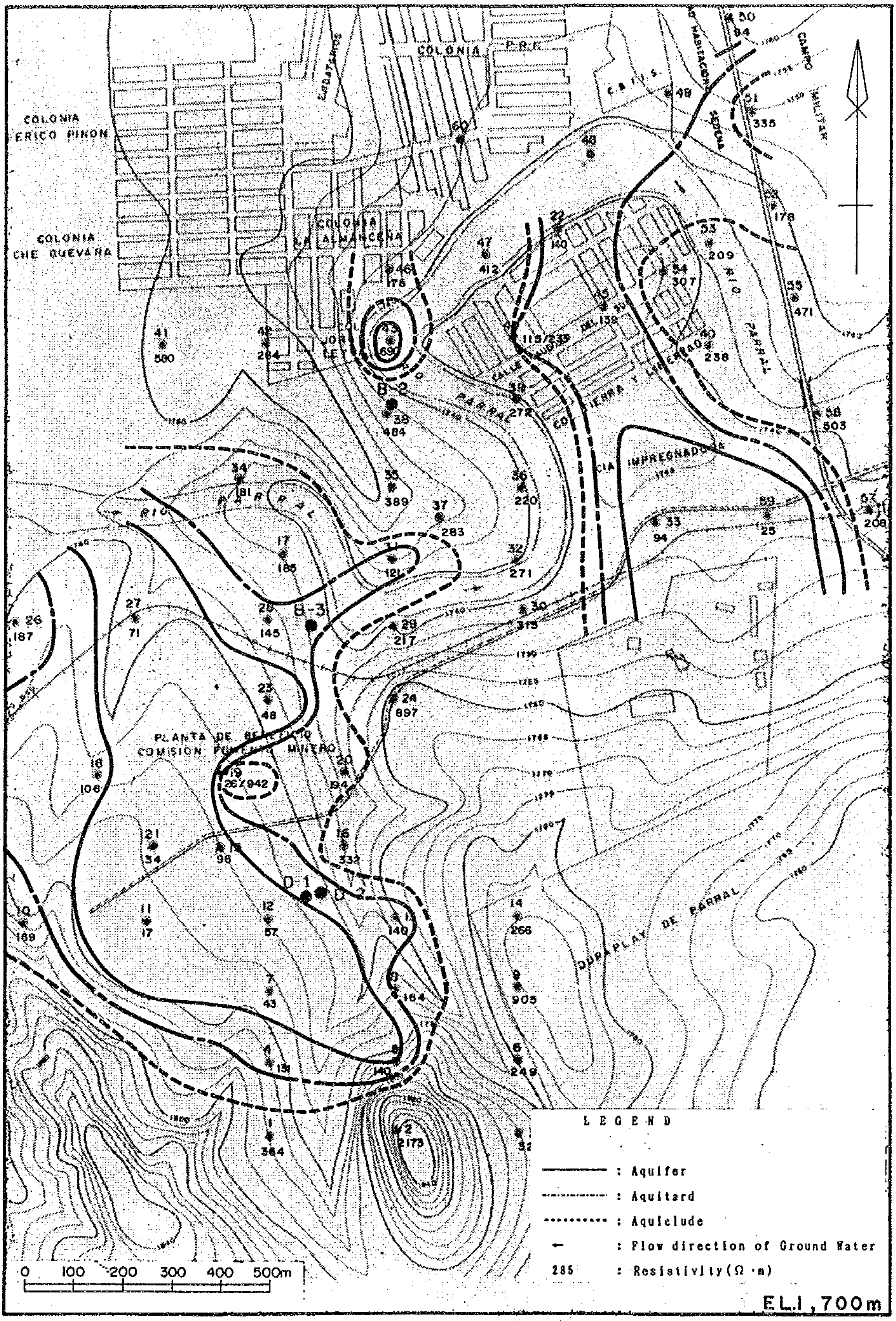


Fig. 4-4-5 Analysis Map of Groundwater Reservoir (4)

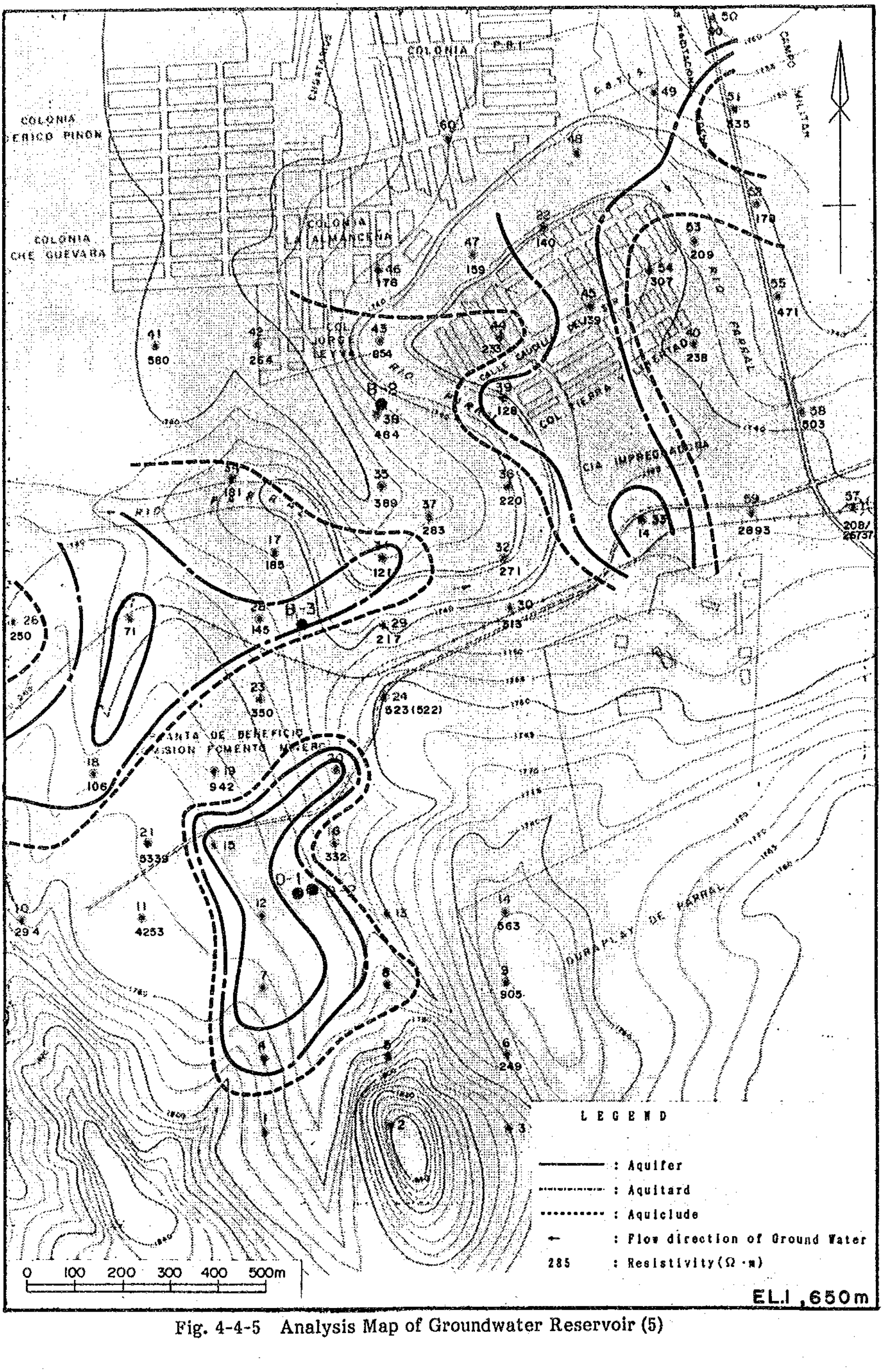


Fig. 4-4-5 Analysis Map of Groundwater Reservoir (5)

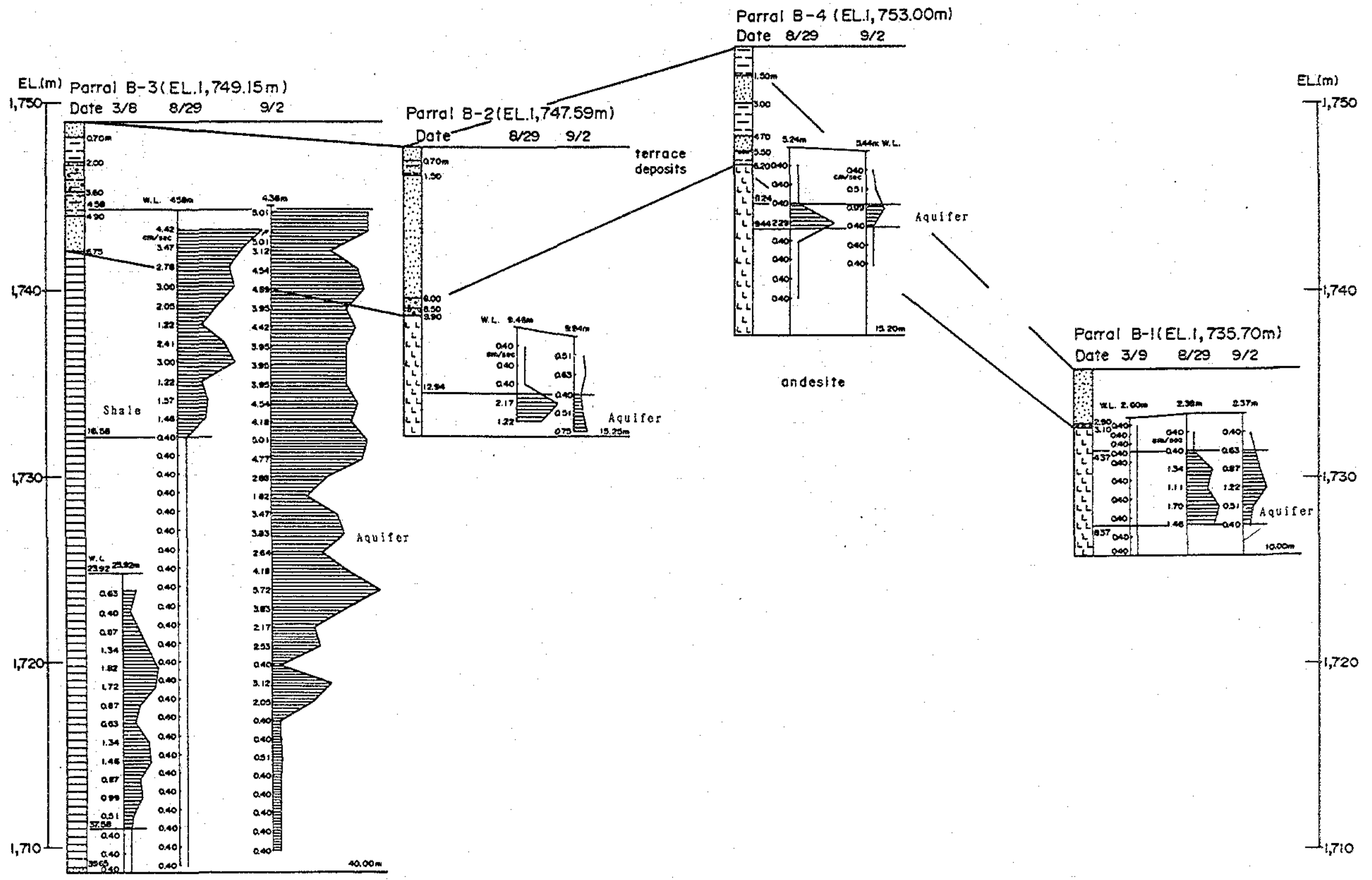


Fig. 4-4-6 Analysis Map of Groundwater Reservoir (Cross Section)

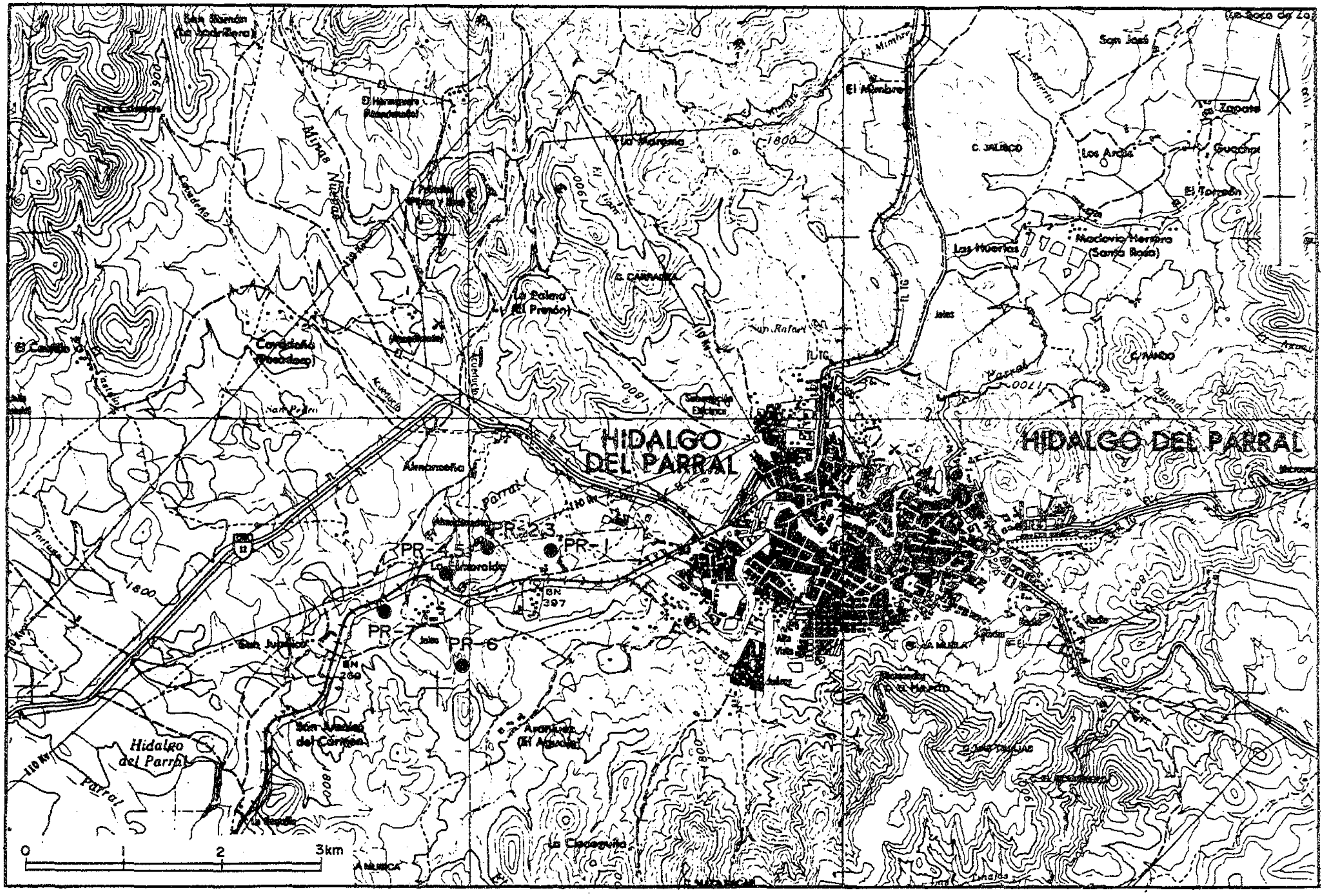


Fig. 4-4-7 Location Map of Permeability Test Sample

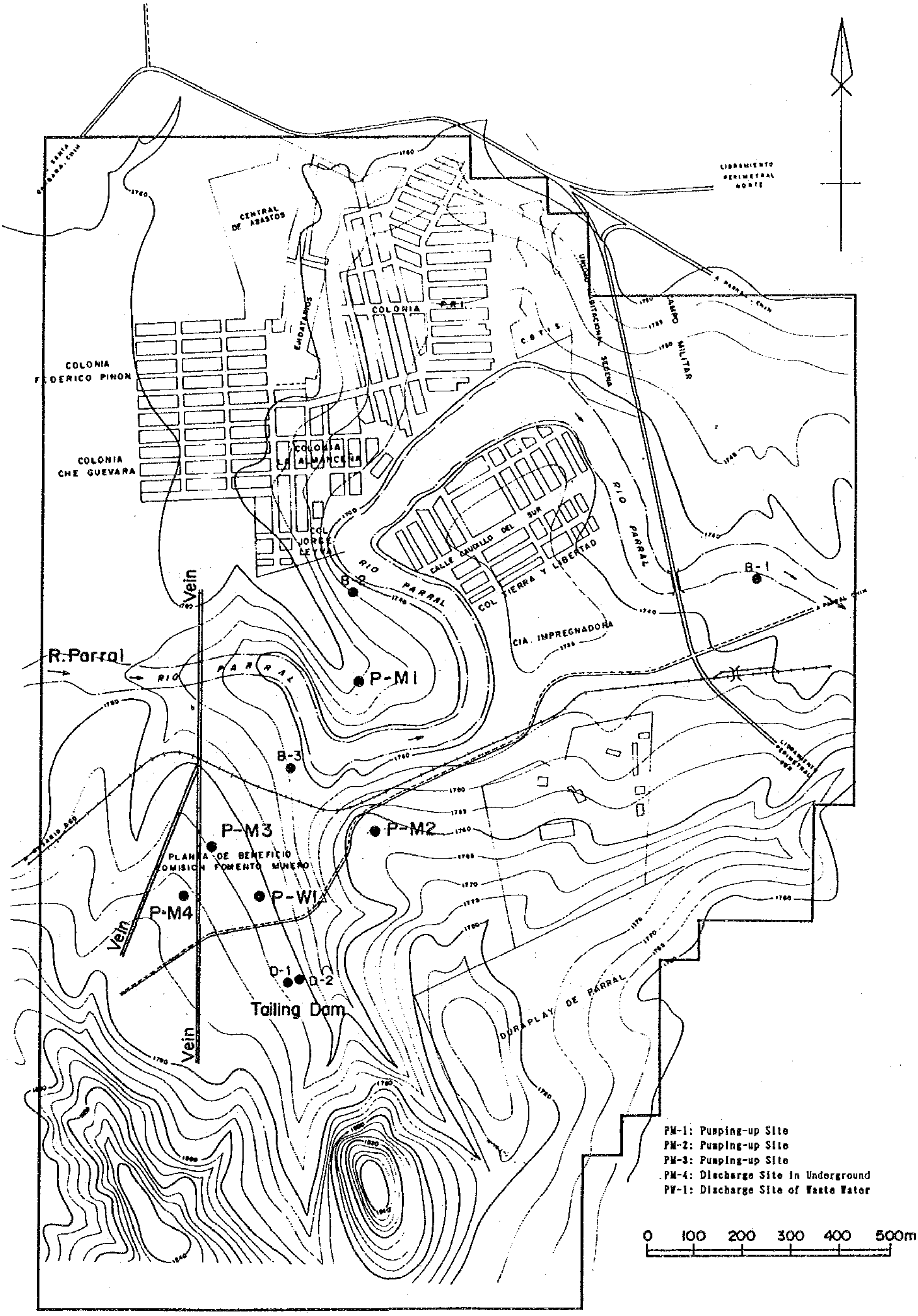


Fig. 4-4-8 Groundwater Simulation Area

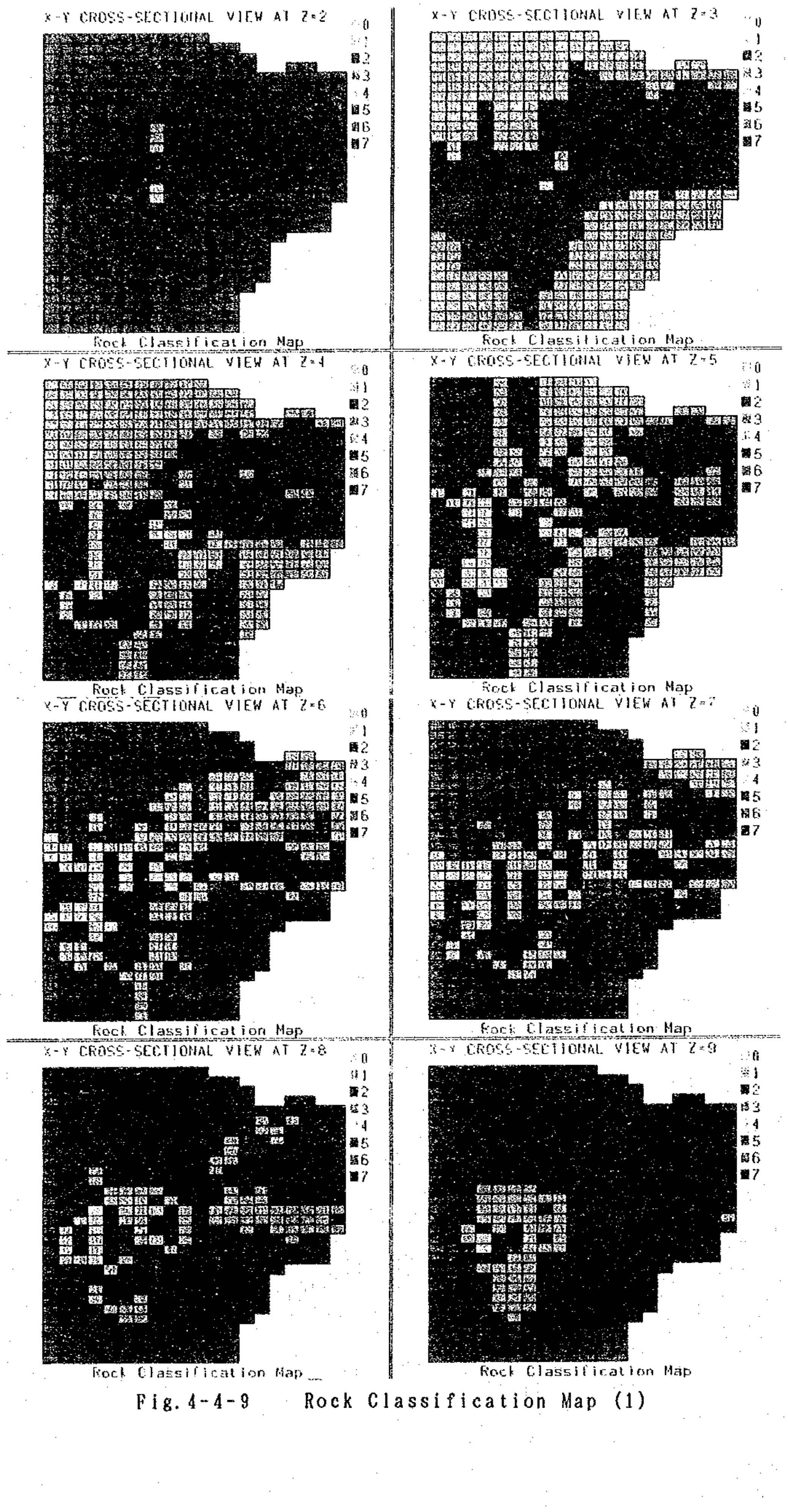


Fig.4-4-9　Rock Classification Map (1)

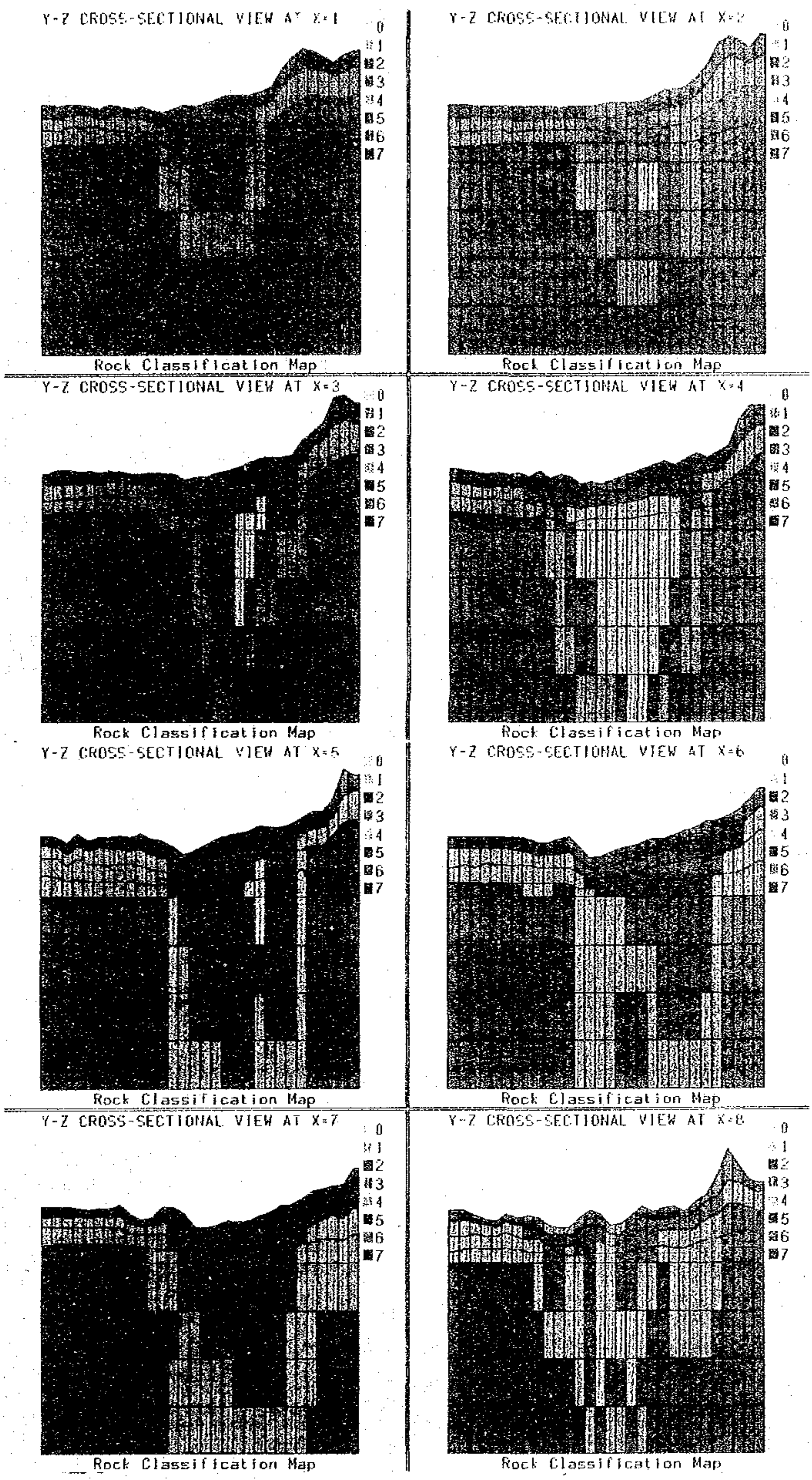


Fig. 4-4-9 Rock Classification Map (2)

