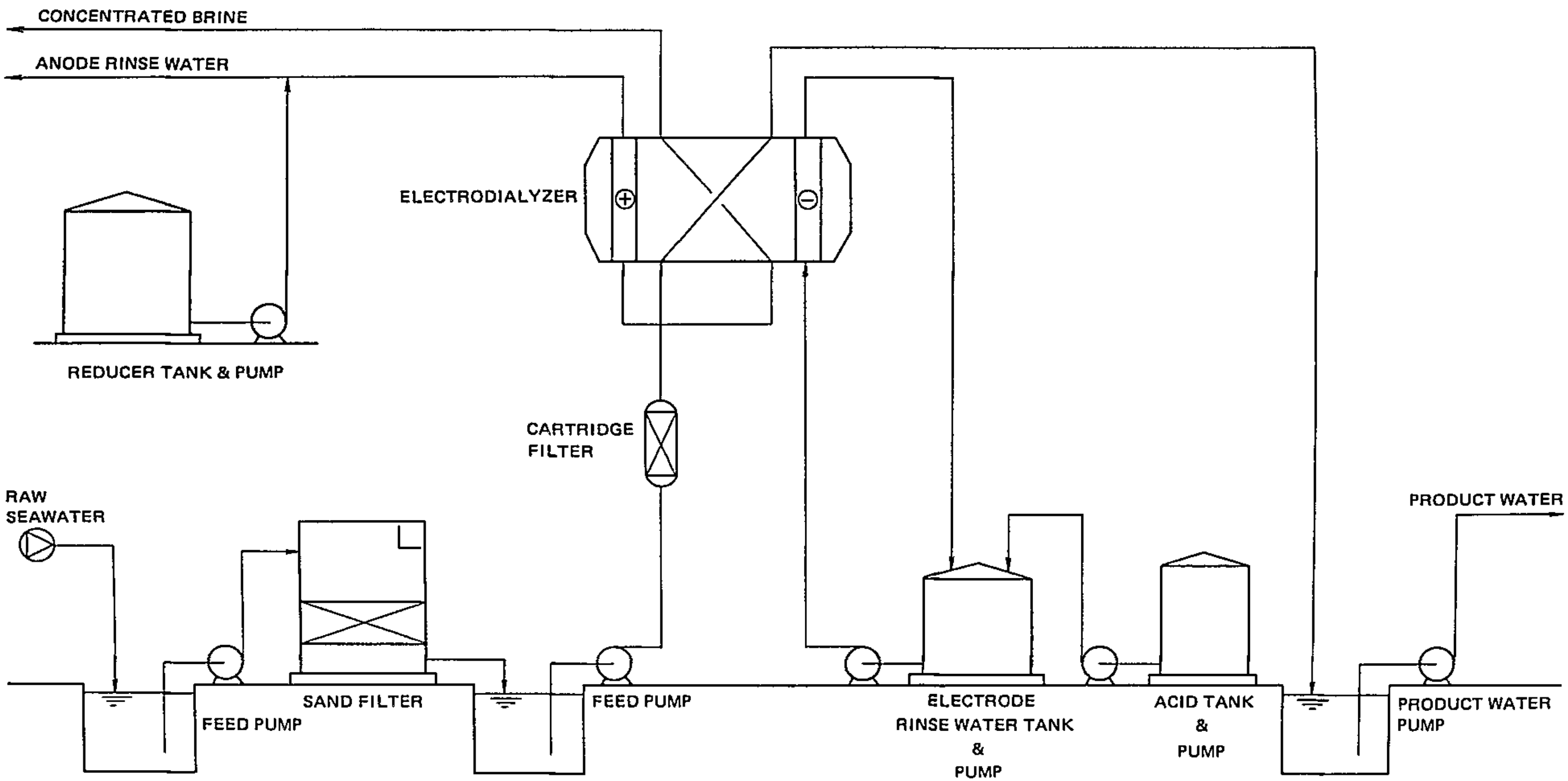


Fig. 4.7 Schematic Flow Diagram for Electrodialysis Process

6) Chemicals: Sodium hypochlorite
Sulfuric acid
Sodium bisulfite

4.5 Process comparison

4.5.1 Plant construction cost

The total plant construction cost for reverse osmosis process is the most inexpensive. This total plant construction cost can be broken down into the desalination facility and other auxiliary facilities. A comparison of each facility is as follows:

1) Desalination facility

The cost of a desalination facility including the civil and building construction work is the same for both the reverse osmosis and evaporation processes. Electrodialysis process costs about 135 % of the above two processes.

2) Other auxiliary facilities

The total cost of auxiliary facilities including seawater intake unit, waste water discharge unit etc. is:

Electrodialysis process	85% of reverse osmosis process
Evaporation process	145% of reverse osmosis process

The cost of such facilities for the electrodialysis process is the cheapest because of smaller quantity of intake seawater. On the other hand, the evaporation process requires a huge amount of seawater for cooling purposes thus resulting in the highest cost for intaking seawater and discharging waste water.

Table 4.1 below shows a comparison of plant construction cost among these three processes, and the percentage of the cost of each facility to the total plant construction cost.

Table 4.1 Comparison of Plant Construction Cost

Item \ Process	Reverse Osmosis	Evaporation	Electrodialysis
Plant Cost Index	100	114	121
Desalination Facility	(70)	(70)	(95)
Auxiliary Facility	(30)	(44)	(26)

4.5.2 Operation cost

The total operation cost for the reverse osmosis process is the most inexpensive. The total operation cost for seawater desalination plant can be broken down into:

- Operating labor cost
- Utility cost
- Chemical cost
- Maintenance cost

The operating labor cost is exactly the same for each process, as about two operators per shift are required for the plant..

1) Utility cost

The evaporation process requires both fuel oil and electricity, but the other two process consume only electricity. Table 4.2 below shows the energy consumption per cubic meter of product water by each process. The electric power consumption for the evaporation process in this project is higher than usual mainly because the candidate plant sites are in an inland area, thus requiring a large amount of electricity for sea-water intake and discharging waste water.

