A higher concentration of fitoplankton / zooplankton and a greater diversity of species are identified in Laguna Huasco. A lesser diversity of species is confirmed in Laguna Cerro Huasco, different from other lagoons in biological components.

3) Plants

Four (4) species of aquatic plants are identified in the fresh water area.

4) Birds

Birds of 40 species are identified in or around Salar del Huasco. Among them, the following seven (7) species of birds are designated by CONAF as endangered species or vulnerable species to be preserved.

(1) Endangered Species: Lesser Rhea

(2) Vulnerable Species: Punta Tiramou, Chilean Flamingo, Andean Flamingo, Puna Flamingo, Andean Goose, Giant Coot

4.3.3 Flamingo

1) Species and Population

Three (3) species of flamingos are identified in Salar del Huasco. The maximum population by species counted during the period of November 1993 to January 1994 are as follows.

Species	Population
Chilean Flamingo	544
Andean Flamingo	1,267
Puna Flamingo	1,533
Total	3,344

These are designated by CONAF as vulnerable species and further authorized by CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) as endangered ones.

2) Population Share in Northern Chile

The population of flamingos in Northern Chile were surveyed in 1985 to 1987 by Corporation National Forest of U.S.A. The maximum counted population

by species during the survey period are shown below, compared with the population of Salar del Huasco.

Species	Northern Chile	Salar del Huasco	Share (%)
Chilean Flamingo	15,464	544	3.5
Andean Flamingo	40,747	1,267	3.1
Puna Flamingo	17,268	1,533	8.9
Total	73,479	3,344	4.6

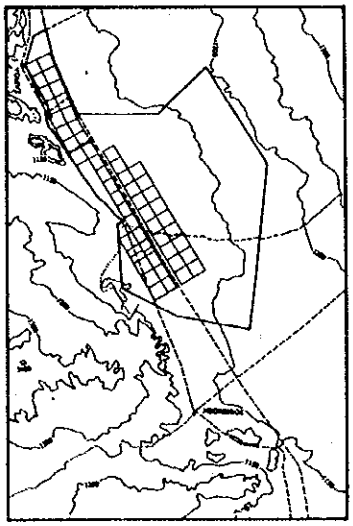
Share of the population of Salar del Huasco to the total population of Northern Chile is also shown in the above table.

Puna Flaming is the most rare species. The total population in the world in 1973 was reported as 15,000. They are all living in Andes Mountains.

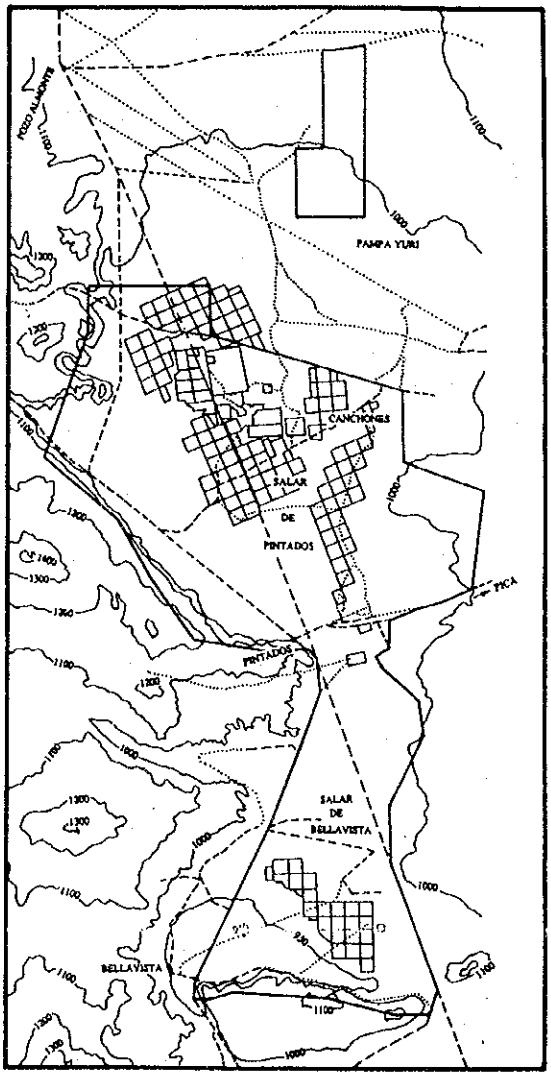
3) Nesting

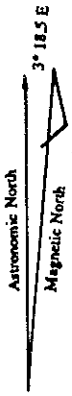
Chickens, nests and eggs of Puna Flamingos were identified by this study. Salar del Huasco provides one of the nesting areas to this rare species.

Zapiga



Salar de Pintados and Salar de Bellavista

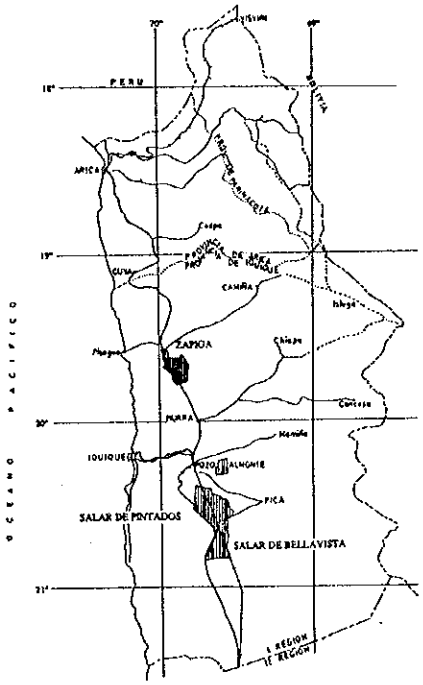




LEGEND

- : I Class Road
- : Trace
- : National Reserved Area
- : Contour Line
- : Plantation of Tamarugo and/or Algarrobo

Reference



Scale

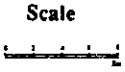


Fig. 4.1 National Reserved Area and Tamarugo Plantation

< Area de Reserva Nacional y Plantación de Tamarugo >

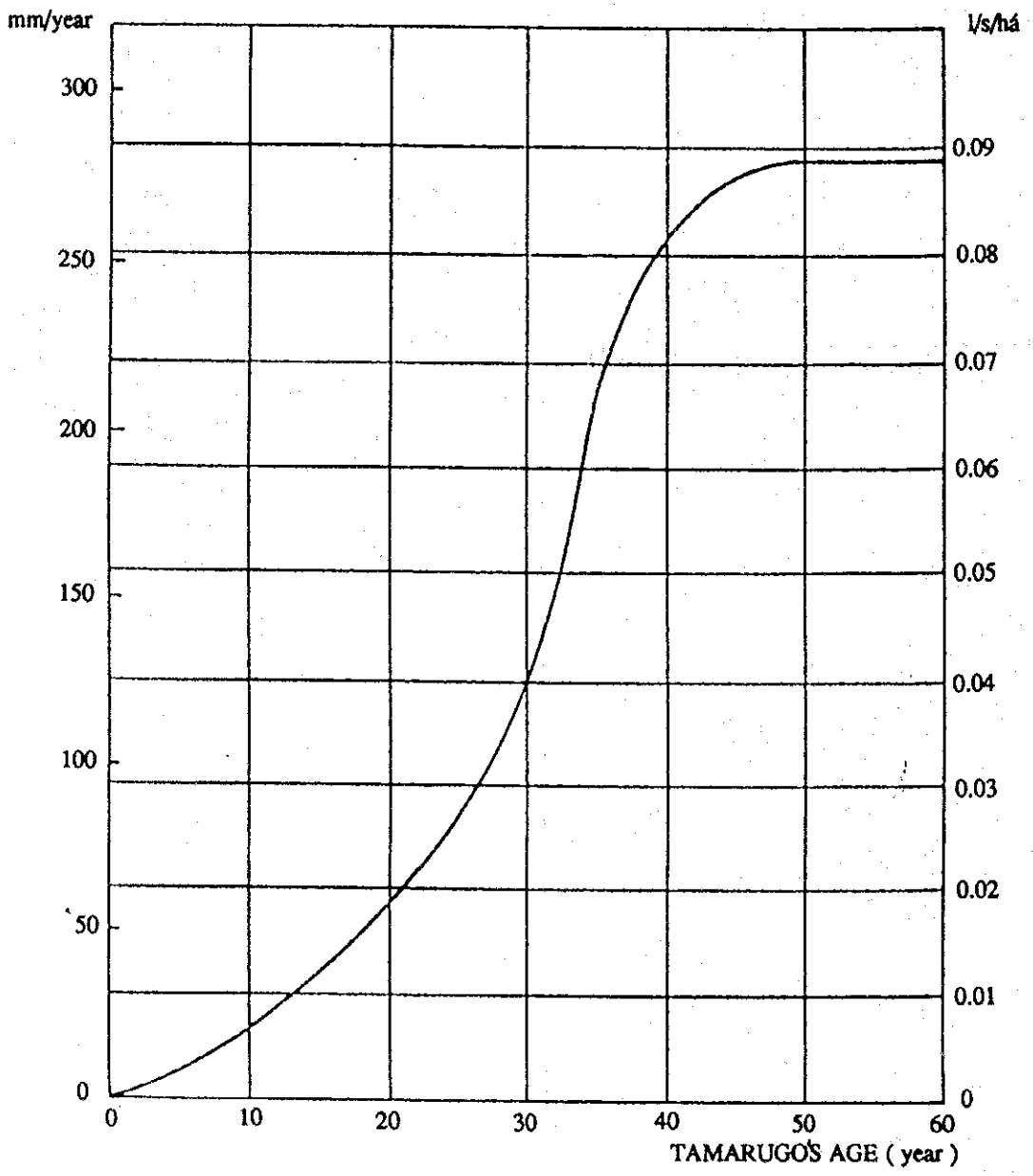
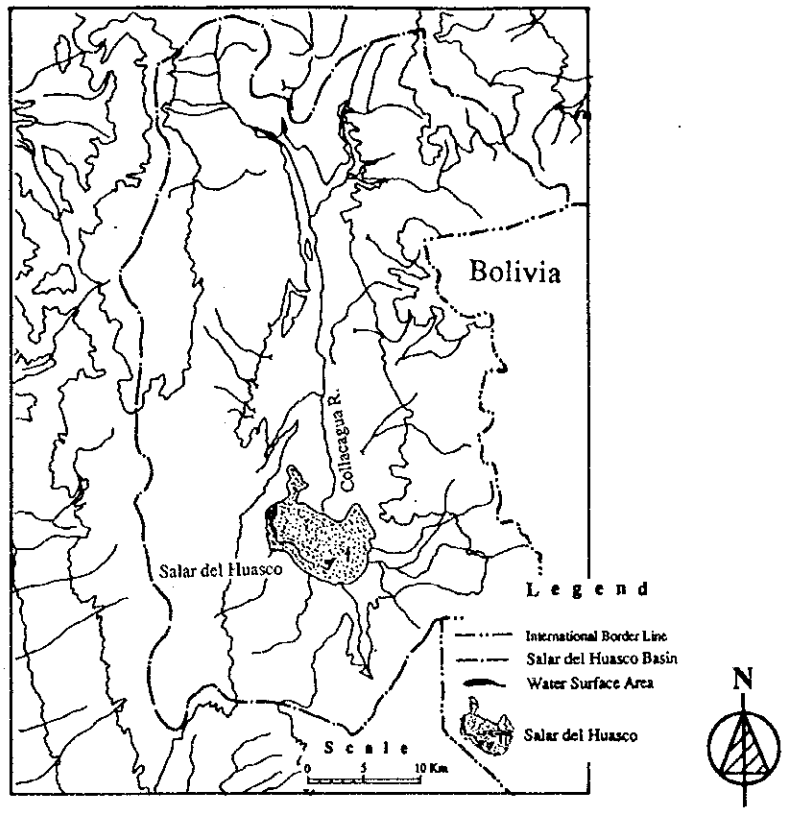


Fig. 4.2 Evapotranspiration by Tamarugo Plantations in Pampa del Tamarugal

<Evapotranspiración de las Plantaciones de Tamarugo en Pampa del Tamarugal>



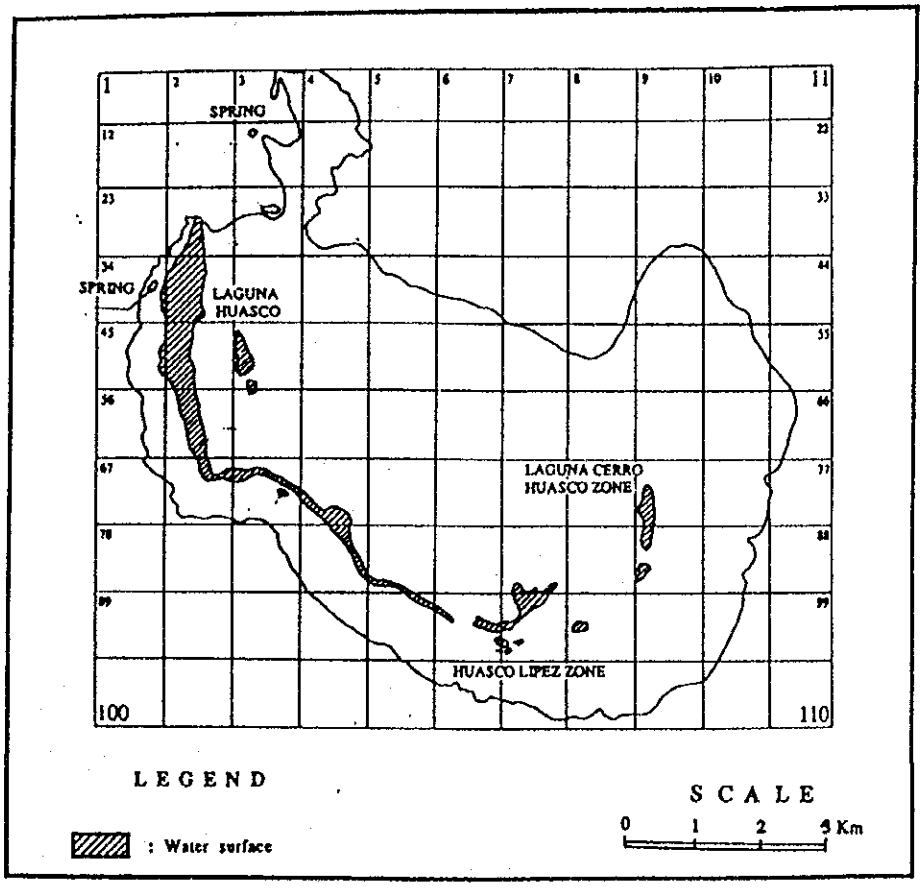


Fig. 4.3 Location of Salar del Huasco

< Ubicación del Salar del Huasco >

CHAPTER V WATER SUPPLY AND DEMAND BALANCE

Chapter V WATER SUPPLY AND DEMAND BALANCE

5.1 Water Supply and Demand Balance of Arica Area

5.1.1 Groundwater Development Potential of Azapa Valley

1) Existing Water Balance

(1) Inflow to Azapa Valley

The annual average flow rate of the San José River is estimated to be 1,101 l/s at Ausipar/Antes Bocatoma station. This is considered as the total inflow to Azapa Valley.

No groundwater inflow to Azapa Valley is identified because the river beds at the station is composed of impermeable basement rocks. Groundwater in the upper mountain areas appears in the river as surface water before reaching the station.

(2) Outflow to Sea

Almost all the inflow water to Azapa Valley are consumed in Azapa Valley and city area or infiltrate into ground to recharge groundwater.

Only some water spills over to the sea during large flood in January and February. The average annual outflow to the sea is estimated at 149 l/s.

(3) Water Consumption

The water resources in Azapa Valley and city area are consumed for municipal water of Arica city (ESSAT water), irrigation water in Azapa Valley and other water in Azapa Valley (individual domestic, industrial and miscellaneous).

ESSAT water use has been much curbed due to the lack of water sources. However, it suddenly increased at the end of 1993 by the completion of the Emergency Water Supply Project. This project increased the water supply capacity of ESSAT from 503 l/s to 730 l/s. This increased capacity is fully used after the beginning of 1994.

On the other hand, the actual water production of ESSAT in 1992 was 537 l/s, exceeding the authorized water supply capacity of 503 l/s.

Hence, the following three (3) cases of water use are discussed as the existing water use of ESSAT, considering that the above Emergency Water Supply Project is a temporary one.

Case I	:	Actual water production in 1992	:	537 l/s
Case II	:	Water supply capacity until the end of 1993	:	503 l/s
Case III	:	Water supply capacity after beginning of 1994	:	730 l/s

The existing annual average water consumption of ESSAT, irrigation and other purposes are summarized below.

	Annual Average Water Demand (l/s)	Annual Average Real Water Consump. (l/s)
ESSAT		
Case I	537	470 1)
Case II	503	440 1)
Case III	730	639 1)
Irrigation	1,269	787 2)
Others	53	21 3)

Note : 1) : 25% of the production is water leakage, of which one half (12.5%) recharges groundwater.
2) : Evapotranspiration of crops.
3) : 60% of the extracted water is returned to underground.

4) Water Balance

The existing water balance of Azapa Valley is calculated as follows.

	Case I	Case II	Case III
Inflow (l/s)	+1,101	+1,101	+1,101
Outflow (l/s)	-149	-149	-149
Real Water Consump. (l/s)	-1,278	-1,248	-1,447
Balance	-326	-296	-495

2) Groundwater Development Potential

The existing groundwater storage of Azapa Valley including city area is estimated to be 302 x $10^6 m^3$. However, it will expire before long if the existing water uses continue. The remaining life of the groundwater is calculated as follows.

Case I : 29.4 year ≒ 30 year
Case II : 32.4 year ≒ 30 year
Case III : 19.3 year ≒ 20 year

As evident from the above discussions, further groundwater development of Azapa Valley is difficult.

5.1.2 Surface Water Development Potential of Lluta River

1) Lower Lluta River

Surface water of Lower Lluta River in dry season is almost all consumed for irrigation of the farmlands extending along the River. Surplus water flowing out to the sea is negligibly small in dry season.

Panamericana station is the flow rate observatory station located at the lowermost reaches of Lluta River. The minimum drought discharge at the station occurs during the dry season of October to December. The drought discharge with the exceeding probability of 90% (design probability for drinking water) during the dry season are as follows.

	Oct.	Nov.	Dec.
90% Drought Discharge (l/s)	49	69	72

For monthly drought discharges, see Supporting Report A, Table A, 2.4.

No surplus water is expected in dry season, considering that the custom river water rights of 120.02 acción (maximum quantity: 120.02 x 0.75 = 90.0 l/s) are granted to the agricultural uses in the downstream of Panamericana station as of 1993. For details of the water rights, see Supporting Report C, Appendix C.3.

Note: One acción has the right to withdraw river water up to 0.75 l/s when river water is abundant.

Furthermore, the surface water of Lower Lluta River is much contaminated mainly by the pollutants originated from Azufre and Colpitas rivers. The major water quality parameters of contamination are As, B, Fe, Cl and SO_4.

The average contents of them are shown below, compared with the permissible limits for drinking use in Chile.

	As	B	Fe	Cl	SO_4
Water Quality at Tocontasi (mg/l)	0.305	10.69	3.82	323	310
Water Quality at Panamericana (mg/l)	0.124	16.84	2.37	704	751
Permissible Limit (mg/l)	0.05	5.0*	0.30	250	250

Note : * : There is no standard in Chile. In this report, the actual B content in the municipal water of Antofagasta is adopted.

From the above discussions, no further surface water development for Lower Lluta River is expected.

2) Upper Tributaries

In the upstream basin of Lluta River, comparatively clean water is available in the Caracarani and Guancarane rivers. The contents of the major water quality parameters in both rivers are shown below.

	As (mg/l)	B (mg/l)	Fe (mg/l)	TDS (mg/l)
Caracarani (at Humapalca)	0.120	3.23	1.17	1,328
Guancarane	0.018	0.23	0.31	94
Permissible Limit	0.050	5.0	0.30	1,000

However, the water quantity of both rivers are not much. The monthly drought discharge with an exceeding probability of 90% of both rivers are as follows.

	Jan.~ Sep.	Oct.	Nov.	Dec.
Caracarani (Humapalca)(l/s)	211~258	182	140	142
Guancarane (l/s)	90~110	78	60	61
Total (l/s)	301~368	260	200	203

For details of the monthly 90% drought discharges of Caracarani, see Supporting Report A, Table A, 2.4. The monthly 90% drought discharges of Guancarane are

estimated from those of Caracarani based on the discharge ratio of both rivers obtained by the simultaneous discharge observation conducted in June, 1993.

The existing water demand and supply balance of Lower Lluta River is severe. The water extraction from the upper tributaries will fringe the existing river water rights for agricultural uses in the Lower Lluta Valley.

The monthly drought discharge with the exceeding probabilities of 80% (design probability for irrigation) at Tocontasi/Chapisca station are estimated as follows.

	Jan.~ Sep.	Oct.	Nov.	Dec.
80% Drought Discharge (l/s)	1,302~1,830	1,168	1,089	1,091

For details, see Supporting Report A, Table A, 2.4.

On the other hand, the following river water rights are granted to the agricultural uses in the downstream reaches of Tocontasi/Chapisca station as of 1993.

Legally authorized river water rights: 284.50 l/s
Custom river water rights: 2,558.15 acción
(maximum quantity: 2,558.15 x 0.75
= 1,918.61 l/s)

For details of the water rights, see Supporting Report C, Appendix C.3.

From the above discussions, the surface water development of the upper tributaries is considered difficult.

5.1.3 Groundwater Development Potential of Lower Lluta Valley

1) Groundwater Recharge Potential

The groundwater of the Lower Lluta Valley is all recharged by the surface water of Lluta River. The groundwater development of the areas shall be within the recharge volume of Lluta River since the existing groundwater storage is not large.

The existing groundwater recharge of the Lluta River is small because the aquifers are saturated with water. However, the groundwater development will lower the existing groundwater level, resulting in the increase of groundwater recharge in future.

The capacity of groundwater recharge in Lower Lluta Valley is estimated, referring to the groundwater recharge in Azapa Valley.

The groundwater of Azapa Valley is recharged by the surplus river water at Azapa Intake Dam (river water which spill over the dam). The recharge takes place in the river sections of 22 km distance between Cabuza and the river mouth. The ratio of the groundwater recharge to the surplus river water is estimated as follows.

$$\gamma_A = \frac{Q_A - Q_c - Q_o}{Q_A - Q_c} = \frac{1{,}101-487-149}{1{,}101-487} = 0.757$$

where, γ_A : Groundwater recharge ratio in Azapa Valley

Q_A : Average flow rate at Antes Bocatoma/Ausipar (1,101 l/s)

Q_c : Average extraction rate by Azapa Canal (487 l/s)

Q_o : Average outflow rate to the sea (149 l/s)

For the above discharges, see Supporting Report A, Chapter I.