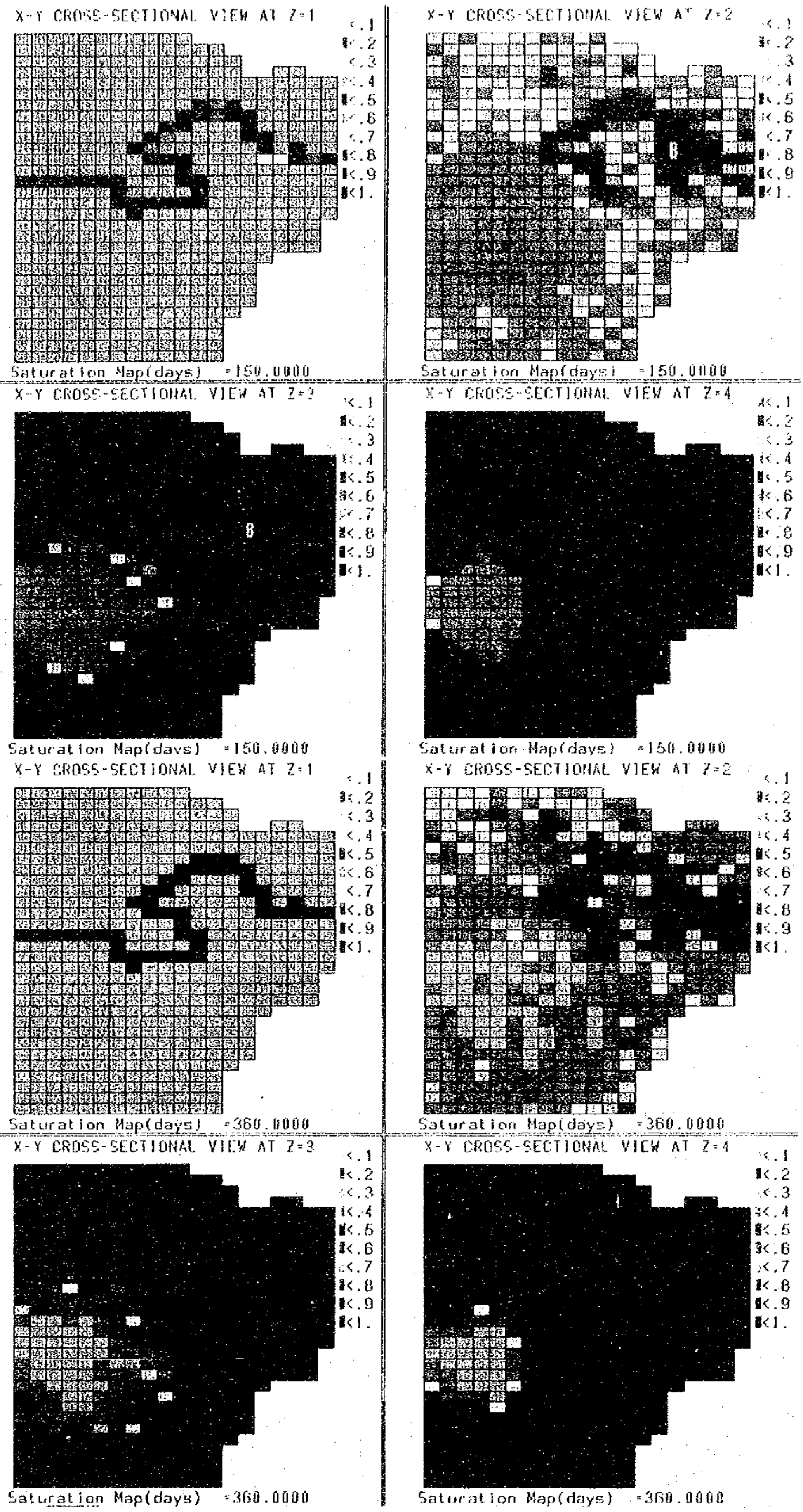
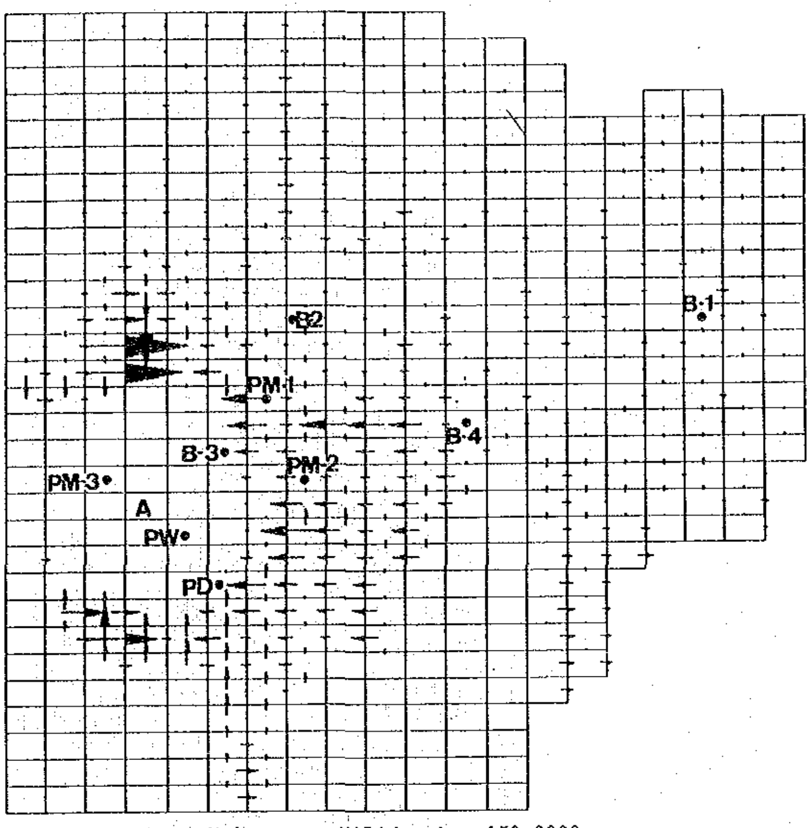


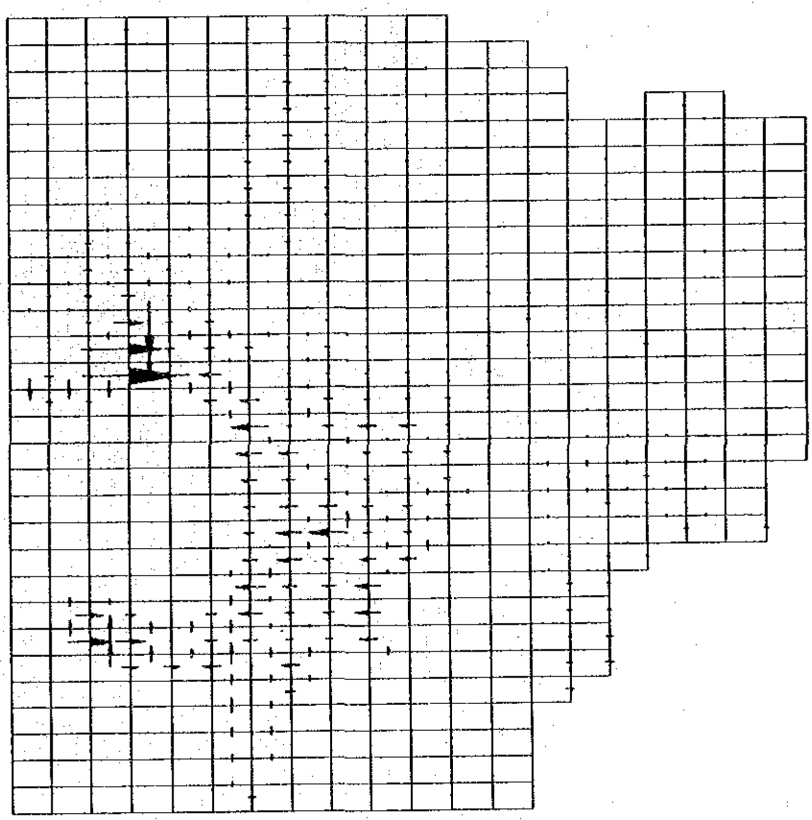
Fig.4-4-10 Groundwater Saturation Map

X-Y CROSS-SECTIONAL VIEW AT Z=4



Velocity MAP(days) =150.0000

X-Y CROSS-SECTIONAL VIEW AT Z=4



Velocity MAP(days) =360.0000

Fig.4-4-11 Groundwater Velocity Map

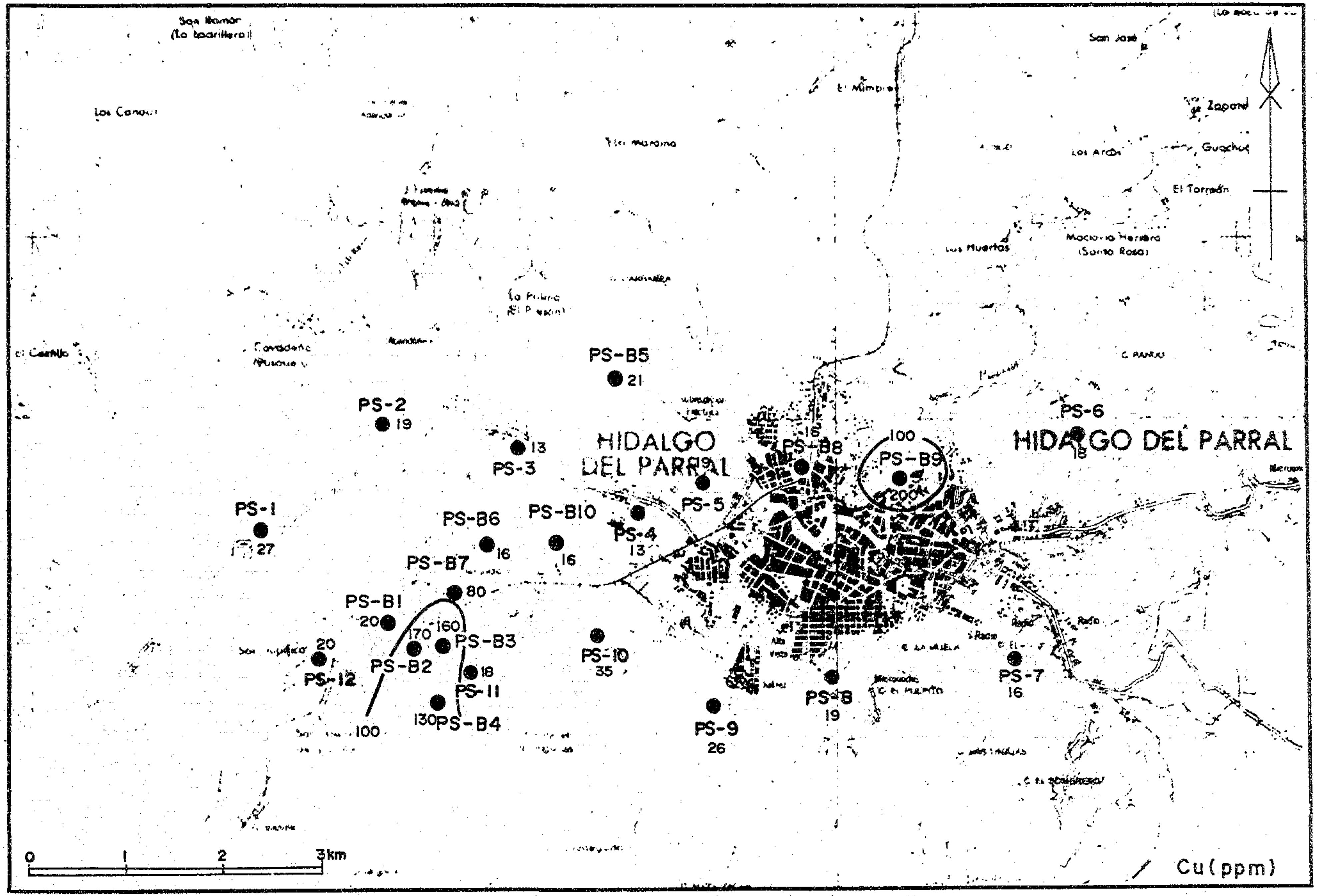


Fig. 4-5-1 Analysis Map of Chemical Data of Soil (1)

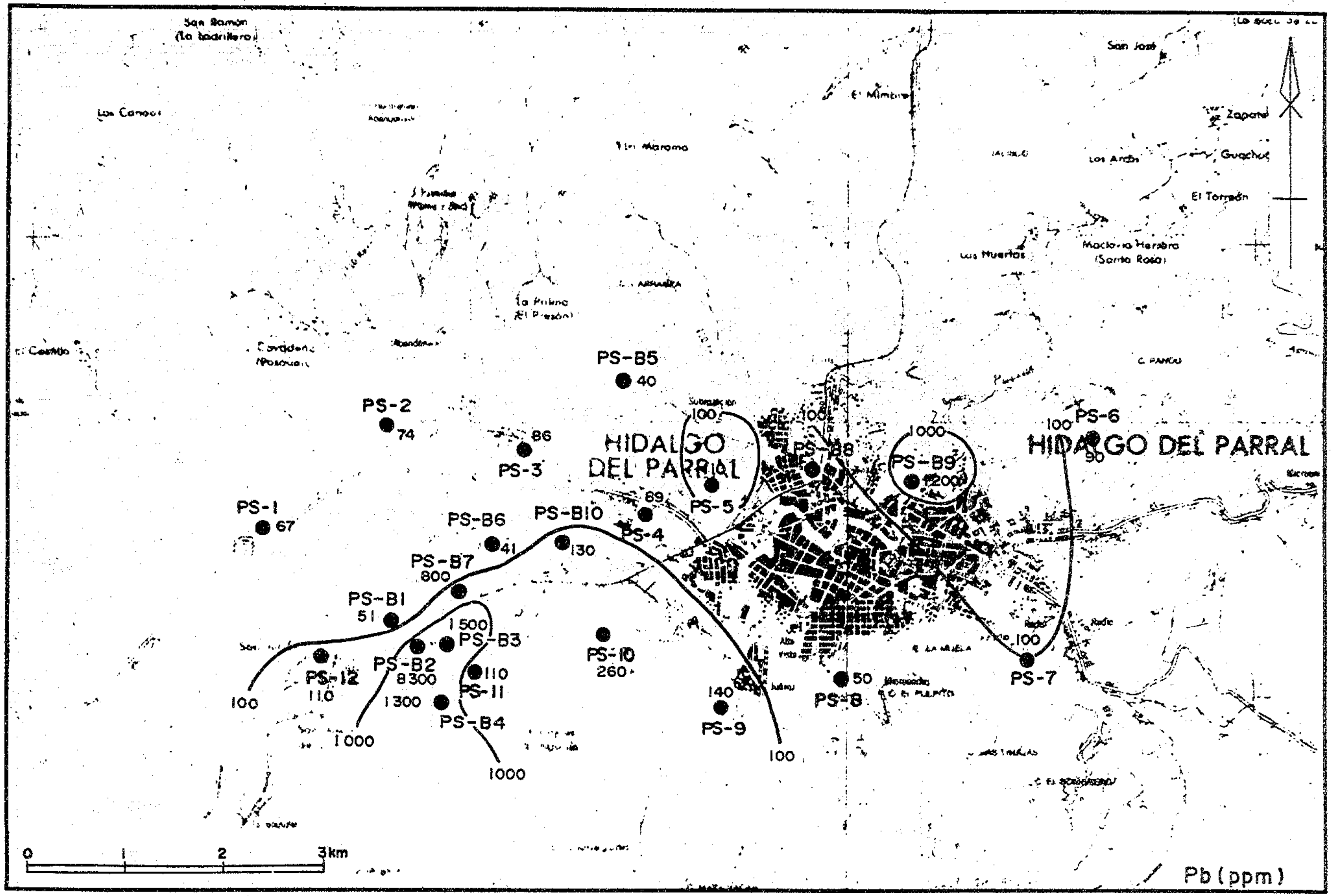


Fig. 4-5-1 Analysis Map of Chemical Data of Soil (2)

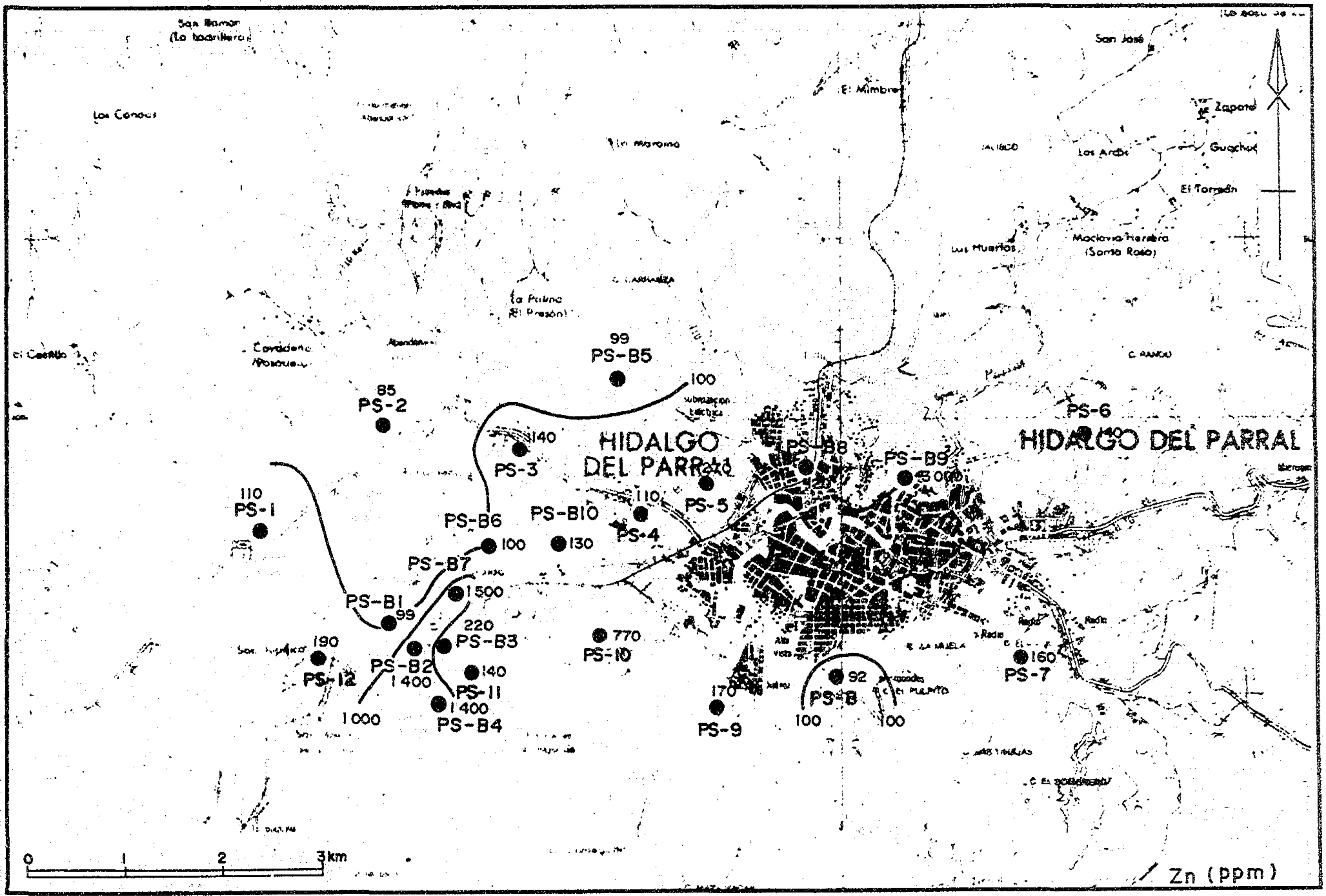


Fig. 4-5-1 Analysis Map of Chemical Data of Soil (3)

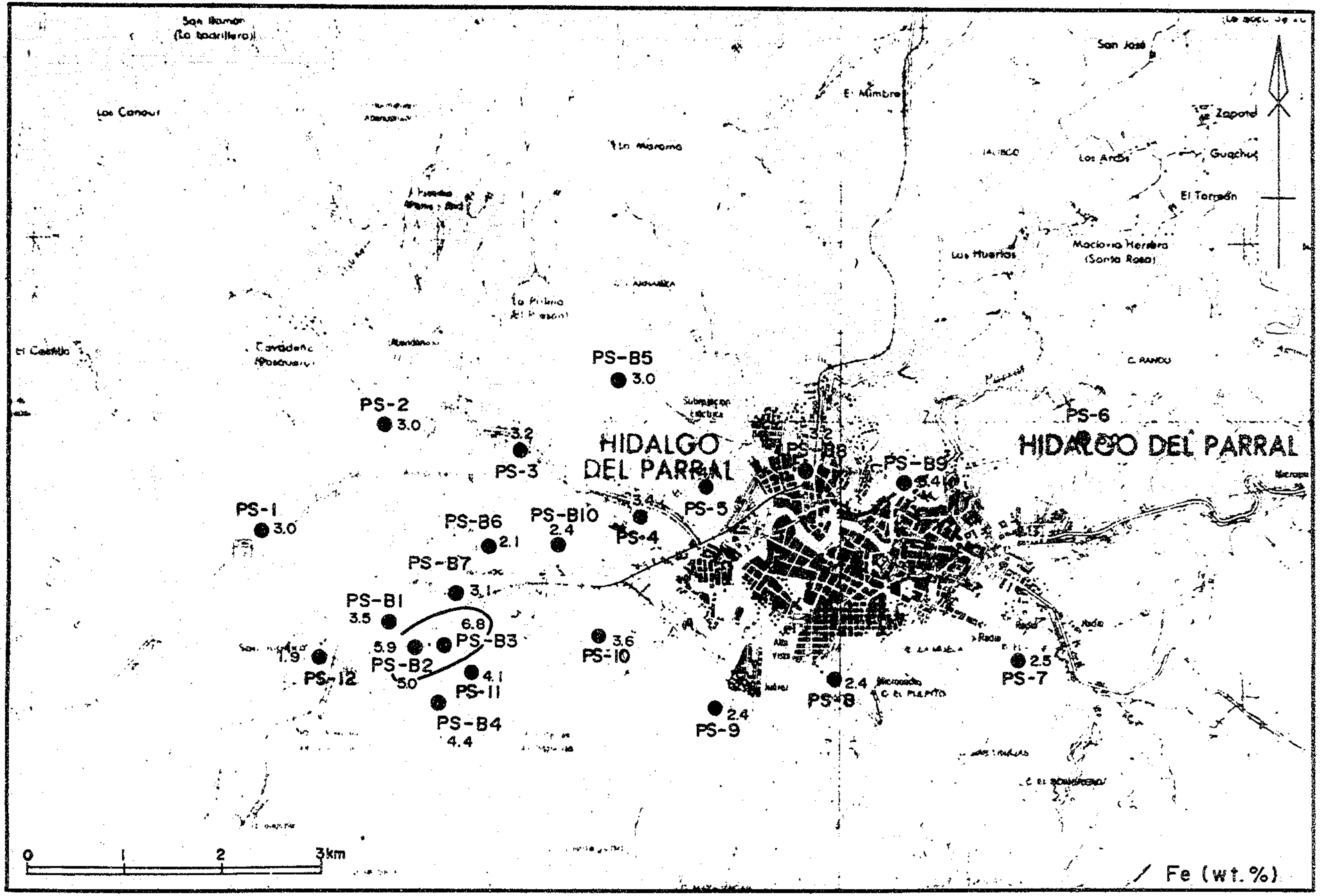


Fig. 4-5-1 Analysis Map of Chemical Data of Soil (4)

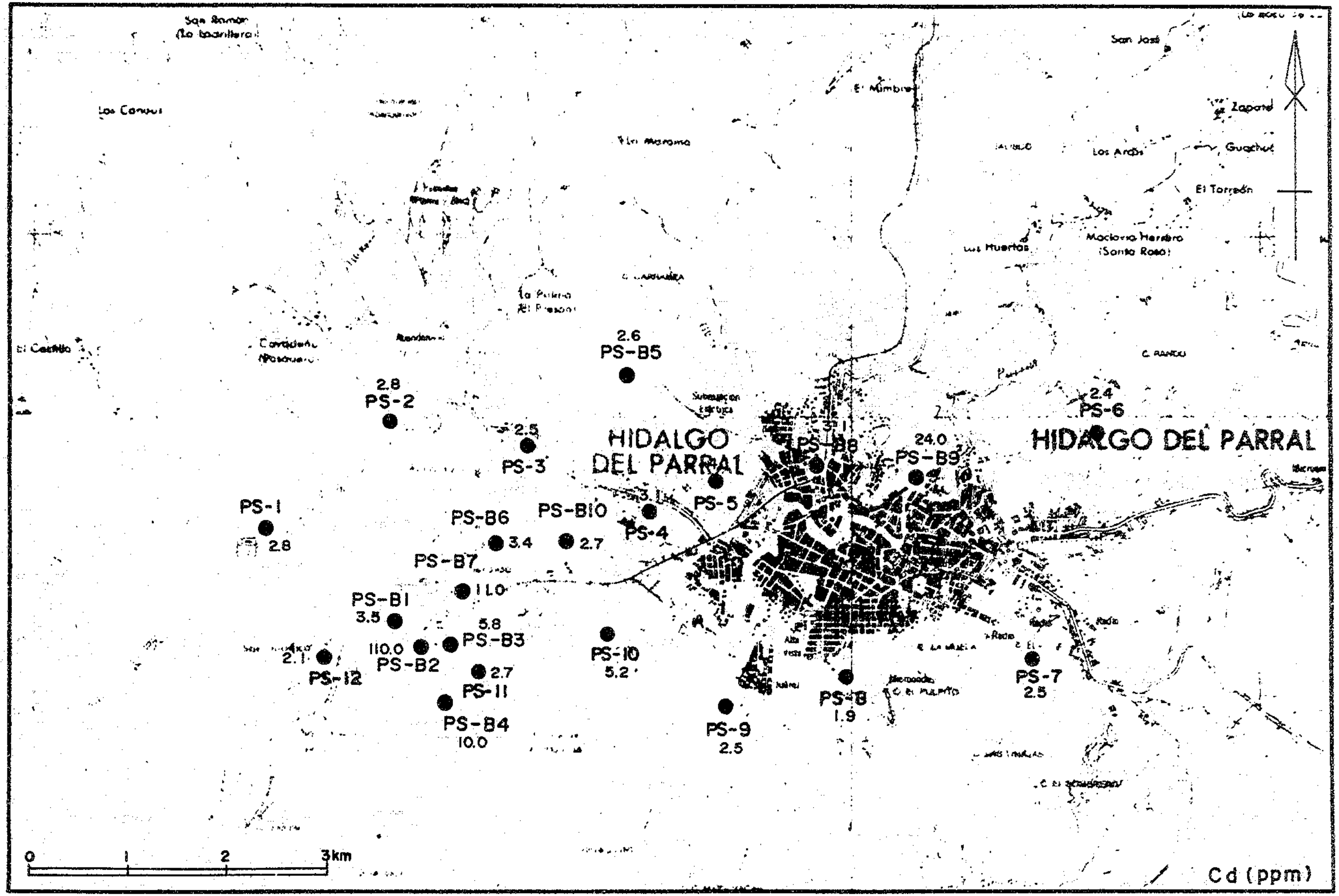


Fig. 4-5-1 Analysis Map of Chemical Data of Soil (5)

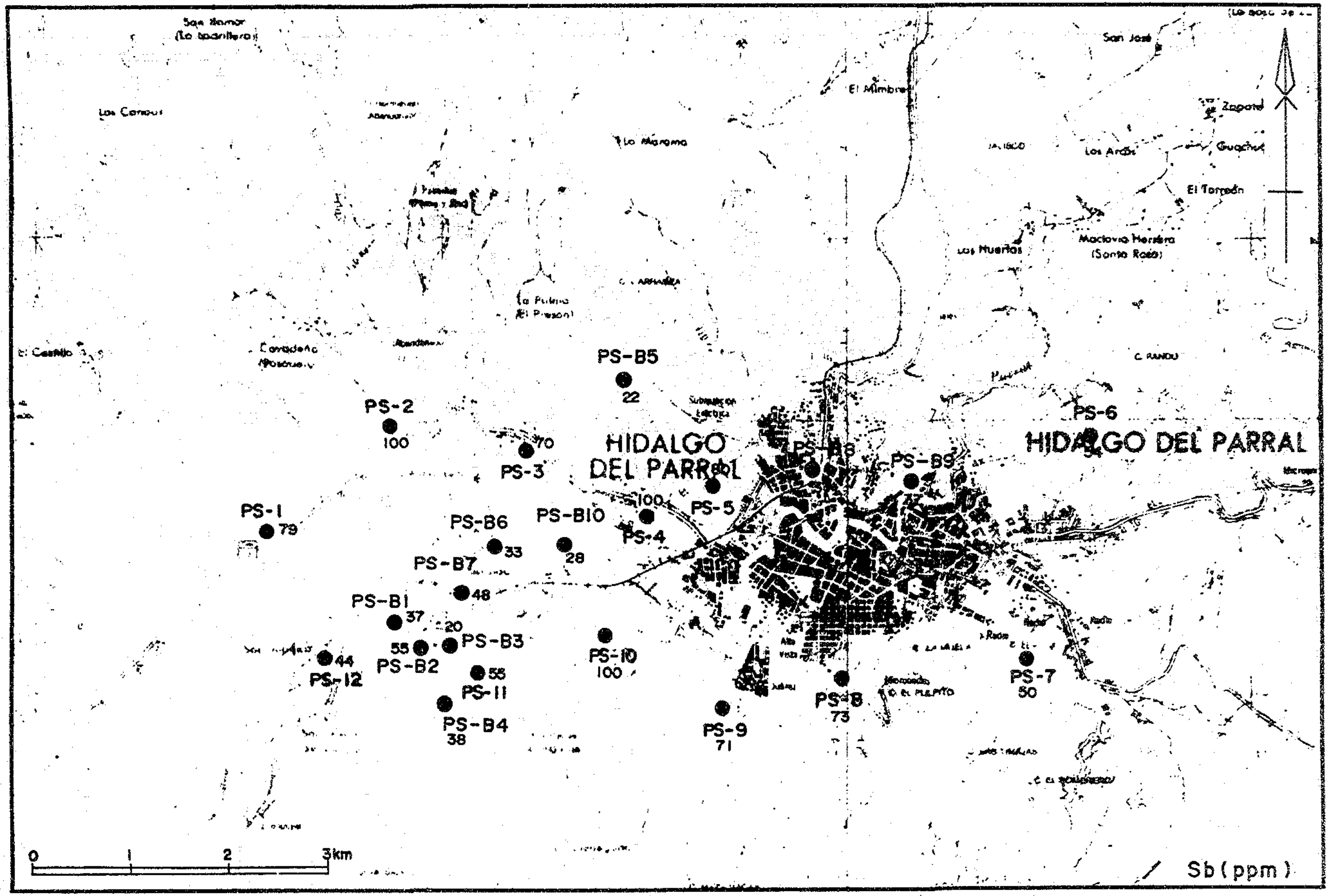


Fig. 4-5-1 Analysis Map of Chemical Data of Soil (6)