The utility cost is:

- Evaporation process   5.6 times of reverse osmosis
- Electrodialysis process   1.4 times of reverse osmosis process

Table 4.2 Comparison of Energy Consumption

Energy \ Process	Reverse Osmosis	Evaporation	Electrodialysis
Electricity (KWH/m^3 Product Water)	7.0	4.3	10 0
Fuel Oil (Kg/m^3 Product Water)	0	9.1	0

2) Chemical cost

The chemical consumption of the electrodialysis process is the highest among these three processes being 3.9 times of the reverse osmosis process. This is chiefly attributable to the fact that sodium bisulfite to be used is difficult to acquire locally, and the price is expensive. Meanwhile, the evaporation process consumes small amounts of chemicals, thus resulting in the lowest chemical cost. The chemical cost is relatively small compared with the utility cost. In the case of the reverse osmosis process, for example, the chemical cost is about 15% of the utility cost.

3) Maintenance cost

Both the reverse osmosis process and the electrodialysis process require the annual

replacement of membranes, in addition to general maintenance costs, thus resulting in higher maintenance costs than that for the evaporation process.
The maintenance cost for the evaporation process is 56% of that for the reverse osmosis process, while that for the electrodialysis process is 162 %.
Table 4.3 below shows a comparison of total running cost including utility, chemical and maintenance costs, and the percentage of each category to the total running cost, for these three processes.

Table 4.3 Comparison of Operation Cost

Items \ Process	Reverse Osmosis	Evaporation	Electrodialysis
Operation Cost Index	100	413	170
Utility Cost	(70)	(390)	(100)
Chemicals Cost	(10)	(10)	(39)
Maintenance Cost	(20)	(13)	(31)

4.5.3 Operability

There is not so much difference in operability during normal operation among these three processes. In case of an emergency shutdown, however, the reverse osmosis process can be restored to normal condition in the easiest and quickest manner, since the plant under the reverse osmosis process is operated only through the fluid handling by means of pumps.

4.6 Selection of most suitable process

The results of the foregoing study are shown in Table 4.4 below.

Table 4.4 Comparison and Evaluation of Studied Processes

Item \ Process	Reverse Osmosis	Evaporation	Electrodialysis
Initial Cost Index	100	114	121
Operation Cost Index	100	412	164
Operability	Easy	Fairly Easy	Fairly Easy
Overall Evaluation	Most Suitable	–	-

The reverse osmosis process has been selected as most suitable process for this project, because of:

- the most inexpensive plant cost
- the lowest operation cost
- good operability

The evaporation process is advantageous for a large-scale plant having a capacity of about several ten thousands cubic meters per day, since the heat efficiency can be attained by the integration with the electric power generation, but this superiority cannot be demonstrated with a plant of the capacity projected in this study.

Further, the electrodialysis process has a good performance with the water of low salf content but it is not economical in seawater desalination, since it electricity consumption is quite high.

Chapter 5: Site Selection

5.1 Summary of candidate sites

The following three sites in the urban section in the northern part of San Andres Island have been selected as candidate sites for this project as shown in Fig. 5.1.

1) Site A: Taller
2) Site B: Plaza de Mercado
3) Site C: Campamento

These candidate sites are close to each other, each situated in the inland area, one to several hundred meters from the San Andres coastline. They are also several hundred meters from the service reservoir at El Cliff from which the potable water is distributed to the San Andres area. Fig. 5.1 shows the locations of each candidate site and the service reservoir. The feature of each candidate site is summarized below.

1) Site A: Taller

   Of the three candidate sites, this site is situated farthest from coastal line, but in the vicinity of this site, there are a small number of houses, and has adequate space as a plant site. The owners of this estate are EMPOISLAS and Intendencia jointly.

2) Site B: Plaza de Mercado

   This site is situated in the urban zone and is of a small area. It is owned by EMPOISLAS.