On the other hand, the groundwater of Lower Lluta Valley is recharged in the river reaches of 17 km length between Poconchile and Sascapa by the surplus river water. The ratio of the groundwater recharge to the surplus river water is estimated as follows, considering that the effective porosity of the aquifers in Lower Lluta Valley is 70% of that in Azapa Valley and the river reach length for the groundwater recharge in Lower Lluta Valley is 5 km shorter than that in Azapa Valley.

$$\gamma_L = 0.757 \times 0.7 \times \frac{17}{22} = 0.41$$

The river water is extracted from 56 intakes for irrigation of the farmlands in the downstream reaches of Tocontasi/Chapisca. The total amount of the granted water rights is 284.50 l/s+2,558.15 accion = 2,203.11 l/s.

According to the Water Code of Chile, the above water right owners can use the river water for any other purposes than irrigation, or divert the water to the outside of the Lluta River Basin. Therefore, it can not legally be denied that the whole quantity of the water rights may be really consumed in future.

In this case, the groundwater recharge potential of the Lower Lluta Valley is estimated as follows.

$$R_L = (Q_T - Q_R) \times 0.41 = (2{,}216.0 - 1{,}779.3) \times 0.41 = 179.0 \text{ l/s}$$

R_L = Groundwater recharge potential of Lower Lluta Valley
Q_T = Average flow rate at Tocontasi/Chapisca (2,216.0 l/s)
Q_R = Average irrigation use (real consumption) in the downstream reaches of Tocontasi/Chapisca (1,779.3 l/s)

For details, see Table 5.1.

However, in fact, the extracted irrigation water is not completely consumed and a considerable amount of the extracted water is returned to the river. At present, the river water is repeatedly used for irrigation while flowing from Tocontasi to the river mouth. The actual irrigation consumption (real consumption) in the downstream reaches of Tocontasi/Chapisca is estimated to be 894.0 l/s (see, Supporting Report C, Chapter III). Then the existing ratio of the real water consumption to the water right comes to 40% (=894/2,203).

Based on these actual water use situations, the water rights with a considerably larger amount than the drought river discharge have been granted in Lluta River as shown below.

Irrigation water right (downstream of Tocontasi) : 2,203 l/s

River flow rate at Tocontasi :	Yearly Ave.	Dry Season (apr.-dec.)	Driest Season (oct.-dec.)
80% drought flow rate	1,444 l/s	1,342 l/s	1,116 l/s
90% drought flow rate	1,260 l/s	1,227 l/s	1,050 l/s

In case that the existing recycling use of the river water for irrigation is taken into consideration, the groundwater potential of Lower Lluta Valley is estimated as follows.

$$R_L = (Q_T - Q_R) \times 0.41 = (2{,}216 - 894) \times 0.41 = 542 \text{ l/s}$$

Therefore, in this Report, the Study Team evaluates the groundwater recharge potential to be 542 l/s from the technical view-points aiming at the rational and effective use of the limited water resources.

2) Consideration to Adverse Effects on Existing Water Use

The river water is considered to recharge the groundwater aquifer mainly in the reaches between Poconchile and Sascapa.

There are 31 river water intakes to irrigate the irrigation sectors III, IV and V in the downstream reaches of Poconchile (sub-sector Kesler - sub-sector Santa Rosa, see Chapter 3.3, Fig. 3.4). The river water is repeatedly used in this area. The surplus irrigation water is drained to the river for re-use in the downstream.

In Lower Lluta Valley, the groundwater development will lower the existing groundwater table, resulting in acceleration of the river water infiltration into underground. It may make it difficult to maintain the existing river water extraction for irrigation use.

To cope with this problem, it may be necessary to integrate the above-mentioned irrigation intakes to one (1) headworks proposed in the upstream of Poconchile (uppermost intake site of the irrigation sector III: Kesler). All the irrigation water of the sector III, IV and V will be extracted from this headworks. The required extraction quantity is determined, considering the recycling use of the irrigation water which is being performed in the existing irrigation system. The extracted water will be distributed to all the irrigation sectors by constructing the new irrigation canals. Further, the collection channels to collect the surplus water (drain water) will also newly be constructed along the river banks to make the recycling use of irrigation water possible.

The proposed new irrigation system including headworks, irrigation canals, collection channels and return channels (channel to return the collected water to irrigation canal for re-use) is shown in Fig. 5.1.

The groundwater recharge potential can be obtained by multiplying the surplus river water at the above-mentioned headworks by 0.41. The average monthly surplus river water are estimated for the following two (2) cases.

(1) Case 1

This case satisfies all the existing water rights including the legally authorized and custom ones.

The required water extraction from the headworks is calculated under the following conditions.

i) Each irrigation sub-sector extracts the water quantity equivalent to its water right from the irrigation canal.

ii) The above extracted irrigation water is really consumed by 50%. The remaining 50% is collected by the collection channel for re-use.

For the above calculations, see Supporting Report B-II, Table B-II, 3.2.

The groundwater recharge potential is calculated by the following equation.

$$R_L = Q_S \times 0.41 = (Q_T - Q_U - Q_E) \times 0.41$$

where, R_L : Groundwater recharge potential of Lower Lluta Valley
Q_S : Surplus river water at the Headworks
Q_T : River flow rate at Tocontasi/Chapisca (2,216 l/s)
Q_U : Real irrigation water consumption between Tocontasi and Headworks, assumed as 50% of the existing water right quantity (275 l/s)
Q_E : Extracted water (819 l/s)

The yearly average groundwater recharge is estimated to be:

$$R_L = (2{,}216 - 275 - 819) \times 0.41 = 460 \text{ l/s}$$

The monthly average groundwater recharge is shown in Table 5.2.

(2) Case 2

This case satisfies all the actual water demand which varies by month.

The required water extraction from the headworks is calculated under the following conditions.

i) Each irrigation sub-sector extracts the water quantity equivalent to its actual irrigation water demand from the irrigation canal. The actual irrigation water demand is estimated based on the existing cropping pattern, evapotranspiration of crops and irrigation efficiency (see, Supporting Report C, Chapter III).

ii) Among the above extracted water, the water quantity equivalent to the evapotranspiration is really consumed and the remaining water is collected by the collection channel for re-use.

For the above calculation, see Supporting Report B-II, Table B-II, 3.3 and Table B-II, 3.4.

The yearly average groundwater recharge is estimated as shown below in the same way as Case 1.

$$R_L = (2{,}216 - 250 - 711) \times 0.41 = 515 \text{ l/s}$$

The monthly average groundwater recharge is shown in Table 5.2.

3) Limitation of Number of Well Development

The groundwater development potential area of Lower Lluta Valley extends from Rosario to Chuilona. The distance between both sites is approximately 14 km. The well development in this area shall be planned so that the proposed wells may not interfere with each other. The distance between each well should be kept longer than 500 m to avoid mutual hydraulic interference (see, Supporting Report B-II, Chapter III, 3.4.3).

The number of the possible well drilling is estimated to be 28 of which 20% will be for emergency use and 30% will be used to meet the daily maximum demand of the municipal water (peak demand). Hence, 18 wells will be available for the municipal water demand on average basis.

From the above considerations, the annual average groundwater development potential is estimated to be 450 l/s by assuming the groundwater extraction capacity of one (1) well as 25 l/s.

4) Proposed Groundwater Development

The groundwater development potential of Lower Lluta Valley is concluded to be 450 l/s from the above discussions. This potential shall be developed to the maximum extent to meet the increasing municipal water demand of Arica city. Therefore, the groundwater development of 425 l/s on average basis by 26 wells including 9 wells for emergency and peak demand is proposed, considering some allowance.

5) Necessity of Water Treatment

The developed groundwater contains a high content of TDS, Na, SO_4, Cl, B and Fe as shown below.

Element	TDS	Na	SO_4	Cl	B	Fe
Content (mg/l)	3,452	529	852	949	21.9	1.53
Permissible Limit (mg/l)	1,000	200	250	250	5.0	0.30

Such special treatment systems as Reverse Osmosis (RO) or Electrodialysis Reversal (EDR) shall be applied. In such treatment systems, approximately 25%

of the developed water will be wasted. Hence, 319 l/s (=425 x 0.75) will be actually supplied to Arica city.

5.1.4 Municipal Water Supply and Demand Balance of Arica City

1) Municipal Water Demand of Arica City

The future municipal water demand of Arica city on average production basis is estimated as follows.

Year	Demand (l/s)
1995	779
2000	797
2005	840
2010	959
2015	1,091

2) Municipal Water Supply to Arica City

To meet the above water demand, the following water supply developments are proposed.

(1) The Lower Lluta Groundwater Development Project with a water supply capacity of 319 l/s will be completed by the end of 1998.

(2) The Emergency Water Supply Project of Azapa Valley completed at the end of 1993 is considered temporary. Then, the temporarily increased capacity by the Emergency Water Supply Project of 227 l/s (=730 - 503) will expire after completion of the Lower Lluta Groundwater Development Project.

(3) The Lower Lluta Groundwater Development Project will be able to meet the water demand of Arica city only until the year of 2003, along with the existing water supply system of Azapa Valley. The water shortage of Arica city is estimated to be 137 l/s for the year 2010 and 269 l/s for the year 2015.

Therefore, the water resources in the other river basins than San José and Lluta River Basins shall be developed soon after the year 2003.

5.2 Water Supply and Demand Balance of Iquique Area

5.2.1 Groundwater Development Potential of Pampa del Tamarugal

1) Existing Water Balance

The inflow water into the aquifers of Pampa del Tamarugal consists of surface water of the indigenous rivers originated from the Andes Mountains, and groundwater from Salar del Huasco and other eastern neighbouring basins.

Existence of this groundwater inflow has been suggested by the previous reports and it is supported by this study (see, Supporting Report B-III Chapter I, 1.2.3). The groundwater is considered to intrude through the geological fissures.

On the other hand, the groundwater of Pampa del Tamarugal is consumed for the municipal water of Iquique, and for domestic, irrigation and mining water within the areas of Pampa del Tamarugal. It is further consumed by the evaporation / evapotranspiration of Tamarugo trees and Salar areas. No water flows out from the Pampa del Tamarugal Basin.

The water of Pampa del Tamarugal Basin is imbalanced. The groundwater level has lowered at an average rate of 7 cm/year during the recent period of 1985 to 1993. This drawdown is equivalent to the reduction of 514 l/s of the groundwater storage.

The existing water balance of Pampa del Tamarugal aquifers is summarized below.

(1) Average Inflow

- Surface water of the indigenous rivers : 976 l/s
- Groundwater from Salar del Huasco and the other neighbouring basins : X l/s

(2) Average Real Water Consumption

The total existing average water demand of Pampa del Tamarugal in 1992 is estimated to be 1,192 l/s of which the real water consumption is assumed to be 887 l/s. The real water consumption is broken down as follows (see, Chapter III, Table 3.1).

- Municipal water of Iquique : 547 l/s
- Domestic water in Pampa : 47 l/s

- Irrigation water in the river valley areas : 130 l/s
- Irrigation water in Pampa : 119 l/s
- Mining water in the river valley areas : 21 l/s
- Mining water in Pampa : 23 l/s

(3) Average Evaporation/Evapotranspiration (E)

Average evaporation/evapotranspiration during the period of 1985 to 1993 of the Tamarugo trees and Salar areas are as follows.

- Tamarugo trees : 904 l/s
- Salar areas : 145 l/s

(4) Average Reduction of Groundwater Storage (R)

The average reduction of the groundwater storage during the period of 1985 to 1993 is estimated to be 514 l/s.

In the above data, the real consumption of the irrigation and mining water in the river valley areas of 151 l/s is already counted in the surface water of the indigenous rivers. Hence, this amount is neglected in the calculation of the existing water balance.

Then, the groundwater inflow from Salar del Huasco and the other neighbouring basins is estimated as follows.

$$R = I - C - E$$
$$-514 = (976 + X) - (547 + 47 + 119 + 23) - (904 + 145)$$
$$X = 289 \text{ l/s}$$

For details, see, Supporting Report B, B-III, Chapter IV.

2) Future Water Balance

The total future water demand in 2015 is projected to be 2,746 l/s of which the real water consumption is estimated to be 2,096 l/s. Their break-downs by water use area are shown below, compared with the existing ones.

	Existing (1992)		Future (2015)	
	Demand (l/s)	Real Consump. (l/s)	Demand (l/s)	Real Consump. (l/s)
Iquique	547	547	1,062	1,062
River Valley Areas	324	151	41	25
Pampa Areas	321	189	1,643	1,009
Total	1,192	887	2,746	2,096

For details, see Chapter III, Table 3.1.

Further, the evapotranspiration of Tamarugo trees in 2015 is estimated to be 1,523 l/s (see, Supporting Report E, Table E, 2.3). Evaporation of the Salar areas is considered to become negligibly small due to the draw-down of the groundwater level.

The future water balance of the aquifers of Pampa del Tamarugal in 2015 is calculated as follows.

$R = I - C - E + \alpha = -2{,}203$ l/s

where R : Reduction of groundwater storage

I : Average inflow : 1,265 l/s

C : Real water consumption of water uses in Iquique and Pampa : 2,071 l/s

E : Evaporation /evapotranspiration in Pampa : 1,523 l/s

α : Increase of surface water of the indigenous rivers : due to reduction of real water consumption in the river valleys: 126 l/s (= 151 - 25)

3) Groundwater Development Potential

The existing and future yearly reduction of the groundwater storage in 1992 and 2015 are estimated to be 16.2 million m^3/year and 69.5 million m^3/year. Then, the total reduction of the groundwater storage during 23 years until 2015 is estimated at 986 million m^3 or 3.7% of the existing groundwater storage of 26,908 million m^3.

Groundwater development potential of Pampa del Tamarugal is considered large enough to meet the future water demand. Its development is restricted by quality rather than by quantity.

The groundwater aquifer with a suitable water quality for drinking use is located to the east of the line connecting La Tirana and Pintados {see, Chapter II, Fig. 2.23 (8)}.

This clean groundwater aquifer (prospective aquifer) has a storage volume of 10,700 million m^3. On the other hand, the groundwater extraction (real consumption) for the water supply to Iquique are estimated to be 17.3 million m^3/year for the year 1992 and 33.5 million m^3/year for the year 2015. Therefore, the total extraction of the water supply to Iquique during 23 years until 2015 comes to 584 million m^3 or 5.5% of the existing groundwater storage of 10,700 million m^3.

The above prospective aquifer is considered large enough to meet the future water demand of Iquique City.

5.2.2 Groundwater Simulation

1) Construction of Simulation Model

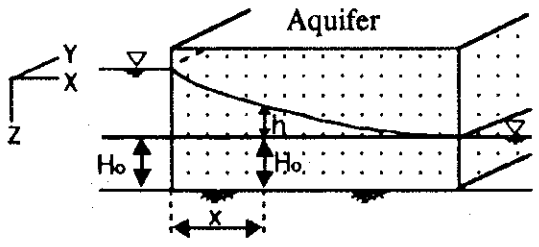
(1) Computer Program

The computer program for groundwater simulation employed in this study is prepared based on the following dominant equation

The dominant equation relating to infiltration handled here is based on Dupuit's hypothesis that the head is equal on the perpendicular section of the aquifer.

Using Dupuit's hypothesis, the continuation formula relating to three-dimensional (x, y, z) flow is, from $Vz = 0$ as follows.

$$S\frac{\partial h}{\partial t}+\frac{\partial}{\partial x}\{(H_O+h)Vx\}+\frac{\partial}{\partial y}\{(H_O+h)Vy\}=0 \quad \text{..... (1)}$$



S :	coefficient of storage
Vx, Vy, Vz :	apparent flow velocity in x, y, z directions
q :	spring flow or discharge per unit time

Putting Darcy's formula of motion (equation 2) into equation (1) yields:

$$\left.\begin{aligned} Vx &= -Kx\frac{\partial h}{\partial x} \\ Vy &= -Ky\frac{\partial h}{\partial y} \\ Vz &= -Kz\frac{\partial h}{\partial z} \end{aligned}\right\} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (2)$$

$$S\frac{\partial h}{\partial t} = \frac{\partial}{\partial x}\left\{Kx(Ho+h)\frac{\partial h}{\partial x}\right\} + \frac{\partial}{\partial y}\left\{Ky(Ho+h)\frac{\partial h}{\partial y}\right\} + q$$

$$= \frac{\partial}{\partial x}\left(Tx(h)\frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(Ty(h)\frac{\partial h}{\partial y}\right) + q \cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (3)$$

where Tx, Ty : coefficients of transmissivity in x, y directions, being functions of head h

This is the dominant equation relating to infiltration using Dupuit's hypothesis.

From equation (3), after finite element formulation by using the weighted remainder method, the solution is obtained under proper initial conditions and environmental conditions.

The computer program prepared by the above mentioned method can easily be applied for not only aquifer formed of a single layer but also aquifer consisting of multiple layers. Further, it can perform quasi-three-dimensional groundwater analysis in a well manner.

(2) Modeling of Aquifer

(i) Shape and Geology of Aquifer

The aquifer shapes of Pampa del Tamarugal are simplified for construction of the simulation model. The surface area of the aquifer model covers the whole Pampa del Tamarugal as shown in Fig. 5.2. However, the aquifer in the Pica and Matilla areas is excluded since it is hydraulically independent from that of the Pampa del Tamarugal. The longitudinal profile of the aquifer model is shown in Fig. 5.3.

The aquifer model consists of two (2) sub-aquifers: lower aquifer (Q_3) of conglomeratic facies and upper aquifer (Q_4) of sandy facies. No impermeable layer exists between them.

(ii) Constants of Aquifer

The aquifers of Q_3 and Q_4 are both regarded as unconfined. The coefficients of permeability and storage are assumed as follows.

	Q_3	Q_4
Permeability Coefficient (cm/sec)	1.0×10^{-3}	1.0×10^{-4}
Storage Coefficient	0.35	0.30

(3) Existing Groundwater Consumption

The existing groundwater consumption of the aquifer includes the consumption for municipal water of Iquique, and domestic water of local towns, irrigation water, mining water and evapotranspiration of Tamarugo trees in Pampa del Tamarugal excluding Pica and Matilla areas.

The total existing groundwater extraction of the municipal, domestic, irrigation and mining water from Pampa del Tamarugal aquifer is estimated to be 642.2 l/s. However, some portion of the extracted water is returned to underground to recharge the groundwater. The remaining portion is really consumed. The total existing real water consumption is estimated to be 594.2 l/s. Break-down by water use category is shown below.

	Extraction (l/s)	Real Consump. (l/s)
Municipal Water of Iquique	546.7	546.7
Domestic Water of Local Town	60.5 *	24.5 *
Irrigation Water	0	0
Mining Water	35.0	23.0
Total	642.2	594.2

Note : This table shows only extraction and real consumption of Pampa del Tamarugal aquifer.

* : Extraction and real consumption for Dupliza and Pisagua.

The total evapotranspiration of Tamarugo trees is estimated to be 1,019 l/s.

(4) Existing Groundwater Recharge

The groundwater is recharged by the surface water of seven (7) rivers originated from Andes Mountains, and underground water from Salar del Huasco and other eastern neighbouring basins.

The total groundwater recharge by the river water is estimated to be 976 l/s. The existing irrigation and mining water consumption in the river valleys are already counted in this amount. For break-down by river, see Chapter II, 2.3.2.

The underground inflow from Salar del Huasco and the other neighboring basins recharges the groundwater of Pampa del Tamarugal aquifer and Pica/Matilla aquifer. The total groundwater recharge by the underground inflow is estimated to be 289 l/s. On the other hand, some quantity of the underground inflow is used for the domestic and irrigation purposes in Pica/Matilla areas as shown below.

	Extraction (l/s)	Real Consump. (l/s)
Domestic for Pica/Matilla	33.0	13.2
Irrigation for Pica/Matilla	169.4	119.0
Domestic for Huayca/Tirana/ Pozo Almonte/Huara*	19.6	7.9

*: The domestic water for Huayca/Tirana/Pozo Almonte/Huara is extracted from Pica/Matilla aquifer and consumed in Pampa del Tamarugal.

Therefore, the total real groundwater recharge to Pampa del Tamarugal aquifer by the underground inflow comes to 137.2 l/s (= 289 - 13.2 - 119.0 - 19.6). Apart from this recharge, the surplus domestic water of 11.7 l/s (= 19.6 - 7.9) is recharged to Pampa del Tamarugal aquifer at the above local towns.

(5) Calibration of Model

The calculated groundwater level contours are in well agreement with the actual ones as shown in Fig. 5.4. The existing groundwater flow vector is also shown in this figure.

2) Simulation of Future Groundwater Table

(1) Future Groundwater Consumption

The future total groundwater extraction of the municipal, domestic, irrigation and mining water from Pampa del Tamarugal aquifer in 2015 is estimated to be 2,293 l/s of which the real consumption is estimated at 1,804 l/s. Break-down by water use category is as follows.

	Extraction (l/s)	Real Consump. (l/s)
Municipal Water of Iquique	1,062.3	1,062.3
Domestic Water of Local Town	60.6 *	24.6 *
Irrigation Water (CAPPTA)	258.1	168.0
Mining Water	911.6	549.0
Total	2,292.6	1,803.9

Note : This table shows only extraction and real consumption of Pampa del Tamarugal aquifer.

* : Extraction and real consumption for Dupliza and Pisagua.

The future total evapotranspiration of the Tamarugo trees in 2015 is estimated to be 1,523 l/s.

(2) Future Groundwater Recharge

It is assumed that the farming in the river valleys will be entirely shifted to the CAPPTA Project area by 2015. It will result in increase of surface water. On the other hand, some additional mining's are expected to develop in the river valleys in future. It will reduce the surface water.

The total irrigation and mining uses in the river valleys in 2015 are shown below, compared with those in 1993.

	Extraction (l/s)			Real Consumption (l/s)		
	1993	2015	Difference	1993	2015	Difference
Irrigation	290	0	-290	130	0	-130
Mining	34.2	41.2	+7.0	20.5	24.7	+4.2

Thus, the total groundwater recharge by the surface water in 2015 is estimated to be 1,102 l/s (= 976 + 130 - 4.2).

The real water consumption in Pica/Matilla areas will increase in future, resulting in decrease of the underground inflow to Pampa del Tamarugal aquifer.

The water extraction and real consumption for Pica/Matilla areas in 2015 are shown below.

