3.4 Cost Estimation

The cost involved in the construction of deep wells to extract raw water, collection and transmission of raw water up to the treatment plant, and water treatment facilities including wastewater drainage facilities is summarized below. (See Table D-I, 3.5 for more details.)

Summary of Construction Cost
(Lower Lluta Scheme)

Facilities	Amount (Peso : $)
(A) Intake facilities	$4,811,728,000
(B) Transmission facilities	$757,702,000
(C) Treatment plant	$16,987,214,000
(D) Distribution Networks	$2,312,464,000
(E) Electric Transmission Line	$158,000,000
Total =	$25,027,108,000

3.5 Implementation Schedule

The implementation schedule of the Lower Lluta Scheme is proposed as below:

1) Detailed design period : 1996
2) Construction period : 1997-98
3) Commissioning : 1999

3.6 Operation and Maintenance Cost

The operation and maintenance (O&M) cost composed of electric power cost, chemicals cost , personnel expenditure, repairing and replacement cost for water supply facilities, as of September 1994, is summarized below. (See Table D-I, 3.6 for more details)

Summary of O&M Cost
(Lower Lluta Scheme)

[Unit : Chilean Peso]

Year	Electric Power	Chemicals	Personnel	Repairing & Replacement	Total
1999	535,173,000	183,608,907	56,448,000	413,412,745	1,188,642,652
2000	541,601,000	185,423,719	56,448,000	413,412,745	1,196,885,464
2001	556,912,000	190,993,315	56,448,000	413,412,745	1,217,766,060
2002	572,398,000	196,250,011	56,448,000	413,412,745	1,238,508,756
2003	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2004	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2005	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2006	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2007	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2008	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2009	587,884,000	199,629,316	56,448,000	7,813,532,745	8,657,494,061
2010	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2011	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2012	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2013	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2014	587,884,000	199,629,316	56,448,000	2,923,870,745	3,767,832,061
2015	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2016	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2017	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2018	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2019	587,884,000	199,629,316	56,448,000	18,137,979,745	18,981,941,061
2020	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2021	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2022	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2023	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2024	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2025	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2026	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2027	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2028	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2029	587,884,000	199,629,316	56,448,000	10,323,990,745	11,167,952,061
2030	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061

(Note) :
- Cost : as of September 1994
- Cost without Value Added Tax (IVA)
- Foreign exchange rate (as of March 1994) :
  US$ 1.00 = Chile Peso : $ 435.00
  US$ 1.00 = Japanese Yen : $ 110.00
  Japanese Yen 1.00 = Chile Peso : $ 3.955

Table D-I, 3.1 Additional Production Capacity Required by Lower Lluta Scheme for Arica

Year	Daily Average Production Capacity (l/sec)	Yearly Production Capacity (m^3/year)
(1995)	-	-
(1996)	-	-
(1997)	-	-
(1998)	-	-
1999	210.1	6,625,714
2000	220.1	6,941,074
2001	241.2	7,606,483
2002	262.3	8,271,893
2003	283.5	8,940,456
2004	304.5	9,602,712
2005	325.7	10,271,275
2006	351.8	11,094,364
2007	377.8	11,914,300
2008	403.8	12,734,236
2009	429.9	13,557,326
2010	456.0	14,380,416
2011	485.2	15,301,267
2012	514.3	16,218,964
2013	543.4	17,136,662
2014	572.5	18,054,360
2015	601.7	18,975,211

(Note): Construction Period : 1997-98
Commissioning year : 1999

Table D-I, 3.2 Hydraulic Calculations for Transmission Pipelines for Lower Lluta Scheme to Arica Water Supply

Transmission Pipeline
From Deep Well No.26 to Lluta Treatment Plant (Well No.1)

Total Length: L= 12,500 m

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Point (Accumulated Distance) (m)	Altitude above Sea Level (+m)	Distance between Two Points (m)	Flow Q (l/s)	Pipe Dia. (mm)	V (m/s)	I (x10*-3)	H (m)	Dynamic Water Level (+m)
0	+347	0	-	-	-	-	-	+348.00
(Deep well No.26 : Intake = 25 l/sec)								
Tank No.1: GL=+347, HWL=+348							WL	+348.00
500	+327	500	25	150 ACP	1.41	14.65	7.32	+340.68
(Deep well No.25 : Intake = 25 l/sec)								
1,000	+327	500	50	200 ACP	1.59	13.01	6.51	+334.17
(Deep well No.24 : Intake = 25 l/sec)								
1,500	+317	500	75	250 ACP	1.53	9.29	4.65	+329.52
(Deep well No.23 : Intake = 25 l/sec)								
2,000	+308	500	100	250 ACP	2.04	15.82	7.91	+321.61
(Deep well No.22 : Intake = 25 l/sec)								
2,500	+298	500	125	250 ACP	2.55	23.91	11.95	+309.66
(Deep well No.21 : Intake = 25 l/sec)								
3,000	+286	500	150	300 ACP	2.12	13.78	6.89	+302.77
(Deep well No.20 Intake + 25 l/sec)								
Tank No.2: GL=+286, HWL=+287							WL	+287.00
3,500	+274	500	175	300 ACP	2.48	18.33	9.17	+277.83
(Deep well No.19 : Intake = 25 l/sec)								
4,000	+262	500	200	350 ACP	2.08	11.08	5.54	+272.29
(Deep well No.18 : Intake = 25 l/sec)								
4,500	+250	500	225	300 ACP	2.34	13.78	6.89	+265.40
(Deep well No.17 : Intake = 25 l/sec)								
5,000	+240	500	250	350 ACP	2.60	16.74	8.37	257.03
(Deep well No.16 : Intake = 25 l/sec)								
5,500	+232	500	275	350 ACP	2.86	19.97	9.98	+247.05
(Deep well No.15 : Intake = 25 l/sec)								
Tank No.3: GL=+232, HWL=+233							WL	+233.00
6,000	+223	500	300	400 ACP	2.39	12.24	6.12	+226.88
(Deep well No.14 : Intake = 25 l/sec)								
6,500	+213	500	325	400 ACP	2.59	14.20	7.10	+219.78
(Deep well No.13 : Intake = 25 l/sec)								
7,000	+205	500	350	450 ACP	2.20	9.17	4.59	+215.19
(Deep well No.12 : Intake = 25 l/sec)								

(1) Point (Accumulated Distance) (m)	(2) Altitude above Sea Level (+m)	(3) Distance between Two Points (m)	(4) Flow Q (l/s)	(5) Pipe Dia. (mm)	(6) V (m/s)	(7) I (x10*-3)	(8) H (m)	(9) Dynamic Water Level (+m)
7,500	+196	500	375	450 ACP	2.35	10.42	5.21	+209.98
(Deep well No.11 : Intake = 25 l/sec)								
8,000	+188	500	400	450 ACP	2.52	11.75	5.87	+204.11
(Deep well No.10 : Intake = 25 l/sec)								
8,500	+180	500	425	450 ACP	2.67	13.14	6.57	+197.54
(Deep well No.9 : Intake = 25 l/sec)								
Tank No.4: GL=+180, HWL=+181							WL	+181.00
9,000	+172	500	450	500 ACP	2.30	8.74	4.37	+176.63
(Deep well No.8 : Intake = 25 l/sec)								
9,500	+164	500	475	500 ACP	2.42	9.66	4.83	+171.80
(Deep well No.7 : Intake = 25 l/sec)								
10,000	+156	500	500	500 ACP	2.55	10.62	5.31	+166.49
(Deep well No.6 : Intake = 25 l/sec)								
10,500	+149	500	525	500 ACP	2.67	11.63	5.82	+160.67
(Deep well No.5 : Intake = 25 l/sec)								
11,000	+150	500	550	500 ACP	2.80	12.67	6.34	+154.33
(Deep well No.4 : Intake = 2.5 l/sec)								
11,500	+145	500	552.5	500 ACP	2.81	12.78	6.39	+147.94
(Deep well No.3 : Intake = 0)								
12,000	+136	500	552.5	500 ACP	2.81	12.78	6.39	+141.55
(Deep well No.2 : Intake = 0)								
12,500	+131	500	552.5	500 ACP	2.81	12.78	6.39	+135.16
(Deep well No.1 : Intake = 0)								
Tank : GL=+131, HWL=+135 (Receiving tank at Lluta Treatment Plant)							HWL	+135.16

Length of Pipes from Deep Well No.26 to Lluta Treatment Plant

Diameter	Length
500 mm ACP	4,000 m
450 mm ACP	1,500 m
400 mm ACP	1,500 m
350 mm ACP	2,000 m
300 mm ACP	1,000 m
250 mm ACP	1,500 m
200 mm ACP	500 m
150 mm ACP	500 m
Total =	12,500 m

(From Deep Well No.26 to Lluta Treatment Plant)

Table D-I, 3.3 Hydraulic Calculation for Intake Facilities for Lower Lluta Scheme

Deep Wells in Lower Lluta Scheme for Arica Water Supply

Well No.	Well Yield (l/sec)	Well Depth (m)	Altitude above Sea Level (+m)		
			Ground Level	Static W. Level	Dynamic W. Level
1	25	150	+131.0	+94	+54
2	25	"	+136.0	+104	+64
3	25	"	+145.3	+115	+75
4	25	"	+150.0	+125	+85
5	25	"	+149.0	+136	+96
6	25	"	+156.3	+145	+105
7	25	"	+164.3	+155	+115
8	25	"	+172.2	+165	+125
9	25	120	+180.2	+170	+130
10	25	"	+188.1	+176	+136
11	25	"	+196.0	+181	+141
12	25	"	+204.5	+186	+146
13	25	"	+213.6	+192	+152
14	25	"	+222.7	+198	+158
15	25	"	+231.8	+207	+167
16	25	"	+240.9	+217	+177
17	25	"	+250.0	+226	+186
18	25	"	+261.9	+235	+195
19	25	"	+273.8	+249	+209
20	25	"	+285.7	+263	+223
21	25	"	+297.6	+277	+237
22	25	"	+307.7	+291	+251
23	25	"	+317.3	+305	+265
24	25	"	+316.9	+320	+280
25	25	"	+337.0	+332	+292
26	25	"	+347.0	+344	+304

(Total number of deep wells = 26 wells)

Intake Pump Power Calculation for Lower Lluta Scheme

		(A)	(B)	(C)=B-1	(D)=C+4.00		
Well No.	Ground Level (+m)	Dynamic W. Level in the Well (+m)	W. Level to be Pumped (+m)	Pump Head (m)	Design Head incl. loss around the Pump (m)	Pump Power (kw)	Motor Power (kw)
1	+131.0	+ 54	+135.16	81.16	86.16 --> 87	31.3	36.0 --> 40
2	+136.0	+ 64	+141.55	77.55	82.55 --> 83	29.9	34.4 --> 35
3	+145.3	+ 75	+147.94	72.94	77.94 --> 78	28.1	32.3 --> 35
4	+150.0	+ 85	+154.33	69.33	74.33 --> 75	27.0	31.1 --> 35
5	+149.0	+ 96	+160.67	64.67	69.67 --> 70	25.2	29.0 --> 30
6	+156.3	+105	+166.49	61.49	66.49 --> 67	24.1	27.7 --> 30
7	+164.3	+115	+171.80	56.80	61.80 --> 62	22.3	25.6 --> 30
8	+172.2	+125	+176.63	51.63	56.63 --> 57	20.5	23.6 --> 25
9	+180.2	+130	+197.54	67.54	72.54 --> 73	26.3	30.2 --> 35
10	+188.1	+136	+204.11	68.11	73.11 --> 74	26.6	30.6 --> 35
11	+196.0	+141	+209.98	68.98	73.98 --> 74	26.6	30.6 --> 35
12	+204.5	+146	+215.19	69.19	74.19 --> 75	27.0	31.1 --> 35
13	+213.6	+152	+219.78	67.78	72.78 --> 73	26.3	30.2 --> 35
14	+222.7	+158	+226.88	68.88	73.88 --> 74	26.6	30.6 --> 35
15	+231.8	+167	+249.45	82.45	87.45 --> 88	31.7	36.6 --> 40
16	+240.9	+177	+259.43	82.43	87.43 --> 88	31.7	36.5 --> 40
17	+250.0	+186	+268.70	82.70	87.70 --> 88	31.7	36.5 --> 40
18	+261.9	+195	+274.69	79.69	84.69 --> 85	30.6	35.2 --> 40
19	+273.8	+209	+277.83	68.83	73.83 --> 74	26.6	30.6 --> 35
20	+285.7	+223	+302.77	79.79	84.79 --> 85	30.6	35.2 --> 40
21	+297.6	+237	+309.66	72.66	77.66 --> 78	28.1	32.3 --> 35
22	+307.7	+251	+321.61	70.61	75.61 --> 76	27.4	31.5 --> 35
23	+317.3	+265	+329.52	64.52	69.52 --> 70	25.2	29.0 --> 30
24	+326.9	+280	+334.17	54.19	59.19 --> 60	21.6	24.8 --> 25
25	+337.0	+292	+340.68	48.68	53.68 --> 54	19.4	22.3 --> 25
26	+347.0	+304	+348.00	44.00	59.00 --> 60	21.6	24.9 --> 25

Total (26 pumps) installation capacity = 880 kw

Daily maximum power consumption = 880 kw x (552.5)/(25x26) = 748 kw
Daily average power consumption = 748 / 1.30 = 575 kw

(Note):
Type of Pump : Submersible Motor Pump
Pump Discharge = 25 l/sec = 1.50 m^3/min
Pump Diameter = 146 x (1.50/1.9)(*0.5) = 129.7 --> 150 mm

Pump Power: P = 0.163 x Q(m^3/min) x H(m) / f = 0.360 x H
(f: Pump efficiency = 0.68)

Motor Power: R = P x (1+g)
g = Allowance = 0.15

Table D-I,3.4
Calculation of Equipment Capacity for Lluta Treatment Plant

1. Design Condition

(1) Design Capacity
Intake Capacity

: Daily Average 425 l / sec (36,720 m^3 / day)
: Daily Maximum 552.5 l / sec (47,740 m^3 / day : Q_1)

Production Flow Rate

: Daily Average 319 l / sec (27,560 m^3 / day)
: Daily Maximum 414 l / sec (35,770 m^3/ day : Q_2)

(2) Water Quality

Water quality items of raw water, treated water (target) and permissible limit in Chile are as follows.

Item	Unit	Raw Water	Treated Water	Permissible Limit in Chile
Temperature	deg	23	----	----
pH	---	6.9	6.0 ~ 8.5	6.0 ~ 8.5
TDS	mg / l	3,300	1,000	1,000
Na	mg / l	530	200	200
SO4	mg / l	860	250	250
Cl	mg / l	950	250	250
NO3	mg / l	5.6	<5.6	10.0
As	mg / l	0.03	<0.03	0.05
F	mg / l	1.0	<1.0	1.5
Cd	mg / l	0.01	0.005	0.005
B	mg / l	22	5.0	----
Fe	mg / l	1.53	0.3	0.3
Mn	mg / l	0.72	0.1	0.1
SiO2	mg / l	27.2	0.5	----

2. Calculation of Equipment Capacity

(1) Receiving Tanks

1) Number : 2 pcs

2) Capacity (V) : 2,000 m^3 (1,000 m^3 * 2)

$V = Q_1 * (1/24)$

$= 47,740 * (1/24) = 2,000\ m^3$

3) Dimensions : 10 m * 25 m * 4 mH x 2 pcs

4) Material : Reinforced Concrete

(2) Raw Water Pumps

1) Number : 3 pcs (including one stand-by)

2) Type : Centrifugal pump

3) Capacity : 17 m^3 / min

4) Pump Head : 30 m

5) Motor : 120 kw

(3) Filters

1) Number : 12 pcs (include stand-by)

2) Type : Pressure Rapid Filter

3) Dimensions : Diameter 3,200 mm; Height 2,400 mm x 12 pcs

$D = \{ [Q_1 / V_1 * n] / (3.14/4) \}^{1/2}$

$= 3.2\ m$

Where

D : Diameter (m)

V_1 : Filtration Rate (m/hour)

4) Filtration Rate : 22.5 m/hour (540 m/day : V_1)

5) Backwashing : One Time/Three days / Each Filter

Method of Backwashing : By Backwashing Water

Necessary Water Capacity for Backwashing : 80.4 m^3 / Time / Each Filter

[0.5 m/min * 20 min * (3 .2 $)^2$ * 3.14 / 4 = 80.4 m^3]

* Backwashing water required = 80.4 * (12/3)
= 321.6 m^3 / day

* Percentage of Backwashing water = [80.4 * (12/3) *100] / 47,740
= 0.67 %

(4) Reverse Osmosis (RO)

1) Number : 12 Units

2) Unit Capacity : 3,000 m^3- Production Water / day / Unit

3) Recovery : 75 %

Raw Water Volume : Q_1 = 47,740 m^3/day

Production Volume : Q_2 = 35,770 m^3/day

4) Membrane : For Brackish Water

5) Electric Motor : 160 kw / Unit

(5) Distribution Tanks

1) Number : 2 pcs

2) Capacity (V) : 12,000 m^3 (6,000 m^3 * 2)

V = Q_2 * (8 / 24)

= 35,770 * (8 / 24) = 11,923 ==> 12,000 m^3

3) Dimensions : Diameter 39.2 m * 5 mH x 2 pcs

4) Material : Reinforced Concrete

(6) Conditioning Tank

1) Number : 1 pc

2) Capacity (V) : 400 m^3

V = Q_2 * (15/24 * 60)

= 35,770 * (15/1140) = 372.6 ==> 400 m^3

3) Dimensions : 7 m * 11 m * 5.3 mH

4) Material : Reinforced Concrete

(7) Backwash Tank

1) Number : 1 pc

2) Capacity (V) : 150 m^3

V = Two times' capacity of backwashing

= 80.4 * 2 =160.8 ==> 150 m3

3) Dimensions : 3.6 m * 14 m * 3 mH

4) Material : Reinforced Concrete

(8) Backwashing Pumps

1) Number : 2 pcs (including one stand-by)

2) Type : Centrifugal pump

3) Capacity : 4 m^3 / min

4) Pump Head : 20 m

5) Motor : 18.5 kw

(9) Wastewater Tank

1) Number : 1 pc

2) Capacity (V) : 210 m^3

V = One time of backwashing Capacity + 15 minutes * Concentrated Water Rate

= 80.4 + (8.3 m^3/min * 15 min)

= 210 m^3

3) Dimensions : 5 m * 14 m * 3 mH

4) Material : Reinforced Concrete

Table D-I, 3.5 (1) Construction Cost for Lower Lluta Scheme
- Arica Water Supply System
(Water Source: Groundwater in Lower Lluta Basin)

Summary

Item	Amount (Peso:$)
(A) Intake Facilities .... (Deep wells/ Pumps/ Electrical facilities)	$4,811,728,000
(B) Transmission Facilities .... (Pipelines/ Valves/ Crossing work/ Tanks)	$757,702,000
(C) Treatment Plant .... (Desalination Plant)	$16,987,214,000
(D) Distribution Networks	$2,312,464,000
(E) Electric Transmission Line	$158,000,000
Total (A+B+C)....................................... (Lower Lluta Scheme)	$ 25,027,108,000

(Note): - Cost : as of March 1994
- Cost without Value Added Tax (IVA)
- Foreign exchange rate (as of March 1994):
US$1.00 = Chile Peso: $435.00
US$1.00 = Japanese Yen: \110.00
Japanese Yen 1.00 = Chile Peso: $3.955

Table D-I, 3.5(2) Cost Estimation for Lower Lluta Scheme - Arica Water Supply
(Water Source: Groundwater in Lower Lluta Basin)

(Note):
- Cost : as of March 1994
- Cost without Value Added Tax (IVA)
- Foreign exchange rate (as of March 1994):
  US$1.00 = Chile Peso: $435.00
  US$1.00 = Japanese Yen: \110.00
  Japanese Yen 1.00 = Chile Peso: $3.955

Item		Q'ty	Unit Price ($)	Amount ($)
(A)	Intake Facilities (along the Lluta River/ Highway)			
1.	Deep Wells (Total 26 wells)			
1.1	Construction of deep well (12" x 150 m depth, screen: 45 m)	8 wells	62,546,000	500,368,000
1.2	Construction of deep well (12" x 120 m depth, screen: 36 m)	18 wells	53,665,000	965,970,000
1.3	Pump house 5.5 m x 4.0 m	26 Nos.	2,200,000	57,200,000
			Sub Total (26 wells) =	$1,523,538,000
2.	Pump (Submersible pump with motor, column pipe, electric cables, base plate, water level indicator, check valve, gate valve, flow meter, station pipes) Q= 25 l/sec = 1.50 m^3/min Diameter = 125 mm			
2.1	Pump (40 kw)	6 Nos.	43,505,000	261,030,000
2.2	Pump (35 kw)	12 "	41,525,500	498,306,000
2.3	Pump (30 kw)	4 "	37,572,500	150,290,000
2.4	Pump (25 kw)	4 "	33,618,000	134,472,000
			Sub Total (26 pumps) =	$1,044,098,000
3.	Electrical facilities for the above (Including pump control panel, transformer, telemeter transfer panel, uninterrupted power supply)			
3.1	For 40/35 kw pumps	13 units	31,640,000	411,320,000
3.2	For 30/25 kw pumps	13 units	30,849,000	401,037,000
			Sub Total =	$812,357,000
4.	Power transmission line, including power cable, control cable for telemeter, wooden pole,insulator, etc.	1 lot		1,028,300,000
5.	Sub station (11 kv/1,500 kvA) (in the treatment plant) including incoming panel, receiving panel, transformer	1 lot		276,850,000

6.	Electrical equipment (11 kv/1,500 kvA) including intake pump feeder panel, low voltage panel, cables	1 lot		126,585,000
Total of (A)				$4,811,728,000

(B) Transmission Facilities (fromRosario to Lluta Treatment Plant)

1.	Pipelines (Materials and installation cost)			
1.1	500 mm Pipelines	4,000 m	63,424	253,696,000
1.2	450 mm "	1,500 m	57,558	86,337,000
1.3	400 mm "	1,500 m	49,169	73,754,000
1.4	350 mm "	2,000 m	40041	80,082,000
1.5	300 mm "	1,000 m	32,754	32,754,000
1.6	250 mm "	1,500 m	22,591	33,887,000
1.7	200 mm "	500 m	17,408	8,704,000
1.8	150 mm "	500 mm	13,231	6,615,000
1.9	Miscellaneous	1 lot	(5%)	28,792,000
			Sub Total =	$604,621,000
2.	Valves			
2.1	Valve 500 mm (Sluice)	2 Nos.	9,396,000	18,792,000
2.2	" 450 mm (")	1 No.	5,197,000	5,197,000
2.3	" 400 mm (")	1 No.	4,115,000	4,115,000
2.4	" 350 mm (")	1 No.	2,968,000	2,968,000
2.5	" 300 mm (")	2 Nos.	2,271,000	4,542,000
2.6	" 150 mm (")	4 Nos.	623,000	2,492,000
			Sub Total =	$38,106,000
3.	Crossing work			
3.1	River crossing work	1 site	15,000,000	15,00,000
3.2	Road crossing work	17 sites	3,000,000	51,000,000
3.3	Railway crossing work	3 sites	2,000,000	6,000,000
			Sub Total =	,$72,000,000
4.	Break-pressure Tanks (TC: Reinforced Concrete)			
4.1	15 m^3 tank	1 No.	3,148,000	3,148,000
4.2	105 m^3tank	1 No.	6,565,000	6,565,000
4.3	180 m^3 tank	1 NO.	13,130,000	13,130,000
4.4	270 m^3 tank	1 No.	19,154,000	19,154,000
4.5	Land acquisition	978 m^2	1,000	978,000
			Sub Total =	$42,975,000
Total of (B)				$757,702,000

(C) Lluta Treatment Plant
(Production capacity:
= 552.5 x 75% = 414 l/sec = 35,800 m^3/day)

1.	Civil works			
1.1	Concrete structures			
1)	Receiving tanks (1,000 m^3)	2 Nos.	43,709,000	87,418,000
2)	Conditioning tank (400 m^3)	1 No.	20,000,000	20,000,000
3)	Backwash tank (150 m^3)	1 No.	9,000,000	9,000,000
4)	Wastewater tank (210 m^3)	1 No.	12,180,000	12,180,000
5)	Foundations			

	- Raw water pump (5m/11m/1.5mH)	85 m^3	109,000	9,265,000
	- Filters (15m/30m/1.5mH)	680 m^3	109,000	74,120,000
	- sub-power station (10m/10m/0.5mH)	50 m^3	109,000	5,450,000
1.2	Landscaping (200 m x 200 m)	40,000 m^2	2,000	80,000,000
1.3	Land preparation	40,000 m^2	3,400	136,000,000
1.4	Distribution tanks (6,000 m^3)	2 Nos.	193,800,000	387,600,000
1.5	Wastewater pipeline (350 mm, CP)	8,750 m	15,695	137,331,000
			Sub Total =	$958,364,000
2.	Building works			
2.1	Administration building (10mx54m)	1 No.		118,800,000
2.2	RO building (25mx90m)	1 No.		382,500,000
2.3	Disinfection building (5mx10m)	1 No.		8,500,000
2.4	Warehouse (8mx24m)	1 No.		19,200,000
2.5	Guardhouse (3mx5m)	2 Nos.		6,000,000
2.6	Garage (3mx15m)	1 No.		1,350,000
			Sub Total =	$536,350,000
3.	Mechanical equipment			
3.1	Filters (12 Nos.)	1 lot		2,846,200,000
3.2	RO unit (12 Nos.)	1 lot		7,400,120,000
3.3	Others	1 lot		1,138,480,000
			Sub Total =	$11,384,800,000
4.	Electric equipment			
4.1	Transformer station (4,500kvA)	1 lot		472,500,000
4.2	Electric equipment	1 lot		3,595,200,000
			Sub Total =	$4,067,700,000
5.	Others			
5.1	Water quality analyzer	1 lot		22,000,000
5.2	Office equipment	1 lot		6,000,000
5.3	Miscellaneous works	1 lot		12,000,000
			Sub Total =	$40,000,000
Total of (C)				$16,987,214,000

(D)	Distribution Networks			
1.	Pipelines (Materials and installation cost)			
1.1	Distribution Main 700 mm (from Lluta Treatment Plant to entrance of Arica City; from Lluta Bridge to 2.5 km more near Arica City	7,000 m	266,537	1,865,759,000
1.2	Distribution Network	12,763 m	35,000	446,705,000
Total of (D)				$2,312,464,000

(E) Electric Transmission Line			
1. High voltage (23kvA) electric power line from Substation/ EMELARI/Arica	20 km	7,900,000	158,000,000
Total of (E)			$158,000,000
Grand Total (A + B + C + D + E) (Lower Lluta Scheme)			$25,027,108,000

Table D-I, 3.6 Operation and Maintenance Cost for Lower Lluta Scheme - Arica Water Supply System

(Water Source : Groundwater in Lower Lluta Basin)

Summary

[Unit : Chilean Peso]

Year	Electric Power	Chemicals	Personnel	Repairing & Replacement	Total
1999	535,173,000	183,608,907	56,448,000	413,412,745	1,188,642,652
2000	541,601,000	185,423,719	56,448,000	413,412,745	1,196,885,464
2001	556,912,000	190,993,315	56,448,000	413,412,745	1,217,766,060
2002	572,398,000	196,250,011	56,448,000	413,412,745	1,238,508,756
2003	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2004	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2005	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2006	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2007	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2008	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2009	587,884,000	199,629,316	56,448,000	7,813,532,745	8,657,494,061
2010	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2011	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2012	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2013	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2014	587,884,000	199,629,316	56,448,000	2,923,870,745	3,767,832,061
2015	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2016	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2017	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2018	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2019	587,884,000	199,629,316	56,448,000	18,137,979,745	18,981,941,061
2020	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2021	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2022	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2023	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2024	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2025	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2026	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2027	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2028	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061
2029	587,884,000	199,629,316	56,448,000	10,323,990,745	11,167,952,061

2030	587,884,000	199,629,316	56,448,000	413,412,745	1,257,374,061

(Note) : - Cost : as of September 1994

- Cost without Value Added Tax (IVA)
- Foreign exchange rate (as of March 1994) :

  US$ 1.00 = Chile Peso : $ 435.00

  US$ 1.00 = Japanese Yen : $ 110.00

  Japanese Yen 1.00 = Chile Peso : $ 3.955

Table D-I, 3.6' **Operation and Maintenance Cost for Lower Lluta Scheme - Arica Water Supply System**

(Water Source : Groundwater in Lower Lluta Basin)

(Note) : - Cost : as of September 1994
- Cost without Value Added Tax (IVA)
- Foreign exchange rate (as of March 1994) :
US$ 1.00 = Chile Peso : $ 435.00
US$ 1.00 = Japanese Yen : $ 110.00
Japanese Yen 1.00 = Chile Peso : $ 3.955

[A] Electric Power Consumption Cost

Annual electric power consumption (Y-kw) cost of maximum water demand year (2003) is estimated as shown below.
(Daily Maximum = 414 l/s, Daily Average = 319 l/s)
Intake Facilities = 575 kw / day (Daily Average)
Treatment Plant = 2,160 kw (Daily Maximum) / 1.3
= 1,662 kw / day (Daily Average)
Total = 575 + 1,662 =2,237 kw /day (Daily Average)
Y-kw = 2,237 kw /day x 24 hr/day x 365 day x $30 /kwh
= 587,884,000 $ / Year (after year 2003 is same value)

Annual electric power consumption from 1999 to 2030 is shown below.

