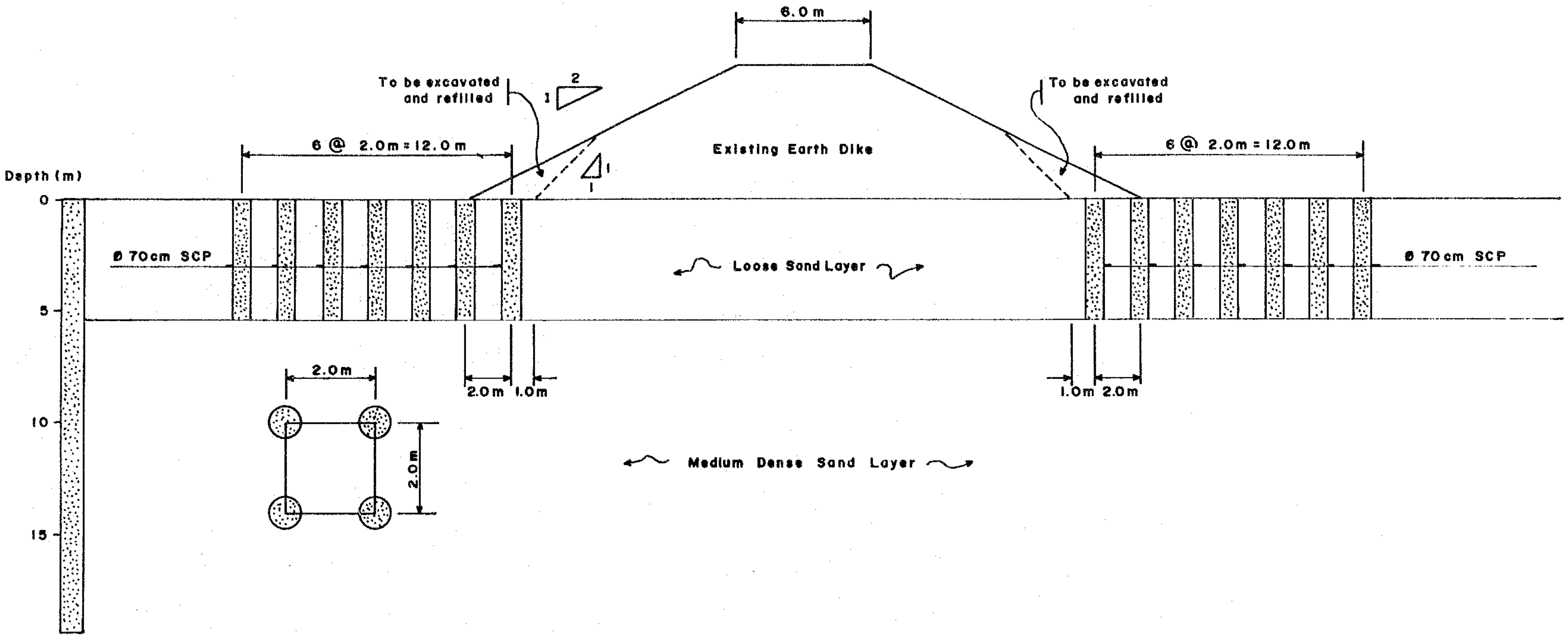
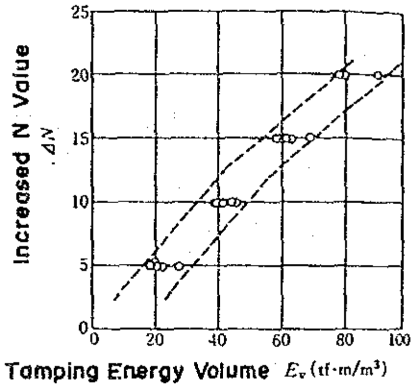


Fig. 9.7 SAND COMPACTION PILE METHOD



ΔN vs. E_u of Sandy (Gravelly) Soils

Improved Ground and Tamping Energy

	Tamping Condition	
	Tamping Energy E(tf·m/m³)	Series Number n
Rock Sand and Gravel	200~400	2~3
Sandy Soil	200~500	2~3
Wastes	300~600	2~3
Clay, Peat	300~500	4~6

$E = E_u \cdot D$

D : Improvement Depth (m)