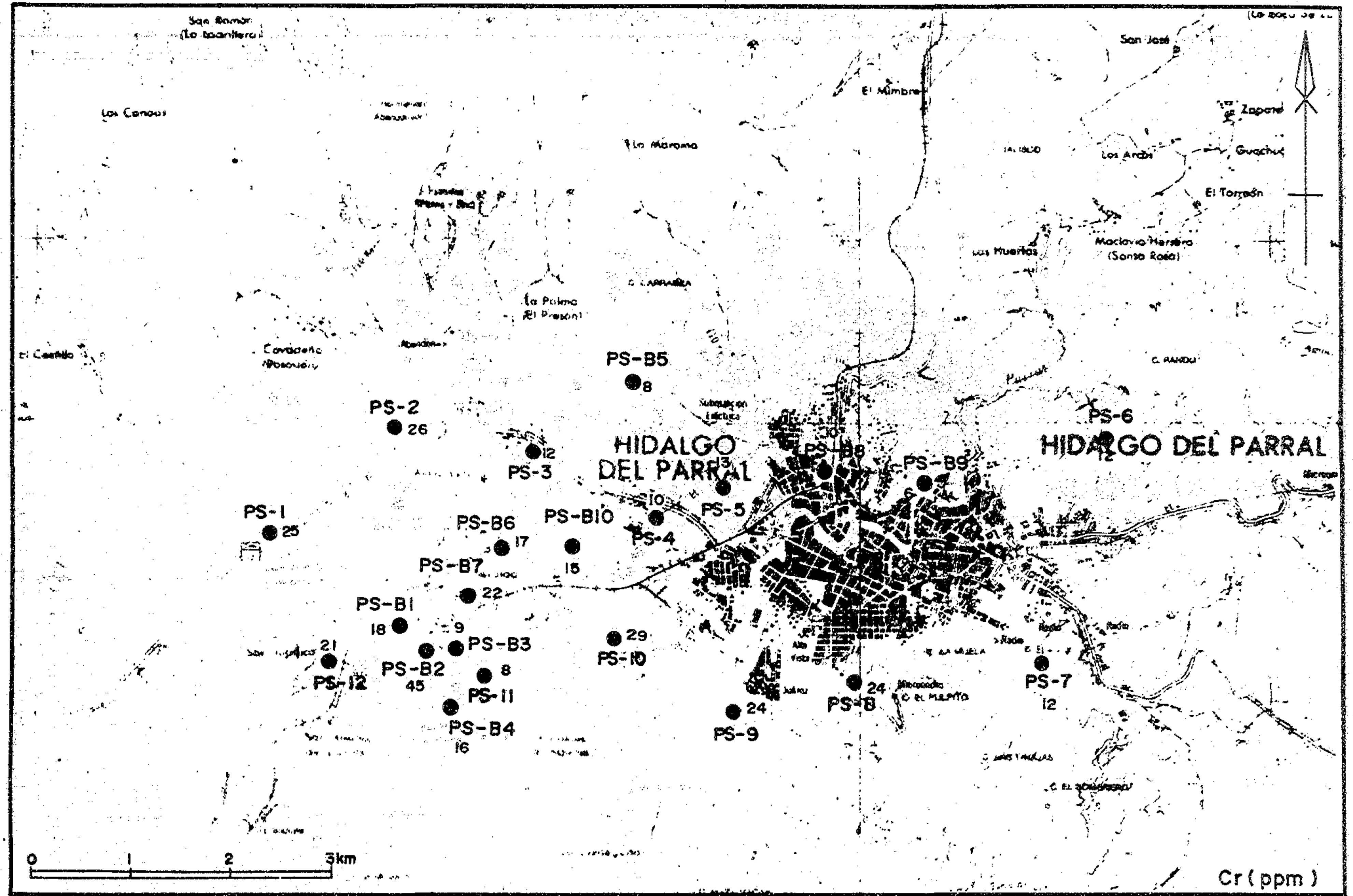


Fig. 4-5-1 Analysis Map of Chemical Data of Soil (7)

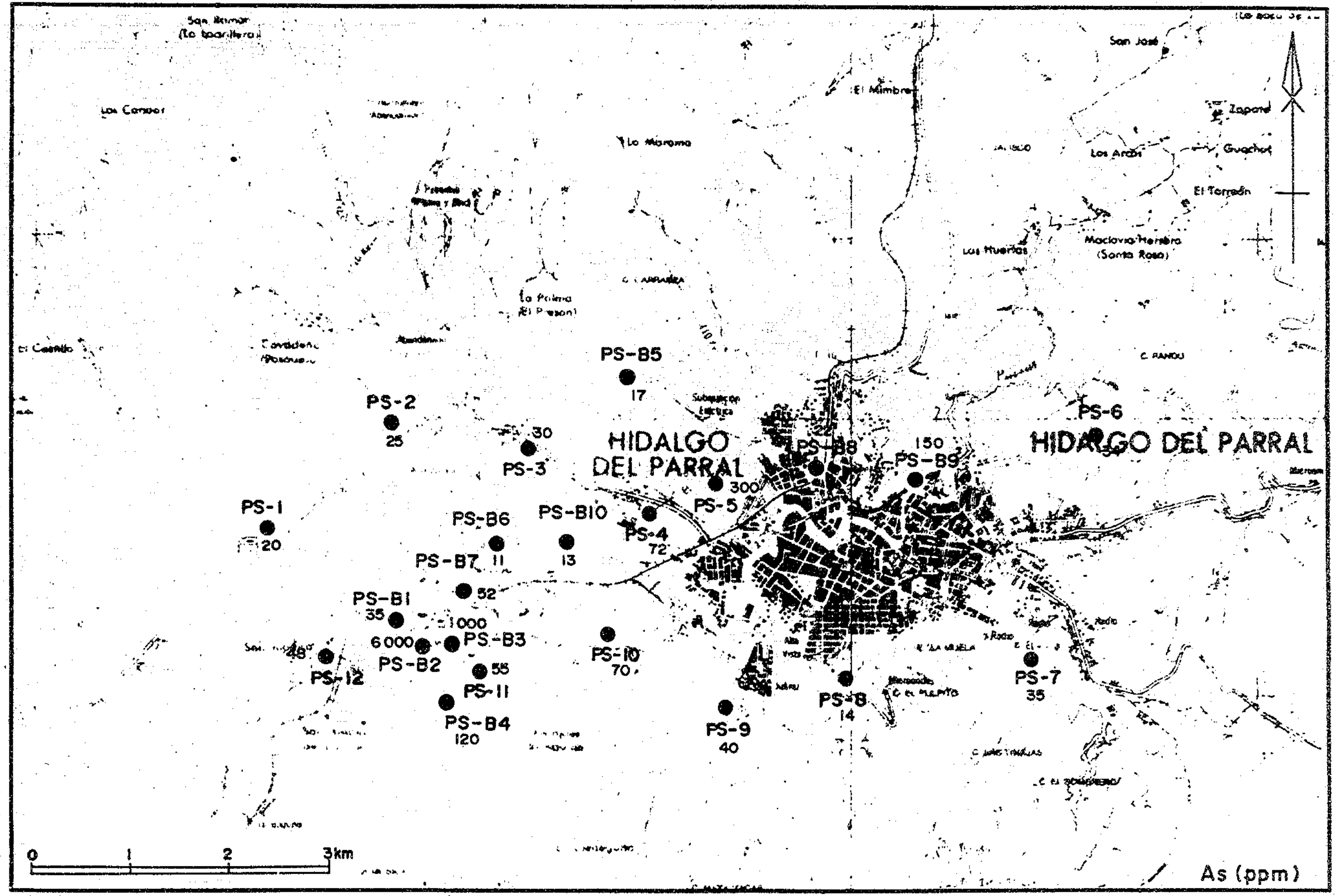


Fig. 4-5-1 Analysis Map of Chemical Data of Soil (8)

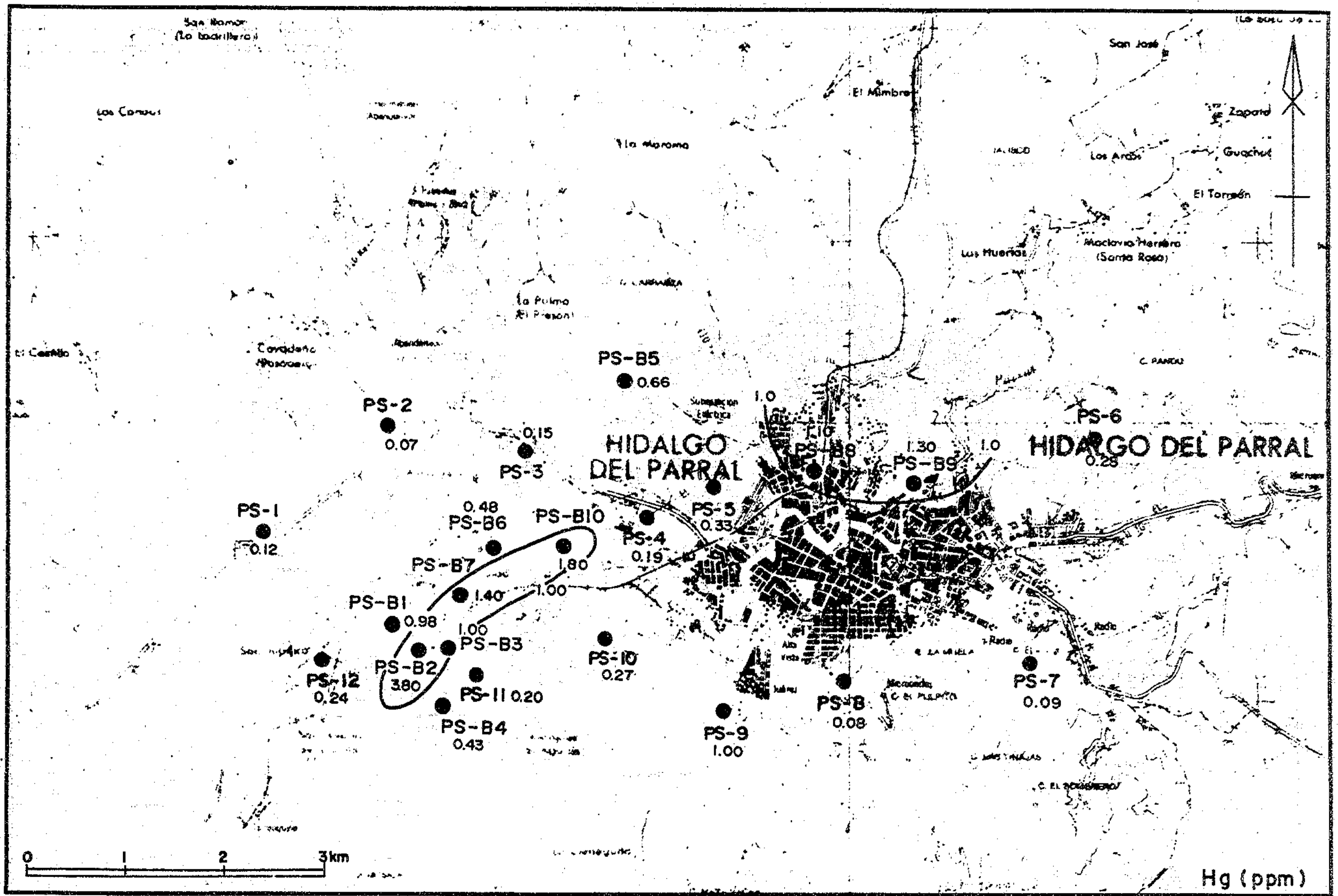


Fig. 4-5-1 Analysis Map of Chemical Data of Soil (9)

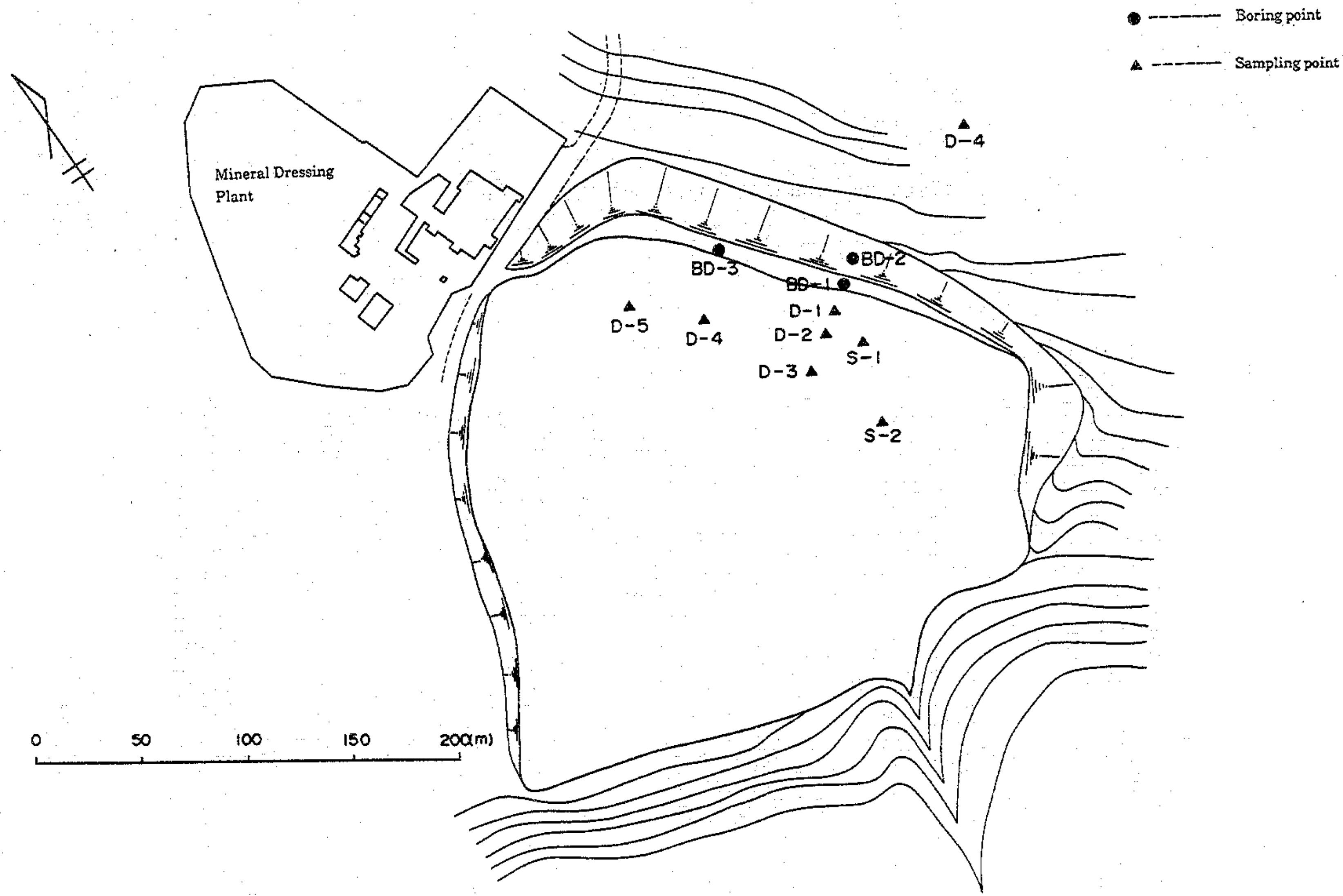


Fig. 4-6-1 Boring and Soil Test Sample Point

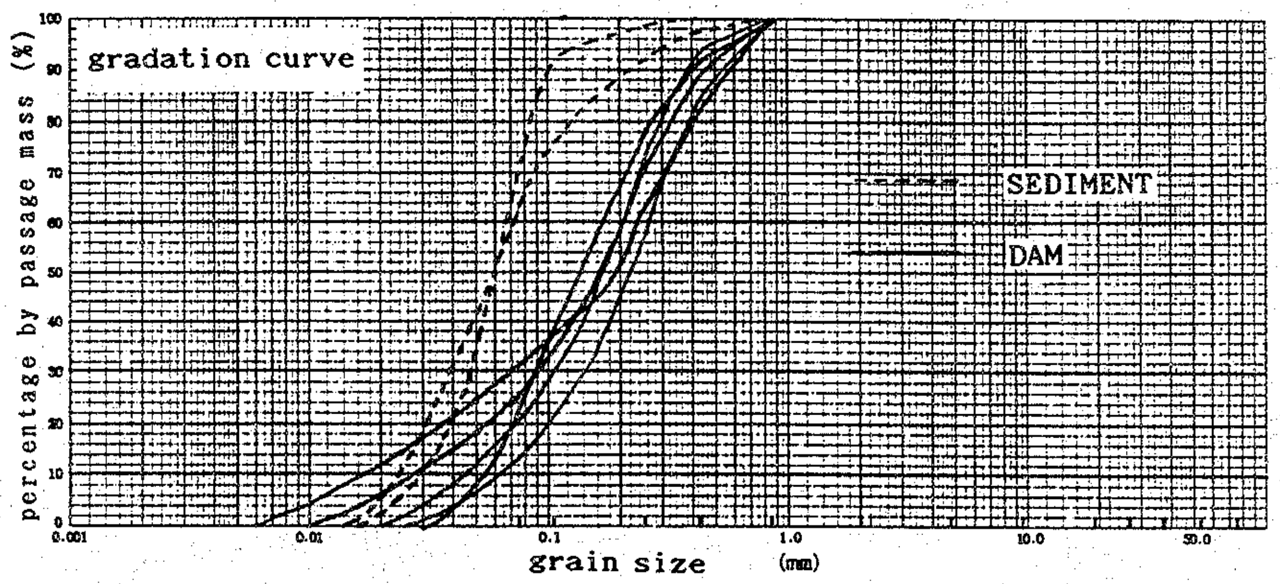


Fig. 4-6-2 Grain Size Accumulation Curve

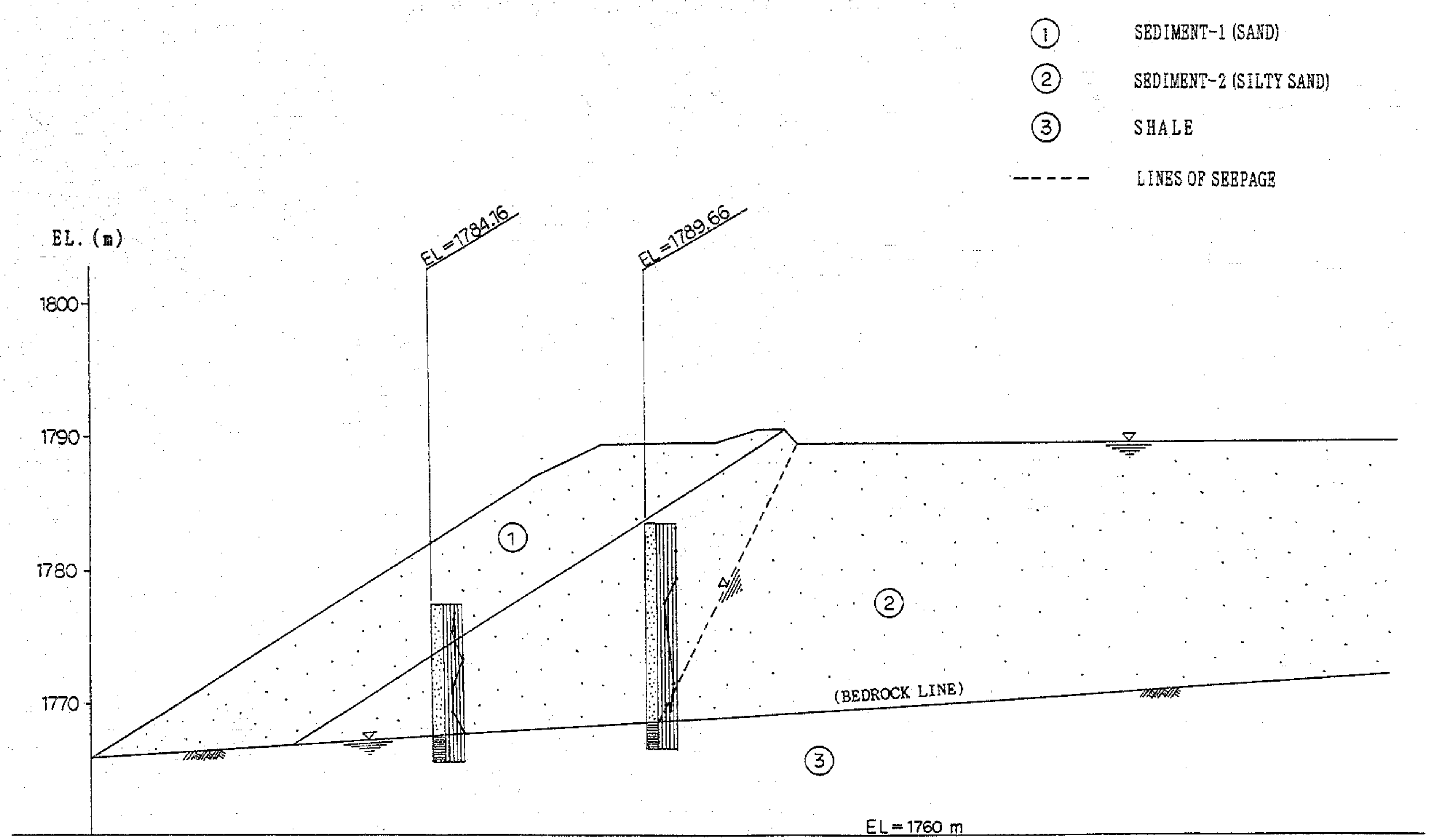


Fig. 4-6-3 Parral Tailing Dam Geological Cross Section

PARRAL TAILING DAM

CONDITION OF SOIL

Zone No.	SOIL	PARTIAL SATURATION DENSITY ρ_t (g/cm^3)	SATURATION DENSITY ρ_{sat} (g/cm^3)	COHESION C (kgf/cm^2)	SHEARING RESISTANCE ANGLE ϕ (°)
①	SEDIMENT-1	1.910	2.094	0.00	30.0
②	SEDIMENT-2	1.689	1.816	0.10	23.0

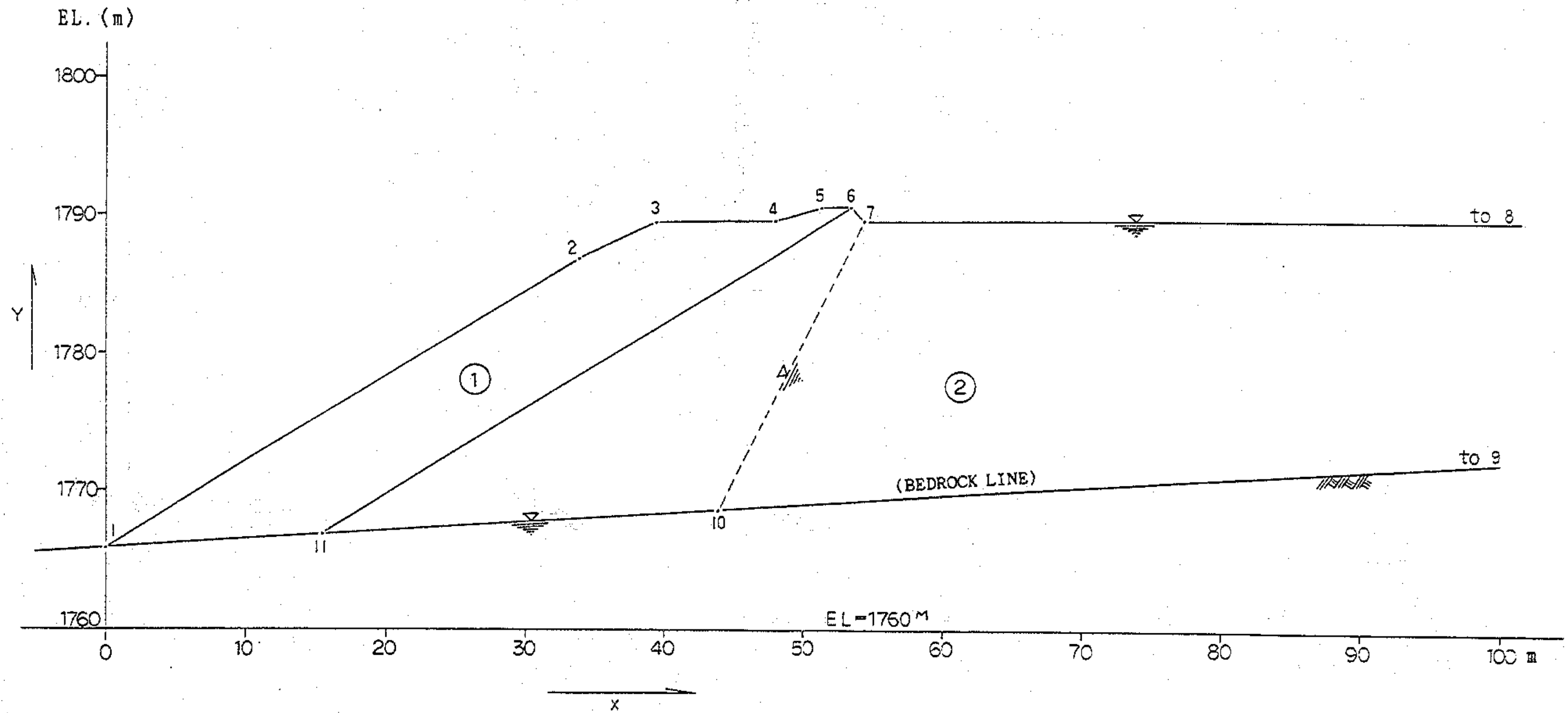


Fig. 4-6-4 The Model of Tailing Dam Stability Analysis

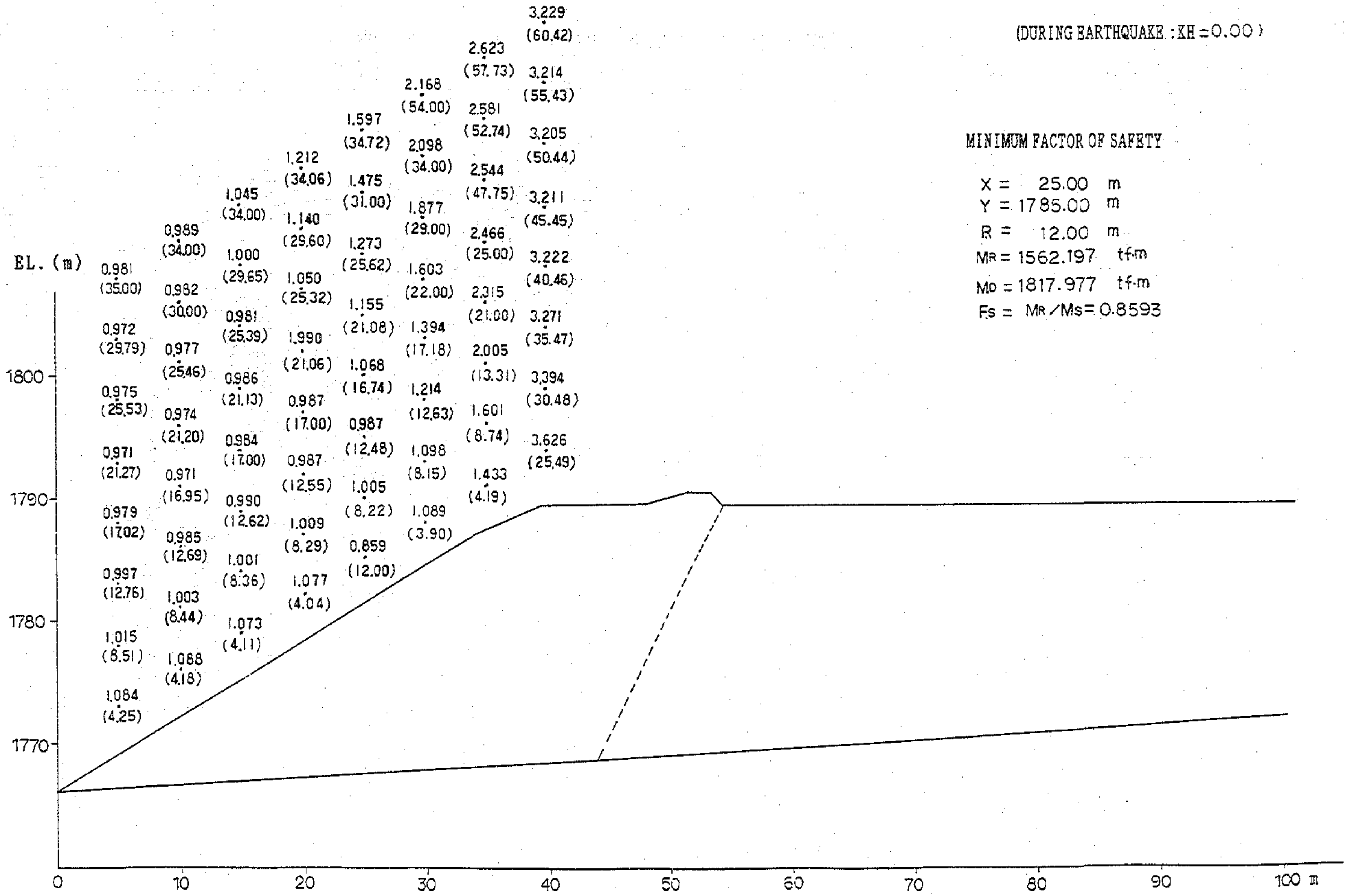


Fig. 4-6-5 A Result of Tailing Dam Stability Analysis (1)

