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DIRECTORATE GENERAL OF WATER
MINISTRY OF PUBLIC WORKS
THE REPUBLIC OF CHILE

THE STUDY
ON
THE DEVELOPMENT OF WATER RESOURCES
IN
NORTHERN CHILE

SUPPORTING REPORT C : WATER USE

MARCH 1995

PACIFIC CONSULTANTS INTERNATIONAL, TOKYO

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Chapter I. MUNICIPAL WATER OF ARICA CITY

1.1 Existing Water Supply Service

1.1.1 Area and Population Served

The existing municipal water supply system covers about 1680 ha of the urbanized area of Arica city, serving almost the entire population of the city.

The service area is divided into 4 sectors: Sector I, II, III and IV as shown in Fig. C.1.1. Water is distributed to the 4 sectors from 5 distribution tanks: La Cruz, La Lisera, Chuño, Saucache and Rosado. The estimated area served, 1990 population served, and distribution tank capacity of each sector are summarized below.

	Area (ha) Served	Population Served (1990)	Distribution Tank Capacity (m^3)	
Sector I	513	50,600	La Cruz	(2,500)
			La Lisera	(200)
Sector II	727	64,200	Chuño	(5,000)
Sector III	365	37,300	Saucache	(2,500)
Sector IV	68	7,900	Rosado	(800)
Totals	1,673	160,000		

Source: <1>

According to preliminary census results, the total population had increased to 169,217 by 1992. ESSAT estimates that 99% of the 1992 population was served by the water system.

Sector I is covered by the La Cruz and La Lisera distribution tanks. Most of the area is served by the La Cruz tank, and a small part of the southern portion is served by the La Lisera tank. Water for Sector I and Sector IV is supplied from the wells located in the city. Water for the Sector II and Sector III is provided from the wells located in the Azapa Valley.

A sketch of the existing water supply system is shown in Fig. C.1.1

1.1.2 Water Source and Water Rights

The municipal water supply sources, as of November 1992, consisted of 28 wells located in the city area and Azapa Valley. The location, number of wells, capacity and ownership are summarized as follows:

Location	Number of Wells	Total Capacity (l/sec)	Ownership
City Area	12	243	ESSAT
Azapa Valley			
(1)	13	186	ESSAT
(2)	3	74	Rental
Total	28	503	

Source: ESSAT, as of Nov. 1992

The capacity of each well is shown in Table C.1.1.

At the beginning of 1994, ESSAT was operating a total of 45 wells, including newly drilled or rented 17 wells. The total installed pumping capacity of the 45 wells was 730 l/sec. The location of the wells are shown in Fig. C.1.1.

ESSAT has 4 legally authorized water rights for groundwater extraction in the city area and Azapa Valley. These are summarized as follows.

(1)	83 l/s	in the city area
(2)	30 l/s	in the city area
(3)	30 l/s	in Azapa Valley
(4)	20 l/s	in Azapa Valley
Total	463 l/s	

Moreover, they rent water rights from farmers and have no customary water rights.

All legally authorized and customary water rights in the city area and Azapa Valley are listed in Appendix C.1 and Appendix C.2.

1.1.3 Water Production and Consumption

In 1990, ESSAT produced 17,292x$10^3$$m^3$ of municipal water, of which 10,655x10^3 m^3 was consumed for residential, commercial, industrial and public uses. The estimated water loss including water leakage and uninvoiced water use was 6,637x$10^3$$m^3$, corresponding to 38.4% of the production volume.

The 1990 consumption by category, and total estimated production are summarized below.

	Quantity ($10^3$$m^3$) 1990	%
Production	17,292.0	
Consumption	10,655.0	100.0
Residential	7,331.0	68.8
Commercial	795.5	7.5
Industrial	660.0	6.2
Public	1,868.5	17.5
Loss	6,637.0	(38.4)*

* Percentage of Production
Source: ESSAT

The monthly water production and consumption by category in 1990 are shown in Table C.1.2.

In 1991 there was a reclassification of consumers which resulted in significant changes in the amounts consumed by certain categories in subsequent years. The "Public" category in 1990 included public buildings and public standpipes. However, in 1991 public buildings were reclassified and included in the Residential Category. The "Other" category then included only public standpipes.

The water production, consumption by purpose, and losses in 1992 are summarized as follows:

	1992 Quantity (10^3m^3)	%
Production	16,940.7	
Consumption	10,635.2	100.0
Residential	8,170.8	76.8
Commercial	1,087.3	10.2
Industrial	919.3	8.6
Other	457.8	4.3
Losses	6,305.5	(37.2)*

* Percentage of Production

The water losses in the above tables consist of physical and commercial losses. The physical loss is the water leakage from the water transmission lines and distribution networks. The commercial loss is the unbilled water consumption which occurs mostly in the residential category as the result of meters in poor conditions and illegal connections.

The per capita water production and consumption in 1990 and 1992 are estimated as follows.

	Per Capita Water Use Liters/person/day	
	1990	1992
Production Basis :	299	277
Total Consumption Basis	184	174
Residential Consumption Basis	127	134

Due to the condition of existing meters and the lack of comprehensive leak detection studies, it is not possible to accurately estimate how much of the total losses are physical losses from the transmission mains and distribution networks, and how much is due to other factors. However, based on experience with similar systems, it is estimated that about 25% of production is lost as leakage. The remaining portion is discharged to the sea by the sewerage system or evaporates. The entire city area is served by a sewerage system and all sewage is discharged offshore through a sewer outfall.

The real yearly municipal water consumption in 1992 is estimated at 14,823 x 10^3m^3 by assuming that 25 % of the pruduction is lost to

leakage, and that one half of this (12.5 %) infiltrates into the ground to recharge the groundwater.

1.1.4 Water Restrictions

Due to the shortage of water in Arica city, water supply in the year 1993 was limited to 10.5-15.0 hours per day, during the mornings, afternoons and evenings. The water supply service for different areas varied depending on the condition of the water distribution system. The normal water supply hours, by sector, are shown below.

	Supply Time	Supply Time	Hours/day
Sector I	6:30-13:00	15:30-24:00	15.0 hours
Sector II	6:30-12:00	15:30-20:30	10.5 hours
Sector III	6:30-12:00	15:30-24:00	14.0 hours
Sector IV	6:30-14:00	17:00-20:00	10.5 hours

The above water supply restrictions were relaxed after the completion of the emergency water supply project of ESSAT. The normal water supply hours by sector, as of January 1994, are as follows.

	Supply Time	Supply Time	Hours/day
Sector I	-------	-------	24.0 hours
Sector II	6:00-13:30	15:30-23:30	14.5 hours
Sector III	6:30-12:30	16:00-24:00	14.0 hours
Sector IV	-------	-------	24.0 hours

1.2 Future Water Demand

1.2.1 Projected Populations

Census population data is available for the period 1940-1992, as follows:

CENSUS	POPULATION
1940	14,064
1952	18,847
1960	43,344
1970	87,795
1982	139,628
1992	169,212*

* Preliminary Results of 1992 Census

Unfortunately the final 1992 Census results, including the latest demographic data, are not available.

In this report, several methods, corresponding to different growth scenarios, were used for projecting the future populations of Arica:

1. Linear growth (straight line), based on 1982-92 census data
2. Exponential growth based on 1970-92 census data
3. Exponential growth based on 1982-92 Region I growth rate.

Growth rates prior to 1970 are of interest historically, but are not considered relevant to future projections.

As can be seen in the attached Figure C.1.2, an exponential growth rate based on 1970-92 census data for Arica, results in a 2020 population projection of almost 400,000, whereas a lineal growth rate based on the 1982-1992 census data results in a 2020 population of only 250,000.

The population growth of Arica city will depend on its economical developments in the future. Both central and local governments are enforcing various policies for the recovery of the existing depressed economy of the city. Therefore, the population growth in the future is assumed to be linear growth until 2000 and exponential growth of Region I after 2000.

The results are summarized as follows:

1995	178,087
2000	192,879
2005	214,524
2010	238,599
2015	265,375
2020	295,157

1.2.2 Per Capita Water Consumption

Recent per capita water demands for Arica were presented in Section 1.1.3. However, due to the existing water restrictions, adjustments were

made to obtain the appropriate per capita demands for future conditions when a 24 hour unrestricted water supply is desired.

Based on data from a 1991 report by B&S Ingenieros y Consultores <1> and recent data available from the ESSAT Planning Department, the adjusted per capita consumption, including commercial, industrial and other uses, is estimated at 220 l/c/d in 1992. It is assumed that the ratio of residential to other uses (commercial, industrial and "other") will remain relatively constant, and that future per capita consumption will increase as the standard of living improves and the uses of potable water expand. This increase is estimated at 0.3% per year. Projected water consumption and production were estimated based on the above population projections, per capita demands, and other assumptions.

1.2.3 Future Water Demand

1) Future Water Consumption

Total future consumption in Arica is calculated based on the population projections and estimated per capita consumption, as shown in the following table:

Year	Population Served	Per Capita Consumption (l/c/d)	Projected Consumption (m3/day)	(l/sec)
1995	178,087	221.99	39,533.5	457.6
2000	192,879	225.34	43,463.4	503.0
2005	214,524	228.74	49,070.2	567.9
2010	238,599	232.19	55,400.3	641.2
2015	265,375	235.69	62,546.2	723.9
2020	295,157	239.25	70,616.3	817.3

The above consumption figures do not include water for the tourism development in the Chinchorro area, as discussed in Section 1.4. It was considered that, even without the tourism development program, some urbanization would take place in the Chinchorro area, and the population of such urbanization would be included in the population projections presented in Section 1.2.1. As discussed in Section 1.4, it is therefore considered appropriate to add, for the tourism development, an average consumption of 10 l/sec in 1995, and that this would gradually increase to about 50 l/sec in the year 2020.

Projections which include the allowance for tourism are as follows:

Year	Consumption w/o Tourism (l/sec)	Allowance For Tourism* (l/sec)	Total Consumption (l/sec)
1995	457.6	10	467.6
2000	503.0	15	518.0
2005	567.9	20	587.9
2010	641.2	30	671.2
2015	723.9	40	763.9
2020	817.3	50	867.3

* CORDESERVIU (Chinchorro)

2) Projected Production

ESSAT is initiating a leakage control program and efforts to reduce un-accounted-for water. These programs include the use of leak detection equipment, gradual replacement of residential meters, and efforts to reduce the number of illegal connections. It is therefore estimated that the total leakage, as a percentage of total production, will gradually decrease from almost 40% at present, to 30% by the year 2005. Future losses, as a percentage of total production, and the projected production are estimated as follows:

Year	Total Consumption (l/sec)	Losses % of Production	Total Production (l/sec)
1995	467.6	40	779.3
2000	518.0	35	796.9
2005	587.9	30	839.9
2010	671.2	30	958.9
2015	763.9	30	1,091.3
2020	867.3	30	1,239.0

The above projections of water production are based on the assumption that adequate production capacity will be provided as required, even though this is optimistic for the year 1995. It is further noted that these projections are very sensitive to the assumption regarding unaccounted-for water. For example, if unaccounted-for water could be reduced to 20% of production in the year 2020, the production requirements would be reduced to 1,084 l/sec, a reduction of 155 l/sec.

These projections are depicted in Figure C.1.3. It should be kept in mind that these are average day production requirements, and that the water

production facilities should be designed for the maximum day requirements. For the maximum day requirement, see Supporting Report D.

1.2.4 Real Water Consumption

The real municipal water consumption for Arica in the years 2015 and 2020 are estimated at an average of 982.2 l/sec and 1,115.1 l/sec respectively, by assuming that 20% of the production will be lost to leakage, and that one half of this (10%) will infiltrate into the ground to recharge groundwater.

1.3 Water for Industrial Use

The industrial park "Parque Chacalluta" is now in the initial phases of development about 16 kilometers to the northwest of Arica; refer to Figure C.1.4. The park is being developed by ZOFRI (Zona Franca de Iquique), a joint venture of CORFO and private enterprise. About 10 industries are now under construction. Recent projections by ZOFRI indicate that the ultimate development will consist of about 60 industries on 130 hectares.

Water consumption was estimated by ZOFRI, based on an estimated total population working at the park of 5,290 people and a unit consumption of 250 l/day. The resulting future demand was estimated at 15.3 l/sec. This projection does not contemplate the watering of green areas or that required for possible water intensive industries.

Water for the development will be completely supplied by groundwater in the immediate vicinity of the industrial park. Current water sources and those to be constructed in the near future, are as follows:

Existing Well #1:	20 l/sec
Planned Well #2:	30-40 l/sec (test drilling complete)

Construction of Well #2 started in late 1993.

The existing water quality for well #1 is somewhat saline with initial values for several parameter exceeding permissible limits for potable water. However, the quality is reportedly improving as pumping continues. Test well results indicate that Well #2 is of potable water quality.

Studies by Consultants for the industrial park indicate that sufficient groundwater is available in the vicinity of the park, for ultimate development. Additional wells, treatment and/or recycling of the water may be required or desirable depending on the results of Well #2 development and the specific types of industries which locate at the industrial park.

Source: ZOFRI (Zona Franca de Iquique)

1.4 Water for Tourism Development

Tourism development is being planned for the area known as "Bajos del Chinchorro", along the coast in the northwest part of Arica city; see Figure C.1.1. The development contemplates residential areas, hotels and recreational facilities. The first phase, to be initiated in 1994, consists of 17.5 ha of urban development located on a site with a total area of 90 ha including recreational areas. The population of the first phase is estimated at 6,000. Using a per capita water demand of 350 l/day, the projected average water demand for this phase is 24.3 l/sec (2,100 m^3/day).

Depending on the success of the initial phase, preliminary medium to long range planning (5-20 years) contemplates future developments with a total area of several hundred hectares and a total water demand of up about 100 l/sec (8640 m^3/day).

It is assumed that some urbanization would take place in the Chinchorro area, even without this tourism development, and would result in a population equivalent of about one half of that with the tourism program. The water requirements of the additional population resulting from the tourism development is therefore considered to be about half of the calculated amounts.

It is planned to serve this development from the Arica city water system, as it is expanded and improved. Future water demand is therefore considered along with that for Arica City in Section 1.2.

Source: CORDESERVIU (CORDENOR and SERVIU)

REFERENCES

<1. Análisis Programa de Desarollo de ESSAT, Prefactibilidad
B&S Ingenieros Consultores Ltda, Marzo 1992.

Table C.1.1. Existing Well Capacity of Arica Municipal Water Supply
<Capacidad de Pozos Existentes Para el Abastecimiento de Agua Municipal en Arica>

City Area		Azapa Valley	
Name of Well	Capacity (l/s)	Name of Well	Capacity (l/s)
(ESSAT Property)		(ESSAT Property)	
(A) San José	20	(A) No.1472 Recinto U.T.A.	21
(B) Liga Empleados	28	(B) No.1471 San Miguel	18
(C) Tucapel	28	(C) No. 3 Pago de Gómez	17
(D) Retén Estadio	24	(D) No. 2 Pago de Gómez	13
(E) Copaja	22	(E) No. 1 Pago de Gómez	18
(F) 18 de Septiembre	30	(F) No. 491 Loteo Algodonal	8
(G) Saucache	27	(G) No. 492 Planta Azapa	21
(H) Los Pinos	16	(H) No. 184 Planta Azapa	18
(I) Rodoviario	0	(I) No. 48 Planta Azapa	12
(J) Estadio	3	(J) No. 434 Planta Azapa	12
(K) Mejidos Fabres	23	(K) No. 47 Planta Azapa	10
(L) Nueva Esperanza	22	(L) No. 491 Planta Azapa	12
Total	243	(M) Las Mitas	18
		Total	186
		(Rental)	
		(N) No. 1 San Miguel	41
		(O) Ordóñez	23
		(P) Fernández	10
		Total	74

Data Source : ESSAT (as of Nov. 1992)

Note : (Rental) : Wells rented from farmers.

Table C.1.2. Existing Municipal Water Production and Consumption of Arica City (1990).

<Producción y Consumo de Agua Municipal Existente en Arica (1990)>

(Unit:10^3m^3/month)

Month	Production	Consumption				
		Residential	Commercial	Industrial	Public	Total
Jan.	1,438.7	652.8	67.1	48.3	135.9	904.2
Feb.	1,432.6	646.9	70.1	50.1	124.8	891.8
Mar.	1,523.7	632.5	68.5	57.3	131.9	890.2
Apr.	1,491.1	620.7	64.5	56.8	137.8	879.8
May	1,474.2	625.5	67.5	58.7	177.1	928.9
Jun.	1,505.2	599.1	60.7	45.0	162.5	867.4
Jul.	1,454.4	591.3	62.5	54.9	156.3	865.1
Aug.	1,476.3	579.8	62.5	59.6	156.4	858.4
Sep.	1,354.8	580.7	60.6	55.7	166.8	863.8
Oct.	1,376.9	593.2	68.5	47.2	162.4	871.4
Nov.	1,351.9	603.3	67.0	62.4	163.4	896.0
Dec.	1,412.2	605.0	76.0	64.0	193.1	938.1
Total	17,292.0	7,331.0	795.5	660.0	1,868.5	10,655.0
Percentage		68.8%	7.5%	6.2%	17.5%	100%

