3.2.3 Surface Water Observation

The surface water is one of the prarameters necessary for calculating water balance. In order to know the inflow (Is) and the outflow (Os) of the surface water, the flow measurement was made on the related rivers. Measuring positions are shown in Fig.3.2.3-1.

To know the seasonal fluctuations, the measurement was made in the rainy season (July) and dry season (February). The results are shown in Table 3.2.3-1. From this table, the following items can be judged.

① In the El Alto district, the rivers are liable to be affected by rainfall in the rainy season, and the water flow is easily changed. It is characteristic that the single river shows flow fluctuations by a factor of 10, but from the viewpoint of water balance in this district, all these fluctuations were negligibly small. (Groundwater flowing quantity $\geqq$ surface water) Moreover, in the dry season, most points dried up.

② In the main stream of Rio La Paz, the flow is stable throughout the year, but in the branches, the flow is liable to be affected by rainfall as in rivers of El Alto.

③ Insofar as the change in flow from upstream to downstream areas of Rio La Paz is concerned, there is little groundwater outflow from the El Alto district. The outflow from the whole of the El Alto district in the dry season is about 0.5 lit/s at most.

④ When the water balance is considered, in the El Alto district, it can be said that the flow of the surface water is negligibly small. Therefore, it is sufficient to perform simulations mainly on the groundwater.

The surface water which passes the study area is max. 2.5 m^3/s (in the rainy season) and the surface water which passes the area around the study area is max. 2.1 m^3/s

in the rainy season. (Of course, the surface water flow is nearly zero in the dry season.

In contrast, the groundwater flowing quantity, taken down to 200m under the ground, is as follows.

$$1.0 \times 10^{-1} \times \frac{1}{\alpha} \times 8000 \times (2000-30) = \frac{1}{\alpha} 1360 \ m^3/sec.$$

Permeability coefficient	Running water slope	Mean width	Groundwater diameter

The above is only an approximate calculation, but if it is assumed that $\alpha = 10$, then, the groundwater flowing quantity is two orders higher than the surface water flow, and therefore, it is judged that the surface water flow can be neglected.

Table 3.2.3-1 Results of surface water observation

Name of River	Point of Observation	Rainy season: Date	Quantity of Flaw (m³/sec.)	Rainy season: Date	Quantity of Flaw (m³/sec.)	Dry season: Date	Quantity of Flaw (m³/sec.)
SECO	A-1	9 Feb.	0.14	23 Feb.	0.03	1 July	0
	2		0.37		0.02		≒0
	3		0.29		0.48		0
SEQUE	B-1	9 Feb.	0.81	23 Feb.	0.26	9 July	0
	2		2.10		0.11		0
	3		0.50		0.13		0
SAN ROQUE	C-1	10 Feb.	-				0
	2		0.10			9 July	≒0
KOKOTA	D-1	10 Feb.	0.03			9 July	0
	2		0.03				0
VILAQUE	E-1	10 Feb.	0.57			9 July	0
LA PAZ	F-1	12 Feb.	1.50	24 Feb.	1.02	3 Aug.	0.034
	2		1.34		2.05		0.22
	3		1.57		0.60		0.037
	4		2.70		1.50		0.048
	5		0.22		1.50		0.004
	6		5.18		5.90		0.32
	7		0.18		-		0.004

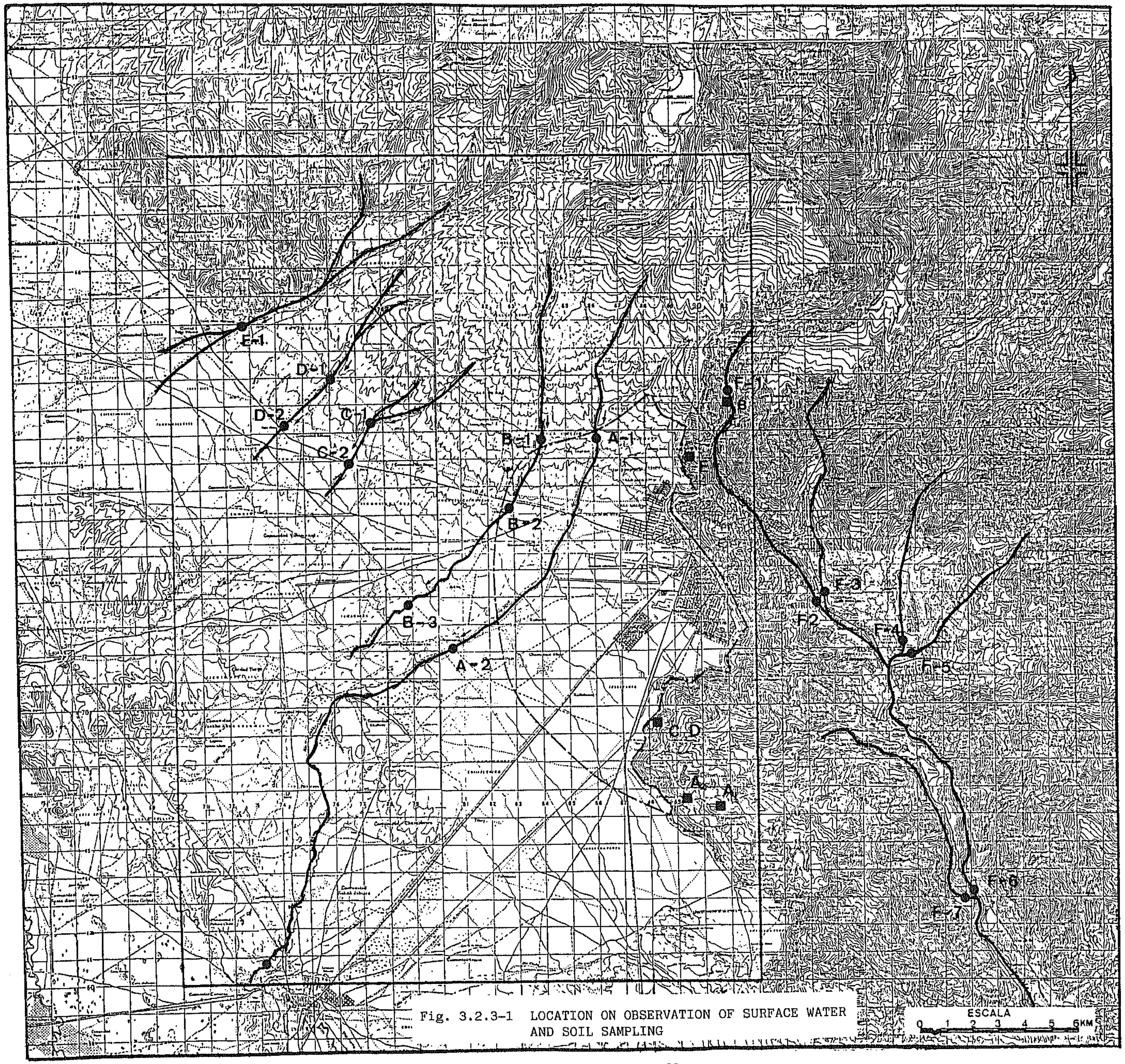


Fig. 3.2.3-1 LOCATION ON OBSERVATION OF SURFACE WATER AND SOIL SAMPLING

LEGEND

C ■ SOIL SAMPLING
A-1 ● OBSERVATION OF SURFACE WATER

3.3 Well Inventory

The well inventory from the existing data and the data obtained by the survey of rainy and dry seasons is as shown in Tables 3.3-1 through 3.3-3.

Table 3.3 -1

INVENTARIO DE POZOS (1)

POZO	NOMBRE DEL	COTA	NIVEL DE AGUA			DIAMETRO	PROFUNDIDAD	MAXIMA	OBSERVASIONES
No.	POZO	TERRENO	CONSTRUCTION	FEB / 87	JUL / 87	DEL POZO		DESCARGA	
1(1)	PIL	4037.67	—						
1(2)	PIL	4037.36			4023.47				
2(3)	FANVIPLAN	4032.01	4007.11	4006.98	4006.66	8″	70m	6.2 ℓ/sec	− 0.32
3	LABOFARMA	4028.04	4007.04	4007.51	4007.51	6″	60m	6.25ℓ/sec	0.00
4	MORALES	4027.20	4006.90			$6^{5}/_{8}$″	60m	8.0 ℓ/sec	
5	UIQUID CARCONIC	4037.64	4021.14	4025.67	4024.17	6″	66m	10.0 ℓ/sec	− 1.50
6	BERA BOLIVIA	4038.78	4021.08	3997.72	3998.06	6″	54m	3.14ℓ/sec	+ 0.34
7(1)	VASCAL S.A.	4035.52	4004.97	3986.01	3985.97	8″	83m	5.5 ℓ/sec	− 0.04
8	HORMITABOL	4022.70	4004.43	4006.86	4007.06	10″	63m	8.5 ℓ/sec	+ 0.20
9	GEOBOL	4022.48		4008.16	4008.10	6″		8.0 ℓ/sec	− 0.06
10	Y.P.F.B.	3965.80	3933.58	3936.04	3936.50	6″	64m	4.4 ℓ/sec	+ 0.46
11	COMANING	3971.15	3939.70			6″	60m	4.34ℓ/sec	
12	COVIMA	3947.02	3928.84	3930.03	3930.69	6″	66m	6.2 ℓ/sec	+ 0.69
13	CONVIFAG	3971.04	3942.78	3944.51	3945.75	6″	58m	4 ℓ/sec	+ 1.24
14	INDUVAR	4028.47	3986.47			4″	57m	18.6 ℓ/sec	
15	TEXPUNTO	4032.23	4003.33	4006.20		6″	60m	4.57ℓ/sec	
16	ACRIBOL	3960.97	3944.82		3948.87	6″, 4″	60m	3.7 ℓ/sec	
17	ELMEC	3958.75	3944.62	3947.07	3946.54	6″	60m	6.15ℓ/sec	− 0.53
18	BANVI	3946.03	3947.36	3940.14	3939.27	10″	48m	10.2 ℓ/sec	− 0.87
19	FATRAVI	3947.82	3935.82			6″	60m	13.11ℓ/sec	

Table 3.3 -2

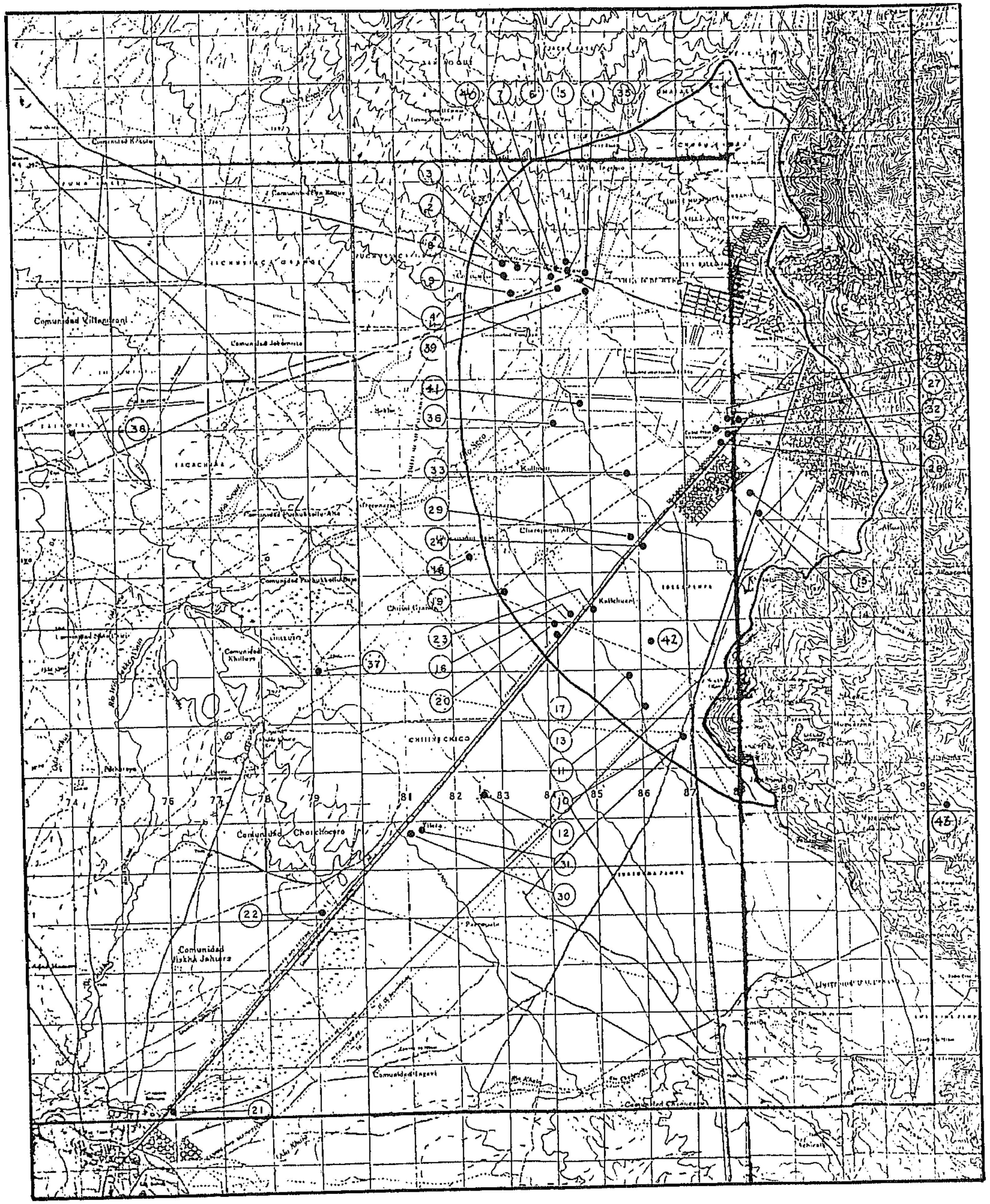
INVENTARIO DE POZOS (2)

POZO No.	NOMBRE DEL POZO	COTA TERRENO	NIVEL DE AGUA			DIAMETRO DEL POZO	PROFUNDIDAD	MAXIMA DESCARGA	OBSERVASIONES
			CONSTRUCTION	FEB / 87	JUL / 87				
20	JABONES PATRIA S.A.	3954.40	3941.40	3943.94	3943.78	$6^5/_8$"	60m	4.5 ℓ/sec	− 0.16
21	POZO(VIACHA)	3848.00	3844.00						
22	INFOL	3884.65	3871.15	3871.70	3872.37	$8^5/_8$"	52m	5 ℓ/sec	+ 0.67
23	LA CASCADA	3974.41	3950.91			6"	70m	4.2 ℓ/sec	
24	INTI	3996.32	3966.32			6"	70m	6 ℓ/sec	
25	LA CIMA	4032.78	3999.78		4003.33	6"	60m	3.7 ℓ/sec	
26	TEXTURBOL	4034.37	4001.66			6"	60m	1.5 ℓ/sec	
27	INBOLSA	4039.51	4003.51	4007.16	4004.93	6"	70m	1.1 ℓ/sec	− 2.23
28	ARAND S.A.	4035.63	4000.63	4006.64	4004.33	$6^5/_8$"	68m	4 ℓ/sec	− 2.31
29	CENACO	3993.78	3965.98	3974.35	3972.80	$6^5/_8$"	64m	3.3 ℓ/sec	− 1.55
30	INSA PO-1	3938.12	3925.29			4"	35m	3 ℓ/sec	
31	INSA PP-1	3938.65	3925.57	3929.65	3930.04	$8^5/_8$", $6^5/_8$"	62m	10.5 ℓ/sec	+ 0.39
32	OSSIO					4"	30m	0.6 ℓ/sec	
33	JAURECUI LTDA					6"	61m	3.1 ℓ/sec	
34	BUSTILLOS					6"	66m	3.5 ℓ/sec	
35	FANDA LTDA	4039.79				$6^5/_8$", 4"	42m	3 ℓ/sec	
36	VILLA ADELA	3990.00				6"	60m		
37	MARISCAL SANTA CRUE	3916.00		3914.00					

Table 3.3 -3

INVENTARIO DE POZOS (3)

POZO No.	NOMBRE DEL POZO	COTA TERRENO	NIVEL DE AGUA			DIAMETRO DEL POZO	PROFUNDIDAD	MAXIMA DESCARGA	OBSERVASIONES
			CONSTRUCTION	FEB / 87	JUL / 87				
38	CORDEPAZ	3890.00	3882.65	3888.26		8″, 6″	48m		
39	SAMAPA	4035.00	4021.66		4021.66	6″	40m		
40	VASCAL (4)	4032.00	4015.07		4015.07	8″	84m	8 ℓ/sec.	
41(1)	AASANA	4012.76	4005.52	4010.40		8″	53m		
41(2)	AASANA	4012.83	4002.41	4008.22		4″	30m		
42	CONVIPET	3985.0			3959.93	6″	60m		
43	ACHOCALLA	3665.			3662.00	4″	6m		



REFERENCIA

No.de Pozo	Nombre de Pozo	Cota Terreno	Nivel de Agua
1	PIL	4037.67	4019.65
2	FANVIPLAN	4032.01	4006.98
3	LABOFARMA	4028.04	4007.51
4	MORALES	4027.20	4006.90
5	LIQUID CARBONIC	4037.64	4025.67
6	BERA BOLIVIA	4038.78	3997.72
7	VASCAL S.A.	4035.52	3986.01
8	HORMITABOL	4022.70	4006.86
9	GEOBOL	4022.48	4008.16
10	Y.P.F.B.	3965.80	3936.04
11	COMANING	3971.15	3939.70
12	COVIMA	3947.02	3930.03
13	CONVIFAG	3971.04	3944.51
14	INDUVAR	4028.47	3986.47
15	TEXPUNTO	4032.23	4006.20
16	ACRIBOL	3960.97	3944.82
17	ELMEC	3958.75	3947.07
18	BANVI (Kiswaras)	3946.03	3940.14
19	FATRAVI	3947.82	3935.82
20	JABONES PATRIA	3954.40	3943.94
21	POZO SUPERFICIAL	3848.00	3847.70
22	INFOL	3884.65	3871.70
23	LA CASCADA	3974.41	3950.91
24	INTI	3996.32	3966.32
25	LA CIMA	4032.78	3999.78
26	TEXTURBOL	4034.37	4001.66
27	IMBOLSA	4039.51	4007.16
28	ARANDO S.A.	4035.63	4006.64
29	CENACO	3993.78	3974.35
30	INSA PO -1	3938.12	3925.29
31	INSA PP -1	3938.65	3925.57
35	FANDA LTDA.	4039.79	4027.59
36	VILLA ADELA	3990.00	3973.50
37	MARISCAL S/C	3916.00	3914.00
38	CORDEPAZ	3980.00	3888.26
39	SAMAPA	4035.00	4021.66
40	VASCAL	4032.00	4015.07
41	AASANA	4012.76	4010.40
42	CONVIPET	3985.00	3959.93
43	ACHOCALLA	3665.00	3662.00

Fig. 3.3-1 LOCATION OF EXISTING WELLS

3.4 Study of The Water Quality

3.4.1 Purpose and Method of Survey

1) Existing Circumstances at Water Utilization

In La Paz City, thawed water from the Andes on the east (Andes orientales) is used as the water source to supply drinking water. This water source region also serves as the water source for the groundwater in the study area.