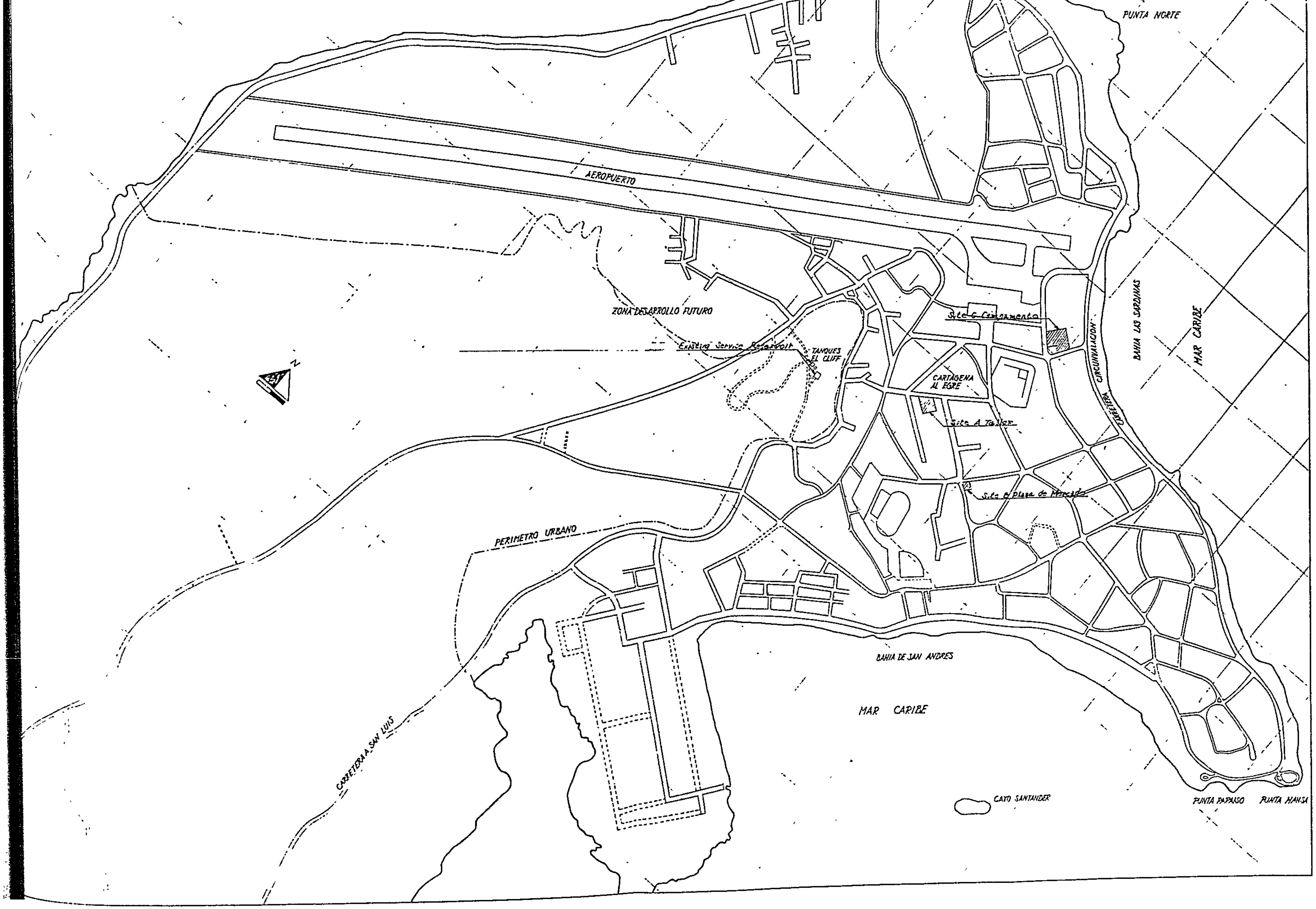
3) Site C: Campamento

   This site is the nearest to the sea. Close to this site, there is no house and the largest total area. It is owned jointly by Intendencia and the tourism corporation. There is an EMPOISLAS field office at present within the premises (total area: 1,300 m^2). Table 5.1 below shows the total premises area of each candidate site.

Table 5.1 Area of Each Site

Site	A Taller	B Plaza de Mercado	C Campamento
Area m^2	1,400	500	7,500

Fig. 5.1 Location of Candidate Plant Sites.
and Existing Service Reservoir.



5.2 Comparative study of candidate sites

Study items for determining the plant site are:

1) Size of site

Site B is too small as a plant site. To construct the plant within this premise by multi-story construction may be possible. However, this is quite uneconomical, as the construction cost is too high. Site A looks slightly small, if future expansion is considered.

Site C has a sufficient area, even if future expansion is considered.

2) Availability of the premises

Considering from the current status of premises ownership, superiority is in the order of Site B, Site A and Site C. According to EMPOISLAS, this item is not an important factor for selecting the plant site and any site can possibly be acquired.

3) Seawater intake

Since private houses are situated close to Site B, the seawater intake wells is not likely to be installed in the vicinity of Site B.

As for sites A and C, the seawater intake wells seem to be installed close to the sites because of having no private houses around the sites, but, at site A, it would be necessary to drill wells deeper than at site C, because it is situated in a more inland area.

4) Economic comparison of waste water discharge, product water transfer and electricity supply.

The cost of piping work for waste discharge and product water transfer, as well as the cost of cabling for electric power supply, depend greatly upon lengths of piping/wiring.

Table 5.2 below shows the piping and cabling distances, and a comprehensive economic comparison of each site. Although, owing to the sites being situated closely to each other, there are no large economic differences among them, site C is slightly more advantageous.

Table 5.2 Comparison of Piping/Wiring Length and Investment Cost for Waste Discharge, Product Transfer and Power Supply.

Item \ Site	A Taller	B Plaza de Mercado	C Campamento
Piping Length for Waste Discharge m	1,800	1,900	1,200
Piping Length for Product Transfer m	1,000	1,100	1,600
Wiring Length for Power Supply m	1,700	1,800	2,300
Comparison of Total Investment Cost for 3 Items Mentioned above	105	105	100

5) Accessibility for construction and maintenance work

It is necessary to mobilize equipment and materials at the site for the construction and maintenance work.

Site A has no obstacles around the site, but the access road condition is slightly bad.

Site B is situated at a corner in densly built-up area and access road is narrow.

Site C has no obstacle around the site, has good access roads, and is also near main roads.

5.3 Overall assessment and selection of plant site

Site C is considered to be the most suitable plant site by reason of the following advantages, although the lengthes of piping for the product water transfer and of cabling for electric power supply are slightly longer than those in other sites.

Advantages

- The area are sufficiently large.
- Seawater intake is easy.
- Only a short run of piping is necessary for discharging the concentrated brine
- There is easy access to the site.

The results derived throughout the above-mentioned study are summarized in Table 5.3 below.

Table 5.3 Comparison and Evaluation of Candidate Plant Sites

Item \ Site	A Taller	B Plaza de Mercado	C Campamento
Area Size of Site	Enough	Critically small	Enough
Availability of Site	B	A	C
Seawater Intake	B	C	A
Comparison of Cost for Waste Discharge, Product Water Transfer and Power Supply	105	105	100
Accesibility for Construction and Maintenance	Rather easy	Rather difficult	Easy
Overall Evaluation	Appropriate	Inappropriate	Most appropriate

Chapter 6: Outline of Prpposed Plant

6.1 General

6.1.1 Equipment configuration

The proposed plant consists of the following equipment.

1) Seawater intake facility
   Pretreatment unit
   Reverse osmosis unit
2) Auxiliary facilities
   Water intake unit
   Product transfer unit
   Waste discharge unit
   Cable for power receiving

The flow sheet of these facilities is given in Fig. 6.1 and the layout plot plan and building plan are shown in Fig. 6.2.

6.1.2 Water balance

The water balance of the proposed plan, given in Fig. 6.3, is summarized below.

1) Water intake: 9,000 m^3/day
2) Product output: 3,000 m^3/day
3) Waste discharge: 6,000 m^3/day

6.2 Process description

6.2.1 Seawater intake

The raw seawater pumped from three wells installed close to Campamento is stored in the raw seawater basin. The sodium hypochlorite generated by electrolysis is added to raw seawater to prevent the growth of micro-organisms and algae in the seawater.

6.2.2 Pretreatment

And then ferric chloride is added to raw seawater to coagulate the turbid substances. The coagulated turbid substances are removed through the dual media filters from seawater. Three filters are used in parallel and each is back-washed once a day. The pH value of the filtered water is adjusted between 5.5 and 6.5 by addition of sulfuric acid, and then stored in the filtered water basin. The waste water from filter back wash is also transferred and stored in the waste water basin.