MINIMUM FACTOR OF SAFETY BY EACH DISTANCE

(DURING EARTHQUAKE : KH=0.00)

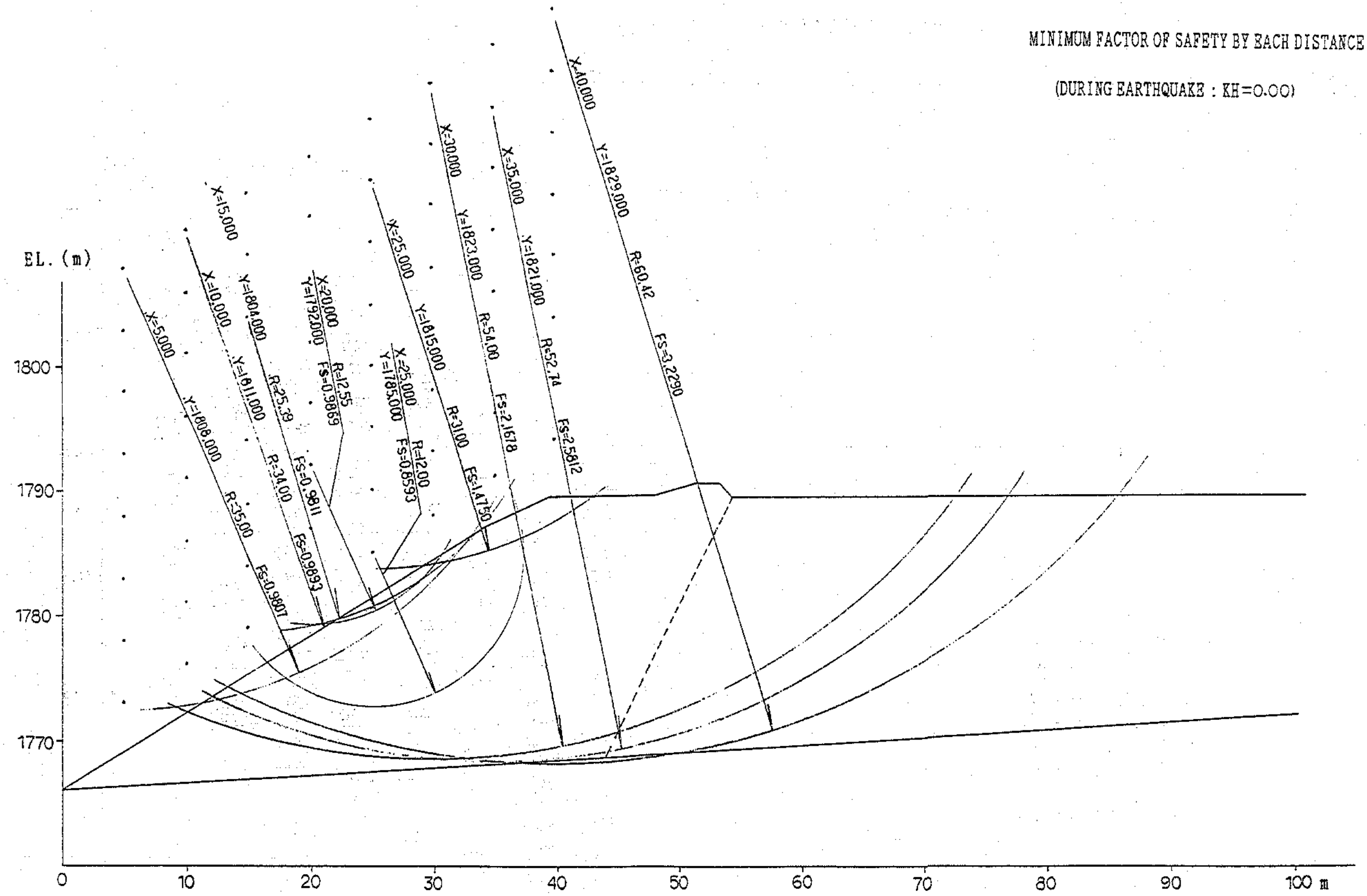


Fig. 4-6-6 A Result of Tailing Dam Stability Analysis (2)

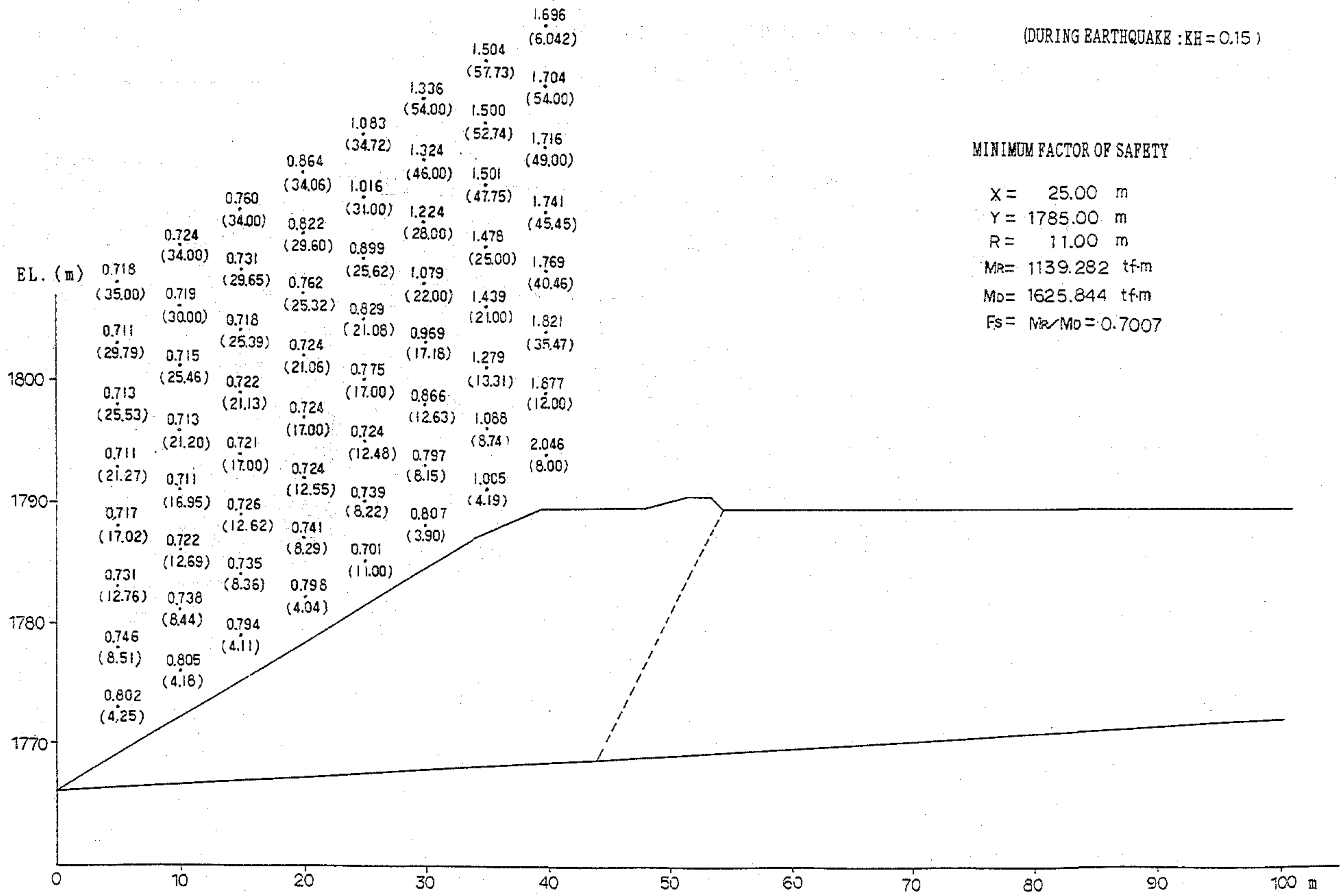


Fig. 4-6-7 A Result of Tailing Dam Stability Analysis (3)

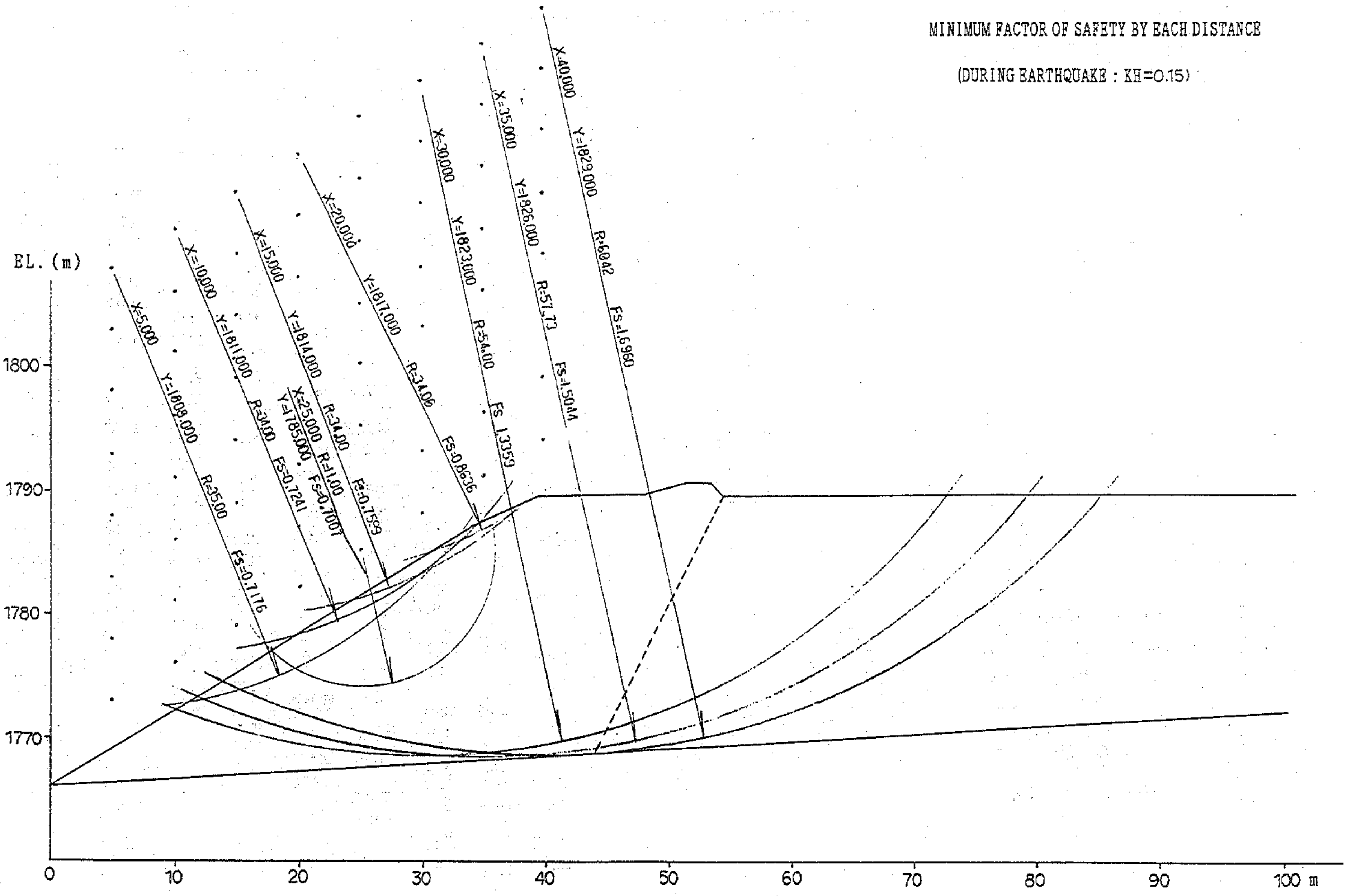


Fig. 4-6-8 A Result of Tailing Dam Stability Analysis (4)