In this water source region, metal mines, one of the major industries in Bolivia, are scattered, and part of the water sources are affected by the mine wastewater.

The El Alto district of La Paz City, which is planned as the water supply area this time, is supplied mainly by public water supply from the El Alto water purification plant. However, a part of the peripheral area is still not supplied, and many factories have been making use of groundwater by their own wells. The El Alto district, except a very small part (eastern part), does not have public facilities of sewage. Most of wastewater from households is discharged into the side ditches of the road, and the wastewater flows over the road and becomes puddle. Therefore, part of the groundwater may be possibly polluted by the wastewater.

2) Purpose of the study

The purpose of study is to collect the information relating to the water quality in order to prospect the future plan against the above-mentioned circumstances. Water samples were taken and examined.

3) Classification

Water sources and water supply systems were classified by their special features as follows, and their water quality and environment were surveyed.

A. Raw water for waterworks

B. Treated water for drinking (water supply to La Paz City)

C. Water systems affected by Milluni mine wastewater, and water requiring examination for pollution by heavy metals

D. Well water (groundwater) in the El Alto district (examination of water pollution)

E. Groundwater (in the future)

F. Surface water and artesian flow water (reference for environment assessment)

The number of tests by the above classification is as shown in Table 3.4.1-1.

Table 3.4.1-1 Number of classified water tests

CLASSIFICATION	RAINY SEASON	DRY SEASON
A	9	5
B	8	6
C (HEAVY METAL)	10 (12)	6 (10)
D	24	15
E	5	11
F	9	9

4) Method

At the same time as sampling, the water temperature, pH, EC, etc. were measured at the site, and the samples were tested at the SAMAPA central laboratory within the same day or two days for the other items.

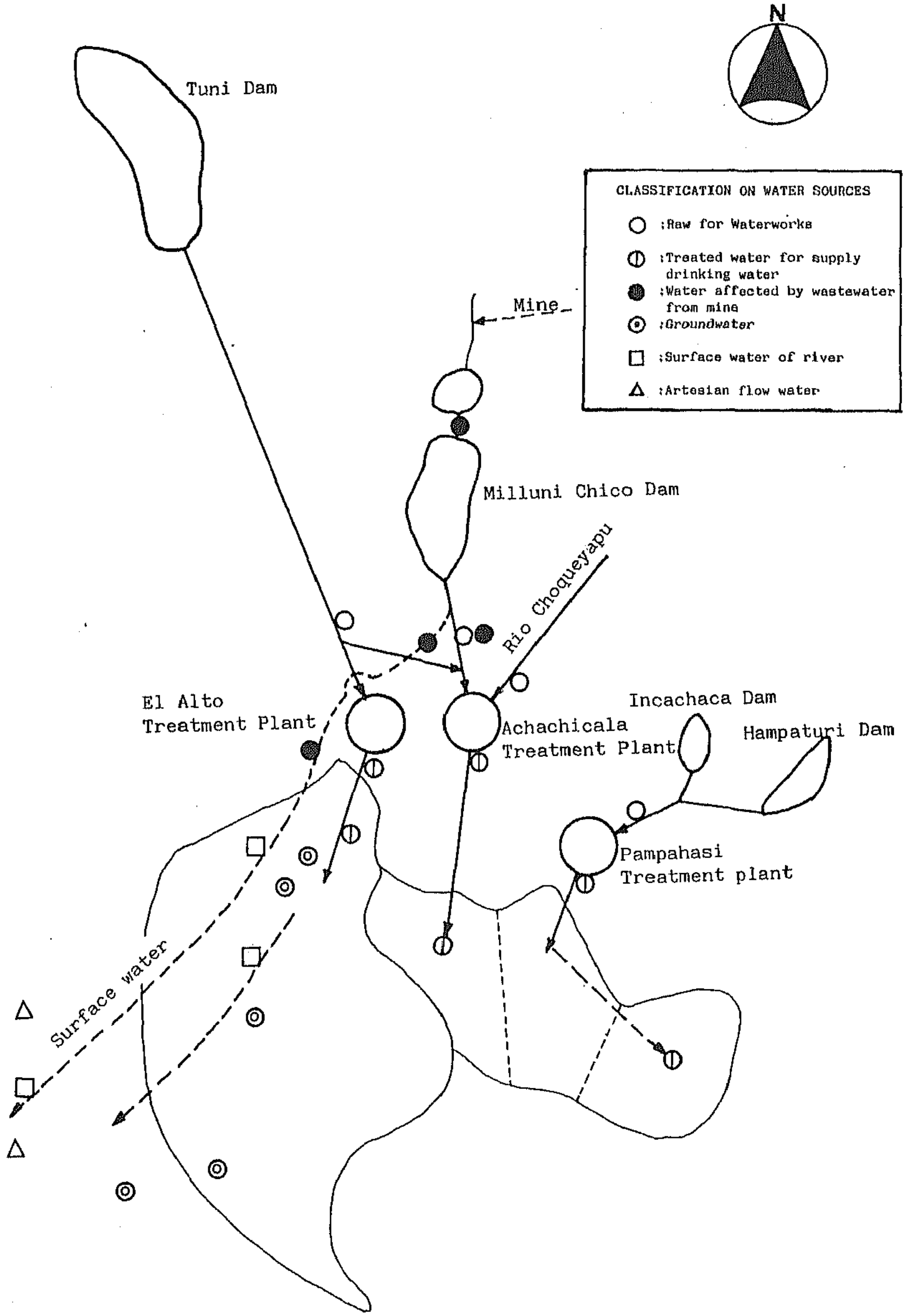


Fig. 3.4.1-1 GENERAL VIEW OF WATER SUPPLY SISTEM IN THE PROJECT AREA & LOCATION OF WATER SAMPLING FOR QUALITY TEST

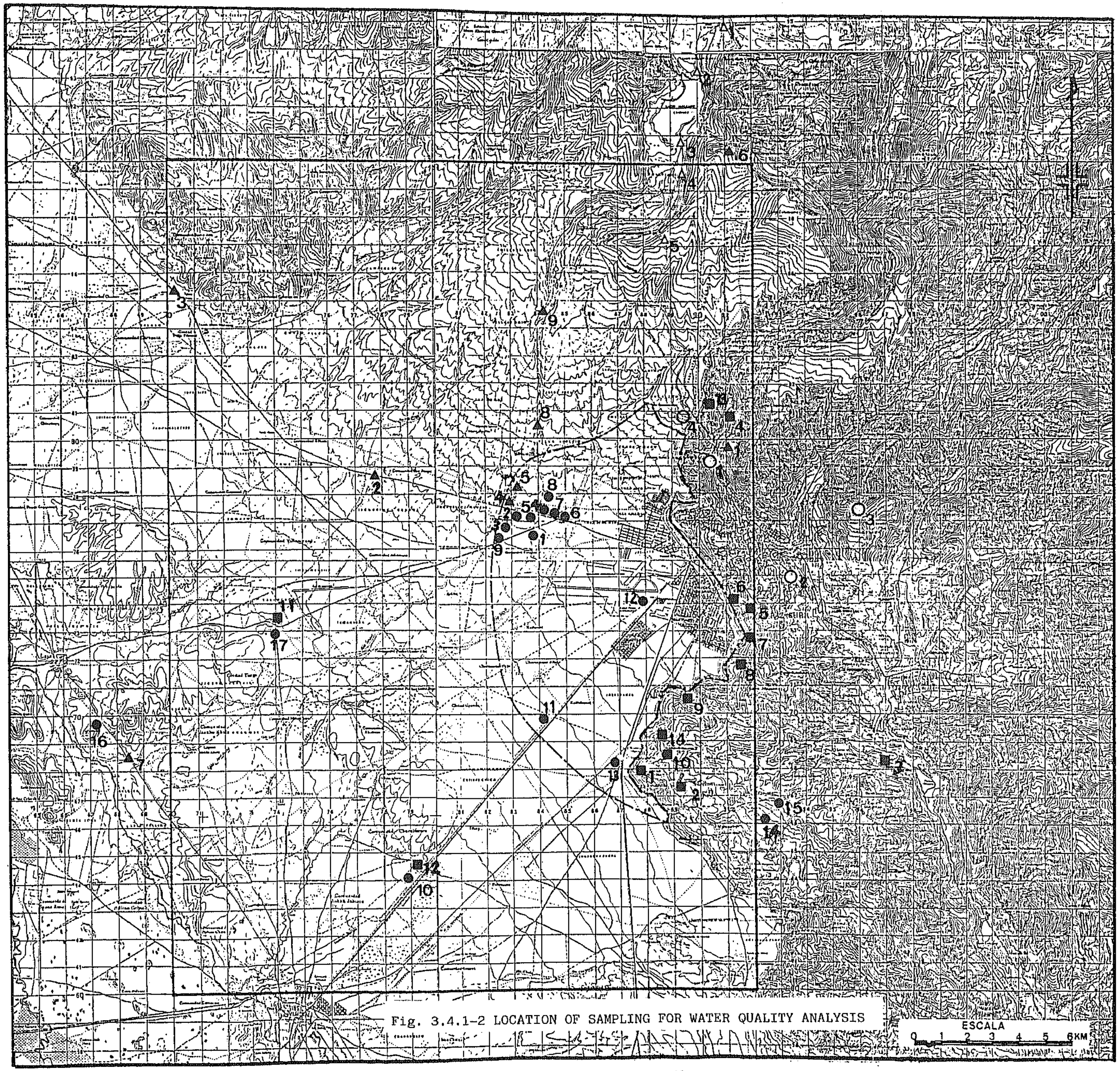


Fig. 3.4.1-2 LOCATION OF SAMPLING FOR WATER QUALITY ANALYSIS

POZOS INVESTIGADOS

1. Poso Morales
2. FANVIPLAN
3. HORMITABOL
4. VASCAL
5. LABOFARMA
6. PIL
7. Liquid Carbonic
8. Pozo Vera
9. GEOBOL
10. INFOL
11. ELMEC
12. La Cima
13. Y.P.F.B
14. Achocalla
15. Kanuma (Achocalla)
16. Sullcataca Alta Jalaquiri
17. CORDEPAZ (Kallutaca)

RIOS INVESTIGADOS

1. Rio Choqueyapu
2. Rio Ponkora
3. Puente Villuyo
4. Rio Seque
5. Rio Seque
6. Rio Seco
7. Rio Camino (Laja-Viacha)
8. Rio Seque
9. Rio Seque

AGUAS SUPERFICIALES

1. Comunidad Sarmiento (Achocalla)
2. Laguna Achocalla
3. Laguna Golf Club
4. Parte Alta Rio Choqueyapu
5. Av. Buenos Aires (Final)
6. Tacagua (Parte Alta)
7. Llojeta
8. Comunidad Alpacoma
9. Comunidad Kayo
10. Comunidad Uni
11. CORDEPAZ (Kallutaca)
12. Laguna Chochocoro
13. Purapura
14. Khututu

PLANTAS DE TRATAMIENTO Y RED DE ABASTECIMIENTO DE AGUA POTABLE

1. Planta de tratamiento de Achachicala
   a) Salida Sedimentador
2. Hotel Crillon
3. Planta Pampahasi
   a) agua cruda (Incachaca)
   b) Salida filtros
4. Planta El Alto
   a) Agua cruda
   b) Salida Filtros
   c) Distribuda Topak Katari

CUENCA DE MILLUNI

1. Drenage principal nivel Cero
2. Milluni Chico
3. Represa Milluni
4. Canal (Antes de Alcalizacion)
5. Canal (Despues de Alcalinizacion)

3.4.2 Results of Water Quality Study

1) Raw water for waterworks

Water quality of five dams and lakes:

Water quality was surveyed on five storage reservoirs shown in Fig.3.4.2-1. The water at Tuni and Condoriri is the best among the samples: EC 100 uS/cm, pH 7.0 to 7.5, and both hardness and iron are the lowest, and the appearance (turbidity and color) is very low. Next is Incachaca and Hampaturi dams: all EC, pH, hardness and iron were low, and the appearance (color) and $KMnO_4$ consumption are somewhat high. This seems to be caused by the pollution with organic substances. However, the outflow water of Milluni dam has abnormally low pH (3.5), and contains much iron and manganese. This raw water sometimes contains heavy metals and poisonous substances: Cd, Co, Zn, Sn, As.

Surface water (river water) used as water source:

The water quality of Rio Choqueyapu fluctuates largely with time and is affected by pollution. All items show larger fluctuations (EC 110 to 280 uS/cm, hardness 50 to 130 ppm, $KMnO_4$ up to 5). The bacteria test was "positive" in most cases, and SAMAPA's bacteria test records also show higher polluted conditions. (Some annual records show maximum several thousand ppm to 2% TDS.)

Except Tuni Condoriri, other 4 water sources have trends that dissolved salts are more concentrated in the dry season than in the rainy season. In Tuni Condoriri, the annual fluctuation of TDS ranged from 50 to 70 ppm, not varying largely in dry and rainy seasons. For these reasons, the seasonal fluctuation of salts may be small.

Annual records of water quality measured by SAMAPA:

The water of each water source was sampled and analyzed by SAMAPA periodically (twice a month, 1983 to 1984). The results are shown in Table 3.4.2-1. (June, 1983 to June, 1984)

Table 3.4.2-1

River/ dam	Water temp. max.-min.	pH max.- min.	TDS max- min.	Alkalinity/ acidity	Total hardness	Other item
Tuni	4.0-11.0	6.4-8.3	34-123	3.7-12.7	-	11.4-27.2
Condoriri	6.0-15.0	6.8-8.3	40- 98	7.6-19.6	-	15.3-29.4
Incachaca	1.5-10.5	6.7-7.3	56-265	9.5-23.3	-	19.4-73.1
Hampaturi	0.5-12.0	7.2-7.6	39-129	10.8-17.9	-	17.0-27.2
Choqueyapu	3.5-17.0	6.6-7.8	191- *	9.0-25.1	-	25.9-613 Fe 0.1-310,
Milluni	4.5-16.5	3.0-3.7	453-2013	-	138-626	-879.6 **

TDS of Choqeyapu : * max:21230, 4658 etc. Mn -- 12.7, SO_4 26.0-102

For Milluni : ** Fe 41.8-242.1 Mn 0-32.6, SO_4 221.4-613.

The results of bacteria test (January to June, 1984) show that, except the water of Milluni which is always acidic, the bacteria value detected (MPN count) increases from above to below in the table. It is minimum in the water from Tuni•Condoriri and maximum at Choqueyapu. The areas of Incachaca dam and Hampaturi dam water sources are the cattle areas and the water is polluted by the wastes, and organic substances and color components in the water are somewhat more than in Tuni•Condoriri.

2) Treated water for drinking (water supply to La Paz City)

a. The treated water of each water purification plant and the distributed water are applied with the water quality standards of AWWA (American Waterworks Association) to judge the water quality for public supply. Normally, the good quality water with proper chlorination was confirmed in both rainy and dry seasons.

<u>El Alto and Pampahasi Purification Plants</u>

The raw water has usually good quality, and accordingly the treated water has good water quality. According to the data of SAMAPA, the treated water has higher pH (pH > 9), low EC, low hardness, and low iron. And the residual chlorine was also detected in the distributed water. However, treated water is potable.

Achachicara Purification Plant

The quality of treated water at Achachicara purification plant varies by the quantities of raw water supplied from Milluni, Rio Choqueyapu, and Tuni・Condoriri. Especially, much lime is used to treat iron anhd manganese in the season the water of Milluni dam is used. According to the results of water quality test, the treated water satisfies the water quality standards except high values of evaporation residue, pH and hardness. The residual chlorine was also detected in the distributed water.

b. Results of water quality analysis of treated water of each purification plant

The records of water quality analysis in 1985 of SAMAPA (once a month, 12 times a year) were as follows.