	Extraction (l/s)	Real Consump. (l/s)
Domestic for Pica/Matilla	41.7	16.7
Irrigation for Pica/Matilla	338.8	238.0
Domestic for Huayca/Tirana/ Pozo Almonte/Huara*	24.8	9.9

*: The domestic water for Huayca/Tirana/Pozo Almonte/Huara is extracted from Pica/Matilla aquifer and consumed in Pampa del Tamarugal.

Therefore, the total real groundwater recharge to Pampa del Tamarugal aquifer by the underground inflow in 2015 comes to 9.5 l/s (= 289.0 - 16.7 - 238.0 - 24.8). Apart from this recharge, the surplus domestic water of 14.9 l/s (= 24.8 - 9.9) is recharged to Pampa del Tamarugal aquifer at the above local towns.

(3) Results of Simulation

The groundwater table in 2015, 2043 (after 50 years) and 2093 (after 100 years) are simulated as shown in Fig. 5.5, based on the following assumptions.

- The water demand will linearly increase up to 2015 and thereafter, it will be constant.

As known from the above figure, the groundwater table will continue lowering ever after 2015.

The above figure also shows the groundwater flow rate per unit aquifer width (m^3/d) at each location in future.

Draw-downs of the groundwater table in the years of 2015, 2043 and 2093 measured from the existing level are shown in Fig. 5.6. The draw-down in the future are not large. The maximum draw-down is estimated to be 10 m in 2015, 20 m in 2043 and 30 m in 2093.

3) Forecasting of Groundwater Quality

The prospective aquifer for the water supply development (clean water aquifer) is located to the east of the line connecting La Tirana and Pintados (see, Chapter II, Fig. 2.23 (8)). At present (1992), it has a storage volume of 10,700 million m^3 of which 584 million m^3 will be extracted for the water supply of Iquique for 23 years until the year 2015.

On the other hand, the groundwater quality in the surrounding areas of the above prospective aquifer is contaminated to some extent and is not suitable for drinking use without treatment.

As known from Fig. 5.5, the groundwater in Pampa del Tamarugal mainly flows down in the north-south direction. Some quantity of the contaminated groundwater enters the prospective aquifer form the north. However, the quantity is small. It is estimated at only approximately 200 million m^3 for a total period of 23 years until 2015, equivalent to 2.0% of the storage volume of the prospective aquifer in 2015 (=200/10,700-584).

As evident from the above discussions, deterioration of the groundwater quality of the prospective aquifer in the future is considered negligibly small.

5.2.3 Groundwater Development Potential of Salar del Huasco Basin

1) Existing Water Balance

The whole surface water of the Basin infiltrate into underground to recharge the groundwater. However, some portion of the groundwater is discharged to the Pampa del Tamarugal Basin through the geological fissures. The remaining portion is consumed by the evaporation of the lake areas to keep the hydrological balance of the Basin. There is no water use in the Basin.

At present, water of the groundwater aquifer is well balanced. No significant historical variation of groundwater level is identified. The groundwater discharge to Pampa del Tamarugal is estimated as follows.

$D = I - E = 234$ l/s

where, D : Average groundwater discharge to Pampa del Tamarugal
I : Average surface water of Basin : 809 l/s
E : Average evaporation of the lake areas : 575 l/s

For details, see Supporting Report B-IV, Chapter II, 2.7.

2) Groundwater Development Potential

The existing groundwater storage is not large (465 million m^3). Hence, the sustainable development potential of the groundwater is considered as 575 l/s, equivalent to the evaporation of the lake areas.

This amount of groundwater development is enough to meet the increase of the municipal water demand of Iquique city by the year 2015.

However, any amount of the groundwater development will reduce or dry up the existing lake areas of Salar del Huasco to keep the hydrological balance of the Basin. It may resultingly cause damages to the environments of the lake areas, especially to the living of flamingos.

Further detailed environmental impact studies are considered necessary to reach the final conclusion on the water resources development potential of Salar del Huasco.

5.2.4 Municipal Water Supply and Demand Balance of Iquique City

The future municipal water demand of Iquique city on average production basis is estimated as follows.

Year	Demand (l/s)
1995	708
2005	807
2015	1,062

On the other hand, the existing water supply capacity is estimated to be 523* l/s on average production basis. Additional groundwater developments of 284 l/s and 539 l/s on average production basis are required by 2005 and 2015 respectively to meet the future municipal water demand.

These additional groundwater developments are proposed for Pampa del Tamarugal. The groundwater development of Salar del Huasco is considered as the alternative to be applied in case that the groundwater development of Pampa del Tamarugal is difficult.

* : 523 l/s is obtained from the existing water supply capacity of 680 l/s on daily maximum production basis by assuming the peak factor as 1.30.

Table 5.1 Monthly Average Groundwater Recharge Potential (1)

<Potencialidad Medio Mensual de Recarga de Agua Subterránea>

(unit : l/s)

Month	Ave. Flow Rate at Tocontasi	Water Right in Downstream	Actual Extraction	Surplus Flow Rate	Potential Recharge
Jan.	2,887	2,203	2,203	684	280.4
Feb.	4,741	2,203	2,203	2,538	1,040.6
Mar.	4,222	2,203	2,203	2,019	827.8
Apr.	1,759	2,203	1,759	0	0
May	1,809	2,203	1,809	0	0
Jun.	1,802	2,203	1,802	0	0
Jul.	1,937	2,203	1,937	0	0
Aug.	1,746	2,203	1,746	0	0
Sep.	1,542	2,203	1,542	0	0
Oct.	1,332	2,203	1,332	0	0
Nov.	1,307	2,203	1,307	0	0
Dec.	1,508	2,203	1,508	0	0
Ave.	2,216	2,203	1,779.3	436.7	179.0

Table 5.2 Monthly Average Groundwater Recharge Potential (2)

<Potencialidad Medio Mensual de Recarga de Agua Subterránea>

(Case 1)

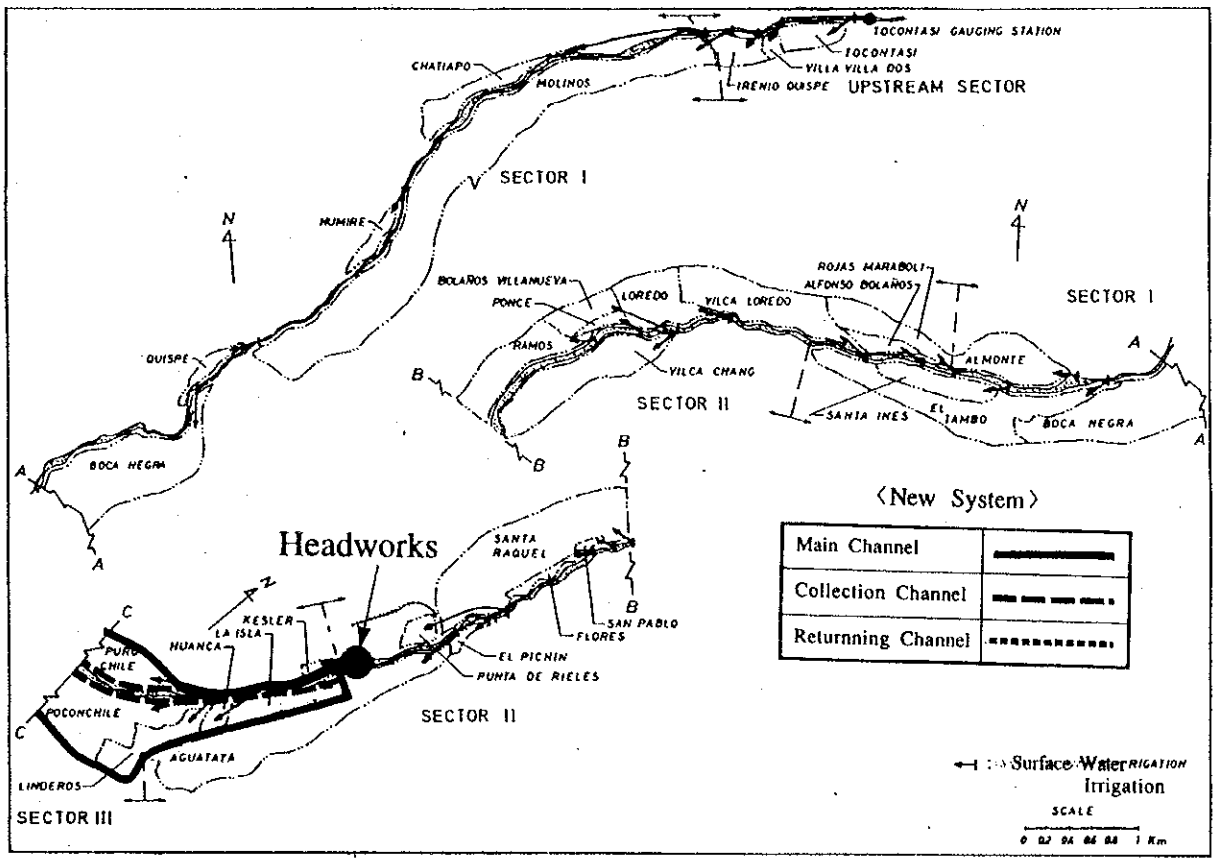
(unit : l/s)

Month	River Flow at Tocontasi	Upstream Consump.	River Flow at Headworks	Required Extraction	Actual Extraction	Surplus River Water	Groundwater Recharge
Jan.	2,887	275	2,612	819	819	1,793	735
Feb.	4,741	275	4,466	819	819	3,647	1,495
Mar.	4,222	275	3,947	819	819	3,128	1,282
Apr.	1,759	275	1,484	819	819	665	273
May	1,809	275	1,534	819	819	715	293
Jun.	1,802	275	1,527	819	819	708	290
Jul.	1,937	275	1,662	819	819	843	346
Aug.	1,746	275	1,471	819	819	652	267
Sep.	1,542	275	1,267	819	819	448	184
Oct.	1,332	275	1,057	819	819	238	98
Nov.	1,307	275	1,032	819	819	213	87
Dec.	1,508	275	1,233	819	819	414	170
Ave.	2,216	275	1,941	819	819	1,122	460

(Case 2)

(unit : l/s)

Month	River Flow at Tocontasi	Upstream Consump.	River Flow at Headworks	Required Extraction	Actual Extraction	Surplus River Water	Groundwater Recharge
Jan.	2,887	448	2,439	433	433	2,006	822
Feb.	4,741	446	4,295	431	431	3,864	1,584
Mar.	4,222	393	3,829	1,212	1,212	2,617	1,073
Apr.	1,759	193	1,566	878	878	688	282
May	1,809	150	1,660	709	709	951	390
Jun.	1,802	118	1,684	583	583	1,101	451
Jul.	1,937	114	1,823	156	156	1,667	683
Aug.	1,746	128	1,618	189	189	1,429	586
Sep.	1,542	164	1,378	859	859	519	213
Oct.	1,332	201	1,132	927	927	205	84
Nov.	1,307	236	1,071	1,056	1,056	15	6
Dec.	1,508	407	1,101	1,209	1,101	0	0
Ave.	2,216	250	1,966	720	711	1,255	515



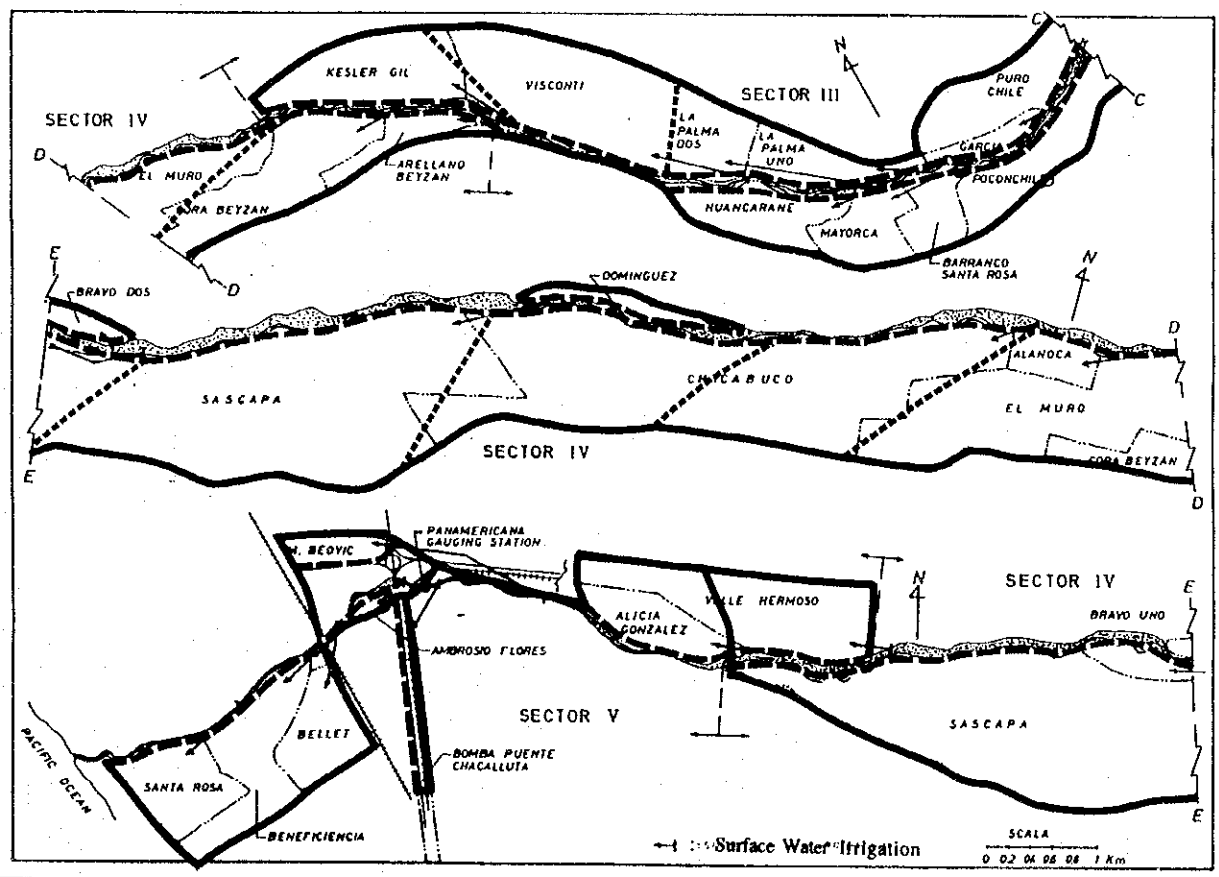


Fig. 5.1 Proposed New Irigation System

<Nuevo Sistema del Irrigación Prospuesta>

Surface Area and Longitudinal Profile of Aquifer Model

<Area Superficial y perfil Longitudinal del Modelo Acuífero>

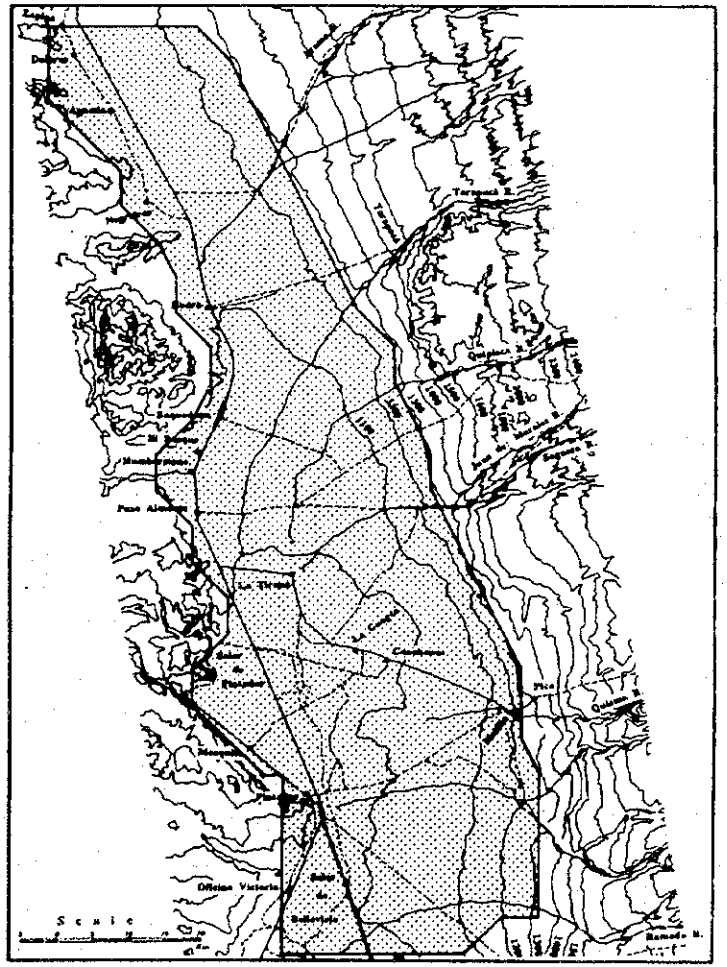


Fig. 5.2 Surface Area of Aquifer Model
<Area Superficial del Modelo Acuífero>

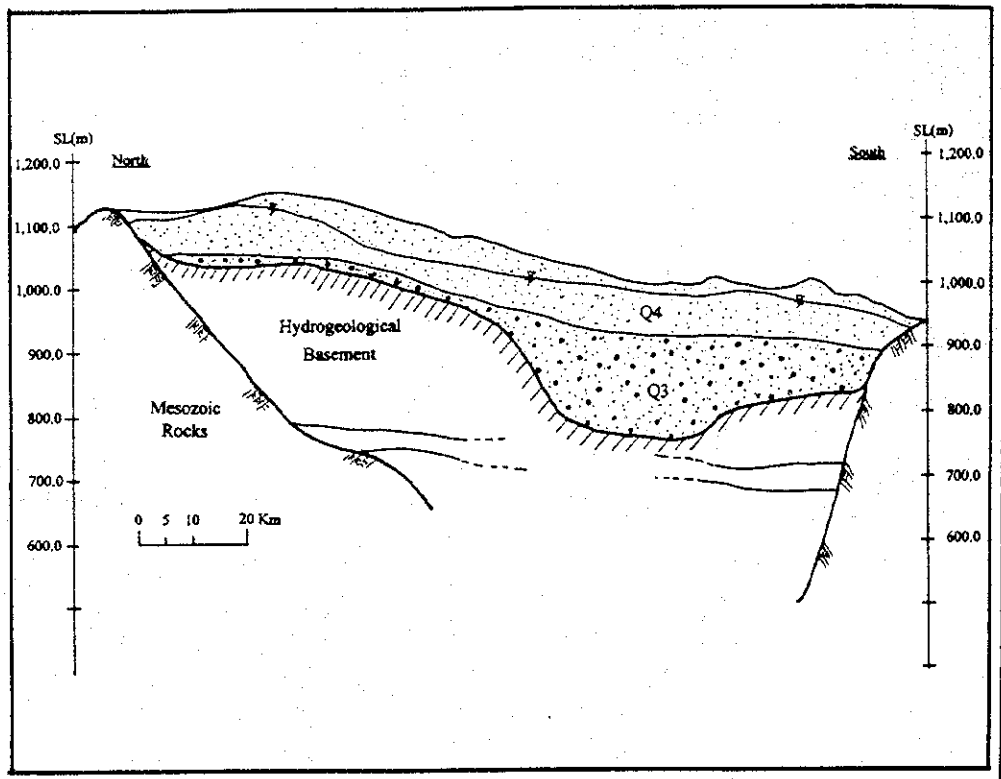


Fig. 5.3 Longitudinal Profile of Aquifer Model
<Perfil Longitudinal del Modelo Acuífero>