6.2.3 Desalination

The filtered water stored in the basin is sent via a booster pump into the cartridge filter where it undergoes final filtering. It is then sent into the suction side of the high-pressure pump where it is pressurised to 55 – 60 kg/cm^2. The flow and pressure of the

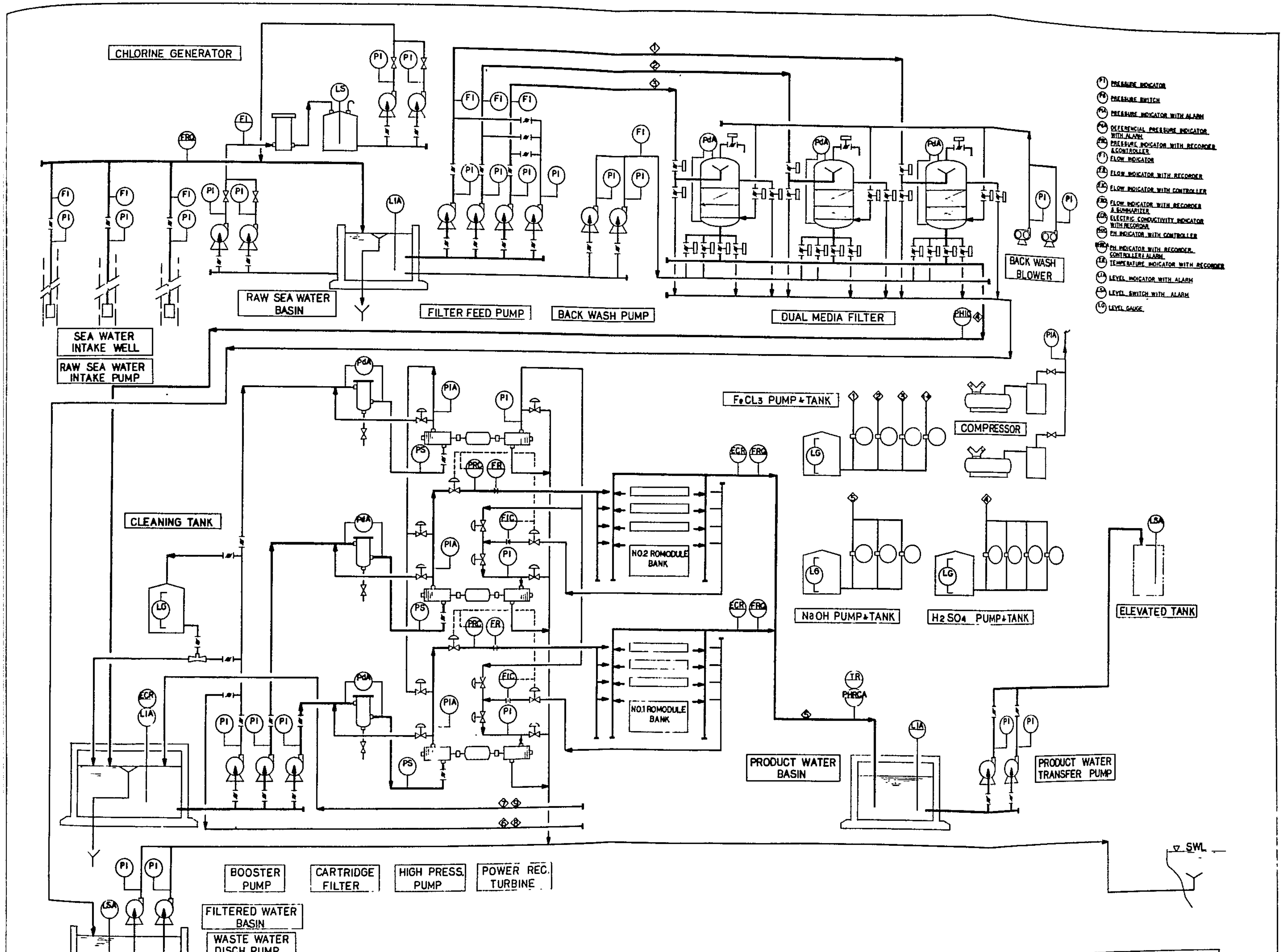
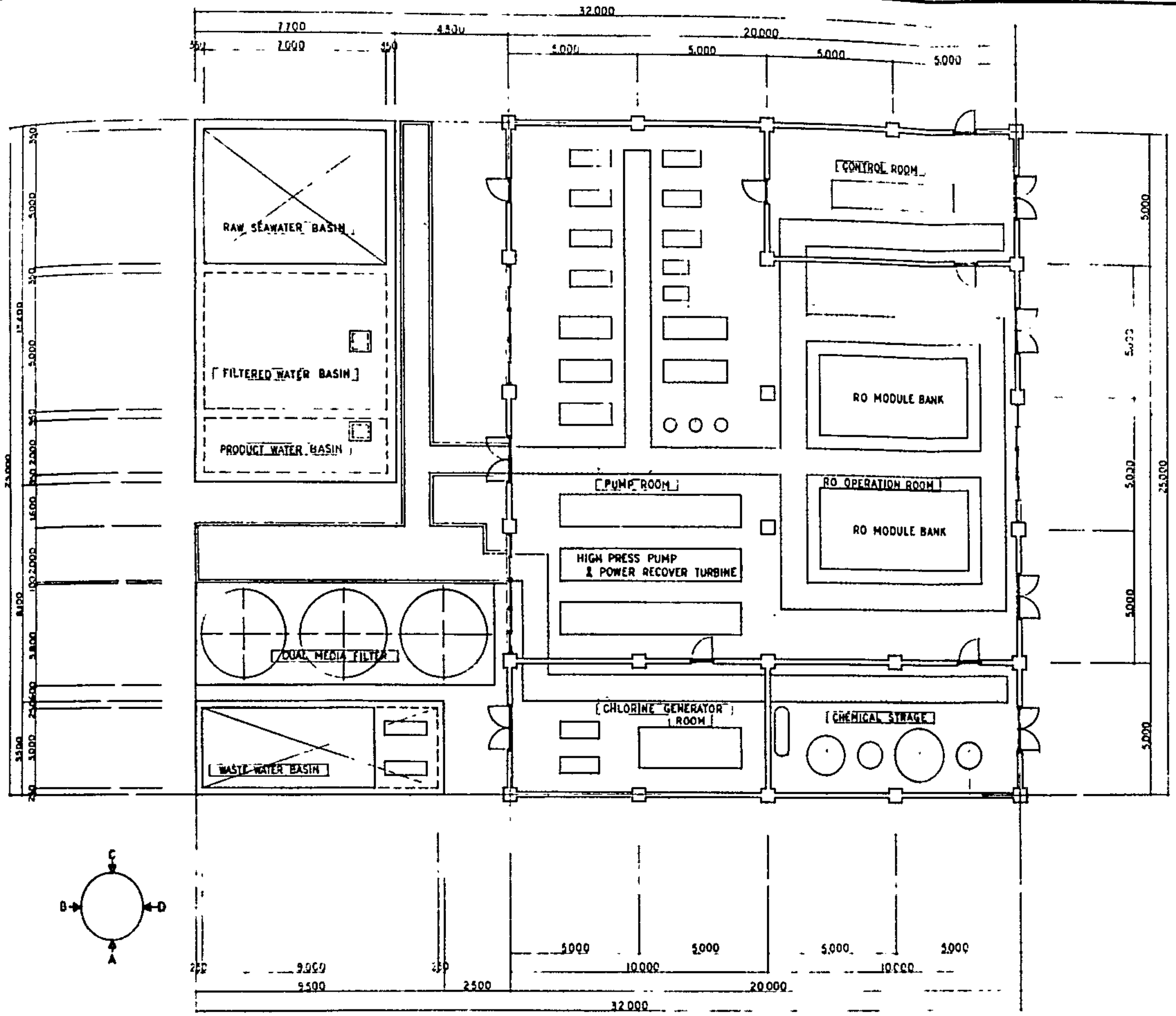
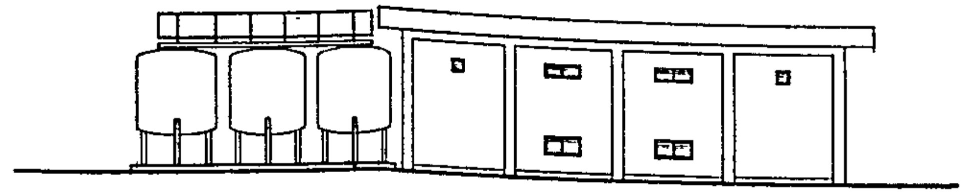