Data Source : <1>

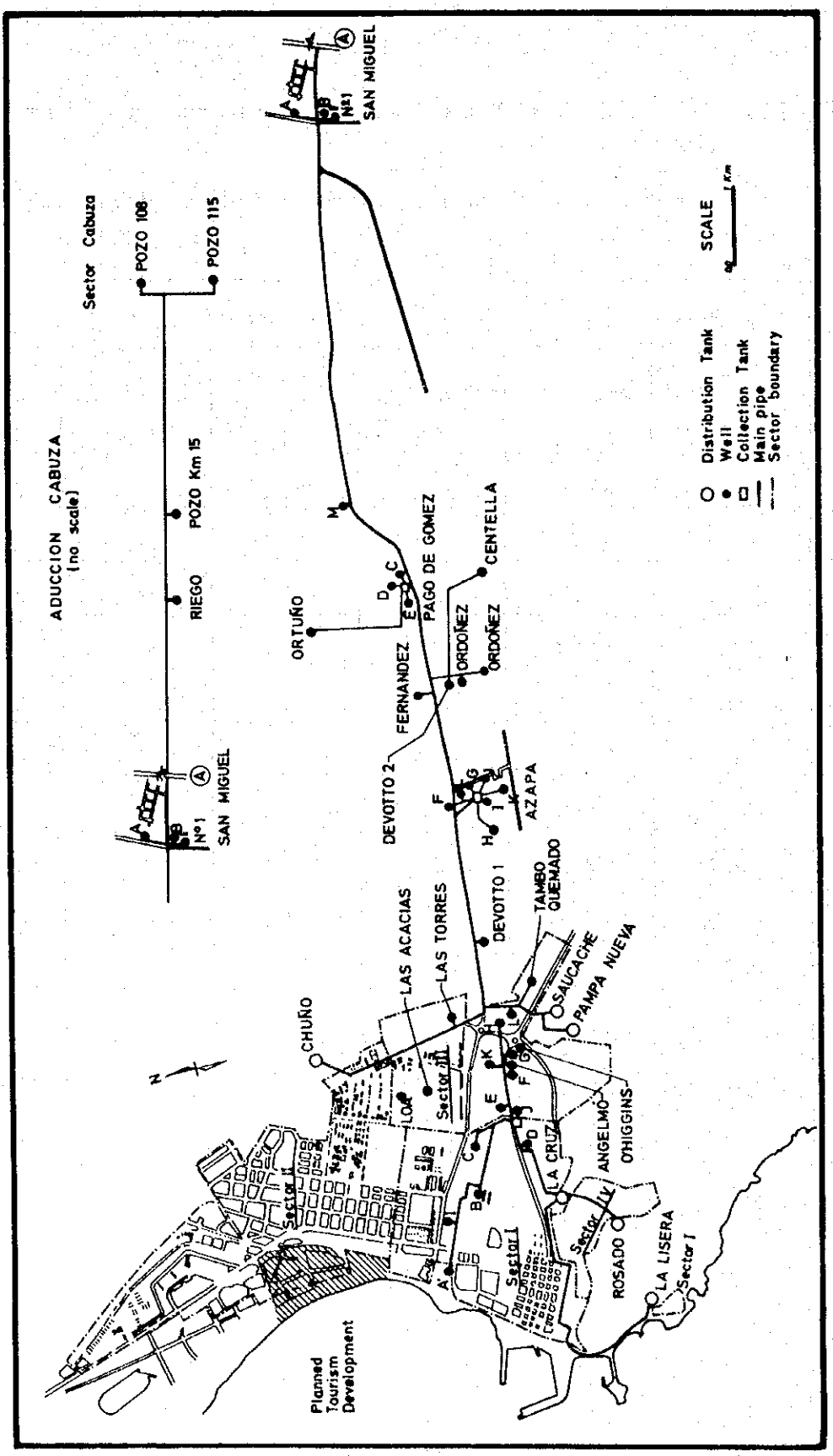


Fig. C.1.1 Existing Municipal Water Supply System of Arica City

<Sistema de Abastecimiento de Agua Potable Existente de Arica>

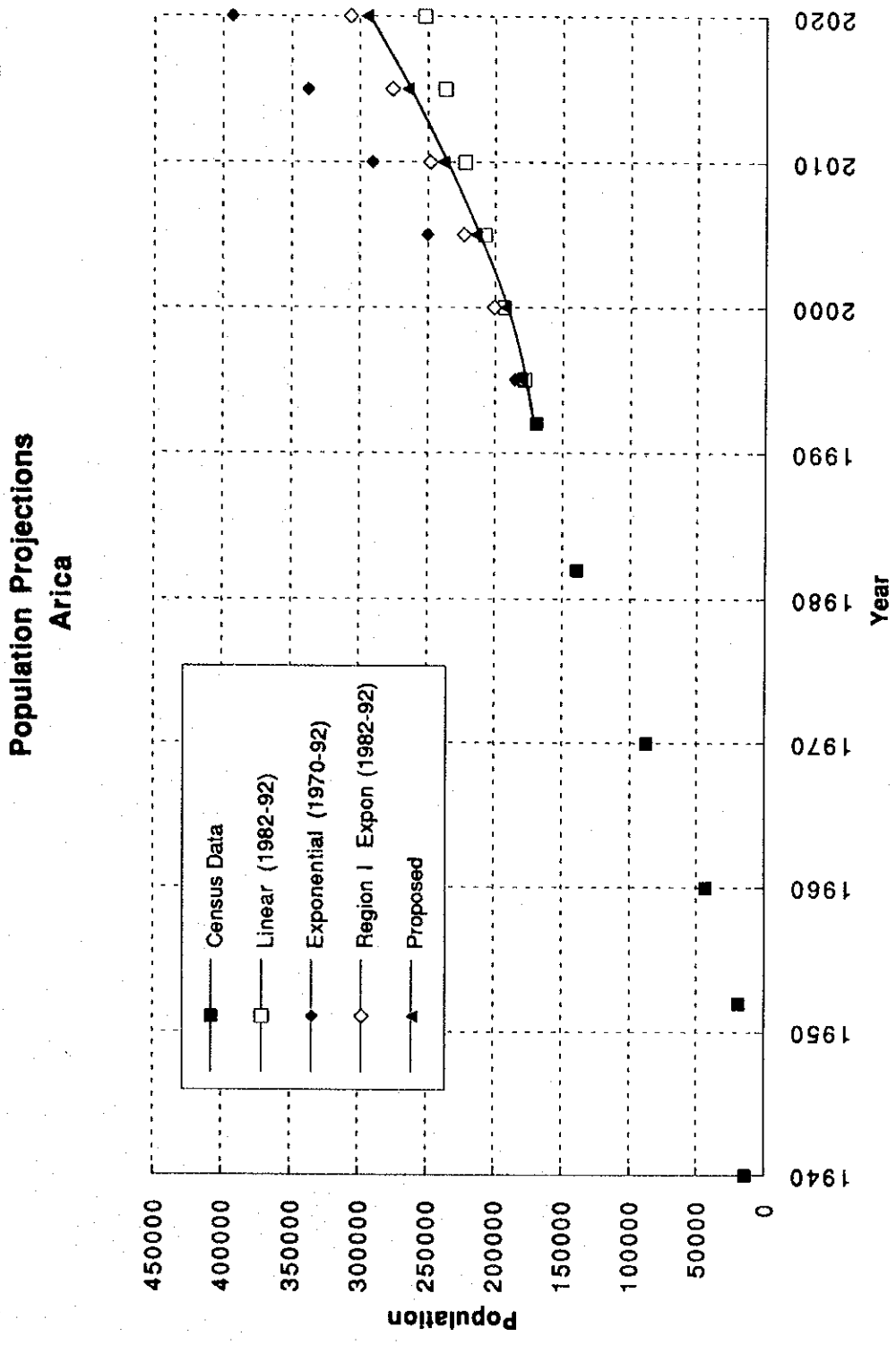


Fig. C.1.2 Population Projections - Arica

< Proyección de la Población - Arica >

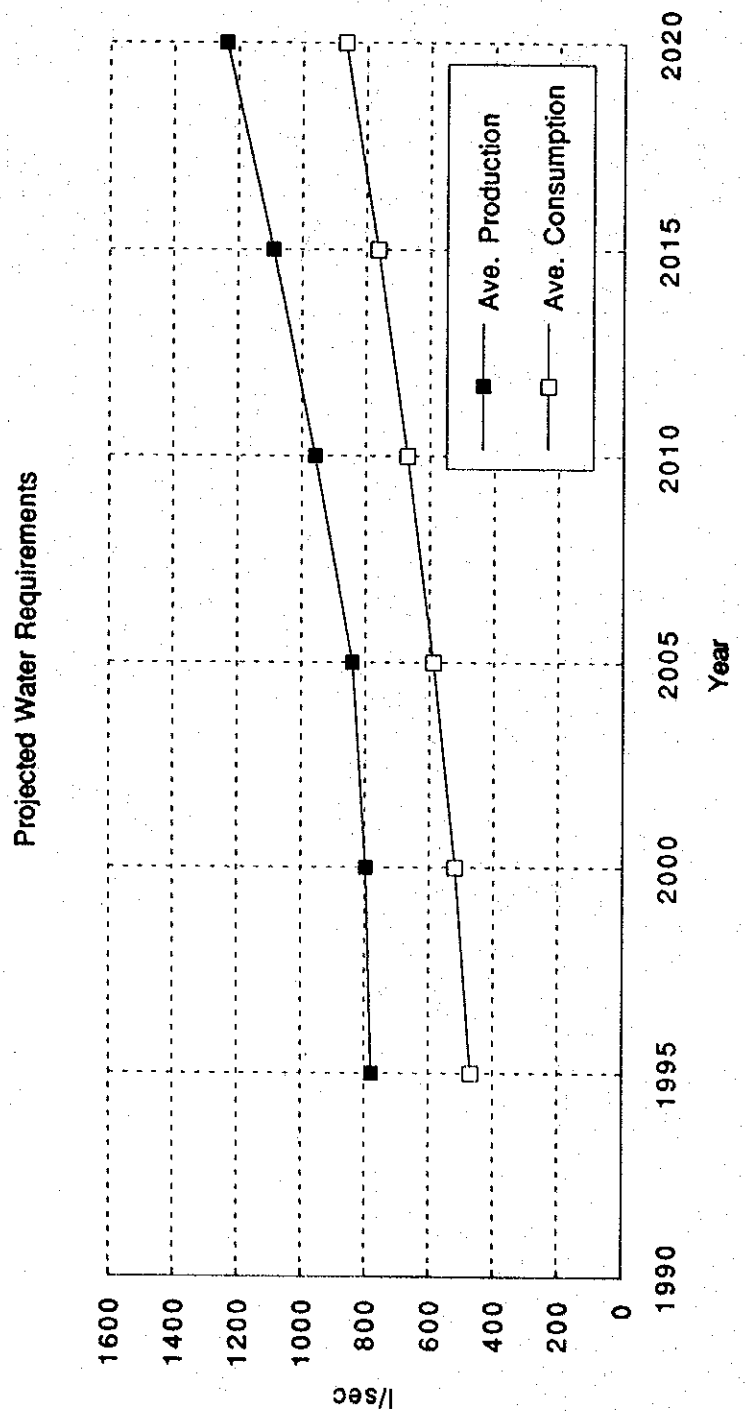


Fig. C.1.3 Projections of Water Consumption and Production - Arica

< Proyección de Consumo y Producción de Agua - Arica >

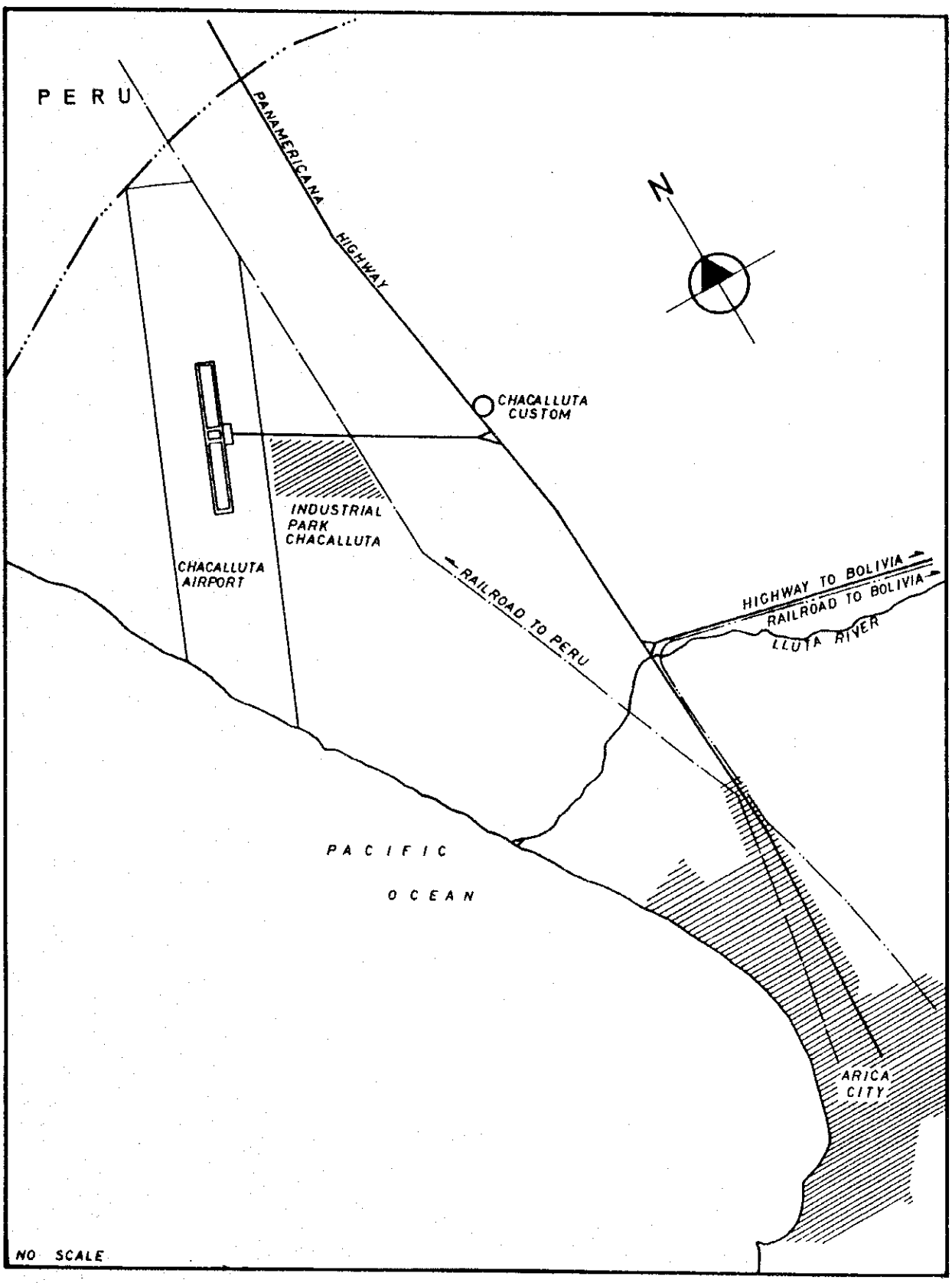


Fig. C.1.4 Location of Industrial Park , ZOFRI - Arica
<Ubicación del Parque Industrial, ZOFRI - Arica>

Chapter II. IRRIGATION AND OTHER WATER USES IN AZAPA VALLEY

2.1. Existing Irrigated Areas

2.1.1. Irrigation Sectors

The total cultivated area in the Azapa Valley is estimated to be 3,213 ha. The entire cultivated area is irrigated by river water, spring water and groundwater.

The cultivated area of Azapa Valley has increased considerably during recent years. The historical changes are shown below.

1975	: 2,053 ha.	1)
1984	: 2,319 ha.	1)
1989	: 2,522 ha.	1)
1993	: 3,213 ha.	2)

Source: 1) <1>)
2) : SAG, Region I.

The existing cultivated area of 3,213 ha. is divided into 27 irrigation sectors. Of these, 12 sectors, located in the upper reaches (Bocatoma-Cabuza), are irrigated by surface water from the Azapa Canal. Another 10 irrigation sectors, located in the lower reaches (Cabuza-Saucache), are irrigated by surface water of Azapa Canal, supplemented by groundwater. The remaining 5 irrigation sectors, located in the lower reaches (Cabuza-Saucache), are irrigated by spring water supplemented by groundwater.

The above irrigation sectors are listed as follows:

1). Upper Reaches: Irrigated by Azapa Canal water.

(a) Comunidad Andina Area.
Bocatoma, Surire, Ticnamar-Belen, La Cruz, Camina, Hijos de Livicar.

(b) Sobraya/Casa Grande Area.
Livicar, 18 de Septiembre, Sobraya Norte, Sobraya Sur, Cerro Blanco, Cabuza.

2). Lower Reaches (A) (Chuval/Saucache Area) :Irrigated by Azapa Canal water with supplementary groundwater.

Santa Irene Sur, Santa Irene Norte, Cerro Moreno, San Miguel, Las Riveras, Alto Ramírez Sur, Alto Ramírez Norte, Cerro Sombrero, Pago de Gómez Norte, Pago de Gómez Sur.

3). Lower Reaches (B) (Chuval/Saucache Area) :Irrigated by spring water with supplementary groundwater

Juan Noé, Foccaci, Las Maitas, Media Luna, Mita Chica.

The locations of the above irrigation sectors are shown in Fig. C.2.1.

2.1.2 Irrigated Areas

1) Cultivation Areas

In Azapa Valley, such crops as olives, tomatoes, grape fruit, tropical fruit, green beans, green vegetables, flowers and alfalfa are cultivated. The crops are all irrigated by conventional or drip irrigation methods.

The existing cultivation areas by crop type and by irrigation method are summarized as follows.

Crop Type	Conventional Irrigation (ha)	Drip Irrigation (ha)	Total (ha)
Fruit (olive, tomato, other fruits)	1,166	528	1,694
Vegetables (green beans, green veget., flowers)	640	753	1,393
Pasture (alfalfa)	126	-	126
Total	1,932	1,281	3,213

Note : Flowers are classified as vegetable for convenience in the estimation of irrigation water demand.

Cultivation areas by crop and by irrigation method are detailed in Table C.2.1.

2) Cropping Pattern

The aforementioned total cultivation areas are not constantly cropped throughout the year. According to the information of SAG, the actual crop areas are as follows.

(1) Fruit

- Olives : The whole cultivation area (959 ha) are cropped throughout the year.
- Tomatoes : 30% of the total cultivation areas (158 ha) are cropped twice a year. The remaining 70% areas (367 ha) are cropped once a year. One cropping period is four (4) months.
- Other Fruits : The whole cultivation area (210 ha) are cropped throughout the year.

(2) Vegetables

- Green Beans : 30% of the total cultivation areas (42 ha) are cropped twice a year. The remaining 70% areas (97 ha) are cropped once a year. One cropping period is four (4) months.
- Green Vegetables : 30% of the total cultivation areas (362 ha) are cropped twice a year. The remaining 70% areas (844 ha) are cropped once a year. One cropping period is four (4) months.
- Flowers : 30% of the total cultivation areas (14 ha) are cropped twice a year. The remaining 70% areas (34 ha) are cropped once a year. One cropping period is four (4) months.

(3) Pasture

- Alfalfa : The whole cultivation area (126 ha) are cropped throughout the year.

3) Actual Irrigated Areas

The perennial crops of olives, other fruits and alfalfas are constantly raised for the total cultivation areas throughout the year. However, the actual crop areas of such annual crops as tomatoes, green beans, green vegetables and flowers seasonally change.

According to the previous report by Araya, Cabrera/Asociados Ltda., Ingenieros Consultores, the actual crop areas of the annual crops during the period of November to February are considered very small, compared to those during the other periods of the year due to the marketing limitations.

In this report, therefore, it is assumed that cropping of tomatoes, green beans, green vegetables and flowers concentrate only during the eight (8) months of March to October of the year and their monthly crop areas are uniformly distributed during the eight (8) months. Furthermore, the actual crop areas are constantly irrigated.

The actual monthly irrigated areas by crop type and by irrigation method are estimated based on the above assumptions as follows.

Crop Type	Conventional Irri. (ha)		Drip Irri. (ha)		Total	
	Mar.-Oct.	Nov.-Feb.	Mar.-Oct.	Nov.-Feb.	Mar.-Oct.	Nov.-Feb.
Fruit	1,143	1,101	367	68	1,510	1,169
Vegetables	416	-	490	-	906	-
Pasture	126	126	-	-	126	126
Total	1,685	1,227	857	68	2,542	1,295

For details, see Table C.2.2.

2.2. Existing Irrigation Water Use

2.2.1. Existing Water Demand

1) Unit Water Demand

Irrigation water demand per hectare varies mainly according to climate, type of crop and irrigation method. It is estimated by crop type and irrigation method based on the monthly potential evapotranspiration of the Azapa Valley.

The unit irrigation water demand of Azapa Valley was studied in detail by Araya, Cabrera/Asociados Ltda., Ingenieros Consultores in 1989 <1>, as described below.

(1) The potential evapotranspiration of Azapa Valley was first estimated from the observed pan evaporation as follows.

$$ETo = Kb \times E$$

where,

ETo : Potential evapotranspiration

Kb : Coefficient

E : Pan evaporation

In Azapa Valley, monthly average pan evaporation varies from 3.6 mm/day in July to 7.9 mm/day in January and February with an average of 5.73 mm/day. Monthly average relative humidity is in the range of 66% in December and 78% in July, averaging 71.8%. Wind velocity is low. The coefficient Kb was assumed to be 0.85.

As a result, yearly potential evapotranspiration was estimated to be 1,776.5 mm/year.

Monthly potential evapotranspiration are shown in Table C.2.3.

(2) The actual evapotranspiration of the crops was then estimated by multiplying the above potential evapotranspiration by another coefficient as follows.

$$ET = Kc \times ETo$$

where,

ET : Actual evapotranspiration of crop

Kc : Coefficient varying according to kind of crop

ETo: Potential evapotranspiration.

Kc was assumed at 0.625-0.725 for fruit, represented by the olive, 0.65 for vegetables and 0.80-0.95 for pasture (alfalfa) based on previous research and studies.

As a result, the actual yearly evapotranspiration of fruit, vegetables and pasture were estimated as follows.

Fruit	: 1,236.8 mm/year
Vegetables	: 1,154.7 mm/year
Pasture	: 1,593.1 mm/year

Monthly evapotranspiration values by crop are shown in Table C.2.4.

(3) Finally, unit irrigation water demand by crop and irrigation method was estimated by dividing the above actual evapotranspiration by the irrigation efficiency.

The irrigation efficiency varies according to the kind of crop and irrigation method.

(i) Based on the interview survey with the farmers in Azapa Valley, and various studies and research, the irrigation efficiencies of conventional irrigation methods were assumed as follows:

Fruit	: 60%
Vegetables	: 45%
Pasture	: 60%

(ii) The efficiency of drip irrigation for fruit was assumed at 95%, based on the previous studies and research.

(iii) The efficiency of drip irrigation for vegetable was estimated at 75%, based on the actual irrigated water volume in Azapa Valley.

As a result, yearly unit irrigation water demands by crop and irrigation method were estimated as follows.

Conventional Irrigation

Fruit	: 20,612m^3/ha/year (0.654 l/s/ha.)
Vegetables	: 25,659 m^3/ha/year (0.814 l/s/ha.)
Pasture	: 26,555 m^3/ha/year (0.842 l/s/ha.)

Drip Irrigation

Fruit	: 13,020 m^3/ha/year (0.413 l/s/ha.)
Vegetables	: 15,395 m^3/ha/year (0.488 l/s/ha.)

Monthly unit irrigation water demand by crop and by irrigation method are shown in Table C.2.5.

2) Total Water Demand.

The total irrigation water demand is estimated by multiplying the actual irrigated areas by the above unit irrigation water demand.

The total yearly irrigation water demand of Azapa Valley is estimated to be 40.0 million m^3/year, with the following break-down.

(Units: 10^3m^3/year)

	Conventional Irrigation	Drip Irrigation	Total
Fruit	23,173	3,049	26,222
Vegetable	6,121	4,324	10,445
Pasture	3,345	0	3,345
Total	32,639	7,373	40,012

Monthly irrigation water demands by crop and by irrigation method are shown in Table C.2.6 (1) and Table C.2.6 (2).

2.2.2. Actual Water Extraction

The water sources for irrigation in the Azapa Valley include surface water from the Azapa Canal, spring water and groundwater.

1) Surface Water Extraction of Azapa Canal.

The Azapa Canal began operations in 1962 when the Lauca Canal was completed. The Lauca Canal diverts water from the Lauca River (an international river flowing into Bolivia across the border) to

Central Chapiquiña in the upstream portion of the San José River. The diverted water joins the indigeneous water of the San José River and flows down the San José River to the Azapa Canal Intake which is located approximately 40 km upstream from the river mouth (see Fig. C.2.2.).