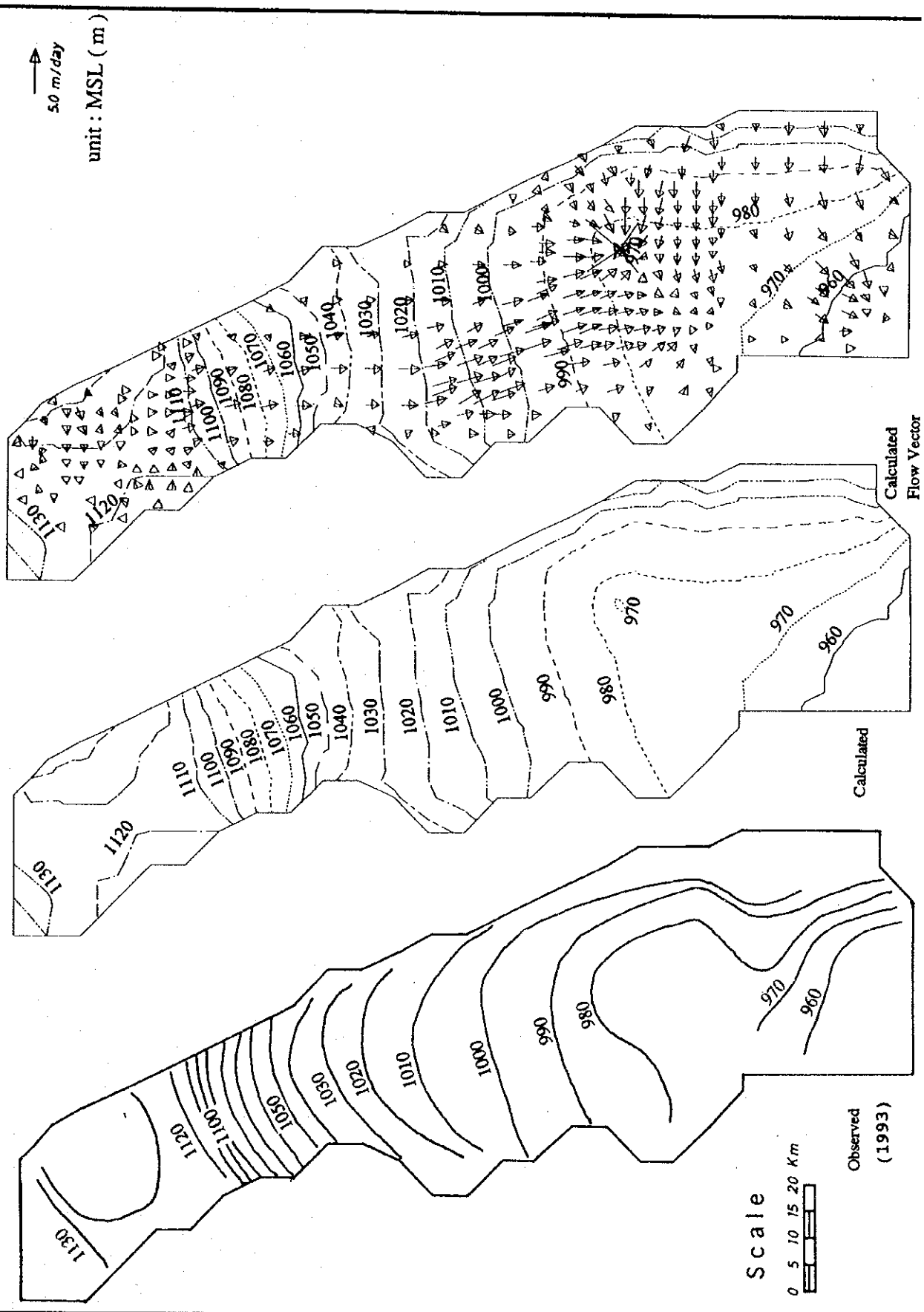


Fig. 5.4 Comparison Between Observed and Calculated Groundwater Level

<Comparacion Entre Mueles Freaticos Observados y Calculados>

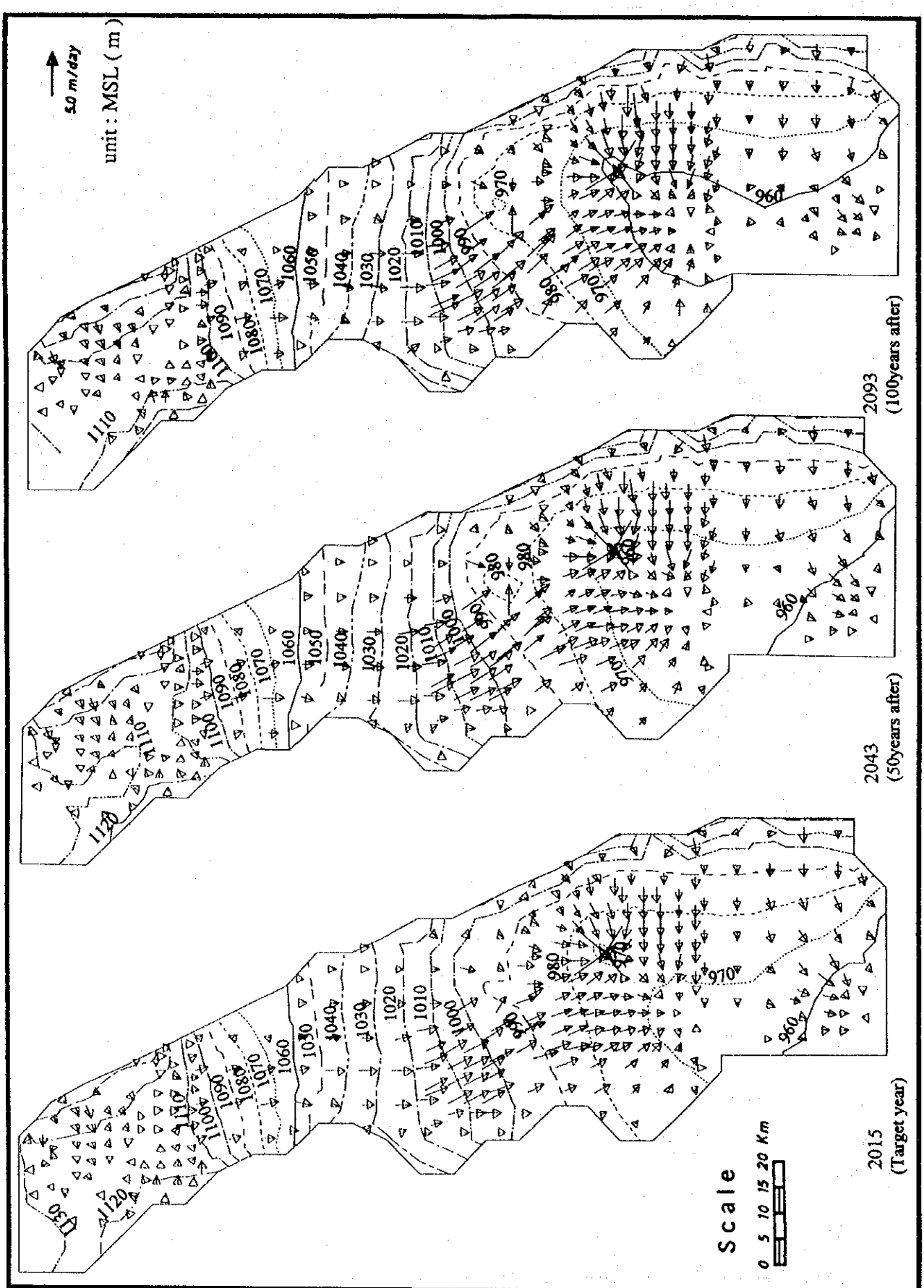


Fig. 5.5 Simulated Groundwater Level and Flow Vector in Future

<Nivel Freatico Simulado y Vector de Flujo Futuro>

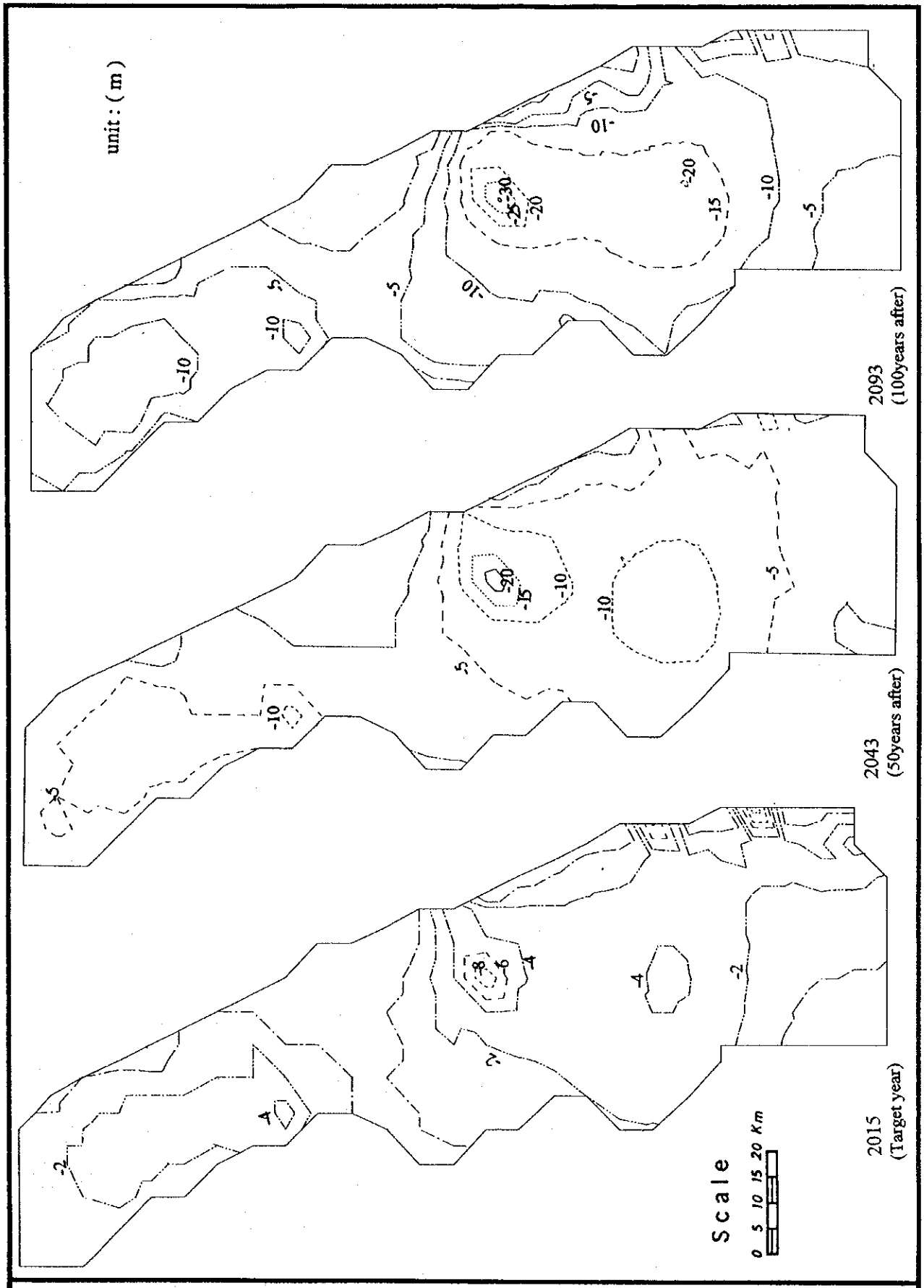


Fig. 5.6 Drawdown of Groundwater Level in Future (2015, 2043 & 2093)

<Mapa del Nivel Freatico en el Futuro (2015, 2043 & 2093)>

CHAPTER VI MUNICIPAL WATER SUPPLY DEVELOPMENT OF ARICA CITY

Chapter VI MUNICIPAL WATER SUPPLY DEVELOPMENT OF ARICA CITY

6.1 Existing Water Supply System

6.1.1 Outline of the System

The existing municipal water supply system for Arica city is operated and maintained by ESSAT.

The water source is groundwater of San José River Basin. The groundwater is extracted from the deep wells located in Azapa Valley and city area by means of submergible pumps installed in each well.

Water taken from the wells is first transmitted through an intake pipeline to a collection tank located nearly at the central place in the well-field. At the collection tank, the water is sterilized by hypo-chlorite which is injected to the inlet pipeline or to the outlet pipeline of the tank. Then, the chlorinated water is transmitted to distribution tanks located on the hilly areas in the east of the city. From the distribution tanks, water is supplied by gravity through distribution networks to consumers in the city.

The existing water supply system covers about 1,680 ha divided into four (4) service sectors of the urbanized area of the city.

For the existing water supply system, see Chapter 3, Fig. 3.1.

In 1992, ESSAT produced 16,941 x $10^3 m^3$ (=537 l/s) of municipal water of which 10,635 x $10^3 m^3$ was consumed for residential, commercial, industrial and other uses. The estimated water loss was 6,306 x 10^3, corresponding to 37.2% of the production volume.

The above production was obtained from 28 deep wells located in Azapa Valley and city area. During the year 1993, additional 17 wells were developed and commissioned by ESSAT, increasing the total production amount to 730 l/s.

6.1.2 Water Supply Facilities

1) Deep Well and Intake Pump

The existing deep wells of ESSAT water supply system count 45 in number as of February 1994. Depth of the wells ranges approximately from 50 m to

110 m, their casing pipe diameter 250 - 340 mm and their yield approximately 15 - 25 l/s. All the wells are equipped with submergible pump.

The groundwater extracted from the deep wells is lifted up by the submergible pumps to a collection tank in principle, through pressured intake pipelines.

Power for the pumps is supplied by the electricity enterprise.

2) Collection Tank

There are three (3) collections tanks;

(1) Pago de Gomez Station located in Azapa Valley
(2) Azapa Station located in Azapa Valley
(3) Estadio Station located in the city area

They are made of steel or reinforced concrete and situated slightly below the ground level.

The collected water is transmitted to distribution tanks through transmission pipelines. Water of Pago de Gomez and Azapa stations is transmitted by gravity to Chuño distribution tank and Saucache distribution tank, and further to Pampa Nueva distribution tank. Water of Estadio Station is lifted by pumps to La Cruz distribution tank. Some of La Cruz tank water is further transferred to Rosado and La Lisera distribution tanks by pumping up.

3) Distribution Tank

There are (6) distribution tanks as of February 1994. All the tanks are made of steel or reinforced concrete and located slightly below the ground level in the eastern or southern hills of the city.

Salient features of the tanks are as follows.

(1) Chuño Tank (V=5,000 m^3, HWL= 84.5 m ; to Service Sector II)
(2) Saucache Tank (V=2,500 m^3, HWL=104.6 m ; to Sector III)
(3) Pampa Nueva Tank (V=1,000 m^3, HWL= 129.1 m ; to higher land of Sector III)
(4) La Cruz Tank (V=2,500x2 = 5,000 m^3, HWL= 81.5 m ; to Sector I)
(5) Rosado Tank (V=800 m^3, HWL= 109.5 m ; to Sector IV)
(6) La Lisera Tank (V=200 m^3, HWL= 30.0m; to south-coastal area of Sector I)

The water being stored in the distribution tanks is supplied, by gravity in principle, through distribution networks to the service sectors in Arica city.

4) Transmission Pipeline

Most of the groundwater extracted from Azapa Valley is transmitted by two (2) major transmission pipelines to the distribution tanks located in the city area. One connects Cabuza and Chuño, and another connects Pago de Gomez and Saucache. Their salient features are as follows.

Line	Length (km)	Dia. (mm)	Material
Cabuza - Chuño	22.3	300 - 400	mostly asbest cement
Pago de Gomez - Saucache	8.3	250 - 400	asbest cement

Outline of the existing water supply facilities and service area are shown in Fig. 6.1. and Fig. 6.2 respectively.

6.1.3 Existing Water Supply Problems

1) Supply Capacity

The water supply service was limited to 10.5-15.0 hours per day for all the service sectors until the end of 1993 due to shortage of water. This water restriction was relaxed by the emergency water supply project which was completed at the end of 1993. However, water supply service in two (2) service sectors (II and III) are still limited to 14-15 hours per day.

2) Water Source

Groundwater of San José River Basin has been developed to excess for irrigation of Azapa Valley and municipal water of Arica city. No further development in the Basin can be expected. Hence, water for the future demand shall be obtained from Lluta Valley and other river basins.

3) Water Quality

Water quality of the groundwater in the Azapa Valley and city area is getting worse due to the excessive development. Especially TDS in the wells of city area is increasing.

4) Water Loss

The existing water loss is as high as approximately 40% of the total production.

6.2 Existing Institutional and Financial Aspects

6.2.1 Organization of ESSAT

ESSAT is a stock company, 99% of which shares are owned by CORFO. ESSAT serves municipal water supply and sewerage for the cities/towns of Region I including Arica, Iquique, Pozo Almonte, Pica, Matilla, La Tirana, La Huayca, Huara and Pisagua.

It has the following four (4) departments and two (2) branch offices under the top management.

(1)	General Management	(4)	Planning
(2)	Engineering	(5)	Arica Branch
(3)	Administration and Finance	(6)	Iquique Branch

The personnel of the organization totals 289 as of the end of 1993, being classified as follows.

Top Management	10
Technical Staff	53
Other Staff	226
Total	289

6.2.2 Tariff

1) Number of Client

Number of the clients received the water supply services of Arica city in the recent years are shown below, along with their coverage.

	Nos. of Client	Coverage(%)
1991	34,770	99
1992	37,423	99
1993	38,821	99

2) Tariff Structure

Water tariffs are set by the Government, aiming to cover the costs of water supply services. The Government sets the target tariff which must be attained in a period of five (5) years.

The existing water tariff of Arica city, as of February 1994, are as follows.

(1) Monthly Fixed Charge

Monthly fixed charge varies according to service pipe diameter.

Pipe Dia. (mm)	Charge ($)	Pipe Dia. (mm)	Charge ($)
13	231	50	5,005
15	334	75	11,678
19	667	100	20,019
25	1,335	125	30,028
32	2,002	150	45,042
38	3,003	200	80,075

(2) Monthly Variable Charge

Monthly variable charge includes charge during off season (April - November), charge during peak season (December - March) and overconsumption charge. These charges depend on the consumed water volume measured in m^3.

Overconsumption charge is applied for peak season to the consumption over the average consumption during off season. This charge is applied to the consumption over 30 m^3.

The monthly variable charges of Arica city are shown below.

Category	Normal ($/m^3)	Rebated ($/m^3)
Off Season	140.02	108.68
Peak Season	140.02	108.68
Overconsumption	363.74	363.74

3) Tariff Collection Efficiency

Invoicing is done on monthly basis for all clients. During the recent four (4) years (1990-1993), 96% of the total invoiced tariff was actually collected on an average for the whole ESSAT service area.

6.3 Short-term Development Plan

6.3.1 Development Capacity

As discussed in Chapter V, the groundwater of Lower Lluta Valley is only one potential water resources which can be developed in the Study Area for the water supply of Arica city. However, this groundwater development can meet only a short-term water demand since its potential is limited. Therefore, the available groundwater of Lower Lluta Valley will be exploited to the maximum extent.

The development capacity of the water supply to Arica is estimated as follows.

1) Daily average raw water production capacity (l/s) : 425 l/s

2) Daily maximum raw water production capacity (l/s) : 552.5 l/s

3) Daily average treated water production capacity (l/s) : 319 l/s

(4) Daily maximum treated water production capacity (l/s) : 414.4 l/s

The above estimations are made based on the following assumptions.

1) The ratio of daily maximum demand and daily average demands is 1.30.

2) The raw water is treated by a special process of desalination and its treatment efficiency is 75% (see, the next Section, 6.3.2,(3)).

The above treated water production capacity (319 l/s) may be able to meet only the water demand upto the year 2003 on average basis, comparing with the average water demands for the year 2000 (294 l/s) and the year 2005 (337 l/s).

6.3.2 Proposed Water Supply Development Facilities

1) Water Source Development

The groundwater of 553 l/s on daily maximum basis (425 l/s on daily average basis) is developed by 26 deep wells including three (3) wells for standby. The

wells are equipped with submergible pumps with an average discharge capacity of 25 l/s each.

The salient features of the proposed intake facilities are summarized below.

(1) Deep Well: 26 wells (12 inch x 150 m depth x 8 wells, 12 inch x 120 m depth x 18 wells)

(2) Submersible Pump: 26 pumps including three (3) for standby (each capacity: 25 l/s, total required electric power: 880 KW)

They are located on a line along the Lluta River between Chuilona and Rosario (see Fig. 6.3).

2) Transmission Main

All the well water is transmitted by a transmission pipeline to the treatment plant proposed in Chuilona by gravity. The pipeline runs a 12.5 km distance along the Highway Route 11 from the uppermost well in Rosario (Ground Elevation: 347 m) to the treatment plant (Ground Elevation: 131 m), crossing Lluta River at one (1) place en route. The proposed pipeline is made of asbestos cement pipe (ACP) with a diameter varying from 150 mm to 500 mm.

Four (4) tanks made of reinforced concrete are proposed en route for the purpose of water collection as well as pressure break.

The salient features of the proposed transmission main are summarized below.

(1) Transmission Pipeline (Asbestos Cement)

150 ~ 250 mm x 1 x 2,500 m
300 ~ 400 mm x 1 x 4,500 m
450 ~ 500 mm x 1 x 5,500 m

(2) Collection/Pressure-break Tank (Reinforced Concrete)

15 m^3 x 1 unit x 1 site
105 m^3 x 1 unit x 1 site
180 m^3 x 1 unit x 1 site
270 m^3 x 1 unit x 1 site

The route and longitudinal profile of the transmission main are shown in Fig. 6.3 and Fig. 6.4 respectively.

3) Water Treatment

(1) Treatment Method

The raw water contains a high concentration of TDS, Na, SO_4, Cl, Fe and B exceeding the permissible limit of drinking use (see, Chapter V, 5.1.3). For treatment of such brackish water, Reverse Osmosis (RO) or Electrodialysis (EDR) method is generally employed.

In RO method, the raw water is forced to pass through a membrane against the natural osmotic pressure. This is accomplished by applying counter pressure against the osmotic pressure. Only the desalted water passes through the RO membrane.

EDR method is based on the principle of ion-exchange. Cations pass selectively through cation membranes and anions pass through anion membranes. When direct current voltage is applied to these membranes, ions in dilute chambers are transferred to concentrated chambers. Thus, the raw water is desalinated.

In general, brackish water can be treated by RO or EDR method upto the permissible limits for drinking use with a recovery efficiency of 70-80%. Here, the recovery efficiency is defined as the ratio of treated water volume and raw water volume.

However, there is no experience of the treatment of such brackish water with a high content of Boron as the groundwater of Lower Lluta Valley in actual potable water supply. Therefore, the groundwater of Lower Lluta Valley was experimentally treated in this Study. The experiment was conducted by using a small-scale RO treatment plant with a cooperation of ESSAT in Arica during August to September 1994. The results are summarized below.

	TDS	Na	SO_4	Cl	Fe	B
Raw Water (mg/l)	3,438	565	1,018	929	0.12	22
Treated water (mg/l)	43	8.7	2.5	14	0.02	4.5
Treatment Efficiency (%)	99	98	99	98	82	79
Permissible Limit (mg/l)	1,000	200	250	250	0.3	5.0

In the above test, the recovery efficiency was 76.2% under the pump pressure of 20 kg/cm^2.

As evident from the above table, RO method is effective for the treatment of the groundwater of Lower Lluta Valley. Boron is considered the most critical water quality element for the treatment.

For details of the experiment, see Supporting Report D, Appendix 5.

(2) Treatment Plant

Design water quantity of the treatment plant on daily maximum basis is determined as follows, by assuming the recovery efficiency as 75%, based on the above-mentioned experiment.

Raw Water	:	552.5 l/s (47,700 m^3/day)
Treatment Water	:	414.4 l/s (35,800 m^3/day)
Wastewater	:	138.1 l/s (11,900 m^3/day)

The treatment plant is constructed in Chuilona on the right bank of Lluta River. The plant yard covers 3.8 ha of land with a ground elevation of 131 m. The treated water is distributed to the northern part of Arica city from the distribution tanks attached to the treatment plant. The wastewater is directly drained to the sea nearby the river mouth of Lluta River by gravity through a concrete pipe with a total length of 8,750 m.

The salient features of the proposed treatment plant are summarized below.

i) Tank (Reinforced Concrete)

Receiving Tank	:	1,000 m^3 x 2 units
Conditioning Tank	:	4,000 m^3 x 1 unit
Backwash Tank	:	150 m^3 x 1 unit
Wastewater Tank	:	210 m^3 x 1 unit
Distribution Tank	:	6,000 m^3 x 2 units

ii) Treatment Equipment (total required electric power: 4,500 KW)

Filter	:	12 units
RO	:	12 units

iii) Wastewater Drainage Pipe (Concrete, 350 mm x 8,750 m)

The flow diagram and layout of the treatment plant are shown in Fig. 6.5 and Fig. 6.6 respectively.

4) Land Acquisition and Compensation Works

(1) Land Acquisition

The required land area for the construction of the facilities are as follows.

Intake facilities	:	0.07 ha
Transmission main	:	2.5 ha
Treatment plant	:	3.8 ha
Wastewater drainage pipe	:	0.9 ha

The intake facilities and transmission main are constructed in the government reserved land, located between the Highway Route 11 and railway. The wastewater drainage pipe is installed under the roads. Hence, the construction of the intake facilities, transmission main and wastewater drainage pipe does not require any land acquisition although it may need the right of using the lands.

However, a private land of 3.8 ha shall be acquired for the treatment plant. The land is now idle.

