

Increase Rate of Investment Cost (%)	NPV (10 <sup>6</sup> Peso \$)	FIRR (%)
60.00	-2,885	11.47
50.00	-495	11.91
47.93	0	12.00
40.00	1,865	12.39
30.00	4,285	12.90

Reduction Rate of Revenue (%)	NPV (10 <sup>6</sup> Peso \$)	FIRR (%)
-30.00	-2,764	11.20
-25.00	-394	11.89
-24.17	0	12.00
-20.00	1,976	12.54
-15.00	4,346	13.16

#### 7.4.9 Environmental Impact Assessment

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

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

##### 1) Pre-construction Stage

The transmission pipeline is laid under the roads (shoulder of the road). Then, no land acquisition is necessary. However, the construction of the well-field and tanks requires the land acquisition of 261 ha.

No negative impact is anticipated concerning the land acquisition since the land is now entirely idle and most of it belong to the government.

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

##### 2) Construction Stage

###### (1) Vibration, Noise and Dust

Vibration, noise and dust may be caused by the construction of the proposed facilities to some extent. The adverse impacts are assessed as less important since the construction works are done in the dessert areas except Pozo Almonte and Alto Hospicio town areas.

The transmission pipeline passes through the town areas of Pozo Almonte and Alto Hospicio. However, the affected area and population are small, and the vibration, noise and dust can easily be minimized by proper construction management.

(2) Traffic Disturbance

The transmission pipeline is installed under the shoulder of the roads including Pan American Highway and Highway Route 1, and crosses the railway at one (1) location.

The traffic disturbance due to the pipeline installation is considered not significant since the traffic density of the roads is small, and as to the railway traffic, it is several times a week.

(3) Lowering of Groundwater Table

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

3) Operation Stage

The major environmental impacts in operation stage are those on the existing wells and Tamarugo trees due to the lowering of the groundwater table.

The existing groundwater table will be lowered in future by such various water developments as municipal water of Iquique city, domestic water of local towns, irrigation water and mining water. The total draw-down by the proposed project and other water developments after 100 years is estimated as follows.

- by 25 ~ 30 m in the most seriously affected area
- by less than 15 m in most part of the aquifer area
- by less than 15 m in the existing Tamarugo tree area

(1) Impact on Existing Wells

At present, 12 independent wells and two (2) well-fields (managed by ESSAT) are extracting the groundwater from the Pampa del Tamarugal aquifer. Among them, six (6) independent wells with a total extraction

quantity of less than 0.3 l/s are as shallow as 15 m in depth. All the other wells are deep enough.

The above six (6) independent wells shall be deepened or reconstructed at a proper time in the future.

(2) Impact on Existing Tamarugo Trees

The Tamarugo trees are widely distributed in the National Reserved Area of approximately 100,000 ha designated in the aquifer area. Roots of the Tamarugo tree are generally considered to reach a depth of 25 ~ 30 m, 50 m in some cases, to absorb the groundwater.

Hence, no significant adverse impact on the Tamarugo trees is anticipated.

Table 7.1 Estimated Construction Cost and Power Consumption  
<Costo de Construcción Estimado y Consumo de Energía>

	Alt. (1)	Alt. (2)	Alt. (3)	Alt. (4)	Alt. (5)
<b>Construction Cost (Million Peso : M\$)</b>					
Well-Field Cost (well/pump/electricity/pipeline)	4,336	4,336	4,142	4,142	5,548
Transmission/Booster Pump Cost (pump/electricity/house)	2,031	3,620	3,621	3,092	6,429
Transmission Pipeline Cost (pipeline/pressure relief valve)	29,081	27,534	36,891	39,367	63,468
Tank Cost (collection/break-pressure/distribution)	1,373	1,534	1,447	1,476	2,179
Treatment Plant Cost (for Mn/Fe)	-	-	-	-	12,360
<b>Total Construction Cost</b>	<b>36,821</b>	<b>37,024</b>	<b>46,101</b>	<b>48,077</b>	<b>89,984</b>
<b>Power Consumption (kw)</b>					
Transmission/Booster Pumps	1,280	2,320	2,260	1,320	4,540
Intake Pumps	981	981	738	738	713
<b>Total Power Consumption</b>	<b>2,261</b>	<b>3,301</b>	<b>2,998</b>	<b>2,058</b>	<b>5,253</b>

Note : - Cost as of March, 1994  
 - Cost without Value Added Tax (IVA)  
 - Foreign exchange rate as of March, 1994  
     US\$1.00 = Chile Peso : \$435.0 = Japanese Yen : ¥110.0  
 - Construction cost includes M\$1,822 for the section between Alto Hospicio and Cavancha.