Year	Yearly Production Capacity (m^3/Year)	Yearly Electric Power Consumption Cost ($ / Year)	Remarks
1999	9,158,054	535,173,000	Start of Operation
2000	9,268,430	541,601,000	
2001	9,530,179	556,912,000	
2002	9,795,081	572,398,000	
2003	10,059,984	587,884,000	Maximum Demand
2004	10,059,984	587,884,000	
2005	10,059,984	587,884,000	
2006	10,059,984	587,884,000	
2007	10,059,984	587,884,000	
2008	10,059,984	587,884,000	
2009	10,059,984	587,884,000	

2010	10,059,984	587,884,000
2011	10,059,984	587,884,000
2012	10,059,984	587,884,000
2013	10,059,984	587,884,000
2014	10,059,984	587,884,000
2015	10,059,984	587,884,000
2016	10,059,984	587,884,000
2017	10,059,984	587,884,000
2018	10,059,984	587,884,000
2019	10,059,984	587,884,000
2020	10,059,984	587,884,000
2021	10,059,984	587,884,000
2022	10,059,984	587,884,000
2023	10,059,984	587,884,000
2024	10,059,984	587,884,000
2025	10,059,984	587,884,000
2026	10,059,984	587,884,000
2027	10,059,984	587,884,000
2028	10,059,984	587,884,000
2029	10,059,984	587,884,000
2030	10,059,984	587,884,000

[B] Chemicals Cost

Annual chemicals cost from 1999 to 2030 is shown below.

[Unit : Chilean Peos]

Year	Water Flow Rate		Chemicals Consumption			Total
	Daily Maximum (l / sec)	Daily Average (l / sec)	for RO	Chlorine	for pH Control (NaOH)	
1999	381	293.4	175,800,586	6,198,359	1,609,963	183,608,907
2000	385	296.3	177,538,219	6,259,624	1,625,876	185,423,719
2001	397	305.2	182,870,957	6,447,645	1,674,713	190,993,315
2002	408	313.6	187,904,102	6,625,103	1,720,806	196,250,011
2003	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2004	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2005	414	319	191,139,696	6,739,183	1,750,437	199,629,316

2006	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2007	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2008	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2009	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2010	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2011	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2012	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2013	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2014	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2015	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2016	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2017	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2018	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2019	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2020	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2021	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2022	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2023	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2024	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2025	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2026	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2027	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2028	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2029	414	319	191,139,696	6,739,183	1,750,437	199,629,316
2030	414	319	191,139,696	6,739,183	1,750,437	199,629,316

[Chemical cost of maximum water demand year (2003)]

for RO = 0.319 m^3/s * 86,400 * 365 day * @ 19 $/$m^3$

Chlorine = 0.319 m^3/s * 86,400 * 365 day * 0.001 kg/m^3 * @ 1.54 US$/kg * 435 $/US$

for pH Control = 0.319 m^3/s * 86,400 * 365 day * 0.0004 kg-NaOH/m^3 * @ 435 $/kg-NaOH

[C] Personnel Expense

The kind of water works and number of persons for O&M of intake facilities and treatment plant is assumed as follows.

	Kind of Works	The Number of Persons
1	Director	1
2	Sub director	1
3	Engineers	3
4	Operators	9
5	Maintenance Workers	4
6	Guard Men	4
7	Accountancy & Affairs	2
8	Secretaries	4
9	Labor	4
	Total	32

[D] Repairing and Replacement Cost

Annual repairing and replacement cost is composed of repairing and replacement cost for intake facilities, treatment plant and distribution facilities.

Annual repairing cost and life spans for replacement of equipment are as follows.

	Kind of Facilities	Repairing Cost (% of Construction Cost)	Life Spans for Replacement (Year)
1	Intake and Transmission Facilities		
1.1	Wells and Intake Pumps	1.0	15
1.1	Pipeline	2.0	40
1.2	Equipment	1.0	20
2	Treatment Plant		
2.1	RO Unit	3.0	10
2.2	Pipeline	2.0	40
2.3	Other Equipment	1.0	20
3	Distribution Facilities		
3.1	Pipeline	2.0	40

The details of these cost are shown in next tables.

The Summary of Annual Repairing and Replacement Cost

[Unit : Chilean Peso]

Year	Water Rate Daily Maximum (l / sec)	Water Rate Daily Average (l / sec)	Intake Facilities Total (1/3)	Treatment Plant Total (2/3)	Distribution Facilities Total (3/3)	Total
1999	381	293.4	48,035,890	319,127,855	46,249,000	413,412,745
2000	385	296.3	48,035,890	319,127,855	46,249,000	413,412,745
2001	397	305.2	48,035,890	319,127,855	46,249,000	413,412,745
2002	408	313.6	48,035,890	319,127,855	46,249,000	413,412,745
2003	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2004	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2005	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2006	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2007	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2008	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2009	414	319	48,035,890	7,719,247,855	46,249,000	7,813,532,745
2010	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2011	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2012	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2013	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2014	414	319	2,558,493,890	319,127,855	46,249,000	2,923,870,745
2015	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2016	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2017	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2018	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2019	414	319	2,292,102,890	15,799,627,855	46,249,000	18,137,979,745
2020	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2021	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2022	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2023	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2024	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2025	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2026	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2027	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2028	414	319	48,035,890	319,127,855	46,249,000	413,412,745
2029	414	319	2,558,493,890	7,719,247,855	46,249,000	10,323,990,745
2030	414	319	48,035,890	319,127,855	46,249,000	413,412,745

Annual Repairing and Replacement Cost of Intake Facility in Lower Lluta

[Unit : Chilean Peso]

Year	Water Rate Daily Maximum (l / sec)	Water Rate Daily Average (l / sec)	Repairing Cost Pipeline 2.0%	Repairing Cost Equipment 1.0%	Replacement Cost Wells & Intake Pumps each 15 Years	Replacement Cost Other Equipment each 20 Years	Total (1/3)
1999	381	293.4	15,154,020	32,881,870	0	0	48,035,890
2000	385	296.3	15,154,020	32,881,870	0	0	48,035,890
2001	397	305.2	15,154,020	32,881,870	0	0	48,035,890
2002	408	313.6	15,154,020	32,881,870	0	0	48,035,890
2003	414	319	15,154,020	32,881,870	0	0	48,035,890
2004	414	319	15,154,020	32,881,870	0	0	48,035,890
2005	414	319	15,154,020	32,881,870	0	0	48,035,890
2006	414	319	15,154,020	32,881,870	0	0	48,035,890
2007	414	319	15,154,020	32,881,870	0	0	48,035,890
2008	414	319	15,154,020	32,881,870	0	0	48,035,890
2009	414	319	15,154,020	32,881,870	0	0	48,035,890
2010	414	319	15,154,020	32,881,870	0	0	48,035,890
2011	414	319	15,154,020	32,881,870	0	0	48,035,890
2012	414	319	15,154,020	32,881,870	0	0	48,035,890
2013	414	319	15,154,020	32,881,870	0	0	48,035,890
2014	414	319	15,154,020	32,881,870	2,510,458,000	0	2,558,493,890
2015	414	319	15,154,020	32,881,870	0	0	48,035,890
2016	414	319	15,154,020	32,881,870	0	0	48,035,890
2017	414	319	15,154,020	32,881,870	0	0	48,035,890
2018	414	319	15,154,020	32,881,870	0	0	48,035,890
2019	414	319	15,154,020	32,881,870	0	2,244,067,000	2,292,102,890
2020	414	319	15,154,020	32,881,870	0	0	48,035,890
2021	414	319	15,154,020	32,881,870	0	0	48,035,890
2022	414	319	15,154,020	32,881,870	0	0	48,035,890
2023	414	319	15,154,020	32,881,870	0	0	48,035,890
2024	414	319	15,154,020	32,881,870	0	0	48,035,890
2025	414	319	15,154,020	32,881,870	0	0	48,035,890
2026	414	319	15,154,020	32,881,870	0	0	48,035,890
2027	414	319	15,154,020	32,881,870	0	0	48,035,890
2028	414	319	15,154,020	32,881,870	0	0	48,035,890
2029	414	319	15,154,020	32,881,870	2,510,458,000	0	2,558,493,890
2030	414	319	15,154,020	32,881,870	0	0	48,035,890

Annual Repairing and Replacement Cost of Lluta Water Treatment Plant

[Unit : Chilean Peso]

Year	Water Rate Daily Maximum (l / sec)	Water Rate Daily Average (l / sec)	Repairing Cost RO Unit 3.0%	Repairing Cost Other Equipment 1.0%	Repairing Cost Civil & Build 1.0%	Repairing Cost Wastewater Pipe 2.0%	Replacement Cost RO Unit each 10 Years	Replacement Cost Other Equipment each 20 Years	Total (2/3)
1999	381	293.4	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2000	385	296.3	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2001	397	305.2	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2002	408	313.6	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2003	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2004	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2005	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2006	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2007	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2008	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2009	414	319	222,003,600	81,563,800	12,813,830	2,746,625	7,400,120,000	0	7,719,247,855
2010	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2011	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2012	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2013	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2014	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2015	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2016	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2017	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2018	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2019	414	319	222,003,600	81,563,800	12,813,830	2,746,625	7,400,120,000	8,080,380,000	15,799,627,855
2020	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2021	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2022	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2023	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2024	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2025	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2026	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2027	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2028	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855
2029	414	319	222,003,600	81,563,800	12,813,830	2,746,625	7,400,120,000	0	7,719,247,855
2030	414	319	222,003,600	81,563,800	12,813,830	2,746,625	0	0	319,127,855

Annual Repairing and Replacement Cost of Distribution Facilities in Lower Lluta

[Unit : Chilean Peso]

Year	Water Rate Daily Maximum (l / sec)	Water Rate Daily Average (l / sec)	Repairing Cost Pipeline 2.0%	Replacement Cost Pipeline	Total (3/3)
1999	381	293.4	46,249,000	0	46,249,000
2000	385	296.3	46,249,000	0	46,249,000
2001	397	305.2	46,249,000	0	46,249,000
2002	408	313.6	46,249,000	0	46,249,000
2003	414	319	46,249,000	0	46,249,000
2004	414	319	46,249,000	0	46,249,000
2005	414	319	46,249,000	0	46,249,000
2006	414	319	46,249,000	0	46,249,000
2007	414	319	46,249,000	0	46,249,000
2008	414	319	46,249,000	0	46,249,000
2009	414	319	46,249,000	0	46,249,000
2010	414	319	46,249,000	0	46,249,000
2011	414	319	46,249,000	0	46,249,000
2012	414	319	46,249,000	0	46,249,000
2013	414	319	46,249,000	0	46,249,000
2014	414	319	46,249,000	0	46,249,000
2015	414	319	46,249,000	0	46,249,000
2016	414	319	46,249,000	0	46,249,000
2017	414	319	46,249,000	0	46,249,000
2018	414	319	46,249,000	0	46,249,000
2019	414	319	46,249,000	0	46,249,000
2020	414	319	46,249,000	0	46,249,000
2021	414	319	46,249,000	0	46,249,000
2022	414	319	46,249,000	0	46,249,000
2023	414	319	46,249,000	0	46,249,000
2024	414	319	46,249,000	0	46,249,000
2025	414	319	46,249,000	0	46,249,000
2026	414	319	46,249,000	0	46,249,000
2027	414	319	46,249,000	0	46,249,000
2028	414	319	46,249,000	0	46,249,000
2029	414	319	46,249,000	0	46,249,000
2030	414	319	46,249,000	0	46,249,000

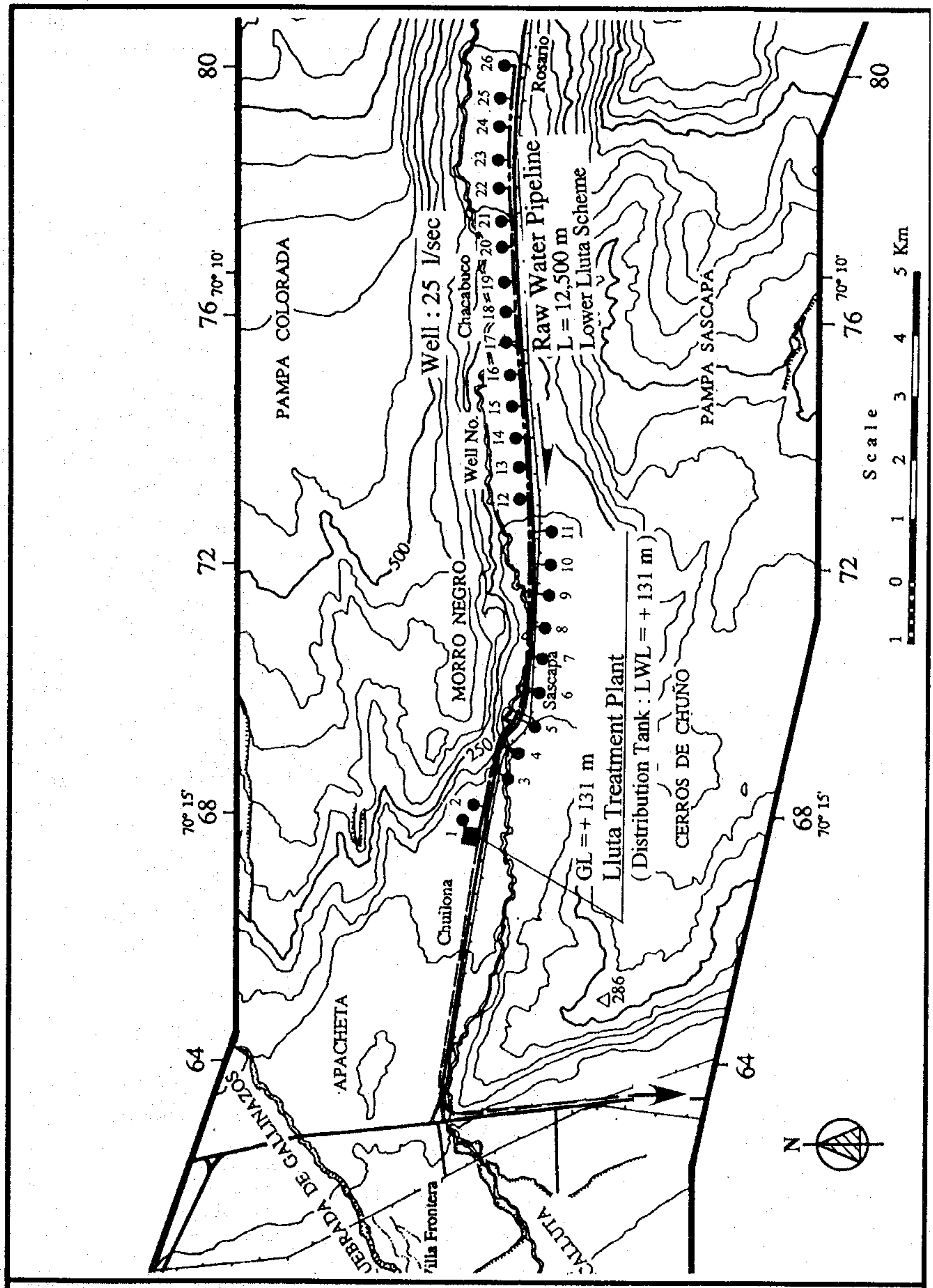


Fig. D-I, 3.1 Lower Lluta Scheme to Arica Water Supply

< Esquema Lluta Bajo a Suministro de Agua de Arica >

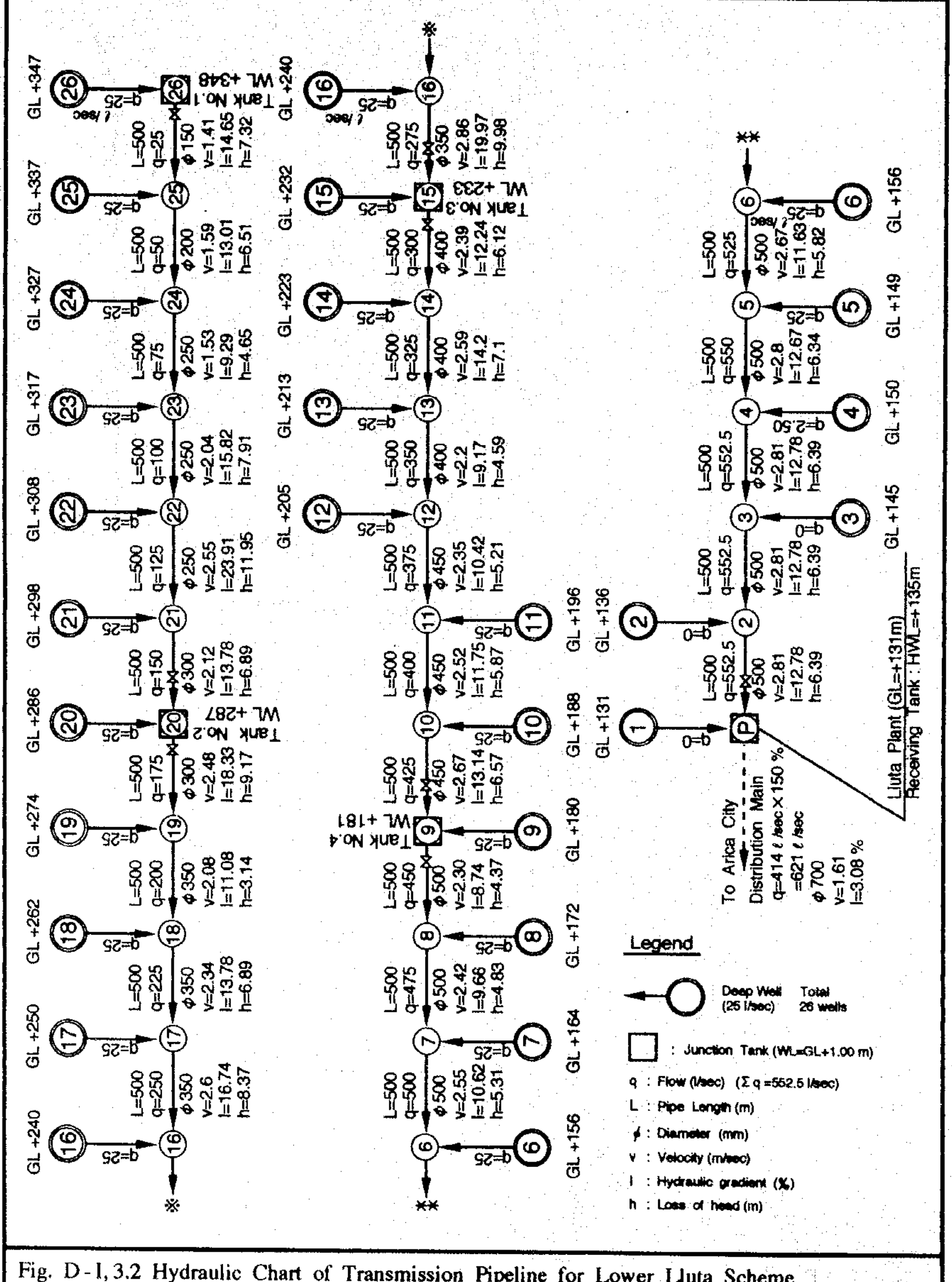


Fig. D-I, 3.2 Hydraulic Chart of Transmission Pipeline for Lower Lluta Scheme to Arica Water Supply

< Diagrama hidaulico de la Cañeria de Conduccio'n para el Esquema Lluta Bajo al Abastecimiento de Agua de Arica >

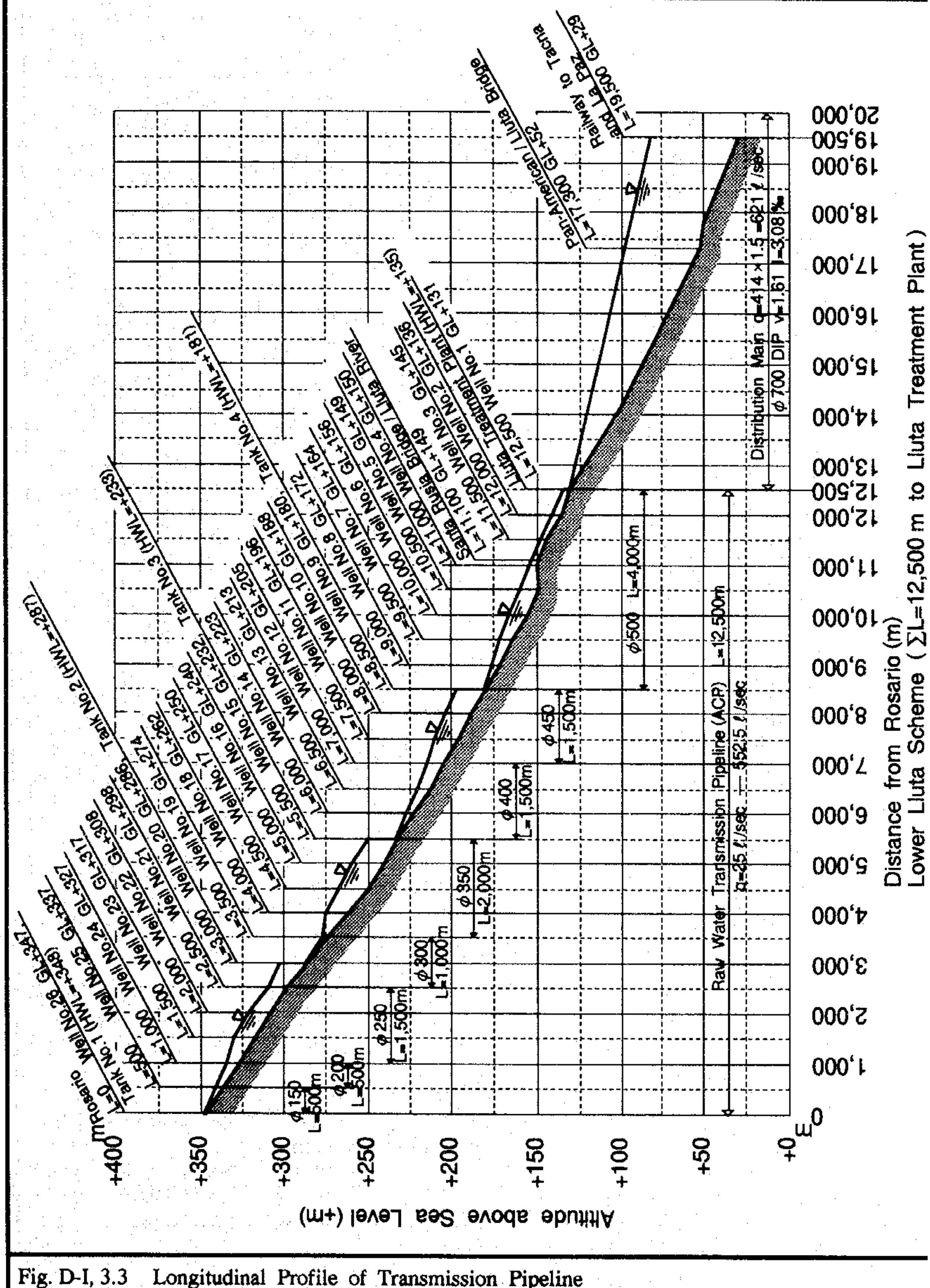
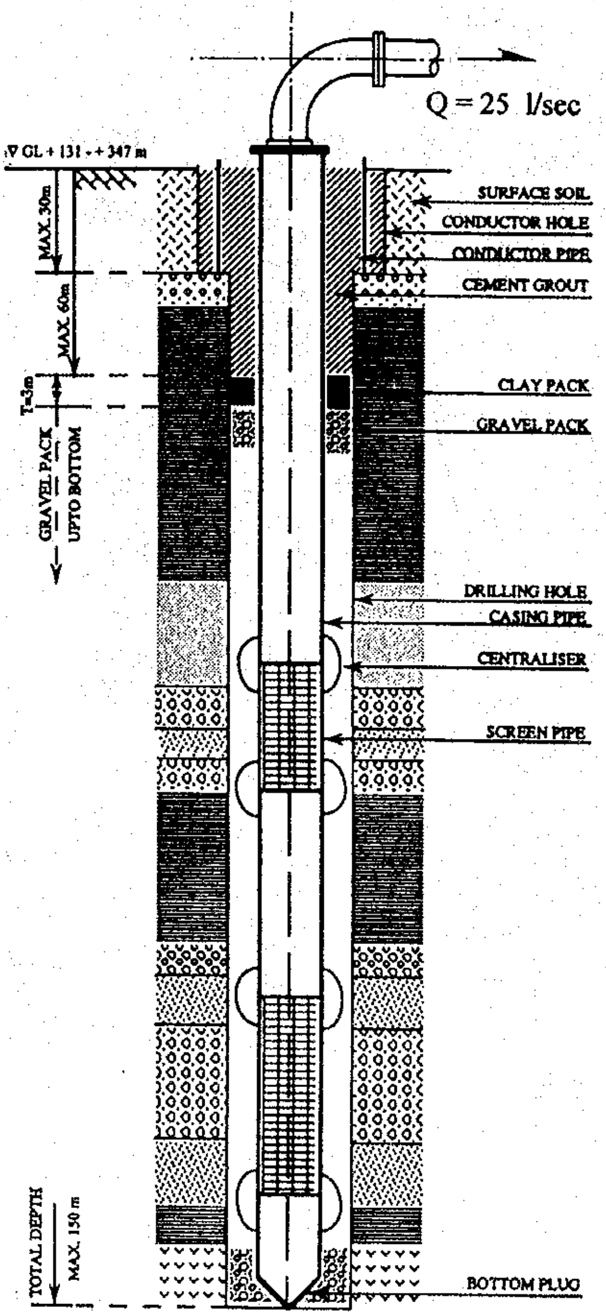


Fig. D-I, 3.3 Longitudinal Profile of Transmission Pipeline for Lower Lluta Scheme to Arica Water Supply

< Perfil Longitidinal de la Cañeria de Conduccio'n del Esquema Lluta Bajo al Abastecimiento de Agua de Arica >

Well Structure



HOLE DIAMETER
CONDUCTOR : 558.8mm (22")
DRILLING : 444.5mm (17-1/2")

PIPE DIAMETER
CONDUCTOR : 508.0mm (20")
SCREEN : 318.5mm (12")
CASING : 318.5mm (12")

List of Wells and Intake Pumps
(Lluta / Arica)

Well No.	Ground Level	Well Depth	Well Yield	Pump Power
1	+ 131 m	150 m	25 l/sec	40 Kw
2	+ 136 m	150 m	25 l/sec	35 Kw
3	+ 145 m	150 m	25 l/sec	35 Kw
4	+ 150 m	150 m	25 l/sec	35 Kw
5	+ 149 m	150 m	25 l/sec	30 Kw
6	+ 156 m	150 m	25 l/sec	30 Kw
7	+ 164 m	150 m	25 l/sec	30 Kw
8	+ 172 m	150 m	25 l/sec	25 Kw
9	+ 180 m	120 m	25 l/sec	35 Kw
10	+ 188 m	120 m	25 l/sec	35 Kw
11	+ 196 m	120 m	25 l/sec	35 Kw
12	+ 205 m	120 m	25 l/sec	35 Kw
13	+ 213 m	120 m	25 l/sec	35 Kw
14	+ 223 m	120 m	25 l/sec	35 Kw
15	+ 232 m	120 m	25 l/sec	40 Kw
16	+ 240 m	120 m	25 l/sec	40 Kw
17	+ 250 m	120 m	25 l/sec	40 Kw
18	+ 262 m	120 m	25 l/sec	40 Kw
19	+ 274 m	120 m	25 l/sec	35 Kw
20	+ 286 m	120 m	25 l/sec	40 Kw
21	+ 298 m	120 m	25 l/sec	35 Kw
22	+ 308 m	120 m	25 l/sec	35 Kw
23	+ 317 m	120 m	25 l/sec	30 Kw
24	+ 329 m	120 m	25 l/sec	25 Kw
25	+ 337 m	120 m	25 l/sec	25 Kw
26	+ 347 m	120 m	25 l/sec	25 Kw
	Total Pump Power = (26 pums)			880 Kw

(Note)

- Type of Pump : Submersible motor pump
- Total Intake Capacity :
  = 552.5 l/sec (Daily Maximum)
  or 425.0 l/sec (Daily Average)