(2) Compensation Works (Reconstruction of Existing Irrigation System)

As mentioned in Chapter V, 5.1.3, the proposed groundwater development will lower the existing groundwater level, resulting in acceleration of the river water infiltration into underground. It may make it difficult to extract the river water in the downstream of Poconchile in dry season.

The existing irrigation system for the downstream reaches of Poconchile is reconstructed to cope with the above problems and to protect the existing water use rights. The proposed compensation works include the following ones.

i) Head Works : one (1) at Kesler (upstream of Poconchile)

ii) Irrigation Channel : 77.6 km
- Main Channel : 43.3 km
- Collection Channel

(to collect the drained water for reuse) : 15.9 km

- Return Channel

(to return the collected water to the main channel) : 18.4 km

6.3.3 Estimated Invesment Cost

The total investment cost, consisting of direct construction cost, land acquisition cost, engineering cost, administration cost and physical contingency amounts to $32,694 million Pesos at 1994 price with a foreign currency portion of 48,177 thousand US$ and a local currency portion of 11,737 million Pesos. Its break-down is shown below.

	Work Item	Foreign Currency (10^3 US$)	Local Currency (10^3 Pesos $)	Total (10^3 Peso $)
1)	Direct Construction Cost	42,080	6,722,117	25,027,108
	(1) Intake Works	7,153	1,700,006	4,811,728
	(2) Transmission Facilities	1,470	118,258	757,702
	(3) Treatment Plant	29,597	4,112,572	16,987,214
	(4) Distribution Networks	3,850	633,281	2,312,464
	(5) Electric Transmission Line	0	158,000	158,000
2)	Land Acquisition Cost	0	2,912,000	2,912,000
	(1) Land Acquisition	0	12,000	12,000
	(2) Compensation Works	0	2,900,000	2,900,000
3)	Engineering Cost {6% of 1)}	1,782	726,456	1,501,626
4)	Administration Cost {3% of 1)}	0	750,813	750,813
5)	Physical Contingency {10% of 1)}	4,315	625,678	2,502,711
	Total	48,177	11,737,064	32,694,258

Note: Cost: as of March 1994, excluding Value Added Tax (IVA)
Exchange Rate: US$1.00 = Chilean Pesos $435.00 = Japanese Yen ¥110.00

The direct construction and land acquisition costs are further broken down as shown in Table 6.1 For further details, see Supporting Report D, Table D-1, 3.5 and Appendix 6.

6.3.4 Implementation Program

1) Implementation Schedule

The proposed short-term project will be completed within three (3) years from 1996 to 1998. The detailed design and land acquisition will be completed within the year of 1996. The construction works including direct construction works and compensation works will commence in 1997 and be completed in 1998. It will be commissioned in 1999.

2) Disbursement Schedule

The proposed disbursement schedule of the project cost is shown in Table 6.2.

6.3.5 Operation and Maintenance

1) General

The project will start functioning in 1999 and will reach the full operation stage in 2003. The treated water supply will gradually increase from 293 l/s in 1999 to 319 l/s in 2003 on daily average basis.

The daily operation and maintenance of the project will be performed by a new section to be set up in the Arica Branch Office of ESSAT. The office of the new section will be provided at the site of the Lluta treatment plant.

2) O&M Cost

The O&M cost of the project consists of annual O&M cost including electric consumption, chemical consumption, personnel and repair costs, and replacement cost.

The required annual O&M cost at the full operation stage are estimated to be 1,257,374 thousand Pesos at 1994 price with the following break-down.

		(10^3 Pesos $ at 1994 price)
(1)	Electric Consumption Cost	587,884
(2)	Chemical Consumption Cost	199,629
(3)	Personnel Cost	56,448
(4)	Repair Cost	413,413
	Total Annual O&M Cost	1,257,374

Furthermore, the pumps and other equipment of the intake facilities, and RO units and other equipment of the treatment plant will be periodically replaced according to their life spans. Their life spans and replacement costs at 1994 price are estimated as follows.

		Life Span (Year)	Replacement Cost (10^3 Peso $, 1994 price)
(1)	Intake Facilities		
	i) Pump	15	2,510,458
	ii) Other Equipment	20	2,244,067
(2)	Treatment Plant		
	i) RO Unit	10	7,400,120
	ii) Other Equipment	20	8,080,380

For details, see Supporting Report D, Table D-1, 3.6.

6.3.6 Economic Evaluation

1) General

The economic evaluation of this project is made by using the computerized evaluation model called as SIMOP (Simulación de Obras Publicas: Simulation of Public Works) which was developed by MIDEPLAN (Ministerio de Planificación: Ministry of Planning).

This model identifies and quantifies the social economic benefits of the project. The computation program classifies the consumers into the following four (4) groups based on their demand curves estimated from price (tariff), water demand and price-consumption elasticity.

(1) Low-income class residential
(2) Middle-income class residential
(3) High-income class residential
(4) Commercial, industrial and fiscal

2) Concept of Benefits and Costs

(1) Concept of Benefits

The benefit coming from an increased water supply can be perceived from the greater willingness to pay of the consumers for the water use price (tariff) charged for the project. In economic terms, the benefit accrued from the additional water supply is represented by the marginal value-in-use of each water unit contributed by the project. The marginal value-in-use is measured on the demand curves of the consumers.

The water demand of the different consumer groups grows as time goes by, due to the incorporation of new water users and the increase of the per

capita water consumption. The willingness to pay varies corresponding to the changes in the per capita water consumption. In view of these facts, it is necessary to consider several different types of demand curves for the consumer groups. These demand curves simulate the willingness to pay based on the water consumption patterns and their changes through time.

In this Study, the following three (3) types of demand curves are applied for the consumer groups.

Type I: This type of demand curves have a constant price elasticity at each price level through time. This type is used when the shift of the demand curves through time is caused by the incorporation of new consumers, however the per capita water consumption of the old consumers are kept constant. This type is generally applied for the commercial, industrial and fiscal consumption group. Fig. 6.7(1) represents this type.

Type II: This type of demand curves have the same slope of the demand curves through time. However, the price elasticity varies through time. The shift of the demand curves through time is caused by the increase of the per capita water consumption of the consumers. This type assumes no incorporation of new consumers. This type is generally applied for the middle-income class and high-income class residential consumption groups. Fig. 6.7 (2) represents this type.

Type III: This type of demand curves keep the same price elasticity through time, irrespective of the different price-quantity combinations which constitute the demand curves. This type is characterized by the fact that an increase in price would bring about a greater water consumption decrease compared with Type I and Type II demand curves. This type is generally applied for the low-income class consumption group. Fig. 6.7(3) represents this type.

For details of the types of the demand curves, see Supporting Report F, Chapter IV, 4.2.2.

(2) Concept of Costs

The social project costs (costs based on shadow prices) are used in the economical evaluation of the project. The market prices of the discount rate, labor and foreign exchange are converted into the social prices

according to the guidelines of MIDEPLAN. Further, taxes, duties and other specific taxes are excluded from the market prices to obtain the social project costs.

2) Assumptions and Input Data for Economic Evaluation

(1) Incremental Investment

The incremental investment is the difference between the investments in With-Project and Without-Project. The investment in Without-Project is assumed to be the investment costs included in the on-going development plan of ESSAT.

(2) Adjustment of Market Prices

The market prices of labor and foreign exchange are converted into the social prices by using the following adjustment factors based on the guidelines of MIDEPLAN.

Labor	:	Skilled	:	no adjustment
		Non-skilled	:	0.66
		Semi-skilled	:	0.73
Foreign Exchange			:	1.06

Further, the social discount rate of 12% is employed also based on the suggestions of MIDEPLAN.

The incremental investment costs on market prices are converted into the incremental investment costs on social prices based on the above adjustment factors and the following shares of imported component and labour in the project.

Type of Works	Imported Component	Labor	
		Non-skilled	Semi-skilled
Intake Works	32%	3.8%	2.6%
Transmission	35%	2.6%	13.8%
Treatment Plant	60%	3.6%	2.5%
Distribution	35%	2.6%	13.8%
Electric Works	61%	1.0%	15.0%

(3) Evaluation Period : 36 years (1993-2028)

(4) Consumer Groups and Demand Characteristics

The consumers are classified into the following four (4) groups.

Group 1: Residential consumption between 1-20 m^3/month/connection (low-income class)

Group 2: Residential consumption between 20-30 m^3/month/connection (middle-income class)

Group 3: Residential consumption greater than 30 m^3/month/connection (high-income class)

Group 4: Commercial, industrial and fiscal consumption

Their characteristic features of water demand are as follows:

	Group 1	Group 2	Group 3	Group 4
Price Elasticity	-0.52	-0.20	-0.25	-0.20
Demand Curve Type	3	2	2	1
Annual Demand Growth Rate (%)	3.89	3.89	7.40	7.78
Initial Tariff ($/$m^3$)	114.00	114.00	129.03	129.03
Initial Water Consumption. ($10^3 m^3$/yr)	3,515	950	3,230	1,805

(5) Water Consumption Capacity

The total yearly water consumption capacity (water supply capacity at connection points) in future are estimated for Without-Project and With-Project cases. The water consumption capacity in Without-Project case will increase to some extent in future by the water loss reduction program. The additional water consumption capacity in With-Project case will be yielded by the proposed project.

For the estimated water consumption capacity in future, see Supporting Report F, Chapter IV, 4.6.1.

(6) Project Costs

The project costs used in the economic evaluation consist of periodic costs, non-periodic costs and variable costs. The periodic costs cover personnel costs and operation & repairing costs annually incurred. The non-periodic costs are the incremental investment costs evaluated at social

price. The variable costs include electricity and treatment chemicals costs varying according to the produced water volume.

The above costs are summarized below.

Periodic costs	:	Peso $469,861 x 10^3/year	
Non-periodic costs	:	year 1996	: Peso $688,073 x 10^3
		year 1997	: Peso $5,225,071 x 10^3
		year 1998	: Peso $20,123,170 x 10^3
Variable costs	:	Peso $112/$m^3$	

3) Results of Economic Evaluation

The present value of benefits and present value of costs computed by SIMOP are shown below.

Present Value of Benefits (10^6 Peso $)		Present Value of Costs (10^6 Peso $)	
Group 1	3,463	Periodic	2,146
Group 2	991	Non-periodic	15,229
Group 3	11,738	Variable	2,774
Group 4	2,382	Total	20,148
Total	18,574		

The socio-economic profitability is evaluated in terms of Net Present Value (NPV), Benefit Cost Ratio (B/C) and Economic Internal Rate of Return (EIRR) as follows.

NPV : Peso $ - 1,574 x 10^6
B/C : 0.92
EIRR : 11.36 %

The NPV is a little negative and EIRR is a bit smaller than 12% as requested by the guideline of MIDEPLAN.

However, this project is considered profitable in case that such intangible benefits as the improvements of sanitary/hygienic conditions and living standards in Arica city are taken into account.

4) Sensitivity Analysis

In order to make the NPV positive and EIRR greater than 12%, the investment cost needs to be decreased by 10.35% or the social discount rate needs to be decreased down to 11.36% as shown below.

Reduction Rate of Investment Cost (%)	NPV (10^6 Peso $)	EIRR (%)
-17.00	1,050	12.49
-14.00	525	12.25
-10.35	0	12.00
-7.00	-525	11.79
-3.00	-1,050	11.57

Social Discount Rate (%)	NPV (10^6 Peso $)
9.00	8,979
10.00	4,427
11.36	0
12.00	-1,576
13.00	-3,502

6.3.7 Financial Evaluation

1) General

A standard financial analysis is performed for the project. The financial aspects are evaluated in terms of Net Present Value (NPV) and Financial Internal Rate of Return (FIRR). Apart from the above indexes, a financial statement is prepared to make an income analysis.

2) Assumptions and Input Data for Financial Evaluation

(1) Evaluation Period : 33 years (1996-2028)

(2) Annual Price Escalation : 8%

(3) Water Tariff : Average water tariff is estimated at Peso $ 154/m^3 at the end of 1994. It will increase at a rate of 16% per year.

(4) Cash Flow : See, Table 6.3

(5) Financial Discount Rate : 12% (based on the guideline of MIDEPLAN)

(6) Loan Conditions : The loan covers all investment costs. The loan conditions are shown below.

Interest Rate : 7%

Repayment Period : 25 years

Grace Period : 5 years

(7) Income Tax : 25%

3) Results of Financial Evaluation

The estimated Net Present Value is Peso $7,199,009 x 10^3 and FIRR is 13.06%. The project is considered profitable.

The calculated financial statement is shown in Table 6.4. As known from the Table 6.4, the project is profitable enough to cover the running costs and to repay the loan within the evaluation period.

4) Sensitivity Analysis

The project is still profitable for the increase of the investment cost by 22.46% or for the decrease of the revenue by 9.59% as shown below.

Increase Rate of Investment Cost (%)	NPV (10^6 Peso $)	FIRR (%)
40.00	-5,619	11.32
30.00	-2,414	11.69
22.46	0	12.00
20.00	790	12.10
15.00	2,392	12.63

Reduction Rate of Revenue (%)	NPV (10^6 Peso $)	FIRR (%)
-20.00	-7,814	10.71
-15.00	-4,061	11.35
-9.59	0	12.00
-5.00	3,446	12.52
-3.00	4,947	12.74

6.3.8 Environmental Impact Assessment

The project will much contribute to the economical development of Arica city and the improvement of the living standards of the citizen. However, it may cause some negative impacts on the environments of the project area.

The anticipated negative impacts in the three (3) stages of pre-construction, construction and operation are evaluated as follows.

1) Pre-construction Stage

The deep wells are drilled in the land lying between the National Highway Route 11, and the railway connecting Arica and La Paz in principle. The land all belongs to the government and is now entirely vacant. Hence, no negative impact is anticipated concerning the land acquisition.

The transmission pipeline is also installed in the above-mentioned government land located between the Highway Route 11 and the railway. No negative impact is anticipated concerning the land acquisition.

The Lluta treatment plant requires a land acquisition of 3.8 ha in Chuilona area. No negative impact is anticipated concerning the land acquisition since the land is vacant and no resettlement is involved.

The wastewater pipeline is laid under the existing road. No land acquisition is necessary.

There are no valuable historical assets, flora and fauna in the project sites.

2) Construction Stage

(1) Vibration, Noise and Dust

Vibration, noise and dust may be caused by the construction of the proposed facilities. The impacts are assessed as less important since the anticipated vibration, noise and dust are small and the project sites are sparsely inhabited.

(2) Traffic Disturbance

The transmission pipeline crosses the Highway Route 11 at one (1) place. The wastewater pipeline crosses the Highway Route 11 and Pan American Highway at one (1) location respectively.

Traffic disturbance due to the crossing works of the pipelines is assessed as small due to the little traffic volume of both highways.

(3) Lowering of Groundwater Table

No pipeline is installed below the groundwater table. Well drilling generally causes no impact on the groundwater table. Therefore, lowering of groundwater table due to the construction works of the project is not anticipated.

3) Operating Stage

(1) Lowering of Groundwater Table

The project plans to extract the groundwater within the extent of its recharge potential. Hence, the existing groundwater table will be maintained on a long-term average basis although it may seasonally or yearly fluctuate.

There are now two (2) deep wells and 10 shallow wells at work in Lower Lluta Valley. However, they are more than 4,000 m away from the proposed wells. On the other hand, the radius of influence of the proposed groundwater pumping is estimated at less than 200 m.

Therefore, no adverse impact on the existing wells is anticipated.

However, the lowering of the groundwater level in dry period will accelerate the groundwater recharge of the river water. It may cause some negative impacts on the river water extraction at the existing irrigation intakes in the downstream reaches of Poconchile.

To cope with this problem, the project includes the construction of a new irrigation system which integrates the existing irrigation intakes into one (1) headworks proposed in the upstream of Poconchile.

(2) Sea water Intrusion

The proposed well production is within the limit of groundwater recharge potential. Hence, no sea water intrusion into the aquifers in Lower Lluta Valley is considered.

(3) Discharge of Wastewater

A daily maximum raw water of 553 l/s is treated by the RO process of which 138 l/s or 25% is directly discharged to the sea through a drainage pipe at the river mouth of Lluta. The expected wastewater quality is as follows.

TDS	:	13,000 mg/l
Cl	:	3,800 mg/l
B	:	70 mg/l

The wastewater is considered to cause no significant adverse effects on the sea water environments in view that the sea water itself contains TDS of 30,000 mg/l and Cl of 20,000 mg/l and that the wastewater is diluted with sea water, immediately after entering the sea.

Table 6.1 Break-down of Direct Construction and Land Acquisition Cost

<Detalle de Costos Directos de Consutrucción y Adquisición de la Tierra>

No	Work Item	Quantity	Foreign Currency (1000 x US$)	Local Currency (1000 x Peso $)	Total (1000 x Peso $)
1	Direct Construction		42,080	6,722,117	25,027,108
1)	Intake Works		7,153	1,700,006	4,811,728
(1)	Deep Wells	26Wells	350	1,371,184	1,523,538
(2)	Pumps	26 Submergible Pumps	2,160	104,410	1,044,098
(3)	Electric Facilities		4,643	224,412	2,244,092
2)	Transmission Facilities		1,470	118,258	757,702
(1)	Pipeline	D=150~500 mm, L=12,500 m	1,251	60,462	604,621
(2)	Valve	11 Valves	70	7,621	38,106
(3)	Crossing Works		149	7,200	72,000
(4)	Breake-pressure Tank	4 Tanks	0	42,975	42,975
3)	Treatment Plant		29,597	4,112,572	16,987,214
(1)	Civil Works		0	958,364	958,364
(2)	Building Works		0	536,350	536,350
(3)	Mechanical Equipment	12 RO units	21,657	1,963,878	11,384,800
(4)	Electric Equipment		7,894	633,780	4,067,700
(5)	Others		46	20,200	40,000
4)	Distribution Network		3,860	633,281	2,312,464
(1)	Distribution Main Pipe	D=700 mm, L=7,000m	3,860	186,576	1,865,759
(2)	Distribution Network	L=12,800 m	0	446,705	446,705
5)	Electric Transmission Line		0	158,000	158,000
(1)	Electric Transmission Line	23 kVA, L=20km	0	158,000	158,000
2	Land Acquisition Cost		0	2,912,000	2,912,000
1)	Land Acquisition	3.8 ha	0	12,000	12,000
2)	Compensation Works	Irrigation Channel L=77km, etc	0	2,900,000	2,900,000

Note: Cost: as of March 1994, excluding Value Added Tax (IVA)

Exchange Rate: US$1.00= Chilean Peso $435.00= Japanese Yen ¥110.00

Table 6.2 Disbursement Schedule of Investment Cost (Arica)

<Programa de Desembolso de los Costos de Inversión (Arica)>

[Unit : Thousands US$ or Thousand Pesos]

Work Item	1996			1997			1998			TOTAL		
	Foreign Currency (1000 x US$)	Local Currency (1000 x Peso)	Sub Total (1000 x Peso)	Foreign Currency (1000 x US$)	Local Currency (1000 x Peso)	Sub Total (1000 x Peso)	Foreign Currency (1000 x US$)	Local Currency (1000 x Peso)	Sub Total (1000 x Peso)	Foreign Currency (1000 x US$)	Local Currency (1000 x Peso)	TOTAL (1000 x Peso)
1 Direct Construction	0	0	0	6,242	2,595,156	5,310,330	35,839	4,126,962	19,716,778	42,080	6,722,117	25,027,108
1) Intake Works	0	0	0	3,577	850,003	2,405,864	3,577	850,003	2,405,864	7,153	1,700,006	4,811,728
2) Transmission Facilities	0	0	0	735	59,129	378,851	735	59,129	378,851	1,470	118,258	757,702
3) Treatment Plant	0	0	0	0	1,369,383	1,369,383	29,597	2,743,189	15,617,831	29,597	4,112,572	16,987,214
4) Distribution Network	0	0	0	1,930	316,640	1,156,232	1,930	316,640	1,156,232	3,860	633,281	2,312,464
5) Electric Transmission Line	0	0	0	0	0	0	0	158,000	158,000	0	158,000	158,000
2 Land Acquisition Cost	0	12,000	12,000	0	1,450,000	1,450,000	0	1,450,000	1,450,000	0	2,912,000	2,912,000
1) Land Acquisition	0	12,000	12,000	0	0	0	0	0	0	0	12,000	12,000
2) Compensation Works	0	0	0	0	1,450,000	1,450,000	0	1,450,000	1,450,000	0	2,900,000	2,900,000
3 Engineering Cost	890	363,228	750,378	446	181,614	375,624	446	181,614	375,624	1,782	726,456	1,501,626
4 Administration Cost	0	250,271	250,271	0	250,271	250,271	0	250,271	250,271	0	750,813	750,813
5 Physical Contingency	0	0	0	2,158	312,839	1,251,356	2,158	312,839	1,251,356	4,315	625,678	2,502,711
TOTAL	890	625,499	1,012,649	8,845	4,789,879	8,637,581	38,442	6,321,686	23,044,029	48,177	11,737,064	32,694,258

Note: Cost: as of March 1994, excluding Value Added Tax (IVA)
Exchange Rate: US$1.00 = Chilean Peso $435.00 = Japanese Yen ¥110.00

Table 6.3 Cash Flow Analysis (Arica)
<Analisis de Flujo de Caja (Arica)>
(Unit : Pesos)

Year	Investment	O & M Cost (*)	Total Cost	Revenue	Cash Flow
1996	1,181,661,551		1,181,661,551		-1,181,661,551
1997	10,880,589,950		10,880,589,950		-10,880,589,950
1998	31,350,850,600		31,350,850,600		-31,350,850,600
1999		1,746,506,022	1,746,506,022	2,082,922,022	336,416,000
2000		1,899,306,810	1,899,306,810	2,454,053,437	554,746,626
2001		2,087,037,027	2,087,037,027	2,896,114,364	809,077,337
2002		2,292,393,272	2,292,393,272	3,407,257,961	1,114,864,689
2003		2,513,496,566	2,513,496,566	4,007,826,981	1,494,330,415
2004		2,714,576,291	2,714,576,291	4,713,352,284	1,998,775,993
2005		2,931,742,395	2,931,742,395	5,542,045,313	2,610,302,918
2006		3,166,281,786	3,166,281,786	6,428,772,563	3,262,490,777
2007		3,419,584,329	3,419,584,329	7,457,376,173	4,037,791,844
2008		3,693,151,075	3,693,151,075	8,650,556,360	4,957,405,285
2009		27,463,035,267	27,463,035,267	10,034,645,378	-17,428,389,889
2010		4,307,691,414	4,307,691,414	11,640,188,638	7,332,497,224
2011		4,652,306,727	4,652,306,727	13,502,618,820	8,850,312,093
2012		5,024,491,266	5,024,491,266	15,663,037,832	10,638,546,566
2013		5,426,450,567	5,426,450,567	18,169,123,885	12,742,673,318
2014		17,561,703,762	17,561,703,762	21,076,183,706	3,514,479,945
2015		6,329,411,941	6,329,411,941	24,448,373,099	18,118,961,158
2016		6,835,764,896	6,835,764,896	28,360,112,795	21,524,347,899
2017		7,382,626,088	7,382,626,088	32,897,730,843	25,515,104,754
2018		7,973,236,175	7,973,236,175	38,161,367,777	30,188,131,602
2019		129,997,352,532	129,997,352,532	44,267,186,622	-85,730,165,911
2020		9,299,982,675	9,299,982,675	51,349,936,481	42,049,953,806
2021		10,043,981,289	10,043,981,289	59,565,926,318	49,521,945,029
2022		10,847,499,792	10,847,499,792	69,096,474,529	58,248,974,737
2023		11,715,299,775	11,715,299,775	80,151,910,454	68,436,610,679
2024		12,652,523,757	12,652,523,757	92,976,216,126	80,323,692,369
2025		13,664,725,658	13,664,725,658	107,852,410,706	94,187,685,049
2026		14,757,903,710	14,757,903,710	125,108,796,419	110,350,892,709
2027		15,938,536,007	15,938,536,007	145,126,203,847	129,187,667,840
2028		17,213,618,888	17,213,618,888	168,346,396,462	151,132,777,574
				NPV	7,199,009,275
				FIRR	13.06%