Fig. 9.8 TAMPING ENERGY AND INCREASED N VALUE BY DYNAMIC CONSOLIDATION

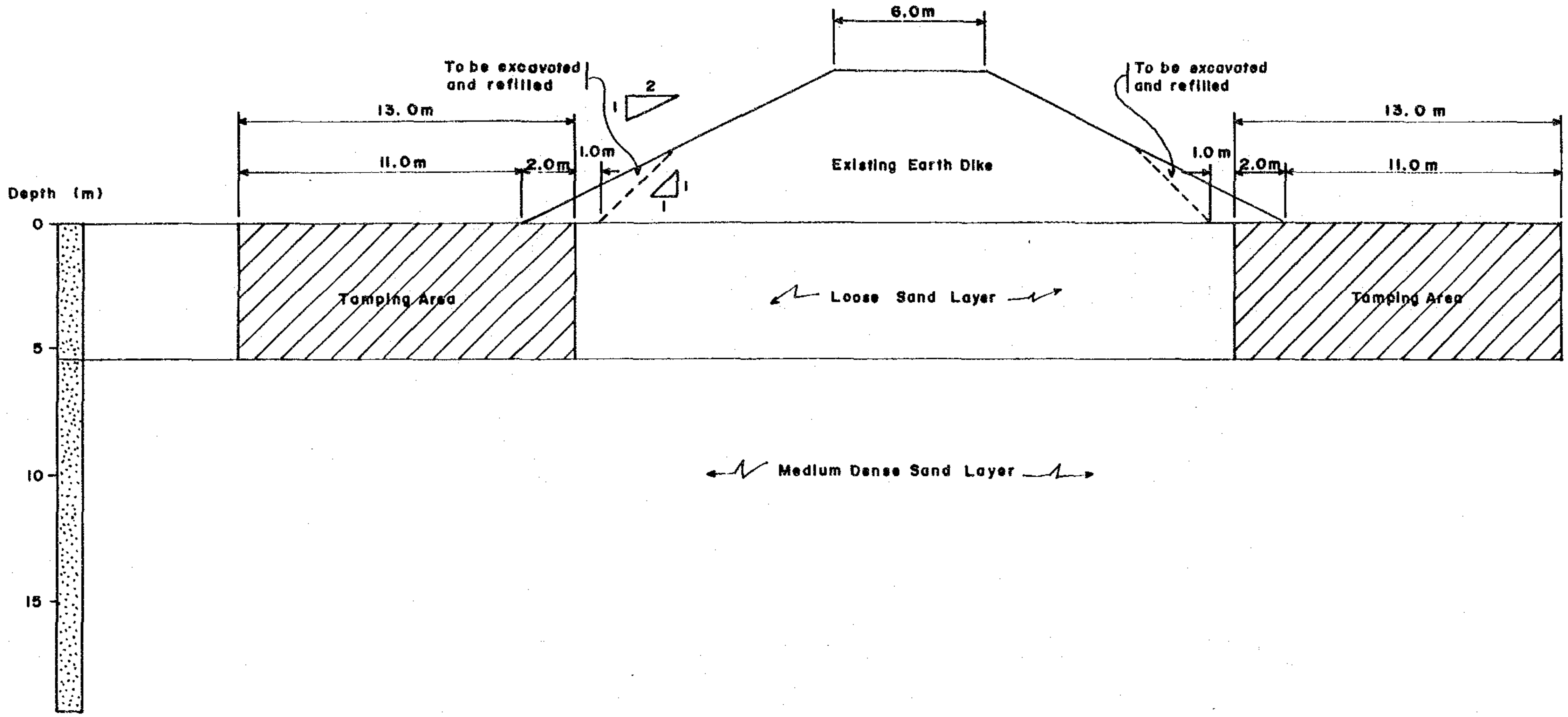