Fig. D-I, 3.4 Deep Wells for Lower Lluta Scheme

< Pozos para el Esquema del Bajo Lluta >

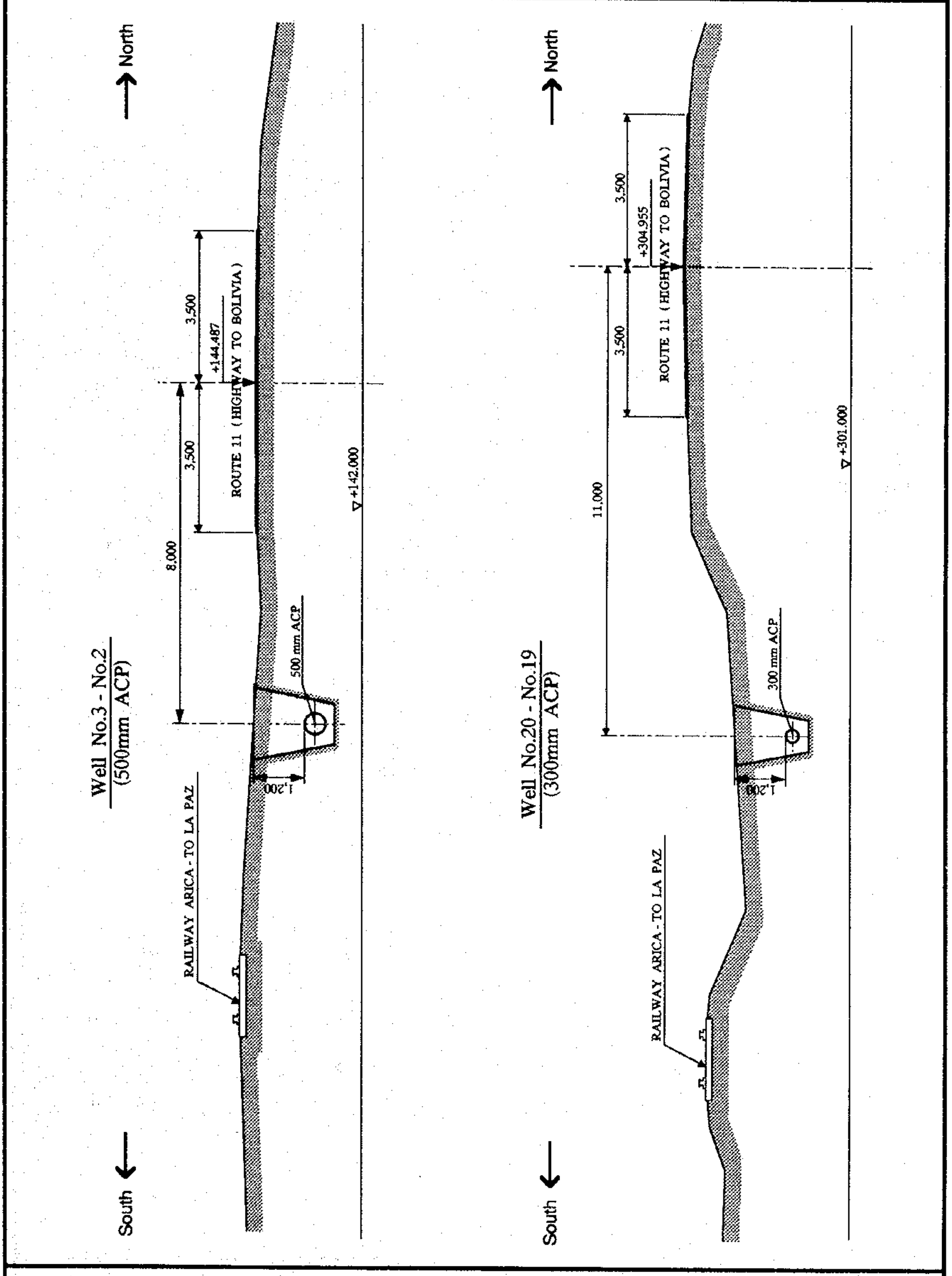


Fig. D - I, 3.5 Typical Cross Section of Pipe Installation for Lower Lluta Scheme

< Sección Típica Transversal de los Tubos para el Esquema de Bajo Lluta >

List of Break - Pressure Tanks

(Transmission Pipeline / Lower Lluta)

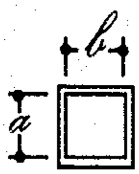
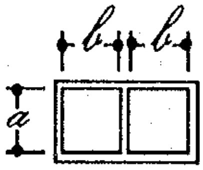
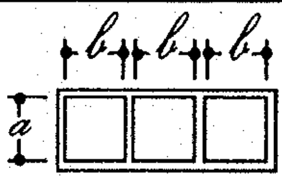
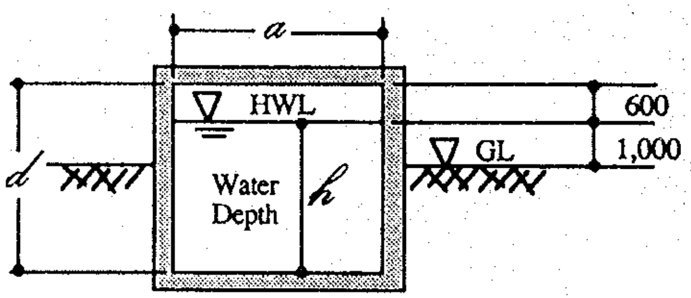
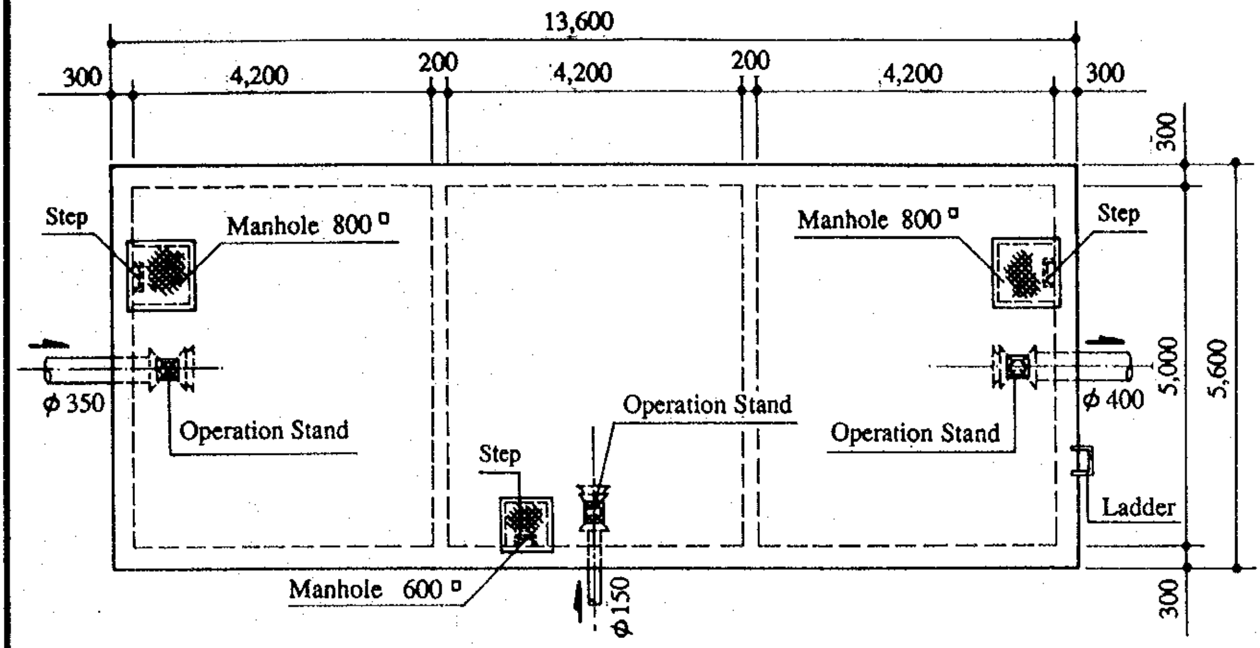
<table>
<tr><td>Tank No.</td><td>No. 1</td><td>No. 2</td><td>No. 3</td><td>No.4</td></tr>
<tr><td>Location</td><td>Well No. 26</td><td>Well No. 20</td><td>Well No. 15</td><td>Well No. 9</td></tr>
<tr><td>Distance from Rosario</td><td>L = 0 m</td><td>L = 3,000 m</td><td>L = 5,500 m</td><td>L = 8,500 m</td></tr>
<tr><td>GL (+ m)</td><td>+ 347 m</td><td>+ 286 m</td><td>+ 232 m</td><td>+ 180 m</td></tr>
<tr><td>HWL(+ m)</td><td>+ 348 m</td><td>+ 287 m</td><td>+ 233 m</td><td>+ 181 m</td></tr>
<tr><td>Flow (l/sec)</td><td>25 l/sec</td><td>175 l/sec</td><td>300 l/sec</td><td>450 l/sec</td></tr>
<tr><td>Inlet Pipe (mm)</td><td>ϕ 150 mm</td><td>ϕ 300 mm & ϕ 150 mm</td><td>ϕ 350 mm & ϕ 150 mm</td><td>ϕ 450 mm & ϕ 150 mm</td></tr>
<tr><td>Outlet Pipe (mm)</td><td>ϕ 150 mm</td><td>ϕ 300 mm</td><td>ϕ 400 mm</td><td>ϕ 500 mm</td></tr>
<tr><td>Storage Hours</td><td>10 min.</td><td>10 min.</td><td>10 min.</td><td>10 min.</td></tr>
<tr><td>Tank Capacity</td><td>15 m³</td><td>105 m³</td><td>180 m³</td><td>270 m³</td></tr>
<tr><td>Tank Plan (Horizontal Section)</td><td>
</td><td>
</td><td colspan="2">
</td></tr>
<tr><td>Cross Section of Tank</td><td colspan="4">
</td></tr>
<tr><td>Dimensions :
a : Width
b : Length
h : Water Depth
d : Tank Depth</td><td>a = 2,000
b = 2,800
h = 2,700
d = 3,300</td><td>a = 4,600
b = 4,100
2b = 8,200
h = 2,800
d = 3,400</td><td>a = 5,000
b = 4,200
3b = 12,600
h = 2,900
d = 3,500</td><td>a = 6,000
b = 5,000
3b = 15,000
h = 3,000
d = 3,600</td></tr>
<tr><td>Land Area</td><td>9.4 m x 8.6 m
= 81 m²</td><td>15.0 m x 11.2 m
= 168 m²</td><td>22.6 m x 15.0 m
= 339 m²</td><td>25.0 m x 15.6 m
= 390 m²</td></tr>
</table>

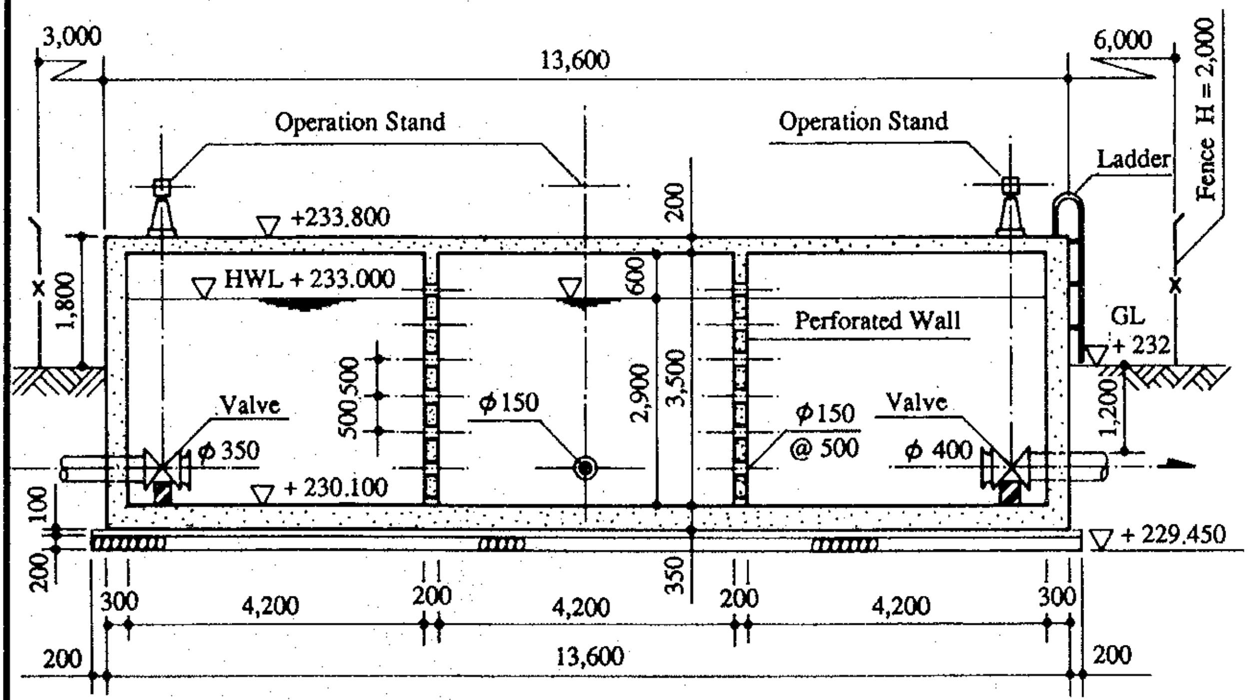
Fig. D-I, 3.6 Break - Pressure Tanks for Lower Lluta Scheme

< Estanques Corta - Presión del Esquema del Bajo Lluta >



Break - Pressure Tank No.3 - Plan

Scale = 1/100



Break - Pressure Tank No.3 - Elevation

Scale = 1/100

Fig. D-I, 3.7 Standard Design of Break - Pressure Tank for Lower Lluta Scheme

< Diseño Estandar del Estanque Corta - Presión para el Esquema del Bajo Lluta >

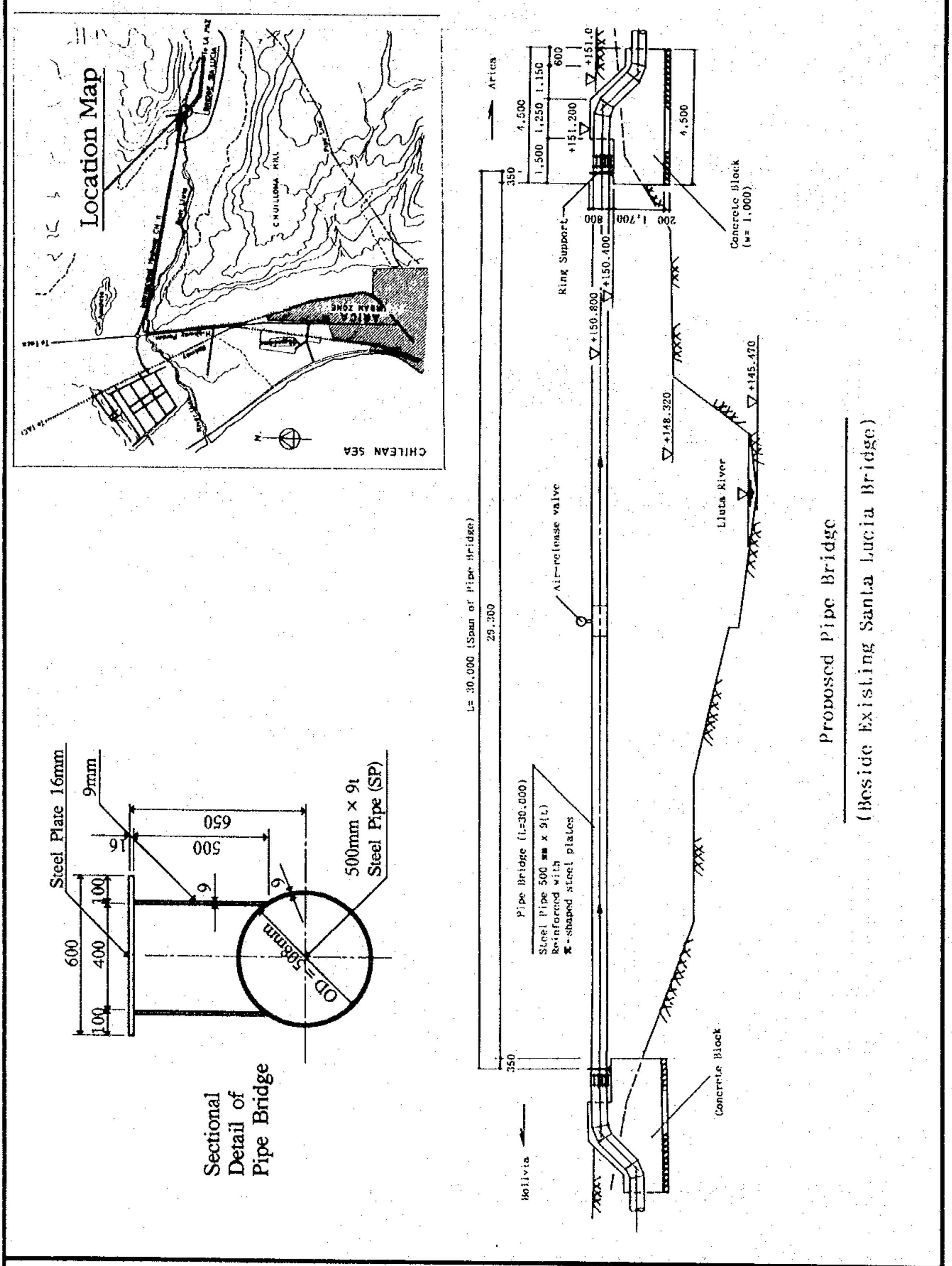


Fig. D - I, 3.8 Pipe Bridge for Transmission Pipeline
< Puente de Tubos para las Tuberías de Transmisión >