* Considering replacement costs

Table 6.4 Financial Statement (Arica)
<Estado Financiero (Arica)>

(Unit : Pesos)

Year	O&M (*)	Interest Payment	Capital Repayment	Total Expenditure	Gross Revenue	Net Revenue Before Depreciation	Depreciation	Net Revenue After Depreciation	Tax	Net Revenue After Tax	Accumulated Net Revenue
1996											
1997		59,083,078		59,083,078		-59,083,078		-59,083,078		-59,083,078	-59,083,078
1998		603,112,575		603,112,575		-603,112,575		-603,112,575		-603,112,575	-662,195,653
1999	1,746,506,022	2,170,655,105		3,917,161,127	2,082,922,022	-1,834,239,105	1,720,806,215	-3,555,045,320		-3,555,045,320	-4,217,240,972
2000	1,899,306,810	2,170,655,105		4,069,961,915	2,454,053,437	-1,615,908,479	1,720,806,215	-3,336,714,694		-3,336,714,694	-7,553,955,666
2001	2,087,037,027	2,170,655,105	2,170,655,105	6,428,347,237	2,896,114,364	-3,532,232,873	1,720,806,215	-5,253,039,088		-5,253,039,088	-12,806,994,754
2002	2,292,393,272	2,062,122,350	2,170,655,105	6,525,170,727	3,407,257,961	-3,117,912,766	1,720,806,215	-4,838,718,981		-4,838,718,981	-17,645,713,735
2003	2,513,496,566	1,953,589,595	2,170,655,105	6,637,741,265	4,007,826,981	-2,629,914,284	1,720,806,215	-4,350,720,499		-4,350,720,499	-21,996,434,234
2004	2,714,576,291	1,845,056,839	2,170,655,105	6,730,288,235	4,713,352,284	-2,016,935,952	1,720,806,215	-3,737,742,167		-3,737,742,167	-25,734,176,401
2005	2,931,742,395	1,736,524,084	2,170,655,105	6,838,921,584	5,542,045,313	-1,296,876,271	1,720,806,215	-3,017,682,486		-3,017,682,486	-28,751,858,887
2006	3,166,281,786	1,627,991,329	2,170,655,105	6,964,928,220	6,428,772,563	-536,155,657	1,720,806,215	-2,256,961,872		-2,256,961,872	-31,008,820,759
2007	3,419,584,329	1,519,458,574	2,170,655,105	7,109,698,007	7,457,376,173	347,678,165	1,720,806,215	-1,373,128,050		-1,373,128,050	-32,381,948,809
2008	3,693,151,075	1,410,925,818	2,170,655,105	7,274,731,999	8,650,556,360	1,375,824,362	1,720,806,215	-344,981,853		-344,981,853	-32,726,930,662
2009	3,988,603,161	1,302,393,063	2,170,655,105	7,461,651,329	10,034,645,378	2,572,994,049	1,720,806,215	852,187,834	213,046,958	639,140,875	-32,087,789,787
2010	4,307,691,414	1,193,860,308	2,170,655,105	7,672,206,827	11,640,188,638	3,967,981,811	1,720,806,215	2,247,175,596	561,793,899	1,685,381,697	-30,402,408,090
2011	4,652,306,727	1,085,327,553	2,170,655,105	7,908,289,385	13,502,618,820	5,594,329,436	1,720,806,215	3,873,523,221	968,380,805	2,905,142,415	-27,497,265,675
2012	5,024,491,266	976,794,797	2,170,655,105	8,171,941,168	15,663,037,832	7,491,096,664	1,720,806,215	5,770,290,449	1,442,572,612	4,327,717,837	-23,169,547,838
2013	5,426,450,567	868,262,042	2,170,655,105	8,465,367,714	18,169,123,885	9,703,756,171	1,720,806,215	7,982,949,956	1,995,737,489	5,987,212,467	-17,182,335,371
2014	5,860,566,612	759,729,287	2,170,655,105	8,790,951,004	21,076,183,706	12,285,232,702	1,720,806,215	10,564,426,487	2,641,106,622	7,923,319,866	-9,259,015,505
2015	6,329,411,941	651,196,532	2,170,655,105	9,151,263,578	24,448,373,099	15,297,109,522	1,720,806,215	13,576,303,307	3,394,075,827	10,182,227,480	923,211,975
2016	6,835,764,896	542,663,776	2,170,655,105	9,549,083,778	28,360,112,795	18,811,029,018	1,720,806,215	17,090,222,803	4,272,555,701	12,817,667,102	13,740,879,077
2017	7,382,626,088	434,131,021	2,170,655,105	9,987,412,214	32,897,730,843	22,910,318,628	1,720,806,215	21,189,512,413	5,297,378,103	15,892,134,310	29,633,013,387
2018	7,973,236,175	325,598,266	2,170,655,105	10,469,489,546	38,161,367,777	27,691,878,231	1,720,806,215	25,971,072,016	6,492,768,004	19,478,304,012	49,111,317,399
2019	8,611,095,069	217,065,511	2,170,655,105	10,998,815,685	44,267,186,622	33,268,370,937	1,720,806,215	31,547,564,722	7,886,891,181	23,660,673,542	72,771,990,941
2020	9,299,982,675	108,532,755	2,170,655,105	11,579,170,535	51,349,936,481	39,770,765,946	1,720,806,215	38,049,959,731	9,512,489,933	28,537,469,798	101,309,460,739
2021	10,043,981,289			10,043,981,289	59,565,926,318	49,521,945,029	1,720,806,215	47,801,138,814	11,950,284,704	35,850,854,111	137,160,314,850
2022	10,847,499,792			10,847,499,792	69,096,474,529	58,248,974,737	1,720,806,215	56,528,168,522	14,132,042,131	42,396,126,392	179,556,441,242
2023	11,715,299,775			11,715,299,775	80,151,910,454	68,436,610,679	1,720,806,215	66,715,804,464	16,678,951,116	50,036,853,348	229,593,294,589
2024	12,652,523,757			12,652,523,757	92,976,216,126	80,323,692,369	1,720,806,215	78,602,886,154	19,650,721,539	58,952,164,616	288,545,459,205
2025	13,664,725,658			13,664,725,658	107,852,410,706	94,187,685,049	1,720,806,215	92,466,878,834	23,116,719,708	69,350,159,125	357,895,618,330
2026	14,757,903,710			14,757,903,710	125,108,796,419	110,350,892,709	1,720,806,215	108,630,086,494	27,157,521,624	81,472,564,871	439,368,183,201
2027	15,938,536,007			15,938,536,007	145,126,203,847	129,187,667,840	1,720,806,215	127,466,861,625	31,866,715,406	95,600,146,218	534,968,329,420
2028	17,213,618,888			17,213,618,888	168,346,396,462	151,132,777,574	1,720,806,215	149,411,971,359	37,352,992,840	112,058,978,520	647,027,307,939

(*) Without considering replacement cost

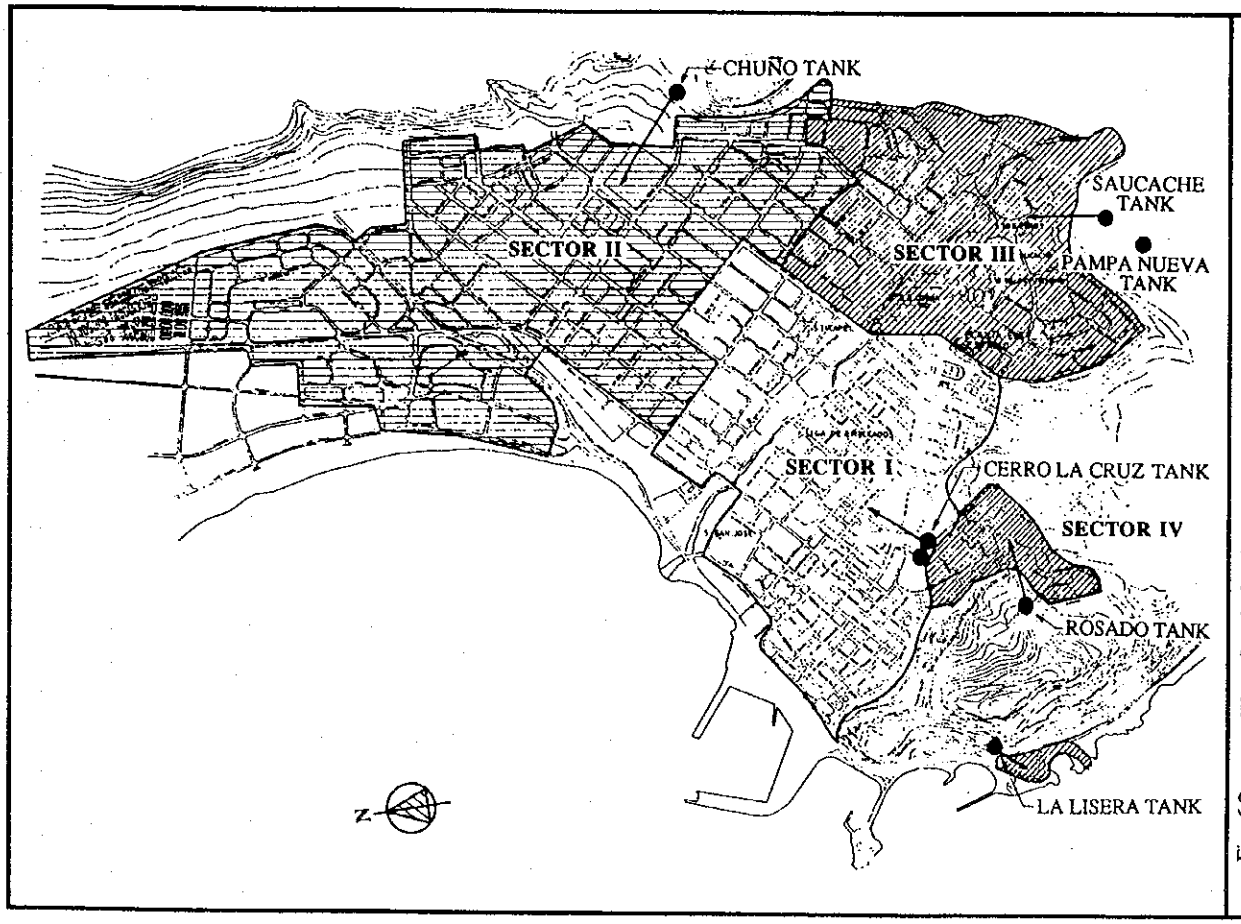


Fig. 6.2 Water Supply Service Area - Arica

< *Area del Servicio de Abastecimiento de Agua - Arica* >

THE STUDY ON THE DEVELOPMENT OF WATER RESOURCES IN NORTHERN CHILE | JICA

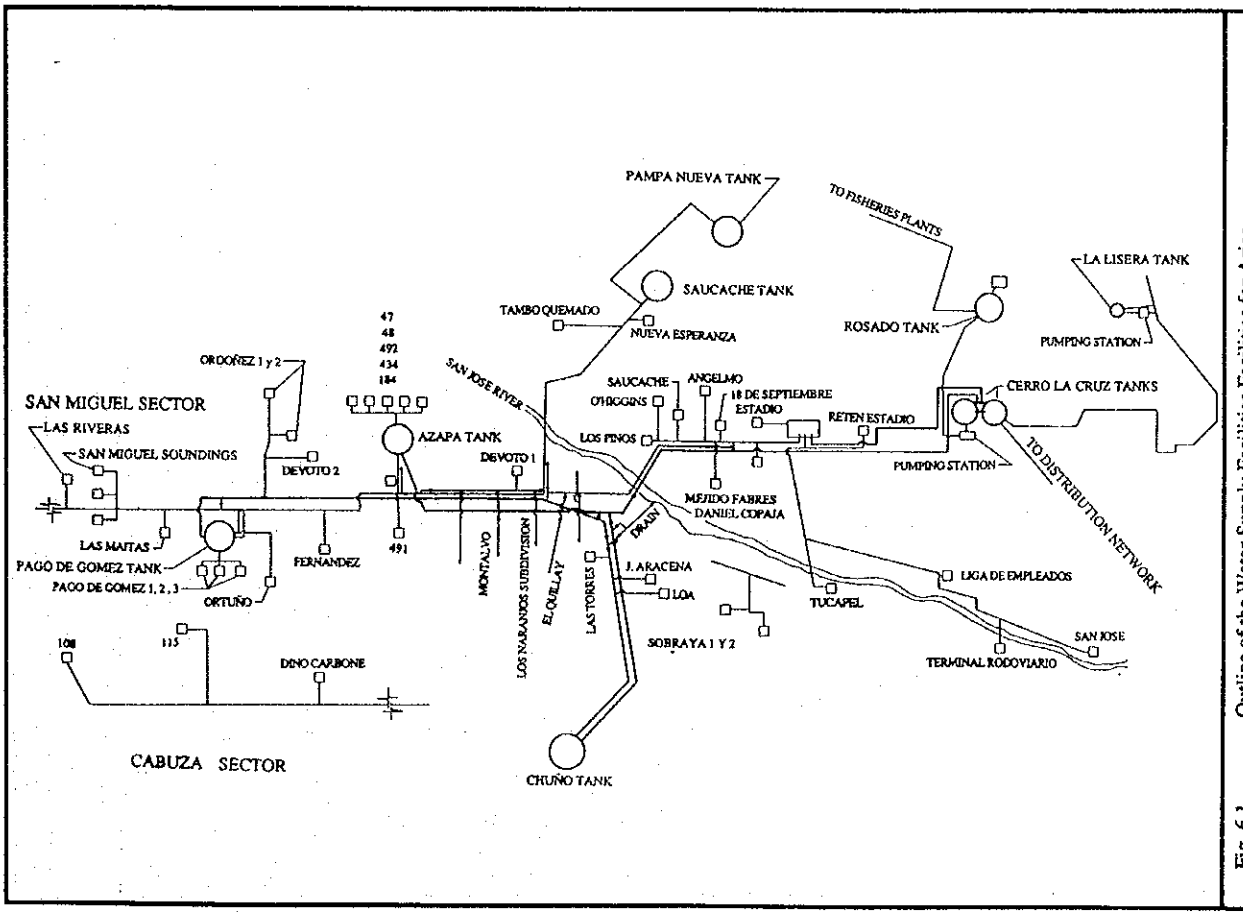


Fig. 6.1 Outline of the Water Supply Facilities Facilities for Arica

<*Bosquejo del Facilidad de Abastecimiento de Agua para Arica*>

THE STUDY ON THE DEVELOPMENT OF WATER RESOURCES IN NORTHERN CHILE | JICA

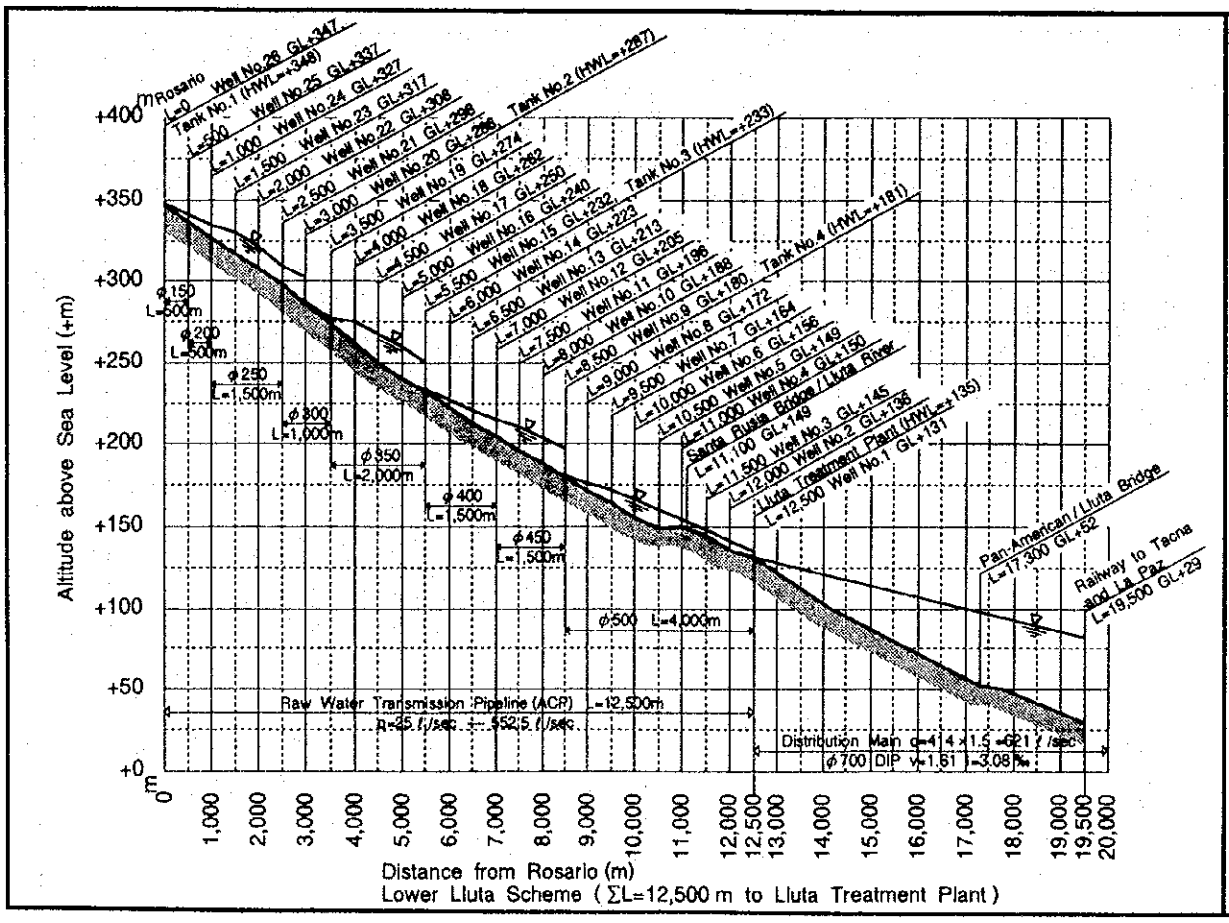


Fig. 6.4 Longitudinal Profile of Transmission Pipeline
<Perfil Longitudinal de la Cañeria de Conducción>

THE STUDY ON THE DEVELOPMENT OF WATER RESOURCES IN NORTHERN CHILE

JICA

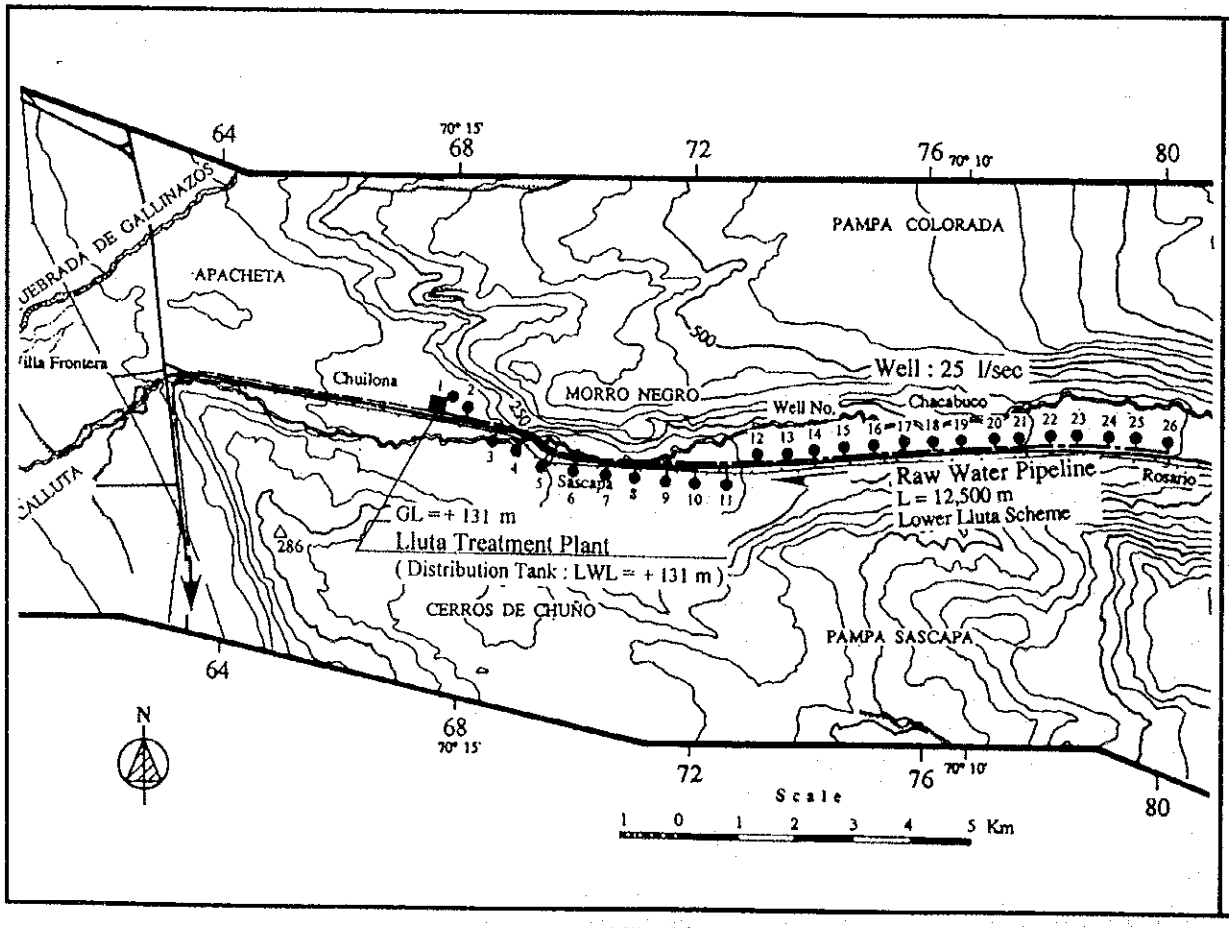


Fig. 6.3 Lower Lluta Scheme to Arica Water Supply
< Esquema Lluta Bajo a Suministro de Agua de Arica >