The maximum design discharge of the Lauca Canal is 1.37 m^3/s. However, the actual amount of water diverted fluctuates seasonally, depending on the flow in the Lauca River. The diverted water generates hydro-electric power at the Central Chapiquiña Hydro-electric Power Station, by taking advantage of the 1,008 m. head available, before being discharged into the San José River. The peak design output is 10.2 MW.

The water drawn by the intake of the Azapa Canal is distributed to the 22 irrigation sectors through the main canal, with a length of 42.8 km, and 22 secondary canals with a total length of 62.9 km (see Fig. C.2.2).

The maximum intake capacity of the Azapa Canal is estimated to be 2,000 l/s. The canal is designed to carry the entire flow of the San José River up to 2,000 l/s. Only the river flows in excess of about 2,000 l/s flow over the spillway back to the river.

The monthly average water extraction during the period 1986 -1990 was in the range of 96 -1,090 l/s with an average of 678 l/s.

Flows diverted to the Azapa Canal for the same period are shown in Table C.2.7.

2) Spring Water Extraction

There were originally 17 springs for irrigation water use in the lower reaches of Azapa Valley (downstream from the confluence of Quebrada del Diablo). They are:

La Moria, La Concepción, San Miguel, Dren El 5to., Matavaca, Pejerrey, Chonchalique, Dren Comunidad, Mama Lorenza, El Socavón, Peñablanca, Media Luna, Mita Chica, El Gallito, Ovando, Las Animas, El Estanque.

During the period of 1964 to 1986, the DGA observed the flow rate of 15 of the springs, excluding Las Animas and El Estanque. The observed yearly average flow rates are shown in Table C.2.8.

The distribution system of the spring water for irrigation use is shown in Fig. C.2.3.

The maximum flow rate of 616.7 l/s was observed in 1976. Thereafter, spring water flow has gradually decreased according to the draw-down of the groundwater table of the valley. Several springs have dried up. According to the 1989 report of Araya, Cabrera/Asociados Ltda., Ingenieros Consultores <1>, 14 springs were functioning in 1989, excluding Mama Lorenza, El Gallito and Ovando. The number of functioning springs has further decreased to five in 1993. They are:

San Miguel, Dren El 5to., Pejerrey, Conchalique, Dren Comunidad.

JICA observed the flow rates of these springs in June, 1993. The observed flow rates of each spring are also shown in Table C.2.8. The total observed flow rate is 73.0 l/s, and the existing spring water extraction for irrigation is presumed to be approximately the same.

3) Groundwater Extraction.

In the Azapa Valley, groundwater for irrigation use is extracted from 122 wells as of 1993. The existing groundwater extraction quantity was estimated based on the interview survey. The estimated yearly extraction quantity is 9,536 x 10^3 m^3/year (302 l/s). For details, see Supporting Report B, B-I, Chapter III.

2.2.3. Real Water Consumption

The yearly irrigation water demand in Azapa Valley was estimated at 40,012 x $10^3 m^3$ (=1,269 l/s) as shown in Section 2.2.1.

However, only a portion is actually consumed. A portion is consumed by the evapotranspiration of crops, and another portion infiltrates into underground. The infiltrated water may be re-used after recharging the groundwater.

The irrigation water consumption by the evapotranspiration of crops in Azapa Valley is estimated to be 24,810 x $10^3 m^3$/year (= 787 l/s). This is considered as the total real irrigation water consumption in Azapa Valley. For details, see Table C.2.9.

2.2.4. Water Rights

Irrigation water is extracted from the river, springs and groundwater based on legally authorized water rights or customary water rights. The number of legally authorized water rights in the Azapa Valley is 22, with a total permitted extraction of 1,038.05 l/s, and the number of customary water rights is 11, including the water rights of the Azapa Canal. The total extraction quantity granted in these water rights is 454.77 l/s plus 2,437.90 shares "acciones".

The water rights by water source are summarized below.

(1) Legally Authorized Water Right.

Water Source	Number of Water Rights	Permitted Quantity (l/s)
River Water	--	--
Spring Water	3	250.00
Groundwater	19	788.05
Total	22	1,038.05

(2) Customary Water Right.

Water Source	Number of Water Rights	Permitted Quantity (l/s)
River Water	2	400 l/s + 2,437.90 acc.
Spring Water	--	--
Groundwater	9	54.77 l/s
Total	11	454.77 l/s+2,437.90 acc.

For details, see Appendix C.1. and Appendix C.2.

2.3. Other Existing Water Use

2.3.1. Existing Water Use.

There are a number of wells extracting groundwater for individual domestic, industrial and miscellaneous uses. Those are 45 wells as of 1993.

The existing groundwater extraction quantity was estimated based on the interview survey. Number of wells and extracting quantity by water use are as follows.

Water Use	Number of Wells	Extraction Quantity
Domestic	30	1,366 x 10^3 m^3/yr (43 l/s)
Industrial	3	126 x 10^3 m^3/yr (4 l/s)
Miscellaneous	12	202 x 10^3 m^3/yr (6 l/s)
Total	45	1,694 x 10^3 m^3/yr (53 l/s)

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

A considerable portion of the extracted water is discharged on the land in the Azapa Valley. They will infiltrate into underground, recharging groundwater for reuse. The total real other water consumption is estimated to be 678 x 10^3 m^3/yr (21 l/s) by assuming that 60 % of the extracted water recharges groundwater.

2.3.2. Water Rights

Individual domestic water is mostly extracted without water rights. There are only three legally authorized water rights for individual domestic use.

On the other hand, there are two legally authorized water rights and four custom water rights for industrial use.

The number of water rights and permitted/customary water quantity by water use in Arica city area and Azapa Valley are shown below.

(1) Legally Authorized Water Rights

Water Use	Number of Water Rights	Water Source	Permitted Quantity (l/s)
Individual Domestic	3	Groundwater	41.1
Industrial	2	Groundwater	65.0
Total	5		106.1

(2) Customary Water Rights

Water Use	Number of Water Rights	Water Source	Permitted Quantity (l/s)
Individual Domestic	--		--
Industrial	4	Groundwater	42.0
Total	4		42.0

For details, see Appendix C.1 and Appendix C.2.

REFERENCES

<1. Modelo de Simulación de las Aguas Subterráneas del Valle de Azapa, January 1989, for DGA, by Araya, Cabrera/Asociados Ltda., Ingenieros Consultores.

Table C.2.1 Existing Cultivated Area by Crop and by Irrigation Method in Azapa Valley.
<Area Existente de Cultivo por Cosecha y por Método de Riego en el Valle de Azapa>

	Conventional Irrigation				Drip Irrigation				Total
	Zone I	Zone II	Zone III	Sub-Total	Zone I	Zone II	Zone III	Sub-Total	
Fruit									
Olive 5	80	848	933	--	6	20	26	959	
Tomato	15	50	--	65	50	410	460	525	
Other fruits	30	65	73	168	--	8	34	42	210
Sub-Total	50	195	921	1,166	50	14	464	528	1,694
Vegetable									
Green Bean	5	70	--	75	14	--	50	64	139
Green Veget.	48	380	93	526	--	680	--	680	1206
Flower	4	30	5	39	4	5	9	48	
Sub-Total	57	480	103	640	14	684	55	753	1,393
Pasture									
Alfalfa	26	78	22	126	--	--	--	--	126
Total	133	753	1,046	1,932	64	698	519	1,281	3,213

Data Source: SAG of I Region.

Note: 1) Zone I : Comunidad Andina area.
Zone II : Sobraya/Casa Grande area
Zone III : Chuval/Saucache area
2) Flowers are classified as vegetables for convenience in the estimation of irrigation water demand.

Table C.2.2 Existing Monthly Irrigation Area by Crop and by Irrigation Method in Azapa Valley

<Area Irrigada Mensual Existente según los Cultivos y Metodo de Riego en el Valle de Azapa>

Crop Type	Conventional Irri. (ha)		Drip Irri. (ha)		Total (ha)	
	Mar.-Oct.	Nov.-Feb.	Mar.-Oct.	Nov.-Feb.	Mar.-Oct.	Nov.-Feb.
Fruit						
Olive	933	933	26	26	959	959
Tomato	42	-	299	-	341	-
Other Fruits	168	168	42	42	210	210
Sub-Total	1,143	1,101	367	68	1,510	1,169
Vegetables						
Green Bean	49	-	42	-	91	-
Green Veget.	342	-	442	-	784	-
Flower	25	-	6	-	31	-
Sub-Total	416	-	490	-	906	-
Pasture						
Alfalfa	126	126	-	-	126	126
Total	1,685	1,227	857	68	2,542	1,295

Table C.2.3. Potential Evapotranspiration of Azapa Valley.
<Evapotranspiración Potencial del Valle de Azapa>

Month	Evaporation mm/day	Evaporation mm/month	Relative Humidity(%)	Coefficient (Kb)	Potential Evapotranspiration ETo (mm/month)
Jan.	7.9	246.0	68	0.85	209.1
Feb.	7.9	221.7	68	0.85	188.5
Mar.	7.0	217.4	69	0.85	184.8
Apr.	5.5	165.5	71	0.85	140.7
May	4.5	139.0	74	0.85	118.2
Jun.	3.7	111.5	76	0.85	94.8
Jul.	3.6	111.6	78	0.85	94.9
Aug.	4.0	122.9	76	0.85	104.5
Sep.	5.0	149.4	74	0.85	127.0
Oct.	5.8	180.9	71	0.85	153.8
Nov.	6.6	198.5	70	0.85	168.8
Dec.	7.3	225.1	66	0.85	191.4
Average	5.73	174.1	71.8		148.0
Total		2,089.5			1,776.5

Data Source : Modelo de Simulación de las Aguas Subterráneas del Valle de Azapa, Jan. 1989 for DGA by Araya, Cabrera/Asociados Ltda., Ingenieros Consultores.

Table C.2.4. Actual Evapotranspiration by Crop

<Evapotranspiración Real por Cultivo>

Month	Fruit (Olive)			Vegetables		Pasture	
	ETo (mm/month)	Kc	ET(mm/month)	Kc	ET(mm/month)	Kc	ET(mm/month)
Jan.	209.1	0.725	151.6	0.65	135.9	0.95	198.7
Feb.	188.5	0.725	136.6	0.65	122.5	0.95	179.0
Mar.	184.8	0.725	134.0	0.65	120.1	0.94	173.7
Apr.	140.7	0.675	95.0	0.65	91.5	0.90	126.6
May.	118.2	0.675	79.8	0.65	76.8	0.85	100.5
Jun.	94.8	0.625	59.2	0.65	61.6	0.80	75.8
Jul.	94.9	0.625	59.3	0.65	61.7	0.80	75.9
Aug.	104.5	0.675	70.6	0.65	67.9	0.82	85.7
Sep.	127.0	0.675	85.7	0.65	82.6	0.84	106.7
Oct.	153.8	0.675	103.8	0.65	100.0	0.88	135.3
Nov.	168.8	0.725	122.4	0.65	109.7	0.92	155.3
Dec.	191.4	0.725	138.8	0.65	124.4	0.94	179.9
Total	1,776.5		1,236.8		1,154.7		1,593.1

Source : Modelo de Simulación de las Aguas Subterráneas del Valle de Azapa, Jan. 1989 for DGA by Araya, Cabrera/Asociados Ltda., IngenierosConsultores.

Table C.2.5. Unit Irrigation Water Demand by Crop and by Irrigation Method
<Demanda Unitaria de Agua para Irrigación por Cultivo y por Método de Riego>

Month	Conventional Irrigation						Drip Irrigation			
	Fruit		Vegetables		Pasture		Fruit		Vegetables	
	Irrigation Efficiency (%)	m3/ha/month	Irrigation Efficiency(%)	m3/ha/month	Irrigation Efficiency(%)	m3/ha/month	Irrigation Efficiency(%)	m3/ha/month	Irrigation Efficiency(%)	m3/ha/month
Jan.	60	2,527	45	3,020	60	3,311	95	1,596	75	1,812
Feb.	60	2,277	45	2,722	60	2,984	95	1,438	75	1,633
Mar.	60	2,233	45	2,669	60	2,895	95	1,410	75	1,601
Apr.	60	1,583	45	2,033	60	2,111	95	1,000	75	1,220
May	60	1,330	45	1,707	60	1,674	95	840	75	1,024
Jun.	60	987	45	1,369	60	1,264	95	624	75	821
Jul.	60	988	45	1,371	60	1,265	95	624	75	822
Aug.	60	1,176	45	1,510	60	1,429	95	743	75	906
Sep.	60	1,429	45	1835	60	1,779	95	903	75	1,101
Oct.	60	1,730	45	2,221	60	2,256	95	1,093	75	1,333
Nov.	60	2,039	45	2,438	60	2,588	95	1,288	75	1,463
Dec.	60	2,313	45	2,764	60	2,999	95	1,461	75	1,659
Total		20,612		25,659		26,555		13,020		15,395

Data Source : Modelo de Simulación de las Aguas Subterráneas del Valle de Azapa,
Jan. 1989 for DGA by Araya, Cabrera/Asociados Ltda., Ingenieros Consultores.

Table C.2.6 (1) Existing Irrigation Water Demand by Crop and by Irrigation Method.
<Demanda Existente de Agua para Riego por Cultivo y por Método de Riego>

Month	Conventional Irrigation									Total
	Fruit			Vegetables			Pasture			
	Cultivation Area (ha)	Unit Water Demand (m3/ha/mo)	Water Demand (103m3)	Cultivation Area (ha)	Unit Water Demand (m3/ha/mo)	Water Demand (103m3)	Cultivation Area (ha)	Unit Water Demand (m3/ha/mo)	Water Demand (103m3)	(103m3)
Jan.	1,101	2,527	2,782		3,020	0	126	3,311	417	3,199
Feb.	1,101	2,277	2,507		2,722	0	126	2,984	376	2,883
Mar.	1,143	2,233	2,552	416	2,669	1,110	126	2,895	365	4,027
Apr.	1,143	1,583	1,809	416	2,033	846	126	2,111	266	2,921
May.	1,143	1,330	1,520	416	1,707	710	126	1,674	211	2,441
Jun.	1,143	987	1,128	416	1,369	570	126	1,264	159	1,857
Jul.	1,143	988	1,129	416	1,371	570	126	1,265	159	1,858
Aug.	1,143	1,176	1,344	416	1,510	628	126	1,429	180	2,152
Sep.	1,143	1,429	1,633	416	1,835	763	126	1,779	224	2,620
Oct.	1,143	1,730	1,977	416	2,221	924	126	2,256	284	3,185
Nov.	1,101	2,039	2,245		2,438	0	126	2,588	326	2,571
Dec.	1,101	2,313	2,547		2,764	0	126	2,999	378	2,925
Total			23,173			6,121			3,345	32,639

Table C.2.6 (2) Existing Irrigation Water Demand by Crop and by Irrigation Method
<Demanda Existente de Agua para Riego por Cultivo y por Método de Riego>

Month	Drip Irrigation									Total
	Fruit			Vegetables			Pasture			
	Irrigation Area (ha)	Unit Water Demand (m3/ha/mo)	Water Demand (103m3)	Irrigation Area (ha)	Unit Water Demand (m3/ha/mo)	Water Demand (103m3)	Irrigation Area (ha)	Unit Water Demand (m3/ha/mo.)	Water Demand (103m3)	(103m3)
Jan.	68	1,596	109		1,812	0				109
Feb.	68	1,438	98		1,633	0				98
Mar.	367	1,410	517	490	1,601	784				1,301
Apr.	367	1,000	367	490	1,220	598				965
May.	367	840	308	490	1,024	502				810
Jun.	367	624	229	490	821	402				631
Jul.	367	624	229	490	822	403				632
Aug.	367	743	273	490	906	443				716
Sep.	367	903	331	490	1,101	539				870
Oct.	367	1,093	401	490	1,333	653				1,054
Nov.	68	1,288	88		1,463	0				88
Dec.	68	1,461	99		1,659	0				99
Total			3,049			4,324				7,373

Table C.2.7 Flow in Azapa Canal 1986 - 1990
<Caudal de Bocatoma del Canal Azapa Durante 1986 -1990>

(Unit: l/s)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	AVG
1986	827	217	401	665	483	332	741	340	723	867	942	1,000	628
1987	412	833	1,010	1,030	1,090	918	910	280	096	254	916	903	721
1988	815	632	1,000	947	901	855	785	775	777	312	920	777	791
1989	815	820	923	955	900	844	842	825	817	736	514	343	778
1990	513	551	503	453	472	552	500	450	420	434	418	416	474
AVG	676	611	767	810	769	700	756	534	567	521	742	688	678

Data Source: D.G.A.

Table C.2.8 Yearly Average Flow Rate of Springs
<Flujo Promedio Anual de Vertientes>

(Unit l/s)

Year	La Moria	La Concepción	San Miguel	Dren el 5to.	Canal Albarracines	Included in Canal Albarracines				Mama Lorenza	El Socavón	Peñablanca	Media Luna	Mita Chica	El Gallito	Ovando	Total
						Matavaca	Pejerrey	Conchaligue	Dren Comunidad								
1964		18.10	108.60		57.40								6.20	9.80	17.30		217.40
1965		9.60	67.00		39.70								3.20	12.30	17.60		149.40
1966		4.60	37.10		31.90								0.00	2.20	5.30		81.10
1967		4.00	46.40		43.60								0.00	6.60	2.70		103.30
1968		11.90	84.00		57.20								15.60	23.80	12.40		204.90
1969		12.00	88.30		48.00								38.00	37.30	28.80		252.40
1970		6.40	50.00		35.30								10.80	28.10	28.20		158.80
1971		0.90	15.10		31.30							11.10	10.80	20.50	21.70		111.40
1972		7.80	35.60		32.10							44.50	39.80	39.00	33.60		232.40
1973		32.80	71.90		45.40							71.10	66.00	57.00	10.70		354.90
1974		61.00	106.10		60.30					1.30	2.30	88.00	83.30	67.00	-		469.30
1975		74.80	131.80		75.00	1.20				6.30	19.30	92.30	90.70	70.30	-	8.80	569.30
1976	9.00	77.30	145.90		88.20	10.70	0.10	10.30		8.00	27.70	87.30	88.60	69.50	-	15.20	616.70
1977	13.60	70.60	153.60		100.50	9.40	7.40	13.30		6.20	30.00	78.60	81.90	66.90	-	8.30	610.20
1978	9.20	61.90	157.60		111.40	8.30	15.90	15.50		1.00	25.80	67.60	72.10	60.60	-	0.20	567.40
1979	10.00	51.40	153.50		120.80	17.60	19.70	15.90		-	15.20	54.70	59.30	58.90	-	-	523.80
1980	5.10	32.70	118.80		104.20	15.50	17.80	14.60		-	5.80	20.80	36.20	44.10	-	-	368.00
1981	4.40	13.60	78.10		66.60	10.80	11.80	12.00		-	2.50	0.00	8.40	18.10	-	-	191.70
1982	1.40	4.10	38.80		40.60	7.10	10.20	9.40		-	4.30	0.00	0.00	1.00	-	-	90.20
1983	0.30	1.30	13.20		35.40	4.20	5.90	8.50	18.30	-	1.30	0.00	0.00	0.00	-	-	51.50
1984	0.00	1.50	23.60	5.80	41.90	2.40	2.90	8.30	32.20	-		0.00	0.00	0.00	-	-	72.80
1985	0.00	14.30	71.90	9.50	58.30	1.40	9.10	10.30	30.40	-	4.80	1.10	0.00	3.90	-	-	163.80
1986	0.00	35.30	121.90	10.80	85.10	3.30	12.90	12.30	74.20	-	10.70	26.40	0.90	20.00	-	-	311.10
1993	-	-	39.00	4.00	30.00	-	3.00	9.00	18.00	-	-	-	-	-	-	-	73.00

Data Source: Modelo de Simulación de las Aguas Subterráneas del Valle de Azapa,
Jan 1989 for DGA by Araya, Cabrera/Asociados Ltda., Ingenieros Consultores.

Table C.2.9 Existing Irrigation Water Consumption by Evaporation
<Consumo de Agua para Riego Existente por Evapotranspiración>

Month	Fruit			Vegetables			Pasture			Total
	ET (mm/month)	Cultivation Area (ha)	Water Consumption (103m3)	ET (mm/month)	Cultivation Area (ha)	Water Consumption (103m3)	ET (mm/month)	Cultivation Area (ha)	Water Consumption (103m3)	(103m3)
Jan.	151.6	1,169	1,772	135.9		0	198.7	126	250	2,022
Feb.	136.6	1,169	1,597	122.5		0	179.0	126	226	1,823
Mar.	134.0	1,510	2,023	120.1	906	1,088	173.7	126	219	3,330
Apr.	95.0	1,510	1,435	91.5	906	829	126.6	126	160	2,424
May	79.8	1,510	1,205	76.8	906	696	100.5	126	127	2,028
Jun.	59.2	1,510	894	61.6	906	558	75.8	126	96	1,548
Jul.	59.3	1,510	895	61.7	906	559	75.9	126	96	1,550
Aug.	70.6	1,510	1,066	67.9	906	615	85.7	126	108	1,789
Sep.	85.7	1,510	1,294	82.6	906	748	106.7	126	134	2,176
Oct.	103.8	1,510	1,567	100.0	906	906	135.3	126	170	2,643
Nov.	122.4	1,169	1,431	109.7		0	155.3	126	196	1,627
Dec.	138.8	1,169	1,623	124.4		0	179.9	126	227	1,850
Total	1,236.8		16,802	1,154.7		5,999	1,593.1		2,009	24,810

Note: ET: Actual Evapotranspiration of Crop.