Fig. 9.9 DYNAMIC CONSOLIDATION METHOD

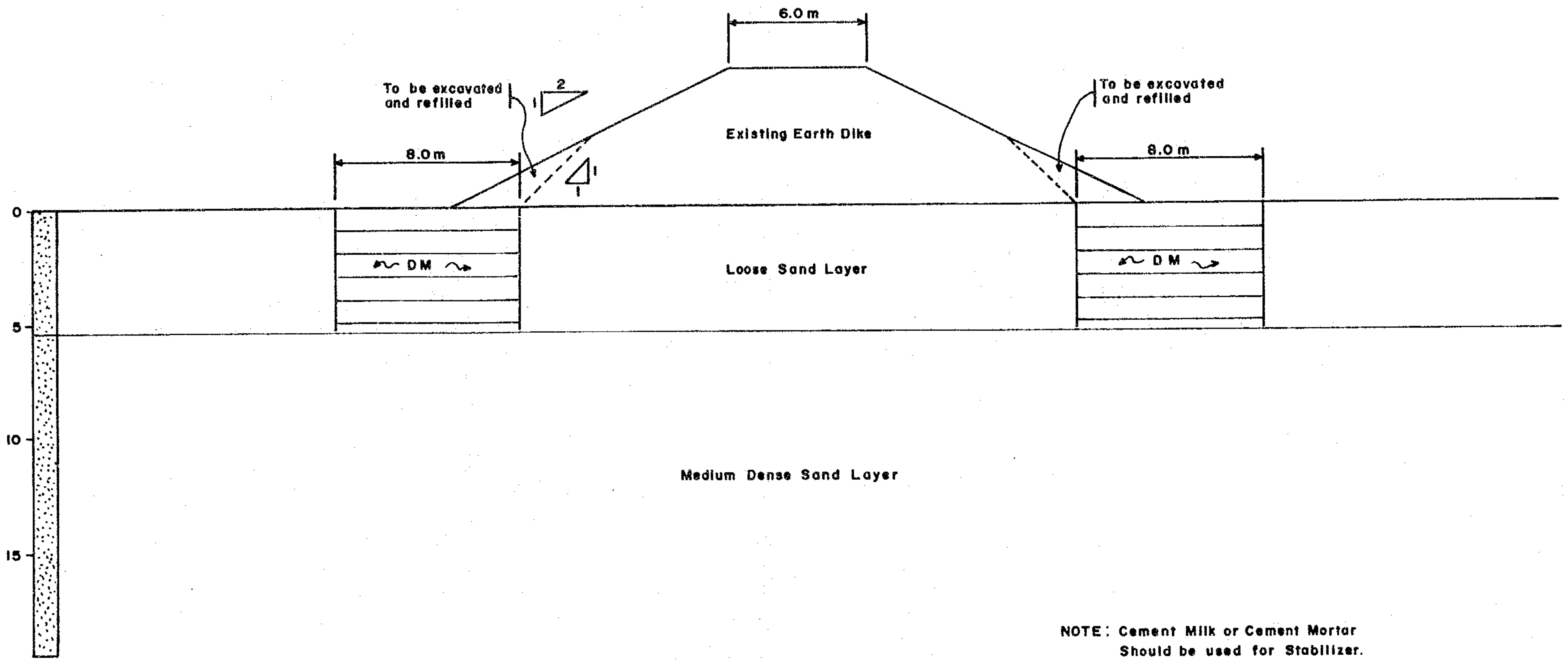


Fig. 9.10 DEEP MIXING METHOD