Table 7.2 Break-down of Direct Construction and Land Acquisition Cost  
<Costo de Construcción Directo y de Adquisición de la Tierra>

No	Work Item	Quantity	TOTAL		
			Foreign Currency (1000 xUS\$)	Local Currency (1000 x Peso)	TOTAL (1000 xPeso)
1	Direct Construction		36,032	4,422,575	20,096,326
1)	Intake Works		2,532	1,193,663	2,295,144
(1)	Deep Wells	8 Wells,	134	524,369	582,632
(2)	Pumps	8 Submergible Pump	1,915	92,547	925,470
(3)	Electric Facilities		380	18,391	183,908
(4)	Collection Pipeline	D=250~800 mm, L=5,750 m	0	285,009	285,009
(5)	Valves	7 Valves	103	11,194	55,972
(6)	Roads		0	144,051	144,051
(7)	Miscellaneous Works		0	118,102	118,102
2)	Transmission Facilities		33,499	2,305,366	16,877,636
(1)	Transmission Pump	420 KW x 3 units	3,126	151,091	1,510,912
(2)	Transmission Pipeline		30,373	1,468,050	14,680,499
(3)	Tanks	1,250m <sup>3</sup> x3, 250m <sup>3</sup> x3, 7,500m <sup>3</sup> x3	0	686,225	686,225
3)	Distribution Network		0	765,546	765,546
4)	Electric Transmission Line		0	158,000	158,000
(1)	Electric Transmission Line	23 kV, L=20 km	0	158,000	158,000
2	Land Acquisition Cost		0	262,000	262,000
1)	Well Field	260 ha	0	260,000	260,000
2)	Tanks	1 ha	0	2,000	2,000

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

Table 7.3 Disbursement Schedule of Investment Cost (Iquique Stage I)  
<Programa de Desembolso de los Costos de Inversión (Iquique Etapa I)>

No	Work Item	1996			1997			1998			TOTAL		
		Foreign Currency (1000 x US\$)	Local Currency (1000 x Peso)	Sub Total (1000 x Peso)	Foreign Currency (1000 x US\$)	Local Currency (1000 x Peso)	Sub Total (1000 x Peso)	Foreign Currency (1000 x US\$)	Local Currency (1000 x Peso)	Sub Total (1000 x Peso)	Foreign Currency (1000 x US\$)	Local Currency (1000 x Peso)	TOTAL
1	Direct Construction	0	0	0	18,016	2,132,288	9,869,163	18,016	2,290,288	10,127,163	36,032	4,422,575	20,096,325
1)	Intake Works	0	0	0	1,266	596,832	1,147,572	1,266	596,832	1,147,572	2,532	1,193,663	2,295,144
2)	Transmission Facilities	0	0	0	16,750	1,152,683	8,438,818	16,750	1,152,683	8,438,818	33,499	2,305,366	16,877,636
3)	Distribution Network	0	0	0	0	382,773	382,773	0	382,773	382,773	0	765,546	765,546
4)	Electric Transmission Line	0	0	0	0	0	0	0	158,000	158,000	0	158,000	158,000
2	Land Acquisition Cost	0	262,000	262,000	0	0	0	0	0	0	0	262,000	262,000
3	Engineering Cost	764	270,550	602,890	382	135,275	301,445	382	135,275	301,445	1,528	541,100	1,205,780
4	Administration Cost	0	200,963	200,963	0	200,963	200,963	0	200,963	200,963	0	602,890	602,890
5	Physical Contingency	0	0	0	1,732	251,204	1,004,816	1,732	251,204	1,004,817	3,465	502,408	2,009,633
	TOTAL	764	733,513	1,065,853	20,130	2,719,730	11,476,387	20,130	2,877,730	11,634,388	41,024	6,330,973	24,176,629

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

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

Table 7.4 Cash Flow Analysis (Iquique Stage I)  
<Análisis de Flujo de Caja (Iquique Etapa I)>

(Unit : Peso)

Year	Investment	O & M Cost (*)	Total Cost	Benefits	Cash Flow
1996	1,243,210,986		1,243,210,986		-1,243,210,986
1997	14,456,942,987		14,456,942,987		-14,456,942,987
1998	15,828,455,682		15,828,455,682		-15,828,455,682
1999		822,723,477	822,723,477	2,095,943,391	1,273,219,915
2000		902,192,259	902,192,259	2,473,951,210	1,571,758,951
2001		989,262,930	989,262,930	2,909,759,834	1,920,496,904
2002		1,084,816,412	1,084,816,412	3,411,511,545	2,326,695,133
2003		1,183,936,597	1,183,936,597	3,945,867,297	2,761,930,700
2004		1,304,922,974	1,304,922,974	4,675,886,358	3,370,963,384
2005		1,431,417,858	1,431,417,858	5,493,917,753	4,062,499,895
2006		1,545,931,287	1,545,931,287	6,098,248,706	4,552,317,419
2007		1,669,605,790	1,669,605,790	6,769,056,063	5,099,450,273
2008		1,803,174,253	1,803,174,253	7,513,652,230	5,710,477,977
2009		1,947,428,193	1,947,428,193	8,340,153,976	6,392,725,782
2010		2,103,222,449	2,103,222,449	9,257,570,913	7,154,348,464
2011		2,271,480,245	2,271,480,245	10,275,903,713	8,004,423,469
2012		2,453,198,664	2,453,198,664	11,406,253,122	8,953,054,457
2013		2,649,454,558	2,649,454,558	12,660,940,965	10,011,486,408
2014		8,489,619,214	8,489,619,214	14,053,644,471	5,564,025,257
2015		3,090,323,494	3,090,323,494	15,599,545,363	12,509,221,869
2016		3,337,549,373	3,337,549,373	17,315,495,353	13,977,945,980
2017		3,604,553,323	3,604,553,323	19,220,199,842	15,615,646,519
2018		3,892,917,589	3,892,917,589	21,334,421,825	17,441,504,236
2019		17,869,798,814	17,869,798,814	23,681,208,225	5,811,409,412
2020		4,540,699,520	4,540,699,520	26,286,141,130	21,745,441,610
2021		4,903,955,481	4,903,955,481	29,177,616,655	24,273,661,173
2022		5,296,271,920	5,296,271,920	32,387,154,487	27,090,882,567
2023		5,719,973,673	5,719,973,673	35,949,741,480	30,229,767,807
2024		6,177,571,567	6,177,571,567	39,904,213,043	33,726,641,476
2025		6,671,777,293	6,671,777,293	44,293,676,478	37,621,899,185
2026		7,205,519,476	7,205,519,476	49,165,980,890	41,960,461,414
2027		7,781,961,034	7,781,961,034	54,574,238,788	46,792,277,754
2028		8,404,517,917	8,404,517,917	60,577,405,055	52,172,887,138
				NPV	11,455,886,611
				FIRR	14.86%