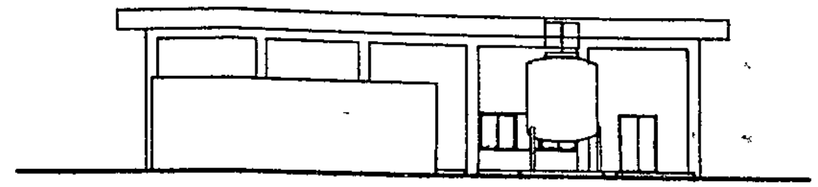
Fig 6.1 FLOW SHEET



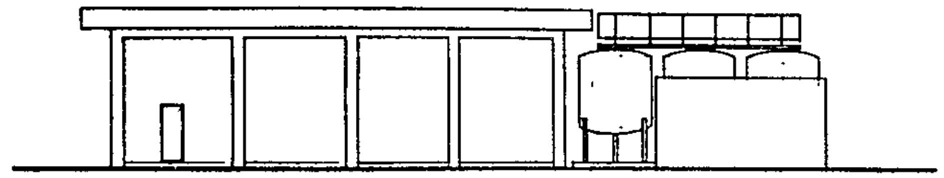
PLAN 1:100



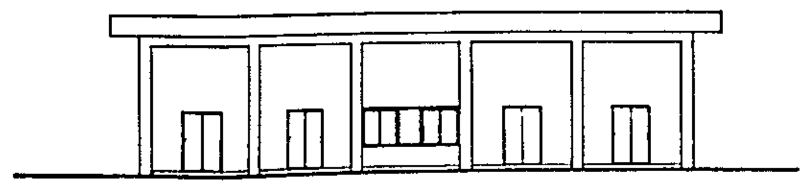
A ELEVATION 1:150



B ELEVATION 1:150



C ELEVATION 1:150



D ELEVATION 1:150

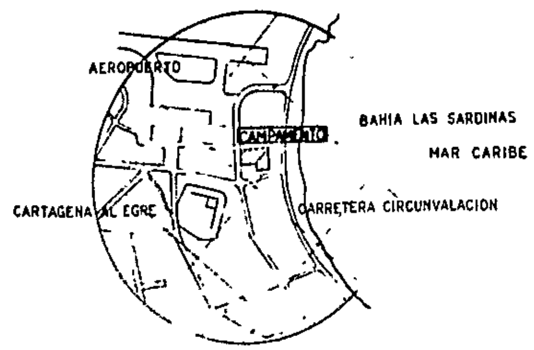
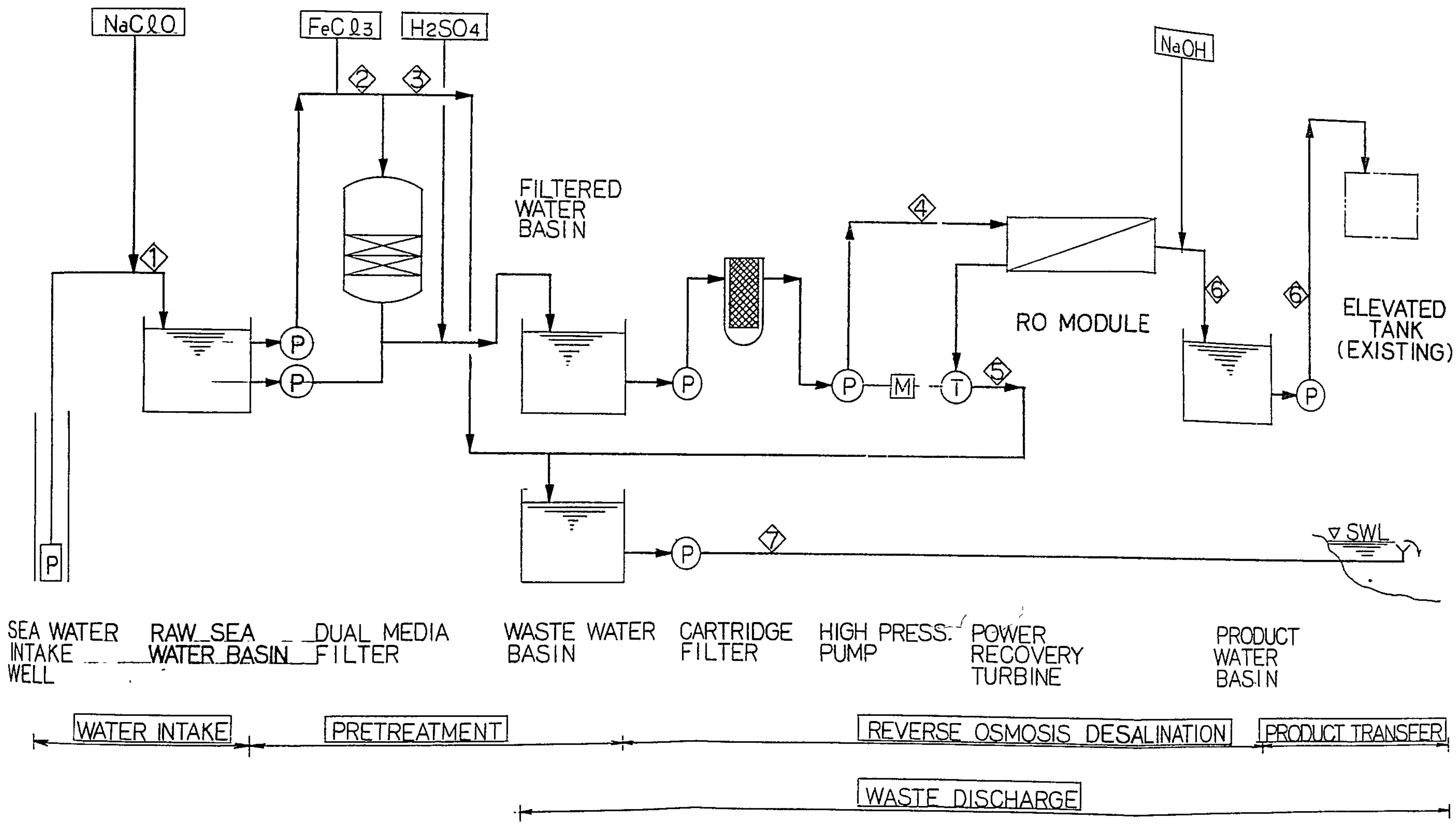