Table 3.4.2-2 Treated water quality

Purification plant	pH	TDS ppm	Total hardness as $CaCO_3$	Residual Cl ppm
Achachicala	8.6 - 9.2	52 - 590	26 - 316	0.1 - 0.2
		(T-Fe - 0.3,	Mn 0.0 - 0.4)	
Pampahasi	9.0 - 9.2	57 - 68	31 - 44	0.1 - 0.2
El Alto	8.8 - 9.1	47 - 49	25 - 28	0.1

The results of water quality analysis show that throughout the year, the treated water of Pampahasi and El Alto have the same trends as the raw water, indicating stable water quality with very small fluctuations.

While, the treated water of Achachicala shows large annual water quality fluctuations. It is comparatively difficult to treat the Milluni water and requires more chemical than in other purification plants. The major reason is the treatment of manganese by sedimentation.

c. It is necessary to take a measure against the wastewater of Milluni mine outlet, water receiving pond, Milluni Chico, Milluni dam, and Milluni canal in the Milluni water stystem.

3) Water systems affected by Milluni mine wastewater

a. Twelve samples were taken in the rainy season survey including the groundwater in the norhtern part of the El Alto district (including the Milluni water system). They were analyzed, and heavy metals, and poisonous substances (arsenic, above the limit in Vascal, Coca Cola) were detected. Therefore, in the dry season survey, 10 samples were selected, including water of the neighboring wells of Vascal (groundwater having slightly higher EC), and brought back and analyzed in Japan.

As the groundwater in the neighborhood of Vascal (Coca Cola), three samples of HORMITABOL, FANVIPLAN and Vascal were examined for heavy metals and poisonous substances. The results are shown in Table 3.4.2-3.

b. In the water quality study in the rainy season, the arsenic in excess of the water quality standard (0.05 ppm) was detected twice in the groundwater of Vascal. In the dry season, it was confirmed again, and its value was below the standards.

In the dry season at present, the tap water is used by the lack of groundwater in Vascal. There might be no problem of arsenic in the dry season, because the groundwater is diluted by mixture with tap water.

c. On the other wells, including the middle-southern and western parts of El Alto, for the sake of caution, the water was checked for heavy metals and poisonous substances and it was confirmed that all values were smaller than the standard values.

4) Groundwater in the El Alto District

a. Results of the study in the rainy season survey

Northern part (along Pan American High Way)

In any well, the appearance (turbidity, color) was almost colorless or transparent, pH was between 6.5 and 7.5, neutral. As compared with most of the wells in the central and southern parts of El Alto, EC and total hardness were higher (200 to 420 μS/cm and 69 to 179). The $KMnO_4$ consumption was from 2 to 5 ppm. In only one sample, ammonia-nitrogen which shows a possibility of pollution with sewage water was detected in the minimum detection limit (0.4 ppm).

The strainer was set at 30 to 40m below the ground surface in most of the wells. And in the factory of Vascal, it was at 80m below the ground surface.

Middle-southern part (south of airport)

In most wells in this area, the water quality was good. EC was below 100 μS/cm in all wells except four (No.17 Elmec 105, No.25 Lacima 140, No.31 Insa 125, Air Port 110), pH was neutral in all wells except one (No.29 Cenaco pH 9), and the $KMnO_4$ consumption was below 5 in all wells.

Shallow wells in the middle-southern part

Water quality study was made at 4 points of shallow groundwater: Lago Chunchocolo spring water, farmer's house shallow well, Urbanization-GEOBOL well, Coredpaz shallow well. The water of Chunchocolo and west of Cordepaz (the west end of the survey area) shows EC 97 and 114 μS/cm, and pH 7.0 and 6.7, respectively, (Cordepaz $KMnO_4$ about 3), and the water quality is similar to the groundwater in other areas of El Alto district.

The groundwater of the well is obviously polluted by waste of cattle, and the appearance is slightly colored. The values of EC and $KMnO_4$ were 255 μS/cm and 5, and the results of coliform and general bacteria test were "positive". Accordingly, it is obvious that water quality is different from deep wells in this part.

b. Results of the surveys in rainy and dry seasons

The EC value of groundwater of each factory along the Pan American Road was 200 to 400 μS/cm. In the central and southern parts of El Alto district, it was 100 to 150 μS/cm.

In the central part of El Alto district, the groundwater in the dry season is almost the same quality as in the rainy season. However, the groundwater of factories along the Pan American Road showed EC which has a trend to become higher in the dry season than in the rainy season. Refer to Table 3.4.2-4 through 3.4.2-8.

This difference on the water quality by location might indicate that each water resource is different. And the groundwater near the Pan American Road in the northern part might be recharged with raw water from any such water source which is affected by the seasonal fluctuations. As a concrete example, the surface water obviously seasonally fluctuates in water quantity, and the water quality showed also a high dissolved salt concentration.

5) Groundwater data as the reference for the time when the groundwater development is implemented in EL Alto district in the future

The water quality of shallow wells and springs neighboring to the El Alto district was surveyed, and serious substances except pollution of organic substances was not contained.

Wide-ranged springs are on the east of El Alto, western sloped area of La Paz City. The water was sampled to examine whether it is the same as the systems of groundwater of El Alto district or not. The EC value at each sampling point is as shown in Fig.3.4.1-2.

The samples of spring water and groundwater, in relation to their positions, altitudes and the flow of the El Alto groundwater, show high EC values owing to dissolved salts in the ground, or show nearly the same quality as that in the central and southern parts of El Alto.

The results of analysis of these samples are as shown in Fig.3.4.2-1. The water of the farmer's well in the Khanma area shows obviously higher EC value than the groundwater in the central part of El Alto.

The tritium test was done to judge the age of water.

6) Surface water and artesian flow water

Water quality was examined on the water of Rio Seco in the El Alto district, Rio Seque running west thereof (originating from the Milluni dam), and Rio Choquenyapu running through the center of La Paz City (utilized partly as the water source for tap water from the upper stream). Also surveyed is the spring water which was considered to be spring-out groundwater, running over the road of Cordepaz to Laja at the west end of the study area, and said not to dry up throughout the year, and also on the well on the east side. (In the rainy season, water analysis was made on the shallow well, west of Cordepaz.)

a. Rio Seco runs from north to south-west, its water flow is not large, and it was used by the local dwellers for washing, etc. The sewage facilities are not furnished in El Alto district except a part of the east-end area of the slope facing La Paz, and the sewage water flows out the street and into Rio Seco.

Both Rio Seco and Rio Seque have very small flow in the dry season as compared with the rainy season (practically zero flow as the surface water), and there were only flows of sewage water. Rio Seque has half a flow of the rainy season at a point of 5 to 10 km upstream of the Pan American road, and the flow confirmed was very small.

In addition, samples were taken also from Ponkola and Viluyo west on the Pan American road, and the water infiltrated into the ground in the dry season.

Rio Seque connects with the surplus of the water flowing from the Milluni dam through canals. It contains mine wastewater, and the results of water analysis indicate it. The appearance of stone in the river beds was red-colored probably caused by iron contained in the water.

As described above, RioSeco and Rio Seque had substntially no water in the dry season except the upstreams, and the results of water analysis at each three points in the rainy season are shown below.

① Rio Seco

		pH	EC	Total hardness	Nitorogen $-NH_3$	Consumption of $KMnO_4$
UPPER STREAM	A1	4.5	160	60.9	-0	20
MID STREAM	A2	5.7	340	92.7	8	150-200
DOWN STREAM	A3	9.95	250	90.1	0	15

Refer to Fig. 3.2.3-1 LOCATION ON OBSERVATION SURFACE WATER CONCERNING A1, A2 and A3

② Rio Seque

	pH	EC	Total hardness	Nitorogen $-NH_3$	Fe	Consumtion of $KMnO_4$
UPPER STREAM	3.2	570	170	< 0.4	2.0	>20
MID STREAM	3.6	540	170.2	< 0.4	0.5-0.1	15-20
DOWN STREAM	3.6	520	178.2	< 0.4	0.2-0.3	>20

b. The water of Rio Choqueyapu running through La Paz City was sampled at the Achachicala purification plant, the intake pond and a point about 1 km upstream. The quality of this water fluctuates largely. The coliform and general bacteria tests were usually "positive." It is not obvious that this fluctuation is caused by the seasonal conditions.

Table 3.4.2-3 Analytical results of heavy metals and poisonous materials by JICA Team (× micro gram/l, for others mg/l)

Samples		As	Cr^{6+}	Hg×	Cd	Pb	Sn	Ba	Sb	Cu	TFe	Mn	Zn
Entrance of Milluni Mine	2/24	1.3	<0.1	<1	0.79	<0.2	3.2	<50	0.09				
	7/21	0.29	<0.1	<0.5	<0.02	<0.1	<0.06		0.06	0	74.7	6.5	8
Outlet of Milluni Chico	2/24	0.19	<0.1	<1	0.09	<0.2	0.5	<50	<0.04				
	7/21									>40	813	111.2	>40
Outlet of Milluni Dam (Down flow)	3/ 6	0.08	<0.1	<1	0.06	<0.1	0.8	<25	<0.04				
	7/21									1	46.7	9.3	7-8
Milluni Canal	3/	<0.08	<0.1	<1	0.06	<0.1	0.5	<25	<0.04				
	7/21	<0.02	<0.1	<0.5	<0.02	<0.1	<0.06		0.06	5	46.7	9.3	8
Milluni bajo	3/	<0.08	<0.1	<1	0.04	<0.1	<0.3	<25	<0.04				
	7/27	<0.02	<0.1	<0.5	<0.02	<0.1	<0.06		<0.02		1.4	2.6	
B1	7/ 9									(0.5	5	1.4	10)
Rio Seque	7/ 9	<0.02	<0.1	<0.5	<0.02	0.1	<0.06		<0.02	0.5	0.2	0.0	8
HORMITABOL	7/ 7	<0.02	<0.1	<0.5	<0.02	<0.1	<0.06		<0.02				
FANVIPLAN	7/ 7	<0.02	<0.1	<0.5	<0.02	<0.1	<0.06		<0.02				
VASCAL	3/ 3	0.07	<0.1	<1	0.02	<0.1	<0.3	<25	<0.04				
	3/25	0.08	<0.03	<0.5	0.005	<0.03	<0.07	<5	<0.01				
	7/ 7	0.04	<0.1	<0.5	<0.2	<0.1	<0.06		0.08		0		
INFOL	3/12	<0.08	<0.1	<0.5	0.02	<0.1	<0.3	<20	<0.04				
	7/26	<0.02	<0.1	<0.5	<0.02	<0.1	<0.06		<0.02				
ELMEC	7/ 8	0.01	<0.03	<0.5	0.005	<0.03	<0.07	6.7	<0.01				
LA CIMA	7/10	<0.02	<0.1	<0.5	<0.02	<0.1	<0.06		<0.02				
CORDEPAZ (POZO)	7/25	<0.02	<0.1	<0.5	<0.02	<0.1	<0.06		0.17				

NOTE: In all data in July, Se <0.05 and V (Vanadium) <0.1.

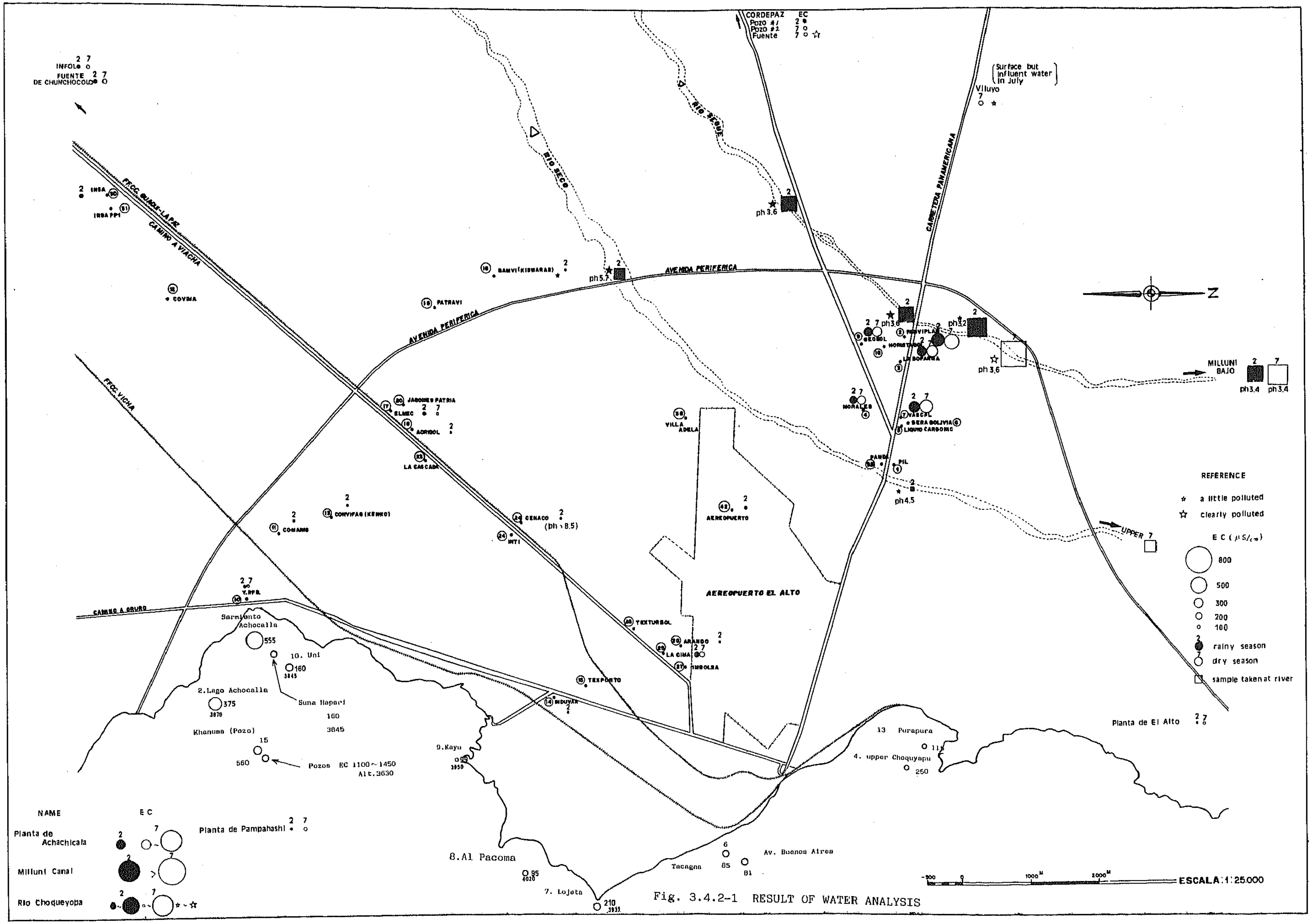


Fig. 3.4.2-1 RESULT OF WATER ANALYSIS

Table 3.4.2-4 RESULTS OF ANALYSIS - 1 (Comparisons of the data between rainy and dry season)

WATER WORKS	Achachicala				Rio Choqueyapu			(Distribuida)		
Date (Fecha)	2/9	2/9	7/21	7/9	2/11	7/9	7/14	2/12	7/8	7/22
Kind of sample (Classe) Sample (Muestra)	(Cruda)	(Filtr.)	(Cruda Milluni)	(Precip.)	Inlet	Inlet	(upper 1 km.)	Hotel Crillon from Acahchicala System		
Appearance (Apariencia) (Turbiedad/color)	T>5,C100	T,C=0	(neutr.)	faint turbid	turbid	turbid	turbid			
p H	5.88	9.0	3.5	9.3	7.3	7.5	7.1	9.1	8.6	8.3
E C(μS/cm)	330	335	835	580	110	65	280	500	610	615
T S (Residue totale)										
P-Alk (Alcalinidad-P)			Acidity	Alk 3.8						
T-Alk (〃 -T)			147.7	15.5	16	23	28	12.2	16.9	18.1
CaH (Dureza-Ca)										
MgH (〃 -Mg)										
Total-H as $CaCo_3$ (〃 -T)	300	178	197.4	304.8	49	119	130	194.5	310	326
$KMnO_4$-cons. (COD)					5	10	5			
Res-Cl_2								0.4	1.0	0.8
Nitrogen-NH_3				0.6	0.5	0.4	0.4		0.4	-
-NO_2				0	<0.006	0.006	0			-
-NO_3				0	<0.23	0.23	0	<0.23	0.23	0.3
Total-Fe (Hierro-T)	1.5-2.0	<0.1	8.3	<0.2	0.2	0.2	0	-	0.2	0.4-0.5
Mn (Manganeso)			9.3	0.62		0.17			0.34	0.6
Heavy Metals (Metal pesado) Cu			0	0						-
Zn			7-8	0.8					4	0.8
Etc.										
Remarks (commentar)										

Table 3.4.2 - 5 RESULTS OF ANALYSIS -2 (Comparisons of the data between rainy and dry season)