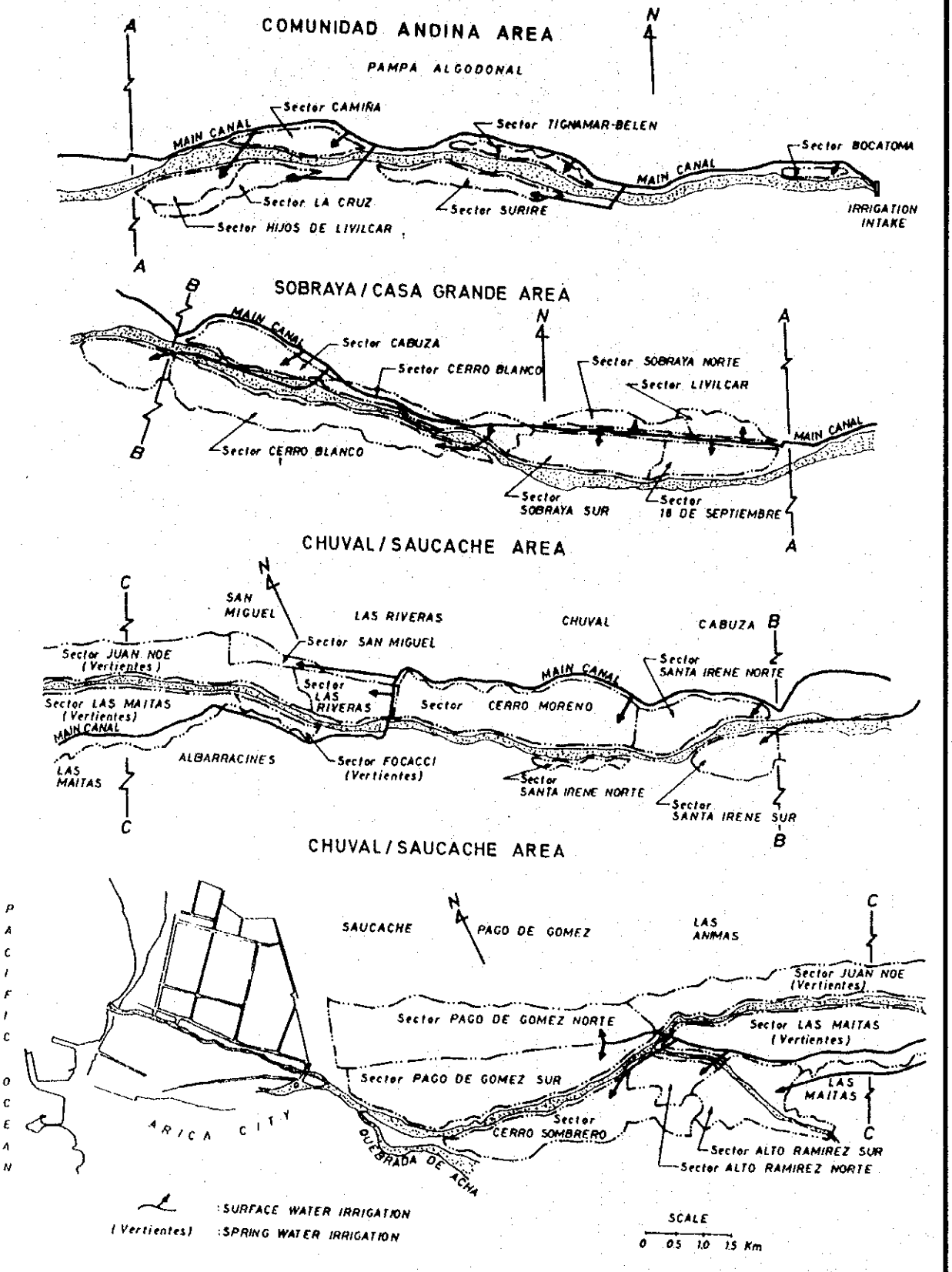


Fig. C.2.1 Location of Irrigation Sectors and Sub-sectors - Azapa Valley

<Ubicación de Sectores y Sub-sectores de Riego -Valle de Azapa

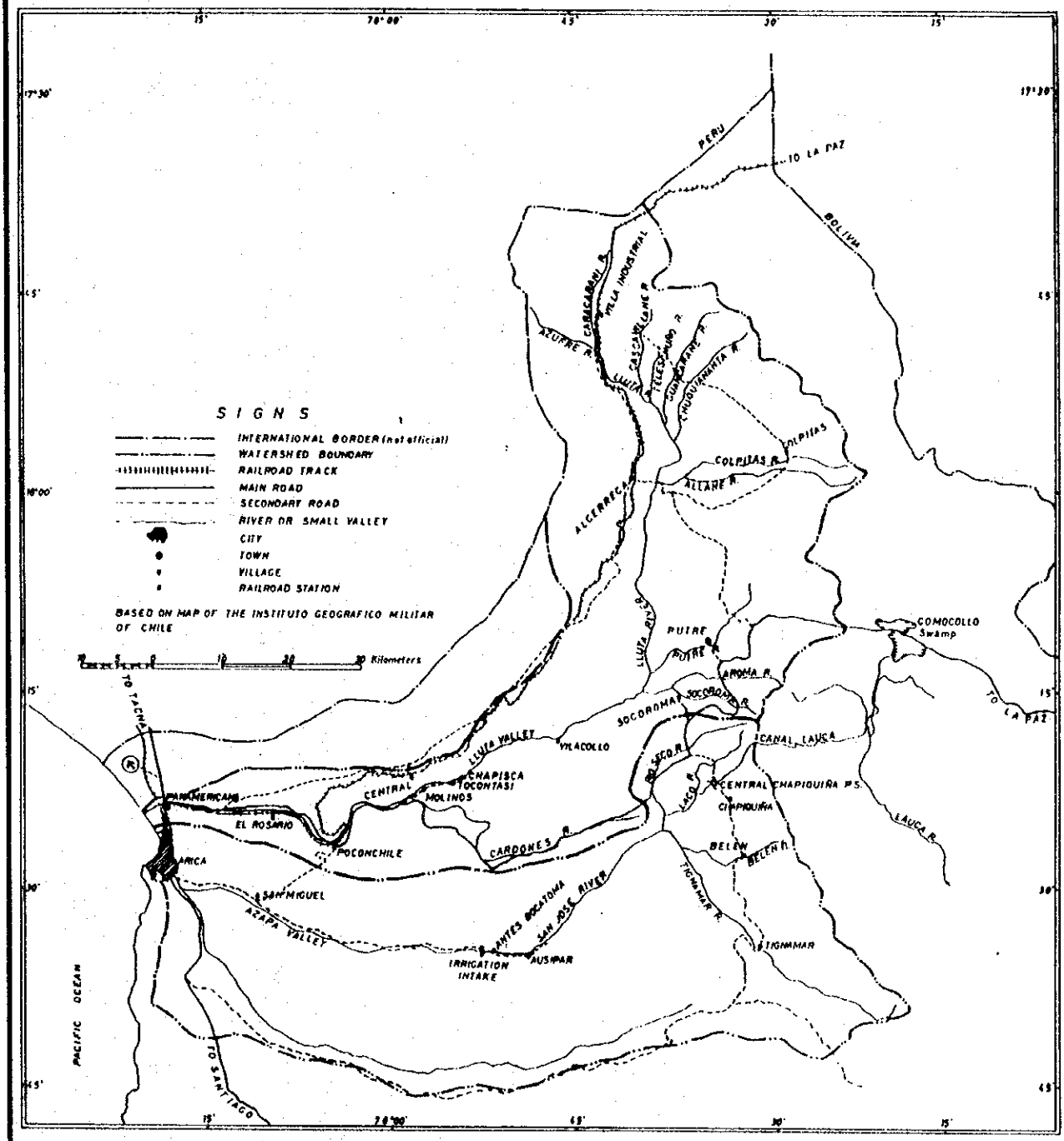


Fig. C.2.2 River System of San José and Lluta River Basin

< Sistema Fluvial de la Cuenca del Río San José y Río Lluta >

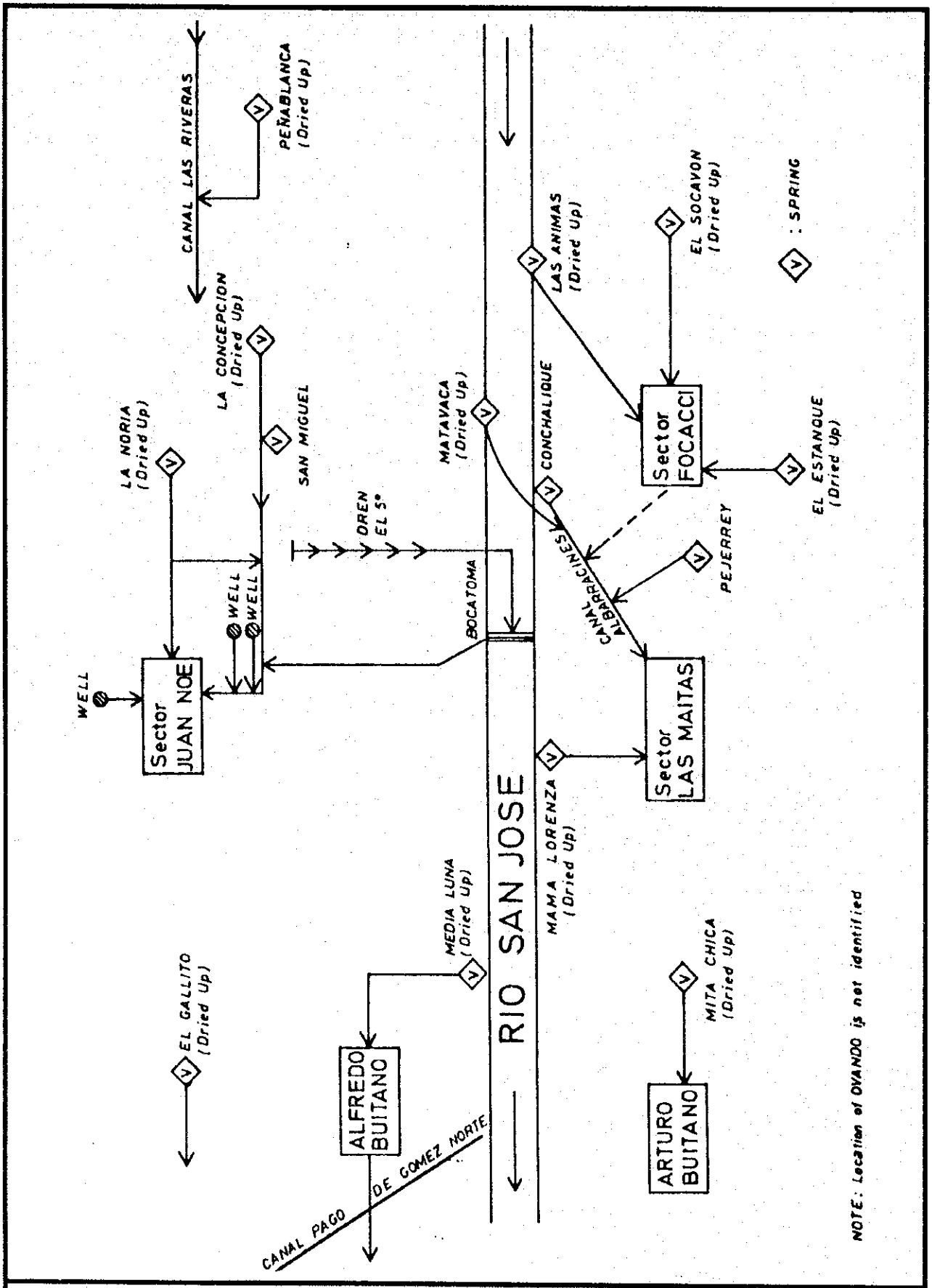


Fig. C.2.3 Spring Water Distribution System for Irrigation Use

<Sistema de distribución de las Aguas de Vertientes para uso de Riego>

Chapter III. IRRIGATION WATER OF LOWER LLUTA VALLEY

3.1 Existing Irrigation Area

3.1.1 Irrigation system

The total farmland area of the Lower Lluta Valley is estimated at 4,032 ha. This area is located along a 65 km reach between Vilacollo and the river mouth, and is supplied by the river water irrigation system of the Lluta. (see Fig. C.2.2)

However, only a portion of the 4,032 ha is cultivated. The cultivated area is normally limited to 2,784.2 ha (69%), and the other 1,248.2 ha (31.0%) is perennially fallow due to lack of irrigation water and the poor drainage capacity of the soil.

The 4,032 ha of farmland along the Lluta River is divided into 6 irrigation sectors and is further divided into 80 irrigation sub-sectors. Each irrigation sub-sector is supplied river water through its own independent irrigation intake and channel network. Conventional irrigation methods are used for all irrigated areas.

The total farmland and estimated irrigated areas, by irrigation sector, are detailed in Table C.3.1 and summarized below.

Name of Sector	Number of Sub -sectors	Total Farmland (ha)	Irrigated (ha)	Area (%)
Upstream Sector	27	275.	213.3	77.5
Sector I	8	496.8	338.3	68.1
Sector II	14	433.2	307.5	71.0
Sector III	14	719.5	575.1	79.9
Sector IV	9	1,558.0	1,127.8	72.4
Sector V	8	549.5	222.2	40.4
Total	80	4,032.4	2,784.2	69.0

Locations of the above irrigation sectors and sub-sectors, along with the irrigation intakes, are shown in Fig. C.3.1.

3.1.2 Irrigated Areas and Cropping Patterns

1) Irrigated Areas

Due to river water contamination, the crop types of the Lluta Valley are limited to maize, pasture (alfalfa), and certain kinds of vegetables. The river water contains a high concentration of Boron (B), which severely affects crop cultivation.

The average content of Boron (B) in the river water is 10.69 mg/l at Tocontasi, 11.17 mg/l at Poconchile, and 16.84 mg/l at Panamericana. The sources of contamination are the upstream tributaries of the Lluta River: the Azufre and Colpitas rivers. For details, see Supporting Report A, Chapter II.

Maize is the predominant crop followed by pasture (alfalfa). The breakdown by crop type is as follows:

Crop	Area (ha)	% of Cultivated Area
Maize	1698.4	61.0
Alfalfa	683.9	24.6
Vegetables	401.9	14.4
Totals	2784.2	100.0

The irrigated areas by crop type and irrigation sector are shown in Table C.3.1, and are summarized as follows:

Areas by Crop Type and Irrigation Sector (ha)

Sector	Maize	Vegetables	Pasture	Fallow	Total
Upstream	131.5	7.2	74.6	62.1	275.4
I	138.5	22.5	177.3	158.5	496.8
II	101.3	51.1	155.1	125.7	433.2
III	349.0	73.0	153.1	144.4	719.5
IV	877.3	180.9	69.6	430.2	1,558.0
V	100.8	67.2	54.2	327.3	549.5
Total	1,698.4	401.9	683.9	1,248.2	4,032.4

2) Cropping Pattern

Maize is cultivated once or twice a year. Double cropping is common for the area downstream of Poconchile. However, there is normally only one crop in the upstream area of Poconchile due to the limitations of climate and marketing. Vegetables and pasture are cultivated throughout the year.

The general cropping calendars of the Lower Lluta Valley are as follows.

(1) Upstream Area (Vilacollo - Linderos Sub-sectors)

Crop	Cultivation Period	Fallow Period
Maize	4 months (Dec.-Mar.)	8 months (Apr.-Nov.)
Vegetables	Year-round	-----
Pasture	Year-round	-----

(2) Downstream Area (Poconchile - Santa Rosa Sub-sectors)

Crop	Cultivation Period	Fallow Period
Maize 1st.	4 months (Mar.-Jun.)	2 months (July-Aug.)
Maize 2nd	4 months (Sep.-Dec.)	2 months (Jan.-Feb.)
Vegetables	Year-round	-----
Pasture	Year-round	-----

3.2 Existing Water Use and Water Rights

There is no existing data on the actual irrigation water use, other than the approximate area irrigated.

However, the actual water use can be roughly estimated by calculating the difference between the river flow rates at upstream and downstream gauging stations.

The observed flow rates during the dry season (Apr.-Dec.) at Tocontasi/Chapisca and Panamericana, and estimated difference (balance) are as follows:

	Tocontasi/ Chapisca	Panamericana	Balance
Average Flow Rate (l/s)	1,638	599	1,039
80% Drought Flow Rate (l/s)	1,342	292	1,050
90% Drought Flow Rate (l/s)	1,227	229	998
Average			1,029

Notes: <1 For the above flow rates, see Supporting Report A, Chapter II.
<2 The balance was calculated for the dry season (Apr.-Dec.) to avoid errors arising from flood data.

The area irrigated by river water, located between Tocontasi/Chapisca and Panamericana, is approximately 2,500 ha. Hence, the unit irrigation water use is estimated to be 0.41 l/s/ha.

3.2.1 Unit Water Demand

The above calculated water balance between Tocontasi/Chapisca and Panamericana may include some loss due to groundwater recharge. The irrigation water use is therefore also calculated based on irrigated areas and estimated irrigation water usage. In the absence of evapotranspiration data for the Lluta valley, values for the Azapa Valley were used <1>. Evapotranspiration values for maize were estimated at 120% of those used for vegetables, based on discussions with SAG (Servicio Ganadero y Agrícola). Estimated evapotranspiration data for the different crop types are as follows:

Estimated Evapotranspiration by Crop Type (mm)

Month	Maize	Vegetables	Pasture
Jan.	163.1	135.9	198.7
Feb	147.0	122.5	179.0
Mar	144.1	120.1	173.7
Apr	109.8	91.5	126.6
May	92.2	76.8	100.5
Jun	73.9	61.6	75.8
Jul	74.0	61.7	75.9
Aug	81.5	67.9	85.7
Sep	99.1	82.6	106.7
Oct	120.0	100.0	135.3
Nov	131.6	109.7	155.3
Dec	149.3	124.4	179.9
Total	1,385.6	1,154.7	1,593.1

Irrigation efficiencies were estimated as follows:

Maize	40%
Vegetables	45%
Pasture	60%

Sources: SAG (Servicio Ganadero y Agrícola)
<1>

3.2.2 Total Water Demand

Total irrigation water demand was estimated using the above evapotranspiration data and irrigation efficiencies, plus the irrigated areas and cropping patterns presented in Section 3.1. The methodology was similar to that described in Section 2.2 of this report. Irrigation water demand per hectare were calculated as shown in Table C.3.2. Water demands by irrigation sector were then calculated as shown in Table C.3.3. The results are summarized as follows:

Existing Irrigation Water Demand by Crop and Irrigation Method
Lower Lluta Valley (Units: $10^3 m^3/yr.$)

Sector	Maize	Vegetables	Pasture	Fallow	Total
Upstream	1,983.9	184.8	1,980.8	0.0	4,149.4
I	2,089.5	577.4	4,707.6	0.0	7,374.5
II	1,528.3	1,311.2	4,118.2	0.0	6,957.7
III	8,027.3	1,873.2	4,065.1	0.0	13,965.6
IV	20,178.8	4,641.9	1,848.0	0.0	26,668.7
V	2,318.5	1,724.4	1,439.1	0.0	5,482.0
Total	36,126.4	10,312.8	18,158.7	0.0	64,597.9

3.2.3 Real Water Consumption

The yearly irrigation water demand in the Lower Lluta Valley, estimated above at 64,597.9 x $10^3 m^3$, is equivalent to 2048.4 l/sec and an overall average of 0.737 l/sec/ha. However this total amount is not completely consumed by the crops. A significant portion is either lost during distribution or infiltrates into the groundwater. The portion which infiltrates into the groundwater is available for reuse. The amount actually consumed by the crops (without considering losses due to irrigation efficiencies) is estimated, based on the evapotranspiration. The results are as follows:

Existing Evapotranspiration by Crop and Irrigation Method
Lower Lluta Valley (Units: 10^3 m^3 / yr.)

Sector	Maize	Vegetables	Pasture	Fallow	Total
Upstream	793.6	83.1	1,188.5	0.0	2,065.2
I	835.8	259.8	2,824.6	0.0	3,920.2
II	611.3	590.1	2,470.9	0.0	3,672.3
III	3,210.9	842.9	2,439.0	0.0	6,492.9
IV	8,071.5	2,088.9	1,108.8	0.0	11,269.2
V	927.4	776.0	863.5	0.0	2,566.8
Total	14,450.6	4,640.7	10,895.2	0.0	29,986.5

The total real irrigation water consumption of the Lluta Valley is 29,986.5 x 10^3 m^3/yr (= 950.9 l/s).