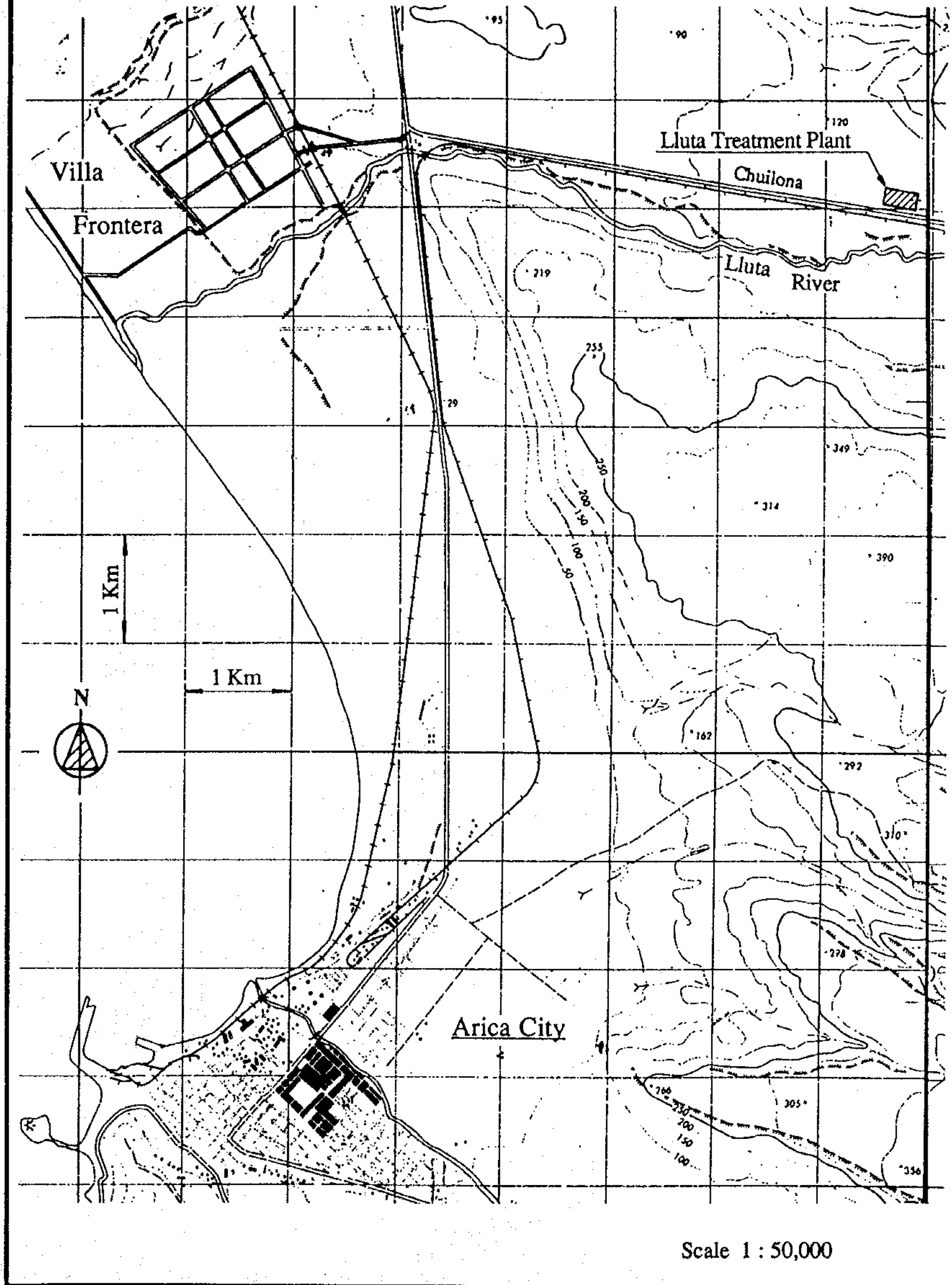


Fig. D-I,3.9 Location of Lluta Treatment Plant

< Localización de Planta Tratamiento del Lluta >

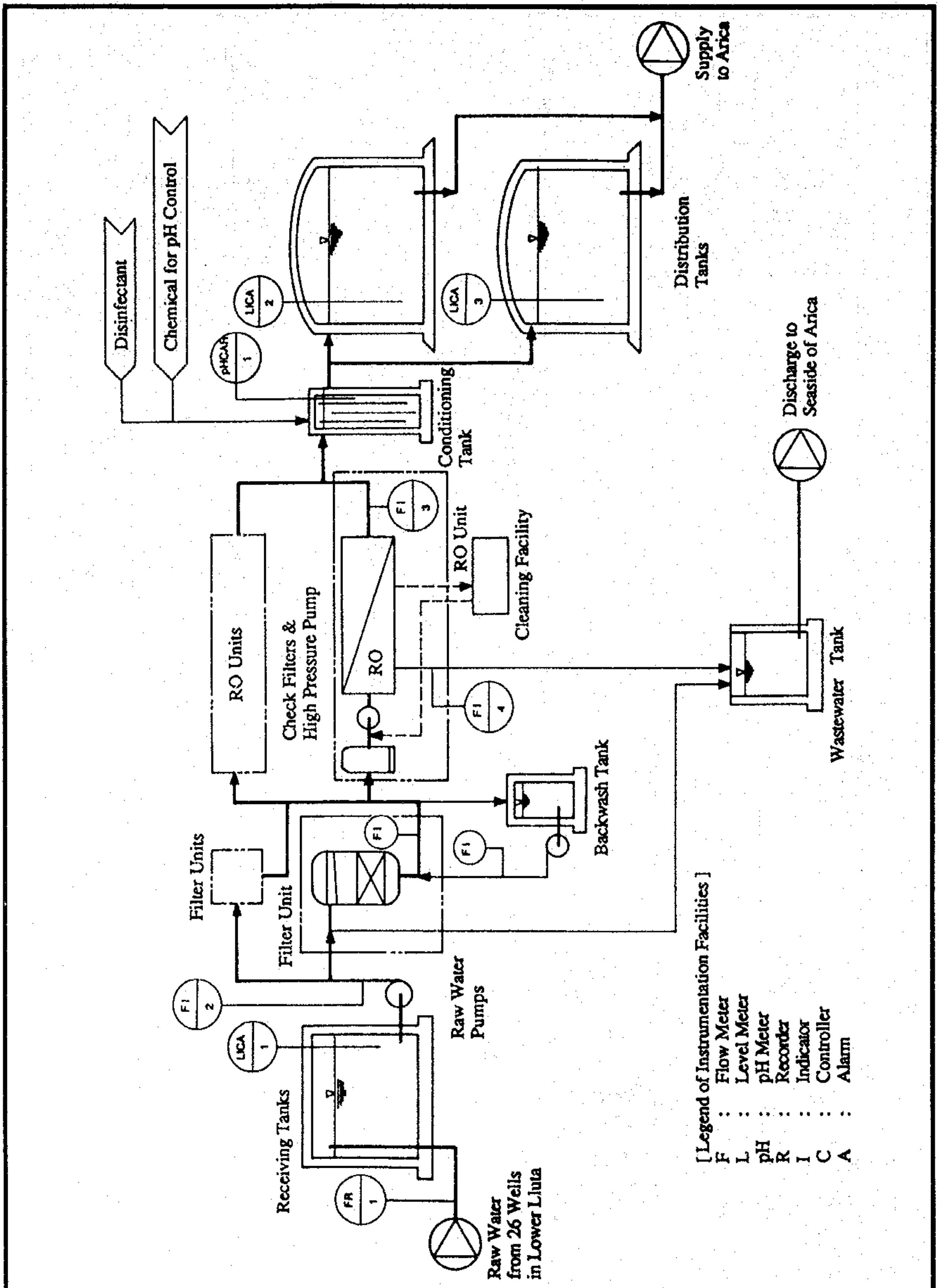


Fig. D-I,3.10 Flow Diagram of Lluta Treatment Plant

< Diagrama Flujo de Planta Tratamiento del Lluta >

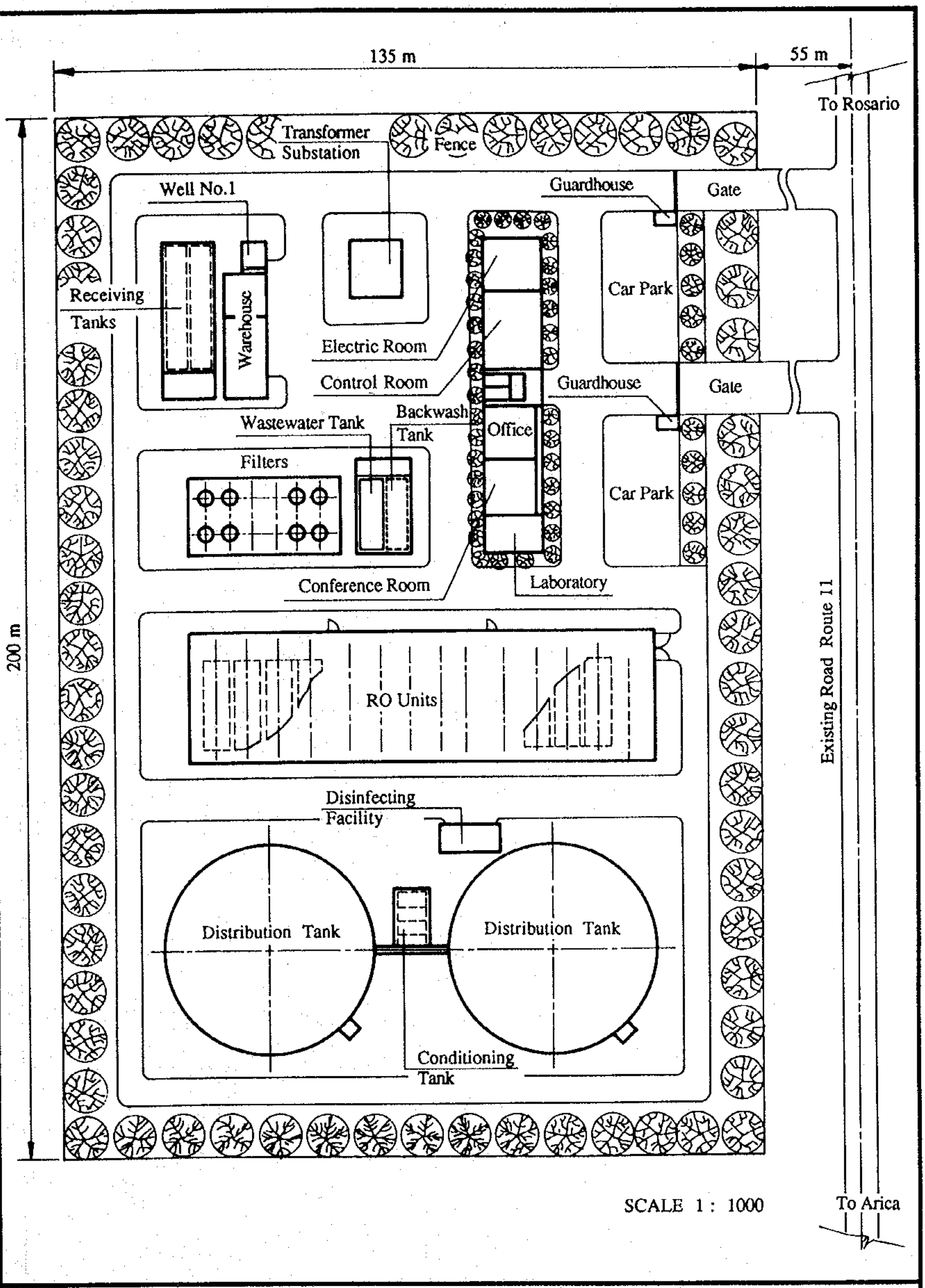
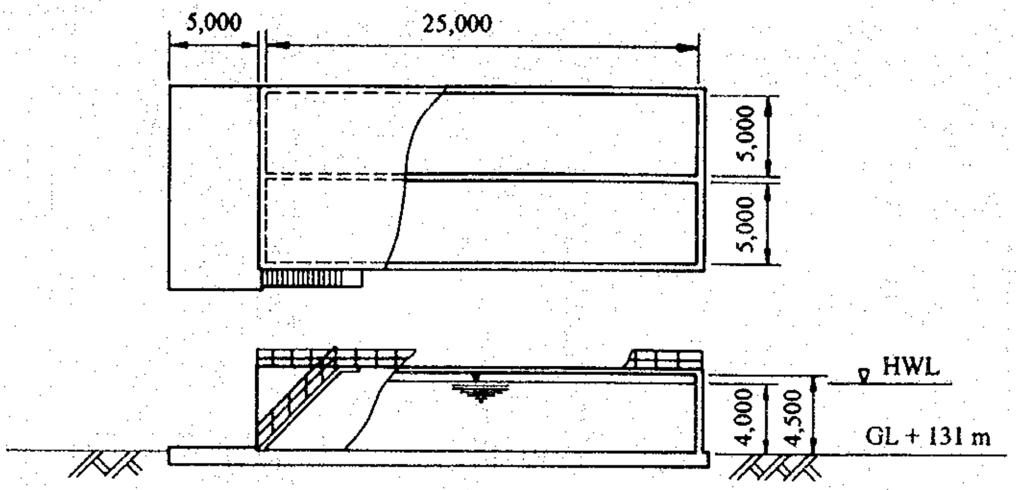
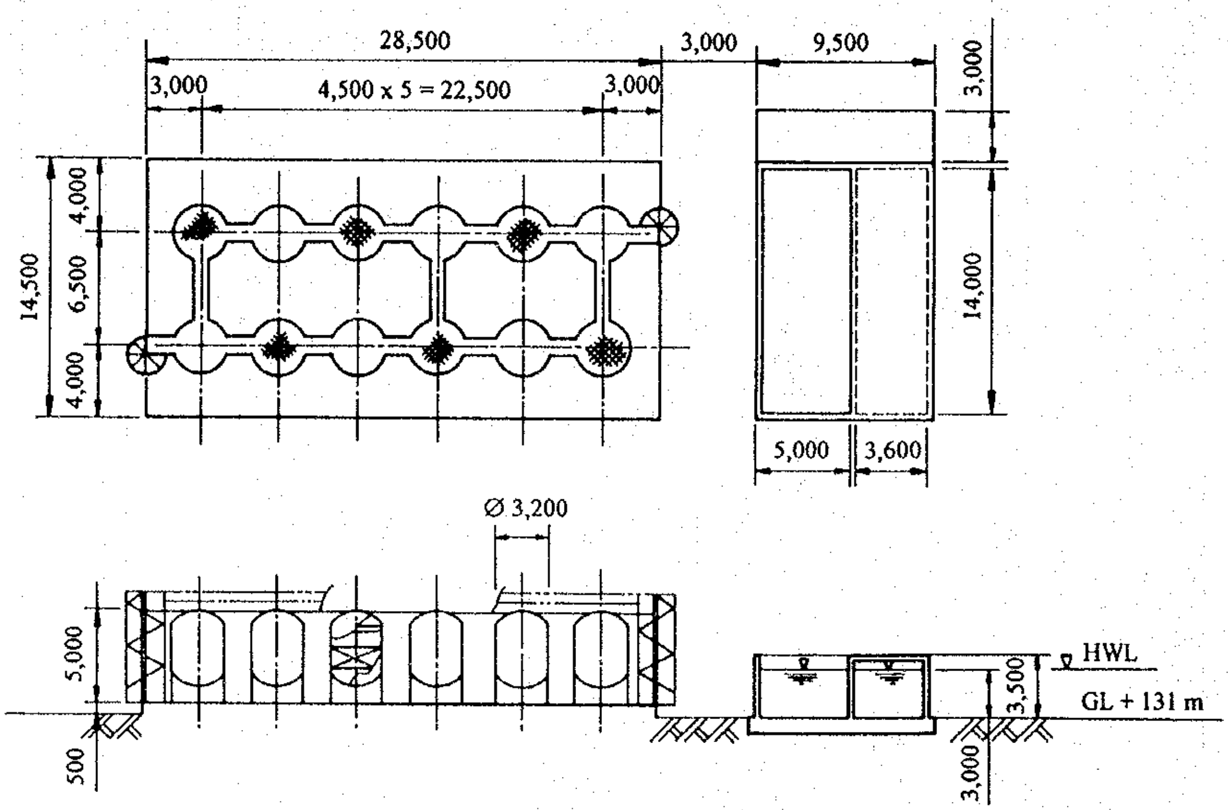


Fig.D-I,3.11 Layout of Lluta Treatment Plant

< Plano de Planta Tratamiento del Lluta >



Receiving Tanks



Filters and Wastewater Tank and Backwash Tank

Scale 1 : 400

Fig. D-I,3.12 Detail Layout of Lluta Treatment Plant (1/2)

< Detalle Plano Planta Tratamiento del Lluta (1/2) >

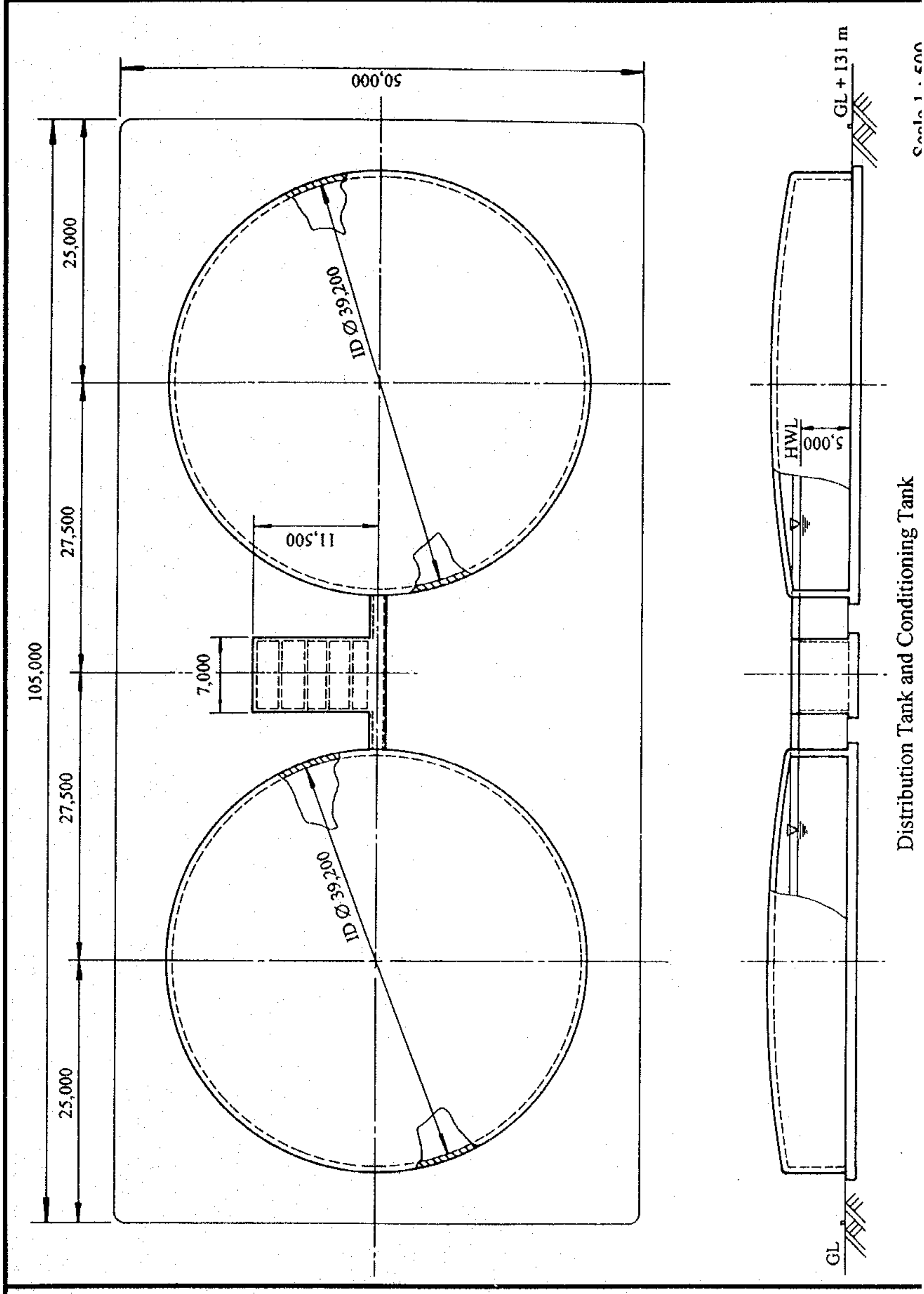


Fig. D-I,3.13 Detail Layout of Lluta Treatment Plant (2/2)

< Detalle Plano Planta Tratamiento del Lluta (2/2) >

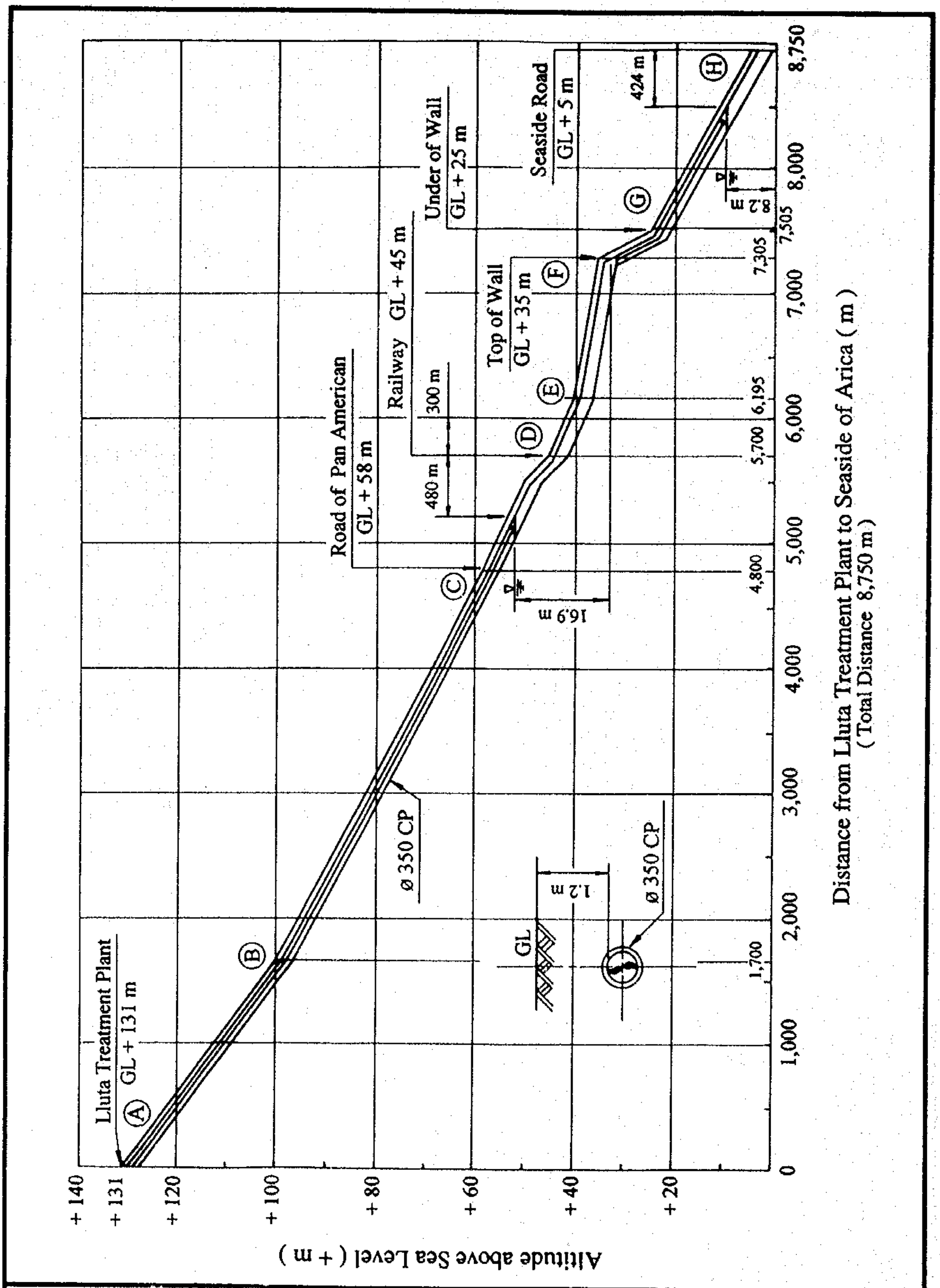


Fig.D-I,3.14 Longitudinal Profile of Wastewater Pipeline from Lluta Treatment Plant

< Perfil Hidraulico de Tuberia de Aguas Residuales Desde la Planta de Tratamiento del Lluta >

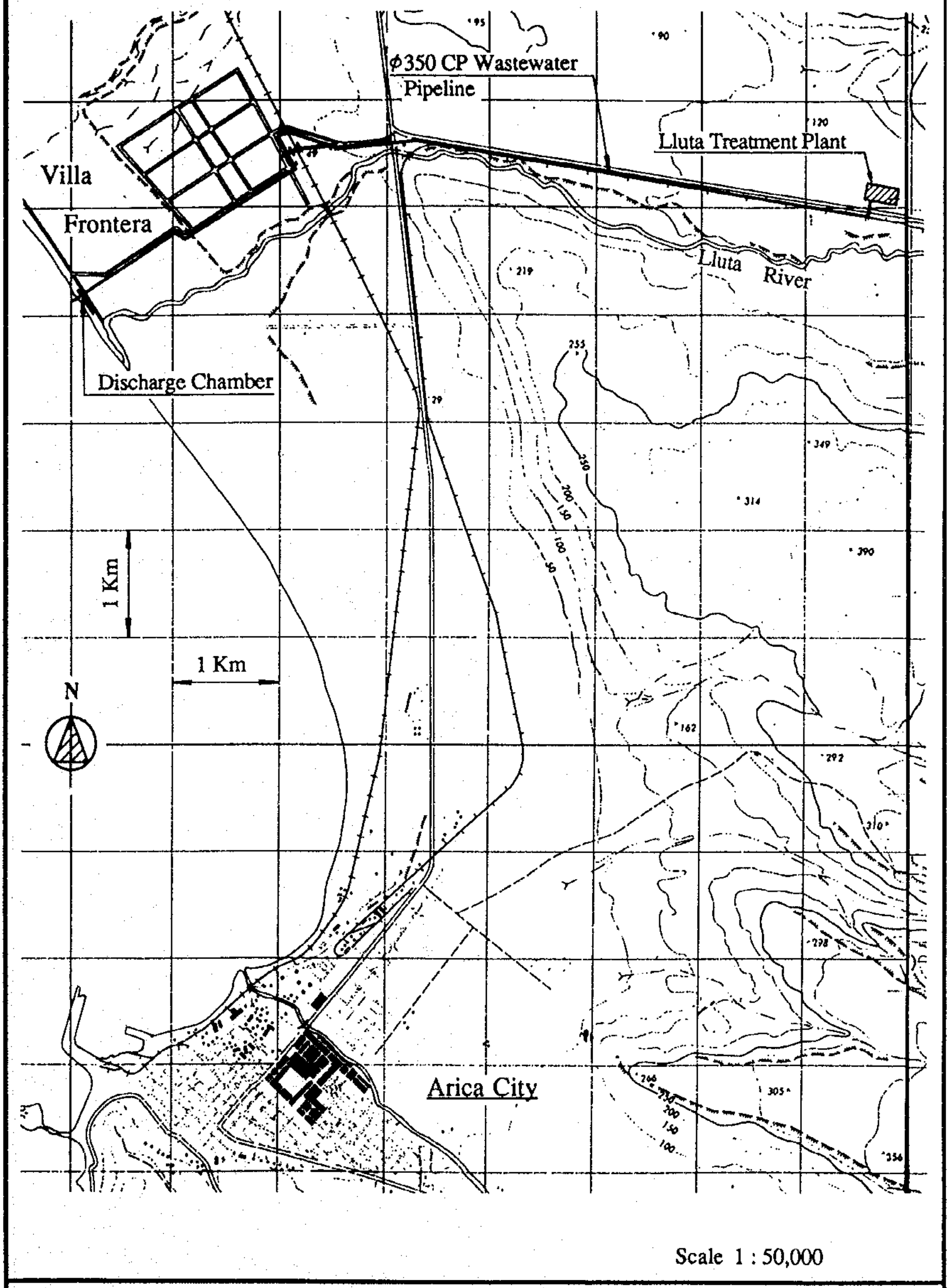


Fig.D-I,3.15 Wastewater Pipeline Route from Lluta Treatment Plant to Seaside of Arica

< Ruta de Tuberia de Aguas Residuales Desde la Planta de Tratamiento del Lluta Hasta la Costa de Arica >

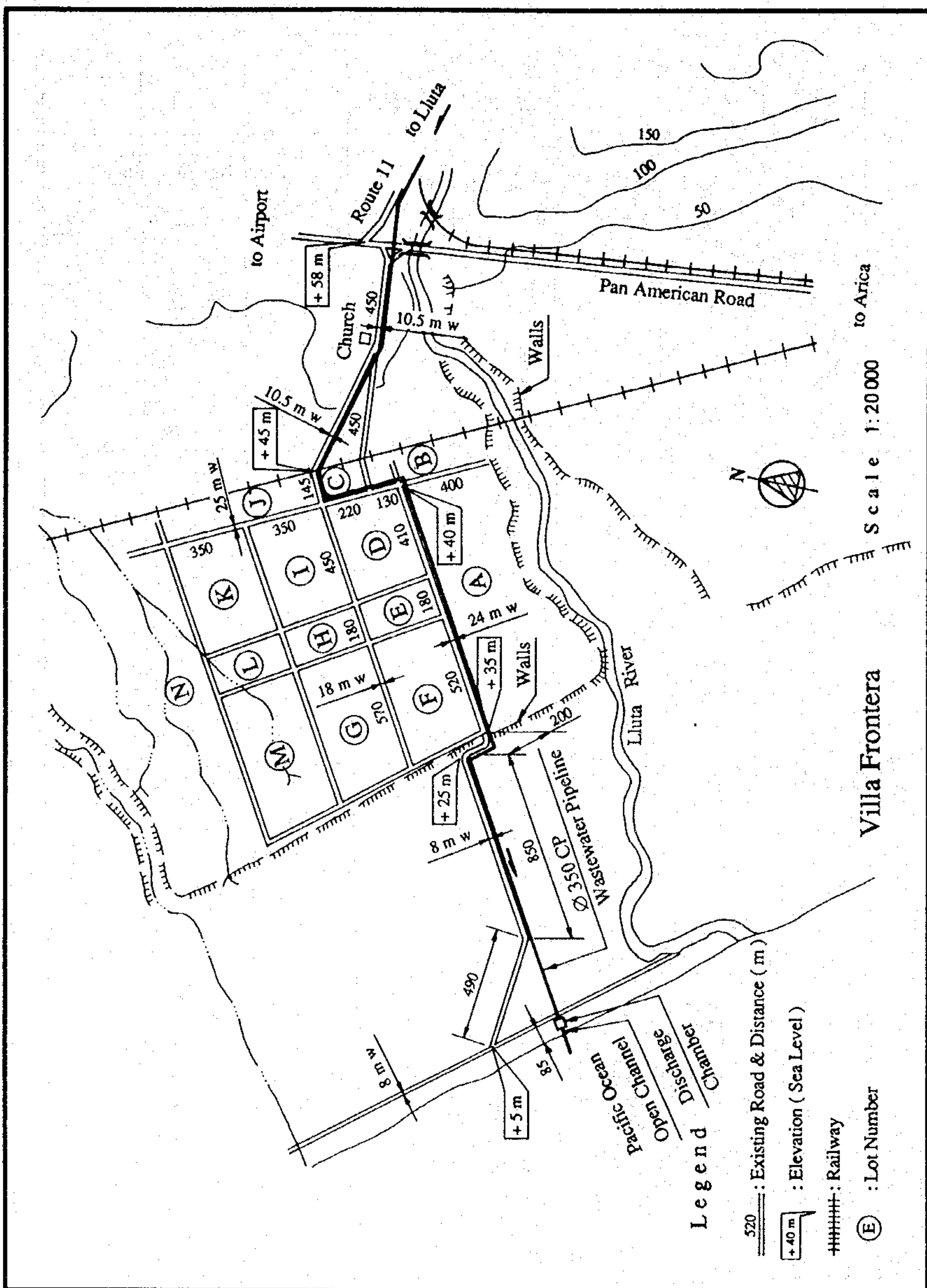
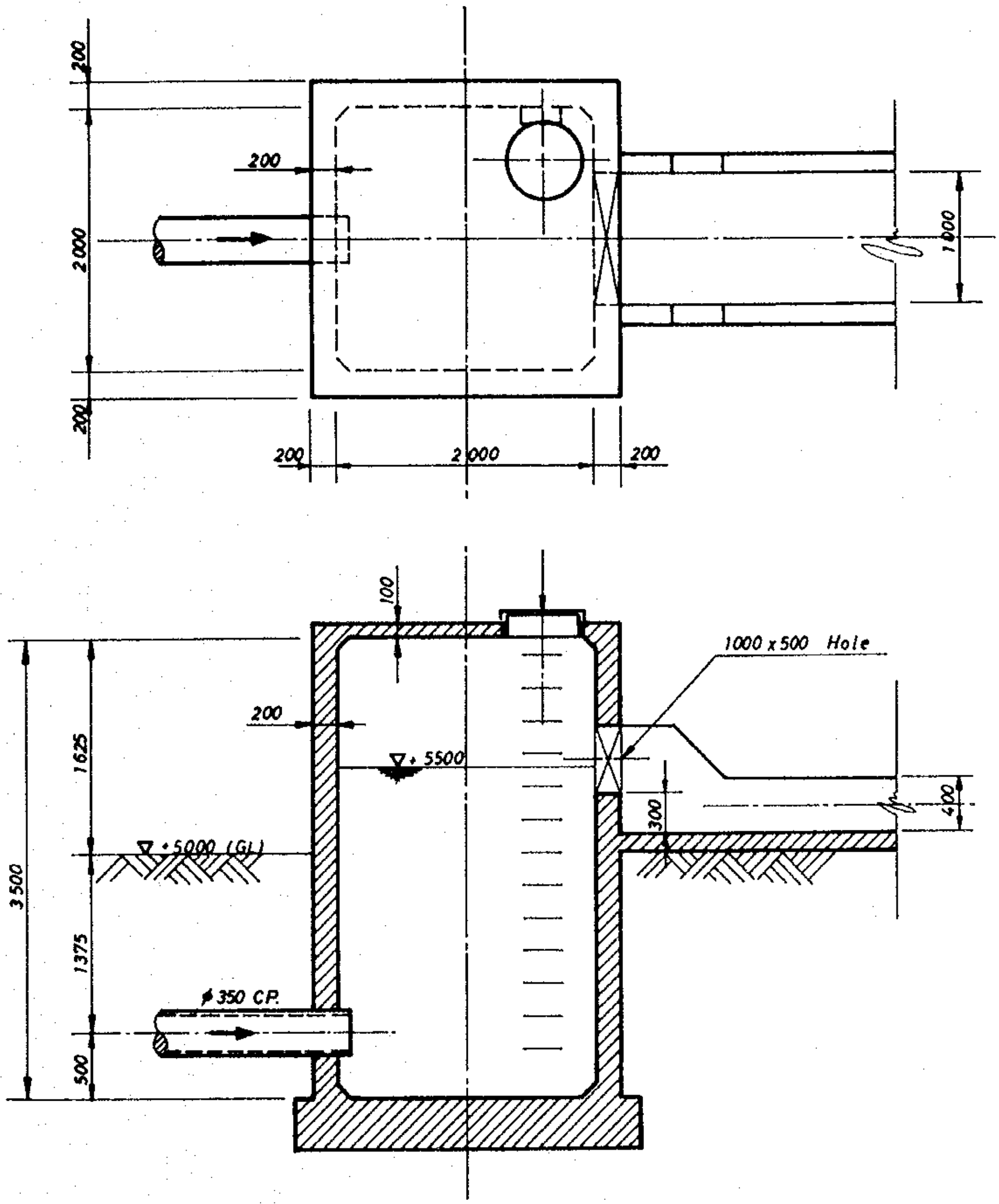


Fig. D-I,3.16 Detail Wastewater Pipeline Route from Lluta Treatment Plant in Villa Frontera

< Detalle de Ruta de la Tuberia de Aguas Residuales Desde la Planta de Tratamiento del Lluta en Villa Frontera >



Scale = 1 : 50

Fig. D-I,3.17 Discharge Chamber of Wastewater to Seaside of Arica

< Camara de Descarga de Aguas Residuales Hacia la Costa de Arica >

D-II IQUIQUE CITY

D-II. IQUIQUE CITY

Chapter I. EXISTING WATER SUPPLY SYSTEM

1.1 Water Supply System

1.1.1 Outline of the System

The existing public water supply system for Iquique City, operated and maintained by a semi-governmental organization, ESSAT (Tarapaca Sanitary Services Enterprise), which also maintains the Arica system, is outlined below:

[Groundwater] --> [Deep Well Pump] --> [Intake Pipeline] --> [Collection Tank]

--> [Transmission Pump] -> [Transmission Pipeline/Tank] --> [Distribution Tank]

--> [Consumers]

The water source is groundwater, submerged in Pampa del Tamarugal. The groundwater is extracted from deep wells located in Canchones area, about 70 km east of Iquique, by submersible pumps installed in each well.

The water extracted from the wells is first transmitted through an intake pipeline to a collection tank located at approximately the center of the well-field in Canchones. The raw water is then pumped from the Canchones Pumping Station (Ground level: GL =+1,013 m above sea level) to the Rinconada Tank (33 km from Canchones) located at the highest peak (GL=+1,155 m) on the transmission pipeline route. On the way to the Rinconada Tank, the raw water is once boosted at the Diana Tank/Pumping Station (GL=+1,038 m). From the Rinconada Tank, the water flows by gravity to the Cavancha Tank (42.2 km from the Rinconada Tank) located on a eastern hill (GL=+114 m) of Iquique City. Along the route from Rinconada to Cavancha, there are 3 tank stations located at strategically important locations for the purposes of reducing the operating pressure and storage of water. They are the Carpas Tank (GL=+978 m; Distance =26.8 km from Rinconada), The Santa Rosa Tank (+682 m; 32.6 km) and the Alto Hospicio Tank (+545 m; 39.3 km).

In Cavancha, the water is sterilized by adding hypo-chlorite. The chlorinated water is then supplied from the distribution tanks (GL=+114 m) by gravity through the distribution networks to the consumers in the city.

1.1.2 Area and Population Served

The existing water supply system covers about 2,160 ha of Iquique City, serving almost the entire population of the city. The total population was 152,500 in 1992, as per the preliminary census results.

The number of service connections registered was 38,843 as of Dec. 1993. The number of connections added during a period of one year from Dec. 1992 to Dec. 1993 was 2,049.

A sketch of the existing water supply system is shown in Figs. D-II,1.0, D-II, 1.1 and D-II, 1.2.

1.1.3 Water Production and Consumption

The rate of water production, consumption by category and losses in 1992 are summarized as follows:

	1992 Quantity ($x1,000\ m^3$)	%
Production	17,241.2 (=47,240 m^3/d=547 l/sec)	
Consumption	10,821.7	100
- 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% of production)	

(Note): The water losses indicated above consist of physical leakage and commercial losses, including the unbilled water consumption occurring in the residential category as a result of meters in poor operating conditions and illegal connections.

The above production, 547 l/s on average was obtained from 12 deep wells (plus 2 emergency wells) in Canchones area which yield 630 l/sec at the maximum. ESSAT is planning to develop the wells to extract additional 50 l/sec in 1994, making a total maximum production rate of 680 l/sec (=58,750 m3/day).