FIG 6.2 LAY OUT PLOT PLAN & BUILDING PLAN



NO	1	2	3	4	5	6	7
FLUID NAME	RAW SEA WATAR	FILTER FEED	BACK WASH WATER	RO MODULE FEED	CONCENTRATED BRINE	PRODUCT WATAR	WASTE WATER
FLOW RATE (M3/DAY)	9.000	9.000	430	8.570	5.570	3.000	6.000

Fig. 6.3 WATER BALANCE

seawater are then regulated and the seawater sent into the reverse osmosis module unit where it is separated into desalinated water (product water) and concentrated brine. As the concentrated brine is discharged at the residual pressure of 56 – 58 kg/cm^2, its flow rate is regulated, then the brine is introduced to the power recovery turbine where waste power is recovered for energy saving. The power recovery ratio with this turbine is approximately 25%.

The pH value of the product water decreases due to the effect of carbonate and bicarbonate dissolved in the seawater. The product water having pH value of 4.8 – 5.2 is discharged from the modules. And then caustic soda solution is added to adjust the pH value between 7.0 and 7.5. The product water is stored into the product water basin.

The reverse osmosis module unit is cleaned at least once every six months with citric acid and aqueous ammonia.

6.2.4 Product water transfer

The product water stored in the product water basin is transferred to the existing service reservoir at El Cliff where it is mixed with ground water from the existing wells, then distributed to each subscriber.

6.2.5 Waste water discharge

The waste water from filter back wash, and waste water from other sources are pumped out and discharged at Punta Norte, together with the concentrated brine discharged from the reverse osmosis module unit.

6.3 Major equipment summary

The major equipment in each facility is listed in Table 6.1. And the layout plot plan and building plan are shown in Fig. 6-3. The major equipment of this proposed plant is summarized, as follows:

6.3.1 Total required space:	800 m^2 (32x25 m)
6.3.2 Total required electricity:	1,200 kVA (13.2 kV, 3ϕ, 60 Hz)

6.3.3 Building

1) Outside dimensions:	25 x 20 x 6 (H) m (500 m^2)
2) Structure:	Reinforced concrete block walls, flat building

3) Auxiliary equipment:
   a) Lighting
   b) Geared trolley, 1 ton

c) Wall fan

d) Air conditioner

6.3.4 Seawater intake method:	Well method
1) Total head:	4,500 m^3/day/well x 3 wells (one for standby)
2) Well specification:	300ϕ mm x 60 m depth
3) Chemicals to be used:	Sodium hypochlorite (by chlorine generator)
Dosage:	2 – 5 ppm

Table 6.1 Major Equipment List

Sec. No.	Designation	Req'd No. Wrk'g	Req'd No. Std-by	Matr'l	Specification	Remarks
A.	Water Intake Unit					
	. Raw sea water intake pump	2	1	SUS316	Multi-stage centrifigal/submerged type 3.2 m^3/min x 50 mAq x 55 kW	
	. Chlorine generator	1	0	Ti/carbon /FRP.	Electrolysis type 0.75 kg/H (Nor.), 7.7 kW (Accessory) . Degassing tank . Generator feed pump . Chlorine injection pump	
B	Pretreatment Unit					
	. Filter feed pump	3	1	SUS316	Centrifugal 2.1 m^3/min. x 20 mAq x 15 kW	
	. Back wash pump	1	1	SUS316	Centrifugal 4.2 m^3/min. x 20 mAq x 30 kW	
	. $FeC\ell_3$ pump	3	1	PVC/Teflon	Diaphragm 5 – 50 mℓ/min. x 20 mAq x 0.1 kW	
	. H_2SO_4 pump	3	1	PVC/Teflon	Diaphragm 10 – 100 mℓ/min. x 20 mAq x 0.1 kW	
	. Back wash blower	1	1	C.I.	Roots blower 4.2 Nm^3/min. x 5000 mmAq x 7.5 kW	
	. Compressor	1	1	C.I.	Baby compressor 600 Nℓ/min. x 7 kg/cm^3 x 7.5 kW	
	. $FeC\ell_3$ tank	1	0	FRP	1 m^3 1000 ϕ x 1480 H	
	. H_2SO_4 tank	1	0	CS	6 m^3 2000ϕ x 2400H	
	. Dual media filter	3	0	CS (Rubber lining)	Dual media pressure filter 3250ϕ x 3000H	
C	Reverse Osmosis Unit					
	. Booster pump	2	1	SUS316	Centifugal 3.0 m^3/mix. 25 mAq x 22 kW	
	High pressure pump	2	1	SUS316	Multi-stage turbine 3.0 m^3/min. x 60 kg/cm^2 x 500 kW	
	. Power recovery turbine	2	1	SUS316	Multi-stage turbine 1.95 m^3/min. x 54 kg/cm^2	
	. NaOH pump	2	1	PVC/ Telfon	Diaphragm 5 – 50 mℓ/min. x 20 mAq x 0.1 kW	