Out of the above real irrigataion water consumption, that in the downstream reaches of Tocontasi/Chapisca stations is estimated to be 28,181.4 x 10^3 m^3/yr (= 893.6 l/s). Its monthly real water consumption are shown in Table C.3.4.

3.2.4 Water Rights

Most of the irrigation water of the Lower Lluta Valley is extracted based on the legally authorized water rights or customary water rights. The number of water rights and quantity, by water source category, as of 1994, are summarized below.

(1) Legally Authorized Water Rights

Water Source	Number of Water Rights Authorized	Quantity (l/s), (Acc.)
River Water	2	284.5 l/s
River Water	78	2,729.84 Acc.
Groundwater	1	0.25 (l/s)
Total	81	284.75 l/s + 2,729.84 Acc.

(2) Customary Water Right

Water Source	Number of WaterCustomary Rights Authorized	Quantity (l/s)
Groundwater	1	10.0 l/s

For details, see, Appendix C.3

REFERENCES

<1. Modelo de Simulación de las Aguas Subterráneas del Valle de Azapa, January, 1989 for DGA by Araya, Cabrera/Asociados Ltda., Ingenieros Consultores.

Table C.3.1 Existing Irrigation Area by Crop of Lower Lluta Valley.
<Area de Riego Existente por Cultivo en el Valle de Lluta>

Irrigation Sector	Irrigation Area by Crop (ha.)					Remarks
	Maize	Vegetable	Pasture	Fallow	Total	
1. Upstream Sector						
Vilacollo Uno					7.0	
Vilacollo Dos	--	--	--	6.7	6.7	
Iqueta Norte	2.0	--	--	1.0	3.0	
Vinto Sur					3.8	
Vinto Norte					23.1	
Cata					3.3	
Buena Vista					5.3	
Anca Collo	--	--	--	1.7	1.7	
Huacharaque	2.0	--	0.5	--	2.5	
Arancha	14.0	--	8.0	1.2	23.2	
Millure					9.3	
Saucine	----	--	1.3	--	1.3	
Challallapo	6.9	--	12.2	3.1	22.2	
Tinare	--	--	--	7.3	7.3	
La Palma	10.0	--	1.0	2.1	13.1	
Zora	11.4	--	7.2	0.4	19.0	
Cala Cala	10.0	2.0	2.5	0.4	14.9	
Chaquire	6.1	1.0	3.0	8.0	18.1	
Tauquia	9.0	1.3	7.5	0.5	18.3	
Chapisca Norte	3.7	--	1.2	--	4.9	
Chapisca Oriente	6.0	--	0.3	--	6.3	
Giron	2.5	--	2.5	3.0	8.0	
Chapisca Sur	4.0	0.5	2.5	6.0	13.0	
Vila Vila					5.3	
Tocontasi					24.7	
Vila Vila Dos					0.8	
Irenio Quispe					9.3	
Sub-Total	(131.5)	(7.2)	(74.6)	(62.1)	275.4	
2. Sector I						
Molinos	80.0	10.0	90.0	77.4	257.4	
Chatiapo	4.0	0.5	10.0	8.6	23.1	
Humire	--	--	4.0	1.0	5.0	
Quispe	--	--	--	1.5	1.5	
Bocanegra	23.0	9.0	39.0	37.0	108.0	
El Tambo	18.0	2.0	22.3	13.0	55.3	
Almonte	5.5	0.5	10.0	2.5	18.5	
Santa Inés	8.0	0.5	2.0	17.5	28.0	
Sub-Total	138.5	22.5	177.3	158.5	496.8	
3. Sector II						
Rojas Maraboli	8.0	2.0	2.0	12.7	24.7	
Alfonso Bolanos	5.0	--	3.0	4.0	12.0	
Vilca Loredo	6.5	3.5	19.8	17.5	47.3	
Loredo	4.0	1.0	9.0	9.0	23.0	
Vilca Chang	6.0	4.5	33.5	5.3	49.3	
Bolanos Villanueva	2.5	--	8.0	0.2	10.7	

Table C.3.1 Existing Irrigation Area by Crop of Lower Lluta Valley.
Page 2 of 2

Irrigation Sector	Irrigation Area by Crop (ha.)					Remarks
	Maize	Vegetable	Pasture	Fallow	Total	
Ponce	5.0	0.3	4.0	--	9.3	
Ramos	8.4	7.0	13.0	9.0	37.4	
Santa Raquel					103.3	
San Pablo	--	--	--	1.3	1.3	
Flores	--	2.0	--	10.0	12.0	
Punta de Rieles	4.0	--	1.0	2.0	7.0	
El Pichin	2.0	--	--	1.3	3.3	
Aquatoya	24.6	18.0	23.0	22.0	87.6	
Sub-Total	(101.3)	(51.1)	(155.1)	(125.7)	433.2	
4. Sector III						
Kesler	--	1.3	--	5.0	6.3	
La Isla	18.0	8.0	--	4.0	30.0	
Huanca					9.4	
Pro-Chile	18.0	6.0	38.0	25.9	87.9	
Linderos	16.0	7.9	8.0	--	31.9	
Poconchile	45.0	15.0	46.0	5.7	111.7	
García					6.7	
Barr'co Sta. Rosa	8.3	1.0	7.0	9.0	25.3	
Mayorga					27.1	
La Palma Uno	16.0	2.0	3.0	9.7	30.7	
Huancarane					65.2	
La Palma Dos	35.5	4.0	0.5	8.0	48.0	
Visconti	100.8	8.7	10.5	39.3	159.3	
Kesler Gil					80.0	
Sub-Total	(349.0)	(73.0)	(153.1)	(144.4)	719.5	
5.Sector IV						
Arellano Beyzan	18.7	--	2.0	6.0	26.7	
Cora Beyzan	93.6	1.0	5.0	30.0	129.6	
El Muro					281.4	
Alanoca	10.5	1.0	1.0	23.0	35.5	
Chacabuco	310.0	30.0	10.0	106.8	456.8	
Dominguez	10.0	--	--	--	10.0	
Sascapa	246.0	110.0	36.7	172.0	564.7	
Bravo Uno					33.3	
Bravo Dos					20.0	
Sub-Total	(877.3)	180.9)	(69.6)	(430.2)	1,558.0	
6. Sector V						
Valle Hermoso	60.0	35.0	12.0	225.0	332.0	
Aica González	24.0	8.0	1.0	7.0	40.0	
M. Beovic	--	----	8.0	2.7	10.7	
B'ba Pte.Chacall.	--	--	6.7	--	6.7	(Green belt
Ambrosio Flores	--	--	2.0	0.7	2.7	along street)
Bellet	--	2.7	--	40.0	42.7	
Beneficiencia	4.8	11.5	16.5	19.5	52.3	
Santa Rosa	12.0	10.0	8.0	32.4	62.4	
Sub-Total	100.8	67.2	54.2	327.3	549.5	
Total	(1,698.4)	(401.9)	(683.9)	(1,248.2)	4,032.4	

Data Source ; Asociación Regantes de Lluta
Note: With Bracket: estimated based on the average ratios of known values.

Table C.3.2 Unit Irrigation Water Demand by Crop Type - Lower Lluta Valley
<Demanda Unitaria de Agua para Riego por Cultivo>

	Maize		Vegetables		Pasture	
Month	Irrig .Effic.	m^3/ha	Irrig .Effic.	m^3/ha	Irrig .Effic.	m^3/ha
Jan.	40%	4,077	45%	3,020	60%	3,312
Feb	40%	3,675	45%	2,722	60%	2,983
Mar	40%	3,603	45%	2,669	60%	2,895
Apr	40%	2,745	45%	2,033	60%	2,110
May	40%	2,304	45%	1,707	60%	1,675
Jun	40%	1,848	45%	1,369	60%	1,263
Jul	40%	1,851	45%	1,371	60%	1,265
Aug	40%	2,037	45%	1,509	60%	1,428
Sep	40%	2,478	45%	1,836	60%	1,778
Oct	40%	3,000	45%	2,222	60%	2,255
Nov	40%	3,291	45%	2,438	60%	2,588
Dec	40%	3,732	45%	2,764	60%	2,998
Total		34,641		25,660		26,552

Table C.3.3 Existing Irrigation Water Demand by Crop Type
<Demanda Existente de Agua para Riego por Cultivo>

Upstream Sectors (Upstream, I, II)

	Maize			Vegetables			Pasture		
Month	Cultivated Area(ha)	Unit Water Demand (m^3/ha)	Total Water Demand (10^3m^3)	Cultivated Area(ha)	Unit Water Demand (m^3/ha)	Total Water Demand (10^3m^3)	Cultivated Area(ha)	Unit Water Demand (m^3/ha)	Total Water Demand (10^3m^3)
Jan	371.3	4,077	1,514	80.8	3,020	244	407	3,312	1,348
Feb	371.3	3,675	1,365	80.8	2,722	220	407	2,983	1,214
Mar	371.3	3,603	1,338	80.8	2,669	216	407	2,895	1,178
Apr		2,745	0	80.8	2,033	164	407	2,110	859
May		2,304	0	80.8	1,707	138	407	1,675	682
Jun		1,848	0	80.8	1,369	111	407	1,263	514
Jul		1,851	0	80.8	1,371	111	407	1,265	515
Aug		2,037	0	80.8	1,509	122	407	1,428	581
Sep		2,478	0	80.8	1,836	148	407	1,778	724
Oct		3,000	0	80.8	2,222	180	407	2,255	918
Nov		3,291	0	80.8	2,438	197	407	2,588	1,053
Dec	371.3	3,732	1,386	80.8	2,764	223	407	2,998	1,220
Total			5,602			2,073			10,807

Downstream Sectors (III, IV, V)

	Maize			Vegetables			Pasture		
Month	Cultivated Area(ha)	Unit Water Demand (m^3/ha)	Total Water Demand (10^3m^3)	Cultivated Area(ha)	Unit Water Demand (m^3/ha)	Total Water Demand (10^3m^3)	Cultivated Area(ha)	Unit Water Demand (m^3/ha)	Total Water Demand (10^3m^3)
Jan		4,077		321.1	3,020	970	276.9	3,312	917
Feb		3,675		321.1	2,722	874	276.9	2,983	826
Mar	1327.1	3,603	4,782	321.1	2,669	857	276.9	2,895	802
Apr	1327.1	2,745	3,643	321.1	2,033	653	276.9	2,110	584
May	1327.1	2,304	3,058	321.1	1,707	548	276.9	1,675	464
Jun	1327.1	1,848	2,452	321.1	1,369	440	276.9	1,263	350
Jul		1,851	0	321.1	1,371	440	276.9	1,265	350
Aug		2,037	0	321.1	1,509	485	276.9	1,428	396
Sep	1327.1	2,478	3,289	321.1	1,836	589	276.9	1,778	492
Oct	1327.1	3,000	3,981	321.1	2,222	714	276.9	2,255	624
Nov	1327.1	3,291	4,367	321.1	2,438	783	276.9	2,588	717
Dec	1327.1	3,732	4,953	321.1	2,764	888	276.9	2,998	830
Total			30,525			8,239			7,352

Table C.3.4 Real Irrigation Water Consumption in the Downstream Reaches of Tocontasi/Chapisca Station

<Consumo Real de Agua de Riego en el Agua Abajo de la Estación de la Confluencia de Tocontasi/Chapisca>

Month	Maize		Vegetable		Pasture		Total Real Consump.	
	Irrigated Area (ha)	ET (mm)	Irrigated Area (ha)	ET (mm)	Irrigated Area (ha)	ET (mm)	(10^3m^3/mon.)	(l/s)
Jan.	256.4	163.1	395.6	135.9	618.7	198.7	2,185.2	815.9
Feb.	256.4	147.0	395.6	122.5	618.7	179.0	1,969.0	813.9
Mar.	1,583.5	144.1	395.6	120.1	618.7	173.7	3,831.6	1,430.6
Apr.	1,327.1	109.8	395.6	91.5	618.7	126.6	2,602.5	1,004.1
May	1,327.1	92.2	395.6	76.8	618.7	100.5	2,149.2	802.4
Jun.	1,327.1	73.9	395.6	61.6	618.7	75.8	1,693.4	653.3
Jul.	-	74.0	395.6	61.7	618.7	75.9	713.7	266.5
Aug.	-	81.5	395.6	67.9	618.7	85.7	798.8	298.2
Sep.	1,327.1	99.1	395.6	82.6	618.7	106.7	2,302.2	888.2
Oct.	1,327.1	120.0	395.6	100.0	618.7	135.3	2,825.2	1,054.8
Nov.	1,327.1	131.6	395.6	109.7	618.7	155.3	3,141.3	1,211.9
Dec.	1,583.5	149.3	395.6	124.4	618.7	179.9	3,969.3	1,482.0
Total		1,385.6		1,154.7		1,593.1	28,181.4	893.6

Note : 1) The downstream reaches of Tocontasi/Chopisca station covers a portion of Upstream Irrigation Sector and the whole Irrigation Sector I, II, III, IV & V

2) ET : Evapotranspiration

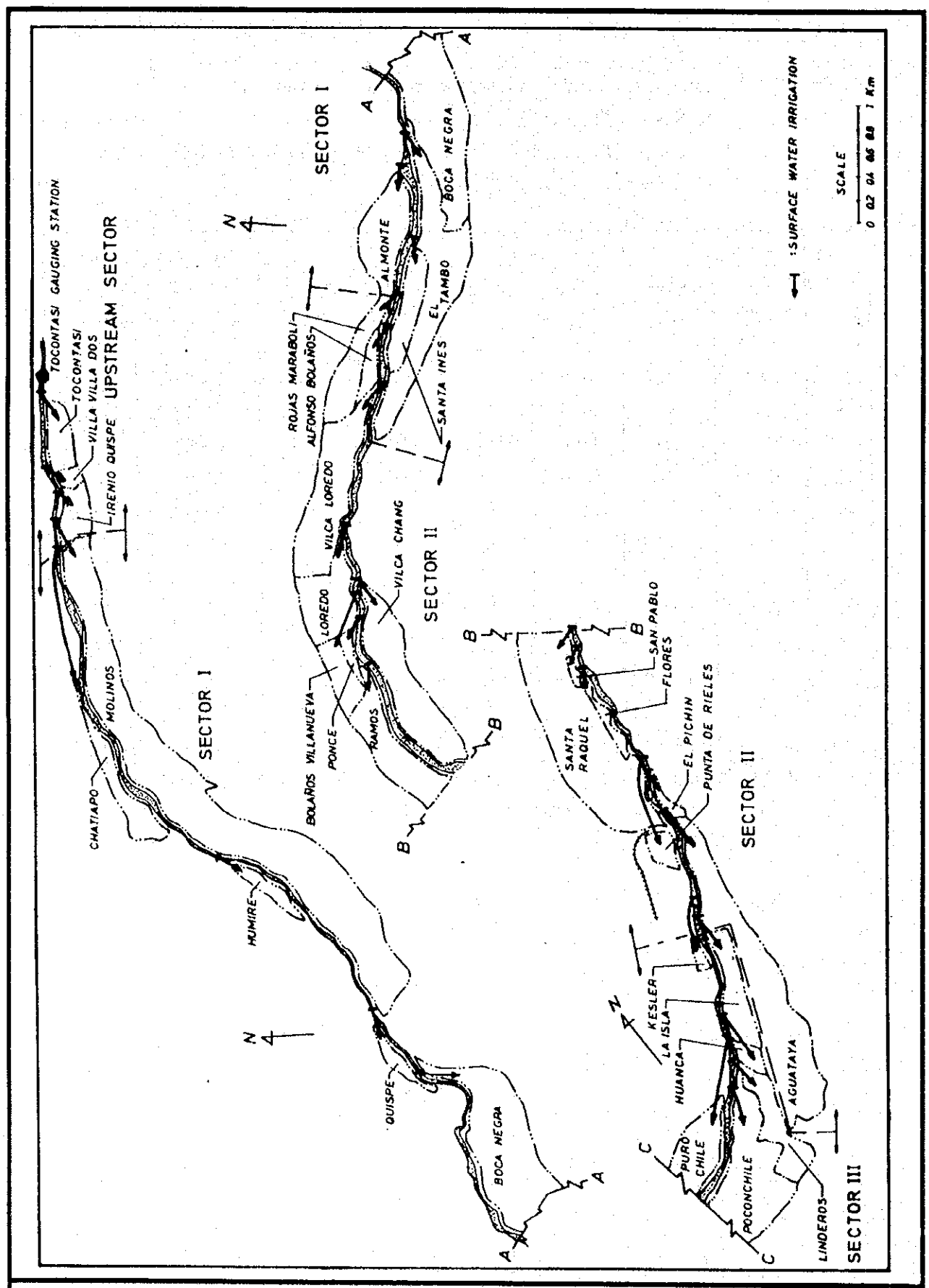


Fig. C.3.1 (1) Location of Irrigation Sectors and Sub-sectors - Lluta Valley

< Ubicación de Sectores y Sub-sectores de Riego - Valle de Lluta>

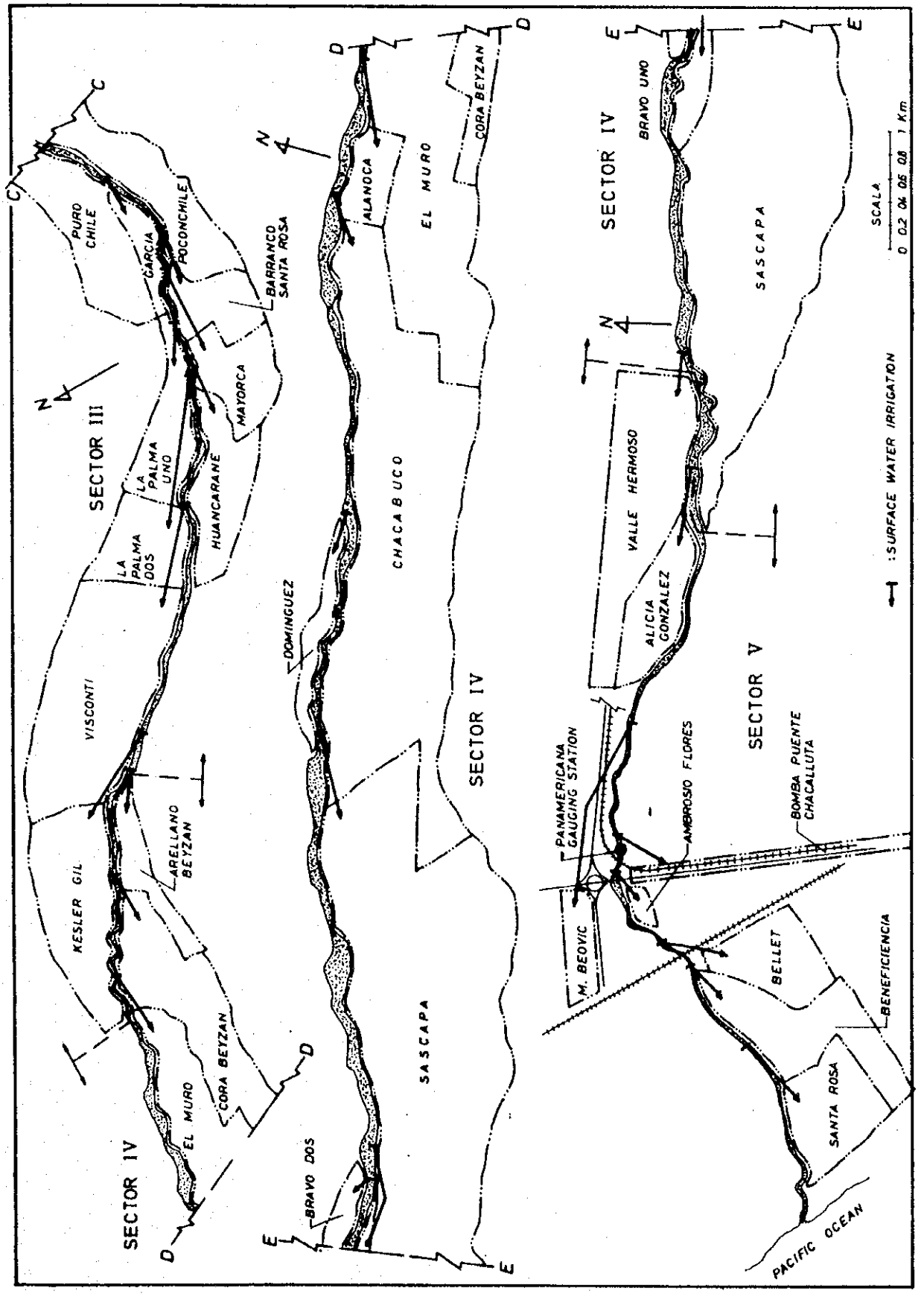


Fig. C.3.1 (2) Location of Irrigation Sectors and Sub-sectors - Lluta Valley

<Ubicación de Sectores y Sub-sectores de Riego - Valle de Lluta>

Chapter IV. MUNICIPAL WATER OF IQUIQUE CITY

4.1 Existing Water Supply Service

4.1.1 Existing Water Supply System

1) Area and Population Served

The existing municipal water supply system covers approximately 2,162 ha of Iquique city, serving almost the entire population of the city. Water is supplied to the city from 3 distribution tanks: Cavancha, Norte and Las Dunas.