\* Considering replacement costs

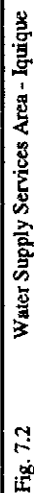
Table 7.5 Financial Statement (Iquique Stage I)  
<Estado Financiero (Iquique Etapa I)>

Year	O&M (*)	Interest	Capital	Total Expenditur	Gross Revenue	Net Revenue Before Depreciation	Depreciation	Net Revenue After Depreciation	Tax	Net Revenue After Tax	Accumulated Net Revenue
1996		62,160,549		62,160,549		-62,160,549		-62,160,549		-62,160,549	-62,160,549
1997		785,007,699		785,007,699		-785,007,699		-785,007,699		-785,007,699	-847,168,248
1998		1,576,430,483		2,399,153,960	2,095,943,391	-303,210,568	227,090,129	-530,300,697		-530,300,697	-1,377,468,945
2000	822,723,477	1,576,430,483		2,478,622,742	2,473,951,210	-4,671,532	227,090,129	-231,761,661		-231,761,661	-1,609,230,606
2001	989,262,930	1,576,430,483	1,576,430,483	4,142,123,896	2,909,759,834	-1,232,364,062	227,090,129	-1,459,454,191		-1,459,454,191	-3,068,684,797
2002	1,084,816,412	1,497,608,959	1,576,430,483	4,158,855,854	3,411,511,545	-747,344,309	227,090,129	-974,434,438		-974,434,438	-4,043,119,235
2003	1,183,936,597	1,418,787,434	1,576,430,483	4,179,154,515	3,945,867,297	-233,287,218	227,090,129	-460,377,347		-460,377,347	-4,503,496,582
2004	1,304,922,974	1,339,965,910	1,576,430,483	4,221,319,367	4,675,886,358	454,566,990	227,090,129	227,476,861	56,869,215	170,607,646	-4,332,888,935
2005	1,431,417,858	1,261,144,386	1,576,430,483	4,268,992,728	5,493,917,753	1,224,925,025	227,090,129	997,834,896	249,458,724	748,376,172	-3,584,512,763
2006	1,545,931,287	1,182,322,862	1,576,430,483	4,304,684,632	6,098,248,706	1,793,564,074	227,090,129	1,566,473,945	391,618,486	1,174,855,459	-2,409,657,305
2007	1,669,605,790	1,103,501,338	1,576,430,483	4,349,537,611	6,769,056,063	2,419,518,452	227,090,129	2,192,428,324	548,107,081	1,644,321,243	-765,336,062
2008	1,803,174,253	1,024,679,814	1,576,430,483	4,404,284,550	7,513,652,230	3,109,367,680	227,090,129	2,882,277,551	720,569,388	2,161,708,164	1,396,372,102
2009	1,947,428,193	945,858,290	1,576,430,483	4,469,716,966	8,340,153,976	3,870,437,010	227,090,129	3,643,346,881	910,836,720	2,732,510,160	4,128,882,262
2010	2,103,222,449	867,036,765	1,576,430,483	4,546,689,697	9,257,570,913	4,710,881,216	227,090,129	4,483,791,087	1,120,947,772	3,362,843,315	7,491,725,577
2011	2,271,480,245	788,215,241	1,576,430,483	4,636,125,969	10,275,903,713	5,639,777,744	227,090,129	5,412,687,615	1,353,171,904	4,059,515,711	11,551,241,289
2012	2,453,198,664	709,393,717	1,576,430,483	4,739,022,865	11,406,253,122	6,667,230,257	227,090,129	6,440,140,128	1,610,035,032	4,830,105,096	16,381,346,385
2013	2,649,454,558	630,572,193	1,576,430,483	4,856,457,234	12,660,940,965	7,804,483,732	227,090,129	7,577,393,603	1,894,348,401	5,683,045,202	22,064,391,587
2014	2,861,410,922	551,750,669	1,576,430,483	4,989,592,074	14,053,644,471	9,064,052,397	227,090,129	8,836,962,268	2,209,240,567	6,627,721,701	28,692,113,288
2015	3,090,323,494	472,929,145	1,576,430,483	5,139,683,122	15,599,545,363	10,459,862,242	227,090,129	10,232,772,113	2,558,193,028	7,674,579,085	36,366,692,373
2016	3,337,549,373	394,107,621	1,576,430,483	5,308,087,477	17,315,495,353	12,007,407,876	227,090,129	11,780,317,747	2,945,079,437	8,835,238,310	45,201,930,683
2017	3,604,553,323	315,286,096	1,576,430,483	5,496,269,903	19,220,199,842	13,723,929,939	227,090,129	13,496,839,810	3,374,209,953	10,122,629,858	55,324,560,541
2018	3,892,917,589	236,464,572	1,576,430,483	5,705,812,644	21,334,421,825	15,628,609,180	227,090,129	15,401,519,051	3,850,379,763	11,551,139,289	66,875,699,830
2019	4,204,350,996	157,643,048	1,576,430,483	5,938,424,527	23,681,208,225	17,742,783,698	227,090,129	17,515,693,569	4,378,923,392	13,136,770,177	80,012,470,006
2020	4,540,699,520	78,821,524	1,576,430,483	6,195,951,527	26,286,141,130	20,090,189,604	227,090,129	24,046,571,044	4,965,774,869	14,897,324,606	94,909,794,612
2021	4,903,955,481			4,903,955,481	29,177,616,655	24,273,661,173	227,090,129	24,046,571,044	6,011,642,761	18,034,928,283	112,944,722,896
2022	5,296,271,920			5,296,271,920	32,387,154,487	27,090,882,567	227,090,129	26,863,792,438	6,715,948,109	20,147,844,328	133,092,567,224
2023	5,719,973,673			5,719,973,673	35,949,741,480	30,229,767,807	227,090,129	30,002,677,678	7,500,669,419	22,502,008,258	155,594,575,482
2024	6,177,571,567			6,177,571,567	39,904,213,043	33,726,641,476	227,090,129	33,499,551,347	8,374,887,837	25,124,663,510	180,719,238,992
2025	6,671,777,293			6,671,777,293	44,293,676,478	37,621,899,185	227,090,129	37,394,809,056	9,348,702,264	28,046,106,792	208,765,345,784
2026	7,205,519,476			7,205,519,476	49,165,980,890	41,960,461,414	227,090,129	41,733,371,285	10,433,342,821	31,300,028,464	240,065,374,248
2027	7,781,961,034			7,781,961,034	54,574,238,788	46,792,277,754	227,090,129	46,565,187,625	11,641,296,906	34,923,890,719	274,989,264,966
2028	8,404,517,917			8,404,517,917	60,577,405,055	52,172,887,138	227,090,129	51,945,797,009	12,986,449,252	38,959,347,757	313,948,612,723