WATER WORKS	El Alto					
Date(Fecha)	2/10	2/10	2/12	7/14	7/14	7/20
Kind of sample(Classe)	(Cruda)	(Filtr.)	(Distrib)	(Cruda)	(Filtr.)	(Distr)
Sample(Muestra)			Vill. Dolo			Tupak
Appearance (Apariencia) (Turbiedad/color)	T-1, C<2					
p H	7.2	(9)	8.7	7.5	9.0	8.8
E C(μS/cm)	53.3	68.8	74	65	66	68.5
T S(Residue totale)						
P-Alk(Alcalinidad-P)					2.6	2.2
T-Alk(〃 -T)			18.7	16.2	20.7	19.6
CaH (Dureza-Ca)						
MgH (〃 -Mg)						
Total-H as$CaCo_3$(〃 -T)	(25)		26.1	22.7	25.9	27.8
$KMNO_4$-cons. (COD)				5	3	3-4
Res-Cl_2			0.1			
Nitrogen-NH_3	0		-	0	0	0
-NO_2	0		-	0	-	0
-NO_3	0		<0.23	0	0	0
Total-Fe(Hierro-T)	<0.2		-	0	0	0
Mn (Manganeso)						
Bacteria(general-total)						
(faecal)						
Bacter Metals, (Metal pesado) Cu						
Zn						
Remarks(commentar)						

Table 3.4.2 - 6 RESULTS OF ANALYSIS - 3 (Comparisons of the data between rainy and dry season)

WATER WORKS	Pampahasi		Hampaturi	Pampahasi		SAMAPA (Misture of El alto of Pampahasi Waters)	
Date(Fecha)	2/10	2/10	3/12	7/13	7/13	3/9	7/20
Kind of sample(Classe)	(Cruda)	(Filtr.)	(Cruda)	(Cruda)	(Filtr.)	(Distribuida)	
Sample(Muestra)				(Hampaturi)		Central Laboratory	
Appearance				A littole turbid			
(Apariencia)	T> 5	1	1				
(Turbiedad/color)	C>10	10	10				
p H	7.0	9.0	7.5	7.6	9.1	8.8	8.8
E C(μS/cm)	51	70	57	110	111	60	96
T S(Residue totale)						(68)	
P-Alk(Alcalinidad-P)					6.2		1.6
T-Alk(〃 -T)			17.7	27.3	34.4	(23.2)	28.4
CaH (Dureza-Ca)							
MgH (〃 -Mg)							
Total-H as$CaCo_3$ (〃 -T)	(25)		24.0	36.8	38.7		44.5
$KMnO_4$-cons. (COD)	10		5	4	4	5	4~5
Res-Cl_2		0.1				(0.4)	
Nitrogen-NH_3	<0.4	-	0	0	0	<0.4	<0.4
-NO_2	<0.02	-	0	0	0	0	0
-NO_3	<0.23	-	<0.46	0	0	0	0
Total-Fe(Hierro-T)	-	-	0	0	0	(0.2)	0
Mn (Manganeso)							
Bacteria(general-total)	(+)						
(faecal)	+						
Heavy Metals, (Metal pesado) Cu							
Zn							
Remarks(commentar)							

Table 3.4.2 - 7　RESULTS OF ANALYSIS - 4　(Comparisons of the data between rainy and dry season)

Date (Fecha)	2/17	7/7	2/17	7/7	2/17	7/7	2/17	7/7	3/3	7/7	2/17	7/10	2/18	7/10	2/19	7/10	3/11	7/10
Kind of sample (Classe)	2		8		9		4		7		10		17		25			
Sample (Muestra)	FANVIPLAN		HORMITABOL		GEOBOL		MORALES		VASCAL		YPFB		ELMEC		LA CIMA		INFOL	
Appearance																		
(Apariencia)	T,C								T,C								slight	
(Turbiedad/color)	~0		~0		~0		~0		~0	~0	~0		~0		~0		turbid	
p H	7.0	7.2	7~7.5	7.1	7.0	6.9	6.5	7.4	7.35	7.0	7.4	7.4	8.0	7.4	7.5	7.0	7.0	6.9
E C (μS/cm)	420	465	290	375	265	310	200	275	345	410	64	67	105	77.0	140	140	95	99
T S (Residue totale)	(15°)	(13°)	(−)	(12°)	(12°)	(13°)	(13°)	(11°)			(14°)	(13°)		13°	(13.5)		(14°)	(14°)
P-Alk (Alcalinidad-P)																		
T-Alk (〃 -T)		81.3		80.2		34.1		23.5		29.1		21.0		25.1		21.6	30.7	27.0
CaH (Dureza-Ca)																		
MgH (〃 -Mg)																		
Total-H as $CaCO_3$ (〃 -T)	178.7	177.4	142.7	175.6	109.6	97.5	69.0	79.4		55.5	15.2	15.2	22.2	19.3	38.8	35.7	31.5	21.3
$KMnO_4$-cons. (COD)	3~4,	~3	3~4	~3	~4	~5	2~3	~3		~3	2~3	~3	<5	3	2~3	~3	~3	~3
Res-Cl_2																		
Nitrogen-NH_3	0	0	<0.4	0	<0.4	0	<0.4	0	0.4~0.8	0	0	0	0	0	0.04	0	0	0
-NO_2	0	0	0	0	0	0	0	0	<0.006	0	0	0	0	0	0.006~15	0	<0.006	0.006
-NO_3	0	0	0	0	0	0	0	0	<0.23	0	0	0	0	0	0.46	0	<0.23	0.23
Total-Fe (Hierro-T)	0.2	0	~0.5	0	0.2~0.3	0	0.2	0	<0.2	0	0	0	<0.2	0	0.5	0	<0.2	0
Mn (Manganeso)																		
Bacteria (general-total)	(+)																	
(faecal)	+																	
Heavy Metals, (Metal pesado) Cu																		
Zn					3/25		3/25											
Etc.					pH6.7 EC300		pH6.6 EC220											
Remarks (commentar)																		

Table 3.4.2 - 8 RESULTS OF ANALYSIS - 5 (Comparisons of the data betwen rainy and dry season)

Date(Fecha)	2/23	7/21	2/23	7/9	7/25	7/27	7/9	2/24	2/11	7/9	7/14	3/11	7/25	3/11	3/25	3/25
Sample(Muestra)	RIO SECO UPPER		RIO SEQUE		RIO SEQUE		RIO SEQUE	CHOQUEYAPU				CHUNCHOCORO		CORDEPAZ DUG WELL		SPRING
Appearance (Apariencia) (Turbiedad/color)		*		*					T,C ~2.0			T,C~0		a little turbid		a little turbid
p H	4.5	4.2	3.2	3.55	3.3	3.4	3.63	7.2	7.3	7.5	7.1	7.0	7.1	6.7	6.82	6.92
E C(μS/cm)	160	415	570	827	865	565	923	150	110	65	280	97	120	114	101	117
T S(Residue totale)	(17°)											(15°)		(13°)		
P-Alk(Alcalinidad-P)	Acid.	Acid.	Acid.	Acid.			Acid.	20.8	16	22.9	27.8	46.9	42.6	32.8	94.4	38.7
T-Alk(〃 -T)	9.1	22.2	89.0	131			150									
CaH (Dureza-Ca)																
MgH (〃 -Mg)																
Total-H as$CaCO_3$ (〃 -T)	60.9	157.1	170.2	272.9		242.2	263	65.6	48.9	119.1	130.1	41.5	39.8	32.6	76.2	41.6
$KMnO_4$-cons. (COD)	20		>20	>200*			>200*	~5	5	~10	5		3	3	60	3
Res-Cl_2																
Nitrogen-NH_3	≦ 0.4		≦0.4	0.8		<0.4	<2~3	0.4	0.5~1	0.4	0.4	≦0.4	0	0	~0.6	<0.4
-NO_2	<0.006		0	0		<0.006	0		<0.006	0.006	0	0		0		
-NO_3	<0.23	<0.23	0	0		0	0		<0.23	0.23	0	0	0	≦0.23	0	0
Total-Fe(Hierro-T)	0	0.8	2.0	~0.2	0.7~0.8	1.4	5	~0	0.2	0.2	0		0	0.2	0.7	0
Mn (Manganeso)	-	2.3	-	0	6.8	2.6	1.4	-	-	0.17	-	-	-	-	-	-
Bacteria(general-total) (faecal)																(-) (-)
Heavy Metals, (Metal pesado) Cu	0	0	~0.5	0.5	≦0.5		0.5	0		0						
Zn	~5	7~8	5~10	~8	10		10	0		0						
Etc.																
Remarks(commentar)							*High									

3.5 Water Balance

3.5.1 Method of Analysis

1) Calculation formula

In order to calculate the obtainable quantity of groundwater, the analysis of water balance is set up based on the collected hydrological, meteorological, groundwater and hydrogeological data, and the results of the field survey and test of groundwater. The model can be expressed by the following equation.

$$P + Is + Ig = E + Os + Og + \Delta s$$

where P : precipitation

Is: inflow as the surface water

Ig: inflow as the groundwater

E: evaporation

Os: outflow as the surface water

Og: outflow as the groundwater

Δs: change in the storage quantity

It is the purpose to obtain Δs in accordance with the above equation. However, since the east side of the expected groundwater development area forms a curved steep cliff, it was expected that the groundwater flow and flow speed at the planned well point would badly be changed.

Therefore, the conventional and two-dimensional method of analysis was progressed a step into the three-dimensional method which takes into account the planar factors, and water balance analysis this time was done by this new method.

2) Calculation of Storage and Obtainable Quantity

In addition to the results of water balance analysis, water quality of each aquifer and the stored quantity were taken into consideration and the obtainable quantity for each region was calculated.

3) Optimum Water Pumping Plan

Taking into account the calculated results of groundwater obtainable quantity, the safe pumping quantity was set up for each region and the proper pumping quantity was calculated.

Based on the calculated proper pumping quantity, the model constructed by balance analysis was used to carry out pumping simulations of production wells, so as to find the planned pumping quantity and the proper arrangement of planned wells.

4) Environment Impact Assessment

Qualitative and quantitative evaluation was done to affect less the other resources.

Regarding the water quality of outflows from mines and mine beds, which may pollute the groundwater resources in this groundwater development project, the specific components are tracked off from the groundwater hydrological view point based on the results of test and analysis made at the site and also in Japan.

3.5.2 Field Survey

In addition to each survey mentioned above, the following tests were conducted, because they seem to be necessary for water balance calculations.

1) Soil Sampling and Testing

When analyzing water samples, it is necessary to grasp the permeability and storage capacity as the conditions of the field. Soil test is conducted to understand them quantitatively. Concretely, from the La Paz layer and the Moraine layer, of which the survey area was composed, representative points were selected, and from each of them, core samples were taken and analyzed.

The data, obtained by the soil test, were compared with the results of topographical and geological survey, electrical prospecting, pumping test, etc. and were expanded into the three dimensional data for the study area. Using these data, numerical model experiments and computer simulations of the groundwater flowing behavior can be made easily. Test items and purposes are as follows.

① Permeability test

This was conducted to measure the easiness (resistance), with which water passes, and was used to calculate the flowing quantity of groundwater which flew by the Darcy's Law.

② Porocity test

This test was conducted to know how much water each component layer could store (contain).

③ Specific gravity test

This test was conducted for the sake of caution, because the component layers were those which did not exist in Japan.

④ Grain size test

This test was conducted as the check for ① and ②, in addition to the purpose similar to ③.

⑤ PF test

This test was conducted to know the water characteristic curve and specific yield. The test results are as follows.

Sample No. (sampling point)	Permeability test (cm/s)	Porosity (%)	Specific gravity test (specific gravity)	Grain size test (median grain size)
A_1	2.48×10^{-4}	54.5 (28.9)	x 2.64	3.90
A_2	4.31×10^{-4}	56.0 (35.5)	2.64	3.90
B	2.39×10^{-4}	49.9 (37.0)	2.66	2.99
C	1.37×10^{-1}	46.6 (18.6)	2.68	3.81
D	6.21×10^{-5}	48.2 (26.3)	2.65	4.68
E	not observed	not observed	2.71	0.93

x: Natural water content

Procedure for analysis

- o Permeability test
  JIS A-1218
- o Porosity measurement
  JIS A-1203
- o PF test
  Attraction method and centrifugal method
  (JIS A-1207)
- o Grain size test
  MARUI (1984)
- o Specific gravity test
  JIS A-1202

According to the test results, the following judgements could be done.

Samples A and B taken from the La Paz Layer

According to the results of permeability test, it was found that the La Paz layer was aquiclude. (Mean: 3.06 cm/s ≒ 100 m/year)

This agrees with the results of grain size test indicating that the median grain size is small.

Moreover, the La Paz layer existing under the Moraine layer as the main aquifer showed a small natural water content, and it seems that the reason for this is that the sample was taken from the outcrop, and deeper parts have become saturated.

The permeability coefficient is of the order of 10^{-4} cm/s in any sample, and has little dispersion, similarly to other test items (porosity, specific gravity and grain size). The reason is probably that the La Paz layer is comparatively uniform.

According to the results of PF Test using the sample B as a characteristic sample, the effective content of water in the groundwater considered to be obtained from this layer is about 25%. Moreover, from the large value of air ingress (staturated capillary tube water line height), it is considered that if a large quantity of pumping is done in this layer, the decrease of the groundwater level will become large.

Samples C, D and E taken from the Moraine Layer

Samples C and E were taken from the typical matrix of the Moraine layer, and sample D was taken from the silt layer of a layer thickness of about 80 cm included in the Moraine layer.

With sample E, the permeability and porosity could not be measured. This is because the permeability was too good, and by the method described above, the permeability test could not be made.

The values of each measurement item have large dispersions, and this indicates that the Moraine layer is not uniform. Therefore, when pumping is to be done, it is desirable to conduct the field permeability test (pumping test) at each point, so as to grasp the permeability coefficient at that point.

On the samples from the good permeability and the large median grain size, it is considered that the specific yield in the pumping will be about 5% in terms of water content larger than in the La Paz layer. Therefore, it is said that the Moraine layer is more suited for pumping than the La Paz layer.

However, because of the large median grain size, the rise height in the capillary tube in this layer is low. Moreover, the absolute value of the porosity is also small, and further, the water content in the adsorbed water is small. All these taken into consideration, it may be said that pumping in the farmed area is not good.

2) Tritium Test

The tritium test is conducted to measure the age of the groundwater.

In general, it is expected that old-aged groundwater contains much substances dissolved from the ground, and accordingly, the content of poisonous substances is increased. Therfore, the tritium test of the groundwater will contribute much to selecting the place where groundwater is to be developed and also to making impact assessment when the development is carried out. For this reason, three specimens were brought back to Japan. As a result of check on these specimens, the following items were found.

Vascal	Jul. 7, 1987	0.5 ± 1.2 tu
Chonchocoro	Jul. 31, 1987	4.6 ± 1.0 tu
Achocalla	Jul. 14, 1987	3.6 ± 1.0 tu

According to the data for South American regions of the International Atomic Energy Agency (IAEA) on the groundwater, the water at Chonchocoro and Achocalla is due to rainfall of several years ago. The water at Vascal is due to rainfall of 30 to 40 years ago. From the results of tritium analysis, it is not obvious whether it is 100 years or 1,000 years old.

That is, the spring water at Chonchocoro and Achocalla is produced by the relatively new rain fall or surface water in the neighborhood, which flows out under the influence of the old groundwater pressure. While, the water at Vascal is produced by the water in the mountains which arrives after a long time.

The PF value test on the soil of Achocalla located in the La Paz layer indicated that this layer contains much dissolved substances. Therefore, it is understandable that the spring water has high EC although it is youthful and the spring water at Chonchocoro has low EC because it has passed the Moraine layer. The water at Vascal is considered to be affected by the La Paz layer because it is old and in deep wells, and also affected by the Milluni mines as shown by the results of heavy metal analysis.

All these findings, in addition to the hydrogeological reasons, clarify that the groundwater development should be done in the Moraine layer.

3) Measurment of Salt Content in Terms of Conductivity of La Paz Layer

Samples of La Paz layer were saturated with a distilled water having EC below 20 μS/cm, and the conductivity was measured on the water after gravity drain and after forced drain.

Gravity drain	1.8	600 μS/cm
Forced drain	4.2	1,030 μS/cm

From the results, it is found that the La Paz layer contains much substances which increase the conductivity, and also it is proven that the longer the retention time in the La Paz layer, the higher the conductivity becomes. This agrees with the survey in which the deeper the survey point in the steep cliff of the La Paz layer, that is, the longer the relention time, the higher the conductivity was.

It is considered that these circumstances can evidence that water intake from the La Paz should be avoided.

4. Optimum Pumping Plan

4.1 Investigations on The Obtainable Quantity

4.1.1 Policies for Investigations

To investigate on the obtainable quantity, it was decided to first make calculating assumptions which are suitable from the results of field survey and various tests in Japan. The value of water level measured in 1973 is set up as the initial value, and the value measured in 1987 is set up as the final value. And these calculating assumptions were corrected until they agree exactly.

The method of testing the program consists of continuously intaking water at the average annual water intake quantity (500 m^3/d) during 15 years from the overall intake water quantity between 1973 and 1987 of 9 wells which exist in operation in the neighborhood of the factory of Vascal. The results indicated that the program provides prediction of the groundwater level with a very high precision. Since the intended test was completed successfully, it was decided then to investigate on the obtainable quantity by the program.

According to the results of the computer simulations on the flow of groundwater level, it is clarified that pumping water results in the lowering of the groundwater level. That is, continued water intake will cause the groundwater level to be lowered year by year, and so, the plan will be set up on the assumption that the groundwater is a limited resource. From these circumstances, in the description in the Interium Report, the annual obtainable quantity was set up to insure stable water intake at least at the target year of 2000.

4.1.2 Conditions of Investigations

1) Selection of Well Field

The well field should be selected based on the following conditions.

- o The well field should have good aquifer.
- o The well field should affect less the existing facilities and land utilization.
- o The well field should be not affected by qualitative water pollution.