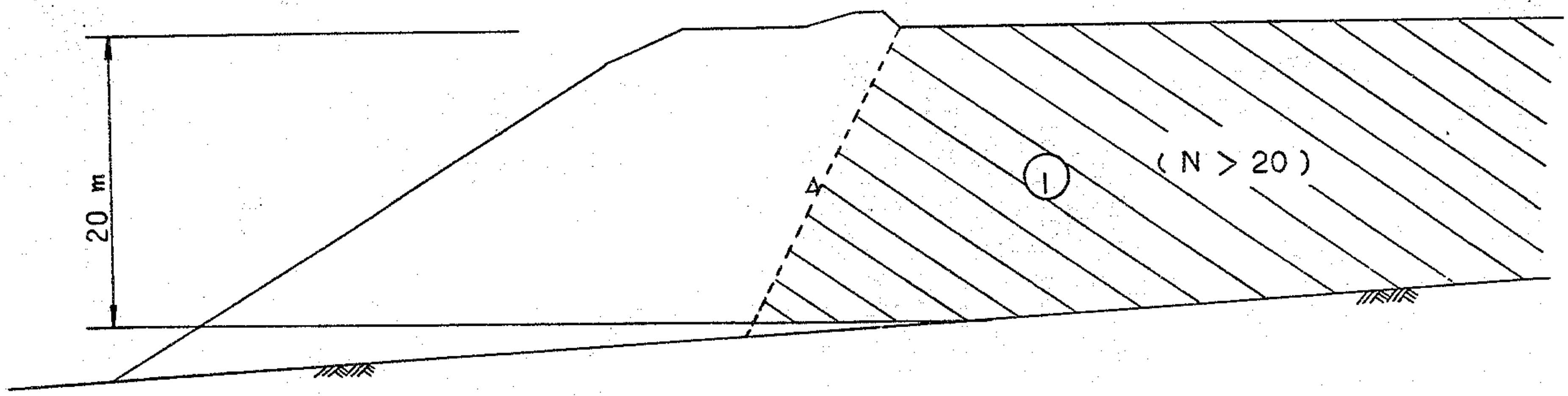


Fig. 4-6-9 The Scope for Danger of Liquefaction

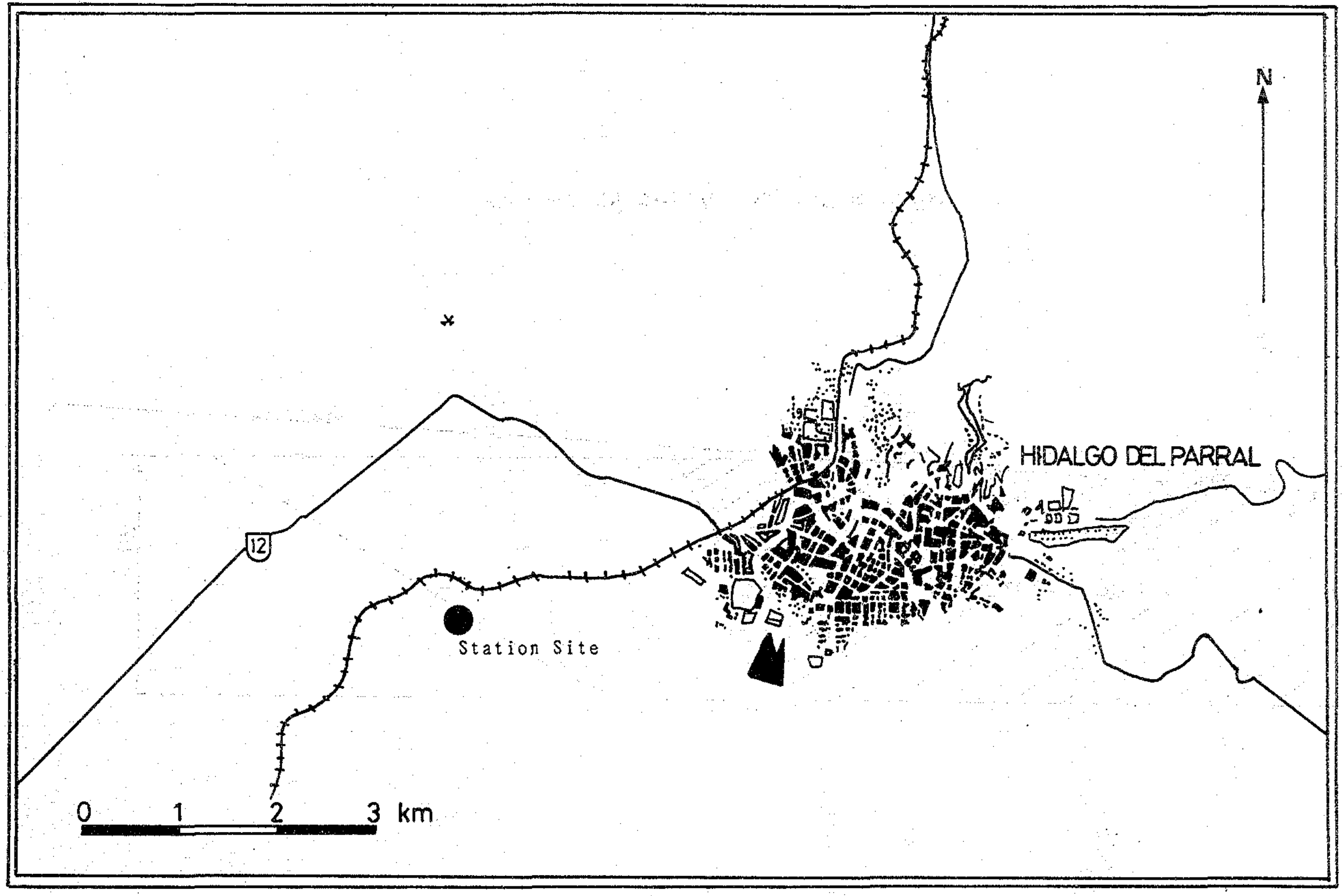


Fig. 4-7-1 Location Map of Meteorological Station

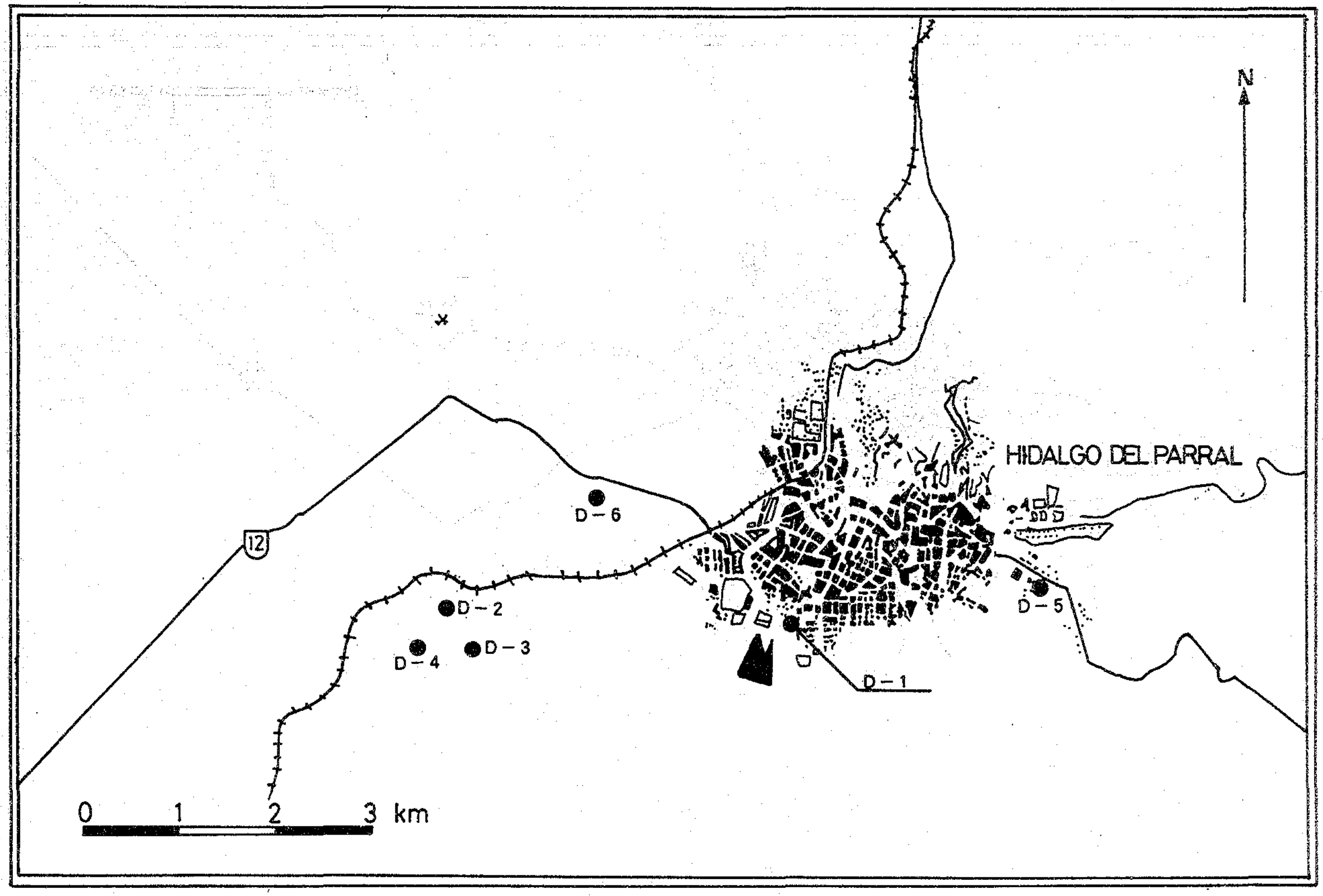


Fig. 4-7-2 Location Map of Dust Jar Sampling

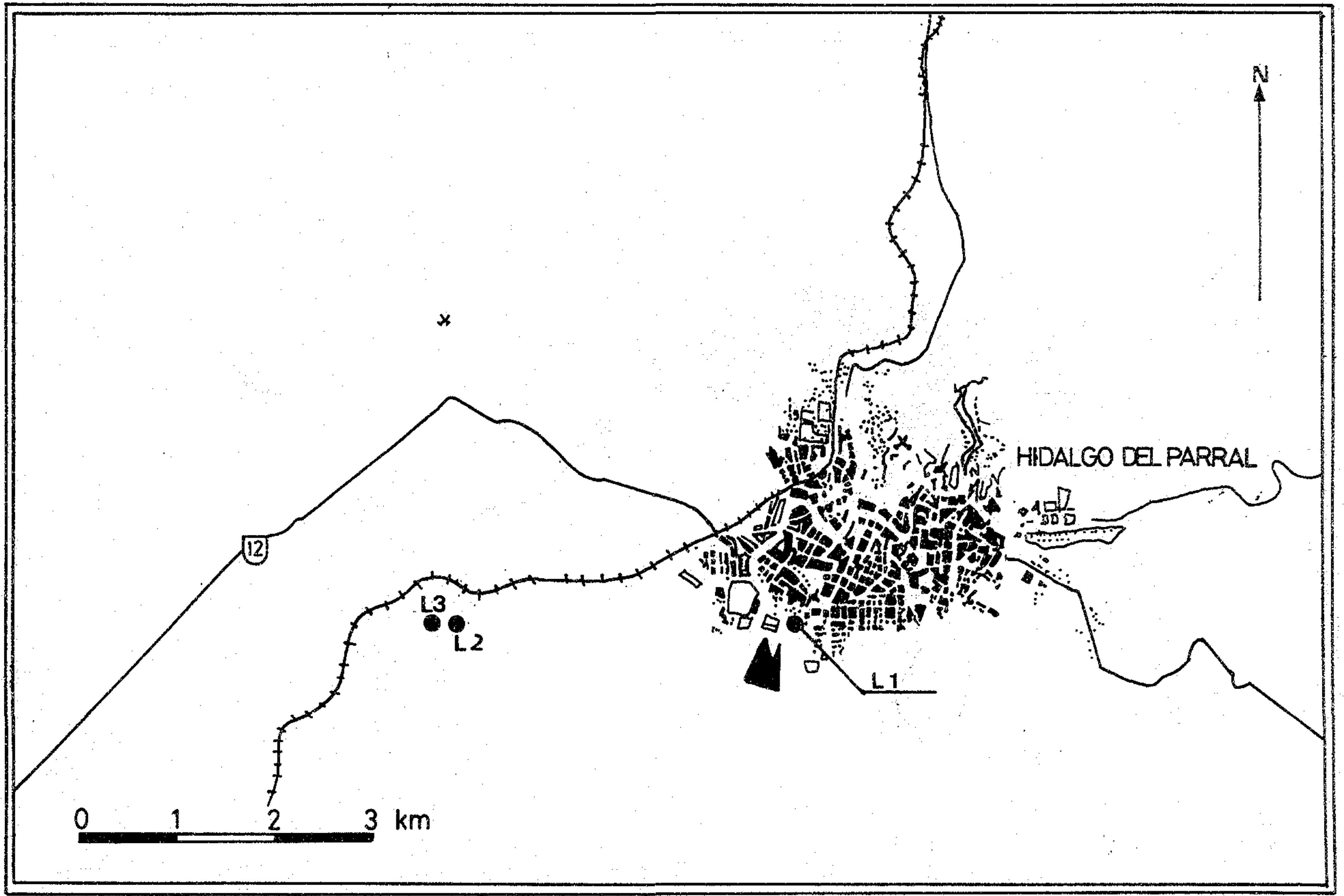


Fig. 4-7-3 Location Map of Low Volume Sampler

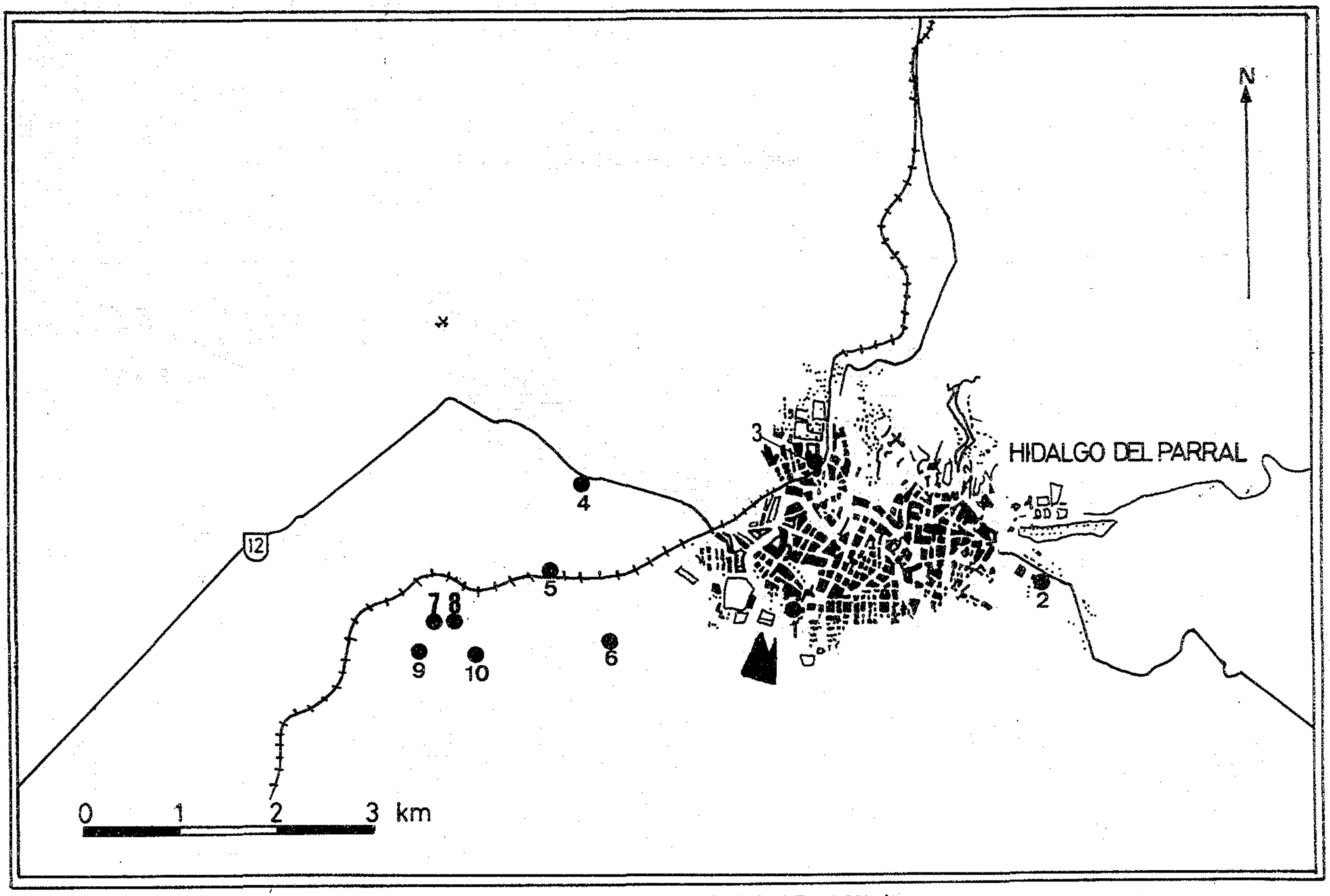


Fig. 4-7-4 Location Map of Digital Dust Monitors

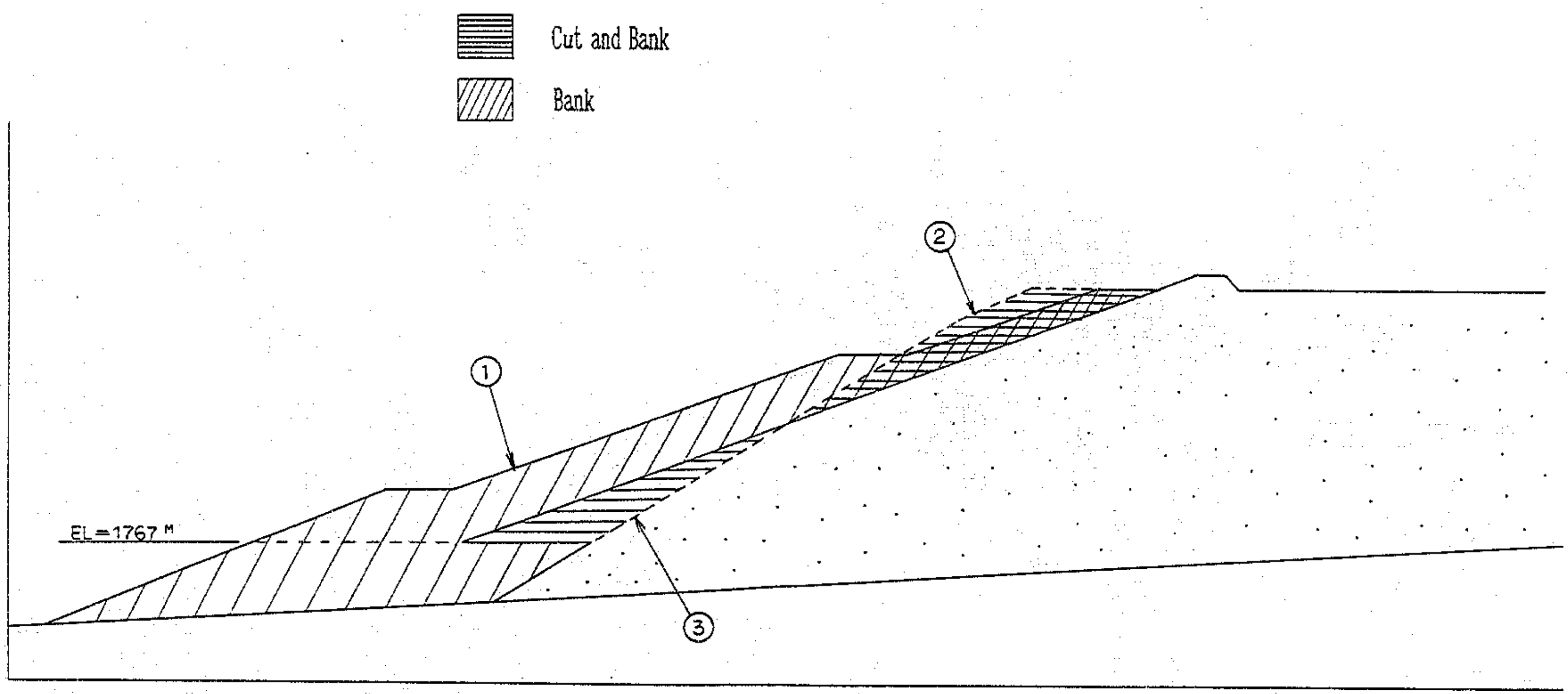


Fig. 4-9-1 The Model of Counter Load

CONDITION OF SOIL

Zone No.	SOIL	PARTIAL SATURATION DENSITY ρ_t (g/cm³)	SATURATION DENSITY ρ_{sat} (g/cm³)	COHESION C (kgf/cm²)	SHEARING RESISTANCE ANGLE ϕ (°)
①	GRAVEL	1.800	1.912	0.00	37.0
②	SEDIMENT-1	1.910	2.094	0.00	30.0
③	SEDIMENT-2	1.689	1.816	0.10	23.0

PARRAL TAILING DAM

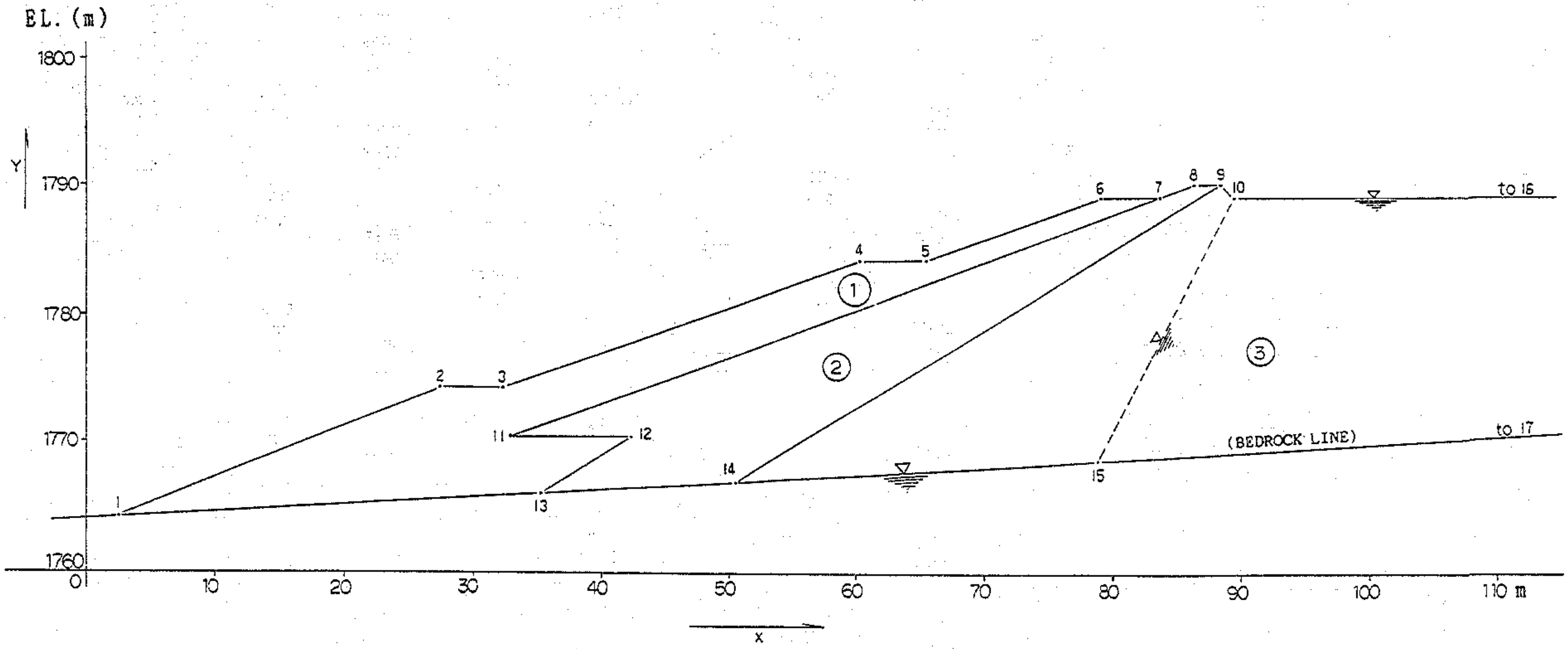


Fig. 4-9-2 The Model of Tailing Dam Stability Analysis

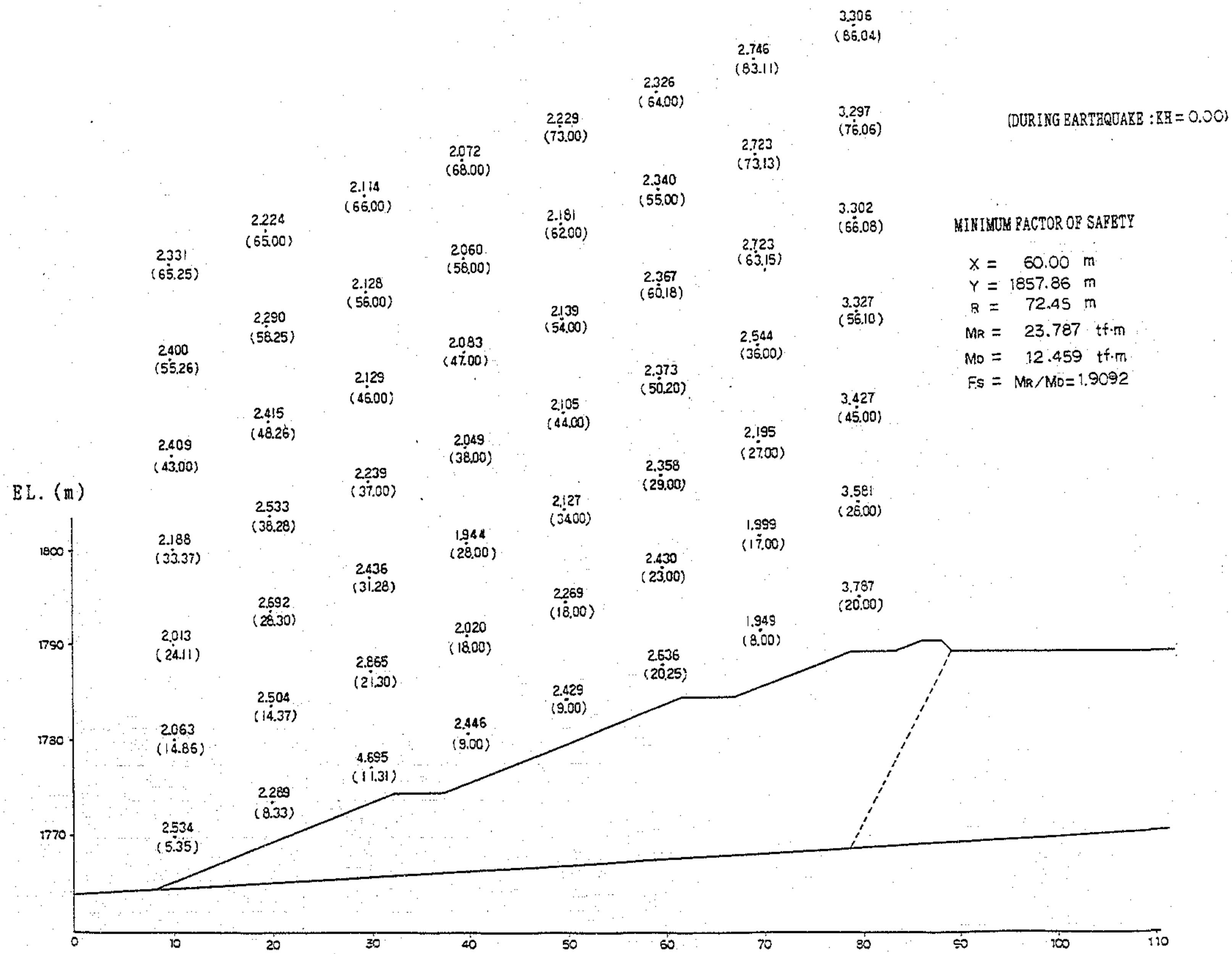


Fig. 4-9-3 A Result of Tailing Dam Stability Analysis (1)

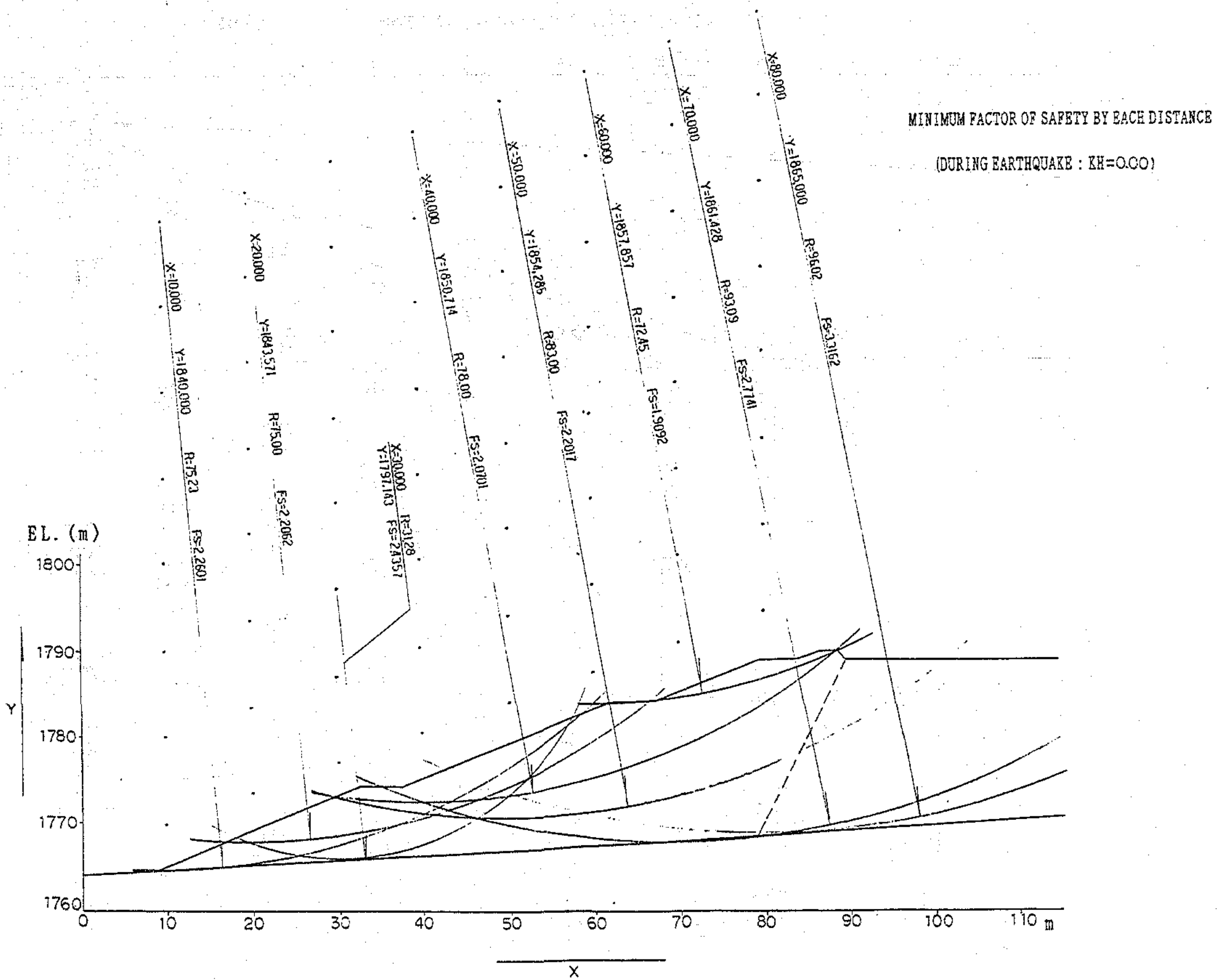


Fig. 4-9-4 A Result of Tailing Dam Stability Analysis (2)

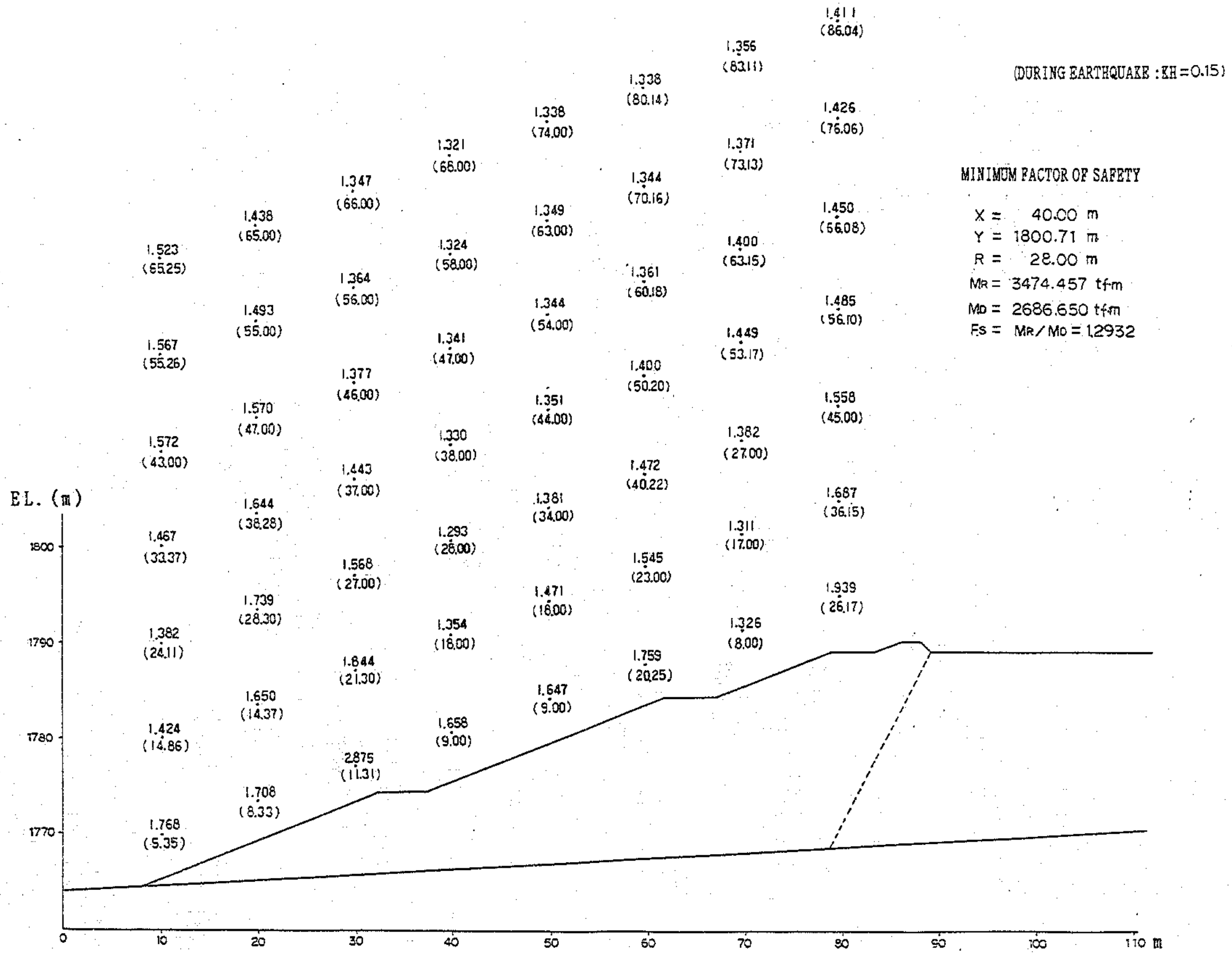


Fig. 4-9-5 A Result of Tailing Dam Stability Analysis (3)

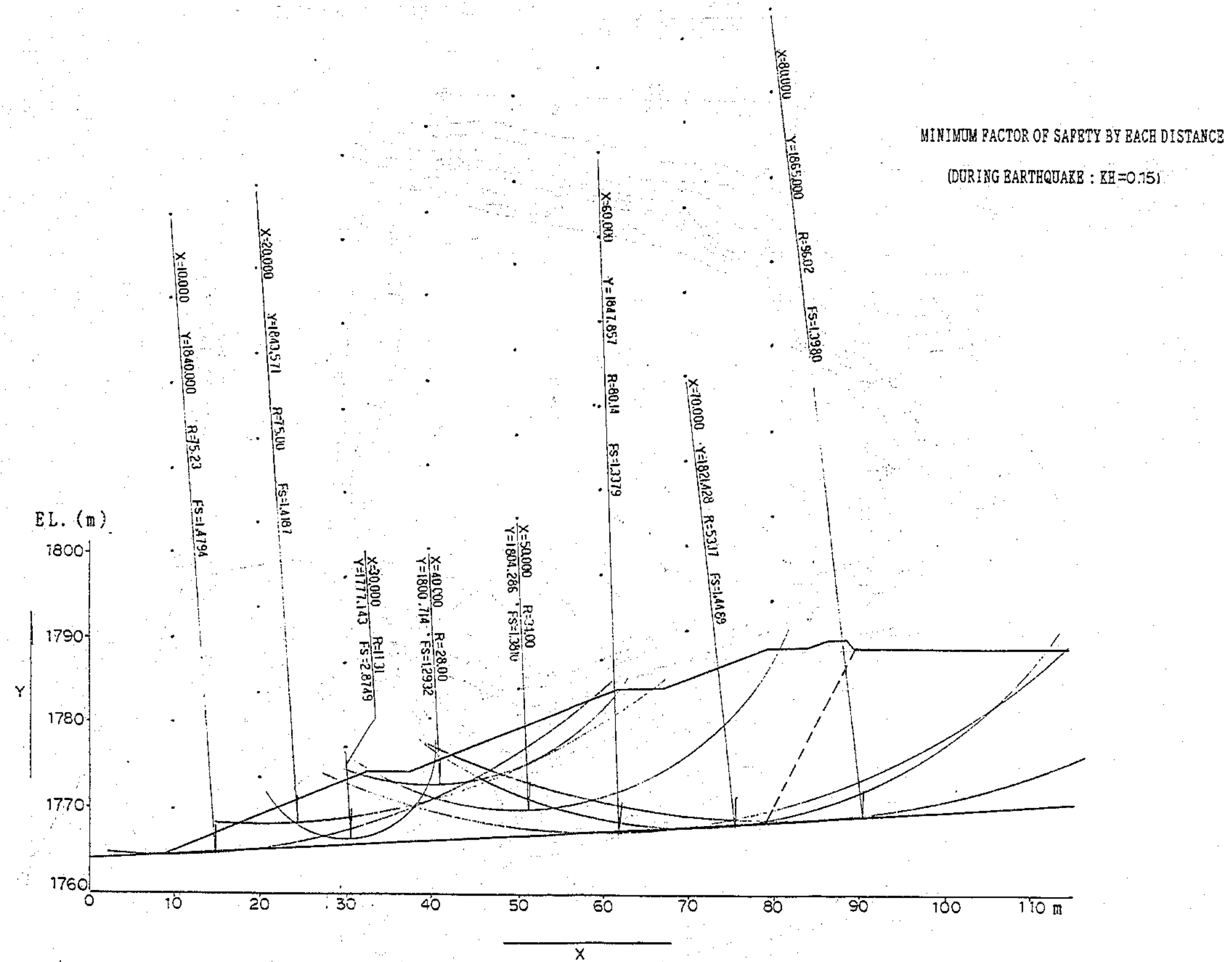


Fig. 4-9-6 A Result of Tailing Dam Stability Analysis (4)