Sec. No.	Designation	Req'd No.		Matr'l	Specification	Remark's
		Wrk'g	Std-by			
	. Cartridge filter	2	1	SUS316	Vertical type 10 μ x 264 pcs.	
	. Cleaning tank	1	0	FRP	2 m^3 1200φ x 2020H	
	. NaOH tank	1	0	FRP	1 m^3 1000φ x 1480H	
	. Reverse osmosis module	186	0	CTA/ FRP	Hollow fiber type 305φ x 2700L (HM8255)	
D.	Product Transfer Unit . Product transfer pump	1	1	C.I.	Multi-stage centrifugal 2.5 m^3/min. x 100 mAq x 75 kW	
E.	Waste Discharge Unit . Waste water discharge pump	1	1	SUS316	Centrifugal 0.6 m^3/min. x 40 mAq x 11 kW	
F.	Civil & Building (Concrete Basin)					
	. Raw sea water basin	1	0	RC	130 m^3 6 m x 6 m x 4 m(H)	
	. Filtered water basin	1	0	RC	130 m^3 6 m x 6 m x 4 m(H)	
	. Product water basin	1	0	RC	50 m^3 6 m x 2.4 m x 4 m(H)	
	. Waste water basin	1	0	RC	50 m^3 3 m x 9 m x 2 m(D)	
	(Building)	1	0	RC/ Block	25 m x 20 m x 6 m(H) (Accessories) 1) Illumination 2) Geared trolley (1 ton) 3) Wall fan 4) Air conditioner	

6.3.5 Pretreatment method: Inline coagulation and filtration

1) Filter type: Dual media pressure filter made by carbon steel

2) Filtration materials:

a) Anthracite (0.9ϕ mm)

b) Sand (0.45ϕ mm)

3) Linear velocity: 15 m/hr

4) No. of filters: 3 units for normal operation

5) Dimensions: 3,250ϕ x 3,000 H mm

6) Coagulant/dosage: Ferric chloride/3 – 6 ppm

7) Type of back wash: Automatic back wash with timer

8) Frequency of back wash: Once per day for each

9) Linear velocity for back wash: 30 m/hr

10) Back wash time: 45 min./unit

11) Filtrated water quality: 4 or below in Fouling Index

6.3.6 Desalination process: Reverse osmosis process

1) Product water capacity: 3,000 m^3/day (1,500 m^2/day x 2 trains)

2) Module to be used: Cellulose-triacetate hollow fiber module for single stage desalination

3) Module performance:

a) Product water capacity: 25 m^3/day/module (at 35,000 ppm NaCl solution/25°C/ 55 kg/cm^2)

b) Rejection: 99% or more (at the same conditions mentioned above)

4) Module operating condition:

a) Operating pressure: Max. 60 kg/cm^2

b) Recovery ratio: Max. 35%

5) High-pressure pump:

a) Type: Multi-stage turbine pump

b) Capacity/No. of unit: 3 m^3/min. x 60 kg/cm^2 x 500 kW x 3 units (one for standby)

c) Material: SUS 316

6) Power recovery turbine:

a) Type: Multi-stage turbine

b) Specification/No. of units: 1.95 m^2/min x 54 kg/cm^2 x 3 units (one for standby)

c) Recovery power: 111 kW

d) Power recovery ratio: 25%

7) Desalinated (product) water quality: TDS: 500 ppm or less
pH: 7 – 8

8) Post-treatment: pH adjustment by dosing caustic soda
Dosage: 12 ppm

9) Module cleaning:

a) Chemicals to be used: Citric acid and aqueous ammonia

b) Cleaning frequency: Max. once per six months

10) Module preservation:

a) Chemicals to be used: Formalin and hydrochloric acid or sulfuric acid

b) Preservation liquid: Formalin 5,000 ppm/pH 5 – 6

c) Requirement criterion for preservation: When the plant is to be shut down continuously for more than a week

6.4 Special considerations for plant configuration

In planning this plant, consideration should be given to the following matters to attain good operability and easy maintenance of the plant.

6.4.1 General

1) Applied standards

In planning this plant, the following Japanese standards have been applied:

a) JIS: Japan Industrial Standards

b) JEC: Standards of Japanese Electric Technical Committee

c) JEM: Standards of Japanese Electic Manufacturing Association

d) Other standards: Related Japanese domestic laws, regulations and rules

2) Standby equipment

At least one standby equipment has been considered for all rotary equipment in order to insure stable continuous operation of this plant.

3) Materials

Non-metallic materials have been selected for the parts contacting with sea water as much as possible to avoid corrosion.

On the other hand, SUS316 and/or materials having corrosion-resistance more than SUS316 are applied for the parts which need metallic material.

a) Equipment and instruments in contact with liquid: SUS 316 (Stainless Steel)

b) High-pressure main piping: Polyethylene-lined pipe

c) High-pressure small-size pipe: SUS 316 (Stainless Steel)

d) Low-pressure piping: PVC or FRP

6.4.2 Seawater intake unit .

The well method has been selected for raw seawater intake based on the study results of Chapter 3. The raw seawater intake well has been planned based on the following conditions assumed by taking account of the boring data on the existing wells for fresh water.