2) Judgement of Pumping Rate

The pumping rate should be judged based on the following conditions.

- o The pumping rate should be satisfied against water demand of each planning year.
- o The pumping rate should be such as to lead to planning effective and reasonable facilities.

4.2 Optimum Pumping Plan

4.2.1 Natural Conditions (Water Sources)

1) Aquifers

The aquifers are judged by the results of survey and test: topographical and geological survey, soil test, electrical prospecting, pumping test, water quality test. And the clarified matters are as follows.

Groundwater development should be done
from the Moraine layers as aquifers.

In the geological age of this area, the old bed rocks consist of paleozoic strata, and on them, cenozoic strata exist. The paleozoic strata contain Silurian clay rocks and Devonian mud and quartzite rocks. The cenozoic strata contain the La Paz layer consisting of clay with sand as the tertiary strata, covered with the glacier deposits consisting mainly of sand and gravel and tha alluvial strata (Moraine) as the quaternary strata. The paleozoic strata are aquicludes and are not aquifers

On the other hand, the cenozoic strata are saturated with groundwater and from them, groundwater development can be done. However, the La Paz layer contains much fine grains, is uniform, and has good water characteristic curve, but is inferior in permeability. Therefore, if water is pumped up from this layer, the water level will be badly decreased and the pumping quantity will be small, and therefore, will be not practical for groundwater development.

The quaternary stratum contains coarse grains, is unuiform, and is superior in permeability. The water level decrease is small. Therefore, it can be said that this stratum is only one from which groundwater development can be done within the study area.

Groundwater development should be done within a triangle zone formed by Kalle Chuani on the north, Tacachira on the west and Junthuma Pampa on the east.

The groundwater development should be implemented at the area, which has a potential of production (1,000 m^3/day) in the Moraine layer-distributed area.

That is, on assumption of well bore 300 mm and water level decrease 25m, if 1,000 m^3 per day is to be insured, the aquifers must be at least 85m. Therefore, as an area where the Moraine layer is more than 100m, the above-mentioned triangle zone is considered as an area in which groundwater development is possible.

2) Water Quality

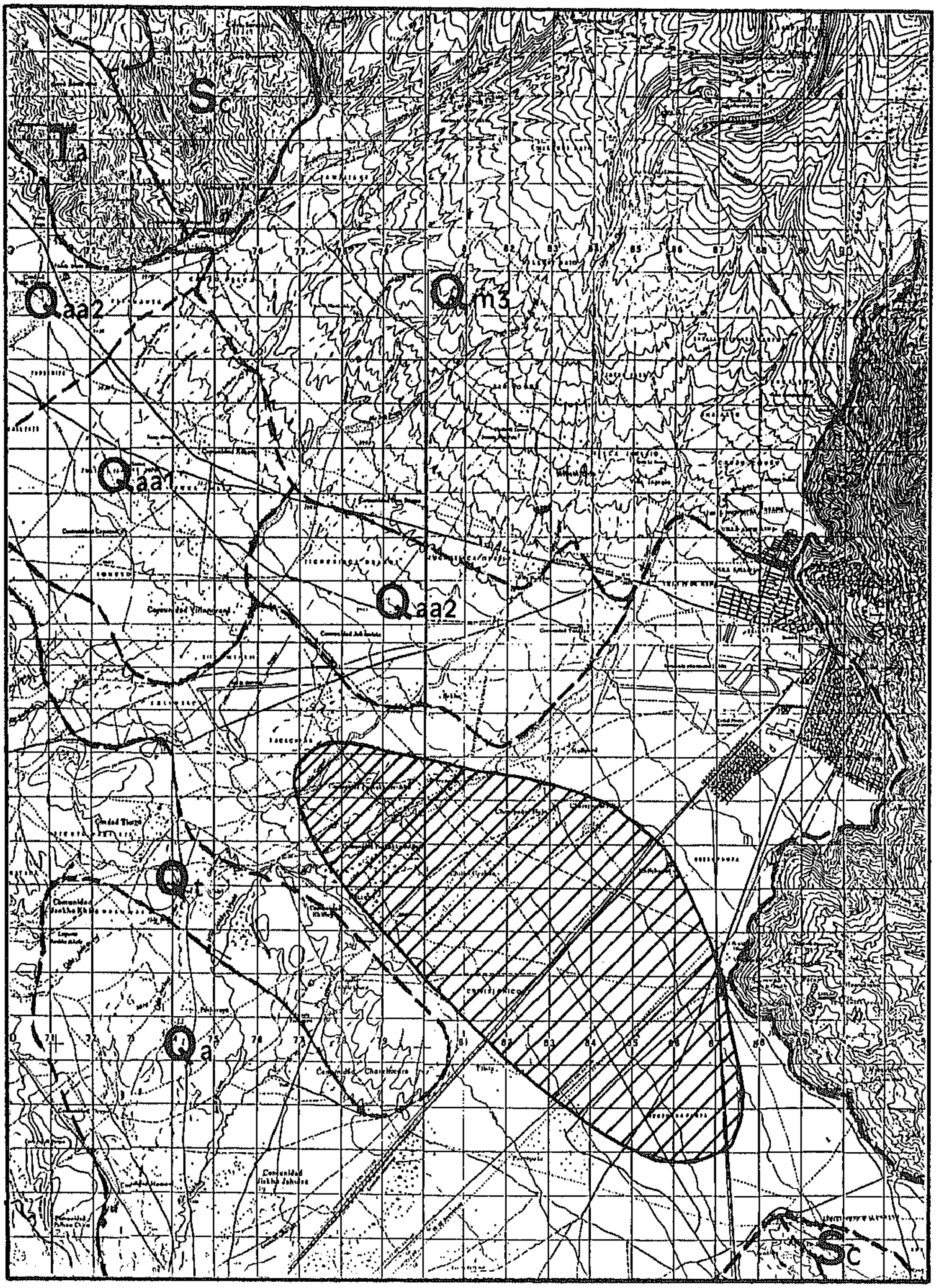
From the results of water test, the possibility of groundwater development can be judged as follows.

The northern part of the El Alto district should be excepted.

In general, the groundwater in the El Alto district contains much dissolved substances and has high electric conductivity at large depths, but the groundwater near the ground surface has good quality because its electric conductivity is as low as snow water.

The reason of the bad water quality in the northern part of the El Alto district has been not obvious, and it will be clarified by analyzing of the data which are obtained after tritium test.

However, whatever the reason may be, traces of poisonous substances exist, although the quantity varies between the rainy season and the dry season. Therefore, in this part, it is judged that further groundwater development should not be attempted.



Potential area for groundwater development on the geological circumstance

Fig. 4.2.1-1 GEOLOGICAL MAP

Groundwater development should not be attempted near Rio Seco.

At present, the surface water of Rio Seco exists only in the rainy season, and infiltrates in the dry season. It was found by this study that the infiltrated water was not diluted with rainy water and snow water, but, it did not contain much heavy metals, etc., especially, poisonous substances, with an exception of organic pollutants. It was also found that the groundwater from deep wells near Rio Seco was not unsuited for drinking, and there was no bad conditiion of water quality.

However, mine waste water contains much arsenic, cadmium, antimony, iron, manganese, tin, etc. It cannot be denied that such water flows down, without being diluted with rainy water and groundwater, and may pollute the groundwater in the neighborhood. That is, there may be influences of hydrological fluctuations of rainfall, air, temprature, etc. and fluctuations of water intake quantity from the Milluni storage reservoir to the Achachicalla water purification plant.

In connection with the treatment plant, if the facility of groundwater can function with only chlorination, its facility will be efficient. But, on the other hand, in case that its facilities require other treatments: neutralization, sedimentation, etc., it will be not efficient.

Therefore, groundwater development should not be attempted in Rio Seco and its neighborhood for the above-mentioned reasons.

Groundwater development involving large well depths should not be attempted.

The artesian flowing water in the steep cliff area, west of El Alto, is the groundwater which exudes from the La Paz layer and its EC increases with increasing depth.

In the Achocalla area, south of the steep cliff, EC is near 1,500 and the evaporation residue is estimated to be over 1,000 ppm. Therefore, this water is not suited for drinking.

Groundwater development, which involves digging up to the La Paz layer underlying the Moraine layer, should not be attempted.

Groundrater development should not be attempted in the existing town area.

At present, the existing town of El Alto district has not enough facility of sanitary sewage, and most sanitary sewage has been discharged on the ground. At the end, it reaches rivers, but during the intermediate parts, may infiltrate into the ground. Therefore, there may be pollution by this wastewater, and groundwater development in the existing town area shoukld not be attempted.

Groundwater development in any area where groundwater begins to return flow should not be attempted.

Coldepaz and Chonchocoro areas have rich groundwater as confirmed from that the ground surface and the groundwater level are very near and it overflows partly. However, these areas are farm and cattle lands, and it is considered that organic pollutants on the ground surface may have made ingress into the ground. Moreover, according to the results of soil test and photos of site, the Moraine layer has inferior water characteristic curves. And it is considered that the groundwater level decrease of several meters affects the water content of the ground surface largely.

For the two reasons mentioned above, groundwater development in these areas should not be attempted. At any place where the groundwater level is 10m or deeper and the groundwater is not polluted by the organic substances of the ground surface, groundwater development is preferable.

4.2.2 Social Conditions (Planned Supply Quantity)

1) Planned Area

a. Planned Population Prediction

La Paz City as a whole, including the El Alto district, has a population of 900,000 as of 1986, with its 76%, 680,000 in the central part of La Paz and the remaining 24%, 220,000, in the El Alto district.

The expansion of existing town against the future increase of population in the central area of La Paz may be impossible, because most of it has already been developed. According to the plan of SAMAPA, the population of La Paz City as a whole in 2010 is predicted to be 1,950,000, with 1,160,000 in the central part of the city and 790,000 in the El Alto district. The population of central part of La Paz City will be 2.6 times as in 1986, and in El Alto district, it will be 3.5 times. Accordingly, El Alto district shall accommodate a larger portion of the increased population.

b. Water Supply Quantity

The total water supply quantity of 1986 in the El Alto district is about 12,000,000 m^3/year, or 33,536 m^3/day, or about 140 lit/day per person on assumption of 240,000 population, including the industrial and public demands and distribution network and plant losses.

By SAMAPA, it is set as 160 lit/day considering not only the increase in drinking water supply quantity corresponding to the population increase, but also, the increase with improved living style and also with water consumption outside the households.

Therefore, in the year of 2,000, the water supply requirement in the El Alto district will become 495,000 persons x 0.16 = 79,200 m^3/day.

However, the El Alto water purification plant has a treating capacity of 53,000 m^3, and even if it is assumed that the portion to be supplied to the El Alto district is kept unchanged, it is 33,500 m^3/day. It is desired by SAMAPA that the difference 45,700 m^3 should be supplied by groundwater development, and regarding the further increase in future water demand, SAMAPA has a similar idea.

c. Water Supply Area

While the population prediction was based on the past rate of increase, the object area should be determined by considering the development progress in the future. The El Alto district urban planning area with a view to the future has not been established. However, many new housing complexes for unemployed mine laborers, public corporation housings for low-incomers, etc. have been planned and being constructed. After analyzing of these plans and further considering the road conditions, electric power supply conditions, etc., the urban planning area and the supply water quantity utilization areas were set up as shown in Fig.4.2.2-1 under cooperation with SAMAPA. The object area is the sum of the area east of Periferica and the presently planned housing complexes, excluding the airport and rivers from water supply area.

The supply water quantity ultilization areas are as follows.

x Individual house water supply area
  Common tap water supply area will be defined as individual house water supply area.

x Common tap water supply area
  The area without urban planning at present east of Periferica, and the area with urban planning west of Periferica, will be defined as common tap water supply area.

x Industrial complex area
  At present, most of the companies use their own wells, but in the future, will be supplied from

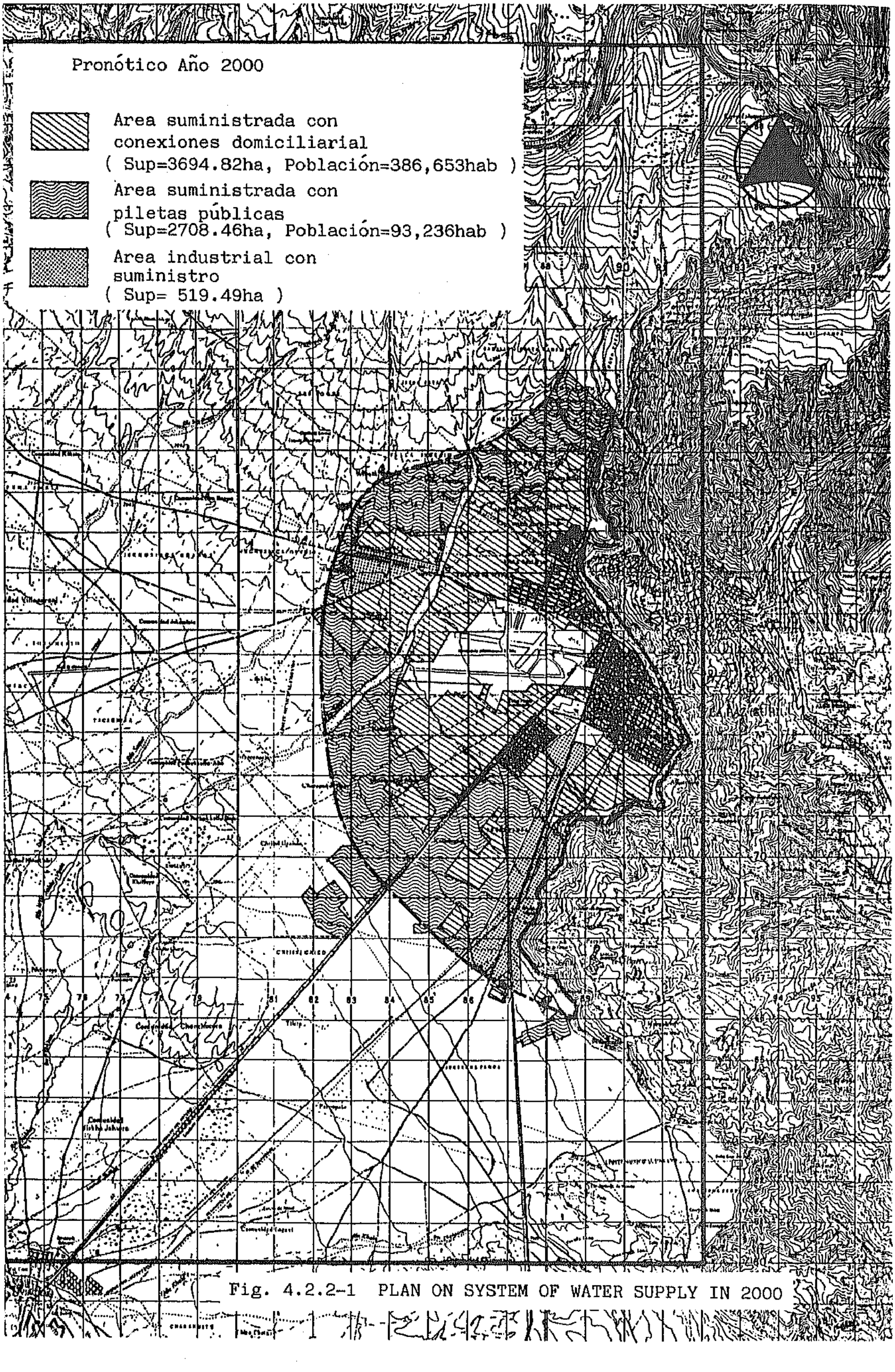


Fig. 4.2.2-1 PLAN ON SYSTEM OF WATER SUPPLY IN 2000

SAMAPA.

x No-water supply area

The river area in Periferica and the international airport will be defined as no-water supply area. For the airport, however, supply of 250 m^3/day is planned.

2) Conformity with Existing Water Supply Systems

Existing water supply systems include the public drinking water systems using the surface water as the water source and managed by SAMAPA, and the private sector drinking water supply systems managed by factories, public corporations, etc.

In Bolivia, there are no legal regulations established regarding the use of groundwater. Therefore, any individual person or corporation who desires to utilize groundwater can freely develop groundwater without being regulated in any way. However, as a result of unregulated groundwater development, it happened that pumping was done in excess of the safety limit, the groundwater level decreased due to too small well interval and pumping became impossible, etc. and it is judged that now is the time when any regulations should be established. In the future, the groundwater development should be planned considering the above-mentioned circumstances and balance with the existing groundwater development systems.

On the other hand, the system using the surface water as the water source and owned by SAMAPA cannot be expected to be increased in water supply quantity enough to cope with the increased water consumption of the El Alto district in the future. Because of using the surface water, serious water shortages in La Paz City as the whole may occur as a result of seasonal fluctuations, annual rainfall fluctuations, etc. Therefore, a groundwater utilization system, which is capable of securing a constant water supply throughout the year, is only possible system to accommodate emergency water shortages. Therefore, in planning new large-scale groundwater development, it will be necessary to provide a complementary relation to the existing water supply systems.

In respect of water quality, the treated water of the Milluni system is not unsuited for drinking, but the water quality cannot be said good. This system is the water source of the largest water quantity to La Paz City, and decreasing the water utilization ratio of this system will serve to improve the water quality of La Paz City as the whole. Accordingly, the measures, which is reducing the consumption of Milluni or diluting by mixing, should be taken against the water quality of Milluni system by utilizing Tuni system and the future system of groundwater.