Thus, the per capita water production and consumption on capacity basis in 1992 and 1994 are estimated as follows:

Year	1992	1994
(A) Production capacity of deep wells	630 l/sec = 54,430 m^3/day	680 l/sec = 58,750 m^3/day
(B) Population served	152,529 (Census)	160,900 (growth rate 2.7% per annum)
(C) Per capita water use		
(1) Production basi	357 l/day	365 l/day
(2) Total consumption basis	224 l/day	229 l/day
(3) Residential consumption basis	177 l/day	180 l/day

Note: (1)=A/B
(2)=(1)x62.8%
(3)=(2)x78.8%

1.1.4 Present Problems

Technical problems in the present water supply for Iquique are summarized as follows:

1) Water Quality

The groundwater, which is currently extracted from the deep wells in Canchones area in Pampa del Tamarugal, contains higher concentration of manganese (Mn) and arsenic (As) than the allowable limits of the Chilean Drinking Water Standard (NCH 409: Mn<0.1 ppm and As<0.05 ppm).

The groundwater in the twelve existing deep wells in Canchones, usually contains 0.3-2.0 ppm of Mn. The water mixed in the collection tank presents about 0.5 ppm of Mn on average. The raw water is pumped from Canchones to Iquique, without undergoing any treatment process, through long-distance pipelines. Owing to the length of the transmission pipelines and the existence of many storage tanks along the route, Mn is oxidized by aeration and the manganese oxide is piled on the bottom of the tanks and adhered to the inside walls of the pipelines. As the distance of the pipelines is so long, 72.1 km, the aeration-mixing time is large enough, about 12 hours or more, and the areas of pipe walls and tanks available for manganese oxide to adhere to is also large enough. Thus, concentration of Mn decreases to the allowable level of 0.1 ppm; less than 0.05 ppm at the Cavancha distribution tank located near the city.

However, the problem exists in the pipe cleaning work as well as the tank cleaning. In some parts of the pipelines, 10-13 mm thick layer of manganese oxide is present in the inner surface of the pipe.

To solve the above problem and to improve water quality, the construc-tion of a treatment plant would be necessary in future.

In addition, the groundwater contains 0.03-0.08 ppm of As, and at present no treatment is carried out to remove excessive As. Fortunately, concentration of As decreases along the transmission pipelines to the allowable level of 0.05 ppm; about 0.03-0.04 ppm at the Cavancha tank, similar to the case of Mn. The reason of As reduction may be owing to aeration; and also due to the entanglement of As particles with Manganese oxide.

Also from the viewpoint of reduction of As concentration, the construc-tion of a treatment plant would be required in future.

2) Water Source

The groundwater in Canchones, the present water source in the area is already fully developed. Therefore, in order to meet the future demand, a new water source needs to be developed in places other than Canchones.

3) Power Cost

One of the most remarkable issues in the operation of the present Iquique water supply system is the huge power consumption cost required for the operation of transmission pumps (1,800 kW at Canchones station including intake pumps, and 1,500 kW in Diana station).

The cost is equivalent to about a half of the total operation and maintenance cost of the Iquique system (annual expense for the system).

At present, it seems to be technically inevitable to avoid this cost. However, this is a critical issue which needs to be addressed.

4) Water Loss

The water loss in the system was comparatively higher; about 37.2% of the total production in 1992.

This situation is just same as that of the Arica system (37.2% in 1992); thus, for this subject, the same countermeasures described in Section 1.1.4 in D-I of this Report should be followed.

1.2 Water Supply Facilities - Iquique

1.2.1 Deep Wells and Intake Pumps (Canchones)

There were 12 deep wells for the public water supply system for Iquique City, as of the end of 1993. They are located at Canchones (about 75 km from Iquique) in Pampa del Tamarugal. The details of wells are; depth 96-120 m, casing pipe diameter 400 mm, and yields 50-83 l/sec (70 l/sec on average). All wells are equipped with submersible pumps, capacity of which is 60-120 l/sec in discharge, 55-140 m in total head and 55-75 kW in motor power. The electric power for all the pumps is supplied by a public electric enterprise (ELIQSA). The groundwater extracted from the deep wells is raised up by the submersible pumps to a collection tank through intake pipelines.

All the existing deep wells are listed in Table D-II, 1.1 and the details of the submersible intake pumps are given in Table D-II, 1.2.

The layout of the well-field is shown in Fig. D-II, 1.3, a typical well structure is sketched in Fig. D-II,1.12 and a typical layout of the intake pump is shown in Fig. D-II,1.13.

(Note): In addition to the above 12 deep wells, there are two (2) wells for emergency purposes. They are located along the route of the transmission pipeline from Canchones to the Diana tank.

1.2.2 Collection Tanks (Canchones)

The groundwater extracted from the wells, first flows into a collection tank which collects all the water and serves as a temporary water storage. There are two (2) collection tanks in the Canchones Station located near the deep wells.

The details of the Canchones Station are given below:

- Name of the tank:	Canchones Collection Tank
- Location:	Canchones in Pampa del Tamarugal
- Ground altitude:	GL=+1,013 m above sea level
- Water inlet/outlet:	From 12 deep wells/ to Diana Tank
- Number of tanks:	Two (2)

- Construction material: Steel
- Water level: HWL =+1,018.15 m
- Capacity: 1,000 m^3 each
- Total capacity: 1,000 x 2 = 2,000 m^3

From the collection tanks, the water is transmitted to the Diana tank (GL=+1,038 m; HWL=+1,041.9 m; 29.9 km away from Canchones), by the transmission pumps installed in the Canchones Station.

The layout of the collection tanks is shown in Fig. D-II, 1.3.

1.2.3 Transmission Pumps (Canchones)

The water stored in the collection tanks of Canchones is transmitted towards Iquique City, situated about 75 km away from Canchones. The altitude at Canchones is +1,013 m and that of Iquique City is less than +100 m. The difference of the altitude between Canchones and Iquique City is so big, about 900 m, that the water seems to be able to flow by gravity to Iquique. However, along the route from Canchones to Iquique, there is a hilly area, named Rinconada, which has an altitude of +1,155 m, 142 m higher than that of Canchones.

Thus, the water needs to be lifted to Iquique City by pumps installed in Canchones. The transmission pump house is located near the collection tanks, in the yard of the Canchones Station.

There are six (6) transmission pumps, including one or two on standby. They are double-suction volute pumps. Total power consumption is approximately 1,250 kWh, which is supplied by ELIQSA. All the pumps are listed in Table D-II,1.3.

1.2.4 Booster Pumps (Diana)

The water pumped at Canchones is not able to cross the Rinconada peak, (GL=+1,155 m; HWL=+1,159.2 m) due to technical difficulties: ie. excessive high pressure and water hammer problem in the transmission pipes. Therefore, the water pumped at Canchones is transmitted to the Diana tank (GL=+1,038 m) located close to Rinconada peak, for the purpose of boosting.

The booster pump house is located beside the Diana tank (1,000 m^3 x 2 Nos. = 2,000 m^3, steel). There are four (4) booster pumps, including one on standby. They are double-suction volute pumps. Total power consumption is approximately 1,500 kW, which is supplied by ELIQSA. All the pumps are listed in Table D-II, 1.4.

1.2.5 Transmission Tanks (Diana, Rinconada, Carpas, Santa Rosa and Alto Hospicio)

There are five (5) transmission tank stations between Canchones and Iquique City (Cavancha Distribution Tank). They are located at i) Diana, ii) Rinconada, iii) Carpas, iv) Santa Rosa and v) Alto Hospicio. Major functions of these tanks are to reduce high pressure and regulate water levels in the transmission pipelines, as well as store the water. Therefore, they are located on technically strategic places.

The tanks are made of either steel or reinforced concrete and are located slightly below the ground level. Their storage capacity is 37,700 m^3 in total, which is equivalent to more than a half a day's demand of Iquique City. These transmission tanks are listed in Table D-II,1.5 and layout of the tank stations are shown in Figs. D-II,1.4 to 1.8.

1.2.6 Distribution Tanks (Cavancha, Norte and Las Dunas)

There are three (3) distribution tank stations for Iquique City. All those tanks were made of steel or reinforced concrete and are located slightly below the ground level, on the eastern side hills in the vicinity of the city.

There are tanks at i) Cavancha, ii) Norte and iii) Las Dunas. Among them, the Cavancha tank is the largest one, having a capacity of 27,000 m^3; about 90% of the total storage volume (30,000 m^3) and equivalent to about 12 hours of supply capacity.

The raw water flows from the Alto Hospicio transmission tank by gravity to the Cavancha distribution tank, Iquique City. The water required for the Norte tank is supplied from the Cavancha tank and that for the Las Dunas tank is obtained from the transmission pipelines.

The water is chlorinated by using hypo-chlorite at the Cavancha tank or at the Las Dunas tank. The chlorinated water is supplied to the consumers in Iquique City by gravity from the distribution tanks, through the distribution networks.

The Cavancha tank supplies water to central Iquique, New Victoria area and sub-sectors 2 & 6. The Norte tank supplies to the industrial sector; and the Las Dunas tank supplies to sector Las Dunas. The distribution tanks are listed in Table D-II,1.6, and layout of the Cavancha tank is shown in Fig. D-II,1.9. The standard structure of the collection and distribution tanks is shown in Fig. D-II, 1.14.

1.2.7 Transmission Pipelines (Canchones - Cavancha)

The Cavancha tank (major distribution tank) in Iquique City and the Canchones tank (water source) in Pampa del Tamarugal are connected by a transmission pipeline approximately 75.2 km long. There are two (2) pipelines in parallel installed between them, the old one and the new, along majority of the route. The old pipeline (600 mm diameter in majority, and made of steel: SP) was installed in 1960 when the Canchones water source was first developed.

In order to meet the increasing demand of Iquique, a new pipeline (800 mm diameter in majority and made of ductile iron: DIP) was installed during 1981-82. The duplicated main was placed along the same route, in parallel with the old. There is a road constructed for the purpose of the pipeline maintenance, along the pipelines.

The capacity of the two pipelines is about 700 l/sec (480 l/sec for the new pipeline and 220 l/sec for the old one). The water is pressurized by pumps between Canchones and Rinconada, about 33 km in length; afterward, it flows by gravity from Rinconada to Cavancha, about 42.2 km. The hydraulic parameters for the transmission pipeline from Canchones to Cavancha are listed in Table D-II,1.8.

A longitudinal profile of the pipelines is shown in Fig D-II,1.10; line diagrams are given in Fig. D-II,1.11. The pipelines are listed in Table D-II,1.7, including span, diameter and material.

Table D-II, 1.1 List of Deep Wells - Iquique/ESSAT

Well No.	Location	Altitude above sea level (+ m)	Year of Constuction	Casing Diameter (mm)	Well Depth (m)	Total Screen Length (m)	Well Yield (l /sec)	Static Water Level (m)	Dynamic Water Level (m)	Water Level Drawdown (m)	Depth of Pump Installed (m)	Remarks
A	Canchones		1960	400	110		70	18	28.9	10.9	60	poor water quality
D	Canchones		1960	400	98		79	32	42	10	60	poor water quality
E	Canchones		1960	400	107		40	34.5	43.4	8.9	54	
F	Canchones		1960	400	102		68.3	31.4	47.74	16.64		
G	Canchones		1960	400	96		83	26.5	33.82	7.32		
I	Canchones		1960	400	105		61.3	33.2	42.99	9.79		poor water quality
1	Canchones		1982	400	110		53.4	33	52.9	19.9		
2	Canchones		1982	400	110		82.9	31.1	35.8	4.7	64	
3	Canchones		1982	400	110		57.3	30.2	49.8	19.6		
4	Canchones		1987	400	120		56.5	14.5	48.8	34.3		
5	Canchones		1989	400	120		60.3	23.1 ?	45.2	22.1		
6	Canchones		1989	400	120		70	?	34.6			
7	Canchones		1989	400	120		50	13.7 ?	46.3	32.6	71.5	
494	Cuminalla		1960	400	100		60	12.3				

Table D-II, 1.2 List of Intake Pumps - Iquique/ESSAT

Well No.	Flow Direction	Type of Pump	Year of Installation	Technical Specification of Pump			
				Diameter (mm)	Discharge (l / sec)	Total Head (m)	Ele. Power (KW)
A/Canchones	To Canchones Collection Tank	Submsersible			80	55	55
D/Canchones	To Canchones Collection Tank	Submsersible			90	60	75
E/Canchones	To Canchones Collection Tank	Submsersible			80	65	75
F/Canchones	To Canchones Collection Tank	Submsersible			120	62	
G/Canchones	To Canchones Collection Tank	Submsersible			90	80	
I/Canchones	To Canchones Collection Tank	Submsersible			100	75	
1/Canchones	To Canchones Collection Tank	Submsersible			60	120	
2/Canchones	To Canchones Collection Tank	Submsersible			60	140	
3/Canchones	To Canchones Collection Tank	Submsersible			80	54	
4/Canchones	To Canchones Collection Tank	Submsersible			?	?	
5/Canchones	To Canchones Collection Tank	Submsersible			?	?	
6/Canchones	To Canchones Collection Tank	Submsersible			?	?	
7/Canchones	To Canchones Collection Tank	Submsersible			75	55	63
494/Cuminalla	To Transmission Pipeline	Submsersible			60	140	

Table D-II, 1.3 List of Transmission Pumps - Iquique/ESSAT

Name of Pump Station	Pump No.	Type of Pump	Year of Installation	Technical Specification of Pump				Name of Manufacturer and Model Number	Remarks
				Diameter (mm)	Discharge (l / sec)	Total Head (m)	Ele. Power (kW)		
Canchones Transmission Pumps (to transmit to Diana Tank)	No. 1	Duble-Suction Volute Pump	1994	490	220	90	250	Pump : KSB/2DL 250-500A Motor : ASEA/MBV 355MA	
	No. 2	Duble-Suction Volute Pump	1994	490	220	90	250	Same as above	
	No. 3	Duble-Suction Volute Pump	1994	490	220	90	250	Same as above	
	No. 4	Duble-Suction Volute Pump	1994	490	220	90	250	Same as above	
	No. 5	Duble-Suction Volute Pump	1962		105			Pump : KSB/WK200 Motor : AEF/A250c4A	Standby
	No. 6	Duble-Suction Volute Pump	1962		105			Pump : KSB/WK200 Motor : AEF/A250c4A	Standby

Table D-II, 1.4 List of Booster Pumps - Iquique/ESSAT

Name of Pump Station	Pump No.	Type of Pump	Year of Installation	Technical Specification of Pump				Name of Manufacturer and Model Number
				Diameter (mm)	Discharge (l / sec)	Total Head (m)	Ele. Power (KW)	
Diana Booster Pumps	No. 1	Dubie-Suction Volute Pump	1989	590	240	127	500	Pump : KSB/RDLA 250
								Motor : KSB/RDLA 250
(to transmit to Iquique city via	No. 2	Duble-Suction Volute Pump	1989	590	260	125	500	Pump : KSB/RDLA 250
								Motor : ASEA/MBR 400M
Rinconada Tank)	No. 3	Duble-Suction Volute Pump	1989	590	260	125	500	Pump : KSB/RDLA 250
								Motor : ABB/HXUR 808
	No. 4	Duble-Suction Volute Pump	1989	590	240	127	500	Pump : KSB/RDLA 250
								Motor : ABB/HXUR 808

Table D-II, 1.5 List of Transmission Tanks - Iquique/ESSAT

Name of Tank	Location	Flow Direction	Ground Altitude above sea level (+ m)	Number of Tanks	Year of Construction	Construction Material	Water Level (=+ m)	Dimension & Water Depth	Capacity (m3)	Total Capacity (m3)	Remarks
1) Diana	29.9 Km from Canchones	From Canchones by pump and to Rinconada by pump	+ 1,037	2		Steel	HWL= + 1,041.85 LWL= +		1,000 ×2	2,000	
2) Rinconada	3.2 Km from Diana	From Diana by pump, and to Carpas by gravity	+ 1,155	2		Steel	HWL= + 1,159.2		6,000	11,000	
					1982	Reinf. Concrete	LWL= +		5,000		
3) Carpas	23.6 Km from Rinconada	From Rinconada by gravity, and to Santa Rosa by gravity	+ 978	3		Steel		15.50m diam. ×	900 ×3	2,700	Demolished in 1993 due to foundation fault
4) Santa Rosa	5.8 Km from Carpas	From Carpas by gravity, and to Alto Hospicio by gravity	+ 696.2	2		R. Concrete		42.40m diam.	10,000	15,000	
						R. Concrete		33.40m diam.	5,000		
5) Alto Hospicio	6.8 Km from Santa Rosa	From Santa Rosa by gravity, and to Cavancha by gravity	+ 554.9	2		R. Concrete		32.54m diam.	5,000	7,000	
						R. Concrete		22.50m diam.	2,000		
									Total Capacity = 37,700 m³		

Table D-II, 1.6 List of Distribution Tanks - Iquique/ESSAT

Name of Tank	Location	Flow Direction	Ground Altitude above sea level (+ m)	Number of Tanks	Year of Const-ruction	Construction Material	Water Level (=+ m)	Dimension & Water Depth	Capacity (m3)	Total Capacity (m3)
1) Cavancha Tank	Iquique : Intersection of Tadeo Haenke Av. and La Tirana Av.	From Alto Hospicio Tank, and to city by gravity	+ 114	2		Reinforced Concrete		D = 22.0m h = 6.3m	4,000 ×2 = 8,000	27,000
				8		Steel			2,375 ×8 = 19,000	
2) Norte Tank	Iquique Access	From Cavancha Tank by gravity, and to city north		1		Reinforced Concrete		D = 22.0m h = 6.3m	2,000	2,000
3) Las Dunas Tank	Dragon hill	From Alto Hospicio Tank by gravity	+ 134.5 + 150.0	3		Reinforced Concrete			500 ×3	1,500
4) Sur Tank	Southern of Dragon hill	From Altos Hospicio Tank, and to city south	+ 250.0	1	1992	Reinforced Concrete	+ 254.7	D = 19.6m h = 6.0m	1,500	1,500
5) Chipana Tank	Northern of Dragon hill	From Alto Hospicio Tank, and to city south	+ 170.0	1	1992	Reinforced Concrete	+ 175.0		300	300
									Total Capacity	= 32,300 m³

Table D-II, 1.7 List of Transmission Pipelines - Iquique/ESSAT (No. 1)

Site Name of Pipeline		Type of Flow	Design Flow (l / sec)	Year of Construction	Diameter (mm)	Distance (m)	Pipe Material (SP : Steel) (DIP : Ductile Iron)	Valves & fittings	Remarks
From Canchones (AO) To Diana (BO)	AO - A1	Pumped	700	1960	700	190	SP		
	A1 - A2	Pumped	224	1960	700	2,721	SP		
	A2 - A3	Pumped	224	1960	600	810	SP		
	A3 - A4	Pumped	224	?	600	933	SP with mortar lining		
	A4 - BO	Pumped	224	1960	600	25,202	SP		
	A1 - BO	Pumped	476	1982	800	29,690	DIP		
From Diana (BO) To Rinconada (CO)	BO - CO	Pumped	220	1960	600	3,120	SP		
	BO - CO	Pumped	480	1982	800	3,120	DIP		

Table D-II, 1.7 List of Transmission Pipelines - Iquique/ESSAT (No. 2)

Site Name of Pipeline		Type of Flow	Design Flow (l / sec)	Year of Construction	Diameter (mm)	Distance (m)	Pipe Material (SP : Steel) (DIP : Ductile Iron)	Valves & fittings	Remarks
From Rinconada(CO) To Carpas(DO)	C0-C1	Gravity	303	1960	550	8,365	SP		
	C1-C2	Gravity	303	1960	500	7,776	SP		
	C2-C3	Gravity	303	1960	500	3,210	SP		In parallel
					400	3,210	SP		
	C3-C4	Gravity	303	1960	400	1,000	SP		In parallel
					400	1,000	SP		
	C4-D0	Gravity	303	1960	500	6,404	SP		
	C0-C5	Gravity	397	1982	600	13,027	DIP		
	C5-C6	Gravity	397	1982	600	2,610	SP		with mortar lining
	C6-C7	Gravity	397	1982	600	6,709	DIP		
	C7-D0	Gravity	397	1982	500	4,409	DIP		

Table D-II, 1.7 List of Transmission Pipelines - Iquique/ESSAT (No. 3)

Site Name of Pipeline		Type of Flow	Design Flow (l / sec)	Year of Construction	Diameter (mm)	Distance (m)	Pipe Material (SP : Steel) (DIP : Ductile Iron)	Valves & fittings	Remarks
From Carpas(DO) To Santa Rosa(DO)	D0-E0	Gravity	293	1960	400	5,858	SP		
	D0-E0	Gravity	407	1982	450	5,858	DIP		
From Santa Rosa(EO) To Alto Hospicio(FO)	E0-E1	Gravity	325	1960	600	998			
	E1-E2	Gravity	325	1960	500	1,600	SP		
	E2-E3	Gravity	325	1960	400	4,063	SP		
	E3-F0	Gravity	700	1960	400	65	SP		
	E0-E3	Gravity	375	1982	450	6,661	DIP		
From Alto Hospicio(FO) To Cavancha(GO)	F0-G0	Gravity	700	1960	400	2,900	SP		

Table D-II, 1.8 Hydraulic Calculations for Existing Transmission Pipelines, Iquique (Canchones - Cavancha)

1) Canchones Pump (A0) - Diana Tank (B0) : L = 29,880 m

Point to Point	Distance L (m)	Nominal Diameter (mm)	Year of Installation	Flow: Q (l/s)	I {x10(*-3)}	Loss: H=IxL (m)	Velocity: V (m/s)
A0 - A1	190 m	700 mm SP	1960	700	4.59	0.87	1.96
A1 - A2	2,721	700 mm SP	1960	224	0.56	1.52	0.63
A2 - A3	810	600 mm SP	1960	224	1.21	0.98	0.86
A3 - A4	933	600 mm (SP)	?	224	1.21	1.13	0.86
A4 - B0	25,206	600 mm SP	1960	224	1.20	30.56	0.86
				Total H (A1 - B0) =		34.19 m	
A1 - B0	29,690 m	800 mm DIP	1983	476	1.15	34.06 m	1.01
				Total H (A0 - B0) =		35.06 m	

Canchones : GL = +1,013 m — HWL of Tank = +1,018.15 m; LWL of Tank = +1,013.15 m

Diana : GL = +1,037 m — HWL of Tank = +1,041.85 m; LWL of Tank = +1,036.85 m

Actual head of Canchones pump = (+1,041.85) - (+1,013.15) = 28.7 m
Head loss of pipeline = 35.06 m
Head loss of pump = 1.50 m

Total pump head = 65.26 m --> 66 m

2) Diana Pump (B0) - Rinconada Tank (C0) : L = 3,120 m

Point to Point	Distance L (m)	Nominal Diameter (mm)	Year of Installation	Flow: Q (l/s)	I {x10(*-3)}	Loss: H=IxL (m)	Velocity: V (m/s)
B0 - C0	3,120 m	600 mm SP	1960	220	1.17	3.65 m	0.85
B0 - C0	3,120 m	800 mm DIP	1983	480	1.17	3.65	1.02
				Total H (B0 - C0) =		3.65 m	

Diana : GL = +1,037 m — HWL of Tank = +1,041.85 m; LWL of Tank = +1,036.85 m

Rinconada : GL = +1,155 m — HWL of Tank = +1,159.2 m; LWL of Tank = +1,154.2 m

Actual head of Diana pump = (+1,159.2) - (+1,036.85) = 122.35 m
Head loss of pipeline = 3.65 m
Head loss of pump = 1.50 m

Total pump head = 127.5 m --> 128 m

3) Rinconada Tank (C0) - Carpas Tank (D0) : L = 26,755 m

Point to Point	Distance L (m)	Nominal Diameter (mm)	Year of Installation	Flow: Q (l/s)	I {x10(*-3)}	Loss: H=IxL (m)	Velocity: V (m/s)
C0 - C1	8,365 m	550 mm SP	1960	303	3.32	27.74 m	1.40
C1 - C2	7,776	500 mm SP	1960	303	5.40	42.01	1.71
C2 - C3	3,210	500 mm SP	1960	197	2.45	7.86	1.11
	3,210	400 mm SP	1960	106	2.45	7.86	0.96
C3 - C4	1,000	400 mm SP	1960	151.5	4.74	4.74	1.38
	1,000	400 mm SP	1960	151.5	4.74	4.74	1.38
C4 - D0	6,404	500 mm SP	1960	303	5.40	34.60	1.71
				Total H (C0 - D0) =		116.95 m	(Old)
C0 - C5	13,027 m	600 mm DIP	1982	397	3.49	45.52	1.53
C5 - C6	2,610	600 mm SP	1982	397	3.51	9.12	1.53
C6 - C7	6,709	600 mm DIP	1982	397	3.51	23.44	1.53
C7 - D0	4,409	500 mm DIP	1982	397	8.91	39.27	2.24
				Total H (C0 - D0) =		117.35 m	(New)

Rinconada : GL = +1,155 m — HWL of Tank = +1,159.2 m; LWL of Tank = +1,154.2 m

Carpas : GL = +978 m — HWL of Tank = +983 m; LWL of Tank = +978 m

Total head = (+1,154.2) - (+983) = 171.2 m
Residual head = (171.2 m) - (117.35 m) = 53.85 m

4) Carpas Tank (D0) - Santa Rosa Tank (E0) : L = 5,858 m

Point to Point	Distance L (m)	Nominal Diameter (mm)	Year of Installation	Flow: Q (l/s)	I {x10(*-3)}	Loss: H=IxL (m)	Velocity: V (m/s)
D0 - E0	5,858 m	400 mm SP	1960	293	16.0	93.73 m	2.66
D0 - E0	5,858 m	450 mm DIP	1982	407	16.0	93.73	2.87
				Total H (D0 - E0) =		93.73 m	

Carpas : GL = +978 m — HWL of Tank = +983 m; LWL of Tank = +978 m

Santa Rosa : GL = +682 m — HWL of Tank = +687 m; LWL of Tank = +682 m

Total head = (+878) - (+687) = 291 m
Residual head = (291 m) - (93.73 m) = 197.27 m

5) Santa Rosa Tank (E0) - Alto Hospicio Tank (F0) : L = 6,726 m

Point to Point	Distance L (m)	Nominal Diameter (mm)	Year of Installation	Flow: Q (l/s)	I {x10(*-3)}	Loss: H=IxL (m)	Velocity: V (m/s)
E0 - E1	998 m	600 mm SP	1960	197	0.95	0.95 m	0.77
E1 - E2	1,600	500 mm SP	1960	197	2.43	3.88	1.11
E2 - F0	4,128	400 mm SP	1960	197	7.70	31.78	1.79
				Total H (E0 - F0) =		36.61 m	(Old)
E0 - F0	6,726 m	600 mm DIP	1982	503	5.44	36.61 m	1.93

Santa Rosa : GL = +682 m — HWL of Tank = +687 m; LWL of Tank = +682 m

Alto Hospicio : GL = +545 m — HWL of Tank = +550 m; LWL of Tank = +545 m

Total head = (+682) - (+550) = 132 m
Residual head = (132 m) - (36.61 m) = 95.39 m

6) Alto Hospicio Tank (F0) - Cavancha Tank (G0) : L = 2,900 m

Point to Point	Distance L (m)	Nominal Diameter (mm)	Year of Installation	Flow: Q (l/s)	I {x10(*-3)}	Loss: H=IxL (m)	Velocity: V (m/s)
F0 - G0	2,900 m	400 mm SP	1960	123	3.22	9.34	1.12
F0 - G0	2,900 m	700 mm SP	1991	577	3.22	9.34	1.61
				Total H (F0 - G0) =		9.34 m	

Alto Hospicio : GL = +545 m — HWL of Tank = +550 m; LWL of Tank = +545 m

Cavancha : GL = +114 m — HWL of Tank = +119 m; LWL of Tank = +114 m

Total head = (+545) - (+119) = 426 m
Residual head = (426 m) - (9.34 m) = 416.66 m

Conditions Applicable to the Above Calculations:

1) Pipe Material

SP : Steel pipe (without lining)

DIP: Ductile cast iron pipe (with cement-mortar lining)

2) Flow Rate (Q)

Q = 700 l/sec (= 60,480 m^3/day) from Canchones to Cavancha

3) Hydraulic Calculation Formula : Hazen-Williams

I (Hydraulic gradient) = 10.666 x C(*-1.85) x D(*-4.87) x Q(*1.85)

C : 130

(Assuming that the inner surface of the pipe wall is adhered with manganese oxide scale, as if it were lined with smooth mortar.)

C(*-1.85) = 1/8,143 (C=130)

D : Hydraulic calculation diameter (Actual diameter)

= (Nominal diameter) - (25 mm)

(Provided that the thickness of the manganese oxides adhered to the inner surface of the pipe wall is 12.5 mm, as of February 1994.)