1) The total well depth is assumed as 60 m, because clay stratum has more than 60 m depth in existing fresh water wells. As seawater infiltration stratum exists between 30 and 40 m below the ground, it is likely that this stratum can supply sufficient raw seawater.
2) Well diameter is 300 ϕ mm.
3) Materials around a well has been selected as follows.
   a) Submersible pump: SUS 316 (Stainless Steel)
   b) Well piping: FRP
   c) Screen: SUS 316 (Stainless Steel)
4) The number of wells is to be 3; one for standby, considering the decrease of well capacity.
5) Each well is 150 m apart from other wells in order to secure sufficient capacity, respectively.

   The three wells shall be installed at the point close to Campamento as much as possible.

6.4.3 Pretreatment unit

From viewpoints of easy operation and convenience of construction, the pretreatment unit has been planned as follows.

1) Inline coagulation followed by filtration is applied for turbid substances removal.
2) Full automatic operation for the dual media filters is adopted.
3) Three trains of the dual media filter are installed out-door, considering difficulty in transportation.

6.4.4 Reverse osmosis unit

The reverse osmosis unit has been planned in consideration of operability and fluctuation of required production.

1) Two trains of 1,500 m^3/day unit are installed to meet variation in product requirements. Each train is to be operated individually.
2) Reverse osmosis module

   Type: Hollow fiber is applied by taking account of high flux and salt rejection.

   Material: Cellulose tri-acetate is adopted because of high chlorine resistant property which leads to stability in chlorine contents in product water and keeps dual-media-filter performance stable.
3) Power recovery turbine is applied for energy-saving.
4) Full automatic operation of high pressure pump and power recovery turbine is considered.

5) For after-treatment of product water, only pH adjustment by caustic soda solution dosing is applied in consideration of mixing with fresh water.

6.4.5 Product water transfer unit

1) The product water transfer line is planned for pumping product to the existing service reservoir.
2) The distance from the plant site to the service reservoir is assumed as 1,600 m. (Refer to Fig. 6.4)

6.4.6 Waste water discharge unit

1) Concentrated brine is discharged to sea by using its pressure.
2) Waste water from filter back wash and other sources is discharged by pumping from the basin.
3) The distance between discharging point and the plant site is assumed as 1,200 m. (Refer to Fig. 6.4)

6.4.7 Civil and building works

Concrete water basin is constructed on the ground. Building to be constructed with reinforced concrete and block.

6.4.8 Primary cable

1) The distance from the power station is assumed as 2,350 m.
2) Armoured cable is to be specified considering direct underground installation. (Refer to Fig. 6.4)

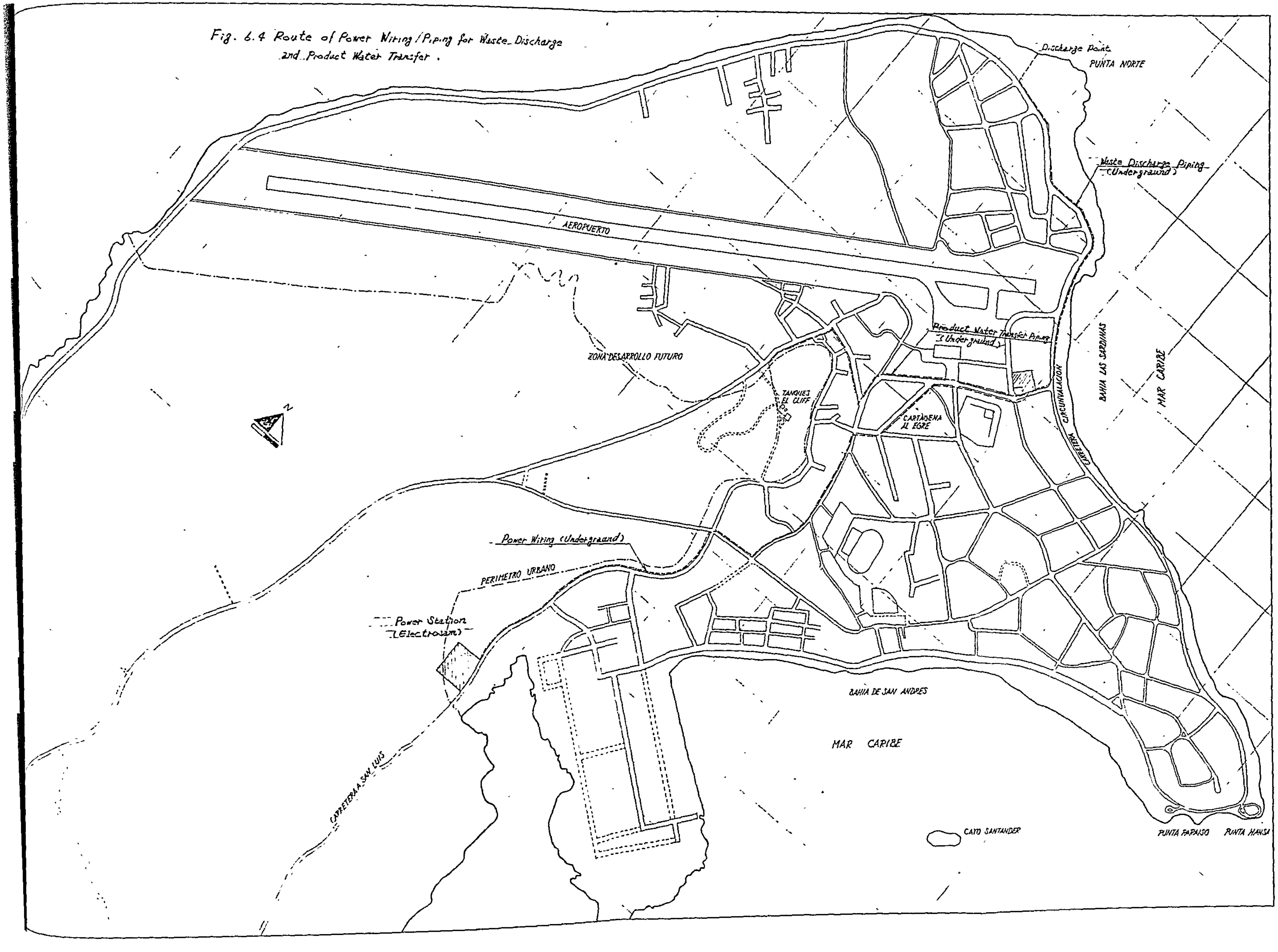


Fig. 6.4 Route of Power Wiring / Piping for Waste Discharge and Product Water Transfer.