3) Arrangement of Well Fields

It was decided that the well field should be arranged in a line in the direction of groundwater flow down in the entire area for which it was judged that groundwater development should be possible. According to the result of computer simulation on the prediction of groundwater flow, it is obvious that the influence on the ground surface is considered to be 1.5 km. Thus, considering that both right and left banks of Rio Seco are safe, the well fields will be arranged starting at a point more than 2 km apart, as shown in Fig.4.2.2-2.

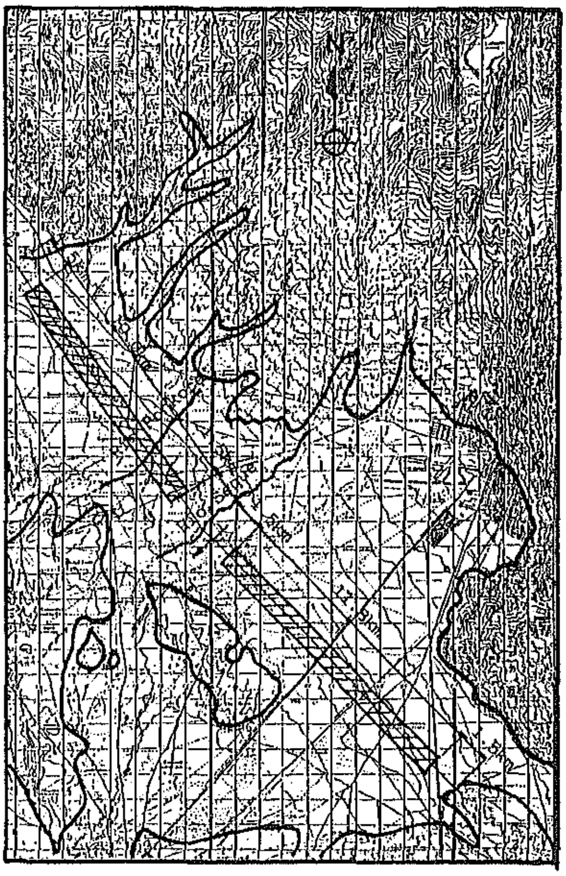


Fig.4.2.2-2

4) Allocation of Pumping Quantity

For the well fields proposed, the average ground level is 3,921m and the average groundwater level is 3,918m. The difference is maximum 13m and minimum 0m. Therefore, for the sake of safety in the allocation of pumping quantity, the groundwater level is assumed as 5m below the ground level in the calculation.

The average thickness of the Moraine layer is about 80m. Thus, by adding a well soil and sand retaining thickness of 10m, the well depth will be taken as 90m. The groundwater will be taken at 26,700 m^3/day which is the target for 1995 from the well group of Zone I. The groundwater level will be as shown by simulation analysis.

The results are as shown in Table 4.2.2-1. Until 2005, water intake at 26,700 m^3/day can be safe in total of 27 wells of 1,000 m^3/day each.

However, from that year on, the water level decrease will be larger. For this reason, and also for the technical reason of pump arrangement, the pumping quantity will be decreased year by year, and it will become necessary to undertake a new project to cope with that situation.

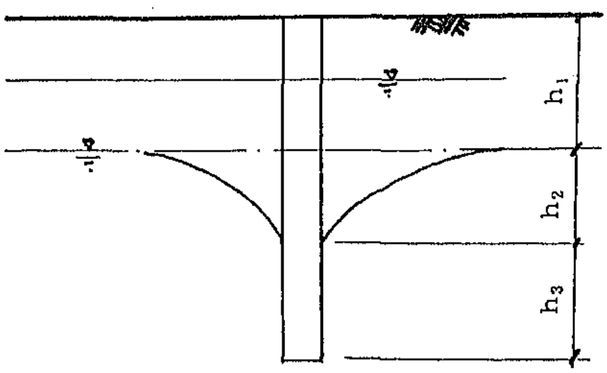
Table 4.2.2-1

Number of years	Year	Running water level decrease (a) NOTE 1	NOTE 2	h_1 (m)	h_2 (m)	h_3 (m)	Planned water intake Q (m^3/day)
0	1989	0	0	5.0	10.0	75.0	1,000
6	1995	14.9	11.2	16.2	10.6	63.2	1,000
11	2000	27.3	23.6	28.6	13.2	48.2	1,000
16	2005	39.7	36.0	41.0	18.2	30.8	1,000
20	2009	50.6	46.9	51.9	16.1	22.0 NOTE 3	670

NOTE 1: Computer calculated

NOTE 2: Corrected....Dynamic water level decrease when the pumping quantity increse with year is taken into consideration on the assumption that the planned intake quantity is pumped up 6 years after the construction.

NOTE 3: Technical minimum value when the strainer (20m) is taken into consideration.



4.2.3 Prediction of Groundwater Flowing

1) Conditions of Calculation

a) Parameters

Permeability coefficient

2.00×10^{-3} cm/sec

Effective porosity

30%

Rain fall

500 mm/year

Evaporation

500 mm/year

b) Input Data

- o Coordinates
- o Flag
- o Ground level
- o Aquifer thickness
- o Groundwater level
- o Water intake quantity

c) Output Data

- o Test of existing groundwater level changes from 1973 up to the present
- o Prediction of water level decrease in every year

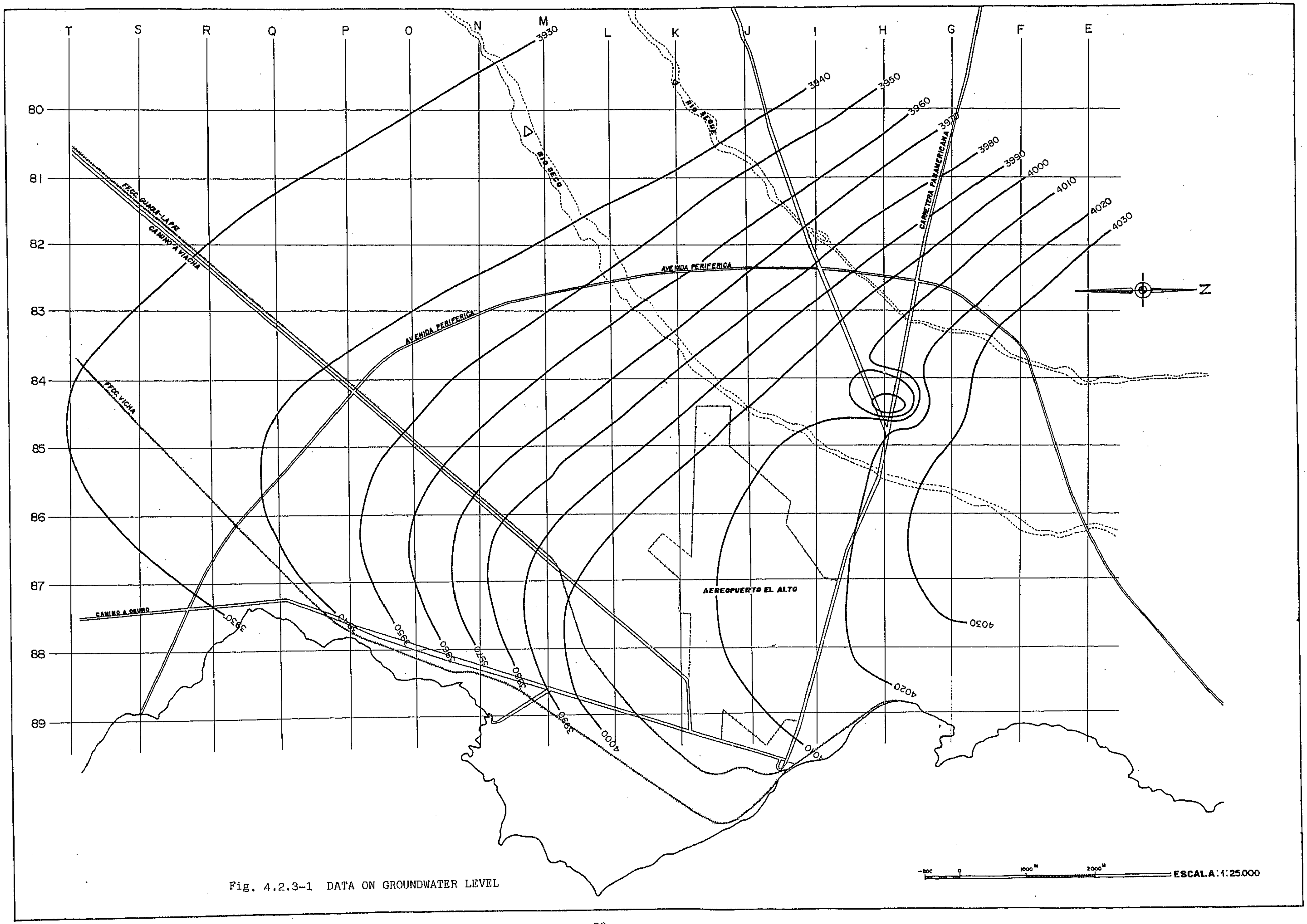


Fig. 4.2.3-1 DATA ON GROUNDWATER LEVEL

***** Initial Parameter *****

X = 13 Y = 18 DX = 1000 m
Area = 1000000 m^2 TOUSUI = 0.0020

<<<<< Calculation Flag >>>>>

1	2	2	2	2	2	2	2	2	2	2	2	2
1	3	3	3	3	3	3	3	3	3	3	3	1
1	3	3	3	3	3	3	3	3	3	3	3	1
1	3	3	3	3	3	3	3	3	3	3	3	1
1	3	3	3	3	3	3	3	3	3	3	3	1
1	3	3	3	3	3	3	3	3	3	3	3	1
1	3	3	3	3	3	3	3	3	3	3	3	1
1	3	3	3	3	3	3	3	3	3	3	3	1
1	3	3	3	3	3	3	3	3	3	3	3	1
1	3	3	3	3	3	3	3	3	3	3	3	1
1	3	3	3	3	3	3	3	3	3	3	3	1
1	3	3	3	3	3	3	3	3	3	3	3	1
1	3	3	3	3	3	3	3	3	3	3	3	1
1	3	3	3	3	3	3	3	3	3	3	3	1
1	3	3	3	3	3	3	3	3	3	3	3	1
1	3	3	3	3	3	3	3	3	3	3	3	1
1	3	3	3	3	3	3	3	3	3	3	3	1
1	1	1	1	1	1	1	1	1	1	1	1	1

<<<<< Ground Level >>>>>

4020.000	3991.000	4013.000	4047.000	4070.000	4095.000	4111.000	4113.000	4125.000	4110.000	4123.000	4152.000	4185.000
3967.000	3981.000	3998.000	4020.000	4049.000	4064.000	4078.000	4092.000	4085.000	4080.000	4100.000	4128.000	4162.000
3957.000	3968.000	3985.000	4007.000	4020.000	4031.000	4059.000	4060.000	4060.000	4063.000	4077.000	4104.000	4123.000
3941.000	3951.000	3969.000	3985.000	3989.000	4011.000	4022.000	4024.000	4033.000	4046.000	4056.000	4080.000	4000.000
3922.000	3935.000	3950.000	3967.000	3973.000	3985.000	3996.000	4007.000	4017.000	4030.000	4044.000	4064.000	4083.000
3916.000	3929.000	3943.000	3955.000	3963.000	3974.000	3985.000	3998.000	4008.000	4023.000	4041.000	4053.000	4062.000
3913.000	3925.000	3933.000	3947.000	3956.000	3966.000	3977.000	3989.000	4002.000	4015.000	4027.000	4042.000	4052.000
3913.000	3919.000	3927.000	3936.000	3948.000	3957.000	3968.000	3979.000	3993.000	4006.000	4016.000	4027.000	4038.000
3908.000	3913.000	3920.000	3930.000	3939.000	3950.000	3960.000	3971.000	3985.000	3992.000	4004.000	4015.000	4029.000
3901.000	3909.000	3913.000	3924.000	3935.000	3943.000	3954.000	3965.000	3973.000	3979.000	3990.000	4002.000	4000.000
3882.000	3908.000	3908.000	3920.000	3929.000	3938.000	3947.000	3954.000	3963.000	3971.000	3980.000	3988.000	3900.000
3894.000	3920.000	3910.000	3915.000	3921.000	3931.000	3938.000	3948.000	3956.000	3964.000	3972.000	3900.000	3900.000
3879.000	3900.000	3920.000	3920.000	3915.000	3925.000	3933.000	3942.000	3950.000	3960.000	3965.000	3900.000	3900.000
3874.000	3890.000	3920.000	3920.000	3915.000	3918.000	3926.000	3936.000	3945.000	3955.000	3963.000	3960.000	3900.000
3865.000	3880.000	3910.000	3920.000	3904.000	3911.000	3921.000	3930.000	3938.000	3949.000	3956.000	3962.000	3900.000
3864.000	3875.000	3900.000	3896.000	3896.000	3904.000	3913.000	3924.000	3932.000	3942.000	3952.000	3960.000	3961.000
3865.000	3877.000	3882.000	3883.000	3890.000	3897.000	3907.000	3918.000	3926.000	3936.000	3947.000	3957.000	3962.000
3863.000	3870.000	3874.000	3877.000	3884.000	3892.000	3902.000	3911.000	3918.000	3930.000	3943.000	3952.000	3960.000

<<<<< Water Bearing Layer >>>>>

150.000	240.000	150.000	120.000	100.000	125.000	150.000	190.000	180.000	150.000	170.000	170.000	200.000
130.000	170.000	130.000	120.000	100.000	120.000	140.000	160.000	175.000	100.000	150.000	170.000	170.000
130.000	130.000	105.000	110.000	110.000	120.000	140.000	145.000	150.000	100.000	130.000	150.000	150.000
100.000	120.000	100.000	100.000	110.000	110.000	135.000	130.000	125.000	100.000	120.000	130.000	130.000
100.000	100.000	100.000	100.000	100.000	100.000	120.000	120.000	120.000	110.000	110.000	120.000	130.000
90.000	90.000	90.000	80.000	90.000	90.000	110.000	120.000	120.000	110.000	110.000	120.000	130.000
80.000	70.000	90.000	80.000	80.000	80.000	100.000	110.000	120.000	110.000	110.000	100.000	120.000
60.000	60.000	85.000	70.000	70.000	60.000	80.000	100.000	110.000	100.000	100.000	80.000	100.000
50.000	50.000	80.000	60.000	40.000	50.000	50.000	90.000	100.000	100.000	90.000	60.000	80.000
20.000	40.000	60.000	60.000	50.000	50.000	20.000	70.000	90.000	90.000	80.000	75.000	80.000
5.000	20.000	40.000	50.000	50.000	50.000	30.000	80.000	90.000	90.000	70.000	80.000	0
5.000	5.000	20.000	40.000	60.000	60.000	40.000	50.000	80.000	90.000	60.000	70.000	0
5.000	5.000	5.000	20.000	60.000	60.000	40.000	50.000	60.000	80.000	90.000	100.000	0
15.000	5.000	5.000	5.000	60.000	60.000	40.000	50.000	60.000	80.000	140.000	130.000	0
20.000	5.000	5.000	5.000	50.000	50.000	40.000	50.000	60.000	70.000	190.000	100.000	100.000
20.000	20.000	5.000	60.000	50.000	40.000	40.000	50.000	60.000	70.000	55.000	75.000	100.000
30.000	25.000	30.000	30.000	40.000	30.000	40.000	50.000	60.000	60.000	50.000	80.000	80.000
30.000	30.000	30.000	30.000	30.000	25.000	40.000	50.000	60.000	60.000	50.000	50.000	60.000

<<<<<   Water Level   >>>>>

4000.000	3990.000	4000.000	4000.000	4010.000	4027.000	4030.000	4030.000	4030.000	4030.000	4030.000	4030.000	4030.000
3950.000	3959.000	3968.000	3977.000	3998.000	4015.000	4029.000	4030.000	4030.000	4030.000	4030.000	4030.000	4030.000
3945.000	3950.000	3955.000	3966.000	3983.000	4002.000	4016.000	4026.000	4030.000	4030.000	4030.000	4027.000	4025.000
3935.000	3945.000	3955.000	3955.000	3972.000	3988.000	4005.000	4010.000	4020.000	4025.000	4025.000	4022.000	3980.000
3919.000	3925.000	3930.000	3946.000	3960.000	3975.000	3992.000	4000.000	4013.000	4016.000	4018.000	4018.000	4014.000
3914.000	3922.000	3930.000	3939.000	3951.000	3965.000	3979.000	3994.000	4005.000	4011.000	4013.000	4012.000	4008.000
3911.000	3918.000	3925.000	3938.000	3944.000	3956.000	3968.000	3981.000	3995.000	4004.000	4007.000	4006.000	4005.000
3911.000	3913.000	3915.000	3936.000	3939.000	3948.000	3960.000	3970.000	3984.000	3997.000	4003.000	4003.000	4002.000
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3877.000	3889.000	3900.000	3905.000	3915.000	3925.000	3933.000	3938.000	3942.000	3941.000	3937.000	3870.000	3870.000
3872.000	3886.000	3900.000	3905.000	3915.000	3915.000	3925.000	3936.000	3937.000	3936.000	3931.000	3931.000	3870.000
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3862.000	3873.000	3900.000	3895.000	3895.000	3900.000	3910.000	3920.000	3930.000	3928.000	3930.000	3930.000	3930.000
3862.000	3874.000	3880.000	3881.000	3888.000	3895.000	3905.000	3916.000	3924.000	3927.000	3933.000	3933.000	3935.000
3861.000	3868.000	3872.000	3875.000	3882.000	3890.000	3900.000	3909.000	3916.000	3925.000	3935.000	3937.000	3940.000