2) Water Source and Water Rights

The water source for the city is groundwater from the Pampa del Tamarugal. The groundwater is extracted by 12 wells at or near Canchones located approximately 70 km east of the city. There are also 2 emergency wells and 2 observation wells.

Of the 12 operating wells, 8 have legally authorized water rights with a total permitted extraction quantity of 835 l/s. For the legally authorized water rights in Pampa del Tamarugal Basin, see Appendix C.4.

3) Water Transmission and Storage

The extracted groundwater is transferred by two transmission mains 75.3 km in length from the Canchones collection tank to the Cavancha and other distribution tanks installed on the hills to the east of the city. The transmission main pipelines are summarized as follows:

System	Material	Diameters
Older System (1960's)	Steel	400 - 700 mm
Newer System (1982)	Ductile Iron	450 - 800 mm

The transmission mains cross the coastal mountains on the way to Iquique city. The water is pumped in two steps, from EL. 1,013 m at the Canchones collection tank to EL. 1,155 m at Rinconada tank. The first step is from the Canchones collection tank to Diana tank and the second is from

the Diana tank to the Rinconada tank. Thereafter, the water is transferred by gravity to the distribution tanks. The transmission system is further provided with 3 pressure control tanks at Carpas, Santa Rosa and Alto Hospicio between the Rinconada, Cavancha and other distribution tanks.

The water levels and capacities of these tanks, and their distances from Canchones are shown as follows:

Tank	Water Level (Elev. m)	Capacity (m^3)	Accumulated Distance (km)
Canchones	1,013	1,000	0
Diana	1,038	2,000	29.9
Rinconada	1,155	11,000	33.0
Carpas	978	2,700	59.8
Santa Rosa	682	15,000	65.7
Alto Hospicio	545	8,800	72.4
Cavancha & Others	114	29,300	75.3

Data Source : ESSAT

The route of the transmission mains is shown in Fig. C.4.1.

4.1.2. Water Production and Consumption

In 1990, ESSAT water production for Iquique city was estimated at $16,355.9 \times 10^3 m^3$, of which $9,892.9 \times 10^3 m^3$ was consumed for residential, commercial, industrial and public uses <1>. The water loss, including leakage and uninvoiced water, was estimated at $6,463.0 \times 10^3 m^3$, or 39.5% of the production.

The estimated water production, consumption by category, and loss in 1990 are summarized below.

	1990 Quantity (10^3m^3)	%
Production	16,355.9	
Consumption	9,892.9	100.0
Residential	6,776.9	68.5
Commercial	1,539.9	15.6
Industrial	461.3	4.6
Public	1,114.0	11.3
Losses	6,463.0	(39.5)*

* Percent of Production
Source: <1>

It is noted that there are no master meters at Cavancha and that water production is estimated by multiplying pump capacities by hours of operation.

The estimated monthly water consumption, by category, and production in 1990, are shown in Table C.4.1.

The water losses in the above table consists of physical and commercial losses. The physical loss is the water leakage from the water transmission mains and distribution networks. The commercial loss results from water consumption by illegal connections and under-registration by domestic meters.

The physical and commercial losses in 1990 were estimated as follows.

	Quantity (10^3m^3)	%
Physical Loss	4,811.0	29.4
Commercial	1,652.0	10.1
Total Loss	6,463.0	39.5

Source: <1>

In 1991 there was a reclassification of consumers which resulted in significant changes to the amounts consumed by each category. In 1991 the consumption classified as "industrial" increased considerably and there was a corresponding decrease in the "commercial' consumption. Also, in 1991 public buildings were reclassified from the "Public" to the Residential Category. The breakdown for 1992 was as follows:

The water production, consumption by purpose and loss in 1992 are summarized as follows:

	1992 Quantity (10^3m^3)	%
Production	17,241.2	
Consumption	10,821.7	100.0
Residential	8,523.8	78.8
Commercial	869.5	8.0
Industrial	1,359.4	12.6
Other	68.9	0.6
Losses	6,419.5	(37.2)*

* Percent of Production

The water losses in the above tables consist of physical and commercial losses as described earlier for the year 1990.

The per capita water production and consumption in 1990 and 1992 are estimated as follows.

	Per Capita Water Use (liters/person/day)	
	1990	1992
Production Basis :	309	313
Total Consumption Basis :	187	180
Resid. Consumption Basis :	128	142*

* Includes public buildings

Due to lack of meters at the source, the condition of existing consumer meters, and the lack of comprehensive leak detection studies, it is not possible to accurately estimate how much of the total losses are physical losses from the networks, and how much is due to other factors. However, based on data from the B &S Study <1>, leakage is estimated at 29.4% of production = 5,069 x 10^3m^3 in 1992.

4.1.3 Water Restrictions

The existing water supply service is available for 24 hours per day. There are no overall limitations on water supply, but some areas have a restricted supply.

4.2 Future Water Demand

4.2.1 Projected Population

Census data is available since 1940 as follows:

CENSUS	DATA
1940	38,094
1952	39,576
1960	50,655
1970	64,435
1982	110,534
1992	152,529*

* Preliminary Results of 1992 Census

The above census data for Iquique show high population growth rates between 1940 and 1992. Although the 1992 census including the latest demographic data is not completed, its preliminary results are now available.

In this report, the following methods, corresponding to different growth scenarios, were used for projecting the future populations of Iquique:

1. Linear growth (straight line) based on 1982-92 census data
2. Exponential growth based on 1970-92 census data
3. Exponential growth based on the 1982-92 Region I growth rate.

As can be seen in Figure C.4.2, an exponential growth rate based on 1970-92 census data for Iquique City, results in a 2020 population projection of about 375,000, whereas a linear growth based on the 1982-1992 Census data results in a 2020 population of only about 275,000.

The growth of Iquique will depend on going economic development planning which cannot be fully appreciated at the present time. It was therefore decided to base the projections of this report on the average of the above methods. The results are summarized as follows:

1995	165,236
2000	188,100
2005	213,356
2010	241,379
2015	272,605
2020	307,540

The above figures are for Iquique City only, and do not include the populations of the towns served by ESSAT, in Iquique Province. Populations and water supply for these towns are covered in Section V of this report.

4.2.2 Per Capita Water Consumption

Existing per capita water consumption data for Iquique were presented in Section 4.1.2. However, some sections of the city are not adequately served. Therefore, adjustments were made to obtain the appropriate per capita demands for future conditions when a 24 hour unrestricted water supply is desired.

Based on data from the 1992 report by B&S Ingenieros y Consultores <1> and recent data available from the ESSAT Planning Department, the total per capita consumption, including commercial, industrial and other uses is estimated at 220 l/c/d. It is assumed that the ratio of residential to other uses (commercial, industrial and "other") will remain relatively constant, and that future per capita consumption will increase as the standard of living improves and the uses of potable water expand. This increase is estimated at 0.3% per year.

4.2.3 Projected Water demand

1) Projected Consumption

Total future consumption is calculated based on the population projections and estimated per capita consumption, as shown in the following table:

Year	Population Served	Per Capita Consumption (l/c/d)	Total Consumption (m3/day)	(l/sec)
1992		220		
1995	165,236	221.99	36,680	424.5
2000	188,100	225.34	42,386	490.6
2005	213,356	228.74	48,802	564.8
2010	241,379	232.19	56,045	648.7
2015	272,605	235.69	64,251	743.6
2020	307,540	239.25	73,578	851.6

2) Projected Production

ESSAT is initiating a leakage control program and efforts to reduce unaccounted-for water. These programs include the use of leak detection equipment, installation of master meters at Canchones, gradual replacement of residential meters, and efforts to reduce the number of illegal connections. It is therefore estimated that the total leakage as a percentage of total production will gradually decrease from almost 40 % at present, to 30% by the year 2005. Future losses, as a percentage of total production, and the estimated total production are estimated as follows:

Year	Consumption (m3/day)	Losses - % of Production	Production (m3/day)	Production (l/sec)
1995	36,680	40	61,133	707.6
2000	42,386	35	65,209	754.7
2005	48,802	30	69,717	806.9
2010	56,045	30	80,065	926.7
2015	64,251	30	91,787	1,062.3
2020	73,578	30	105,112	1,216.6

The above projections of water production are based on the assumption that adequate production capacity will be provided as required, even though this is optimistic for the year 1995. It is further noted that these projections are very sensitive to the assumption regarding unaccounted-for water. For example, if the unaccounted-for water could be reduced to 20% of production in the year 2020, the production requirements would be reduced to 1064 l/sec, a reduction of 152 l/sec.

These projections are depicted in Figure C.4.3. It should be kept in mind that these are average day production requirements, and that the water production facilities should be designed for the maximum day requirements. For maximum day production requirements, see Supporting Report D.

4.2.4 Water Rights

In addition to the existing legally authorized water rights of 835 l/sec, ESSAT has applied for two additional water rights with a total requested amount of 400 l/sec; refer to Appendix C.6.

REFERENCES

<1. Análisis Programa de Desarrollo de ESSAT, Marzo 1992, prepared for ESSAT by Bustamente and Schudeck, Ingenieros Consultores Ltda.

Table C.4.1. Existing Municipal Water Production and Consumption of Iquique City (1990).
<Producción y Consumo de Agua Municipal Existente en Iquique (1990)>

(Unit:10^3m^3/month)

Month	Production	Consumption*				
		Residential	Commercial	Industrial	Public	Total
Jan.	1,374.7	573.0	125.2	32.4	85.7	816.4
Feb.	1,281.0	652.1	129.8	50.0	88.3	920.2
Mar.	1,385.2	630.9	138.9	31.7	88.0	889.5
Apr.	1,348.4	593.3	136.1	38.8	102.3	870.5
May	1,383.4	504.3	126.4	32.3	91.8	754.8
Jun.	1,351.8	567.2	137.7	33.4	99.2	837.5
Jul.	1,444.3	488.1	116.5	34.1	86.4	725.1
Aug.	1,424.0	521.6	124.1	33.7	92.3	771.8
Sep.	1,359.7	550.4	122.0	37.8	92.9	803.1
Oct.	1,360.8	490.4	111.6	35.3	96.0	733.4
Nov.	1,362.3	645.3	132.3	43.3	94.1	915.0
Dec.	1,280.3	560.3	139.1	58.5	97.8	855.8
Total	16,355.9	6,776.9	1,539.9	461.3	1,114.8	9,892.9
Percentage		68.5%	15.6%	4.6%	11.3%	100%

* Excluding water consumption with no invoice.
Source: <1>

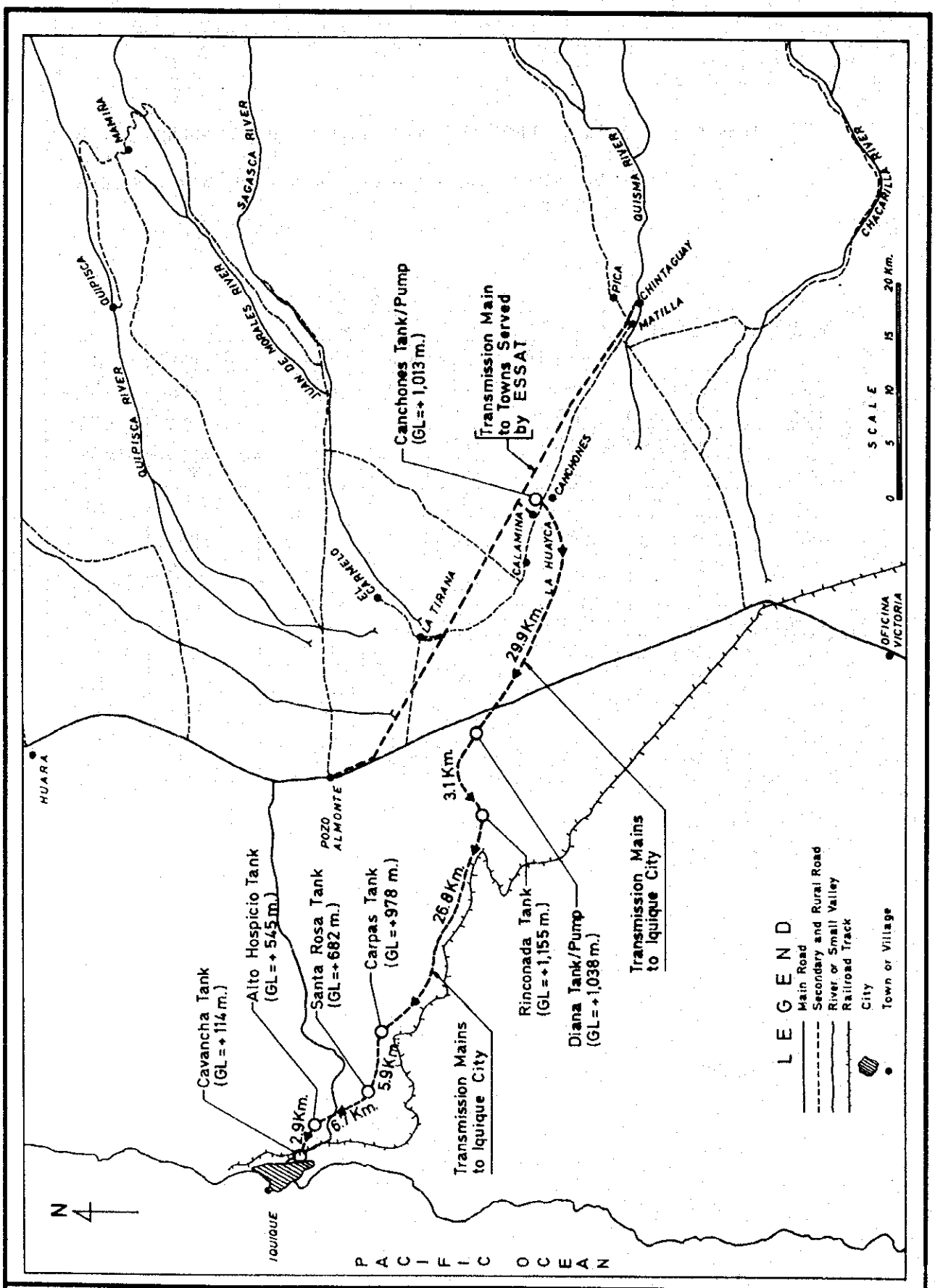


Fig. C.4.1 Water Conveyance Systems of Iquique City and Province

<Sistemas de Conducción de Agua de la Ciudad y Provincia de Iquique>

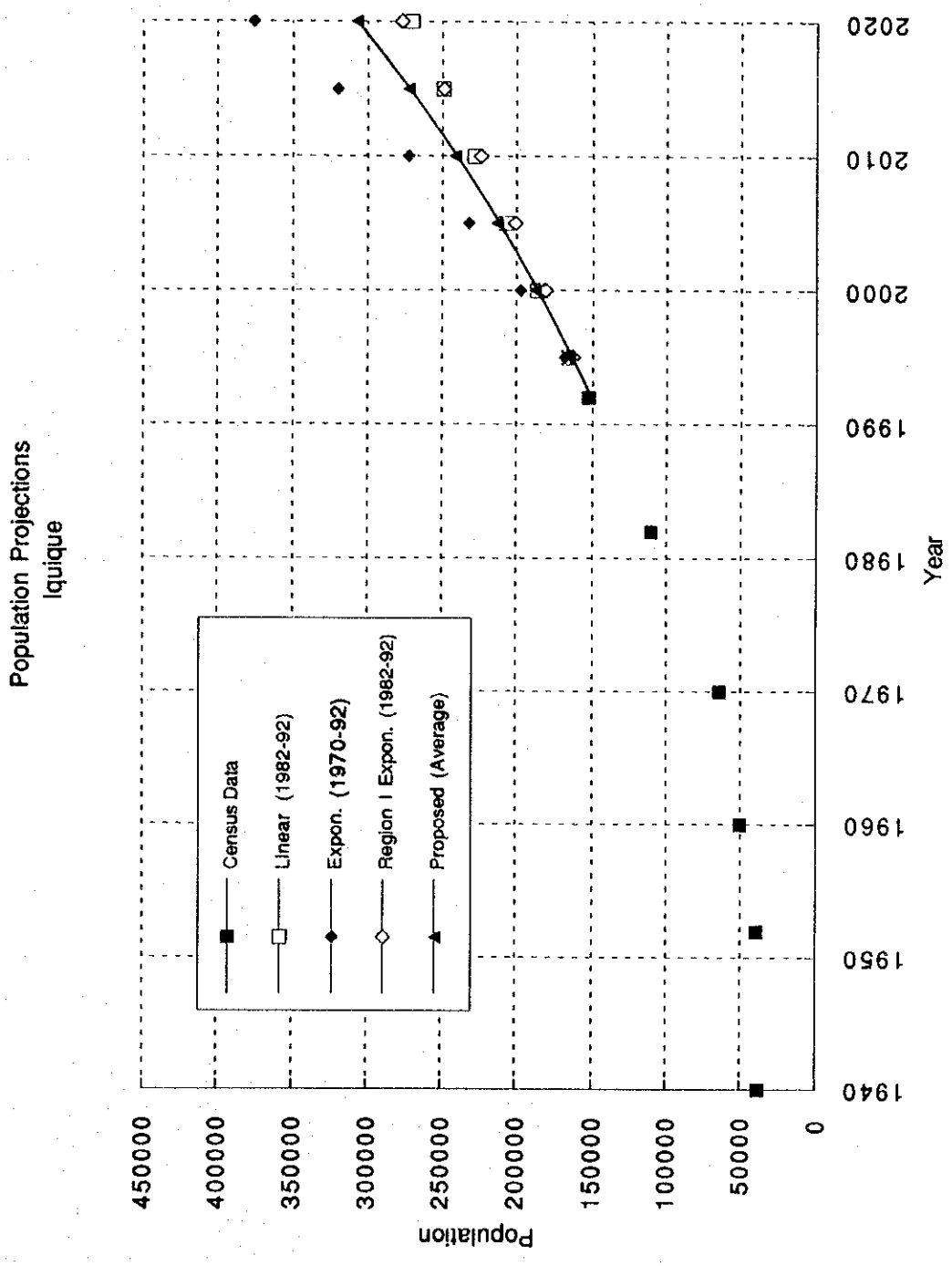


Fig. C.4.2 Population Projections - Iquique

< Proyección de la Población - Iquique >

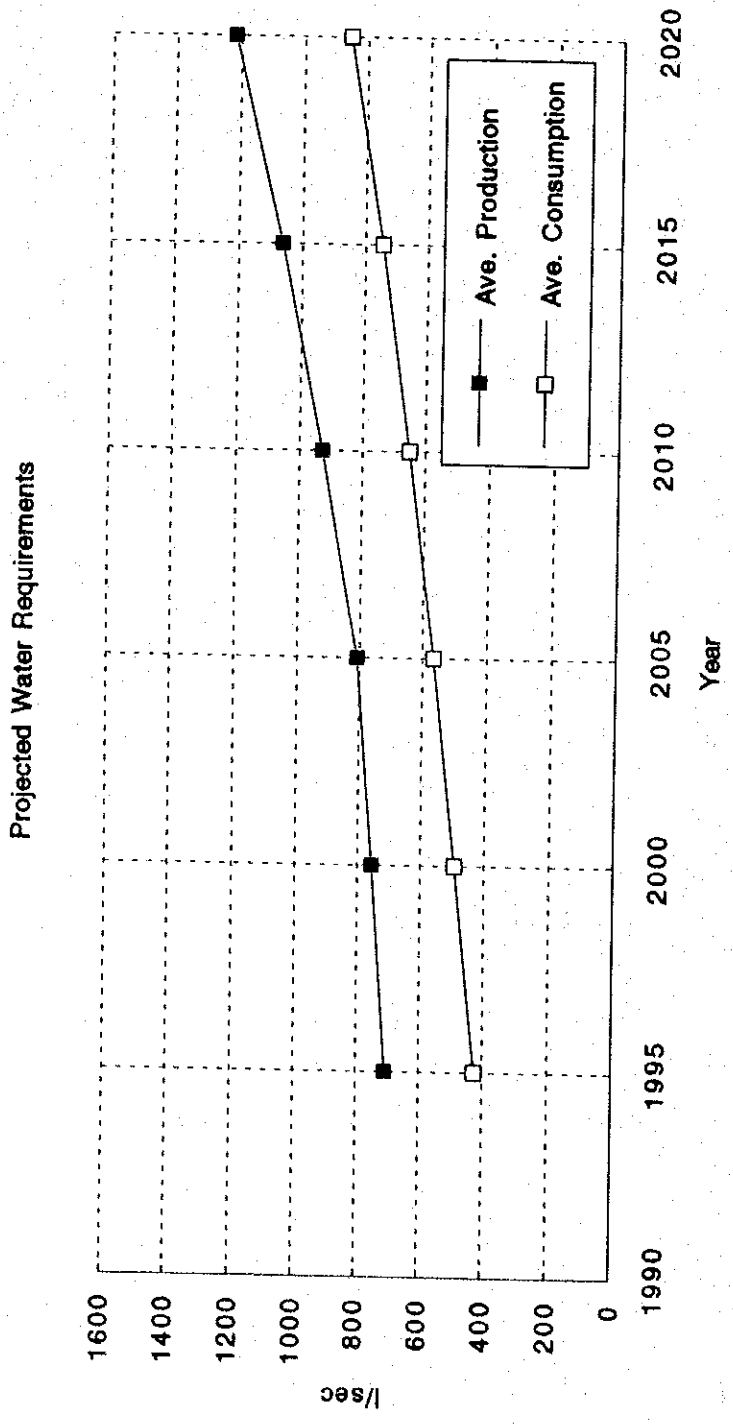


Fig. C.4.3 Projections of Water Consumption and Production - Iquique

< Proyección de Consumo y Producción de Agua - Iquique >

Chapter V. DOMESTIC WATER OF PAMPA DEL TAMARUGAL

5.1 Existing Town Water Use

5.1.1 Towns and Population Served

The Pampa del Tamarugal Basin covers portions of 3 districts (comunas): Huara, Pica and Pozo Almonte with a total population of 11,744 * in 1992. Populations by district are as follows:

District (Comuna)	Population*
Huara	1,964
Pica	2,514
Pozo Almonte	7,266
Total	11,744

* Preliminary results of 1992 Census

The towns served by the ESSAT system, and districts (comunas) in which they are located, are as follows:

Comuna/Town
Huara
Huara
Pisagua
Pica
Pica
Pozo Almonte
Pozo Almonte
Matilla
Huayca
Tirana

The locations of these towns are shown in Figure C.5.1

According to the 1982 Census, the total population of the above 3 comunas was 8,979 of which 5,158 or 57.5% were located in the towns served by the ESSAT system.