(\*) Without considering replacement costs



**JICA**



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

# THE STUDY ON THE DEVELOPMENT OF WATER RESOURCES IN NORTHERN CHILE



<Basquejo del Facilidad de Abastecimiento de Agua para Iquique>

# THE STUDY ON THE DEVELOPMENT OF WATER RESOURCES IN NORTHERN CHILE

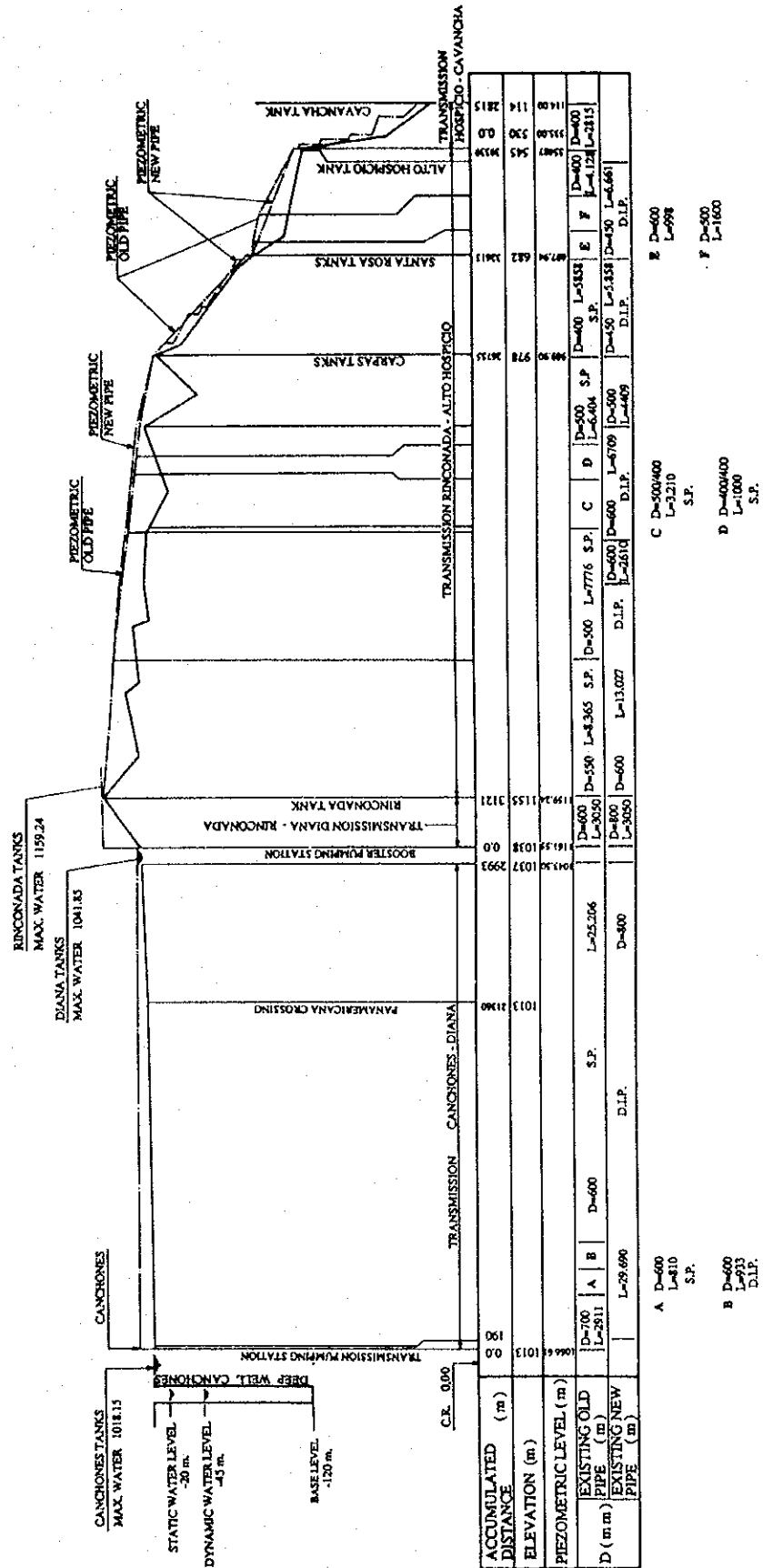


Fig. 7.3