<<<<<   Discharge   >>>>>

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***** Initial Parameter *****

X = 13 Y = 18 DX = 1000 m
Area = 1000000 m^2 TOUSUI = 0.0020

<<<<< Calculation Flag >>>>>

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<<<<< Ground Level >>>>>

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3865.000	3880.000	3910.000	3920.000	3904.000	3911.000	3921.000	3930.000	3938.000	3949.000	3956.000	3962.000	3900.000
3864.000	3875.000	3900.000	3896.000	3896.000	3904.000	3913.000	3924.000	3932.000	3942.000	3952.000	3960.000	3961.000
3865.000	3877.000	3882.000	3883.000	3890.000	3897.000	3907.000	3918.000	3926.000	3936.000	3947.000	3957.000	3962.000
3863.000	3870.000	3874.000	3877.000	3884.000	3892.000	3902.000	3911.000	3918.000	3930.000	3943.000	3952.000	3960.000

<<<<< Water Bearing Layer >>>>>

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90.000	90.000	90.000	80.000	90.000	90.000	110.000	120.000	120.000	110.000	110.000	120.000	130.000
80.000	70.000	90.000	80.000	80.000	80.000	100.000	110.000	120.000	110.000	110.000	100.000	120.000
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<<<<<   Water Level   >>>>>

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3880.000	3900.000	3900.000	3920.000	3928.000	3937.000	3940.000	3947.000	3953.000	3960.000	3960.000	3940.000	3870.000
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3877.000	3889.000	3900.000	3905.000	3915.000	3925.000	3933.000	3938.000	3942.000	3941.000	3937.000	3870.000	3870.000
3872.000	3886.000	3900.000	3905.000	3915.000	3915.000	3925.000	3936.000	3937.000	3936.000	3931.000	3931.000	3870.000
3863.000	3878.000	3900.000	3905.000	3904.000	3910.000	3920.000	3930.000	3934.000	3932.000	3928.000	3930.000	3870.000
3862.000	3873.000	3900.000	3895.000	3895.000	3900.000	3910.000	3920.000	3930.000	3928.000	3930.000	3930.000	3930.000
3862.000	3874.000	3880.000	3881.000	3888.000	3895.000	3905.000	3916.000	3924.000	3927.000	3933.000	3933.000	3935.000
3861.000	3868.000	3872.000	3875.000	3882.000	3890.000	3900.000	3909.000	3916.000	3925.000	3935.000	3937.000	3940.000

<<<<<   Discharge   >>>>>

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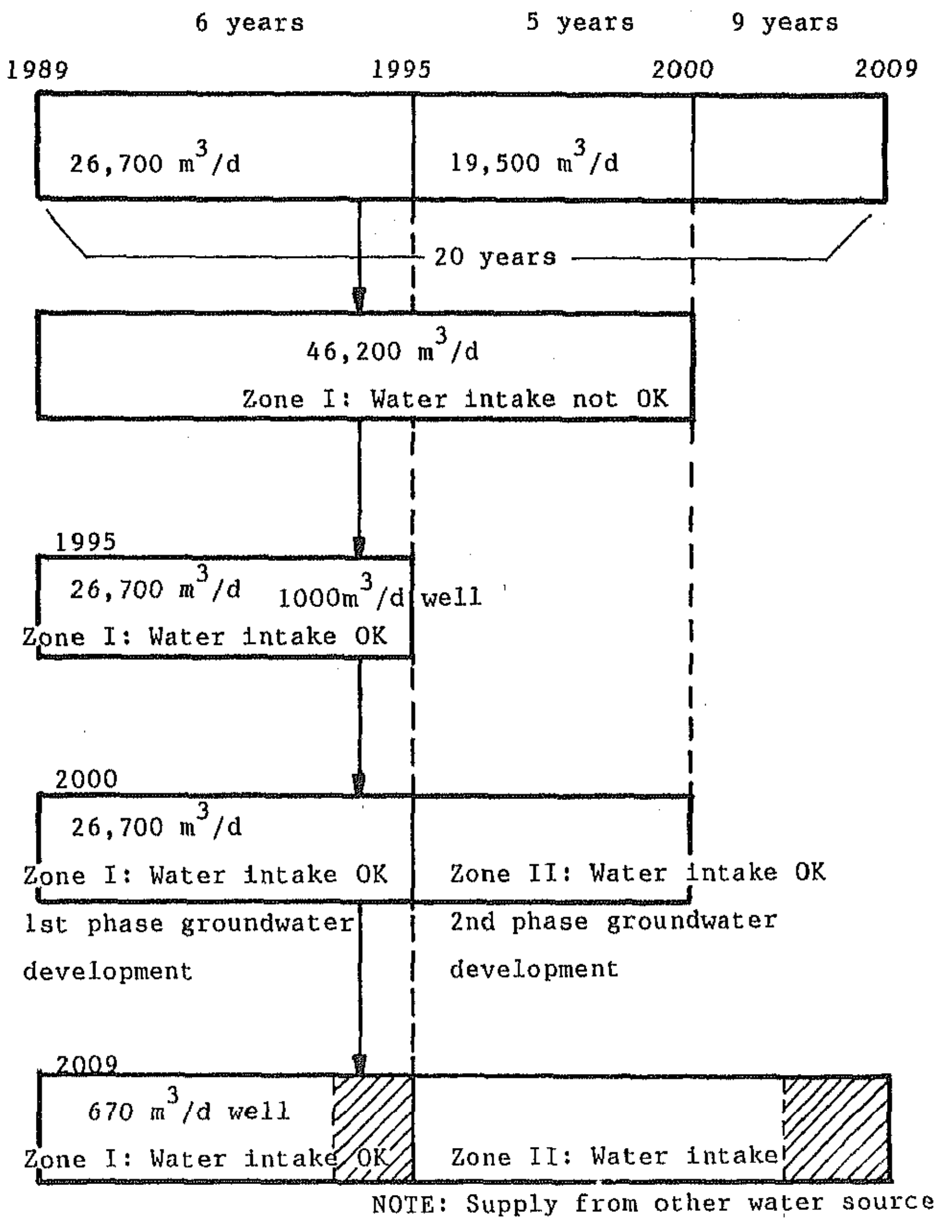
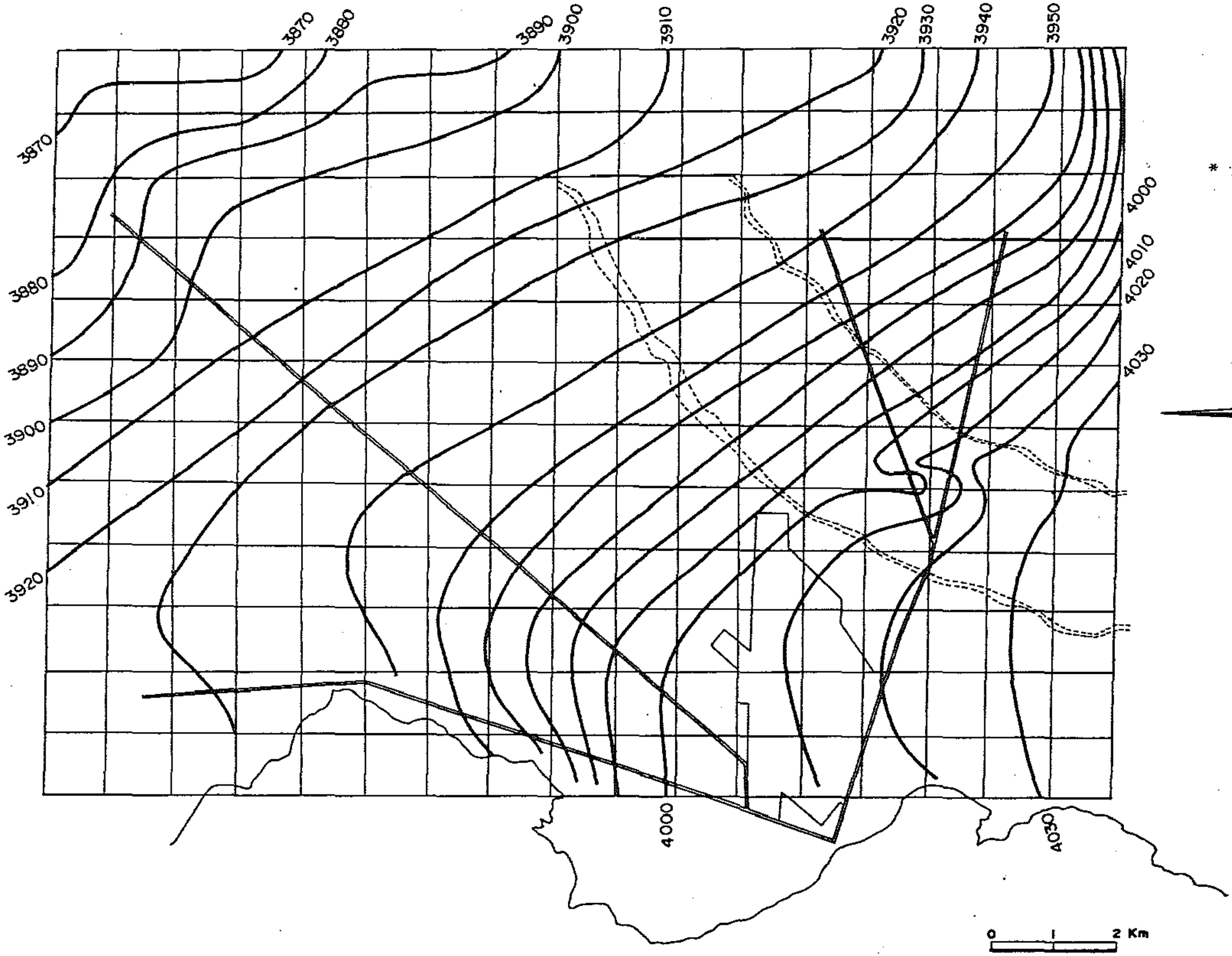
0	0	0	0	0	2050.000	2050.000	0	0	0	0	0	0
0	0	0	0	0	0	2050.000	2050.000	0	0	0	0	0
0	0	0	0	0	0	0	2050.000	2050.000	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0

2) Progresses of Calculation



3) Results of Calculation

The results of calculation are as shown below. (Refer to Fig.4.2.3-2 through Fig.4.2.3.-7.)



* Estimated level of 1987 based on the data of 1973

Fig. 4.2.3-2 ESTIMATED WATER TABLES (1973)

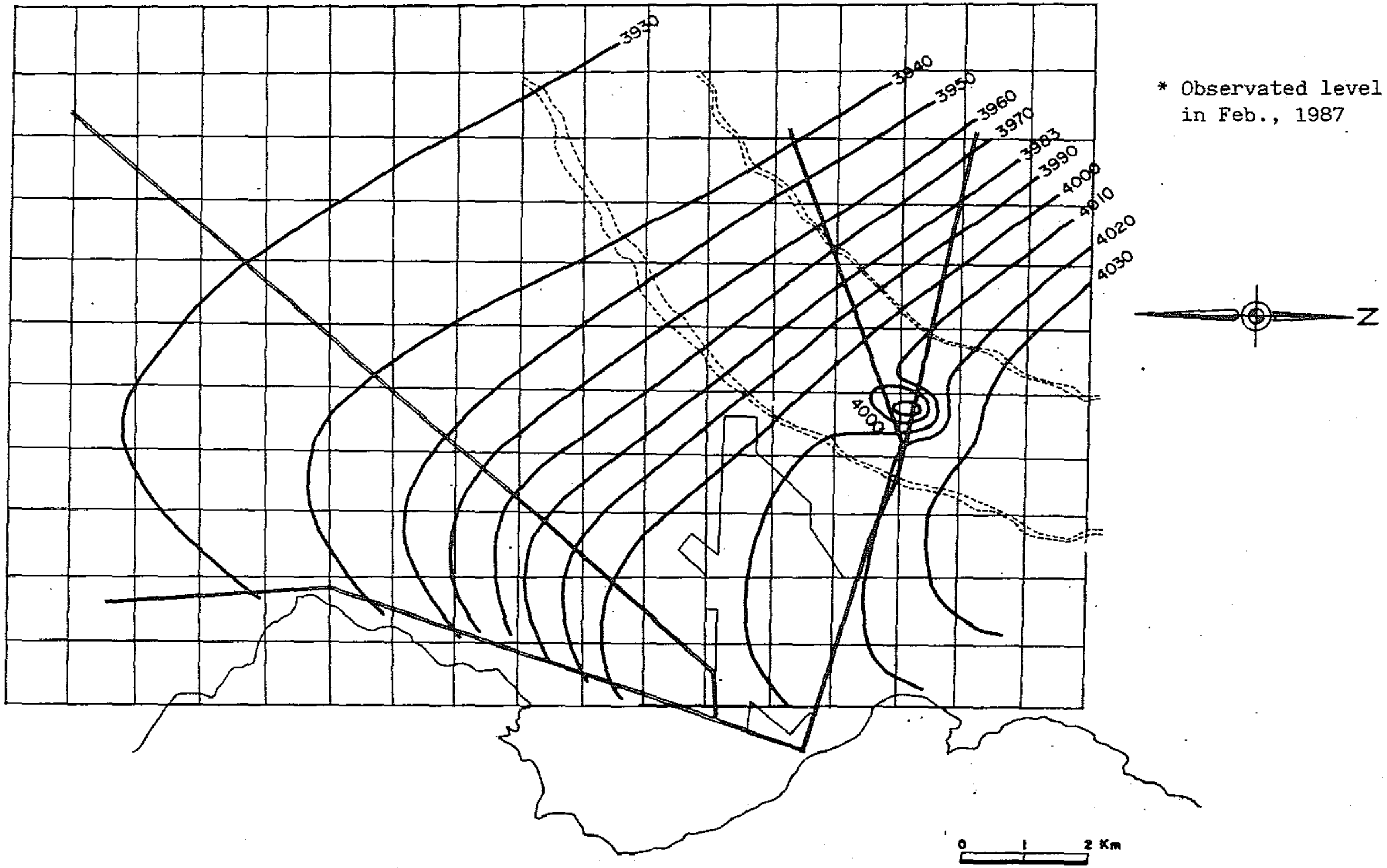


Fig. 4.2.3-3 WATER TABLE IN FEB., 1987

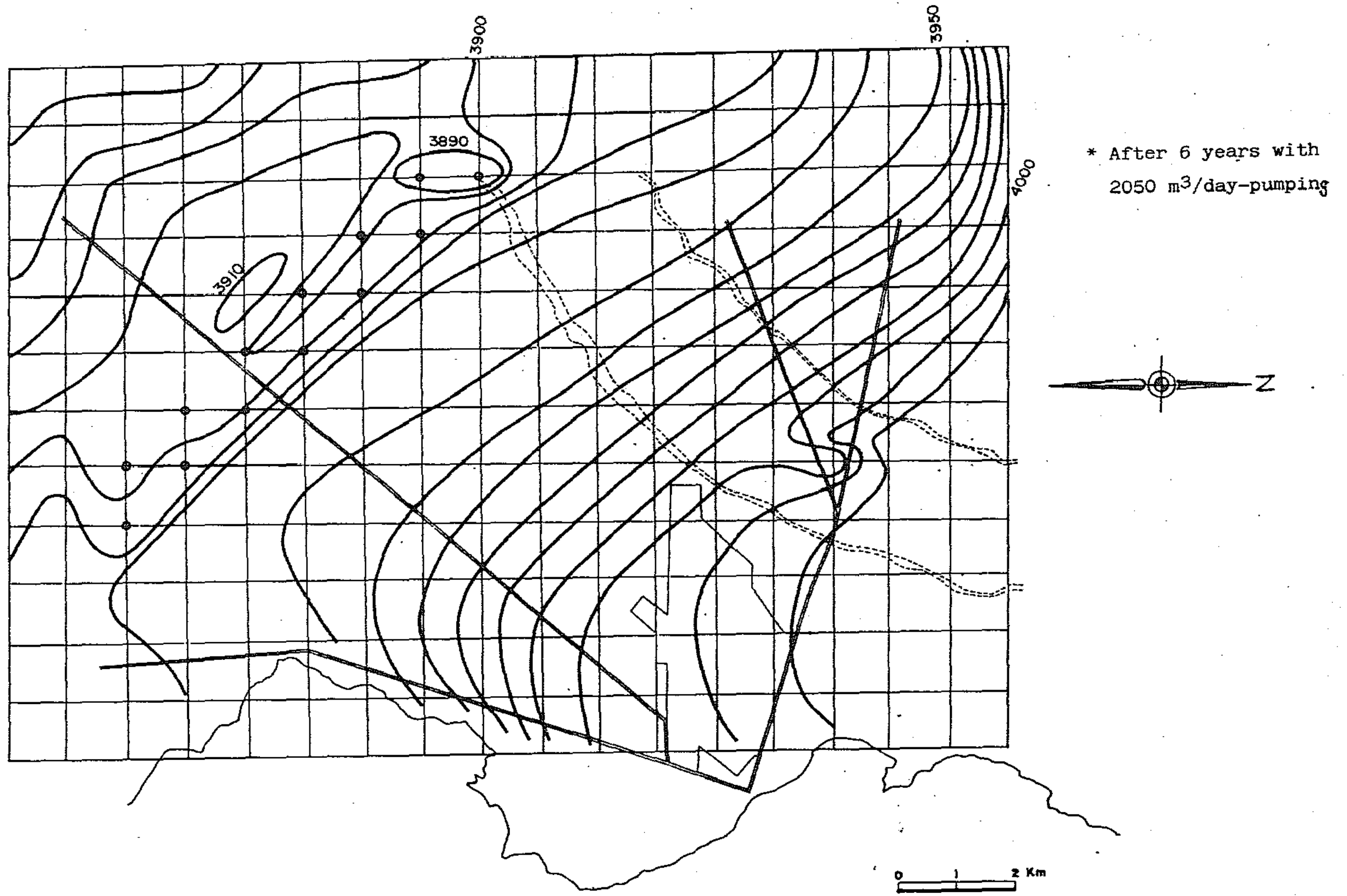


Fig. 4.2.3-4 ESTIMATED WATER TABLE (1995)