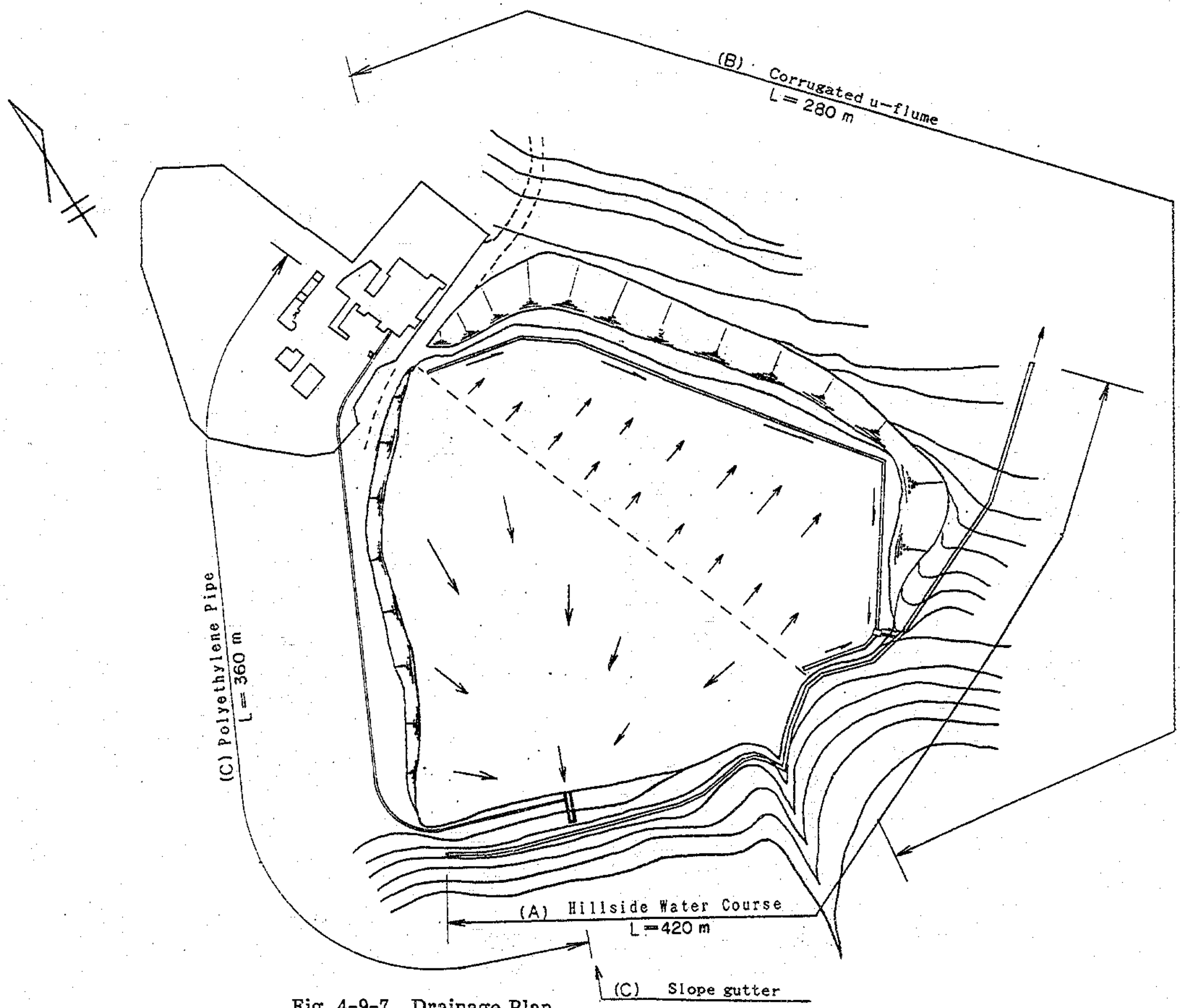
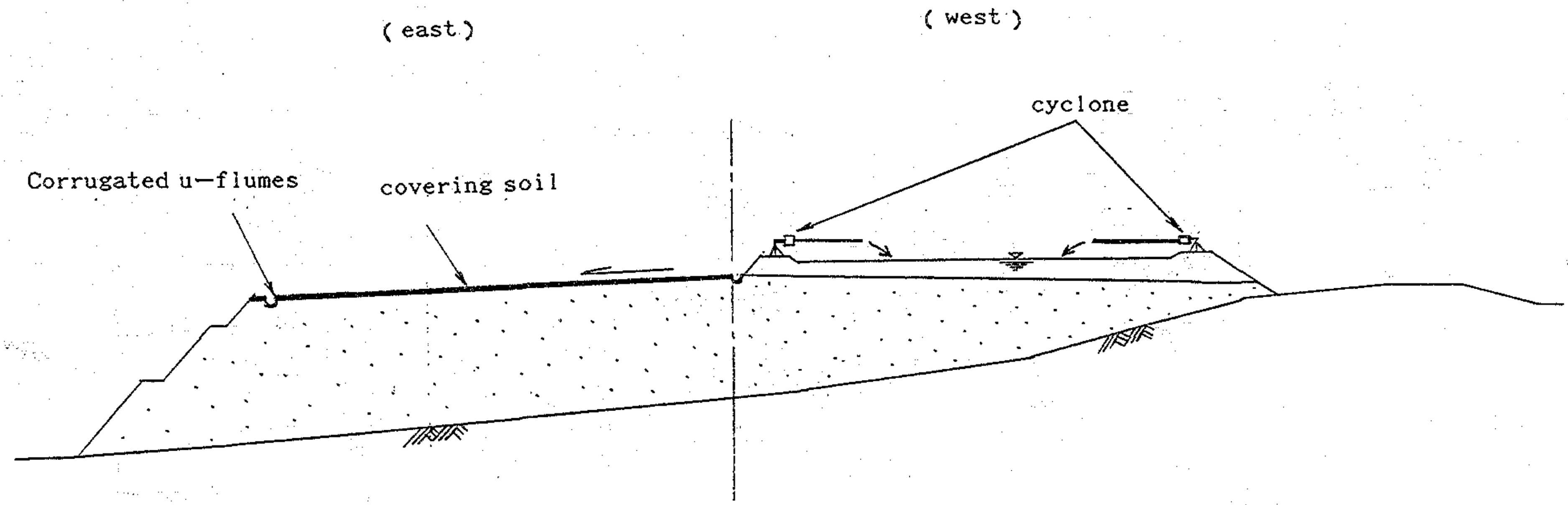


Fig. 4-9-7 Drainage Plan



method of accretion

Fig. 4-9-8 Drainage Section

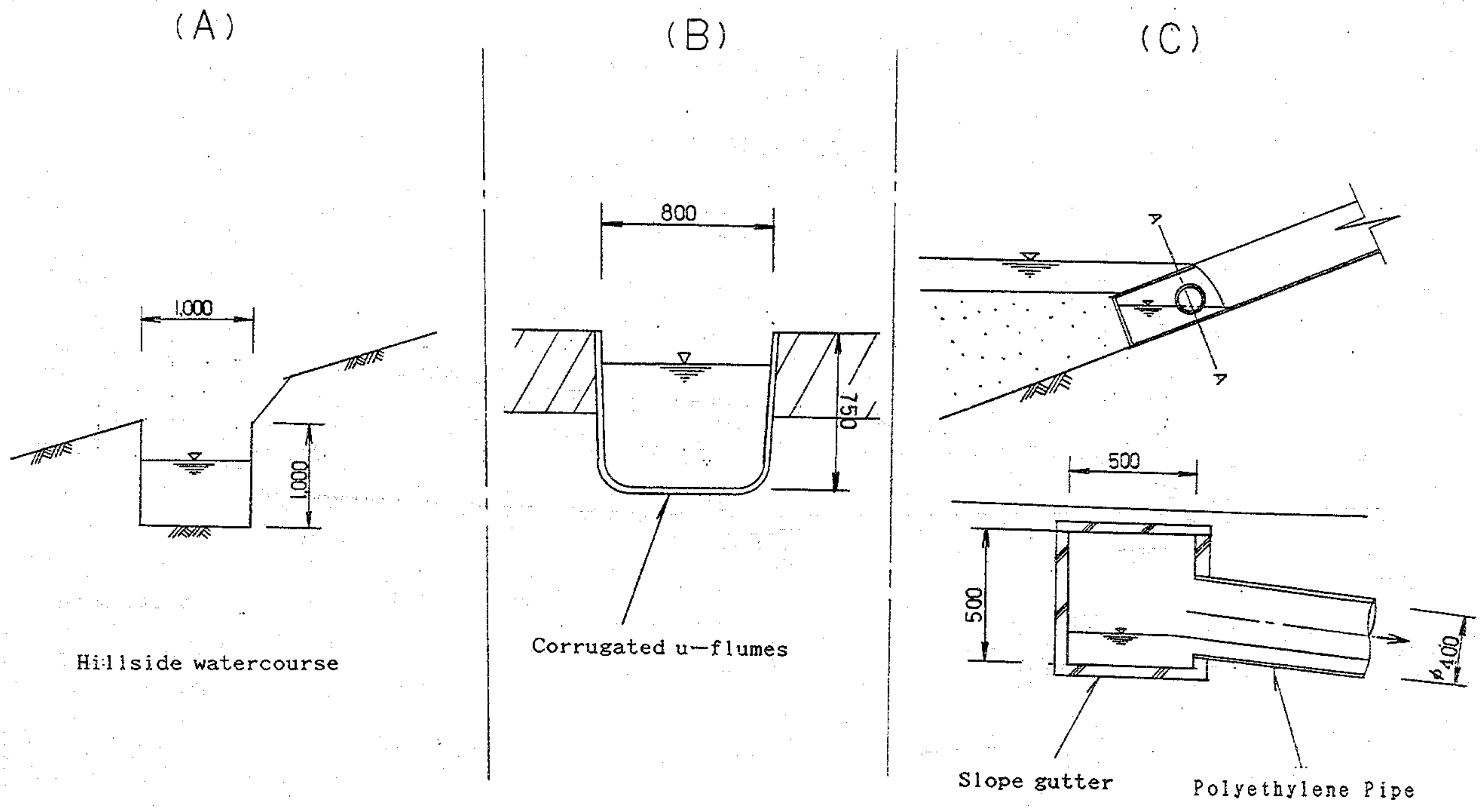


Fig. 4-9-9 Typical Cross Section of Drainage

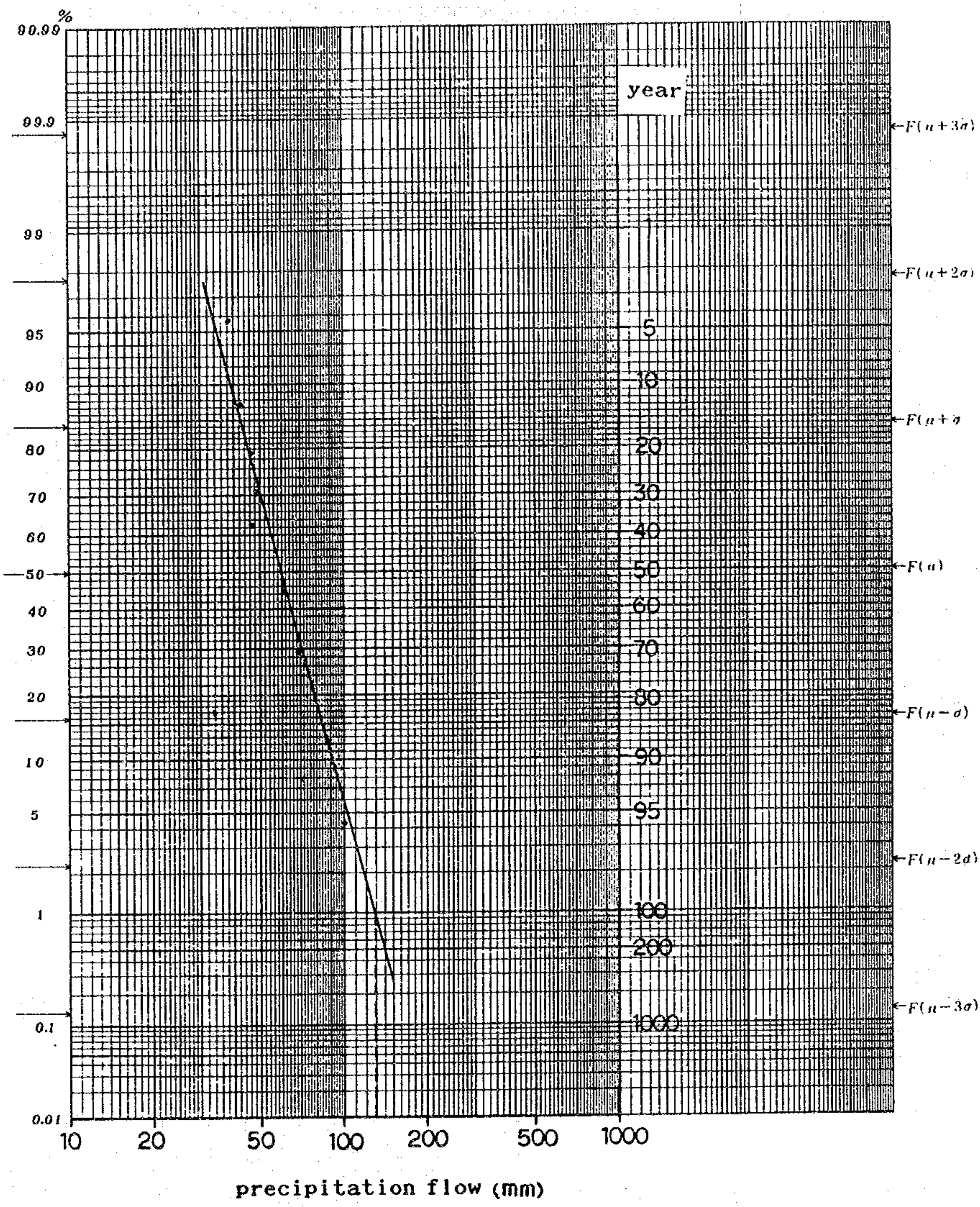


Fig. 4-9-10 Probability Precipitation

Table 4-4-1 Hydrologic Measurement of Surface Water (Parral)

Site	Season	Date	Section of Flow (m^2)	Velocity (m/sec)	Flow Rate (m^3/sec)	Daily Flow (m^3/day)
No. 1	Dry	11, Mar.	0	0	0	0
	Rainy	30, Aug.	0	0	0	0
No. 2	Dry	11, Mar.	0.0305	0.1777	0.542×10^{-2}	468.3
	Rainy	30, Aug.	0.014	0.2754	0.386×10^{-2}	333.1
No. 3	Dry	11, Mar.	0.1875	0.0983	1.843×10^{-2}	1,592.4
	Rainy	30, Aug.	11.182	1.3077	14.623	1.263×10^{6}
No. 4	Dry	11, Mar.	0.0785	0.2143	1.682×10^{-2}	1,453.2
	Rainy	30, Aug.	14.380	1.5829	22.763	1.967×10^{6}
No. 5	Dry	11, Mar.	0.0265	0.4132	1.095×10^{-2}	946.1
	Rainy	30, Aug.	17.0575	1.5071	25.707	2.221×10^{6}

Table 4-4-2 Background and Water Supply Ceiling of Chemical Components in Water

(ppm)

Background Value	Cu	Pb	Zn	Fe	Cd	Total Cr	As	Hg	Cr^{6+}	CN
Fresh Water	0.003	0.003	0.020	0.1	0.032×10^{-3}	0.001	0.002	0.07×10^{-3}	0.001	0
Water Supply Ceiling	1	0.05	5	0.3	0.01	0.05	0.05	0.002	0.05	0

after Rose, W., Hawkes, H. E., and Webb, J. S. (1979): Geochemistry in Mineral Exploration

Water Supply Ceiling is by U. S. Enviromental Protection Agency (1977)

Table 4-4-3 Chemical Analysis of Surface Water (El Bote)

Site	Season	Date	Cu (ppm)	Pb (ppm)	Zn (ppm)	Fe (ppm)	Cd (ppm)	Total Cr (ppm)	As (ppm)	Hg (ppm)	Cr^{6+} (ppm)	CN (ppm)	pH
P-R1	Dry	11, Mar.	0.10	1.1	2.2	43	0.009	0.003	0.36	0.002	n.d.	0.1	8.40
	Rainy	30, Aug.	0.30	0.15	0.11	0.47	0.001	0.013	1.0	0.0009	n.d.	0.1	9.23
P-R2	Dry	11, Mar.	5.0	0.14	1.2	1.4	0.006	0.10	0.04	n.d.	0.04	4.2	8.20
	Rainy	30, Aug.	0.29	0.30	0.20	1.2	0.003	0.022	0.13	n.d.	n.d.	n.d.	9.00
P-R3	Dry	11, Mar.	n.d.	n.d.	n.d.	0.18	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	8.42
	Rainy	30, Aug.	0.017	0.085	0.080	0.84	0.004	0.025	0.028	0.0043	n.d.	n.d.	7.80
P-R4	Dry	11, Mar.	4.9	0.07	0.86	0.07	0.01	0.08	n.d.	n.d.	0.045	3.9	8.37
	Rainy	30, Aug.	0.023	0.053	0.085	1.3	0.002	0.030	0.025	0.0012	n.d.	n.d.	7.92
P-R5	Dry	11, Mar.	0.03	0.23	0.08	1.2	0.004	0.008	0.03	n.d.	n.d.	n.d.	8.48
	Rainy	30, Aug.	0.017	0.040	0.091	0.89	0.002	0.035	0.023	0.0008	n.d.	n.d.	7.93
P-R6	Rainy	30, Aug.	0.020	0.047	0.085	0.95	0.001	0.043	0.022	0.0007	n.d.	n.d.	7.97
P-R7	Rainy	30, Aug.	0.022	0.048	0.057	0.84	0.002	0.051	0.021	0.0004	n.d.	n.d.	7.87
P-D1	Dry	11, Mar.	16	0.47	0.16	0.12	0.009	0.06	0.004	0.0003	n.d.	10	8.90
	Rainy	30, Aug.	43	0.44	25	0.72	0.10	0.059	n.d.	0.0077	n.d.	150	11.05
P-W1	Rainy	31, Aug.	40	0.37	33	0.88	0.058	0.056	n.d.	0.0004	n.d.	120	11.50

Electric Conductivity (μs/cm) is:
P-R1(Dry)=82, P-R1(Rainy)=95, P-R2(Dry)=85, P-R2(Rainy)=90,
P-R3(Dry)=43, P-R3(Rainy)=45, P-R4(Dry)=43, P-R4(Rainy)=45,
P-R5(Dry)=43, P-R5(Rainy)=45, P-R6(Rainy)=45, P-R7(Rainy)=44,
P-D1(Dry)=120, P-D1(Rainy)=155, P-W1(Rainy)=160

R: River, D: Tailing Dam, W: Waste Water

Table 4-4-4 Micro Flow Measurement Data (Parral B-1)

Depth (m)	Time (sec)	Impellor Count	Flow Direction	Velocity (cm/sec)
3.38	60	0	Up-flow	0.40
4.38	60	0	Up-flow	0.40
5.38	60	8	Up-flow	1.34
6.38	60	6	Up-flow	1.11
7.38	60	11	Up-flow	1.70
8.38	60	9	Up-flow	1.46

DATE 29 AUG 1991
TIME 05:02:32 PM
HOLE No. =B-1
WATER LEVEL=2.38m
DEPTH=10m

Depth (m)	Time (sec)	Impellor Count	Flow Direction	Velocity (cm/sec)
3.37	60	0	Up-flow	0.40
4.37	60	2	Up-flow	0.63
5.37	60	4	Up-flow	0.87
6.37	60	7	Up-flow	1.22
7.37	60	1	Up-flow	0.51
8.37	60	0	Up-flow	0.40

DATE 02 SEP 1991
TIME 03:42:53 PM
HOLE No. =B-1
WATER LEVEL=2.37m
DEPTH=10m

Table 4-4-4 Micro Flow Measurement Data (Parral B-2)

Depth (m)	Time (sec)	Impellor Count	Flow Direction	Velocity (cm/sec)
10.46	60	0	Up-flow	0.40
11.46	60	0	Up-flow	0.40
12.46	60	0	Up-flow	0.40
13.46	60	15	Up-flow	2.17
14.46	60	7	Up-flow	1.22

DATE 29 AUG 1991
TIME 05:55:37 PM
HOLE No. =B-2
WATER LEVEL=9.46m
DEPTH=20m

Depth (m)	Time (sec)	Impellor Count	Flow Direction	Velocity (cm/sec)
10.94	60	1	Up-flow	0.51
11.94	60	2	Up-flow	0.63
12.94	60	0	Up-flow	0.40
13.94	60	1	Up-flow	0.51
14.94	60	3	Up-flow	0.75

DATE 02 SEP 1991
TIME 04:36:48 PM
HOLE No. =B-2
WATER LEVEL=9.94m
DEPTH=20m

Table 4-4-4 Micro Flow Measurement Data (Parral B-3)

Depth (m)	Time (sec)	Impellor Count	Flow Direction	Velocity (cm/sec)
5.58	60	34	Up-flow	4.42
6.58	60	26	Up-flow	3.47
7.58	60	20	Up-flow	2.76
8.58	60	22	Up-flow	3.00
9.58	60	14	Up-flow	2.05
10.58	60	7	Up-flow	1.22
11.58	60	17	Up-flow	2.41
12.58	60	22	Up-flow	3.00
13.58	60	7	Up-flow	1.22
14.58	60	10	Up-flow	1.58
15.58	60	9	Up-flow	1.46
16.58	60	0	Up-flow	0.40
17.58	60	0	Up-flow	0.40
18.58	60	0	Up-flow	0.40
19.58	60	0	Up-flow	0.40
20.58	60	0	Up-flow	0.40
21.58	60	0	Up-flow	0.40
22.58	60	0	Up-flow	0.40
23.58	60	0	Up-flow	0.40
24.58	60	0	Up-flow	0.40
25.58	60	0	Up-flow	0.40
26.58	60	0	Up-flow	0.40
27.58	60	0	Up-flow	0.40
28.58	60	0	Up-flow	0.40
29.58	60	0	Up-flow	0.40
30.58	60	0	Up-flow	0.40
31.58	60	0	Up-flow	0.40
32.58	60	0	Up-flow	0.40
33.58	60	0	Up-flow	0.40
34.58	60	0	Up-flow	0.40
35.58	60	0	Up-flow	0.40
36.58	60	0	Up-flow	0.40
37.58	60	0	Up-flow	0.40
38.58	60	0	Up-flow	0.40
39.58	60	0	Up-flow	0.40

DATE 29 AUG 91
TIME 11:58:11 AM
HOLE No. =B-3
WATER LEVEL=4.58m
DEPTH=40m

Table 4-4-4 Micro Flow Measurement Data (Parral B-3)

Depth (m)	Time (sec)	Impellor Count	Flow Direction	Velocity (cm/sec)
5.36	60	39	Up-flow	5.01
6.36	60	39	Up-flow	5.01
7.36	60	23	Up-flow	3.12
8.36	60	35	Up-flow	4.54
9.36	60	38	Up-flow	4.89
10.36	60	30	Up-flow	3.95
11.36	60	34	Up-flow	4.42
12.36	60	30	Up-flow	3.95
13.36	60	30	Up-flow	3.95
14.36	60	30	Up-flow	3.95
15.36	60	35	Up-flow	4.54
16.36	60	32	Up-flow	4.18
17.36	60	39	Up-flow	5.01
18.36	60	37	Up-flow	4.77
19.36	60	21	Up-flow	2.88
20.36	60	12	Up-flow	1.82
21.36	60	26	Up-flow	3.47
22.36	60	29	Up-flow	3.83
23.36	60	19	Up-flow	2.64
24.36	60	32	Up-flow	4.18
25.36	60	45	Up-flow	5.72
26.36	60	29	Up-flow	3.83
27.36	60	15	Up-flow	2.17
28.36	60	18	Up-flow	2.53
29.36	60	0	Up-flow	0.40
30.36	60	23	Up-flow	3.12
31.36	60	14	Up-flow	2.05
32.36	60	0	Up-flow	0.40
33.36	60	0	Up-flow	0.40
34.36	60	1	Up-flow	0.51
35.36	60	0	Up-flow	0.40
36.36	60	0	Up-flow	0.40
37.36	60	0	Up-flow	0.40
38.36	60	0	Up-flow	0.40
39.36	60	0	Up-flow	0.40

DATE 02 SEP 91
TIME 01:46:30 PM
HOLE No.=B-3
WATER LEVEL=4.36m
DEPTH=40m

Table 4-4-4 Micro Flow Measurement Data (Parral B-4)

Depth (m)	Time (sec)	Impellor Count	Flow Direction	Velocity (cm/sec)
6.24	60	0	Up-flow	0.40
7.24	60	0	Up-flow	0.40
8.24	60	0	Up-flow	0.40
9.24	60	16	Up-flow	2.29
10.24	60	0	Up-flow	0.40
11.24	60	0	Up-flow	0.40
12.24	60	0	Up-flow	0.40

DATE 29 AUG 1991
TIME 04:24:53 PM
HOLE No.=B-4
WATER LEVEL=5.24m
DEPTH=15m

Depth (m)	Time (sec)	Impellor Count	Flow Direction	Velocity (cm/sec)
6.44	60	0	Up-flow	0.40
7.44	60	1	Up-flow	0.51
8.44	60	5	Up-flow	0.99
9.44	60	0	Up-flow	0.40
10.44	60	0	Up-flow	0.40
11.44	60	0	Up-flow	0.40

DATE 02 SEP 1991
TIME 03:13:10 PM
HOLE No.=B-4
WATER LEVEL=5.44m
DEPTH=15m

Table 4-4-5 Characteristic of Aquifer (Parral)

Site	Season	Date	Elevation (m)	Thickness of Aquifer	Flow Rate (m/sec)	Flow in Bore Hole(m^3/day)	Width of Aquifer	Total Flow (m^3/day)
B-1	Dry	9, Mar.	1,727 to 1,731	4m	0.0040	69.1	–	–
	Rainy	29, Aug.			0.0120	207.4		
		2, Sep.			0.0073	126.1		
B-2	Rainy	29, Aug.	1,732 to 1,735	3m	0.0070	220.3	–	–
		2, Sep.			0.0055	71.3		
B-3	Dry	9, Mar.	1,712 to 1,742	14m	0.0103	622.9	150m	$1.869x10^6$
	Rainy	29, Aug.		10m	0.0191	825.1		$2.475x10^6$
		2, Sep.		30m	0.0298	3,862.1		$11.586x10^6$
	Rainy	29, Aug.	1,742 to 1,745	3m	0.0395	511.9		$1.536x10^6$
		2, Sep.			0.0438	567.6		$1.703x10^6$
B-4	Rainy	29, Aug.	1,744 to 1,745	1m	0.0135	58.3	250m	$0.175x10^6$
		2, Sep.			0.0070	30.2		$0.091x10^6$

Table 4-4-6 Chemical Analysis of Groundwater (Parral)

Site	Season	Date	Cu (ppm)	Pb (ppm)	Zn (ppm)	Fe (ppm)	Cd (ppm)	Total Cr (ppm)	As (ppm)	Hg (ppm)	Cr^{6+} (ppm)	CN (ppm)	pH
P-B1	Dry	11, Mar.	0.06	0.50	0.52	28	0.006	0.02	0.04	0.0003	n.d.	n.d.	7.45
	Rainy	29, Aug.	0.014	0.063	0.13	0.52	0.003	n.d.	0.0011	0.0031	n.d.	n.d.	7.34
P-B2	Rainy	29, Aug.	0.010	0.051	0.13	0.73	0.003	0.010	0.0003	0.0009	n.d.	n.d.	7.46
P-B3	Dry	11, Mar.	0.04	0.54	4.3	1.7	0.009	0.009	0.005	n.d.	n.d.	n.d.	4.35
	Rainy	29, Aug.	0.020	0.12	35	0.79	0.088	0.019	n.d.	n.d.	n.d.	n.d.	6.70
P-B4	Rainy	29, Aug.	0.056	0.13	0.15	3.4	0.007	0.033	0.013	0.0003	n.d.	n.d.	8.83
P-M1	Rainy	30, Aug.	0.033	0.11	0.067	0.35	0.007	0.035	0.003	0.001	n.d.	n.d.	7.28
P-M2	Rainy	31, Aug.	0.033	0.11	0.055	0.39	0.007	0.041	0.001	0.0058	n.d.	n.d.	7.69
P-M3	Rainy	31, Aug.	0.049	0.17	15	0.44	0.074	0.046	n.d.	0.0049	n.d.	n.d.	4.83

Electric Condectivity (μs/cm) is:
P-B1(Dry)=38, P-B1(Rainy)=37, P-B2(Rainy)=38, P-B3(Dry)=135,
P-B3(Rainy)=54, P-B4(Rainy)=41, P-M1(Rainy)=47, P-M2(Rainy)=46,
P-M3(Rainy)=150

B:Drilling Hole, M:Interior of Mine

Table 4-4-7 Permeability Coefficient Data

(Parral)

Sample Number	PR-1	PR-2	PR-3	PR-4	PR-5	PR-6	PR-7
D 10(mm)	0.0056	0.0010	0.0007	0.0050	0.0040	0.0028	0.0005
D 60(mm)	0.1600	0.1000	0.2600	5.5000	0.1380	0.0460	0.1600
Uniformity Coeffcient	28.6	100.0	371.4	1100.0	34.5	16.4	320.0
K (cm/sec) by Hazen's Formula	4.18E-05	1.33E-06	6.54E-07	3.34E-05	2.13E-05	1.05E-05	3.34E-07

K:Permeability Coefficient(cm/sec)

D10(mm):Particle-size(mm) on 10% Cumulative Curve = Effecitve Size(de)

Table 4-4-8 Permeability and Porosity Model

Legend No.	Matrix Permeabilty pkm(cm/sec)	Fracture Permeability pkf(cm/sec)	Fracture Zone Width hef(m)	Matrix Porosity porm(%)	Fracture Porosity porf(%)
1 (Vein)	10^{-8}	0	0	100	30
2 (Aquifer)	10^{-6}	10^{-3}	25	15	30
3 (Aquitard)	10^{-6}	10^{-8}	12	15	30
5 (Aquiclude)	10^{-5}	10^{-3}	6	15	30
7 (Aquifuge)	10^{-7}	10^{-3}	0	5	30

Model's Block Permeability(K) = $(hef/\triangle x)\times pkf+(1-hef/\triangle x)\times pkm$

$\triangle x$ = block width(m)

Table 4-5-1 Chemical Analysis of Soil

(Parral) (ppm)

No.	Cu	Pb	Zn	Fe(wt%)	Cd	Sb	Cr	As	Hg
PS-1	27	67	110	3.0	2.8	79	25	20	0.12
PS-2	19	74	85	3.0	2.8	100	26	25	0.07
PS-3	13	86	140	3.2	2.5	70	12	30	0.15
PS-4	13	89	110	3.4	3.1	100	10	72	0.19
PS-5	19	110	270	4.7	4.1	80	13	300	0.33
PS-6	18	90	140	3.0	2.4	54	12	34	0.28
PS-7	16	100	160	2.5	2.5	50	12	35	0.09
PS-8	19	50	92	2.4	1.9	73	24	14	0.08
PS-9	26	140	170	2.4	2.5	71	24	40	1.00
PS-10	35	260	770	3.6	5.2	100	29	70	0.27
PS-11	18	110	140	4.1	2.7	55	8	55	0.20
PS-12	20	110	190	1.9	2.1	44	21	48	0.24
PS-B1	20	51	99	3.5	3.5	37	18	35	0.98
PS-B2	170	8,300	14,000	5.9	110.0	55	45	6,000	3.80
PS-B3	160	1,500	220	6.8	5.8	20	9	1,000	1.00
PS-B4	130	1,300	1,400	4.4	10.0	38	16	120	0.43
PS-B5	21	40	99	3.0	2.6	22	8	17	0.66
PS-B6	16	41	100	2.1	3.4	33	17	11	0.48
PS-B7	80	800	1,500	3.1	11.0	48	22	52	1.40
PS-B8	16	77	120	3.2	3.1	37	10	22	1.10
PS-B9	200	1,200	3,000	3.4	24.0	37	6	150	1.30
PS-B10	16	130	130	2.4	2.7	28	15	13	1.80

(Background in Soil) (ppm)

Elemnts	Cu	Pb	Zn	Fe(wt%)	Cd	Sb	Cr	As	Hg
Background	15	17	36	2.1	0.5	2	43	7.5	0.056

by Rose, A.T. et al. (1979): Geochemistry in Mineral Exploration, Academic Press, 657P.