4) Calculation Table

Nominal Diameter	Actual Diameter (D)	Area of Pipe	D(*-4.87)	10.666 x x C(*-1.85) x x D(*-4.87)
800 mm	775 mm	0.471 m^2	3.46	4.53 x 10(*-3)
700	675	0.358	6.78	8.88
600	575	0.260	14.81	19.3
550	525	0.216	23.06	30.2
500	475	0.177	37.54	49.2
450	425	0.142	64.53	84.5
400	375	0.110	118.7	155.5

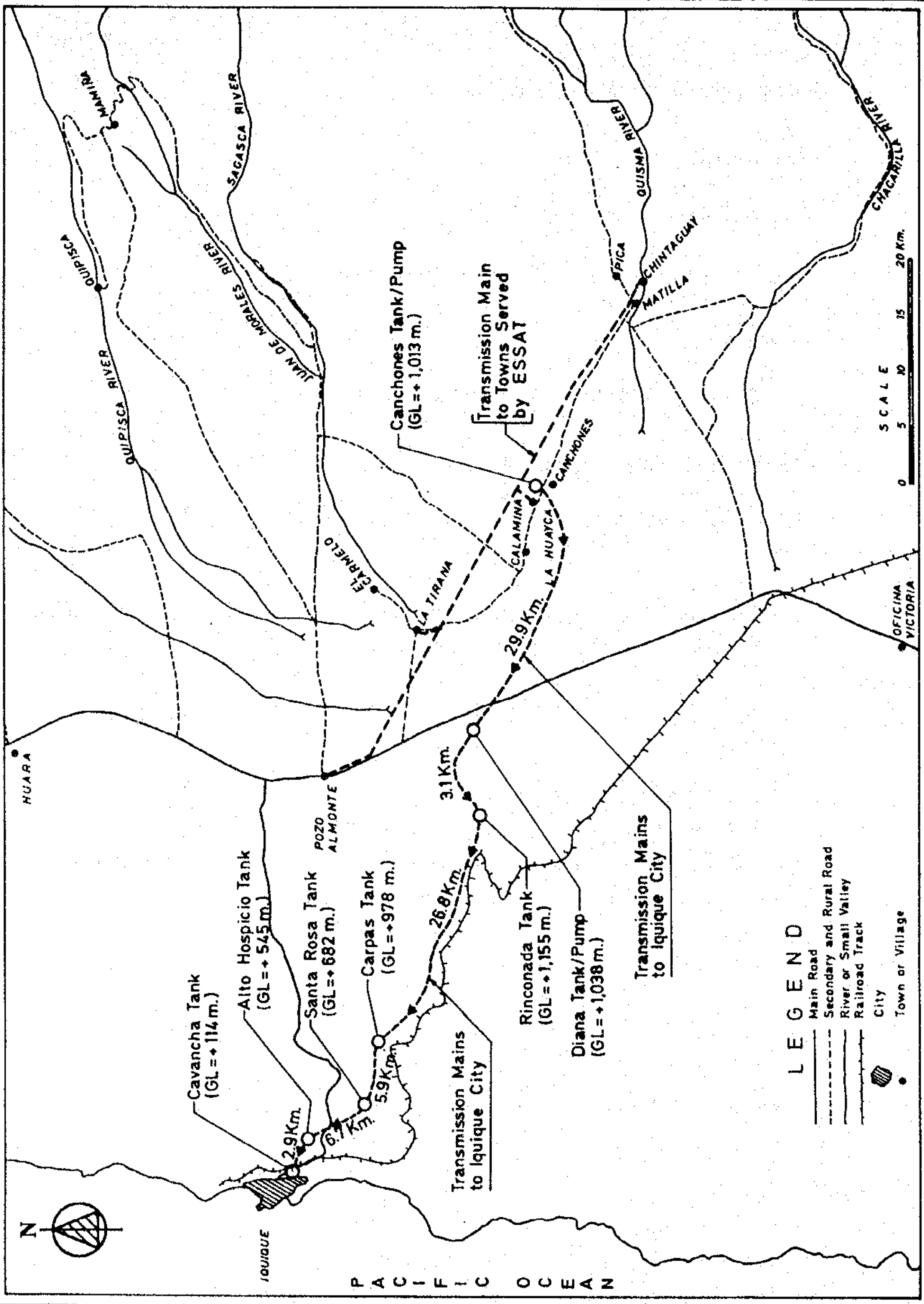


Fig. D-II, 1.0 General Plan of Existing Water Supply System - Iquique

< Planta General del Sistema de Abastecimiento de Agua Existente - Iquique >

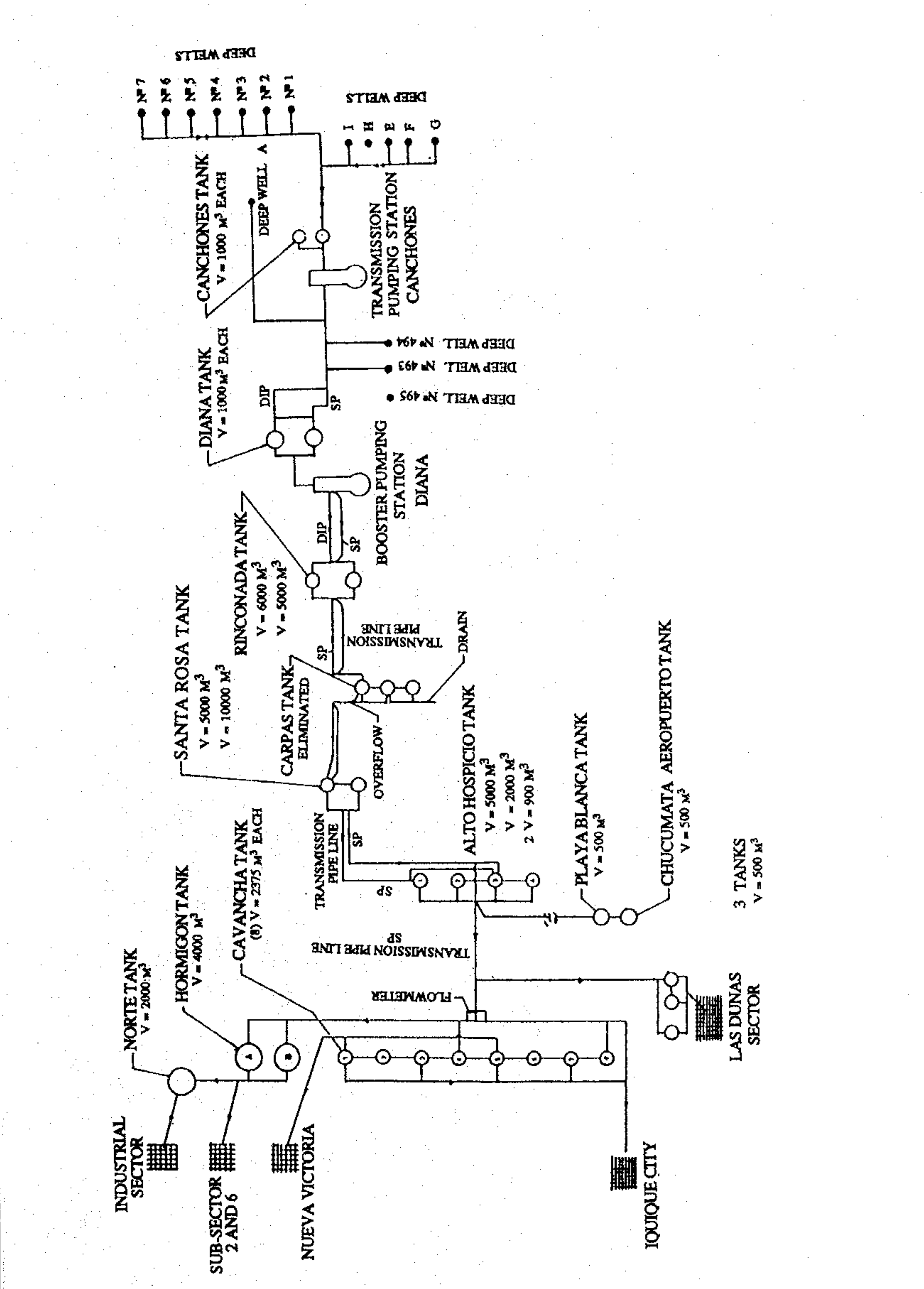


Fig. D-II, 1.1 Outline of the Water Supply System Facilities for Iquique

< Bosquejo del Sistema de Abastecimiento de Agua para Iquique >

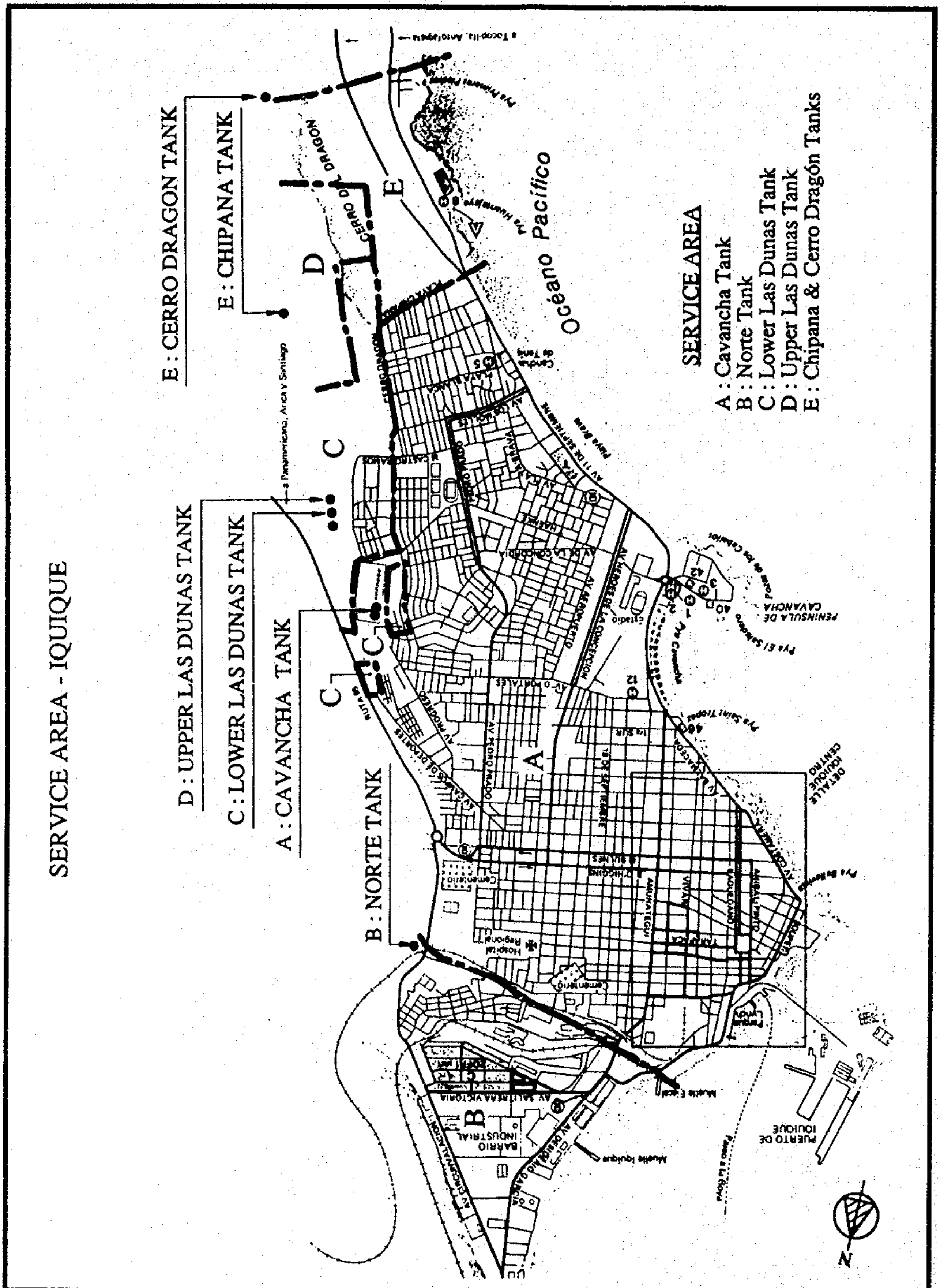


Fig. D-II, 1.2 Water Supply Service Area - Iquique

< Area del Servicio de Abastecimiento de Agua - Iquique >

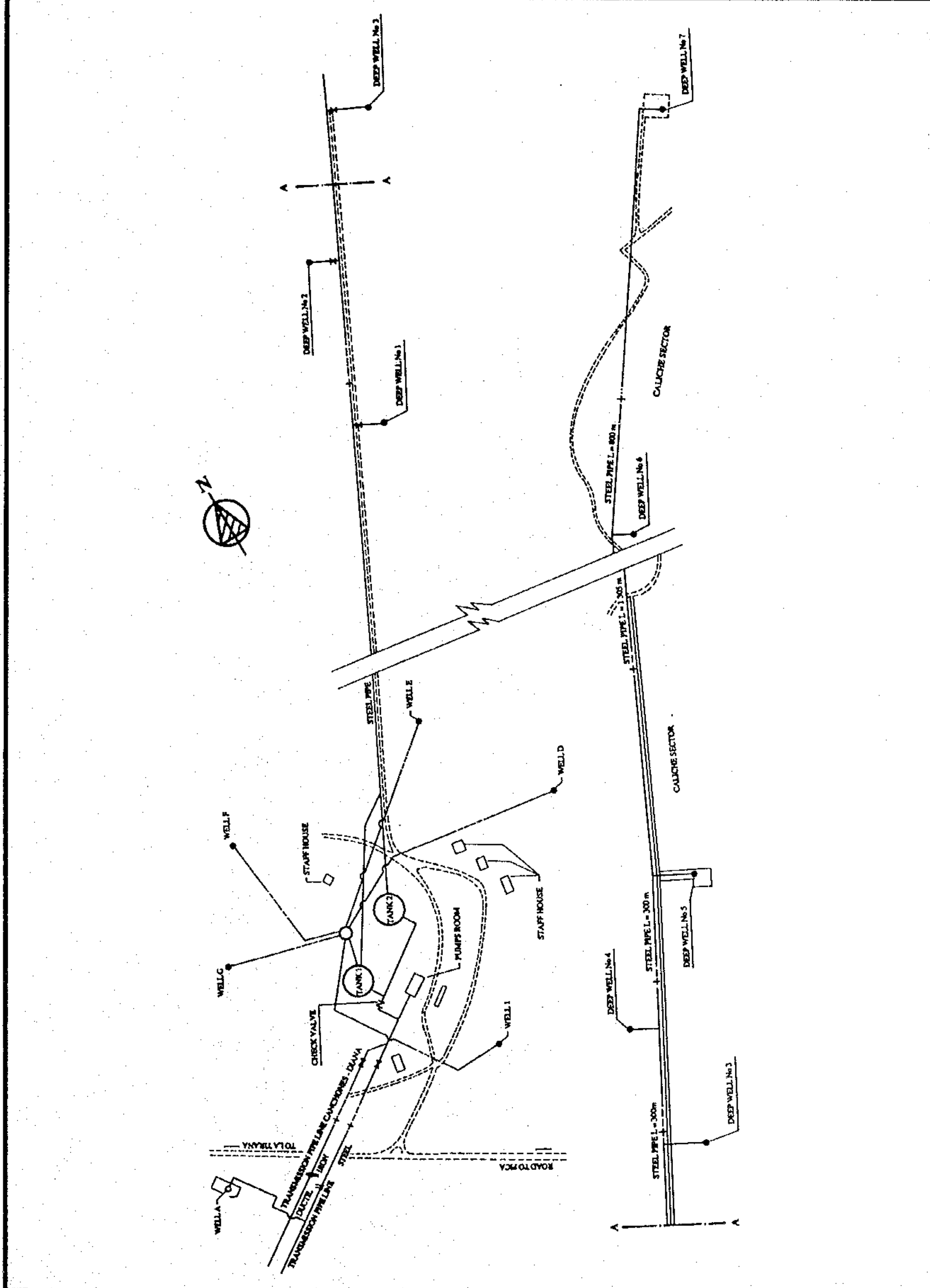


Fig. D-II, 1.3 Layout of Well-Field and Collection Tank in Canchones

< Distribución del Area de Pozos y Estanque Colector en Canchones >

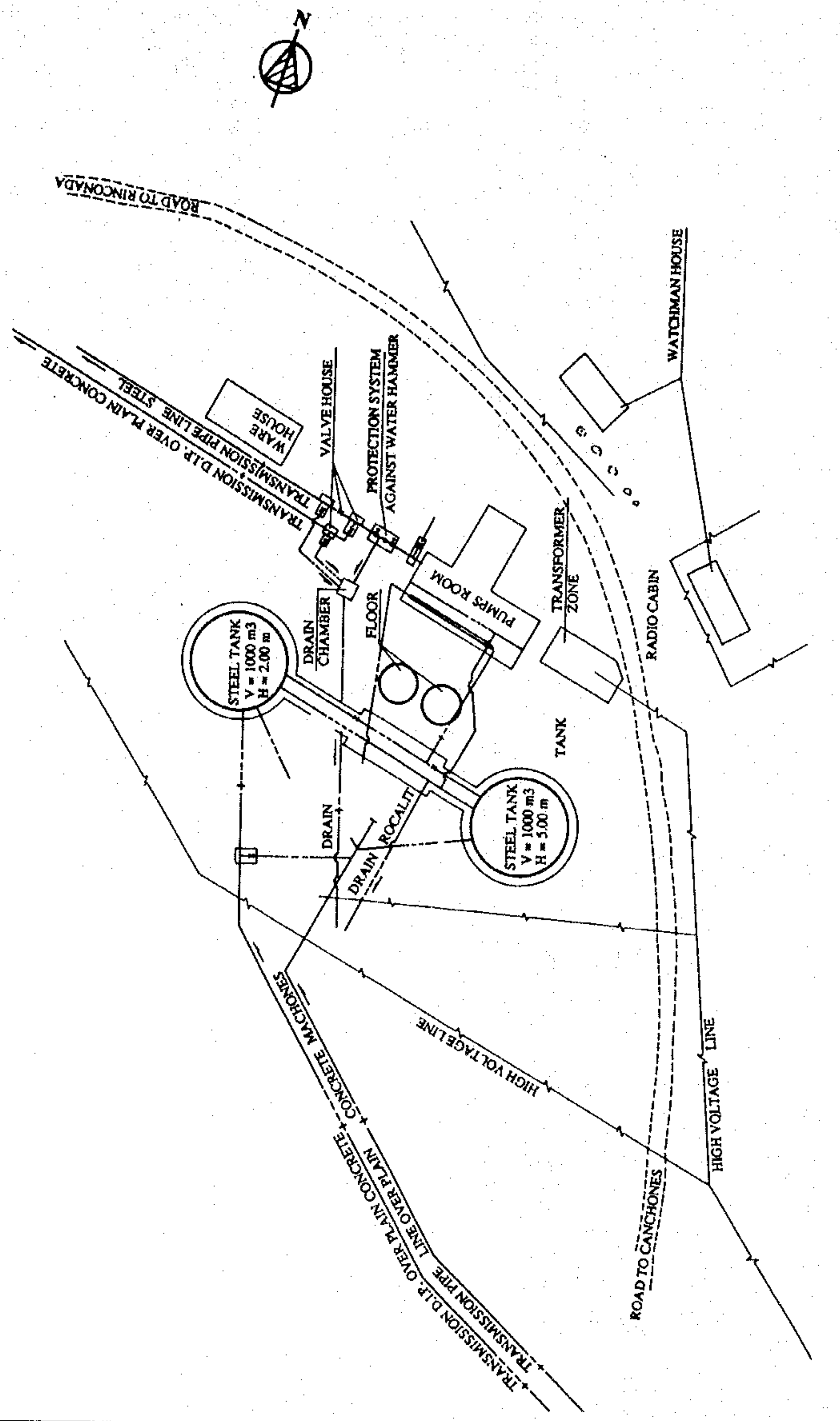


Fig. D-II, 1.4 Diana Tank Layout - Iquique

< Distribución Estanque Diana - Iquique >

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

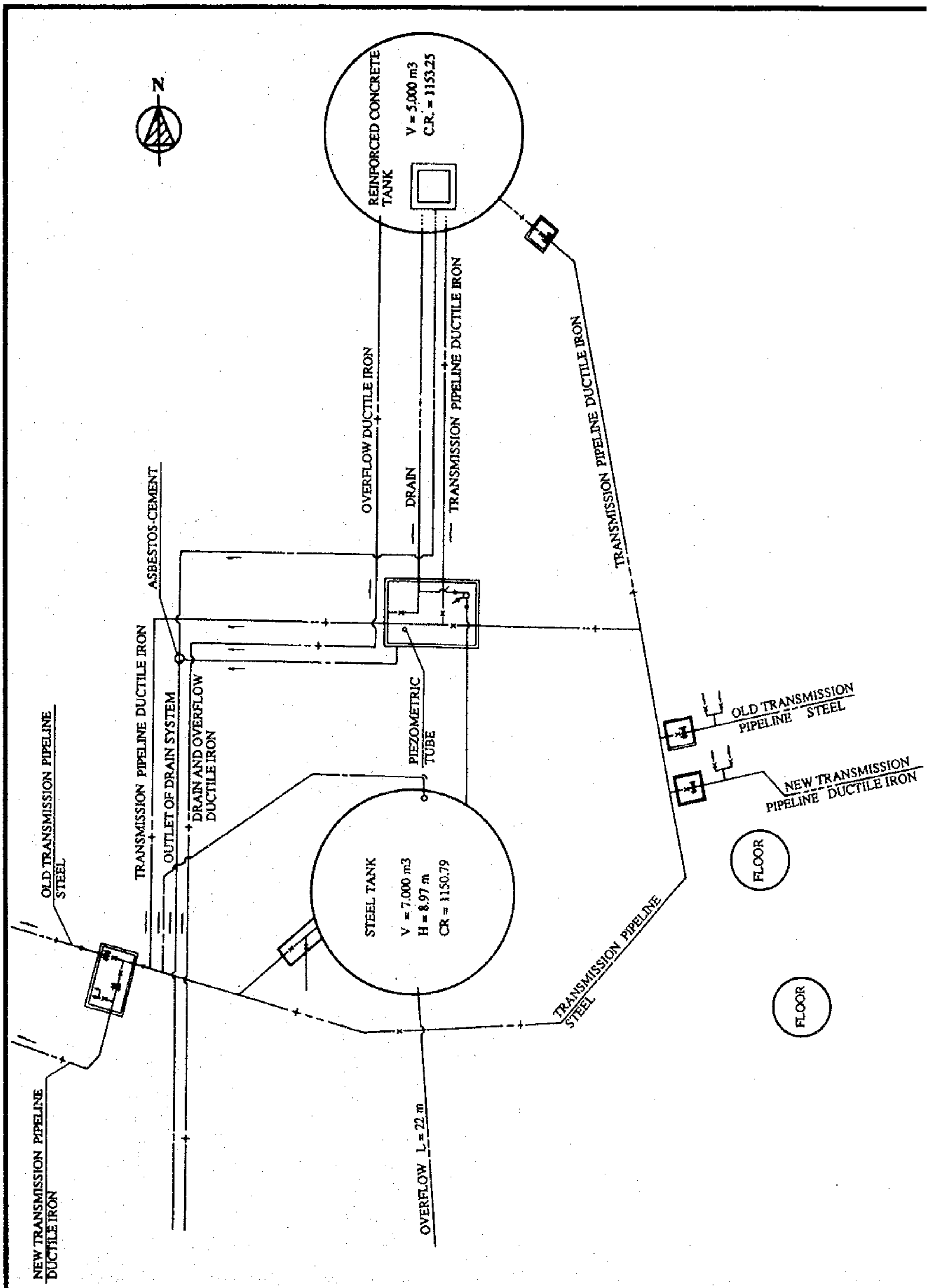


Fig. D-II, 1.5 Rinconada Tank Layout - Iquique