Longitudinal Profile of Transmission Pipeline (Canchones-Cavancha-Iquique)

<Perfil Longitudinal de las cannerías de Transmisión (Canchones-Cavancha-Iquique)>

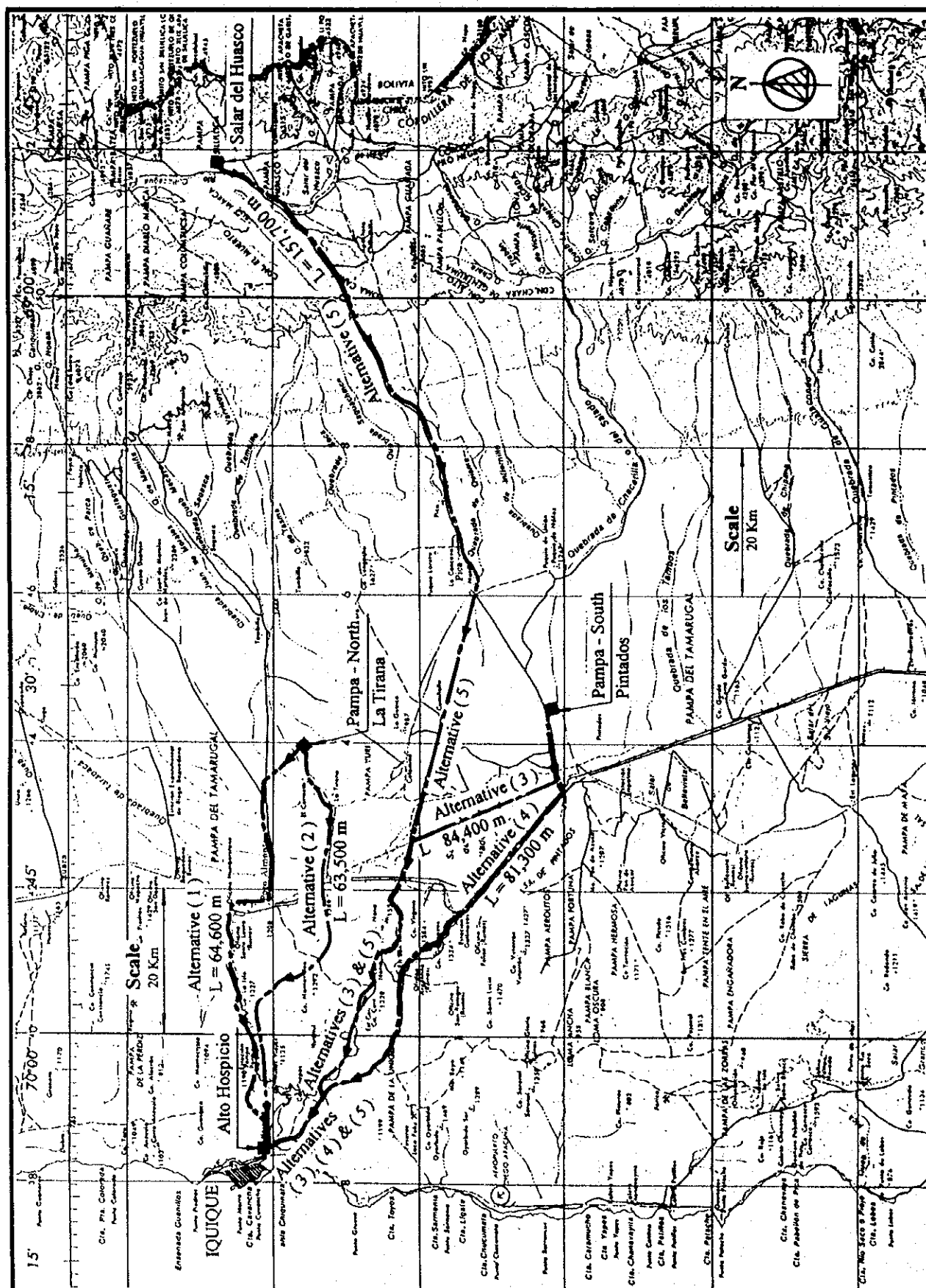


Fig. 7.4 Pipelines Alternatives (1) - (5) for Iquique Water Supply (from Water Resources to alto Hospicio)  
 <Tuberías Alternativas (1) - (5) para el Abastecimiento de Agua para Iquique (desde las Fuentes hasta alto Hospicio)>