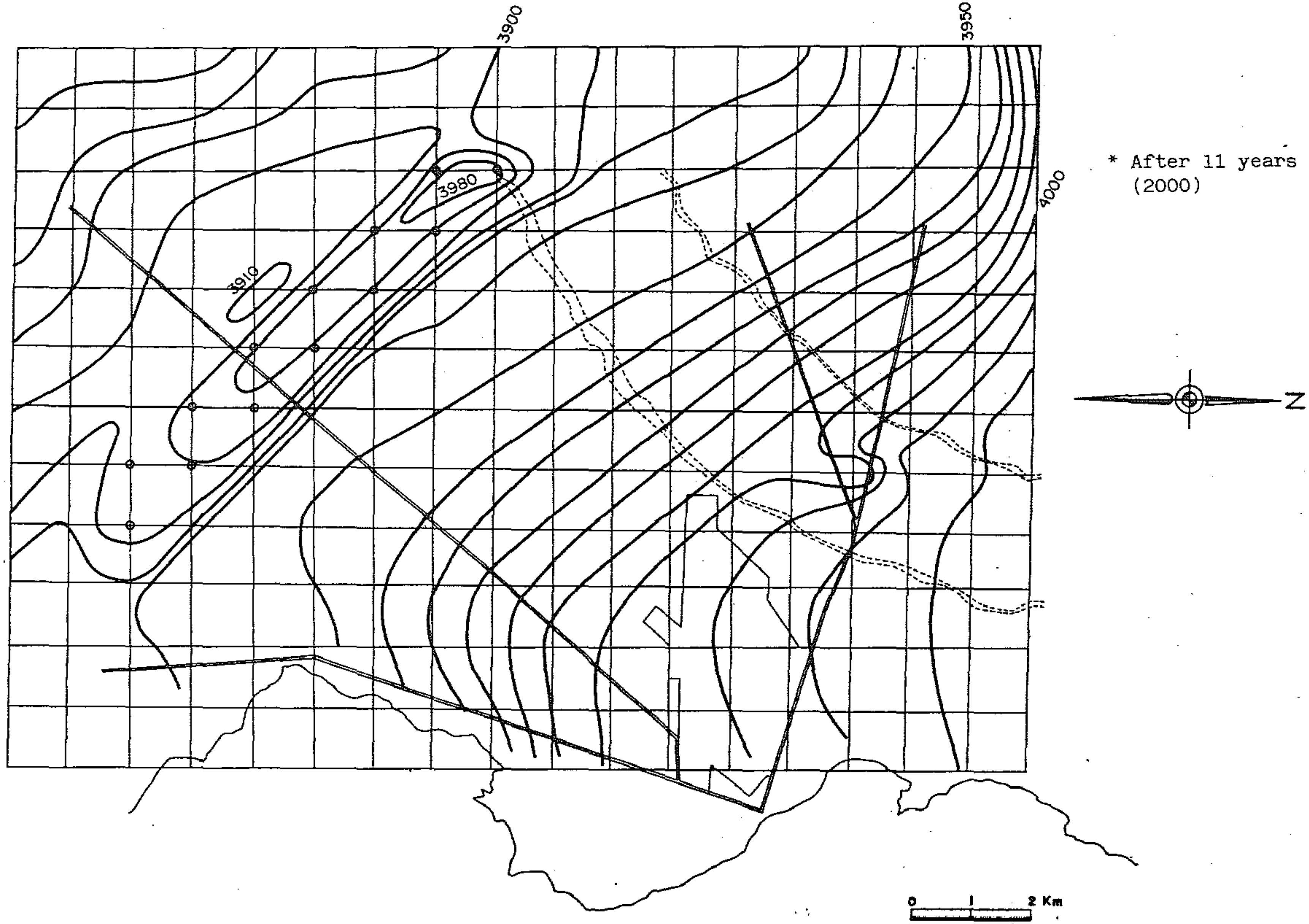


Fig. 4.2.3-5 ESTIMATED WATER TABLE (2000)

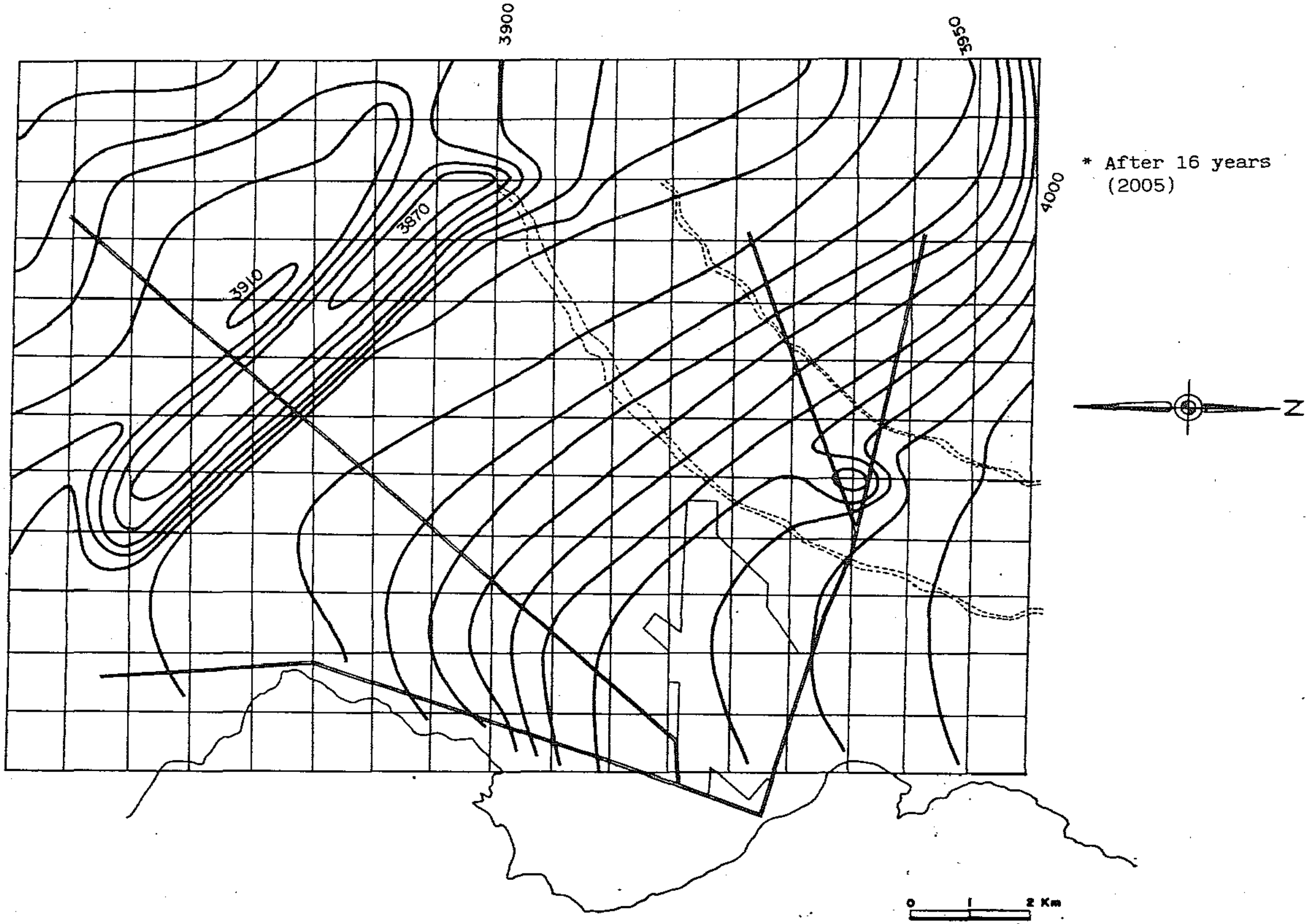


Fig. 4.2.3-6 ESTIMATED WATER TABLE (2005)

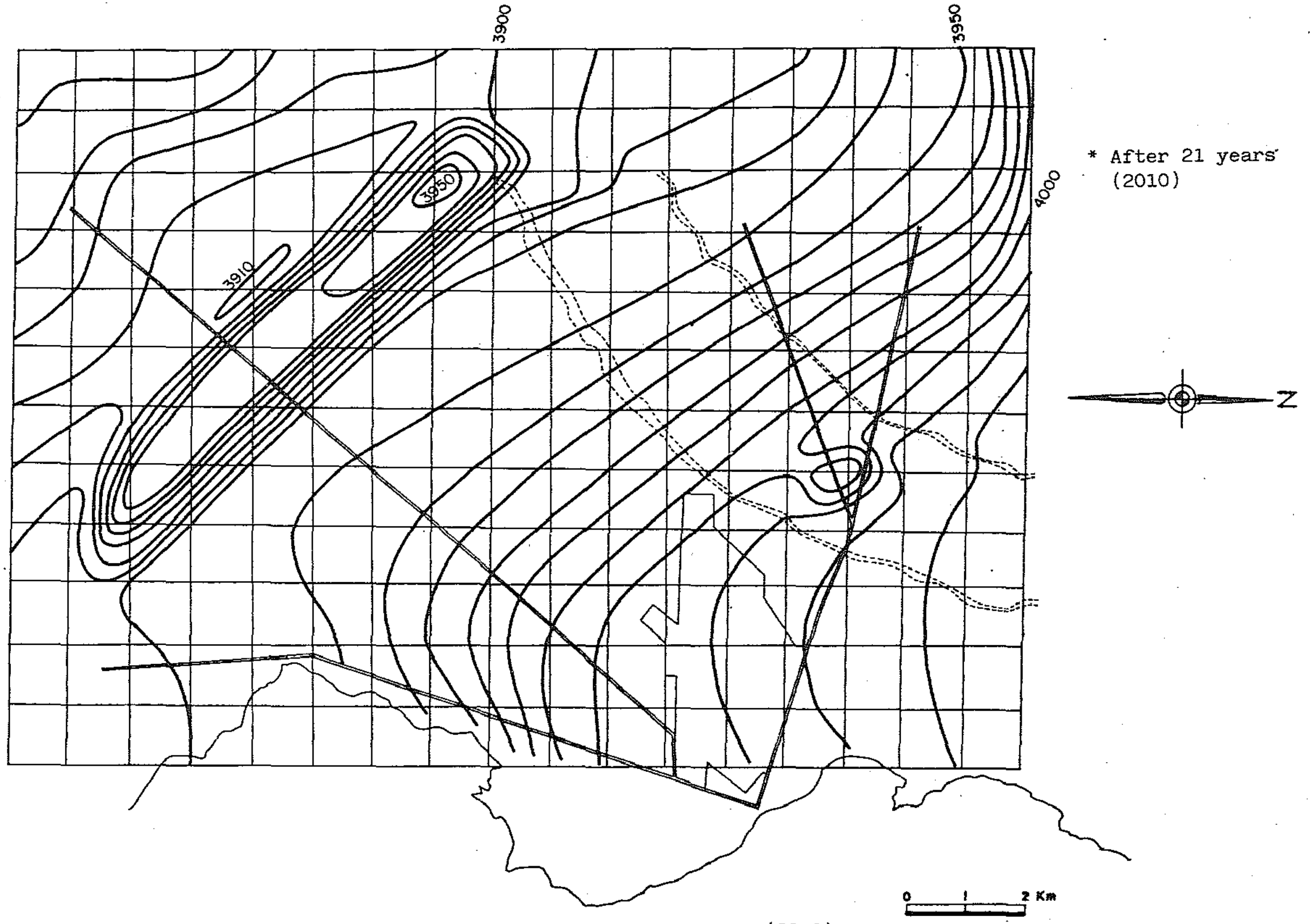


Fig. 4.2.3-7 ESTIMATED WATER TABLE (2010)

5. Planning of The Project

5.1 Draft Facility Plan

5.1.1 Planned Water Supply Population

The propulation of El Alto as of 1995, the intermediate target year of this project, is assumed as 385,000, and as of 2,000, the final target year, as 495,000, considering the natural population increase, domestic immigration measures for mine laborers, etc. in the El Alto district.

5.1.2 Planned Water Supply Quantity

According to the actual data of El Alto district water supply during 1986, the water supply quantity for 240,000 population of El Alto was 33,000 m^3/day, or 140 lit/day/person. However, taking into consideration the increase in consumption as a result of change from the public water tap system to individual home water supply, the increase in consumption due to improvement in the living conditions, etc., the daily maximum water supply quantity is assumed as 155 lit/day/person for 1995, and 160 lit/day/person for 2000. Therefore, the daily maximum water supply quantity after groundwater development in the El Alto area is as follows, on the assumption that the supply quantity 33,000 m^3/day from the Tuni reservoir is unchanged.

1995: 385,000 x 0.155 - 33,000 = 26,700 m^3/day
2000: 495,000 x 0.160 - 33,000 = 46,200 m^3/day

In setting up this plan, it is assumed that the hourly maximum water supply quantity is 1.5 times the daily maximum water supply quantity.

5.1.3 Draft Facility Plan

That area of the El Alto district, where groundwater development can be done, is 22 km in total of about 12 km on the south-east side of Rio Seco and 10 km on the north-west side, from the hydrogeological conditions. (Refer to Fig.4.2.2-2)

By considering from the water balance and technical feasibility of groundwater development, the daily water intake quantity available from about 12 km on the south-east side is about 30,000 m^3. If it is assumed that a similar aquifer exists on the north-west side, about 25,000 m^3/day is available. Therefore, the maximum value of the planned water intake quantity in the groundwater development plan for the El Alto district is estimated as 55,000 m^3/day.

On the other hand, the water demand is 26,700 m^3/day in 1995 and 46,200 m^3/day in 2000. Thus, in planning the facilities with the year of 2000 as the target, the object of development must be a total length of 22 km including an allowance in order to insure stable water supply.

The groundwater of north-west side of Rio Seco is expected to draw the surface water affected by Milluni mine. However, since the groundwater development only on the south-west side of Rio Seco cannot satisfy the water demand in 2000, it is necessary to develop groundwater also on the north-west side of Rio Seco. In case of after targeted year (2000), it should be secured by other ways: construction of new dams, water conveyance from Lake Titicaca, etc. Therefore, it is necessary to urgently set up future plans and design construction plans, but at present, there are no concrete ideas.

Therefore, at the present stage, it is considered that first the plan with the year of 2000 as the target should be set up, and then the facility plan to satisfy the water demand in 1995 should be designed. From such a view point, it will be reasonable that the facility plan should be double-sided, such that, when 1995 comes, either new water sources should be considered, or the construction with the target year 2000 should be started. Therefore, it was decided to set up the plan to carry out the work in two separate phases, the 1st phase work for the years up to the target year 1995 and the 2nd phase work for the years up to the target year 2000.

5.1.4 Planned Facilities

The facilities to be planned in this study are intended only to insure groundwater, that is, the facilities from water intake up to pumping should be included. Major such facilities are as shown in Table 5.1.4-1.

Table 5.1.4-1 List of Facilities

	Item	Q'ty		
		1995	2000	Total
Water intake well	Submersible pump 42 m^3/h x 155m x 3000 x 37 kW with accessories (pumping pipe)	6 sets	-	6 sets
	42 m^3/h x 120m x 3000 x 30 kW	6 sets	2	8 sets
	42 m^3/h x 95m x 3000 x 22 kW	12 sets	12 sets	24 sets
	42 m^3/h x 72m x 3000 x 15 kW	6 sets	6 sets	12 sets
	Consumables for digging (including casing, strainer, etc.)	1 set	1 set	2 sets
	Well work	1 set	1 set	
Water conveyance facility	Water conveyance pipe ⌀150 to ⌀600	35 km	23 km	
	Reducers	1 set	1 set	
	Water conveyance pipe installation work	1 set	1 set	
	Ancillasry work (air valve, sludge discharge valve, sluice valve)	1 set	1 set	
Pump well	Joint valve	77 m^3	-	
	Pump well	185 m^3	-	
	Pump well construction work	1 set	-	
Pump station	Pump (including ancillary facilities)	1 set	1 set	
	Chlorination facility	1 set	1 set	
	Water test facility	1 set	-	
	Office furnitures	1	-	
	Pump station construction work	1 set	-	
	Electrical work	1 set	1 set	
Power receiving facility work	Extra-high tension power station	1 set	1 set	
	Wiring work	1 set	1 set	
Const-ruction machines & materials	Well digging machines (including accessories)	2 sets	-	
	Maintenance & management machines (including accessories)	2 sets	-	
	Construction machines & materials	1 set	-	
Fuel	Fuel for construction work	1 set	1 set	

5.2 Project Costs

The cost of water intake facility is calculated approximately as about ¥1,800,000,000 for the 1st phase work and ¥1,100,000,000 for the 2nd phase work, ¥2,900,000,000 in total. The overall project cost is fixed by adding the cost of water distributing facility to this cost of water intake facility.