< Distribución Estanque Rinconada - Iquique >

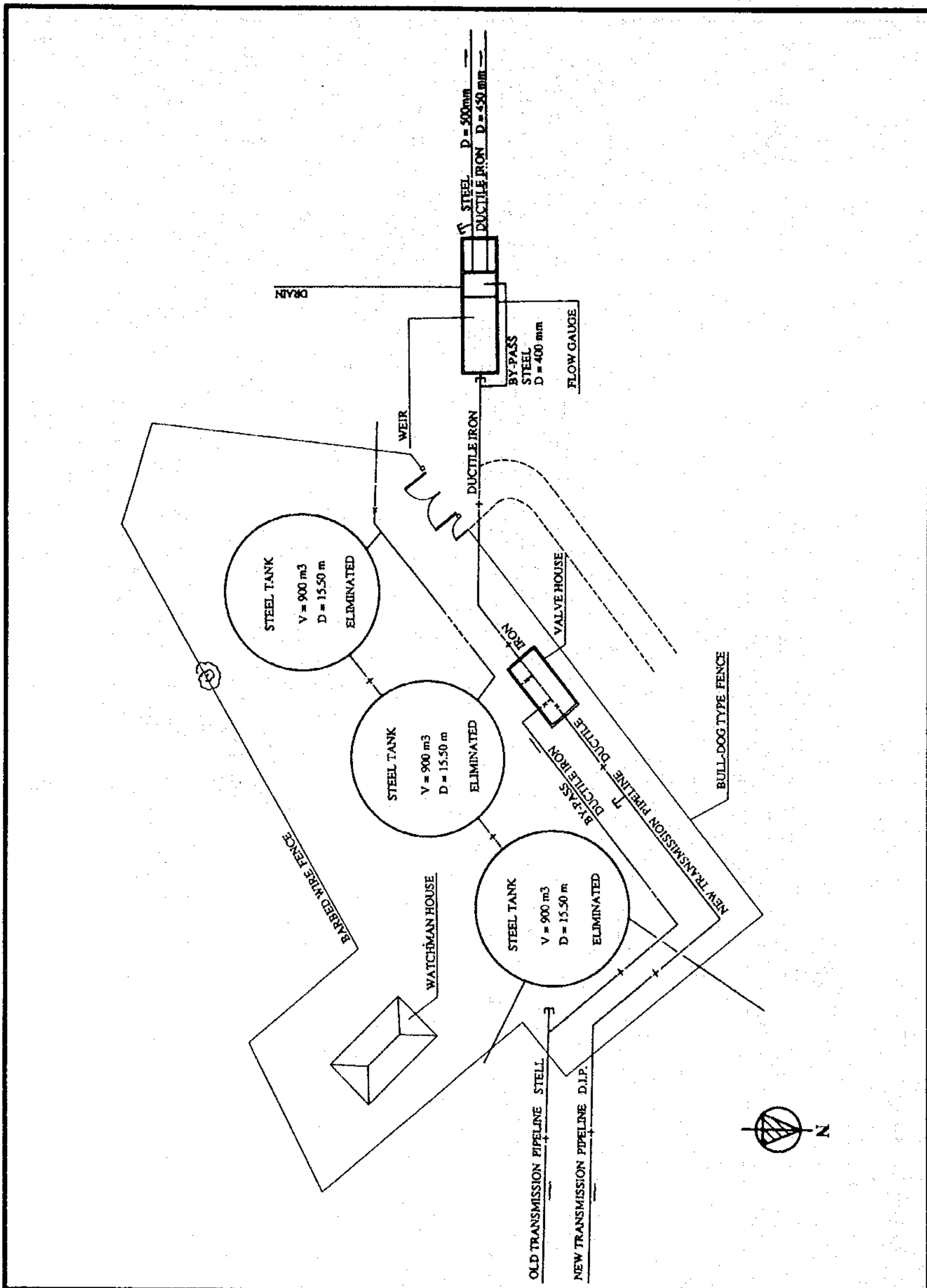


Fig. D-II, 1.6 Carpas Tank Layout - Iquique

< Distribución Estanque Carpas - Iquique >

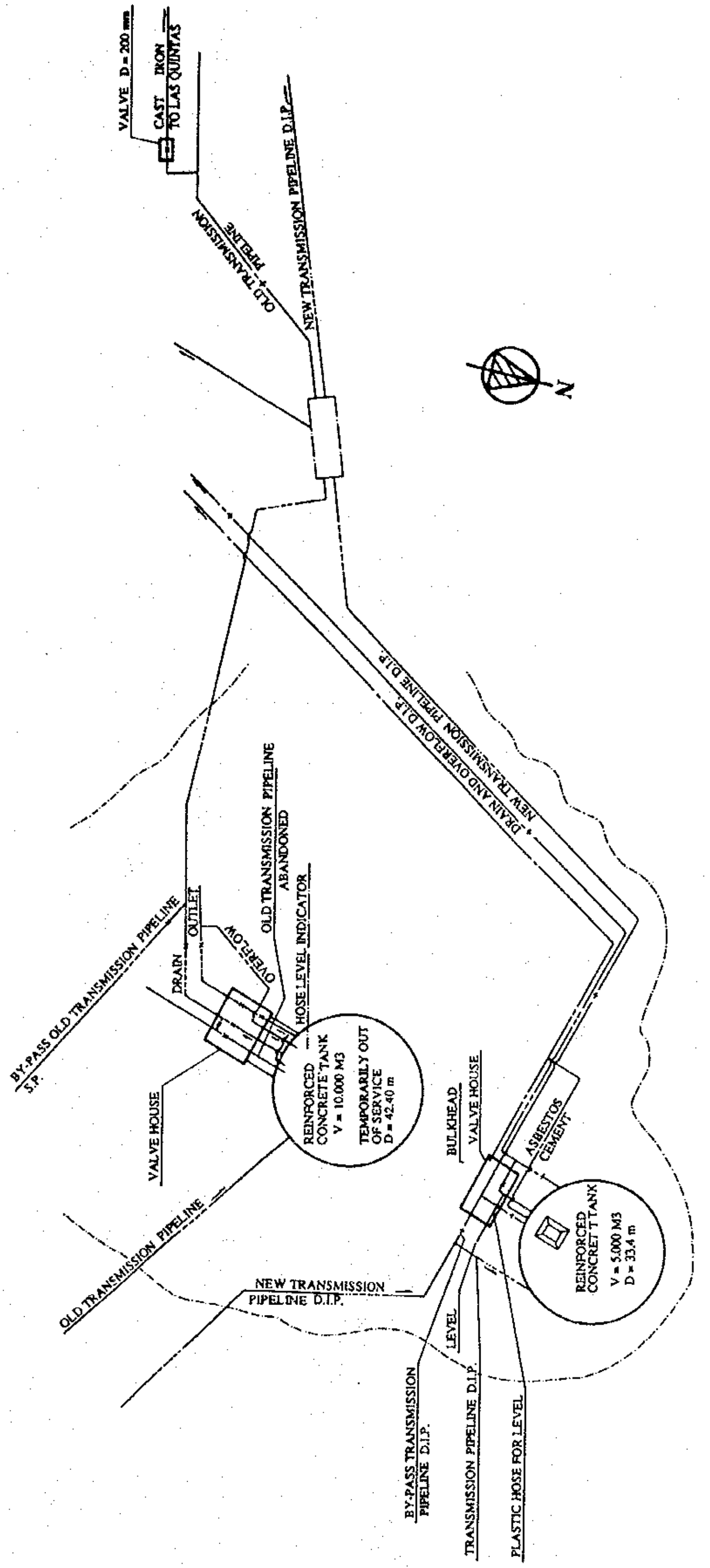


Fig. D-II, 1.7 Santa Rosa Tank Layout - Iquique

< Distribución Estanque Santa Rosa - Iquique >

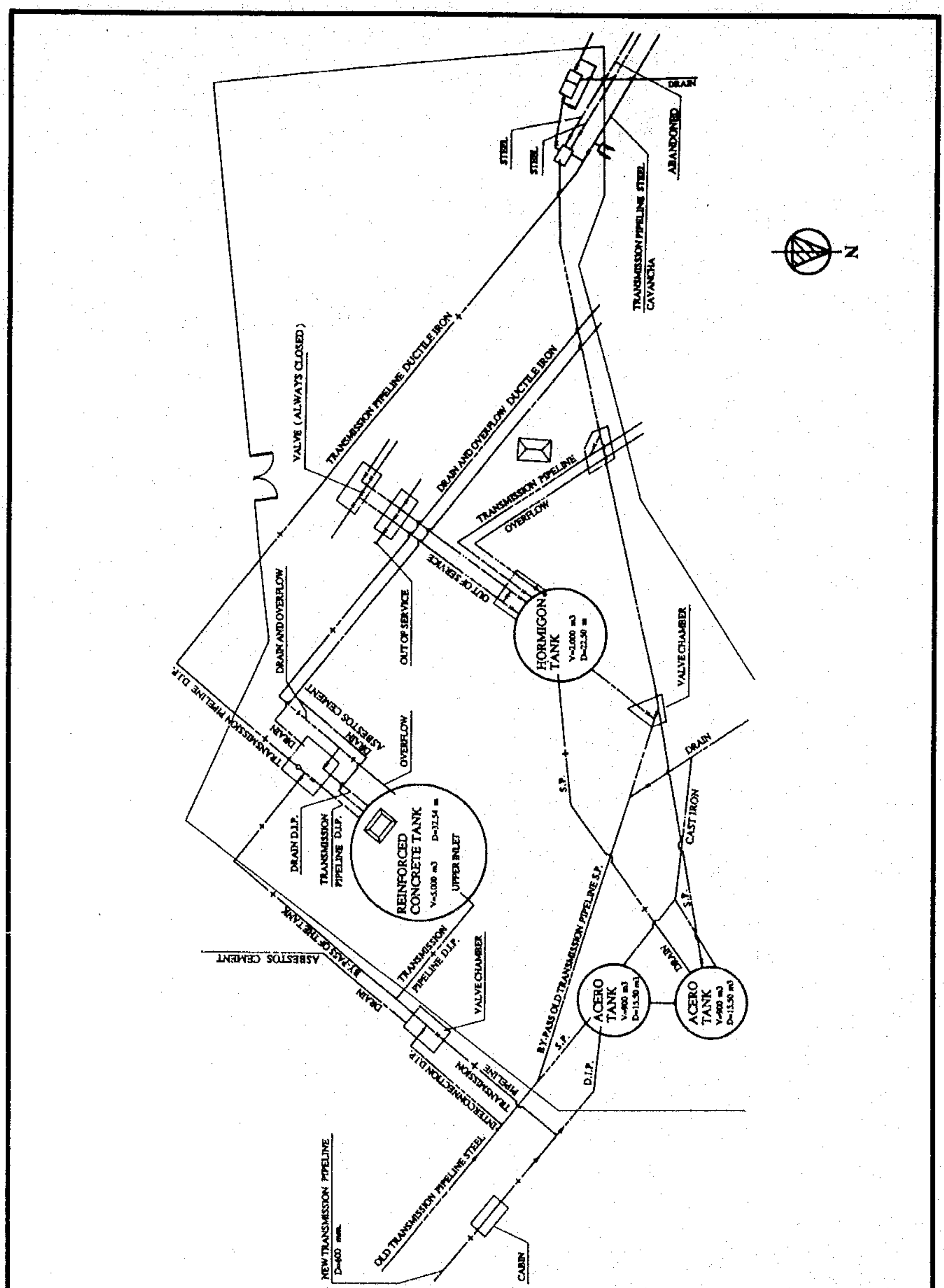


Fig. D-II, 1.8 Alto Hospicio Tank Layout - Iquique

< Distribución Estanque Alto Hospicio - Iquique >

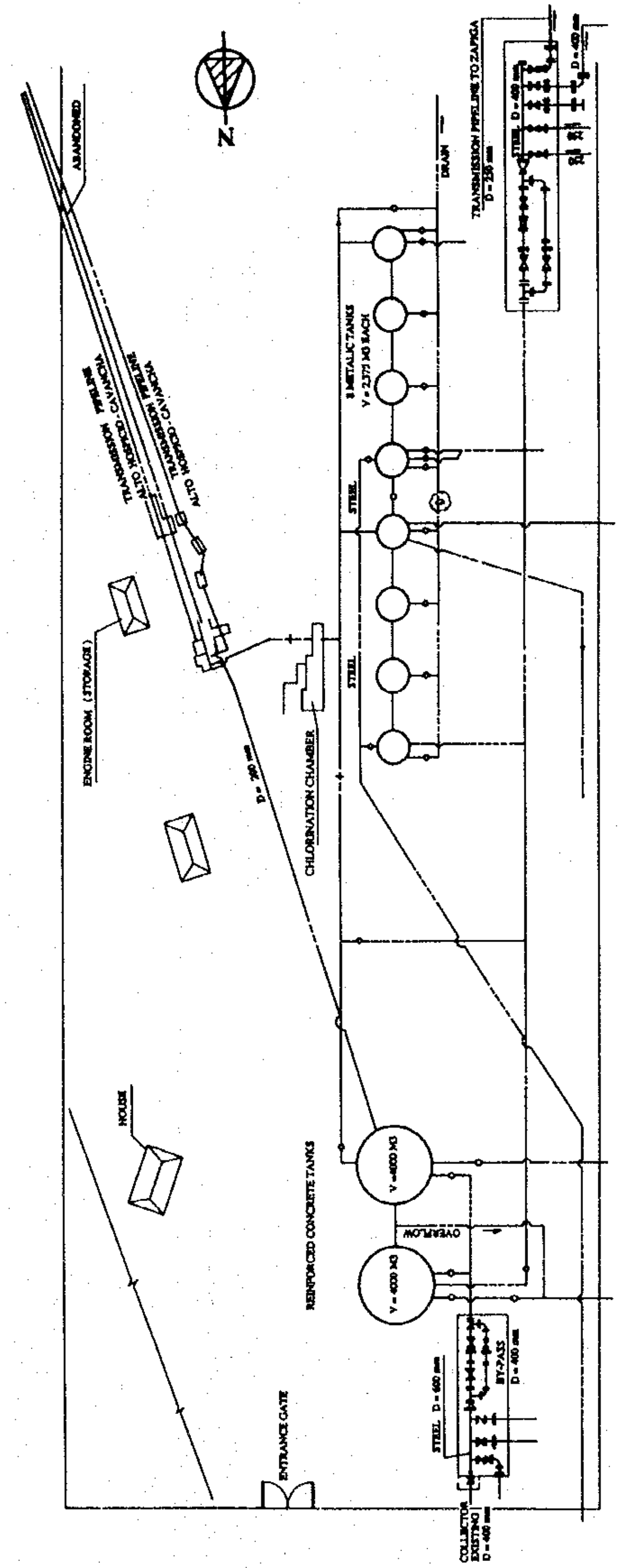


Fig. D-II, 1.9 Cavancha Station Layout - Iquique

< Distribución Planta Cavancha - Iquique >

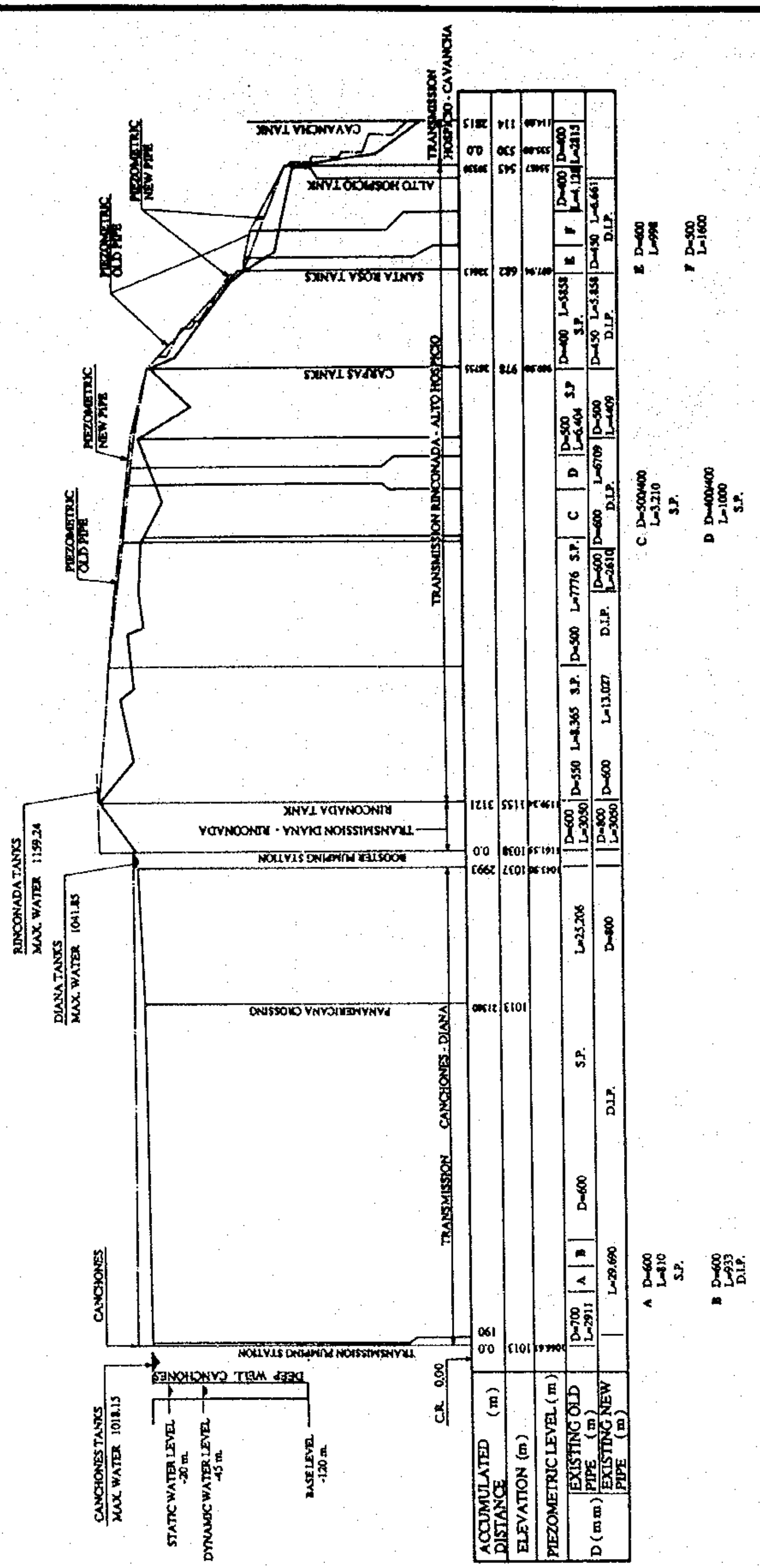


Fig. D-II, 1.10 Longitudinal Profile of Transmission Pipelines (Canchones - Cavancha - Iquique)

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

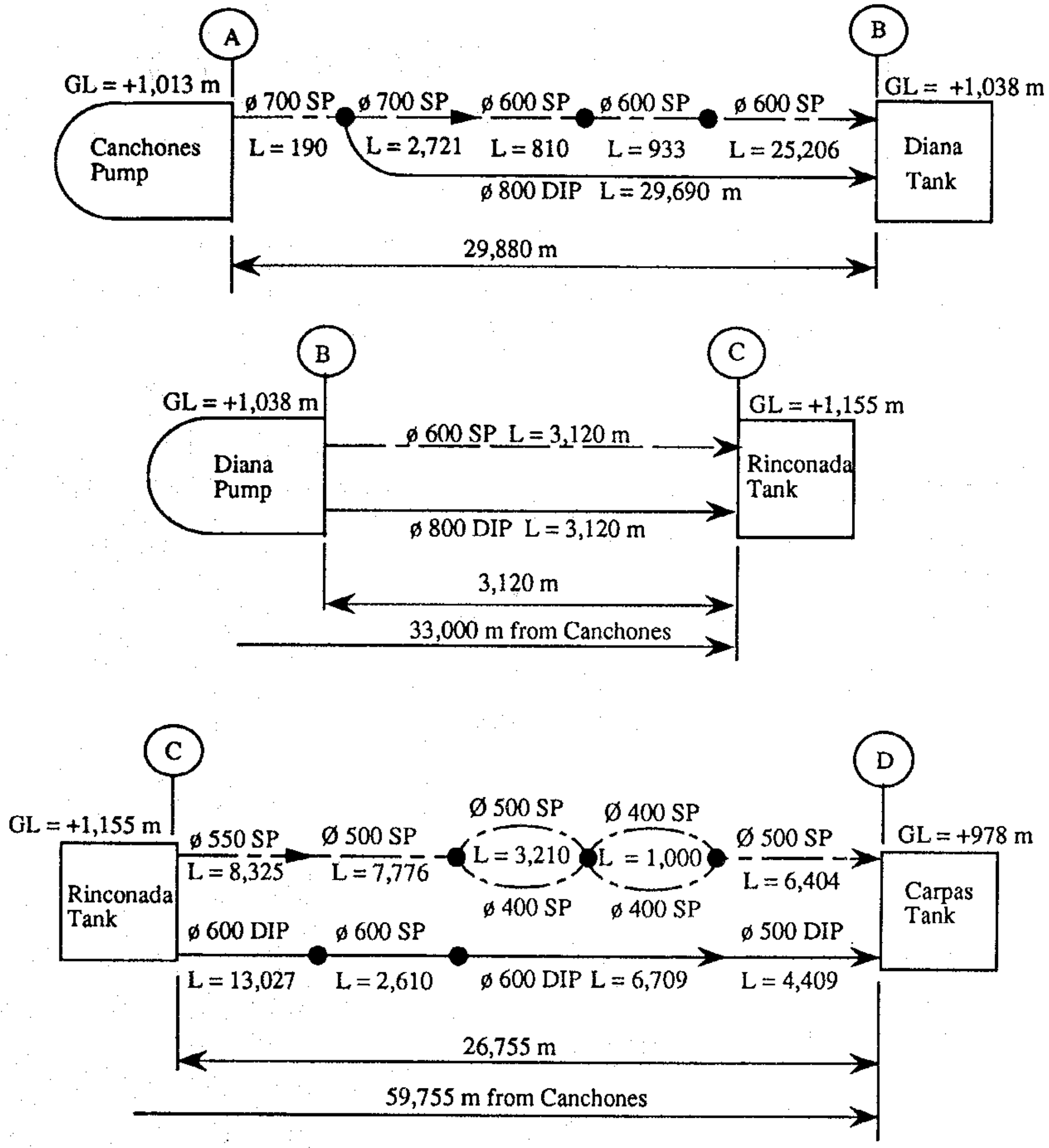


Fig. D-II, 1.11 Skeleton of Transmission Pipelines (Canchones - Cavancha) Nº 1

< Esquema de las Cañerías de Transmisión (Canchones - Cavancha) Nº 1 >

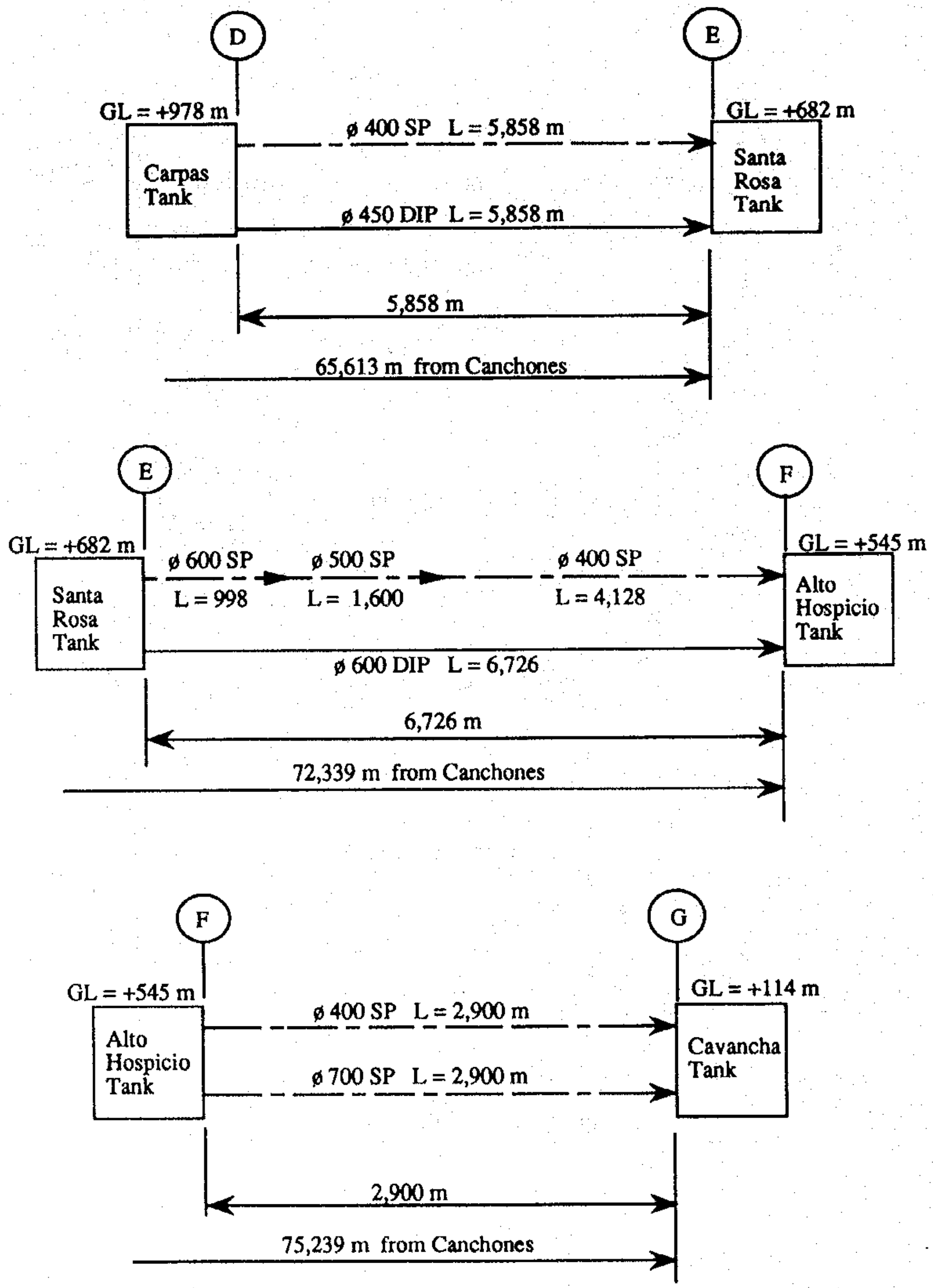


Fig. D-II, 1.11 Skeleton of Transmission Pipelines (Canchones - Cavancha) Nº 2

< Esquema de las Cañerías de Transmisión (Canchones Cavancha) Nº 2 >

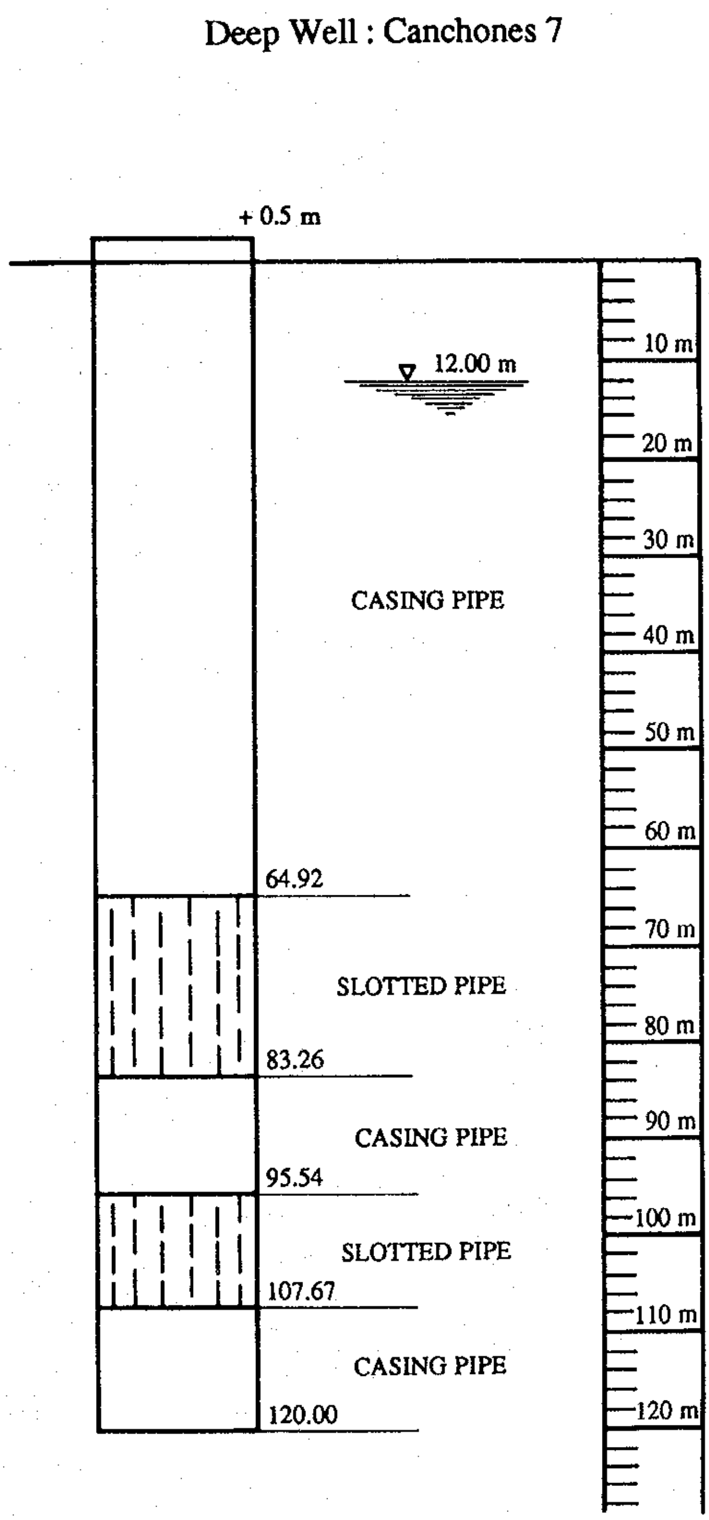
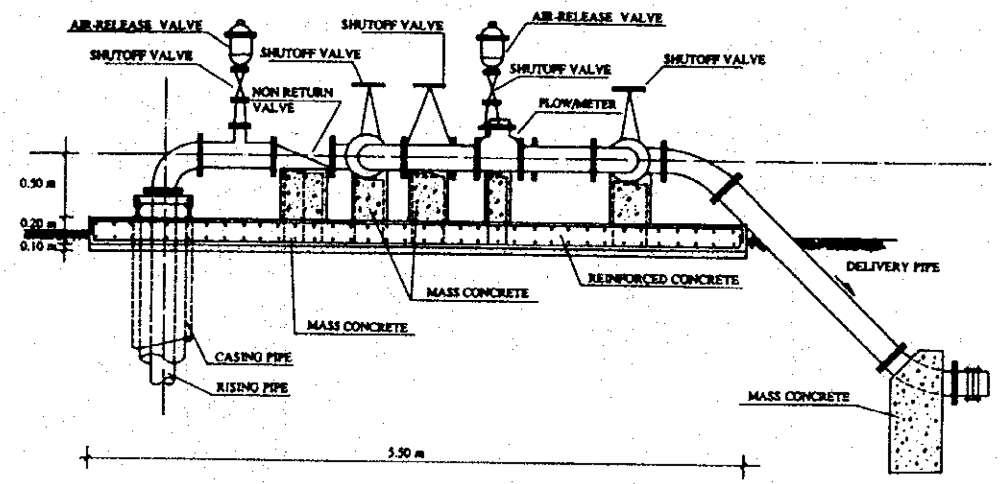
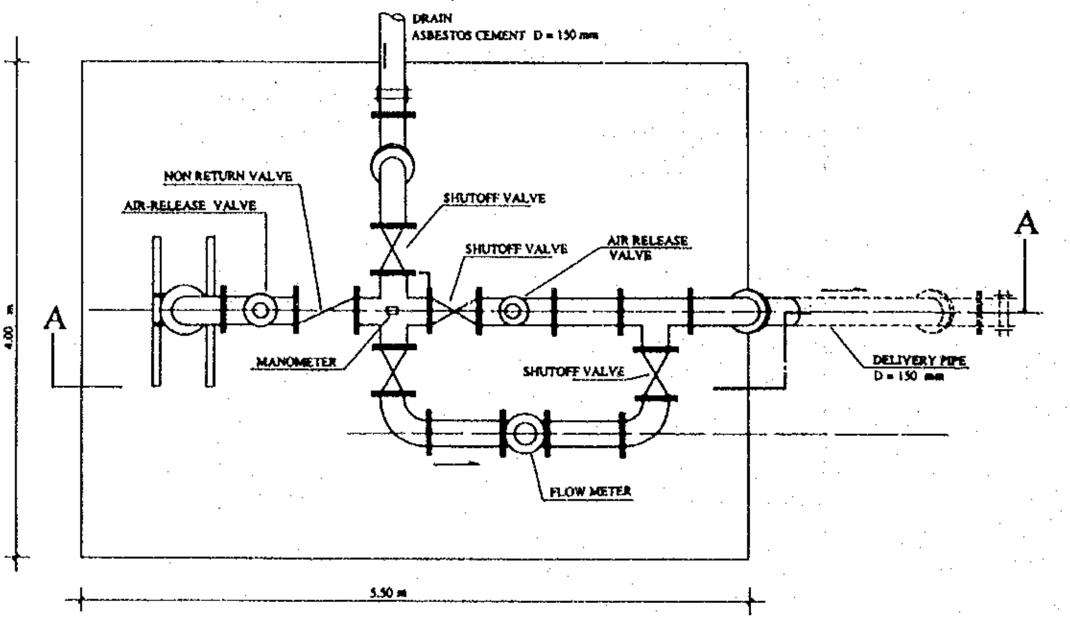