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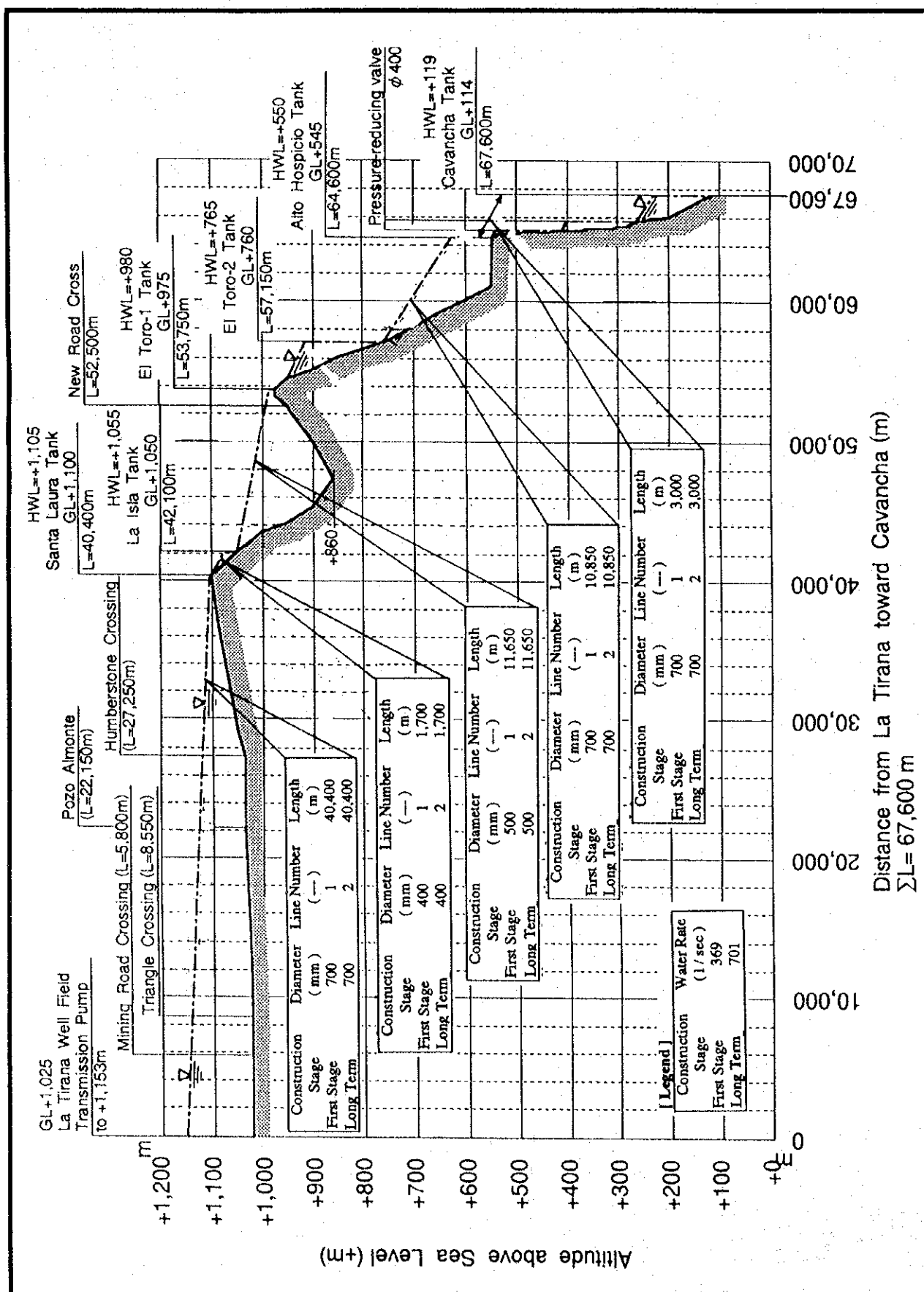