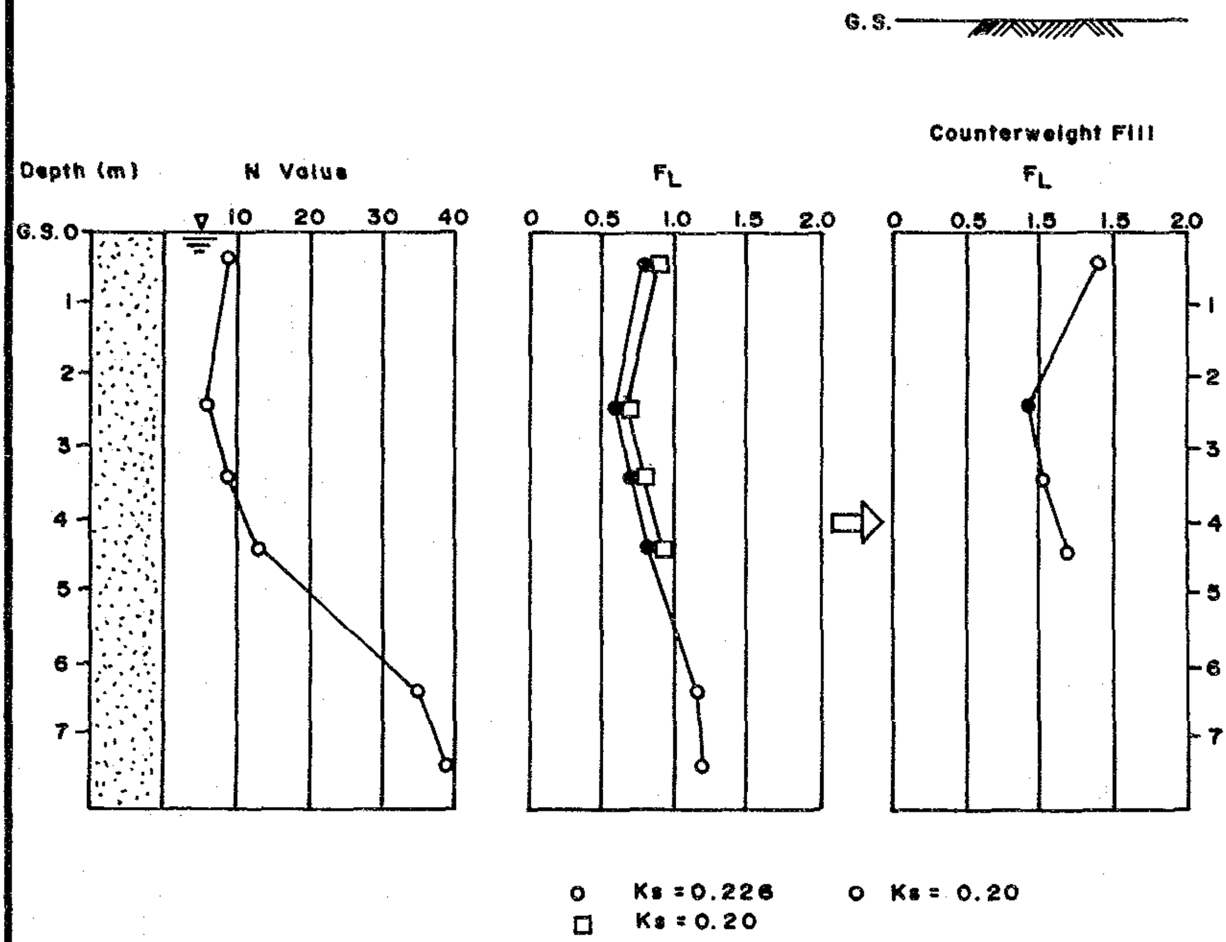


Fig.9.11 EFFECT OF COUNTERWEIGHT FILL

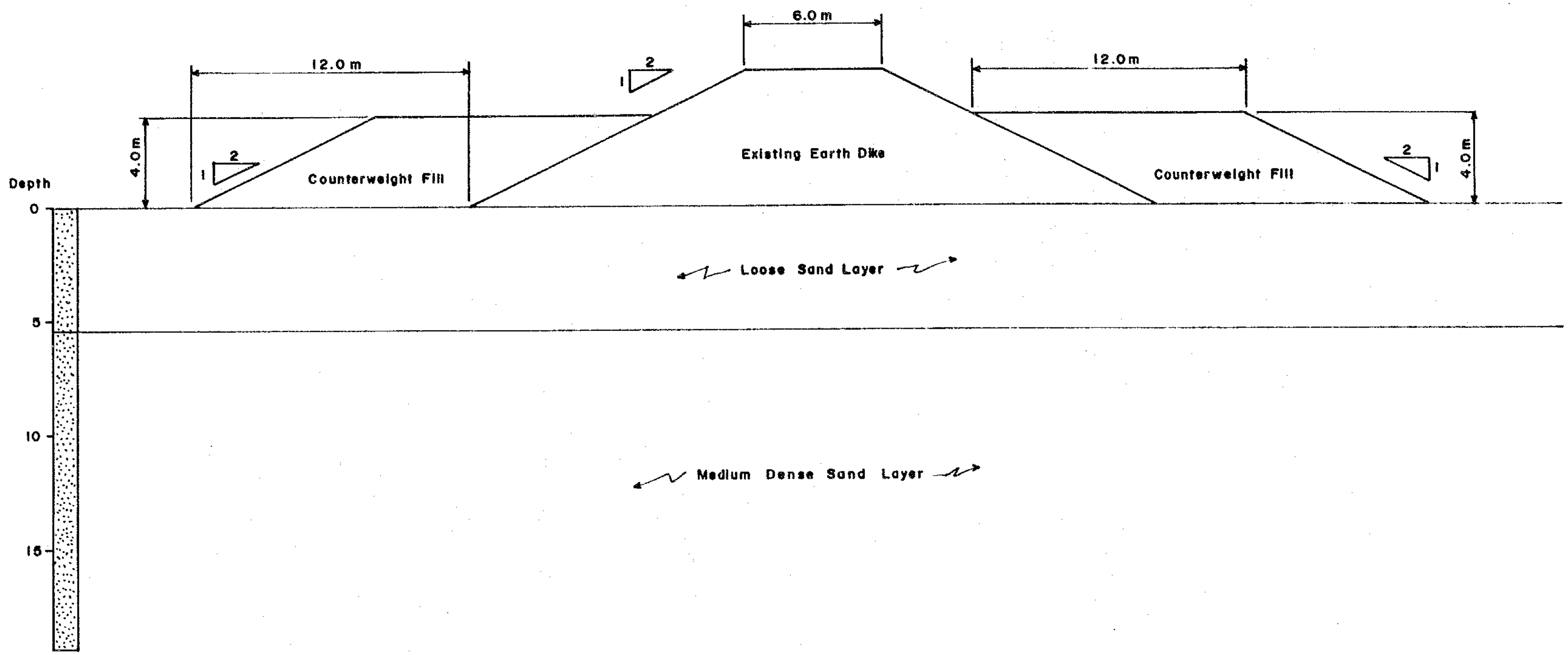