Detailed demographic information on the 1992 population is not yet available. However, the 1992 population of the towns served by ESSAT in the Pampa del Tamarugal was estimated by others <1> at 6,574.

5.1.2 Water Consumption

Most of the existing urban population is served by ESSAT, and the source of water is mainly from springs and groundwater at Chintaguay near Pica; refer to Figure C.4.1. Other minor sources include a well owned by the Chilean army at Dupliza (serving Huara), and a well at Dolores serving Pisagua. Water supply to the Pozo Almonte area is also supplemented by water from Canchones during periods when water is being pumped from Chintaguay to Pica.

Based on water billing data from ESSAT, the 1992 water consumption for the towns in the Pampa del Tamarugal (or served by sources in the Pampa) are as follows:

Town	1992 Water Consumption (without adjustment)<1
Pica	235,296 m^3/yr.
Matilla	360,058
Huayca	84,393
Tirana	49,024
Pozo Almonte	204,503
Huara	19,487
Pisagua<2	9,748
Total	962,509 m^3/yr.

<1 adjustments resulting from complaints on water bills
<2 Pisagua, although outside of the Pampa del Tamarugal is served by a well inside the Pampa.

There is no data available on the adjusted water consumption for these towns in 1992. It is assumed that the adjusted amounts would be about 2-3% lower than those shown, as is the case in Iquique city. However, because of meter under-registration errors, the above total consumption is assumed to approximate the actual consumption .

There is no rationing of water on a regular basis in the towns served by the system, although there are periods when certain towns are without water, generally due to pumping problems.

Unfortunately, there are no master meters at the sources, so it is not possible to accurately estimate the total production and un-accounted-for water. Periodic flow estimates are made from a V-notch weir located at Chintaguay and from the pump capacities and hours of pumping. Based on these measurements and

system knowledge by ESSAT officials, the unaccounted-for water has been estimated <1> as follows:

Type of Loss (% of Consumption)

System	Transmission	Distribution	Billing	Total
Pisagua	15.0	30.0	5.0	50.0
Huara	10.0	30.0	5.0	45.0
Chintaguay	26.9	42.8	5.0	74.7

Using these percentages, the 1992 production and unaccounted-for water are estimated as follows:

1992 (Units: m^3/yr)

Town	Consumption	Unaccounted-for	Production
Pica	235,296	175,766	411,062
Matilla	360,058	268,963	629,021
Huayca	84,393	63,042	147,435
Tirana	49,024	36,621	85,645
Pozo Alm.	204,503	152,764	357,267
Huara	19,487	8,769	28,256
Pisagua	9,748	4,874	14,622
Total	962,509	710,799	1,673,308

The overall unaccounted-for water, as calculated above, is equivalent to 42.5% of the production.

5.1.3 Water Rights

ESSAT has two existing surface water rights for the water source at Chintaguay, with a total amount of 99 l/sec. In addition, they have one groundwater right for 22.5 l/sec in Dolores. These water rights are now in the process of being regularized by court action.

5.2 Future Town Water Demand

5.2.1 Population Projections

Based on the estimated populations of these towns in 1982 and 1992, as shown in Section 5.1.1, the overall population grew at an annual rate of 2.46%. This trend is expected to continue. The population of the area served is therefore projected using a 2.46% annual growth rate, as follows:

Projected Population
Towns in Pampa del Tamarugal

1995	7,070
2000	7,982
2005	9,011
2010	10,173
2015	11,485
2020	12,966

5.2.2 Per Capita Water Consumption

Based on an estimated population served of 6,574, in 1992, the per capita consumption was 401 l/c/day. This is much higher than would be expected for small communities such as these. The high per capita water demand reportedly results mainly from agriculture usage, especially in the Matilla area. For purposes of projecting future water demand, a per capita "domestic" demand of 200 l/c/d, which includes commercial, industrial and public uses, was assumed. It is estimated that future "domestic" per capita consumption will increase as the standard of living improves and the uses of potable water expand. This increase is estimated at 0.5% per year.

The agricultural usage, was assumed to grow at a rate of 0.5%, independent of the population growth. This portion is difficult to estimate, as it relates to historical agreements (before the establishment of ESSAT) and future policy with regard to these uses.

5.2.3 Projected Water Demand

1) Projected Consumption

Basic data and assumptions regarding the "domestic" consumption, as described above, are summarized as follows:

			Domestic Consumption	
Year	Population	% of Population Served	Per Capita (m3/c/d)	Total (m3/day)
1995	7,070	100%	0.203	1,435.4
2000	7,982	100%	0.208	1,661.4
2005	9,011	100%	0.213	1,923.0
2010	10,173	100%	0.219	2,225.7
2015	11,485	100%	0.224	2,576.2
2020	12,966	100%	0.230	2,981.8

Adding the agricultural consumption, the total consumption is then calculated as follows:

Year	Domestic Consumption (m3/day)	Agricultural Consumption (m3/day)	Total Consumption (m3/day)	(l/sec)
1995	1,435.4	1,342.0	2,777.4	32.1
2000	1,661.4	1,375.9	3,037.3	35.2
2005	1,923.0	1,410.7	3,333.6	38.6
2010	2,225.7	1,446.3	3,672.0	42.5
2015	2,576.2	1,482.8	4,059.0	47.0
2020	2,981.8	1,520.2	4,502.1	52.1

2) Projected Production Requirement

ESSAT is undertaking programs to improve metering, reduce leakage and control illegal connections. As a result, unaccounted-for water is expected to gradually decline as a percentage of production. It is estimated that the total unaccounted-for water as a percentage of total production will gradually decrease from more than 40% at present, to 30% by the year 2005. Future estimates of unaccounted-for water, as a percentage of total production, and the average production calculated as follows:

Year	Consumption (m3/day)	Unaccounted (m3/day)	Production (m3/day)	(l/sec)
1995	2,777	40%	4,629	53.6
2000	3,037	35%	4,673	54.1
2005	3,334	30%	4,762	55.1
2010	3,672	30%	5,246	60.7
2015	4,059	30%	5,799	67.1
2020	4,502	30%	6,432	74.4

It should be kept in mind that these are average day production requirements, and that the water production facilities should be designed for the maximum day requirements.

5.3 Other Water Use

The other water uses than the town water use served by ESSAT are rural domestic water use and military water use.

The existing rural population in the year 1992 is estimated to be 5,170. The future population in the years 2015 and 2020 including the relocated families in the CAPPTA Project area, is estimated at 40% of the total population. This

would mean a total rural population of 7,657 and 8,644 in the years 2015 and 2020 respectively.

The existing and future rural domestic water demands are estimated to be 4.2 l/s for 1992, 7.0 l/s for 2015 and 8.0 l/s for 2020 respectively by assuming that the existing per capita water demand is 70 l/c/day and that it increases at an annual rate of 0.5 %.

According to the interview survey, the military of Chile is pumping up groundwater of approximately 60 l/s at Dupliza (Fort Baquedano) for their own use at the present time. In this report, it is assumed that the military water demand does not change in the future.

The existing customary water right for the wells at Dupliza (Fort Baquedano) of 120.0 l/s is being regularized by the Chilean Army.

5.4 Real Water Consumption

The total domestic water production in Pampa del Tamarugal in the years of 1992, 2015 and 2020 are estimated as follows.

	Town	Rural	Military	Total (l/s)
Existing (1992)	53.1	4.2	60.0	117.3
Future (2015)	67.1	7.0	60.0	134.1
Future (2020)	74.4	8.0	60.0	142.4

It is estimated that about 25% of the water production will be lost to leakage in the transmission and distribution systems. A portion of this will infiltrate into the ground and recharge the groundwater.

A significant portion of the water consumption will be returned to the basin in the form of sewage. Pica and Pozo Almonte have sewage systems which discharge to stabilization lagoons. These systems are under-utilized especially in Pica, and the lagoons require repairs to prevent leakage. Most of the inhabitants who are not connected to the sewage systems, and most of the sewage of the other towns is discharged to cesspits.

It is estimated that the portion of domestic water production returned to the Pampa del Tamarugal basin will be on the order of 60%. The real water consumption will then be on the order of 40% of the water production, equivalent to an average of about 47 l/sec in 1992, 54 l/s in 2015 and 57 l/s in 2020.

REFERENCES

<1. Análisis Programa de Desarollo de la ESSAT, Prefactibilidad, Tomo I - Información Básica, Tomo II - Definición Proyecto Inversión, Localidades de la Pampa, Septiembre 1992.

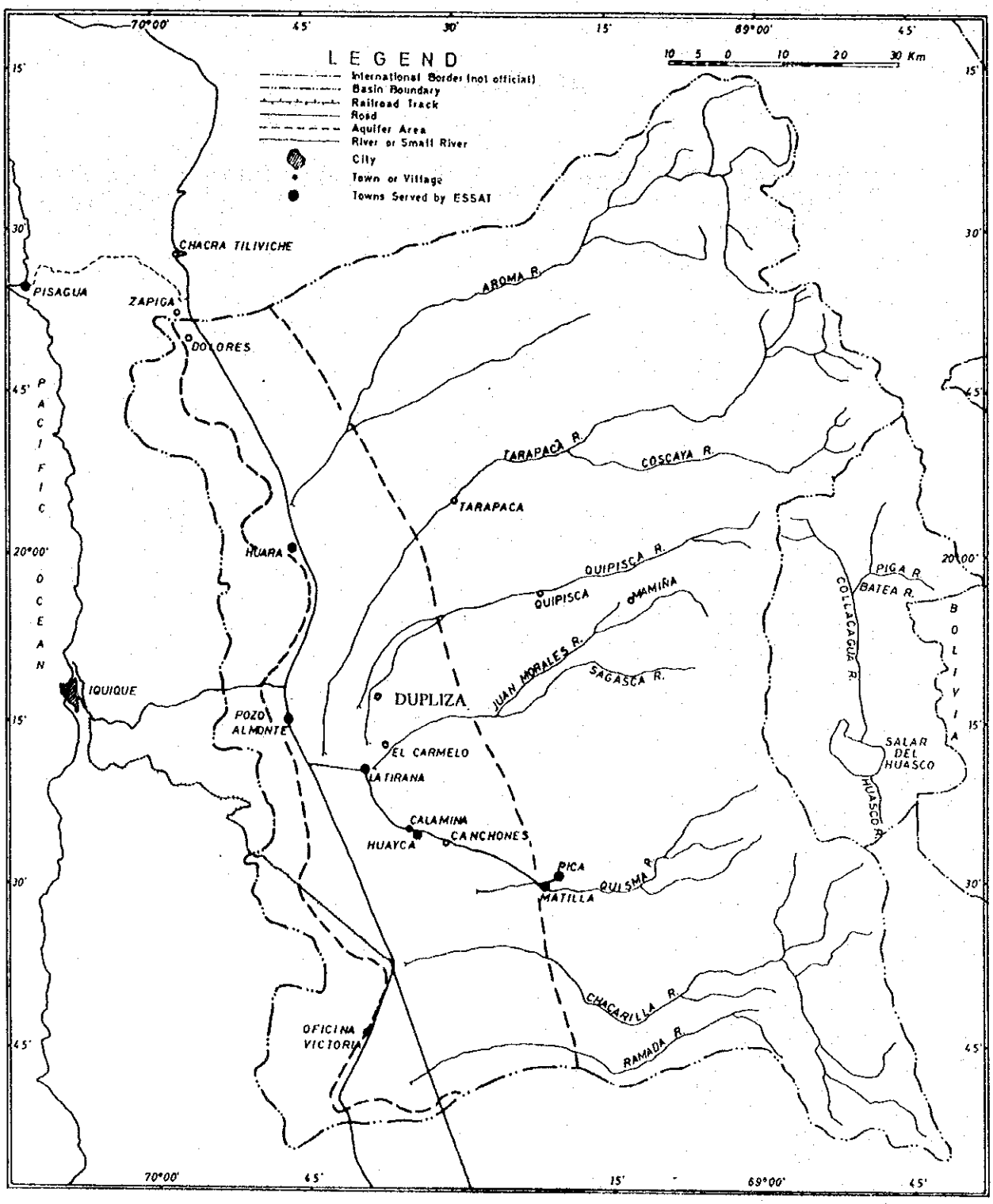


Fig. C.5.1 Towns Served by ESSAT in Pampa Del Tamarugal

<Pueblos Servidos por ESSAT en La Pampa del Tamarugal>

Chapter VI. IRRIGATION WATER USE IN THE PAMPA DEL TAMARUGAL

6.1 Irrigation of River Valleys

In addition to the Pica and Matilla area, irrigated farming is practiced within the Pampa del Tamarugal Basin in the valleys of the Aroma, Tarapacá, Quipisca and Mamiña rivers.

6.1.1 Existing Irrigated Areas

In these river valleys, an area of 275 ha is reportedly irrigated by river and spring water. The major crops are maize and pasture (alfalfa). The irrigated areas and water sources of the various river valleys (Quebradas) are as follows:

River	Irrigation Area (ha)	Water Source
Qda. Aroma	67	River and Spring Water
Qda. Tarapacá	126	River Water
Qda. Quipisca	46	River Water
Qda. Mamiña	36	River and Spring Water
Total	275	

Data Source : Estudio de Síntesis de Catastros de Usuarios de Aguae Infraestructura de Aprovechamiento, Oct. 1991, prepared for DGA by Ricardo Edwards G.- Ingenieros Ltda.

Most of the irrigation is practiced on small plots of land. According to the Iquique office of SAG (Servicio Agrícola y Ganadero), the above irrigated areas appear to be overstated, particularly in the Mamiña valley.

Nevertheless, because of the lack of comprehensive field survey information, existing water demands were approximated using the above data .

6.1.2 Existing Water Use

1) Water Demand

In the absence of evapotranspiration data specifically for the crops irrigated in river valleys, the following values <2> were used for estimating purposes:

Maize: 1,385 mm/yr

Pasture: 1,593 mm/yr

Estimated efficiencies for these crops and the irrigation methods normally practiced in the area are as follows:

Maize - Furrow: 40%

Pasture - Flooding: 50%

Source: <2> and SAG

Annual irrigation water demands were then estimated, assuming that half the irrigated land is used for growing maize and half for pasture, as follows:

Water Demand in River Valleys
Pampa del Tamarugal Basin

Crop	ET mm/yr	Irrigation Efficiency	Area (Ha)	Water Demand ($10^3 m^3$/year)
Maize	1385	40%	137.5	4,760.9
Pasture	1593	50%	137.5	4,380.8
Total				9,141.7

The total irrigation water demand in the river valleys, calculated as shown above, is 9,141.7 x $10^3 m^3$ /yr, which is equivalent to 290 l/sec and an average unit demand of 1.05 l/sec/ha. However, this total amount is not completely consumed by the crops. A significant portion is either lost by evaporation during distribution or infiltrates into the groundwater. The portion which infiltrates into the groundwater is available for reuse. The amount actually consumed by the crops (without considering losses due to irrigation efficiencies) is estimated, based on the evapotranspiration values presented earlier.

The total annual crop evapotranspiration, calculated at 4,094,800 m^3/yr is equivalent to 130 l/sec. This is considered as the total real irrigation water consumption.

2) Water Rights

Existing water rights for users in the Pampa del Tamarugal are shown in Appendices C.4 and C.5. For their locations, see Fig. C.6.2. Those legally authorized for agricultural uses in the River Valleys are summarized as follows:

Number of Water Rights	Source Type	Quantity (l/sec)
6	Rivers	91.66
7	Springs	77.00
1	Ground	30.00
14		198.66

Customary water rights in the river valleys are limited to two users of spring water with total customary rights to 10.88 l/sec.

6.2 Irrigation in the Pica and Matilla Area

Approximately 305 ha of farmland in the Pica and Matilla area are irrigated by spring and groundwater. The major crops are fruits and vegetables. Drip irrigation is performed to a considerable extent. The general locations of irrigation areas in the Pampa del Tamarugal Basin are shown in Figure C.6.1.

6.2.1 Existing Irrigated Areas and Crops

A significant area is now irrigated by springs and groundwater in the Pica and Matilla area. Irrigated areas were estimated in a 1986 report <1>› but there are no recent data available based on actual field surveys. For purposes of this report, approximate areas by crop and irrigation method were provided by the Iquique office of SAG. The approximate areas by crop type and irrigation method are as follows:

Irrigated Areas by Crop Areas and Irrigation Type
(Hectares)

Crop	Fruit		Vegetables	Totals
Location/ Method	Flooding	Micro-jet	Drip	
Pica	120	100	15	235
Matilla	35	30	5	70
Totals	155	130	20	305

6.2.2 Existing Water Use

1) Water Demand

In the absence of evapotranspiration data specifically for the crops irrigated in Pica and Matilla, the following values were used for estimating purposes:

Fruit	1236.7 mm/yr
Vegetables	1154.7 mm/yr

Source: <2>

Estimated efficiencies for the various crops and irrigation methods are as follows:

Fruits -- Flooding	60%
Fruits -- Microspray	80%
Vegetables Drip	90%

The existing irrigation water demands were estimated as the product of irrigated areas times the evapotranspiration divided by the efficiency. The results are as follows:

Existing Irrigation Water Demand by Crop and Irrigation Method
Pica and Matilla (10^3M^3/yr.)

Crop	Fruits		Vegetables	Totals
Location/ Method	Flooding	Microspray	Drip	
Pica	2473.4	1454.9	192.5	4,120.8
Matilla	721.4	436.5	64.2	1,222.0
Totals	3194.8	1891.4	256.6	5,342.8

The irrigation water demand in the Pica and Matilla area was estimated above at 5,342.8 x 10^3m^3/yr, which is equivalent to an average of 169.4 l/sec. This compares with the following estimates based on field investigations in which water users were interviewed, as a part of this study, in October and November, 1993.

Agricultural Water Usage - 1993
(From Interviews)

Holders of water rights	101 l/sec
Users without water rights	10 l/sec
Totals	111 l/sec

For more details refer to Section 6.2.2.3)

2) Real Water Consumption:

The irrigation water demand in the Pica and Matilla, estimated above at 5,342.8 x 10^3m^3/yr, is equivalent to an average of 169.4 l/sec and an

average unit consumption of 0.555 l/sec/ha. However, this amount is not completely consumed by the crops. As previously described, a significant portion is lost during distribution or infiltrates into the groundwater. The portion which infiltrates into the groundwater is available for reuse. The amount actually consumed by the crops is calculated as the irrigated area times the evapotranspiration values presented earlier. The results are as follows:

Existing Evapotranspiration by Crop and Irrigation Method
Pica and Matilla (Units: 10^3 M^3 / yr.)

Crop	Fruits		Vegetables	Totals
Location\Irrig.Method	Flooding	Microspray	Drip	
Pica	1484.0	1236.7	173.2	2,893.9
Matilla	432.8	371.0	57.7	861.6
Totals	1916.9	1607.7	230.9	3,755.5

From the above table, it can be seen that the total evapotranspiration for the crops in the Pica and Matilla area is 3,755,500 m^3/yr = 119 l/sec (0.390 l/s/ha). This is considered as the total real irrigation water consumption.