Fig. 7.6

Longitudinal Profile of Proposed Transmission

<Perfil Longitudinal de la Conducción Propuesta>

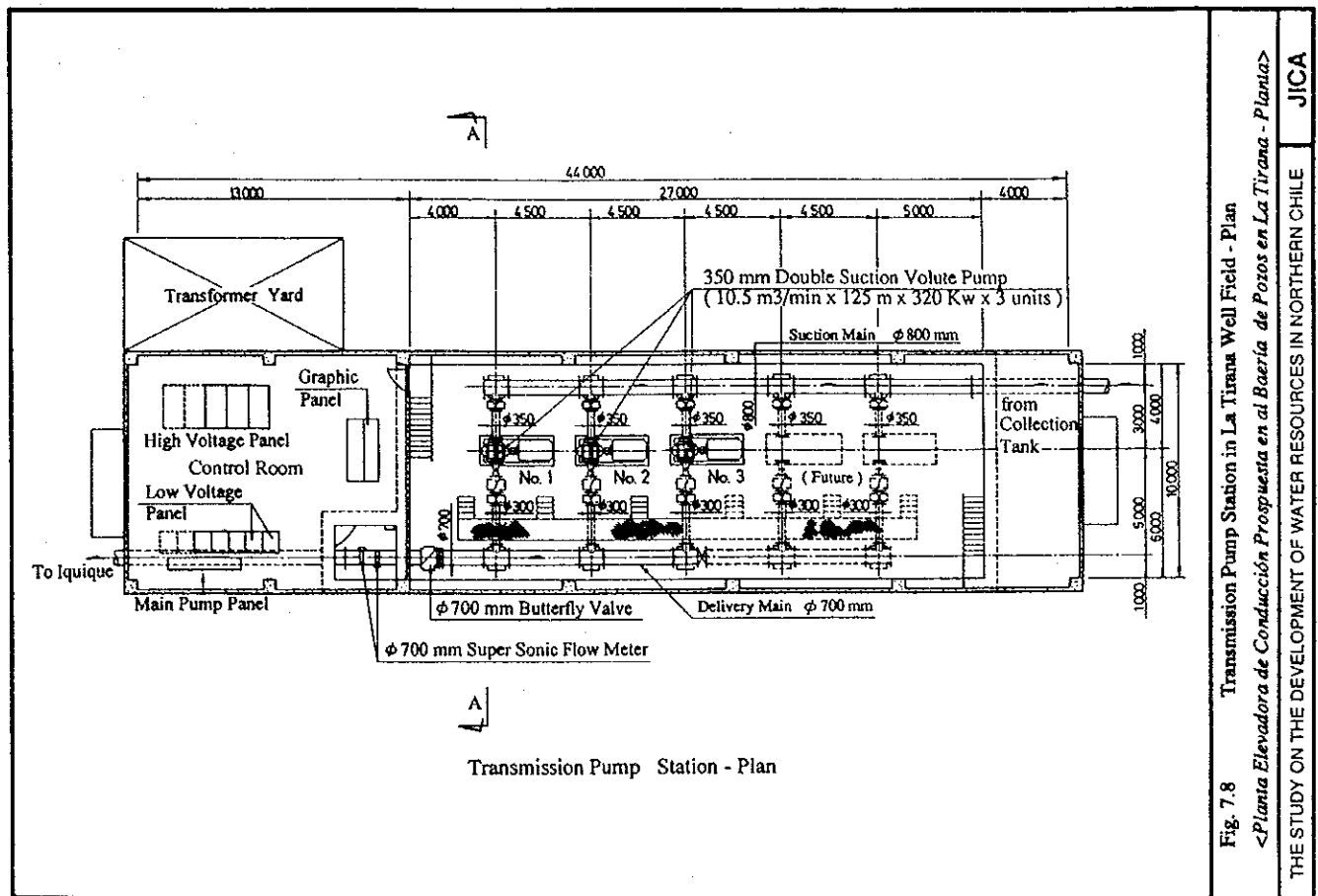


Fig. 7.8 Transmission Pump Station in La Tirana Well Field - Plan

<Planta Elevadora de Conducción Propuesta en la Bateria de Pozos de La Tirana - Planta>

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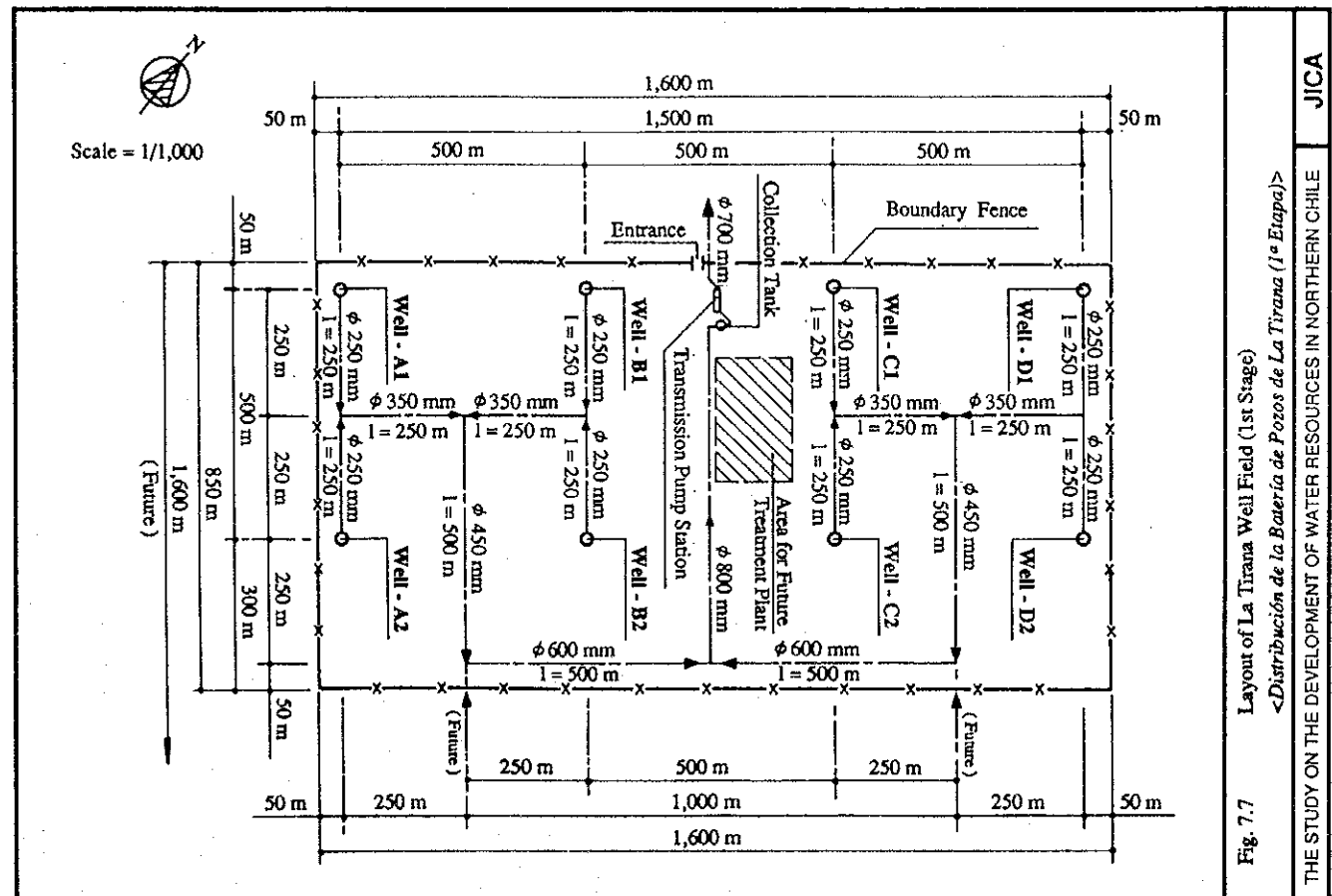