Fig. D-II, 1.12 Typical Existing Well Structure - Iquique

< Estructura Típica de Pozo Existente - Iquique >



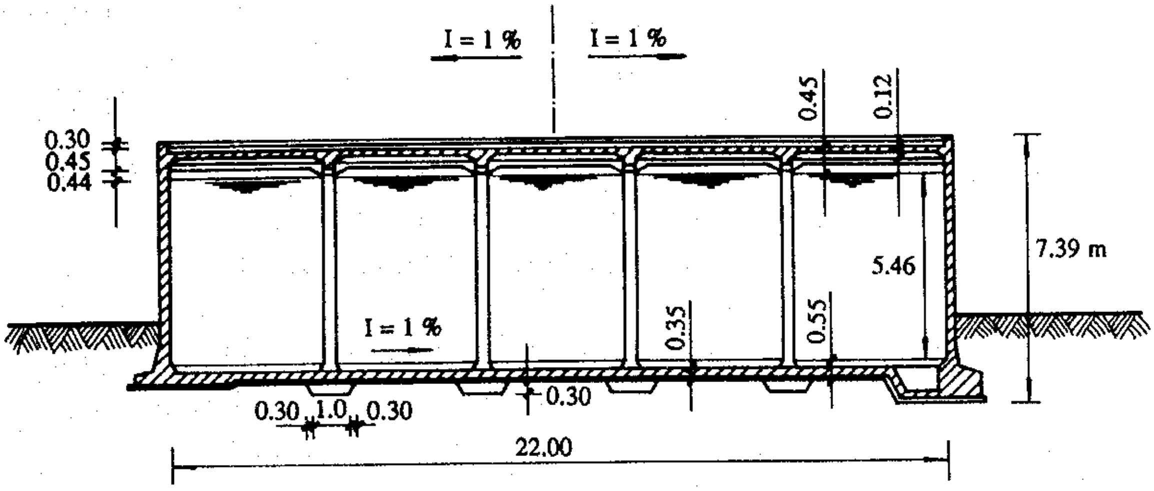
SECTIONAL ELEVATION A - A



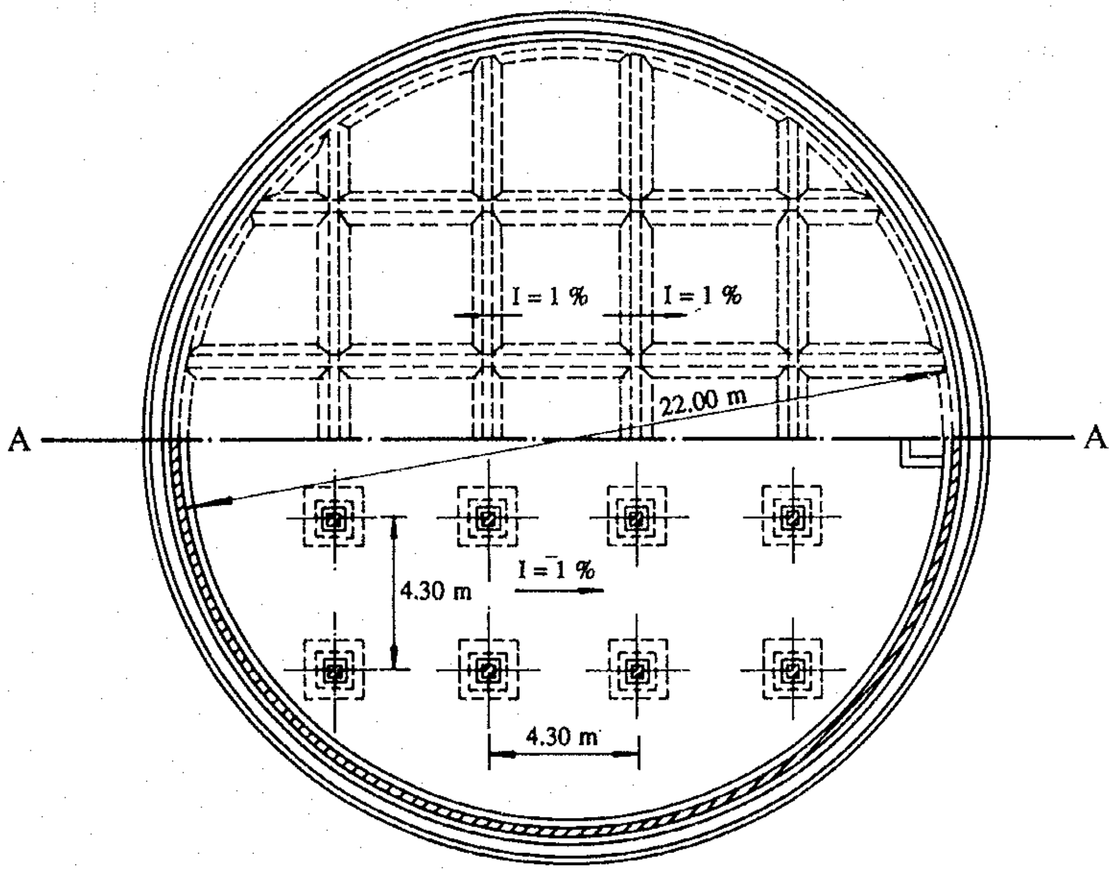
PLAN

Fig. D-II, 1.13 Typical Intake Pump House - Iquique

< Caseta Típica de Bomba de Captación - Iquique >



A -A SECTIONAL ELEVATION



ROOF AND SEMI-PLAN

Fig. D-II, 1.14 Concrete Tank Structure Standard (V= 2,000 m³)

< Estructura Estandar de Estanque Concreto (V= 2,000 m³) >

References

<1: "Analisis Programa de Desarrollo de Empresa de Servicios Sanitarios de Tarapaca S.A:" Prefactibilidad; Book I: Informacion Basica - Ciudad de Iquique.
By Bustamante y Schudeck, Ingenieros Consultores Ltda., March 1992.

<2: "Analisis Programa de Desarrollo de Empresa de Servicios Sanitarios de Tarapaca S.A:" Prefactibilidad; Book II: Definicion Proyecto Inversion - Ciudad de Iquique.
By Bustamante y Schudeck, Ingenieros Consultores Ltda., March 1992.

<3: "Estudio para el Mejoramiento de la Calidad del Agua Potable de Iquique": Diagnostico.
By Hidrosan Chile, Ingenieros Consultores, February 1993.

<4: "Estudio para el Mejoramiento de la Calidad del Agua Potable de Iquique": Estudio de Alternatives.
By Hidrosan Chile, Ingenieros Consultores, May 1993.

Chapter II. SUPPLY AND DEMAND BALANCE

2.1 Future Water Demand

According to the forecast of future population and the projection of future water demand, the following figures of water production demand are estimated for the Iquique City. (See the Supporting Report of "Water Use" for detail.)

- For the year 2005, a production capacity of 807 l/sec on the daily average basis (= 1,049 l/sec on the daily maximum),

and,

- For the year 2015, a production capacity of 1,062 l/sec on the daily average (= 1,381 l/sec on the daily maximum).

(Note): Daily Maximum Demand = 130% of Daily Average Demand

2.2 Supply Capacity and the Balance

The production capacity is 680 l/sec by the end of 1994, hence the future deficit, the capacity to be added to the existing capacity will be as follows:

- For the year 2005:
  The deficit = 1,049 - 680 = 369 l/sec (Daily maximum)

and,

- For the year 2015:
  The deficit = 1,381 - 680 = 701 l/sec (Daily maximum)

(Refer to Tables D-II, 2.1 and 2.2, and Fig. D-II, 2.1.)

Table D-II, 2.1 Water Demand Projection for Iquique

(Unit: l/sec)

	Year	1995	2000	2005	2010	2015
	Target			Short-Term		Long-Term
(A)	Daily Average Production Demand	708	755	807	927	1,062
(B)	Daily Maximum Production Demand	920	981	1,049	1,205	1,381
(C)	Existing Production Capacity as of 1994	680	680	680	680	680
(D)	Deficit (Capacity to be Added to 1994 Capacity)	240	301	369	525	701
(D')	Deficit (Capacityto be Added to 2005 Capacity	-	-	-	156	332

(Note): (A) From the report of "Water Use" (Supporting Report "C" / JICA)
(B) Criteria:
(Daily Average) : (Daily Maximum) = 1.00 : 1.30
(B) = (A) x 130%
(C) Existing capacity:
630 l/sec (in 1993) + 50 l/sec (in 1994) = 680 l/sec (in 1994)
(D) (D) = (B)-(C)

Table D-II, 2.2 Additional Production Capacity Required,by Year for Iquique

	(1)	(2) = (1)/1.30	(3) = (2) x 365 days
Year	Daily Maximum Production Capacity (l/sec)	Daily Average Production Capacity (l/sec)	Yearly Production Capacity (M^3/year)
(1995)	-	-	-
(1996)	-	-	-
(1997)	-	-	-
(1998)	-	-	-
1999	288.4	221.8	6,991,531
2000	301.1	231.6	7,303,738
2001	314.1	241.6	7,619,098
2002	327.4	251.8	7,940,765
2003	336.6	258.9	8,164,670
2004	354.8	272.9	8,606,174
2005	369.0	283.8	8,949,917
2006	400.2	307.8	9,706,781
2007	431.4	331.8	10,463,644
2008	462.6	355.8	11,220,508
2009	493.8	379.8	11,977,372
2010	525.0	403.8	12,734,236
2011	560.2	430.9	13,588,862
2012	595.4	458.0	14,443,488
2013	630.6	485.1	15,298,113
2014	665.8	512.2	16,152,739
2015	701.0	539.2	17,004,211

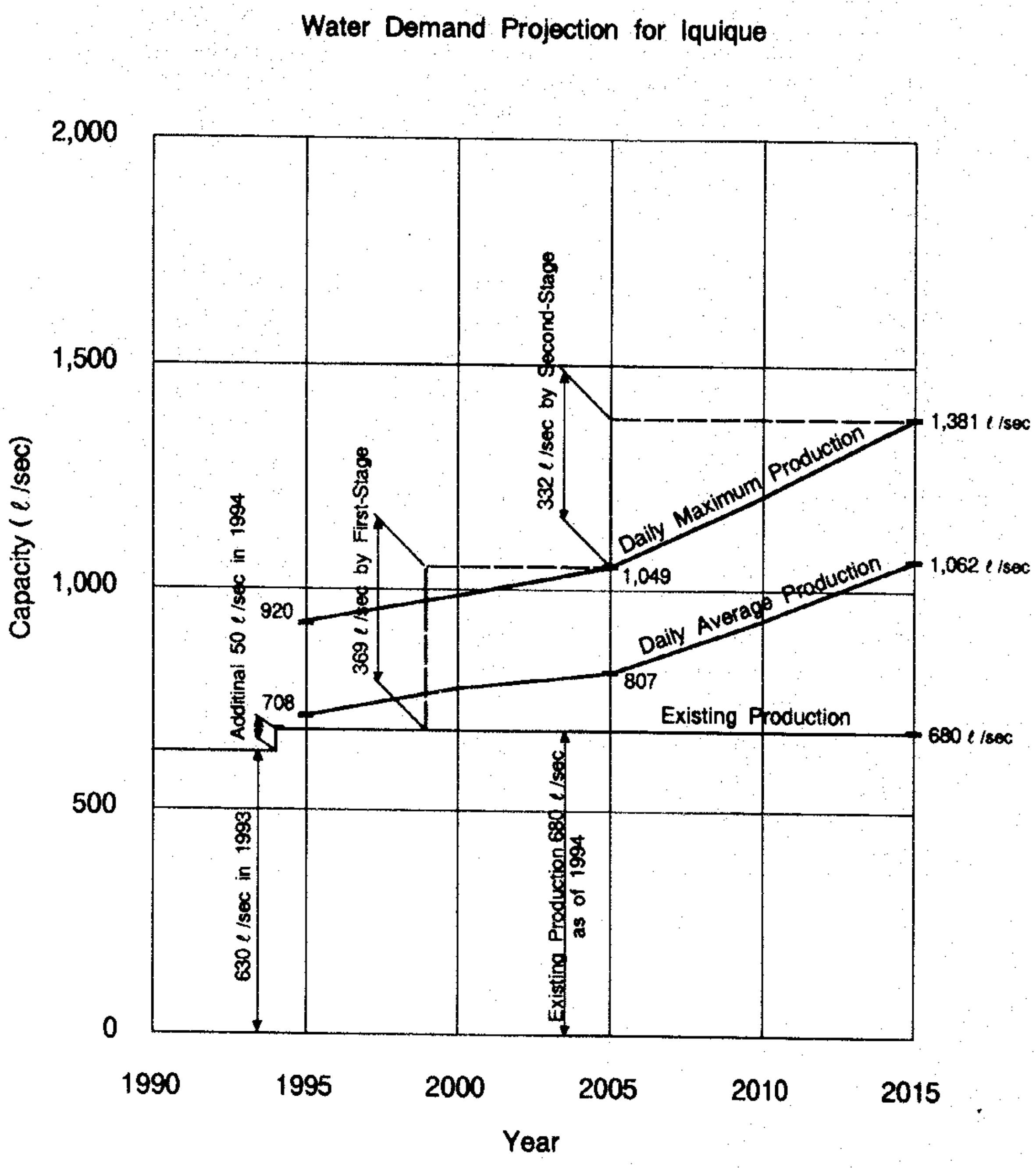


Fig. D-II, 2.1 Water Demand Projection for Iquique

< Proyección de Demanda de Agua para Iquique >

Chapter III. LONG-TERM DEVELOPMENT PLAN

3.1 Development Capacity

	Target (Year)	Long-Term (2015)	Short-Term (2005)
(A)	Daily average production demand	1,062 l/sec	807 l/sec
(B)	Daily maximum production demand	1,381 l/sec	1,049 l/sec
(C)	Existing production capacity as of 1994	680 l/sec	680 l/sec
(D)	Deficit (capacity to be added)	701 l/sec to 1994 capacity or, 332 l/sec to 2005 capacity	369 l/sec to 1994 capacity
(E)	Raw water intake capacity for the deficit	738 l/sec to 1994 capacity or, 350 l/sec to 2005 capacity	388 l/sec to 1994 capacity

(Note) (A): From the report of "Water Use" (Supporting Report C / JICA)

(B): Criteria
(Daily Average) : (Daily Maximum) = 1.00 : 1.30

(C): 630 l/sec (in 1993) + 50 l/sec (in 1994) = 680 l/sec (in 1994)

(D) = (B)-(C)

(E): Intake capacity, including the loss of 5% in the treatment plant
(E) = (D)/95%

The production capacity required for the Long-Term plan (Target year = 2015), which needs to be newly developed, is 701 l/sec on the production basis, or 738 l/sec on the intake capacity basis, as shown in the above table. Accordingly, these capacities (Daily maximum production = 701 l/sec; Daily maximum intake capacity = 738 l/sec) will be dealt with in the following sections, for the future planning.

3.2 Water Source Alternatives

3.2.1 General

The Iquique City, which is located on the Pacific Ocean seacoast, has a projected population of 272,600 in the year 2015. The projected water demand in 2015 is

1,381 l/sec on the daily maximum production basis. (Refer to Table D-II,2.1 and Fig. D-II,2.1)

The present water source of supply was developed by ESSAT to its full capacity and the maximum yield is not sufficient to meet the future demand. A new source of supply is, therefore, required to be developed to meet the future demand.

After intensive field investigations, three possible sources were identified as suitable for supplying water.

They are:

i) Groundwater in La Tirana (Pampa del Tamarugal - North)
ii) Groundwater in Pintados (Pampa del Tamarugal - South)
iii) Groundwater in Salar del Huasco

3.2.2 La Tirana (Pampa del Tamarugal - North) Water Source

The La Tirana well field is located in the Pampa del Tamarugal area, about 60 km to the east of the Iquique City (Refer to Fig. D-II,3.1). It is proposed to have 16 deep wells within the well field, including 2 wells on standby. The wells are located 500 m apart, on a grid of 1.5 km x 1.5 km (Refer to Figs. D-II,3.2 and 3.3) and are 200 m deep including 80 m of screen length. The water can be extracted from the wells at an average rate of 55 l/sec. Each well will be equipped with a submersible pump with a pump head of 76-81 m and an average discharge capacity of 55 l/sec. The details of the pumps are given in Table DT-7 of Technical Data. A sketch of a typical well structure is shown in Fig. D-II, 4.10.

3.2.3 Pintados (Pampa del Tamarugal - South) Water Source

The Pintados water source is located in the Pampa del Tamarugal area about 80 km southeast to the Iquique City (Refer to Fig. D-II,3.1). This well field is similar to the La Tirana well field, in number of wells as well as in the size of the grid; ie. 16 deep wells including 2 wells on standby and the grid size of 1.5 km x 1.5 km (Refer to Figs. D-II, 3.4 and 3.5). Each well is 200 m deep and is equipped with a submersible pump. The required pump head is 61 m and the average discharge capacity is 55 l/sec (Refer to Table DT-8 in Technical Data).

In La Tirana and Pintados, the water is collected into a collection tank located within the well field. The exact location of the collection tank will vary, depending on which transmission pipeline route is selected. The raw water intake pipes from the wells up to the collection tank within the well field are Asbestos Cement pipes (ACP), with diameters varying from 250 mm to 800 mm (Refer to Fig. D-II, 3.5).

According to the sample analysis, the water in the La Tirana and Pintados sources fulfill the requirements of the drinking water standard (NCH 409). Therefore, the water can be served to the customers without any specific treatment. Disinfection of water will be carried out prior to serving the customers, as a precautionary measure, at the distribution tanks to be located in Iquique/Cavancha. However, the groundwater quality of the La Tirana and Pintados sources may deteriorate to the level requiring water treatment in future according to the progress of the aquifer development. Because the existing groundwater quality in some surrounding areas of the proposed water sources exceeds the allowable limits of NCH 409. Therefore, the land for a future treatment plant is reserved within the well field.

3.2.4 Salar del Huasco Water Source

The Salar del Huasco water source is located in the Pampa Huasco area about 157 km to the east of the Iquique City. The location of this water source is shown in Fig. D-II, 3.1 and Fig. D-II,3.6. It is planned to extract water from 22 wells (including 3 for standby) at an average rate of 40 l/sec. Each well is 150 m or 200 m deep, with a screen length of 60 m each, and is located 1,000 m apart. The wells are equipped with submersible pumps, with pump head of 43-78 m and an average discharge capacity of 40 l/sec.

In this well field, 21 junction tanks will be provided to collect water from the wells (Refer to Fig. D-II,3.7). This well field is located on a gradually sloping terrain. Therefore, the water can flow by gravity between the junction tanks.

The Salar del Huasco water source contains considerably higher concentrations of Fe and Mn ions than the allowable limits of the NCH 409. Therefore, the water needs to be treated prior to serving the customers. The raw water will be transmitted to the treatment plant located adjacent to the well field. The raw water intake pipes within the well field, from the wells up to the treatment plant are of Asbestos Cement pipes (ACP) and the diameters vary from 200 mm to 800 mm.

3.3 Transmission System Alternatives

(From the water sources to Alto Hospicio)

3.3.1 General

Five (5) alternative routes have been selected for the transmission of water from the water sources to a new tank at the Alto Hospicio tank site (Refer to Fig. D-II,3.1). For the La Tirana and Pintados sources, two alternative routes per each site are proposed. All five alternatives will follow the routes of existing roads and/or existing pipelines, in order to minimize any construction difficulties. The proposed alternative routes are listed below:

- Alternative (1): La Tirana water source (Route No.1)
- Alternative (2): La Tirana water source (Route No.2)
- Alternative (3): Pintados water source (Route No.1)
- Alternative (4): Pintados water source (Route No.2)
- Alternative (5): Salar del Huasco water source

The hydraulic calculations for different transmission alternatives from water sources to Alto Hospicio/ Cavancha are given in Tables DT-1 to 6.

Three (3) km long transmission pipelines are provided between the Alto Hospicio tanks and new distribution tanks at the Cavancha distribution tank site. The water levels in the new tanks will be same as the existing tanks, in order to avoid any technical difficulties. The elevation difference between the Alto Hospicio tank (LWL:+545 m) and the Cavancha tank (LWL:+114 m) is sufficient to flow the water by gravity (Refer to Fig. D-II,3.16).

The transmission pumps used to transmit water from the collection tanks or from the treatment plant, and the booster pumps used in between to increase the water pressure in the pipelines are of double-suction volute type. All these pumps have a discharge capacity of 10.5 m^3/min. The booster pumping stations have suction wells of capacity 2,500 m^3.

The power required to operate the pumps will be obtained from the public electric power supply company, ELIQSA. In the case of the La Tirana Well-Field, the power will be transmitted from Pozo Almonte Substation/ ELIQSA, 20 km away; Pintados Well-Field from Tamarugal Substation, 20 km away; and Salar del Huasco from Pica Substation, 75 km away.

A structural drawing of a typical pumping station is shown in Figs. D-II, 3.17 and 3.18.

Ductile cast iron pipes (DIP) of diameters ranging from 400-700 mm are proposed to use in all the transmission mains. The pipes will be laid in trenches, on 200 mm thick sand bed, and covered with sand up to 300 mm high above top of the pipe. The pipes will be laid with 1.2 m cover, except in desert areas. In desert areas, the excavated soil will be mounted above the sand filled trench (Refer to Figs. DC-1 and 2 in Cost Estimation Data).

The break-pressure tanks are provided at strategically important locations, in order to reduce the operating pressure within the pipelines to an acceptable level.

Whenever possible, existing tank sites or pumping station sites are selected for the construction of new tanks or booster pumping stations. The water levels of the existing tanks or suction wells are maintained in the new tanks or suction wells too, in order to minimize any technical difficulties.

The existing tank sites considered for the construction of new tanks in Alternatives (3) and (5) are as follows;

- Rinconada tank site
- Diana tank/pumping station site
- Carpas tank site
- Santa Rosa tank site
- Alto Hospicio tank site

All new tanks are made of reinforced concrete. The capacity of a break-pressure tank is 500 m^3. The capacity of a suction well for pumps or a transmission tank is 2,500 m^3.

(Note) Existing tanks will be used for the present water supply as they are. Therefore, in the following discussion, wherever it refers to a tank or booster pumping station at above 5 locations, it means that a new tank or a new booster pumping station is to be additionally constructed at that location.

3.3.2 Alternative (1): La Tirana Water Source (Route No.1)

The transmission route between La Tirana and the Alto Hospicio tank is 64.6 km long. The majority of the pipeline will follow the existing highways. The transmission pipeline consists of 700 mm dia. pumping mains, 40.4 km long; and 500/400 mm dia. gravity mains, 24.2 km long. The raw water will be pumped from the collection tank to another tank located at the highest point of the transmission route. The difference of elevation between the tank at the highest point (LWL: +1,100 m) and the Alto Hospicio tank (LWL: +545 m) is about 550 m. Therefore, the water can flow by gravity between the tanks. Three break-pressure tanks are provided in between, in order to reduce the operating pressure within the pipelines to acceptable levels (maximum: 20 kg/cm2). They are located at chainages L= 42,100 m (GL=+1,50 m), L= 53,750 m (GL=+975 m) and L= 57,150 m (GL=+760 m). (Refer to Fig. D-II, 3.8).

There are five (5) transmission pumps including 1 on standby, with a pump head of 125 m, in the transmission pump station located within the well-field.

3.3.3 Alternative (2): La Tirana Water Source (Route No.2)

This transmission route is 63.5 km long and follows the route of the abandoned pipeline. The raw water will be pumped from the collection tank to a tank located at the highest elevation of the pipeline. In this case, it is necessary to boost the pressure in between, and a booster pumping station is located at chainage L= 21,400 m. The pumping pipeline is of 700 mm dia. and 22.2 km long. The height difference between the tank at the highest point (LWL: +1,205 m) and the Alto Hospicio tank (LWL: +545 m) is about 660 m, and therefore, the water can flow by gravity between the tanks. The gravity mains are of 600/500/400 mm dia. and 41.3 km long. Five (5) break pressure tanks are proposed along the route in between, for the purpose of reducing the pressure within the pipelines to acceptable levels. These tanks are located at chainages L= 36,900 m (GL=+1,150 m), L= 42,100 m (GL=+1,100 m), L= 44,000 m (GL=+1,000 m), L= 54,400 m (GL=+930 m) and 56,750 m (GL=+735 m). (Refer to Fig. D-II, 3.9)

There is 1 transmission pump station (5 transmission pumps including 1 on standby, with a pump head of 114 m each) and 1 booster pump station (5 booster pumps including 1 on standby, with a pump head of 114 m).

3.3.4 Alternative (3): Pintados Water Source (Route No.1)

This route from Pintados to Alto Hospicio, follows the highways and the existing transmission pipelines from the Canchones water source. The transmission pipeline is about 84.4 km long and consists of 700 mm dia., 44.2 km long pumping pipeline; and 500/400 mm dia., 40.2 km long gravity main. The water from the collection tank at Pintados will be pumped to a tank at the Rinconada tank site. The new Rinconada tank (LWL: +1,155 m) is located at the highest point on the transmission pipeline. The water pressure in the pumping pipeline will be increased by the booster pumps at the Diana pumping station site, located at chainage L= 41,700 m (Refer to Fig. D-II, 3.10). For this purpose a new booster pump house will be constructed at the Diana pumping station site.

There are two new tanks between the Rinconada tank and the Alto Hospicio tank, at Carpas and Santa Rosa. These two tanks serve as break-pressure tanks. The water from the Rinconada tank flows by gravity to the Alto Hospicio tank via the Carpas tank and the Santa Rosa tank.

There is 1 transmission pump station (5 transmission pumps including 1 on standby, with a pump head of 95 m each) and 1 booster pump station (5 booster pumps including 1 on standby with a pump head of 127 m).

3.3.5 Alternative (4): Pintados Water Source (Route No.2)

The Alternative (4) route is 81.3 km long and follows the existing railway/road towards Iquique. This transmission line consists of 54.9 km long 700 mm dia. pumping pipelines and 26.4 km long gravity main with diameters of 600/400 mm. The raw water from the collection tank will be pumped to another tank (LWL: +1,050 m) located at the highest point on the transmission line. A booster pumping station is located at chainage L= 37,550 m. The water can flow by gravity from the tank at the highest point to the Alto Hospicio tank. In order to reduce the working pressure within the pipelines, three (3) break-pressure tanks are provided at chainages L= 67,700 m (GL=+1,000 m), L= 70,300 m (GL=+800 m) and L= 73,350 m (GL=+700 m). (Refer to Fig. D-II, 3.11).

There is 1 transmission pump station (5 transmission pumps including 1 on standby, with a pump head of 102 m each) and 1 booster pump station (5 booster pumps including 1 on standby, with a pump head of 26 m).

3.3.6 Alternative (5): Salar del Huasco Water Source

The transmission route between Salar del Huasco and the Alto Hospicio tank is 157.7 km long. This line follows the existing road and pipelines. The transmission pipeline consists of 22.9 km long, 700 mm dia. pumping pipelines and 134.8 km long gravity main with diameters of 700/500/400 mm. The treated water from the Salar del Huasco treatment plant will be pumped to a tank located at the highest point of the transmission pipeline. Two booster pumping stations at chainages L= 12,800 m and L= 15,000 m are provided to increase the water pressure in the pipeline, in order to reach the desired location. The elevation difference between the tank at the highest point (LWL: +4,200 m) and the Alto Hospicio tank (LWL: +545 m) is about 3,650 m. Therefore, 17 break-pressure tanks are provided between the tank at the highest point and the Rinconada tank (including the one at Rinconada), in order to reduce the pressure within the gravity flow pipelines to acceptable levels (Refer to Figs. D-II, 3.12 to 3.15).

There is 1 transmission pump station (5 transmission pumps including 1 on standby, with a pump head of 165 m) and 2 booster pump stations (each equipped with 5 booster pumps including 1 on standby). The pumps in two booster pump stations have two different pump heads; 165 m and 115 m.

3.4 Cost Estimation

The cost associated with the development of the water source, intake facilities, treatment plant (if necessary) and transmission facilities were estimated for 5 alternatives (See Tables DC-1 to DC-5).

(Note): In the case of pipeline installation, two expenditure options were considered: 1) one-time investment and 2) two-steps investment. Cost analysis was carried out using the present value technique at the discount rate of 12% per annum (See Appendix-3: Comparison Study on Investment Timing for Installation of Transmission Pipelines). As discussed in the Appendix, the two-steps investment is recommended.

The construction cost is summarized below: (See Tables DC-1 to DC-5 for the detail.)

Summary of Construction Cost

Alternative	Construction Cost (Chile Peso: $)
Alternative (1)	$ 36,821,000,000
Alternative (2)	$ 37,024,000,000
Alternative (3)	$ 46,100,000,000
Alternative (4)	$ 48,069,000,000
Alternative (5)	$ 89,984,000,000

3.5 Comparison and Selection for Implementation

The each alternative was analyzed in detail and weighed the merits, for the purpose of selecting the most suitable alternative for implementation.