Table 4-5-2 Chemical Analysis of Solution Extracted from the Soil Samples

(ppm)

NO.	Cu	Pb	Zn	Cd	Fe	Sb	Cr	As	Hg	CN	pH
PS-B1	n. d.	0. 83	2. 1	n. d	3. 0	n. d	n. d	2. 9	0. 023	n. d	1. 31
PS-B2	n. d.	4, 300	1, 000	8. 4	1. 6	0. 14	n. d	2, 700	0. 099	9. 6	1. 58
PS-B3	41	29	93	0. 29	100	3. 2	0. 36	69	0. 016	0. 14	4. 61
PS-B4	3	320	140	2. 0	2. 6	6. 26	n. d	39	0. 008	n. d	1. 32
PS-B5	n. d.	2. 0	2. 3	n. d	11	n. d	n. d	6. 2	0. 069	n. d	2. 92
PS-B6	n. d.	4. 3	1. 3	n. d	1. 6	n. d	n. d	5. 1	0. 042	n. d	2. 45
PS-B7	61	170	78	1. 3	5. 0	n. d	n. d	25	0. 012	n. d	1. 21
PS-B8	n. d.	4. 9	4. 5	n. d	6. 2	n. d	n. d	5. 0	0. 003	n. d	1. 44
PS-B9	17	370	730	9. 4	12	n. d	n. d	17	0. 007	n. d	1. 50
PS-B10	n. d.	17	1. 6	n. d	1. 3	n. d	n. d	6. 1	0. 029	n. d	3. 80

n. d. : Not Detected

Table 4-6-1 Soil Test Quantity

Dry Season		Rainy Season	
No.	Depth(m)	No.	Rainy(m)
BD-1	0.0- 0.3	BD-3	3.0- 3.6
	5.0- 5.6		7.0- 7.6
	10.0-10.6		10.0-10.6
BD-2	0.0- 0.5		14.0-14.6
	3.0- 3.6		16.0-16.6
	6.0- 6.6	S-1	1.0- 1.5
	9.0- 9.6	S-2	1.0- 1.5
D-1	0.8- 1.0		
	1.5- 1.7		
D-2	0.8- 1.0		
	1.5- 1.7		
D-3	0.8- 1.0		
	1.5- 1.7		
D-4	0.8- 1.0		
	1.5- 1.7		
D-5	0.8- 1.0		
	1.5- 1.7		
D-6	1.0- 1.2		
Total	18 samples	Total	7 samples

Table 4-6-2 Soil Test Data

(Dry Season)

Sample No.	BD-1			BD-2				D-1	
Depth (m)	0.0~0.3	5.0~5.6	10.0~10.6	0.0~0.5	3.0~3.6	6.0~6.6	9.0~9.6	0.8~1.0	1.5~1.7
Water Content (%)	9.1	8.7	6.8	6.8	9.1	9.2	8.5	38.8	30.5
Specific Gravity	2.66	2.59	2.61	2.64	2.57	2.63	2.67	2.60	2.63
Wet Density (g/cm3)	1.675	1.573	1.594	1.730	1.557	1.652	1.593	1.990	1.853
Liquid Limit (%)	29.7	50.0	34.2	30.5	29.7	35.2	45.3	45.0	53.0
Plastic Limit (%)	16.6	23.0	16.8	18.1	16.6	18.2	22.4	25.0	26.0
Angle of Internal Fliction (°)	35.5	33.8	34.2	33.6	34.4	32.0	30.5	26.0	23.5
Cohesion (tf/m2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	1.5
Coefficient of Permeability (cm/sec)	4.74 $\times 10^{-4}$	5.95 $\times 10^{-3}$	6.45 $\times 10^{-4}$	2.53 $\times 10^{-3}$	9.68 $\times 10^{-4}$	2.15 $\times 10^{-3}$	1.69 $\times 10^{-3}$	2.23 $\times 10^{-5}$	2.02 $\times 10^{-4}$

(Dry Season)

Sample No.	D-2		D-3		D-4		D-5		D-6
Depth (m)	0.8~1.0	1.5~1.7	0.8~1.0	1.5~1.7	0.8~1.0	1.5~1.7	0.8~1.0	1.5~1.7	1.0~1.2
Water Content (%)	41.7	37.0	37.9	35.8	22.7	21.5	23.3	20.8	15.5
Specific Gravity	2.60	2.58	2.61	2.59	2.62	2.62	2.65	2.63	2.55
Wet Density (g/cm3)	1.869	1.832	1.984	1.836	1.575	1.623	1.591	1.600	1.615
Liquid Limit (%)	29.6	35.8	30.2	27.7	25.6	33.5	28.5	28.8	42.6
Plastic Limit (%)	19.1	25.0	22.3	19.5	18.2	23.5	20.2	17.6	18.5
Angle of Internal Fliction (°)	27.0	24.5	22.0	23.5	23.0	21.0	22.5	19.5	17.0
Cohesion (tf/m2)	1.0	0.7	0.5	0.5	1.3	1.2	1.4	1.0	6.8
Coefficient of Permeability (cm/sec)	9.14 $\times 10^{-4}$	8.48 $\times 10^{-4}$	4.39 $\times 10^{-4}$	4.17 $\times 10^{-5}$	4.37 $\times 10^{-5}$	2.10 $\times 10^{-4}$	1.05 $\times 10^{-4}$	2.15 $\times 10^{-4}$	4.18 $\times 10^{-6}$

(Rainy Season)

Sample No.	BD-3					S-1	S-2
Depth (m)	3.0~3.6	7.0~7.6	10.0~10.6	14.0~14.6	16.0~16.6	1.0~1.2	1.0~1.2
Water Content (%)	5.5	5.7	7.8	11.2	9.3	26.7	29.9
Specific Gravity	2.66	2.60	2.61	2.61	2.67	2.57	2.67
Wet Density (g/cm3)	1.930	1.895	1.903	1.910	1.912	1.701	1.677
Liquid Limit (%)	19.0	21.3	19.0	17.2	20.0	36.0	40.0
Plastic Limit (%)	N.P.	N.P.	N.P.	N.P.	N.P.	21.6	23.4
Angle of Internal Fliction (°)	31.0	27.0	29.5	32.5	32.5	23.8	24.2
Cohesion (tf/m2)	0.0	0.0	0.0	0.6	0.0	2.0	1.0
Coefficient of Permeability (cm/sec)	5.76 $\times 10^{-3}$	7.89 $\times 10^{-3}$	3.75 $\times 10^{-3}$	3.27 $\times 10^{-3}$	4.63 $\times 10^{-3}$	0.75 $\times 10^{-3}$	1.11 $\times 10^{-3}$

Table 4-6-3 Natural Moisture Content and Wet Density

	Tailing Dam	Deposits
Natural Water Content (W) Wet Density(ρ_t)	7.9% 1.910g/cm³	28.3% 1.689g/cm³

Table 4-6-4 Consistency Data of Soil

	Tailing Dam	Deposits
Liquid Limit (L.L) Plastic Limit (P.L) Natural Water Content (W)	19.3 % N.P 7.5 %	38.0 % 22.5 % 28.4 %

Table 4-6-5 A Result of Tailing Dam Stability Analysis

Element		Ordinary Condition (Kh=0.00)	Earthquake Condition (Kh=0.15)
Center of Circular Arc	X(m)	25.00	25.00
	Y(m)	1785.00	1785.00
Radius R(m)		12.00	11.00
Resisting Moment MR(tf・m)		1562.197	1139.282
Sliding Moment MD(tf・m)		1817.977	1625.844
Safety Factor Fs=MR/MD		0.8593	0.7007

Table 4-7-1 Wind Speed Data

(Parral in Rainy Season) (m/sec)

Time	8/4	8/5	8/6	8/7	8/8	8/9	8/10	8/11	8/12	8/13	8/14	8/15	8/16	8/17	8/18	8/19
0 h	1.0	3.5	3.5	4.0	1.5	0.0	3.5	1.0	4.5	3.0	4.0	2.5	2.5	3.5	2.5	0.0
1	1.0	5.0	3.5	2.5	1.0	1.0	1.0	3.0	1.0	3.0	4.5	2.5	1.0	1.5	3.0	6.0
2	1.0	5.5	3.5	1.0	1.5	1.5	3.0	0.5	0.5	3.0	4.5	3.5	4.5	2.0	3.0	0.5
3	1.0	4.0	2.5	0.0	1.5	0.0	3.0	2.5	2.0	2.0	5.5	4.0	0.0	0.5	2.0	4.5
4	1.0	1.0	1.0	1.0	0.5	1.0	1.5	2.5	0.5	3.5	5.5	3.5	1.5	1.5	4.5	3.0
5	1.0	1.0	2.0	0.0	1.0	0.0	0.0	1.5	1.0	3.0	2.0	3.5	0.0	3.0	2.5	4.5
6	1.0	1.0	2.0	2.0	1.0	1.0	0.0	0.5	1.0	1.5	4.0	4.0	1.0	2.5	3.5	3.0
7	1.0	1.0	1.0	2.0	0.5	0.0	0.0	0.5	2.0	1.5	4.0	3.5	3.0	3.0	4.5	2.5
8	1.0	2.0	1.5	1.5	0.0	0.0	1.0	1.5	2.5	3.0	3.5	3.0	0.0	1.5	3.5	3.0
9	1.0	1.0	2.5	0.5	2.5	1.0	1.0	2.5	2.0	1.0	2.5	2.0	2.0	3.5	2.5	2.5
10	0.5	1.5	1.0	1.0	2.0	1.5	0.5	0.5	2.5	1.0	0.0	0.0	1.5	2.5	4.0	1.0
11	1.5	2.5	1.0	2.5	2.5	1.5	1.5	0.0	2.0	1.0	1.0	1.0	1.0	2.5	3.5	1.0
12	1.5	2.5	1.5	1.0	3.0	2.5	3.0	1.5	2.0	1.5	3.5	2.5	1.0	3.0	2.5	1.5
13	2.0	1.0	1.5	0.5	1.5	3.5	3.0	1.0	3.0	1.5	3.5	1.0	1.5	2.5	2.5	2.5
14	2.0	2.5	2.0	2.0	2.5	5.0	1.5	1.0	2.0	2.5	2.5	1.5	1.0	2.5	2.5	2.5
15	3.0	2.5	2.5	2.5	6.0	3.5	4.5	1.5	3.0	2.0	2.5	2.0	2.0	2.0	2.5	2.5
16	2.0	2.5	2.5	3.5	2.5	2.5	3.0	1.0	1.5	3.0	2.5	3.5	3.0	2.5	2.0	1.5
17	3.5	4.5	2.5	3.5	1.0	2.5	1.0	3.5	2.5	2.5	2.0	3.5	2.0	2.5	2.0	3.5
18	8.5	3.5	4.5	5.0	1.0	3.0	1.5	1.5	3.5	2.5	2.5	3.0	2.0	2.5	2.0	2.5
19	6.0	6.5	1.0	3.5	1.0	1.5	1.0	1.5	2.5	6.5	2.5	3.0	2.5	1.0	0.5	2.5
20	7.5	3.5	2.5	5.0	0.0	2.5	1.0	1.0	0.5	6.0	1.0	1.0	2.5	0.5	1.0	2.5
21	6.0	0.0	1.5	5.5	1.0	0.0	1.0	2.5	5.0	5.0	0.0	0.0	1.0	2.5	1.5	2.0
22	1.0	4.5	2.5	1.0	1.0	1.5	0.5	3.0	5.0	1.5	0.0	1.0	3.5	2.0	2.0	1.0
23	0.0	2.5	1.5	1.0	1.0	1.0	1.0	5.0	2.5	4.0	1.5	1.0	3.0	3.0	1.0	2.0
Total	55.0	65.0	51.0	52.0	37.0	37.5	38.0	40.5	54.5	65.0	65.0	56.0	43.0	54.0	61.0	58.0
Count	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Mean	2.3	2.7	2.1	2.2	1.5	1.6	1.6	1.7	2.3	2.7	2.7	2.3	1.8	2.3	2.5	2.4
Max	8.5	6.5	4.5	5.5	6.0	5.0	4.5	5.0	5.0	6.5	5.5	4.0	4.5	3.5	4.5	6.0
Min	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0	0.0	0.0	0.0	0.5	0.5	0.0

Time	8/20	8/21	8/22	8/23	8/24	8/25	8/26	8/27	8/28	8/29	8/30	8/31	9/1	9/2	Total	Velocity
0 h	2.5	0.5	1.5	3.0	1.0	2.5	2.5	2.5	0.5	2.5	2.5	3.5	3.5	2.5	71.5	2.4
1	2.5	1.0	2.5	4.0	1.0	4.5	1.5	2.5	0.5	2.5	4.0	3.0	2.5	2.5	75.0	2.5
2	0.5	0.5	1.0	2.0	3.0	3.0	2.5	2.5	2.5	2.5	1.5	3.5	3.0	2.5	69.5	2.3
3	2.5	2.0	2.5	5.0	2.5	3.0	2.5	1.0	2.0	1.0	2.5	3.5	0.5	1.0	56.5	2.2
4	0.5	2.5	3.0	5.0	2.0	5.0	1.0	1.0	1.0	1.0	2.5	1.5	0.5	0.0	59.5	1.7
5	2.5	2.0	3.0	3.5	2.0	1.0	1.0	1.0	1.0	1.0	2.5	3.0	1.0	1.5	52.0	1.7
6	2.5	0.0	2.0	1.5	3.0	3.0	1.0	1.0	1.5	1.0	2.5	3.0	0.0	2.0	53.0	1.8
7	2.5	2.0	0.5	1.0	1.0	3.0	1.0	2.5	2.5	2.5	1.0	1.0	1.5	1.0	53.0	1.8
8	2.0	2.5	0.5	2.5	2.5	3.0	1.0	0.5	2.5	0.5	0.0	2.0	2.0	1.0	51.0	1.7
9	1.0	0.5	3.5	2.5	1.5	3.0	1.0	2.0	1.5	2.0	2.0	2.0	2.0	3.0	57.5	1.5
10	0.5	1.0	1.5	1.5	1.0	3.0	1.0	3.0	1.5	3.0	1.5	2.5	1.5	3.0	46.5	1.6
11	1.5	1.5	0.5	2.0	1.5	3.0	2.5	3.0	1.5	3.0	2.0	1.5	1.0	1.0	51.5	1.7
12	0.5	2.5	0.5	1.0	1.5	3.0	2.5	3.0	1.5	2.0	2.0	3.5	0.0	2.5	50.0	2.0
13	1.5	2.5	1.0	1.5	2.5	2.0	3.0	3.0	1.5	2.5	2.5	4.5	0.0	1.0	61.0	2.0
14	2.5	2.5	2.5	1.5	2.5	3.5	3.5	3.0	1.5	3.5	3.5	5.0	0.0	0.0	70.5	2.4
15	2.5	4.0	2.5	2.5	2.5	3.5	3.0	3.0	4.0	3.0	1.5	2.5	1.0	1.5	81.5	2.7
16	3.5	2.0	1.5	2.5	2.5	3.5	5.0	3.0	1.5	5.0	2.0	1.0	0.0	2.5	74.5	2.5
17	3.0	6.0	1.0	1.5	2.5	3.5	5.0	3.0	1.5	5.5	2.5	2.5	1.5	2.5	84.0	2.8
18	2.5	3.0	1.5	2.0	2.5	3.5	5.0	3.0	2.0	1.5	5.5	2.5	2.0	3.0	88.5	3.0
19	2.5	3.5	2.0	1.0	2.5	2.5	5.0	3.0	1.0	4.0	5.0	2.5	2.5	3.0	83.0	2.8
20	2.5	5.0	2.0	1.0	2.5	2.5	2.0	3.0	2.0	4.5	6.0	1.5	0.5	3.0	76.0	2.5
21	0.0	1.5	0.5	2.5	2.0	2.0	2.0	3.0	1.0	4.0	5.5	1.0	0.5	3.0	63.0	2.1
22	0.0	5.0	2.5	2.5	1.0	1.0	2.0	2.5	1.0	4.0	3.0	2.0	1.5	3.5	62.5	2.1
23	0.0	3.0	0.5	3.0	2.5	2.5	2.0	2.5	1.0	2.5	5.0	1.5	0.5	3.0	60.5	2.0
Total	42.0	56.5	40.0	56.0	49.0	70.0	58.5	57.5	38.0	64.5	58.5	60.0	29.0	49.5	1572	52.4
Count	24	24	24	24	24	24	24	24	24	24	24	24	24	24	720	24
Mean	1.8	2.4	1.7	2.3	2.0	2.9	2.4	2.4	1.6	2.7	2.9	2.5	1.2	2.1	65	2.2
Max	3.5	6.0	3.5	5.0	3.0	5.0	5.0	3.0	4.0	5.5	6.0	5.0	3.5	3.5	147	4.9
Min	0.0	0.0	0.5	1.0	1.0	1.0	1.0	0.5	0.5	0.5	0.0	1.0	0.0	0.0	11	0.5

Table 4-7-2 Wind Direction Data

(Parral in Rainy Season)

Direction	8/4	8/5	8/6	8/7	8/8	8/9	8/10	8/11	8/12	8/13	8/14	8/15	8/16	8/17	8/18	8/19
N	1	1	2	1	4	0	1	0	2	0	0	2	3	8	5	4
NW	0	2	2	0	0	0	0	0	2	0	0	0	0	0	0	1
W	13	7	7	7	1	3	7	13	5	14	10	13	9	10	12	8
SW	1	1	6	3	0	6	0	2	4	3	1	1	1	3	0	0
S	1	3	1	5	12	3	2	5	2	3	4	1	1	0	0	0
SE	2	3	1	0	1	0	0	2	1	4	2	0	3	0	0	0
E	3	5	4	5	5	5	11	1	8	0	4	2	3	1	5	7
NE	2	1	1	1	0	1	0	0	0	0	0	3	1	2	2	3
Count	23	23	24	22	23	18	21	23	24	24	21	22	21	24	24	23
Main Dir.	W	W	SW	W	S	SW	E	W	E	W	W	W	W	W	W	W

Direction	8/20	8/21	8/22	8/23	8/24	8/25	8/26	8/27	8/28	8/29	8/30	8/31	9/1	9/2	Total
N	1	0	0	1	0	0	2	2	0	1	4	3	2	1	51
NW	0	2	0	0	0	0	3	0	0	1	0	0	0	0	13
W	6	6	6	0	4	11	6	0	17	4	11	8	8	4	230
SW	5	5	4	16	7	1	2	4	0	8	4	7	4	10	109
S	2	2	3	0	1	2	2	0	1	0	0	0	2	2	60
SE	1	3	1	0	0	4	0	8	1	4	0	0	0	1	42
E	6	5	7	6	12	6	7	9	5	4	4	2	3	6	151
NE	0	0	2	1	0	0	2	1	0	2	1	4	5	0	35
Count	21	23	23	24	24	24	24	24	24	24	24	24	24	24	691
Main Dir.	W	W	W	SW	E	W	E	E	W	SW	W	SW	W	SW	W

Table 4-7-3 Dust Jar Measurement Data

Site	Start time	End time	Runnig time	Sample weight(g)	pH
D-1	8/2 11:00	9/ 3 09:30	766.5hr.	0.0178	7.12
D-2	8/2 13:30	8/31 15:00	697.5hr.	0.0285	6.48
D-3	8/3 09:30	8/31 15:20	677.8hr.	0.0252	6.36
D-4	8/3 10:15	8/31 15:40	677.4hr.	0.0252	6.90
D-5	8/3 12:00	9/ 2 08:40	716.6hr.	0.0497	6.57
D-6	8/3 12:40	9/ 3 10/30	720.8hr.	0.0232	6.80

Table 4-7-4 Condition of Low Volume Air Sampler

Site	Start time	End time	Running time	Absorption Ratio	Volume(l)
L1	8/ 2 11:00	8/ 5 11:00	72hr.	15 (l/min)	64,800
L2	8/ 8 15:00	8/10 15:00	48hr.	15 (l/min)	43,200
L3	8/12 10:00	8/14 10:00	48hr.	15 (l/min)	43,200

Table 4-7-5 Low Volume Air Sampler Measurement Data

Site	Weight of Collected Particles (mg)	Concentration of Collected Particles(mg/m^3)
L1	3.0	0.046
L2	4.4	0.102
L3	5.7	0.132

Table 4-7-6 Digital Type Dust Monitor Data

(Parral in Rainy Season) (cpm)

Site	8/5	8/6	8/7	8/8	8/9	8/10	8/12	8/13	8/14	8/15	8/16	8/17	Mean
1	25	24	24	25	25	23	25	24	25	23	24	24	24
2	24	24	24	24	27	25	24	25	24	24	25	28	25
3	24	27	25	25	25	24	24	23	24	26	24	26	25
4	25	25	23	24	25	24	23	22	23	24	23	24	24
5	24	24	23	25	24	23	24	22	23	24	23	23	24
6	25	25	24	24	25	24	24	23	23	26	23	24	24
7	25	25	27	24	24	24	24	24	24	25	24	24	25
8	24	24	24	25	24	24	23	23	24	25	23	24	24
9	24	24	24	24	24	24	24	24	24	25	25	24	24
10	24	24	24	24	23	24	23	23	24	25	23	23	24

Table 4-9-1 A Result of Tailing Dam Stability Analysis

Element		Ordinary Condition (Kh=0.00)	Earthquake Condition (Kh=0.15)
Center of Circular Arc	X(m)	60.000	40.00
	Y(m)	1857.857	1800.714
Radius R(m)		72.447	28.00
Resisting Moment MR(tf・m)		23.787	3474.457
Sliding Moment MD(tf・m)		12.459	2686.650
Safety Factor Fs=MR/MD		1.9092	1.2932

Table 4-9-2 Day Probability Precipitation

Order i	Date	Precipitation (mm)	$\frac{2i-1}{2N}$ x100
1	1990.7.18	02	4.17
2	1987.8. 9	89	12.50
3	1981.8.16	78	20.83
4	1980.9.23	69	29.17
5	1988.9. 7	67	37.50
6	1986.8.16	62	45.83
7	1983.7. 4	58	54.17
8	1978.8.14	57	62.50
9	1979.8.19	49	70.83
10	1977.7. 6	47	79.17
11	1982.9. 8	43	87.50
12	1989.8.26	39	95.83

5. Survey Results and Countermeasures in the Area of New El Coco

5. SURVEY RESULTS AND COUNTERMEASURES IN THE AREA OF NEW EL COCO

5-1 General Situation

The present El Coco mineral processing plant is located about 80km east-north-east of Mazatlan in the State of Sinaloa, the Pacific Coast. New Plant and tailing dam are projected in the area closer to Mazatlan by 20km and about 200m above the sea level. This region is within Sabanna zone. Average temperature throughout a year is 24.5° C and in the summer season exceeds 40° C at times. The rainy season starts in June running for five months till October. The rest of the year is almost dry. Annual rainfall averages about 800mm. This region is abundant in vegetation like broad-leaved trees.

The present plant was built in 1979 with capacity of 150 tons a day. Since it was located on the middle slope of a narrow valley, the plant has encountered much difficulties such as ore and concentrate transportation, limited tailing dam capacity and others. To overcome these difficulties CFM decided to move the whole operation by constructing a new processing plant and a tailing dam in different area. The proposed site is a basin beside the Magistral River, 20km west from the existing area. Capacity of the new plant is designed to receive 200 tons of crude ore, larger by 33% than the existing one.

The plant construction site is a plateau with an area of about $0.15km^2$ surrounded by steep hills. The tailing dam is designed on a middle-slope of a hill, which stands to the south and 347m high. One of the water supply sources in this area is located about 3km downstream from the site. For this reason site selection should be made carefully after studying surface and ground water movement from the dam to avoid water contamination in the vicinity.

5-2 Geology

5-2-1 Outline of Geology

The survey area is located in the mountain area, about 60 km east from Mazatlan, a resort place near the southern end of Sinaloa State. The Sinaloa State faces California Bay and Pacific Ocean on the western coast. There are a number of transform faults (crossing the East Pacific Rise) which run parallel to the San Andreas Fault which is a world famous active transform fault with the direction of WNW-ESE. It is obvious that the dislocation by the faults affects geology of the survey area.

The Period of commencement of the activity of the faults is considered in Cenozoic(probably Oligocene) age according to the study of San Andreas Fault by Crowell(1968), Dickinson & Grantz (1968) et al.

Almost all the faults in the survey site might possibly be occurred during the same period.

The basement of the area is metasediments of Pre-Tertiary age which is covered by Tertiary pyroclastic rocks and seen at window area of the overlayer. The metasediments mainly consist of slates. They were often changd into phyllites by low-grade metamorphism. In Tertiary age, volcanism was activated. Porphyrites and dacites intruded into the basement, and Toba pyroclastic rocks covered on the surface of this area, later. Hydrothermal process followed the volcanic activity and alteration zone was formed in the survey area with the direction of NNW to SSE, and pyrite was deposited with a small amount of silver and copper in the contact area of intrusive body and basement slates. During Pleistocene age in Quarternary era erosion by rivers was activated and resulted three steps of terrace. At present, alluvial terrace was formed along the Magistral River, and coarsegrained sediments deposited in the river.

5-2-2 Geology and geological structure

Geological interpretation of aerial photographs, field reconnaissance and drilling works were carried out in order to understand the geology of the survey area. As the result of the survey, it was confirmed that the basement of the site is metasediments of Pre-Tertiary System (Jurassic or Cretaceous). Intraformational foldings are well developed, so strikes and dips are irregular. But, it is presumed that the strike is broadly NNE-SSW or NE-SW and the dip is ESE-SE in general (Fig.5-2-1, 5-2-2 and 5-2-3).

This basement layer of this area is exposed along the lower reaches of the Magistral River to the planned tailing dam site, northern end of the distribution and along the roadside from Route 40 to the dam site. The distribution shows donuts like features.

The intrusive rocks of porphyrites and dacites of Tertiary System intruded into the basement as sheet or dyke. They are exposed along the Magistral River and Route 40. The strike of the intrusive rocks is presumed to be NW-SE direction.