Fig. 7.7 Layout of La Tirana Well Field (1st Stage)

<Distribución de la Bateria de Pozos de La Tirana (1ª Etapa)>

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## CHAPTER VIII RECOMMENDATIONS

## Chapter VIII      RECOMMENDATIONS

### 1)      Studies on Further Water Resources Developments for Arica City

The proposed Lower Lluta Water Supply Development is expected to satisfy the water demand of Arica City only up to the year 2003. Such projects as mentioned below should be studied to meet the water demand after the year 2003.

- (1)      Basin/watershed management of Lluta and San Jose rivers
- (2)      Groundwater development of the river basins in Altiplano
- (3)      Surface water development of Lluta River by dam/reservoir
- (4)      Groundwater development at La Concordia area
- (5)      Recycling use of wastewater in Arica City
- (6)      Desalination of sea water
- (7)      Reduction of water loss in Arica City

### 2)      Groundwater Conservation of Azapa Valley

The groundwater resources of Azapa Valley will be exhausted within the period of 20 years if the existing water use continues. The following actions should be taken to prolong the life of the groundwater.

- (1)      The water rights rented to ESSAT on a temporary basis for the Emergency Water Supply Project must be revoked once a final solution for the water supply of Arica is found.
- (2)      The existing water loss in the distribution networks in Arica City is as large as approximately 40%. It should be reduced to 30% by the year 2005 as assumed in the projection of the future water demand in this Study.
- (3)      The agricultural water uses must be strictly controlled. Further expansion of agricultural land is not recommended and total consumption of irrigation water (on real consumption basis) in future must not exceed the existing level.
- (4)      Some amount of river water spills over to the sea at the time of floods. The construction of groundwater recharge dams in the middle or upstream reaches will be able to retard the flood water for a short period and thereafter, release it slowly to increase the groundwater recharge in Azapa Valley.

Early study on such groundwater recharge dams is recommended.

### 3)      Treatment of Existing Raw Water in Canchones

The groundwater quality in Canchones well-field of Pampa del Tamarugal (existing water source of Iquique) exceeds the standards of drinking water in terms of Mn and



As. The contents of these elements are fortunately decreased to the level below the standards before reaching the consumers due to the natural purification effects in the tanks and transmission pipelines.

However, the natural purification effects are not reliable. Hence, an artificial water treatment must be applied in future.

4) Water Quality Re-confirmation of Proposed Well Field in La Tirana

The water quality of the proposed well-field in La Tirana for the water supply to Iquique was estimated from the observed water quality of the wells existing in the neighbourhood. The water quality of those existing wells are suitable for drinking use with no treatment. The clean water well nearest to the proposed well field exists close to the town of La Tirana approximately 10 km to the southwest from the proposed well-field. Therefore, a clean groundwater requiring no treatment is exploitable within or near the proposed well-field.

However, prior to determination of the detailed location of the well-field, it is recommended to re-confirm the water quality of the proposed well-field by drilling a test well.

5) Groundwater Monitoring

The existing monitoring system of groundwater in Azapa Valley, Lower Lluta Valley and Pampa del Tamarugal must be strengthened.

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33. MAP 3 : BASE MAP WITH BOUGUER VALUES.  
 ESCALA : 1 : 100,000  
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34. MAP 3 : BASE MAP WITH BOUGUER VALUES - C.I. : 10 MGALS.  
 ESCALA : 1 : 100,000  
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 ESCALA : 1 : 100,000  
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 ESCALA : 1 : 100,000  
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 ESCALA : 1 : 100,000  
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 ESCALA : 1 : 250,000  
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