THE STUDY ON THE DEVELOPMENT OF WATER RESOURCES IN NORTHERN CHILE

JICA

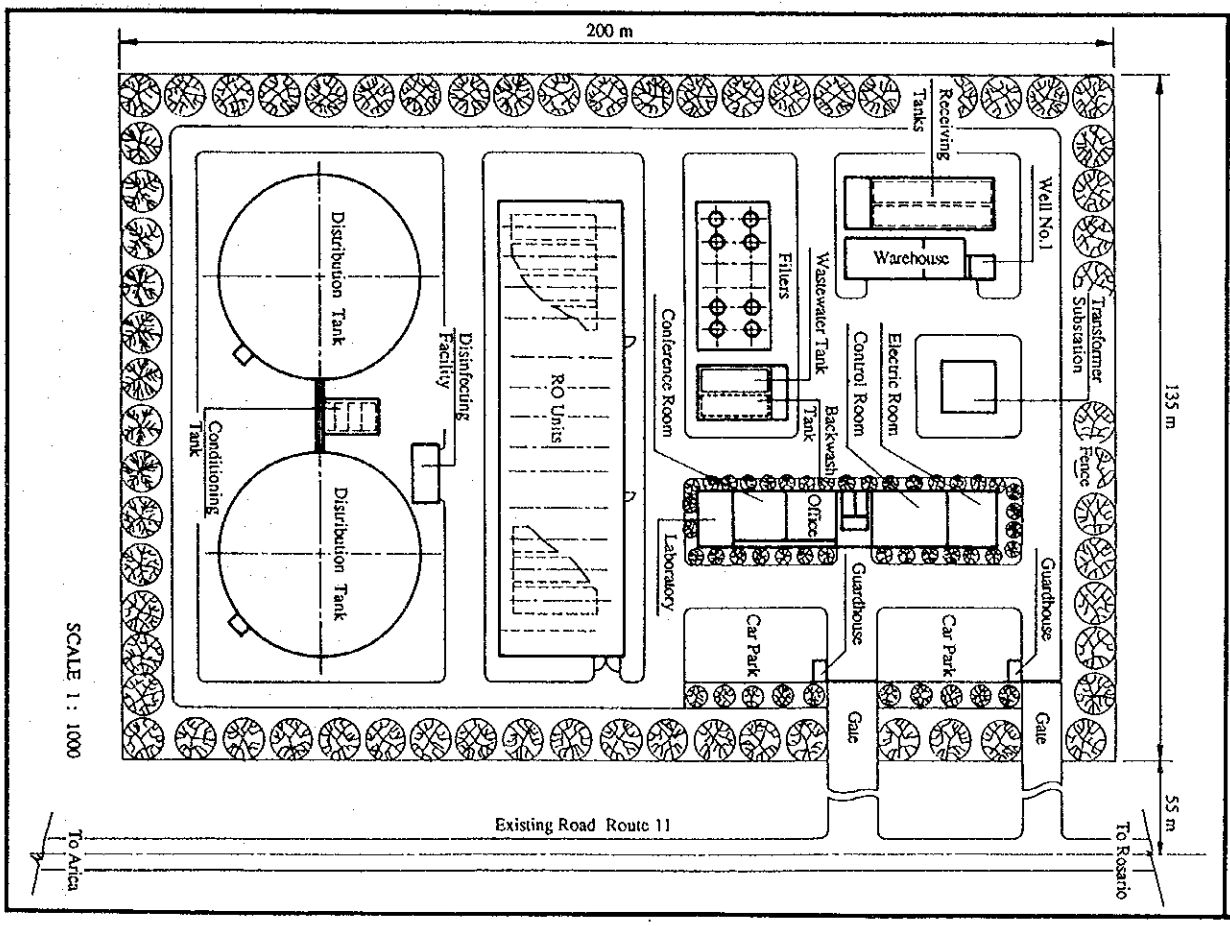


Fig. 6.6 Layout of Lluta Treatment Plant
< *Plano de Planta Tratamiento del Lluta* >

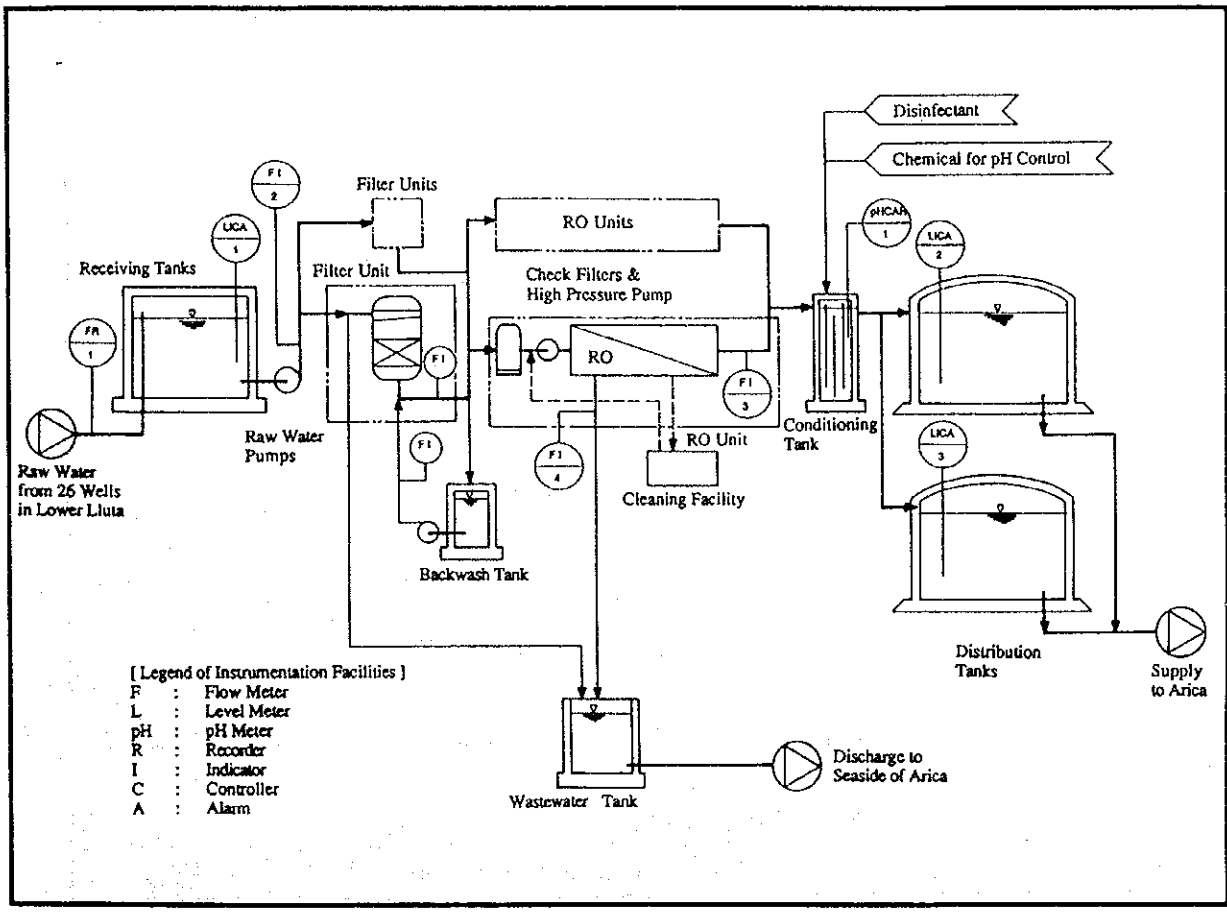


Fig. 6.5 Flow Diagram of Lluta Treatment Plant
< *Diagrama Flujo de Planta Tratamiento del Lluta* >

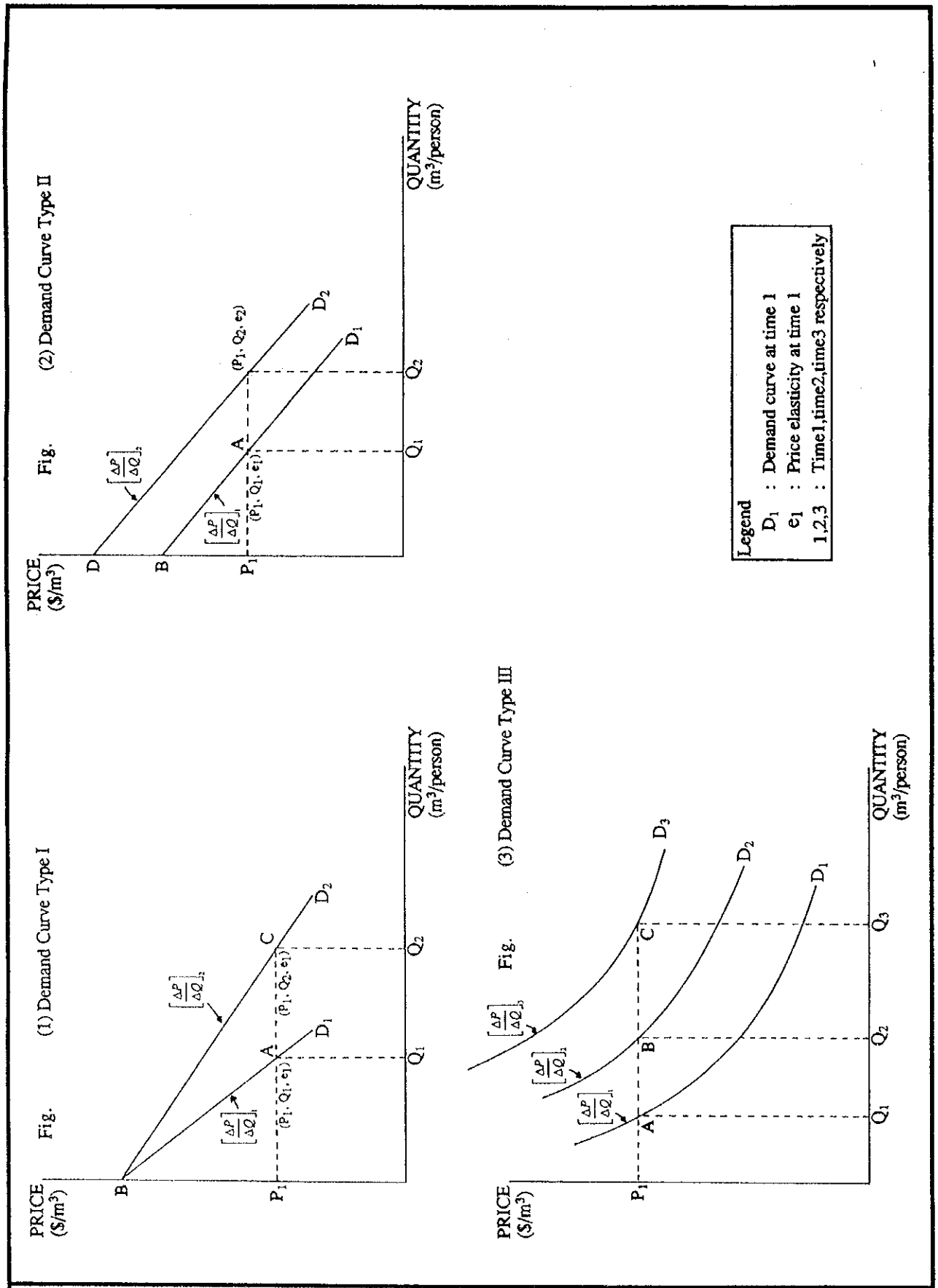


Fig. 6.7 Explanation Chart of Demand Curve Type

<Gráfica de Curva de Demanda>

CHAPTER VII MUNICIPAL WATER SUPPLY DEVELOPMENT OF IQUIQUE CITY

Chapter VII MUNICIPAL WATER SUPPLY DEVELOPMENT OF IQUIQUE CITY

7.1 Existing Water Supply System

7.1.1 Outline of the System

The Existing municipal water supply system is operated and maintained by ESSAT.

The water source is groundwater of Pampa del Tamarugal. The groundwater is extracted from the deep wells in the Canchones well field, located approximately 70 km east of Iquique city, by means of submergible pumps installed in each well.

Water taken from the wells is first transmitted through an intake pipe to a collection tank located nearly at the central place of the Canchones well field.

Then, water is pumped at Canchones pump station (ground level; GL. 1,013 m above sea level) to Rinconada tank (GL. 1,155 m). On the way to Rinconada tank, water is once boosted at Diana tank (GL. 1,038 m). From Rinconada tank, water is conveyed by gravity to Cavancha distribution tank (GL. 114 m) located on the eastern hills of the city.

Between Rinconada and Cavancha, there are three (3) tank stations with pressure break and water storage purposes. They are Carpas tank (GL. 978 m), Santa Rosa tank (GL. 682 m) and Alto Hospicio tank (GL. 545 m).

In Cavancha distribution tank, water is sterilized by hypo-chlorite. The chlorinated water is distributed by gravity to the consumers.

For the above existing water supply system, see Chapter 3, Fig. 3.5.

In 1992, ESSAT produced 17,241 x 10^3 m^3 (=547 l/s) of municipal water of which 10,822 x 10^3 m^3 was consumed for residential, commercial, industrial and other uses. The estimated water loss was 6,420 x 10^3 m^3, corresponding to 37.2% of the production volume.

7.1.2 Water Supply Facilities

1) Deep Well and Intake Pump

There are 12 production wells and two (2) emergency wells. Depth of the wells is 96 - 120 m and their yields are 50 - 83 l/s each. All the wells are equipped

with submergible pumps with each discharge capacity of 60 - 120 l/s and each total head of 55 - 140 m.

The extracted groundwater is lifted up by submergible pumps to the collection tank by means of pressurized intake pipelines.

2) Collection Tank

There are two (2) collection tanks made of steel in Canchones station. Their salient features are as follows.

Ground Level	:	GL. 1,013 m
Capacity	:	1,000 m^3 x 2 = 2,000 m^3
High Water Level	:	HWL. 1,018.15 m

3) Transmission and Booster Pumps

The transmission pipelines cross over the coastal mountains with an altitude of 1,155 m at Rinconada. Transmission and booster pumps are installed to cope with the ground level difference of 142 m between Canchones and Rinconada.

Six (6) transmission pumps are installed at Canchones station to lift up water to Diana tank located between Canchones and Rinconada. Total required electric power is 1,250 kw.

Four (4) booster pumps are installed at Diana tank to further boost to Rinconada. Total required electric power is 1,500 kw.

4) Transmission Tank

There are five (5) transmission tanks between Canchones collection tank and Cavancha distribution tank. They are Diana, Rinconada, Carpas, Santa Rosa and Alto Hospicio. Their major functions are to break high pressure as well as to store water.

They are made of either steel or reinforced concrete and installed slightly below the ground level. Their total storage capacity is 37,700 m^3.

5) Distribution Tank

There are three (3) major distribution tanks on the east hills of the city. They are Cavancha, Norte and Las Dunas. Cavancha distribution tank has a capacity

of 27,000 m^3 or 90% of the total capacity (30,000 m^3) of the three (3) distribution tanks.

Water for Norte tank is branched from Cavancha tank and that for Las Dunas tank is branched from the transmission pipelines.

Water is distributed to the consumers from the above tanks by gravity.

6) Transmission Pipeline

Length of the transmission pipelines between Canchones and Cavancha is 75.3 km. Two (2) pipelines, old and new ones, are installed in parallel for the major part of the route.

The old pipeline (ø 600 mm, steel) was installed in 1960. The new pipeline (ø 800 mm, ductile iron) was constructed during 1981-82.

The capacity of the pipeline is about 700 l/s with the break-down of 220 l/s for the old pipeline and 480 l/s for the new one.

Electric power required for operation of the facilities is all supplied by the electric company.

Outline of the existing water supply facilities and service area are shown in Fig. 7.1 and Fig. 7.2 respectively. Longitudinal profile of the existing transmission pipelines is shown in Fig. 7.3.

7.1.3 Existing Water Supply Problems

1) Water Quality

The groundwater in Canchones contains higher concentration of Mn and As than the standards of drinking water. The standards of Mn and As are 0.1 mg/l and 0.05 mg/l respectively.

The water quality of Mn in Canchones collection tank is about 0.5 mg/l on an average. However, this content of Mn decreases to less than 0.05 mg/l at Cavancha distribution tank. This is because Mn is oxidized by natural aeration in the tanks existing on the way and the manganese oxide is deposited on the bottom of the tanks or adhered to the inner surface of the pipes.

Further, the groundwater in Canchones contains 0.03-0.08 mg/l of As. However, this content decreases to 0.03-0.04 mg/l at Cavancha. This may be due to that As is caught by manganese oxide.

The above natural purification effects are not reliable. Hence, an artificial treatment of Mn and As is considered necessary.

2) Water Source

Groundwater in Canchones area has been fully developed. Development of new water sources is necessary to meet the future water demand of Iquique.

3) Power Cost

A large electric power is necessary for operation of the pumps including the intake, transmission and booster ones. The total required power is 3,300 kw. The electric charge is approximately 50% of the total operation and maintenance cost.

4) Water Loss

The existing water loss is as high as approximately 40% of the total production volume.

7.2 Existing Institutional and Financial Aspects

7.2.1 Organization of ESSAT

See, Chapter VI, 6.2.1.

7.2.2 Tariff

1) Number of Client

Number of the clients received the water supply services of Iquique city in the recent years are shown below, along with their coverage.

	Iquique	
	Nos. of Client	Coverage(%)
1991	30,175	98
1992	33,332	98
1993	35,126	98

2) Tariff Structure

Water tariffs are set by the Government, aiming to cover the costs of water supply services. The Government sets the target tariff which must be attained in a period of five (5) years.

The existing water tariff of Iquique city, as of February 1994, are as follows.

(1) Monthly Fixed Charge

Monthly fixed charge varies according to service pipe diameter.

Pipe Dia. (mm)	Charge ($)	Pipe Dia. (mm)	Charge ($)
13	209	50	5,062
15	337	75	11,812
19	675	100	20,249
25	1,350	125	30,373
32	2,025	150	45,560
38	3,037	200	80,995

(2) Monthly Variable Charge

Monthly variable charge includes charge during off season (April-November), charge during peak season (December - March) and overconsumption charge. These charges depend on the consumed water volume measured in m^3.

Overconsumption charge is applied for peak season to the consumption over the average consumption during off season. This charge is applied to the consumption over 30 m^3.

The monthly variable charges of Iquique city are shown below.

Category	Normal ($/m^3)	Rebated ($/m^3)
Off Season	233.44	130.90
Peak Season	230.82	130.20
Overconsumption	564.20	564.20

3) Tariff Collection Efficiency

See, Chapter VI, 6.2.2.

7.3 Long-term Development Plan

7.3.1 Development Capacity

The future production demands of Iquique on daily average basis are estimated to be 807 l/s for the year 2005 and 1,062 l/s for the year 2015. Those on daily maximum basis are calculated to be 1,049 l/s for 2005 and 1,381 l/s for 2015 by assuming the ratio of peak demand and average demand as 1.30.

On the other hand, the existing capacity in 1994 is estimated to be 680 l/s. Then, the additional production capacity of 369 l/s and 701 l/s shall be developed by the years of 2005 and 2015 respectively.

Further, the required additional raw water intake capacity for the years 2005 and 2015 are estimated to be 388 l/s and 738 l/s respectively, by assuming the water loss in treatment process as 5% of the production water as shown below.

	1995	2005	2015
Daily Ave. Production Demand (l/s)	708	807	1,062
Daily Max. Production Demand (l/s)	920	1,049	1,381
Existing Production Capacity (l/s)	680	680	680
Additional Production Capacity (l/s)	240	369	701
Additional Water Intake Capacity (l/s)	252	388	738

7.3.2 Development Alternatives

1) General

After intensive field investigations and analyses, the following three (3) potential water sources were identified as suitable for the municipal water development of Iquique city.

(1) Groundwater in La Tirana (Pampa del Tamarugal - North)
(2) Groundwater in Pintados (Pampa del Tamarugal - South)
(3) Groundwater in Salar del Huasco

Further, for transmission of the developed water to Iquique city from La Tirana and Pintados, two (2) routes of the transmission main were identified respectively.

Then, the following five (5) alternatives are discussed in this report.

Alternative (1)	:	La Tirana Water Source (Transmission Route No.1)
Alternative (2)	:	La Tirana Water Source (Transmission Route No.2)
Alternative (3)	:	Pintados Water Source (Transmission Route No.1)
Alternative (4)	:	Pintados Water Source (Transmission Route No.2)
Alternative (5)	:	Salar del Huasco Water Source

For location of the water sources and route of the transmission mains, see, Fig. 7.4.

In design of the above alternatives, the following design conditions are applied.

(1) Design capacity for intake is 738 l/s

(2) Design capacity for transmission is 701 l/s

(3) Water treatment;

The groundwater quality in La Tirana and Pintados is suitable for drinking use without any special treatment.

On the other hand, the groundwater in Salar de Huasco contains a high concentration of Mn and Fe as shown below.

	Mn	Fe
Water Quality (mg/l)	0.61-1.40	4.3-18.0
Permissible Limit (mg/l)	0.10	0.30

Those Mn and Fe shall be properly treated.

(4) Design distance of the transmission mains is between the site of water sources and Cavancha Distribution tank.

(5) No existing facilities are used since they are already fully loaded.

2) Alternative (1)

The well field is located in La Tirara area, 20 km to the north of Canchones and 60 km to the east of Iquique city.

The groundwater is developed by 16 deep wells including two (2) wells for standby with an average capacity of 55 l/s. The well depth is 200 m. The water is collected to the collection tank proposed in the well field for which a pump head of 76-81 m is required.

The total length of the transmission main is about 68 km. The major part of the pipeline runs along the existing highways. The raw water is pumped from the collection tank to another tank located at the highest point of the transmission route. Thereafter, the water is transferred to Cavancha distribution tank via Alto Hospicio tank by gravity. Further, three (3) tanks are proposed between the tank at the highest point and Alto Hospicio tank for pressure break.