3) Water Rights

Existing water rights are shown in Appendices C.4 and C.5. For their locations, see Fig. C.6.2. Those legally authorized for irrigation in the Pica and Matilla area are shown in Table C.6.1, and are summarized as follows:

Number of Water Rights	Source Type	Quantity (l/sec)*
6	Springs	81.2
6	Ground water	101.7
12		182.9

* includes 4.2 l/sec between Matilla and Tirana

There are only two customary water rights in the Pica and Matilla area for agricultural purposes. One of these is for spring water and the other is for groundwater. The total amount of customary rights is 2.3 l/sec.

A field survey carried out in October and November of 1993 indicated that the existing water usage of the holders of these water rights is approximately 101 l/sec. The results are shown in Table C.6.1 (Column on Existing Water Use).

6.2.3 Future Irrigation Areas and Crops

There is no specific long range plan with regard to overall crop development in the Pica and Matilla areas. Future irrigation in the area will depend on the availability of additional water, the markets for crops produced in the area, production costs, the initiative of private enterprise and other factors.

6.2.4 Water Rights Applications

Water rights applications for uses in the Pampa del Tamarugal Basin are shown in Appendix C.6. For their locations, see Fig. C.6.2. The total amount of irrigation water applied for in the Pica and Matilla area is 179.7 l/sec. Another 205 l/sec have been applied for in the area between Pica and Tirana. However, both these amounts are considerably in excess of available water resources at the agricultural sites to be developed for these water rights applications. Based on information from DGA, the estimated amount of irrigation water available at the sites of water applicants in the Pica and Matilla area is about 70 l/sec, and about 102 l/sec is available at the sites of applicants in the area between Pica and Tirana.

6.2.5 Future Water Demand

1) Previous Studies

Estimates of additional irrigation water demands in the Pica and Matilla area have been prepared by others <1>, based on several alternative assumptions. The alternative projection based on the assumption that adequate water will be available to completely satisfy the irrigation requirements are as follows:

Year	Water Demand (Delivered - l/sec)
1995	150
2000	900
2005	2250
2010	2400
2015	2400
2020	2400

It has not been possible to verify the basic assumptions used to develop these projections.

According to information available to the Iquique office of SAG, future irrigation water usage is projected to be on the order of ten times the existing usage. This would mean a total future water demand on the order of 1700 l/sec, and a real water consumption of approximately 1,190 l/sec.

2) Estimated Future Water Demand

It is difficult to accurately estimate the future irrigation water demand in Pica and Matilla including the areas between Matilla and Tirana since there is no specific long range agricultural development plan for these areas.

In this report, however, it is assumed that the irrigated area and water demand of these areas will double by the year 2015, taking account of the amount of the water right applications and available water resources at the sites of the applicants in these areas.

The future irrigated area, water production and real water consumption in 2015 are estimated as follows.

	Irrigated Area (ha)	Total Production (l/s)	Total Real Consumption (l/s)
Existing (1992)	305	169.4	119
Future (2015)	610	338.8	238

6.3 CAPPTA Project Irrigation Water

6.3.1 Future Water Demand

1) Previous Studies

CAPPTA (Corporacion Agrícola Proyecto Pampa del Tamarugal) is a private corporation formed for the purpose of promoting productive settlements of people based on agriculture and artesanry. The project contemplates the relocation of families, predominantly Aymara, from the Altiplano to an area generally to the northeast of Huara, as shown in Figure C.6.1. The corporation has been granted rights to the use of 33,550 hectares, and plans to relocate about 430 families to this area.

Preliminary estimates of irrigation water requirements have been based on an irrigated area of 5 hectares per family and a maximum unit water demand of 1.0 l/sec/ha. The irrigation water demand which will occur during the

peak season (October through January) is then estimated at 5 x 430 x 1.0 = 2,150 l/sec. Preliminary estimates of the average water demand are as follows:

Average Water Demand : 2,150 ha x 0.6 l/sec/ha = 1,290 l/sec
(Annual Average)

Real water consumption is estimated at approximately 839 l/sec (=2,150 ha x 0.39 l/s/ha) by applying the same unit real water consumption as that of Pica and Matilla area.

A detailed plan for agricultural development has not yet been prepared due to the lack of sufficient water source data.

2) Estimated Future Water Demand

However, development scale of CAPPTA Project depends on the availability of irrigation water in both quantity and quality. The above estimation is considered optimistic, considering that the water quality of the area contains a high content of boron (B).

According to the water quality analysis conducted during this Study, the surface water of Aroma River contains 22.87 mg/l of B and 3,015 mg/l of TDS. Further, the groundwater of the CAPPTA Project area are mostly much contaminated as shown below (see, Supporting Report B, Table B-III, 3.3).

Well Number	TDS (mg/l)	B (mg/l)	Location in CAPPTA Area
J-3	595.4	2.38	northern fringe
165	1,187	0.46	"
104	1,940	11.62	western fringe
931	1,803	39.87	"
J-4	3,310	26.82	center
947	2,077	13.31	southern fringe
J-C	2,611	6.67	"

Available groundwater for CAPPTA Project is limited only in its northern fringe areas. Therefore, the agricultural development scale of CAPPTA Project will much reduce from the above preliminary studies.

In this report, the agricultural development area of CAPPTA Project is assumed to be 20% of the above preliminary studies. Then, the average water demand and real water consumption are estimated as follows.

Average water demand	:	430 ha x 0.6 l/sec/ha = 258 l/sec
Real water consumption	:	430 ha x 0.39 l/sec/ha = 168 l/sec

6.3.2 Water Rights Application

Water rights were requested for the CAPPTA Project before the actual formation of the corporation; refer to Appendix C.6. Although the application was made for 100 l/sec of surface and spring water, it has since been determined that there are no such water resources available in the project area and that the surface water available has a high boron content. It is now planned to develop groundwater resources for the Project.

In September 1993, a notice of the intention of CAPPTA to apply for water rights was sent to the DGA by the International Cooperation Agency (Government of Israel). However, the estimated water demand (60 l/sec) was only for the first stage of a proposed pilot plan.

REFERENCES

<1. Uso Múltiple de las Aguas del Salar del Huasco
Oficina de Planificación Nacional/Universidad Católica de Chile Julio, 1986

<2. Modelo de Simulación de las Aguas Subterráneas del Valle de Azapa by Ayala, Cabrera y Asociados Ltda, Enero 1989, prepared for DGA.

<3. Estudio de Síntesis de Catastros de Usuarios de Aguae Infraestructura de Aprovechamiento, Oct. 1991, prepared for DGA by Ricardo Edwards G.-Ingenieros Ltda.

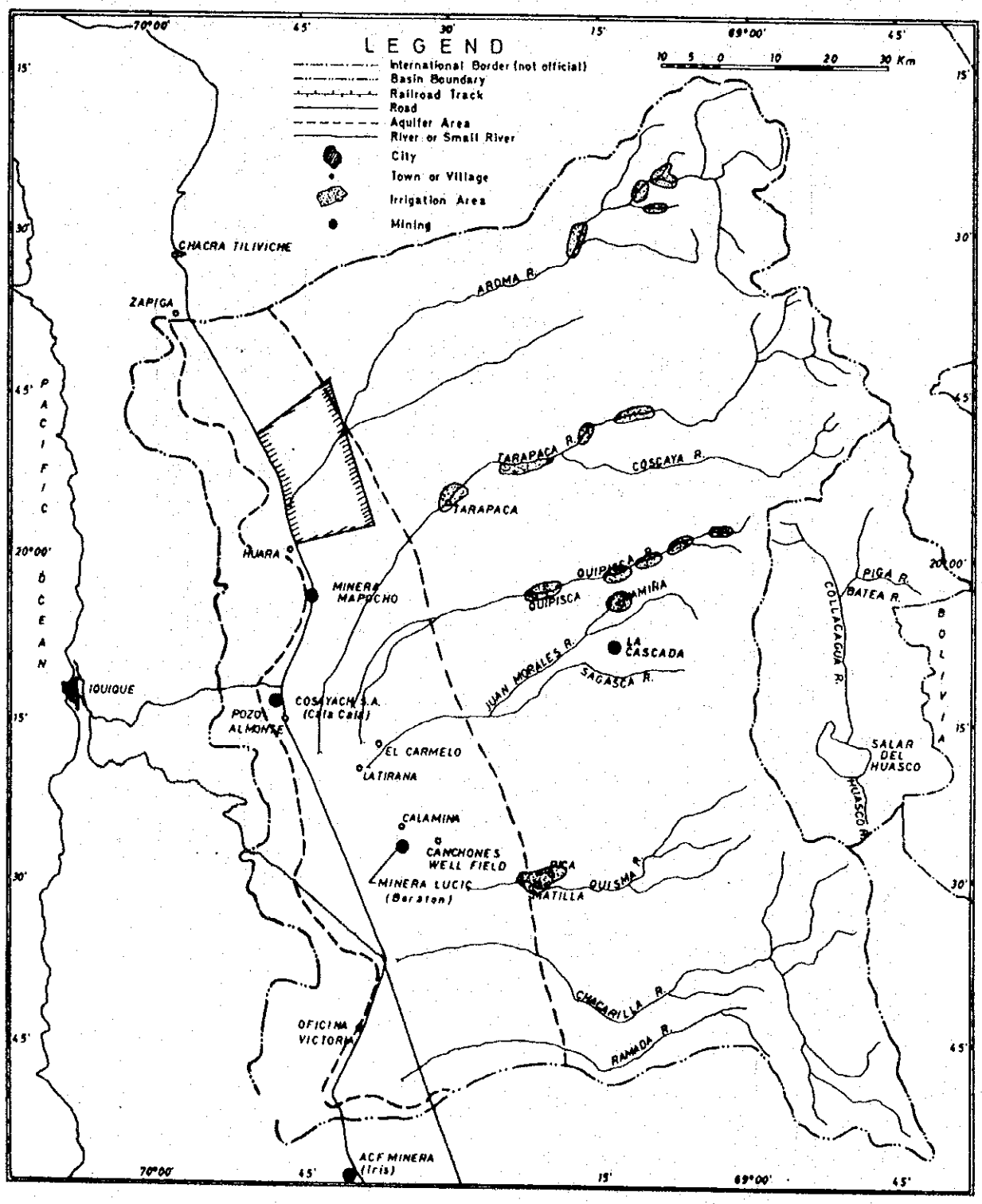
Table C.6.1 **Existing Irrigation Water Rights/Use - Pica and Matilla Area**
<Derechos/Uso de Agua de Riego Existentes - Area de Pica y Matilla>

Map No.	Propietor	No. of Water Right	Now in use	Water Source	Water Use	Quantity (l/s)	Exist. Use (l/s)*	Future Use (l/s)*	Remarks (Location)
	Legally Authorized								
(1)	Wenceslao Carlos Alvarez	T-1-5-4-062	Yes	S	A	1.50	3.00	2.00	Pica
(5)	Ivo Ugrinovic Filipic	NR-1-3-83	Yes	S	A	6.00	6.00	3.00	Pica
(7)	Soc.Exp./Com.Agric.Ugr	NR-1-3-147	Yes	S	A	8.00	2.80	7.00	Pica
(8)	Pedro CIsterna/Otros	NR-1-3-210	Yes	S	A	55.00	46.00	46.00	Pica
(16)	Wenceslao Carlos Alvarez	NR-1-3-387	Yes	G	A	1.50	0.50	1.00	Pica
(17)	M.Cervellino Ragone	NR-1-3-405	Yes	G	A	2.00	2.90	1.20	Pica
(18)	G.Cervellino Giannoni	NR-1-3-406	Yes	G	A	4.20	4.20	4.20	Betw.Tirana/Matilla
(22)	A.Contreras C./Otros	NR-1-3-439	Yes	S	A	1.50	1.50	0.50	Pica
(24)	F. Lasala Sciarafia	NR-1-3-452	Yes	G	A	6.00	10.00	10.00	Pica
(25)	Angel Medina Luza	NR-1-3-453	Yes	G	A	2.50	2.50	2.50	Pica
(46)	Agric./Agroin.Esmeralda	ND-1-3-346	Yes	G	A	85.50	10.00	20.00	Pica
(48)	A.Contreras/T.Barrios	NR-1-3-373	Yes	S	A	9.20	9.20	25.00	Pica
	Sub-totals					182.90	98.60	122.40	
	Customary								
(4)	Cosme F. Lusa Lema	n.a.	Yes	G	A	1.50	1.50	1.00	Pica
(6)	Lidia Olazabel Perez	n.a.	Yes	S	A	0.80	0.80	2.00	Pica
	Sub-totals					2.30	2.30	3.00	
	Totals					185.20	100.90	125.40	

* Estimates based on Interviews

Note: Water Source; G: Groundwater, S: SpringWater, R: River Water

Water Use; A: Agricultural, MI: Mining, D: Domestic



CAPPTA Project Area

Fig. C.6.1 Location of Irrigation and Mining Areas in the Pampa del Tamarugal

<Ubicación de Areas de Riego y Mineras en la Pampa del Tamarugal>

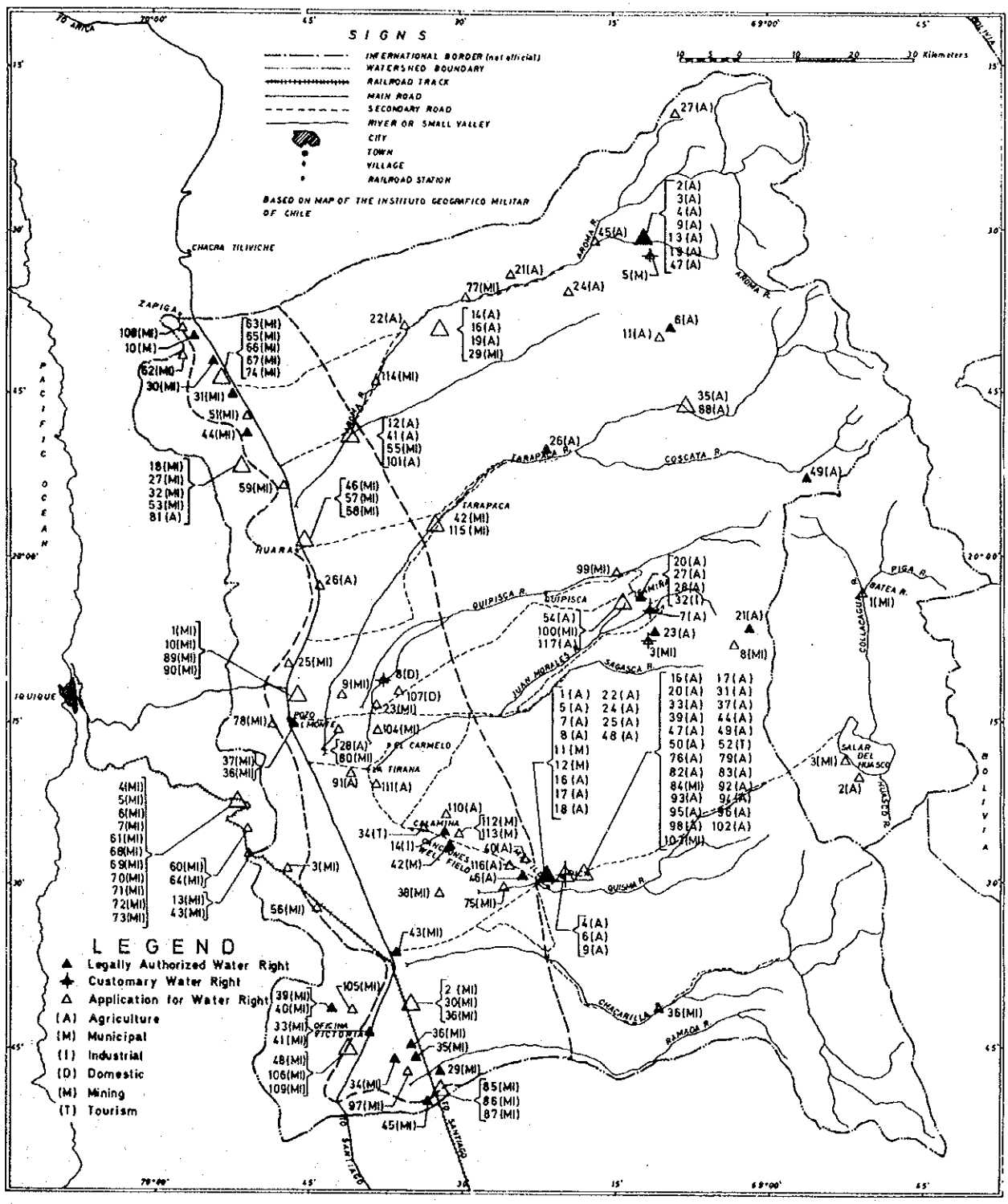


Fig. C.6.2 Location of Water Rights and Water Rights Applications in Pampa del Tamarugal

<Ubicación de Derechos y Solicitudes de Agua en la Pampa del Tamarugal>

Chapter VII. MINING WATER USE IN THE PAMPA DEL TAMARUGAL

7.1. Existing Water Use

7.1.1 Existing Mining Companies and Mines

There are four major companies with mining operations within the Pampa del Tamarugal Basin. These companies and their mining operations are as follows.

Company	Mine Name
Minera Mapocho	Mapocho
Minera La Cascada	La Cascada
Cosayach S.A.	Cala Cala
Minera Lucic	Boraton

The latter mines (Boraton and Cala Cala) were not in production at the time of field surveys (November 1993).

In addition, A.C.F. Minera is operating at Minera Iris to the south of the Pampa del Tamarugal basin, using groundwater sources within the basin, near the southern boundary

The locations of these mining operations are shown in Fig. C.6.1.

There are other mining companies not currently operating in the basin, but with plans to begin operating in the near future; refer to Section 7.2.2

7.1.2 Existing Water Use and Real Consumption

Existing water use for mining operations in the Pampa del Tamarugal were estimated from field interviews of companies which are operating with legal water rights. These interviews were conducted by DGA as a part of the present study. The results are shown in Table C.7.1, indicating a current total demand of about 35 l/sec for existing water rights holders.

The above estimate does not consider the water demand of existing water rights holders which are upstream of the stream gauging points. Another field survey, also carried out for this study, indicated an additional 34.2 l/sec for another mining operations (La Cascada) in the Qb. Sagasca. Water rights for this mining operation are now in the process of being formalized. Other mining operations with customary water rights are also located in these upstream areas.

Mining operations dispose of their wastewaters in a variety of ways, usually involving recycling and some type of sedimentation ponds. Evaporation and infiltration of the wastewaters occurs in varying degrees. In the absence of studies on actual water consumption, it is assumed that 40% of the water used infiltrates back into the groundwater and is available for further use. For one of the water rights (Fig. C.6.2 # 29 -- 5 l/sec) the water is diverted out of the basin. Existing real consumption with respect to the Pampa basin (excluding upstream areas) is therefore estimated at 5 + 60% x 30 = 23 l/sec.

7.1.3 Water Rights

Existing water rights for all uses in the Pampa del Tamarugal Basin are shown in Appendix C.4 and Appendix C.5. For their locations, see Fig. C.6.2. The existing water rights for mining use are summarized as follows:

Type	Number of Water Rights	Number in Use	Source Type	Quantity (l/sec)
Legally Authorized	15	7	Ground	187.00
Customary	1	1	Spring	7.00
Customary	1	1	River	30.00
Totals	18	10		224.00

In addition, rights are in process of being adjudicated for an additional 65 l/sec for La Cascada mine located in the Quebrada Sagasca.

7.2 Future Water Demand

7.2.1 Water Rights Applications

Water rights applications are shown in Appendix C.6. For their locations, see Fig. C.6.2. Those related to mining are picked out as shown in Table C.7.2. and summarized as follows:

Number of Applications	Source Type	Quantity Requested (l/sec)	Estimate of Available Yield* (l/sec)
61	Ground	3721.7	983.8
4	River	352.0	15.0
2	Spring	97.0	10.0
67		4170.7	1,008.8

*At location of applicant; estimated by DGA

From this table it can be seen that the water resources available, at the locations where water rights are requested, are much less than the amounts applied for. This is especially true for the river and spring water sources.

7.2.2 Future Mining Water Demand

It is not possible to accurately estimate future mining water demands. Mining operations are periodically closing down and new ones are being started. The remaining useful life of operating mines in the area is on the order of 8 years. On the other hand, when one mine closes, another company may purchase and utilize the existing water rights.

Although the existing water demand in the Pampa del Tamarugal (excluding upstream areas) is only about 35 l/sec, this could increase considerably if a major mining company were to begin operations. Depending on the results of current studies, one large mining firm reportedly plans to begin operations in the near future, with a water demand of approximately 300 l/sec.

As compared to the uncertainties regarding existing water rights holders, it is even more difficult to accurately estimate the future mining water demands related to water rights applications. Many of the water rights applications are speculative in nature, having been applied for before water extraction or mining feasibility studies have been completed.

Only 24 among the above 67 water rights applications have been applied after water extraction test was completed. The other 43 water rights have been applied without water extraction test and so, they are considered as speculative.

Therefore in this report, the requested water quality of 1,262.3 l/s of the above 24 applications are assumed as the additional future water demand for mining use