Toba pyroclastic rocks of Tertiary System include andesite lava flows within them and they cover the basement with unconformity. Altered acidic rocks show belt like distribution in the western part of the site with approximately NNW-SSE direction. Considering the position of the altered acidic rocks and intrusive rocks, the intrusive rocks are presumed to exist unexposing near the altered area.

Fig.5-2-6 shows the fissure measuring site and Fig.5-2-7 shows the Wulif's net of fissure directions. From this survey, many faults are developed with NW-SE and N-S direction due to the compression from E-W direction which probably began in Oligocene.

Therefore, the strike and the dip of this Tertiary System varied in each block which is divided by these faults (Fig.5-2-1 and 5-2-2).

There are three main blocks divided by the two faults with NW-SE and ENE-WSW which cross at the curving area of the Magistral River in the northern part of the planned tailing dam site. The area of the tailing dam is located in the center of the three blocks and shows the topographycally depression structure. Tertiary System of the western and southern block show that the strike is WNW-ESE or NW-SE direction and the dip is NNE to NE direction. On the other hand, in the eastern block, the strikes have generally same direction with these two blocks, but the dip shows the reversed direction.

In Pleistocene of Quarternary, the erosion of the river relative upheaval by the protrubance of this district or lowering of the sea level, and the three stages of terrace such as higher, middle and lower have been formed each terrace deposit.

(1) Pre-Tertiary systems

The Pre-Tertiary System of the area is considered to be sediments mainly consists of slate partly accompanied with sandstone which formed during Jurassic to Cretaceous.

① Shale

The occurrence of shale is confirmed by drilling and field survey (Fig.5-2-4 and 5-2-5). The study of drilling cores confirmed the existence of shale, which were taken from the drilling holes of B-2, B-3 and B-5, and by the field survey, the shale was found along the lower reaches of Magistral River from B-2 and along the road on the way from Route 40 to the new tailing dam site.

Strikes and dips of the basement irregularly change by strong folding within the layer and the movements by faults. The shale exists in GL. 21.90 ~ 82.90 m in depth at B-2 drilling hole, in GL. 8.40 ~ 10.10 m at B-3 and in deeper part in GL.-12.20m at B-5, respectively.

The shale shows black color in fresh part. The shale is easily fissile along the lamina at the outcrop and estimated that lamina was extremely developed in all parts of the formation. The drilling cores are markedly fractured into small pieces, usually less than 5 cm. Calcite veins and micro-crystals of pyrite are recognized to fill up the fissures. The shale existing in the deeper part of GL -25.60m in the B-2 drilling hole shows grey color, and quartz and calcite veins develop often together with micro-crystals of pyrite. The inclination of crystallization of these crystals remarkably progresses in the contact zone of the intrusive rocks where partly accompanied with galena.

② Sandstone

The sandstone was confirmed to exist in B-2 and B-3 drilling holes, respectively. The outcrops of sandstone are only in the branch flowing into the lowest reaches of Magistral River and along the road to New EL Coco tailing dam site. By the drilling, the sandstone layers appear in GL. 25.30m ~ 25.60m and in GL. 29.80 ~ 31.20m in B-2, and in the deeper part than GL.-10.10m in B-3 drilling hole, respectively. The sandstone layer is composed of gray color and medium to fine-grained sandstones. In B-2 drilling hole, the rock is loose by the affect of ground water. In B-3 drilling hole, the alteration of the rock becomes stronger in deeper zone, small pyrite cubes occurred and filled not only in fissures but also inside the rock.

(2) Tertiary system

The Tertiary System distributes in the greater part of the survey area and consists of intrusive rocks, extrusive rocks, Toba pyroclastic rocks and altered acidic rocks.

① Intrusive rocks

The existence of the intrusive rocks other than small dykes is confirmed by drilling at B-1 and by the field survey at the lowest reaches of Magistral River. The intrusive rocks are porphyrite and dacite, and intruded into the basement metasediments with mineralization.

i) Porphyrite

In B-2 drilling hole, porphyrite is confirmed to intrude into shale in GL. 35.20～ 42.35 m and 56.30m～ 74.00m. The rock color is dark greenish grey and contains feldspar phenocrysts of up to 1cm in size, and sometimes shows diabase structure. Bedding is recognized and the dip is 45° ～55° which has same inclination of the shale layer.

The same type of porphyrite is exposed at both side of Magistal River in the southern end of the site and along Route 40 which partly shows like granodiorite and diabase. The porphyrite is exposed on the western river bed of the Magistral River intruded parallel to shale layer like sheet.

ii) dacite

Dacites occur in the deeper part of GL -82.90m in B-2 and of GL.-12.40m at B-12 drilling hole, the cores show grayish white color.

It characteristically includes quartz phenocrysts of 2 ～3cm in size and generally altered to kaolinite.

② Extrusive rocks

Most of the extrusive rocks are basaltic pyroxine andesite with auto-brecciated and brecciated fragments parts, which distribute in making a belt from north to west of new El Coco dam. The existence is only confirmed in B-1 drilling hole. Erupted rocks exist in GL. 8.25～ 10.65 m in depth as porphyritic andesite with many cracks developed by tension filled with calcite veins.

③ Toba pyroclastic rocks

They are composed of tuff breccia, lappili tuff, tuff and welded tuff, and the distribution is the most widely in the area.

i) Tuff breccia

Tuff breccia is observed in B-1, B-2, B-4,B-6, B-7, B-8, B-9 and B-10 drilling cores. They show purplish gray to reddish brown color in B-1, B-7,B-9 and B-10. The cores from other holes generally show graysh white color. The breccias are mainly composed of subangular to subrounded fragments of andesite and tuff which is less than 3cm in diameter, but sometimes include breccia up to 27 cm in size.

The matrix is andesitic. It is generally altered and the calcite veins or mycro-crystals of pyrite are identified within it.

The outcrops of the rock are observed around B-2 hole site of the upper stream of the Magistral River and along the road east part of new El Coco dam. Particularly, in the northern side of Magistral River near B-2 hole, tuff brecccia is observed covering the basement layer with unconformity.

ii) Lappili tuff

The occurrence is observed at GL. 27.50～ 33.20 m depth in the B-1 drilling hole. It is also observed along the road east part of the tailing dam forming alternation with tuff. The rock shows pale purplish grey and includes much amount of the angular to subangular fragments of andesite which is 0.2～1.5 cm in diameter.

iii) Tuff

Tuff occurred at GL. 10.65 ～ 13.60m in B-1 and GL. 5.10～12.40 m in B-2 drilling holes. Both the cores are coarse grained tuff. The core of B-1 drilling hole has grading structure and the granules increase in lower part. In the core of B-2 hole, grains of quartz and pyrite crystallized by alteration.

The tuff was distributed around the planned place of the new mineral processing plant and is composed of the alternation of fine-grained tuff and coarse-grained tuff.

iv) Welded tuff

The rock is exposed in the eastern part of the new dressing plant. But, it is not observed in any of drilling cores. The rocks are so hard that forms the ridge like topography by erosion. It shows reddish brown color.

④ Altered acidic rocks

These rocks distribute in the western part of the survey area. But, they were not observed in drill cores. As the result of the field survey, the rocks became granular due to kaolinization and silicification, and original rock structure has not been remained in the western branch of Magistral River. The rocks generally show white color and are presumed to be dacitic rocks.

(3) Quarternary system

The terrace plains have developed in the site. The deposit of Pleistocene distribution on the three terrace plains of higher, middle and the deposits of recent exists on the Recent terrace . The obvious topography characterized by detritas is observed in the central part of the area. The detoritas deposits are observed around the planned plant. There are recent talus deposits on the riverbed.

① Higher terrace deposits

The higher terrace deposits distribute along the Panuco River forming the flat plain of approximately EL.225 ~ 235 m in the southern end of the area. The deposits consist of reddish brown sandy silt layer with angular to subangular fragments of andesite and tuff breccia.

② Middle terrace deposits

Middle terrace deposits widely distribute along the Magistral River forming another flat plain of approximately EL.240m in the upper reaches and EL.200 m in the lower reaches, respectively. The planned plant site is located on the terrace plain. The deposits are observed by drilling at B-4, B-5, B-6, B-7 and B-8 drilling holes.

The deposits generally consist of gravel bed, gravelly sand bed and coarse sandy clay bed from lower part to upper part. The thickness of the bed is 8 ~ 10 m or so.

③ Lower terrace deposits

The distribution is limited in the lowest reaches of the area forming the plane of approximately EL.190 ~ 195 m. The deposits consist of gravel bed and sandy silt bed contained gravel. The thickness of the bed is approximately 3～4 m.

④ Recent terrace deposits

The deposits have developed an alluvial terrace plain along the Magistral River and are observed by drilling at B-1,B-2 and B-3 drilling holes. The bed observed at each drilling hole is as follows;

At B-1: Gravel bed

At B-2: Sand bed, gravelly sand bed, gravel bed from the lower to the upper part.

At B-3: Gravel bed, gravelly sand bed including, silt bed from the lower to the upper part.

The thickness of the bed is approximately 4 ～ 6 m and shows generally poor grading.

⑤ Recent river deposits

The deposits are on the riverbed. There are many big gravels which are over 1m in diameter.

⑥ Talus deposits

The deposits mainly distribute on the middle terrace plain in the center of the survey site, and is confirmed in the drilling holes of B-4, B-8. The deposits is composed of gravel bed with sand, sandy silt bed and gravelly sand bed from lower to upper part at B-4, and gravelly sand bed at B-8. On the whole, these sediments is poorly sorted.

5-3 Electrical Prospecting

5-3-1 Method of survey

The Schulumberger's Electrode Arrey was used in the this survey same as in El Bote area. Schinterx Model IPC7(2.5KW) was used and its maximumAB spacing of AMNB electrode system is 400m. The survey was carried out with 26 stations arranged on 9 lines. The location of the stations is shown in Fig.5-3-1. Data of the survey were processed to analysed resistivity with the software for analysis (RESIX PLUS DC).

5-3-2 Result of survey

The analysed resistivity is classified into following four groups and is shown in Fig.5-3-2.

S Zone: tens to thousands of Ω · m

L Zone: Less than 100 Ω · m

M Zone: 100 ~ 200 Ω · m

H Zone: more than 200 Ω · m

L zone shows low resistivity, M zone shows medium resistivity, H zone shows high resistivity and S zone shows complex zone of low and high resistivity.

S zone forms the surface in thickness of 3m ~ 16m, the average thickness is 7m. S zone is composed of the river deposits of recent (Holocene of Quarternary age), terrace deposits of Pliocene of Quarternary time and soil layer of weathered Tertiary System and Pre-Tertiary System.

L zone is widely formed in the lower part of S zone along Magistral River of 1-2-3 and 4-5-8 lines. Large shear zone is confirmed apprximately parallel to the lines, low resistivity zone(L zone) is considerd to be formed by the effect of this shear zone. L zone is composed of dacites and pyroclastic rocks of Tertiary System.

Judging from the survey on 9-11, 12-14 and 15-17 lines, L zone in the lower reaches of Magistral River is not systematically formed. At No. 17 station on 15-17 line, L zone is formed down to the depth of 200m. But., at other stations, the width of L zone is narrow and the depth is also shallow. The L zone is composed of dacite and pyroclastic rock of Tertiary System.

M zone is formed around L zone in each line. The scale is small. M zone is formed comparatively massive in lower part of S zone near planned place of tailing dam under S zone at the stations of 9, 13, 14 and 16. M zone is formed down to 120m in depth except at station No. 16. M zone is composed of pyroclastic rocks and andesite lavas.

H zone is formed in comparatively massive form in 18-20, 21-23, 24-26 and 9-11 lines in the planned place of tailing dam in the lower reaches of Magistral River. The scale of H zone observed in other lines is small. H zone is composed of porphirites which are intrusions of Tertiary System and shales of Pre-Tertiary System.

The movement of groundwater was observed in L zone and M zone by boring test. Judging from the result of survey, L zone is aquifer,M zones is aquitared and H zone is aquiclude or aquifuge.

5-4 Hydrology

The water system in the survey area is shown in Fig.5-1-1. Magistral River flows curving to the south into Panuco River. One big branch flows into in the north side of planned tailing dam from the east, another big branch flows into the Magistral River from the west in the central part of the survey area, respectively. The purpose of this survey is studying the movement of surface and groundwater to collect the fundamental data necessary to design new mineral processing plant. The survey of the flow and water quality was carried out at the points shown in Fig.5-4-1, both in the dry and the rainy season.

5-4-1 The surface water

The surface water of the rivers is little except main stream of the Magistral river in the survey area though the rivers flow down among the mountain area. Many rivers dry up in the dry season except the main stream. Emanation is observed in the bottom layer of the Middle Terrace deposits which form wide flat plane in the planned site of the tailing dam and the central part of the survey area. The measurement of the flow rate and water quality were carried out in the dry and the rainy season at the following points.

In the dry season	The rate of streamflow	No.1 ～ No.5
	Water Quality	C-R1 ～ C-R3
In the rainy season	The rate of streamflow	No.1 ～ No.6
	Water Quality	C-R1 ～ C-R6

(1) The flow rate of surface water

The measurement of cross sections of the rivers was carried out at 6 points, No.1 to No.6, in this survey. At each point, the flow rate(Cross sectional area of flow) was calculated by each current speed measured by Price flow meter and sectional plan of each point. The results are shown in Table 5-4-1.

The modified chart of the flow rate in the dry and the rainy season are shown in Fig.5-4-2, respectively. The measurement was carried out at the ordinary and the rising time of the river level in the rainy season. The difference between the two times is shown in this figure.

Judging from this figure shown above, variation of surface water is big between point No.1 ~ point No.2. The reason of this big variation is considered as follows;

① Variation of the flow rate in the dry season

There is no surface water in the main stream of Magistral River in the dry season. Moreover, surface water is stagnant in the lower reaches of No.2 point, and the water does not flow down. The flow rate rapidly decreases to 1.0m^3/day between the points No.1 and No.2. The reason is considered that there are many cracks developed due to the fault around this area, therefore, the a large amount of surface water penetrate to the underground along the cracks.

② Variation in the flow rate in the rainy season

The surface water increases not only in the main stream of the Magistral river but also in branch rivers in the rainy season. The flow rate between No.1 and No.2 usually increases. On the contrary, the flow rate decreases within this section at the water rising time. This is contradiction at a glance. There are thick deposits of sand and gravels on the riverbed near No.1, and the movement of the sand and glavels is active and flow rate often changes in the rainy season compared with the dry season. It means there are much underground flow near No.1. The flow rate of 4,136.5 m^3/day at ordinary time is only the appearance, and is presumed to be naturally much more of the flow rate than 7,152.1 m^3/day at ordinary time. The penetration amount to underground is also large as in the dry season.

Compared with the flow rate at ordinary time and water rising time, the order of the flow rate is different by approximately one unit.

③ Variation and nature of the flow rate between the dry and rainy season

The seasonal change in the rate of streamflow is remarkable. The flow rate near No.1 was 0 m^3/day, but, in the rainy season increases. For example, compared with the flow rate of near No.1, the amount of the flow rate is approximately 4.2×10^2 m^3/day in dry season, and the amount of that at ordinary time in the rainy season was approximately 4.1×10^2 m^3/day or amount at the water rising time was 8.6×10^4 m^3/day. There is obvious difference between not only dry and rainy season but also at ordinary time and the water rising time in the rainy season.

(2) Water quality of surface water

The sampling of water was carried out at 6 points of C-R1 ~ C-R3 along the main stream of Magistral River and C-R4 ~ C-R6 along the branch in order to analyse pH and contents of 9 heavy metals. The results of the analysis are shown in Table 5-4-3.

Cd, Hg and Cr^{+6} were not detected in the river water in the survey area, but, Cu, Zn, Fe, Total Cr and As were contained all over the survey area. Particularly, Fe is always contained regardless of season. It is not doubtful that these heavy metals exist in this area due to the wide mineralization.

No samples exceed the upper limit of the Environmental Pollutants Content (Table 5-4-2) in C-R1 ~ C-R3 which locate along the Magistral River in the dry season. Only the Fe content in C-R3 exceeds the upper limit of the Environmental Standard of Pollutants Content in the rainy season. Therefore, pollutants of the surface water supplied from the upper reaches of Magistral river is comparatively small (Fig 5-4-3).

Only Fe content exceeds the upper limit of the Environmental Pollutants Content in C-R4. Andesite is distributed around this point. The reason of high Fe content is considered that Fe is supplied from altered andesite contaminates the surface water.

Only As content at C-R5 located near the fault exceeds the upper limit of the Environmental Standard. About As, as it is explained in the chapter of groundwater on the samples of C-B1 and C-B7 later, the reason is not obvious, but As is presumed to concentrate along the fault.

Pb and Fe contents exceed the Environmental Standard at C-R6. The general nature of the surface water in this area is the same of the groundwater in this area where groundwater emanates from middle terrace deposit of the planned tailing plant site.

pH changes from neutral to weak alkalinity from the upper to the lower reaches. The change of pH is considered to have some relationship with pyroclastic flow, andesite and slate of basement layer distributed in the upper reaches and in the lower reaches, respectively.

5-4-2 Groundwater

The electric prospecting and the survey of the flow rate (current speed, current direction, groundwater table and chemical analysis) with observation holes were carried out in order to examine the distribution of groundwater and the water quality.

(1) The flow rate of groundwater

The 13 observation holes were drilled in order to measure the position of aquiferous layer and current speed with micro-flow meter. 3 holes(B-1 ~ B-3) locate along the Magistral River, 9 holes(B-4 ~ B-12) locate in the planned tailing plant and 1 hole(B-13) locates in the southern side of the planned plant site. The result is shown in Fig.5-2-5 for Columnar section by drilling, and Table 5-4-4 and Fig.5-4-4 for measured current speed.

B-2 hole was artesian well due to the existence of confined water. The existence of groundwater was confirmed, but, the water was stagnant in B-7, B-9, B-10 and B-13 holes. The movement of the water occurs discontinuously in B-3, B-6 and B-8 holes.

The aquiferous layer confirmed with micro-flow meter are as follows;

① Aquiferous layer

i) B-1 hole

Aquiferous layer within Toba pyroclastic rocks

approximately EL 210 ~ 221 m

approximately EL 200 ~ 208 m

approximately EL 187 ~ 192 m

ii) B-2 hole

Aquiferous layer within the base of Recent Terrace deposits

approximately EL 216 ~ 220 m

Aquiferous layer within intrusive rocks and Pre-Tertiary System(basement layer) between intrusive rocks

approximately EL 165 ~ 184 m

approximately EL 141 ~ 144 m

confirmed during drilling(confined water)

iii) B-3 hole

Aquiferous layer within the base of Recent Terrace deposits

approximately EL 201 ~ 202 m

iv) B-4 hole

Aquiferous layer within the base of Middle Terrace deposits and altered zone of basement rocks

approximately EL 236 ~ 240 m

v) B-5 hole

Aquiferous layer within the base of Middle Terrace deposits

approximately EL 238 ~ 244 m

vi) B-6 hole

Aquiferous layer within the base of Middle Terrace deposits

approximately EL 244 ~ 246 m

vii) B-8 hole

Aquiferous layer within the base of Middle Terrace deposits

approximately EL 239 ~ 244 m

Aquiferous layers in the survey area exist within Pre-Tertiary System (basement layer), Toba pyroclastic rocks, Middle Terrace deposits and Recent Terrace deposits, respectively. As the movement of groundwater within basement rocks cannot be easily observed, equivalent-resistivity plan was made in the range of EL 110 ~ 210 m sliced every 10 m. Judging from the plane (Fig.5-4-5), current direction of groundwater is presumed to be approximately the same as the current direction of the Magistral River. The low resistivity zone of 100 Ω · m exists in comparatibly deep part around the planned dressing plant. It is considered to be strongly affected by fault.

② Movement of groundwater

The follow-up survey by dosing dye stuffs in B-4, B-9 and B-10 holes in order to examine the movement of groundwater in Middle Terrace deposit in the planned dam site. Only the weak current of groundwater to B-10 was observed. According to Fig.5-4-6, groundwater within Middle Terrace deposits in the planned plant area is stagnant in the basin, because the surface of basement rocks is comparatively flat and shows basin like topography. The reason of the existence of temporary current in B-6 and B-8 is presumed that the water level rises due to precipitation and difference of water levels in the upper reaches and the lower reaches occurs. By the difference of the water level, movement of groundwater is presumed to occur. The movement of groundwater once commence, it does not stop if the water level recovers to the stable position in the normal condition, and the water level goes down. According to this idea, the flactuation of the groundwater level and current of the water shows contradiction in appearance. It can be explained by this idea, the movement of groundwater happens in B-8 hole when water level is the highest, and, the movement of groundwater occurs in B-6 hole when water level is the lowest. The case is the same in B-3 hole located in the lower reaches of the Magistral River. The difference of the flow rate (also current speed) has wide variation in B-4 hole. The steep valley locates behind B-4. The current in B-4 hole is presumed to occur due to quick response to precipitation. The flactuation of water level in the dry season is considered not to occur due to small amount of precipitation. The current of groundwater has no relationship with seasonal change around B-5 hole. Environs of B-5 hole is presumed to be an outlet of stagnant water within Middle Terrace deposits near the planned plant.

There was another aquiferous layer(See Fig.5-4-6) that could be measured the current speed except two layers in B-2 hole in the dry season mentioned above, but, it cannot be recognized in the rainy season. This is considered to happen as a temporary phenomena by drilling. It is considered that the pore water pressure arises and the movement occurs in developed cracks due to gush out of confined water in deeper part. Moreover, movement of ground water is presumed to stop due to saturation by pore water filled the cracks and the movement ceased before the survey in the rainy season.

③ Review of flow

The review of the flow rate is shown in Table 5-4-5. B-2 hole was drilled in order to observe the groundwater and to supply the plant water. Judging from Table 5-4-5, enough water can be supplied from the hole.

Automatic water level recorders were installed in B-1 and B-3 holes in order to examine the relationship between the water level flactuation and precipitation, the measurement was carried out for long time.

Compared with the precipitation record (Fig.5-4-7), precipitation concentrates in early to middle of July and water level also reaches the peak value at the same time. Therefore, it is obvious that the flactuation of groundwater level responses to precipitation amount, and the rate of streamflow is also affected by precipitation.

(2) Water quality of ground water

Groundwater was sampled at 13 holes in order to analyse the contents of 9 heavy metals including measurement of pH. C-B1 ~ C-B3 holes locate along the main stream of the Magistral River and C-B4 ~ C-B13 holes locate around the planned plant. The result are shown in Table 5-4-6.

Considering the result shown in Table 5-4-6, Cr^{+6} is not detected in groundwater in the survey area. Very little Hg was locally included. Zn and Fe are generally contained in groundwater. Particularly, Fe contents in all the samples exceed the upper limit of the Environmental Standard. Cu, Pb, Total Cr and As were detected in all the samples, however, sometimes they were not detected due to the seasonal change of ground water.

① C-B1 Point

The fault with NNW-SSE direction was presumed to exist by the existing data and aerial photographs, The existence was confirmed by drilling test in this survey. The contents of Fe and As in the sample from C-B1 exceed the upper limit of the Environmental Pollutants Content.

The sample C-B7 located on the extensive line of the fault has the same nature of that from C-B1. As regard to the As content, the sample which exceeds the Environmental Standard are C-R5 only except C-B1 and C-B7. The existence of fault with NNW-SSE direction is presumed in C-R5 area. Therefore, As is possible to distribute along the fault (particularly the fault with NNW-SSE direction). Pb content in the dry season exceeds the upper limit of the Environmental Standard.

② C-B2 Point

The fault with ENE-WSW direction was recognized in the area of C-B2 hole by interpretation of aerial photograph, geological survey and drilling. Fe content of the sample from C-B2 only exceeds the upper limit of the Environmental Standard. Groundwater in C-B2 area is planned to use as the mill water. Water quality of the groundwater for the milling water is permitted except high Fe content. Compared with the milling water in Parral,the water quality has no problem for milling.

③ C-B3 Point

Pb and Fe contents of C-B3 sample exceed the upper limit of the Environmental Standard. In this area,porphyllite distributes as intrusive bodies and the rocks have possibility of mineralization. The groundwater in C-B3(B-3 hole) area is considered to be affected by the mineralization.

④ C-B4 to C-B12 Points

C-B4 and C-B12 locate in the planned dressing plant site. Almost all the groundwater in the area is from Middle Terrace deposits. Pb and Fe contents in the water generally exceed the upper limit of the Environmental Standard. Arsenic content of C-B7 sample exceed the upper limit of the Environmental Standard. Very small content of Hg was detected only in C-B8, C-B9 and C-B11 in this area. These points locate in the estimated fault zone and Hg is possible to have some relationship with the fault.

⑤ C-B13 Point

In C-B13 point(B-13 hole) only Fe exceeds the upper limit of the Environmental Standard and has no other characteristics. About pH, pH of 8.46 ～ 8.87 in C-B2 point is the maximum which means alkalinity. In other area, average pH shows neutral to weak alkalinity of 7 ～ 8.

5-4-3 Groundwater Flow System Simulation

Optimum simulation blocks of physical and hydraulic properties are modelled around the New El Coco planned Tailing dam site. A Groundwater flow system is simulated under the condition of these properties which are obtained by integrating the results of meteorological, geological, hydrothermal surveys , boring, pumping test and soil test.

At the first step simulation, clarified are water table, flow direction and flow speed under the condition of no existing of a tailing dam and its periphery constructions to get the present groundwater flow system.

At the next step simulation, a tailing dam, two bore hole for pumping, one surface discharge site, and one deposition pond are set up to clarify the groundwater condition after the construction.

Simulation results are contributed to calculate effective goundwater harness, waste water recycle and mining pollutant dispersion in both safety and economy.

The tailing dam construction guide line of Japan is referred to design this new El Coco tailing dam in article 5-8-1 and 5-8-2, in which a engineering method for drainage system is described to prevent tailing-rainwater contamination and waste water infiltration. On the other hand, a hydraulic method, described here, is recommended as a counterplan to reduce construction cost. The fundamentals of this hydraulic method are proposed from Dr.Atunao Marui of Geological Survey of Japan. The simulation starts from this basis and proceeds to fit to the field observation.

(1) Simulation Method

A numerical simulation for groundwater flow is conducted by the use of three dimension simulator "GWS3D2P" originally developed by Dr. Hiroyuki Tosaka of Tokyo University. In this simulator, Darcy's law and mass balance equations are analysed by Finite Difference Method. The details of this simulator is described in Appendix A "Numerical Simulation Technology for Subsurface Fluid Flow".

(2) Simulation Model

① Block Model

Simulation area takes the form of rectangular, 1.7km wide in the north-west direction and 1.8km wide in the north-east direction (Fig.5-4-9). The Magistral river is situated in the western part of the simulation area, which river has the south-west flow direction after the south-east. The new El Coco Planned tailing dam is located in the southern side of the area. This site is on the river terrace deposits which were formed by the Magistral river. At the present time, The Magistral river curves apart in the western side of the new tailing dam site.

The fissures mainly strike north-west, north-east, east-north-east, and subordinately strike north-south in the simulation area. These fissures control the Magistral river direction and groundwater flow direction. Andesite intrudes in the north-west direction in the southern side apart from this area, which direction is controlled by the main fissure.

The simulation area is framed to predict the drawdown and waste water dispersion from the new planned tailing dam. Consequently, the direction of the simulation area is in accordance with the main fissure strike. The area covers the planned dam and is surrounded with water divide.

The simulation depth is decided to 25m above sea level ,because of the influence prediction of pumping for planned tailing dam.

The simulation area is divided into 25 blocks in the north-west direction, 29 blocks in the north-east direction. The block size is 50m × 50m wide around the planned dam, 50m × 50m wide around the marginal area. X and Y axes are in the directions of north-west and north-east, respectively in the figure. the coordinate of north-west and north-east ends are (X1,Y1), (X25,Y29), respectively.

Vertically, the area is divided into 8 underground layers and 1 atmoshere layer, total 9 layers. The uppermost atmoshere layer is the first layer named Z1. Surface layers are 2 to 20m thick, deep site layers are 100m thick (Fig.5-4-10). At the model after construction of the tailing dam, a tailing dam layer is added between the atmosphere layer and the underground layer, totaled 10 layers as Fig.5-4-13. The height of each block is represented by the elevation of the center of the block.

② Permeability and Porosity Model

Permeability and porosity of each simulation block are determined by integrating the geological,geophysical and hydraulic properties.