Salient features of the transmission main are as follow.

	Collection Tank	Highest Tank	Alto Hospicio Tank	Cavancha Tank
Ground El. (m)	1,025	1,100	545	114
Distance (m)	0	40,400	64,600	67,600
Pipe Dia. (mm)		← 700x2	→|← (400~500)x2	→|← 700x2 →|

Number of the pump station and the estimated total electric power consumption are as follows.

Well Pump	:	16 pumps
Transmission Pump	:	1 station
Booster Pump	:	-
Total Power Consumption	:	2,261 kw

3) Alternative (2)

The water source development is the same as Alternative (1).

The transmission main with an approximately 67 km length runs along the route of the old/abandoned pipe. The raw water is pumped from the collection tank to a tank located at the highest elevation of the pipe line. In this case, it is necessary to boost the pressure on route. After the highest location, the water is transmitted by gravity to Cavancha distribution tank via Alto Hospicio tank. More five (5) tanks are provided between the tank at the highest point and Alto Hospicio tank for pressure break.

Salient features of the transmission main are as follows.

	Collection Tank	Highest Tank	Alto Hospicio Tank	Cavancha Tank
Ground El. (m)	1,025	1,205	545	114
Distance (m)	0	21,400	63,500	66,500
Pipe Dia. (mm)		← 700x2	→|← (400~600)x2	→|← 700x2 →|

Number of the pump stations and the estimated total electric power consumption are as follows.

Well Pump	:	16 pumps
Transmission Pump	:	1 station
Booster Pump	:	1 station
Total Power Consumption	:	3,301 kw

4) Alternative (3)

The well field is located in Pintados area, 20 km to the south of Canchones and 80 km to the south east of Iquique city.

The groundwater is extracted from 16 wells including two (2) emergency wells with an average capacity of 55 l/s. The well depth is 200 m. The water is collected to the collection tank provided in the well field. The required pump head is 61 m.

The transmission main follows the highways for some distance and thereafter, the route of the existing pipe line. The total distance is approximately 87 km. The raw water is pumped from the collection tank to a tank located at the existing Rinconada tank site; highest point on the transmission main. The water pressure is increased by the booster pumps at the site of the existing Diana pump station. After the Rinconada tank site, the water flows down to Cavancha distribution tank through Alto Hospicio tank by gravity. There are two (2) new pressure break tanks between Rinconada and Alto Hospicio.

Salient features of the transmission main are as follows.

	Collection Tank	Rinconada Tank	Alto Hospicio Tank	Cavancha Tank
Ground El. (m)	995	1,155	545	114
Distance (m)	0	44,150	84,400	87,400
Pipe Dia. (mm)		← 700x2	→|← (400~500)x2	→|← 700x2 →|

Number of the pump stations and the estimated total electric power consumption are as follows.

Well Pump	:	16 pumps
Transmission Pump	:	1 station
Booster Pump	:	1 station
Total Power Consumption	:	2,998 kw

5) Alternative (4)

The water source development is the same as Alternative (3).

The transmission pipe follows the existing road and railway. The raw water is pumped from the collection tank to a tank located at the highest elevation of the route. A booster pump station is proposed on route to the tank at the highest point. The water flows down from the tank at the highest location to Cavancha distribution tank through Alto Hospicio tank by gravity.

	Collection Tank	Highest Tank	Alto Hospicio Tank	Cavancha Tank
Ground El. (m)	995	1,050	545	114
Distance (m)	0	54,900	81,300	84,300
Pipe Dia. (mm)	|← 700x2	→|← (400~600)x2	→|← 700x2	→|

Number of the pump stations and the estimated total electric power consumption are as follows.

Well Pump	:	16 pumps
Transmission Pump	:	1 station
Booster Pump	:	1 station
Total Power Consumption	:	2,058 kw

6) Alternative (5)

The well field is located in Pampa Huasco area extending from the northern fringe of Huasco lake areas to Penablanca. It is approximately 160 km distant to the east of Iquique city.

The groundwater is extracted from 22 deep wells including 3 wells for emergency use with an average capacity of 40 l/s. Each well is 150 m or 200 m deep. The raw water is collected to the treatment plant proposed in the well field. The plant will treat Mn and Fe.

The transmission route between the treatment plant and Cavancha distribution tank is approximately 161 km long. This pipe line follows the existing road until Canchones and thereafter, the existing pipeline.

The treated water is pumped from the treatment plant to a tank located at the highest elevation (watershed boundary between Salar del Huasco and Pampa del Tamarugal basins). Two (2) booster pump stations are provided to increase the water pressure in the main on the way to the highest location. The water is transferred by gravity from the tank on the highest point to Cavancha

distribution tank via Alto Hospicio tank through the tank proposed at Rinconada. The transmission main is provided with 15 pressure break tanks between the tank on the highest point and Rinconada tank, and two (2) pressure break tanks between Rinconada tank and Alto Hospicio tank.

The salient features of the transmission main are shown below.

	Treatment Plant	Highest Tank	Rinconada Tank	Alto Hospicio Tank	Cavancha Tank
Ground El. (m)	3,800	4,200	1,155	545	114
Distance (m)	0	22,900	117,450	157,700	160,700
Pipe Dia. (mm)	|← 700x2 →|	|← (400~700)x2 →|	|← (400~500)x2 →|	700x2 →|

Number of the pump stations and the estimated total electric power requirement are as follows.

Well Pump	:	22 pumps
Transmission Pump	:	1 station
Booster Pump	:	2 stations
Total Power Consumption	:	5,253 kw

7) Comparative Evaluation

The construction costs including those for the well-fields, transmission/booster pumps, transmission pipelines, collection/pressure-break/distribution tanks and treatment plant were estimated for the above five (5) alternatives.

They are compared in the following table in which the total electric power consumptions, total transmission lengths and water treatment requirements of the five (5) alternatives are also compared.

	Alt. (1)	Alt. (2)	Alt. (3)	Alt. (4)	Alt. (5)
Const. Cost (Million Peso : M$)	36,821	37,024	46,101	48,077	89,984
Power Consumption (kw)	2,261	3,301	2,998	2,058	5,253
Transmission Length (km)	67.6	66.5	87.4	84.3	160.7
Water Treatment Requirement	-	-	-	-	Mn, Fe

For details of the estimated construction cost and electric power consumption, see Table. 7.1.

As evident from the above table, Alternative (1) is the most recommendable.

7.3.3 Proposed Long-term Development Plan

1) Consideration to Stage-wise Implementation

The recommended long-term development plan (Alternative 1) includes many units of intake facilities, transmission/booster pumps and tanks, and a route of transmission pipeline. Among these works, the intake facilities, transmission/booster pumps, and tanks can be economically implemented in stages, corresponding to the increase of water demand.

However, two (2) construction methods of one (1) time and stage-wise shall be compared to attain an economical completion of the proposed transmission line. In many cases, one time construction method is more economical than stage-wise one in terms of simple total of investment costs but it require a larger advance investment than stage-wise method.

Therefore, the total investment costs of the two (2) construction methods are compared in terms of present value cost as follows.

(1) Alternative Pipeline

The following two (2) alternatives are considered for the transmission pipeline with a total length of 64.6 km between Tirana well-field and Alto Hospicio.

Alternative (A): one time construction
Alternative (B): two (2) stages construction

The proposed pipeline length and diameter are summarized below.

Alternative (A)	Alternative (B)
900 mm x 1 x 40,400 m	(1st Stage)
700 mm x 1 x 11,650 m	700 mm x 1 x 40,400 m
600 mm x 1 x 12,550 m	500 mm x 1 x 11,650 m
	400 mm x 1 x 12,550 m
	(2nd Stage)
	700 mm x 1 x 40,400 m
	500 mm x 1 x 11,650 m
	400 mm x 1 x 12,550m

(2) Calculation Conditions of Present Value Cost

One time construction

Investment : 1997 and 1998, 50% in each year

Two (2) stages construction

1st stage investment : 1997 and 1998, 50% in each year

2nd stage investment : 2004 and 2005, 50% in each year

Discount rate : 12% per annum

Annual O&M cost : Considered

(3) Comparative Evaluation

The present value costs of both alternatives are shown below, compared with their simple total of investment costs.

	Alternative (A)	Alternative (B)
Simple Total Cost (million Peso : M$)*	21,022	28,053
Present Value Cost (million Peso : M$)	17,211	16,689

* : excluding O&M costs

There is not so much difference between the present value costs of both alternatives. However, Alternative (B) is more recommendable in view of the existing financial constraints.

For details, see Supporting Report D, Appendix 3.

2) Proposed Water Supply Development Facilities

(1) General

The groundwater is extracted from the aquifer in the eastern neighbourhood of Tirana. The water is extracted by 16 deep wells including two (2) wells for standby and collected to the collection tank proposed in the well-field.

The water of 701 l/s on daily maximum basis (539 l/s on daily average basis) is transferred by the transmission pipeline of 67.6 km length from the collection tank to Cavancha distribution tank via Alto Hospicio tank. The major part of the pipeline runs along the existing highway.

The water is pumped up by the transmission pump installed in the well-field to cross over the coastal mountain ranges.

The route and longitudinal profile of the transmission pipeline are shown in Fig. 7.5 and Fig. 7.6 respectively.

(2) Salient Features of Proposed Facilities

The salient features of the proposed facilities are summarized below.

i) Intake Facilities

Deep Well: 16 wells (depth: 200 m, diameter: 12 inch)

Submergible Pump: 16 pumps including two (2) for standby (each capacity: 55 l/s, total required electric power: 1,170 kw)

Collection Pipeline (Asbestos Cement) : ø250 ~ 800 mm, 9,750 m

ii) Transmission Pump: 420 kw x 5 units

iii) Transmission Pipeline (Ductile Cast Iron)

700 mm x 2 x 40,400 m
500 mm x 2 x 11,650 m
400 mm x 2 x 15,550 m

iv) Tank (Reinforced Concrete)

Collection Tank:	2 units x 1 site (well-field) ($1,250\ m^3$ x 2 x 1)
Transmission Tank:	2 units x 2 sites (Santa Laura, Alto Hospicio) ($1,250\ m^3$ x 2 x 2)
Pressure-break Tank:	2 units x 3 sites (La Isla, El Toro 1, El Toro 2) ($250\ m^3$ x 2 x 3)
Distribution Tank:	4 units x 1 site (Cavancha) ($7,500\ m^3$ x 4 x 1)

3) Required Land Acquisition

The required land area for the construction of the facilities are as follows.

Well-field including access road	:	260 ha
Transmission pipeline	:	13.5 ha
Tank	:	1.0 ha

The transmission pipeline is laid under the roads, then no land acquisition is necessary. However, the well-field and tanks shall acquire 261 ha of land, most of which belong to the government. The land is now idle.

4) Estimated Investment Cost

The total investment cost, consisting of direct construction cost, land acquisition cost, engineering cost, administration cost and physical contingency amounts to 46,091 million Pesos at 1994 prices. Its break-down is shown below.

		(10^3 Peso:$)
(1)	Direct Construction Cost	38,512,014
	i) Intake Works	4,075,846
	ii) Transmission Facilities	32,327,643
	(i) Transmission Pumps	1,873,190
	(ii) Transmission Pipeline	29,081,203
	(iii) Tanks	1,373,250
	iii) Distribution Networks	1,950,525
	iv) Electric Transmission Line	158,000
(2)	Land Acquisition Cost	262,000
(3)	Engineering Cost {6% of (1)}	2,310,721
(4)	Administration Cot {3% of (1)}	1,155,360
(5)	Physical Contingency {10% of (1)}	3,851,201
	Total	46,091,296

Note: Cost: as of March 1994, excluding Value Added Tax (IVA)
Exchange Rate: US$1.00 = Chilean Peso $435.00
= Japanese Yen ¥110.00

For details of the direct construction cost, see Supporting Report D, Technical Data, Table DC-1.

7.4 First-stage Development Plan

7.4.1 General

The long-term development plan proposed in the previous Section 7.3 will be implemented in two (2) stages. The 1st stage development plan is targeted for the year 2005, while the 2nd stage development plan is targeted for the year 2015.

The 1st stage plan will develop an additional production capacity of 369 l/s on daily maximum basis (284 l/s on daily average basis) to meet the water demand of the year 2005 (See, 7.3.1).

7.4.2 Water Supply Development Facilities

The 1st stage plan will construct an urgent portion of the long-term development facilities. The salient features of the 1st stage plan are as follows.

1) Intake Facilities

Deep Well: 8 wells (depth: 200 m, diameter: 12 inch)
Submergible Pump: 8 pumps including one (1) for standby
(each capacity: 55 l/s, total required electric power: 575 kw)

Collection Pipeline (Asbestos Cement): ø250 ~ 800 mm, 5,750 m

2) Transmission Pump: 420 kw x 3 units

3) Transmission Pipeline (Ductile Cast Iron)

700 mm x 1 x 40,400 m
500 mm x 1 x 11,650 m
400 mm x 1 x 15,550m

4) Tank (Reinforced Concrete)

Collection Tank: 1 unit x 1 site (well-field)
($1,250\ m^3$ x 1 x 1)
Transmission Tank: 1 unit x 2 sites (Santa Laura, Alto Hospicio)
($1,250\ m^3$ x 1 x 2)
Pressure-break Tank: 1 unit x 3 sites (La Isla, El Toro 1, El Toro 2)
($250\ m^3$ x 1 x 3)

Distribution Tank: 2 units x 1 site (Cavancha)
($7,500\ m^3 \times 2 \times 1$)

The route and longitudinal profile of the transmission pipeline are shown in Fig. 7.5 and Fig. 7.6 respectively. Layouts of the well-field and transmission pump station are shown in Fig. 7.7 and Fig. 7.8 respectively.

7.4.3 Land Acquisition

The whole land area necessary for the long-term development plan will be acquired in the 1st stage. The required land areas are shown below.

Well-field including access road	:	260 ha
Transmission pipeline	:	13.5 ha
Tank	:	1.0 ha

The transmission pipelines are laid under the roads, then no land acquisition is necessary. However, the well-field and tanks shall acquire 261 ha of land, most of which belong to the government. The land is now vacant.

7.4.4 Estimated Investment Cost

The total investment cost, consisting of direct construction cost, land acquisition cost, engineering cost, administration cost and physical contingency amounts to 24,177 million Pesos at 1994 price with a foreign currency portion of 41,024 thousand US$ and a local currency portion of 6,331 million Pesos $. Its break-down is shown below.

	Item	Foreign Currency (10^3 US$)	Local Currency (10^3 Pesos $)	Total (10^3 Pesos $)
1)	Direct Construction Cost	36,032	4,422,575	20,096,326
	(1) Intake Works	2,532	1,193,663	2,295,144
	(2) Transmission Facilities	33,499	2,305,366	16,877,636
	i) Transmission Pumps	3,126	151,091	1,510,912
	ii) Transmission Pipeline	30,373	1,468,050	14,680,499
	iii) Tanks	0	686,225	686,225
	(3) Distribution Networks	0	765,546	765,546
	(4) Electric Transmission Line	0	158,000	158,000
2)	Land Acquisition Cost	0	262,000	262,000
3)	Engineering Cost {6% of 1)}	1,528	541,100	1,205,780
4)	Administration Cot {3% of 1)}	9	602,890	602,890
5)	Physical Contingency {10% of 1)}	3,465	502,408	2,009,633
	Total	41,024	6,330,973	24,176,629

Note: Cost: as of March 1994, excluding Value Added Tax (IVA)

Exchange Rate: US$1.00 = Chilean Peso $435.00

= Japanese Yen ¥110.00

The direct construction and land acquisition costs are further broken down as shown in Table 7.2. For more details, see Supporting Report D, Table D-II, 4.2.

7.4.5 Implementation Program

1) Implementation Schedule

The proposed 1st stage project will be completed within three (3) years from 1996 to 1998. The detailed design and land acquisition will be completed within the year 1996. The construction works will commence in 1997 and be completed in 1998. It will be commissioned in 1999.

2) Disbursement Schedule

The proposed disbursement schedule of the investment cost is shown in Table 7.3.

7.4.6 Operation and Maintenance

1) General

The project will start functioning in 1999 and will attain the full operation in 2005. The water supply will gradually increase from 222 l/s in 1999 to 284 l/s in 2005 on daily average basis.

The daily operation and maintenance of the project will be performed by the Iquique Branch Office of ESSAT. For this purpose, the staff of the Iquique Branch Office will be strengthened.

2) O&M Cost

The O&M cost of the project consists of annual O&M cost including electric consumption, chemical consumption, personnel and repair costs, and replacement cost.

The required annual O&M costs at the full operation stage are estimated to be 613,910 thousand Pesos at 1994 price with the following break-down.

		(10^3 Peso $ at 1994 price)
(1)	Electric Consumption Cost	240,683
(2)	Chemical Consumption Cost	5,996
(3)	Personnel Cost	11,520
(4)	Repair Cost	355,711
	Total Annual O&M Cost	613,910

Furthermore, the pumps and other equipment of the intake and transmission facilities will be periodically replaced according to their life spans. Their life spans and replacement costs at 1994 price are estimated as follows.

		Life Span (Year)	Replacement Cot (10^3 Peso $ at 1994 price)
(1)	Intake Works		
	i) Wells and Intake Pumps	15	1,207,522
	ii) Other Equipment	20	484,488
(2)	Transmission Facilities		
	i) Transmission Pumps	20	344,085
	ii) Other Equipment	20	1,166,827

For details, see Supporting Report D, Table D-II, 4.3.

7.4.7 Economic Evaluation

1) General

The economic evaluation of this project is made by using the same computerized evaluation model; SIMOP as the project for Arica city.

2) Assumptions and Input Data for Economic Evaluation

(1) Incremental Investment: is estimated in the same way as Arica

(2) Adjustment of Market Prices

The same adjustment factors, and same shares of imported component and labour as Arica are applied. Those are shown below again.

Labour Adjustment Factor : Skilled : no adjustment
Non-skilled : 0.66
Semi-skilled : 0.73

Foreign Exchange Adjustment Factor : 1.06

Social Discount Rate : 12% (based on the guideline of MIDEPLAN)

Share of Imported Component and Labor : as follows

Type of Works	Imported Component	Labor	
		Non-skilled	Semi-skilled
Intake Works	32%	3.8%	2.6%
Transmission	35%	2.6%	13.8%
Distribution	35%	2.6%	13.8%
Electric Works	61%	1.0%	15.0%

(3) Evaluation Period : 36 years (1993-2028)

(4) Consumer Groups and Demand Characteristics

The consumers are classified into four (4) groups in the same manner as Arica. They are shown below.

Group 1: Residential consumption between 1-20 m^3/month/connection (low-income class)

Group 2: Residential consumption between 20-30 m^3/month/connection (middle-income class)

Group 3: Residential consumption greater than 30 m^3/month/connection (high-income class)

Group 4: Commercial, industrial and fiscal consumption

Their characteristic features of water demand are as follows.

	Group 1	Group 2	Group 3	Group 4
Price Elasticity	-0.52	-0.20	-0.25	-0.20
Demand Curve Type	3	2	2	1
Annual Demand Growth Rate (%)	4.68	4.68	8.89	9.36
Initial Tariff ($/$m^3$)	172.01	172.01	220.42	220.42
Initial Water Consump. (10^3 m^3/yr)	4,781	1,421	4,393	2,325

(5) Water Consumption Capacity

The total yearly water consumption capacity in future are estimated for Without-Project and With-Project cases in the same manner as Arica. For the estimated water consumption capacity, see Supporting Report F, Chapter IV, 4.6.2.

(6) Project Costs

The project costs used in the economic evaluation cover periodic costs, non-periodic costs and variable costs. Those are estimated in the same way as Arica. The estimated costs are summarized below.

Periodic costs : Peso $ 367,231 x 10^3/year
Non-periodic costs : year 1996 : Peso $ 552,511 x 10^3
year 1997 : Peso $9,026,071 x 10^3
year 1998 : Peso $9,320,702 x 10^3
Variable costs : Peso $ 40.32/m^3

3) Results of Economic Evaluation

The present value of benefits and present value of costs computed by SIMOP are shown below.

Present Value of Benefits (10^6 Peso $)		Present Value of Costs (10^6 Peso $)	
Group 1	3,912	Periodic	1,679
Group 2	1,565	Non-Periodic	11,418
Group 3	11,671	Variable	1,041
Group 4	3,720	Total	14,138
Total	20,868		

The socio-economic profitability is evaluated in terms of Net Present Value (NPV), Benefit Cost Ratio (B/C) and Economic Internal Rate of Return (EIRR) as follows.

NPV : Peso $ 6,730 x 10^6
B/C : 1.48
EIRR : 17.33%

The Project is considered profitable since NPV is positive and EIRR is greater than 12% requested by the guideline of MIDEPLAN.

4) Sensitivity Analysis

The project is still profitable for the increase of the investment cost by 58.94% or for the increase of the social discount rate upto 23.22% as shown below.

Increase Rate of Investment Cost (%)	NPV (10^6 Peso $)	EIRR (%)
-59.00	13,460	31.99
0	6,730	17.33
58.94	0	12.00
118.00	-6,730	9.00
177.00	-13,460	6.97

Social Discount Rate (%)	NPV (10^6 Peso $)
21.00	2,585
22.00	1,259
23.22	0
24.00	-634
25.00	-1,299

7.4.8 Financial Evaluation

1) General

The financial evaluation of this project is made in the same way as Arica. The project profitability is indicated by Net Present Value (NPV) and Financial Internal Rate of Return (FIRR). A financial statement is also prepared to make an income analysis.

2) Assumption and Input Data for Financial Evaluation

(1) Evaluation Period : 33 years (1996-2028)

(2) Annual Price Escalation : 8%

(3) Water Tariff : Average water tariff is estimated at Peso \$ 278/m^3 at the end of 1994. It will increase at a rate of 12% per year.

(4) Cash Flow : See, Table 7.4

(5) Financial Discount Rate : 12% (based on the guideline of MIDEPLAN)

(6) Loan Conditions : The loan covers all investment costs.
The loan conditions are shown below.

Interest Rate	:	5%
Repayment Period	:	25 years
Grace Period	:	5 years

(7) Income Tax : 25%

3) Results of Financial Evaluation

The estimated Net Present Value is Peso \$ 11,455,887 x 10^3 and FIRR is 14.86%. The project is considered profitable.

The calculated financial statement is shown in Table 7.5. As known from the Table 7.5, the project is high profitable enough to cover the running costs and to pay the loan within the evaluation period.

4) Sensitivity Analysis

The project is still profitable for the increase of the investment cost by 47.93% or for the decrease of the revenue by 24.17% as shown below.