Fig.9.12 COUNTERWEIGHT FILL METHOD

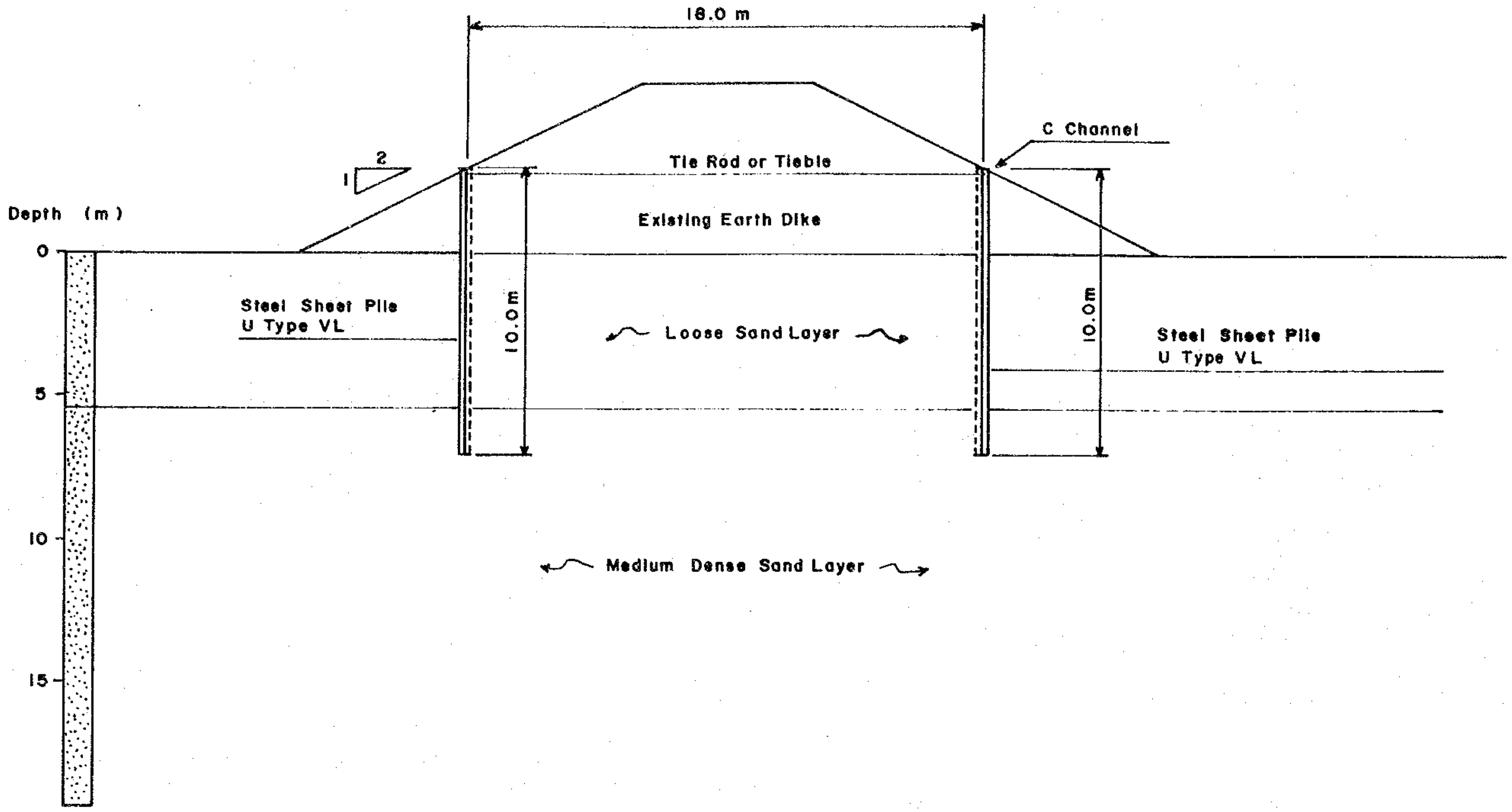
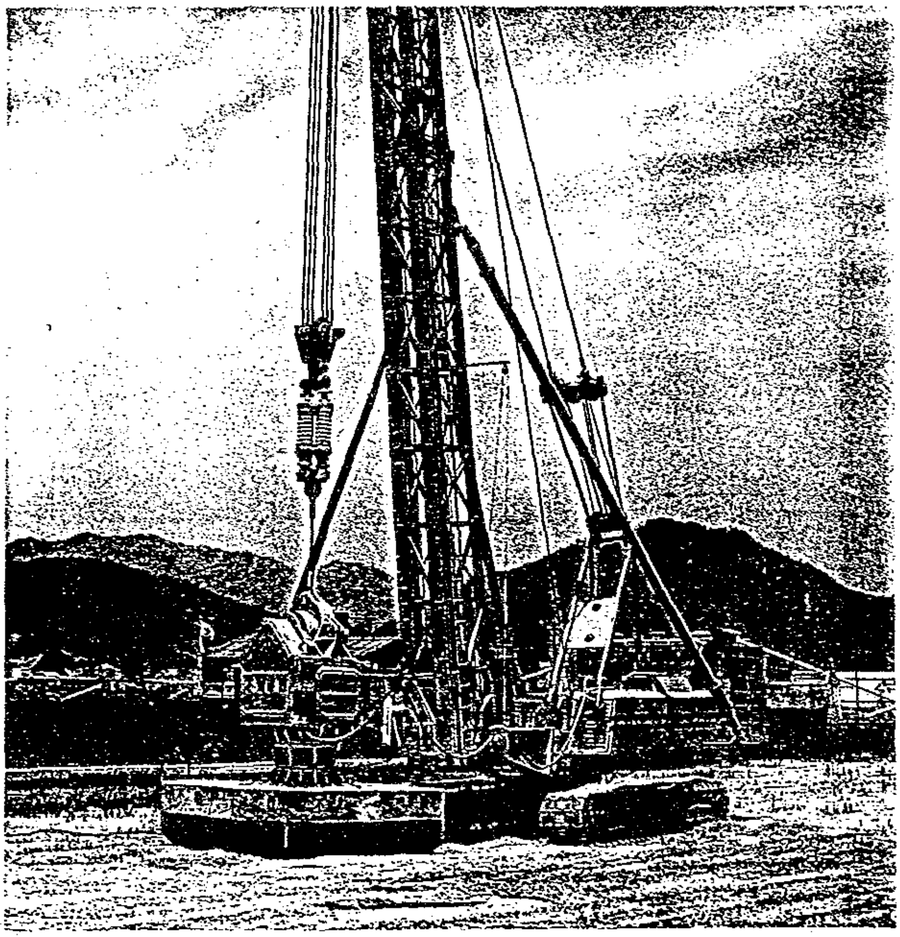


Fig. 9.13 STEEL SHEET PILE METHOD



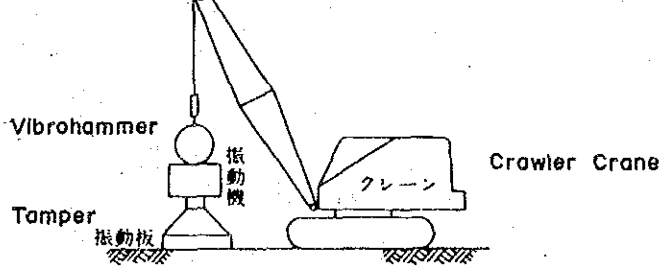


Fig. 9.14 VIBRO TAMPER METHOD

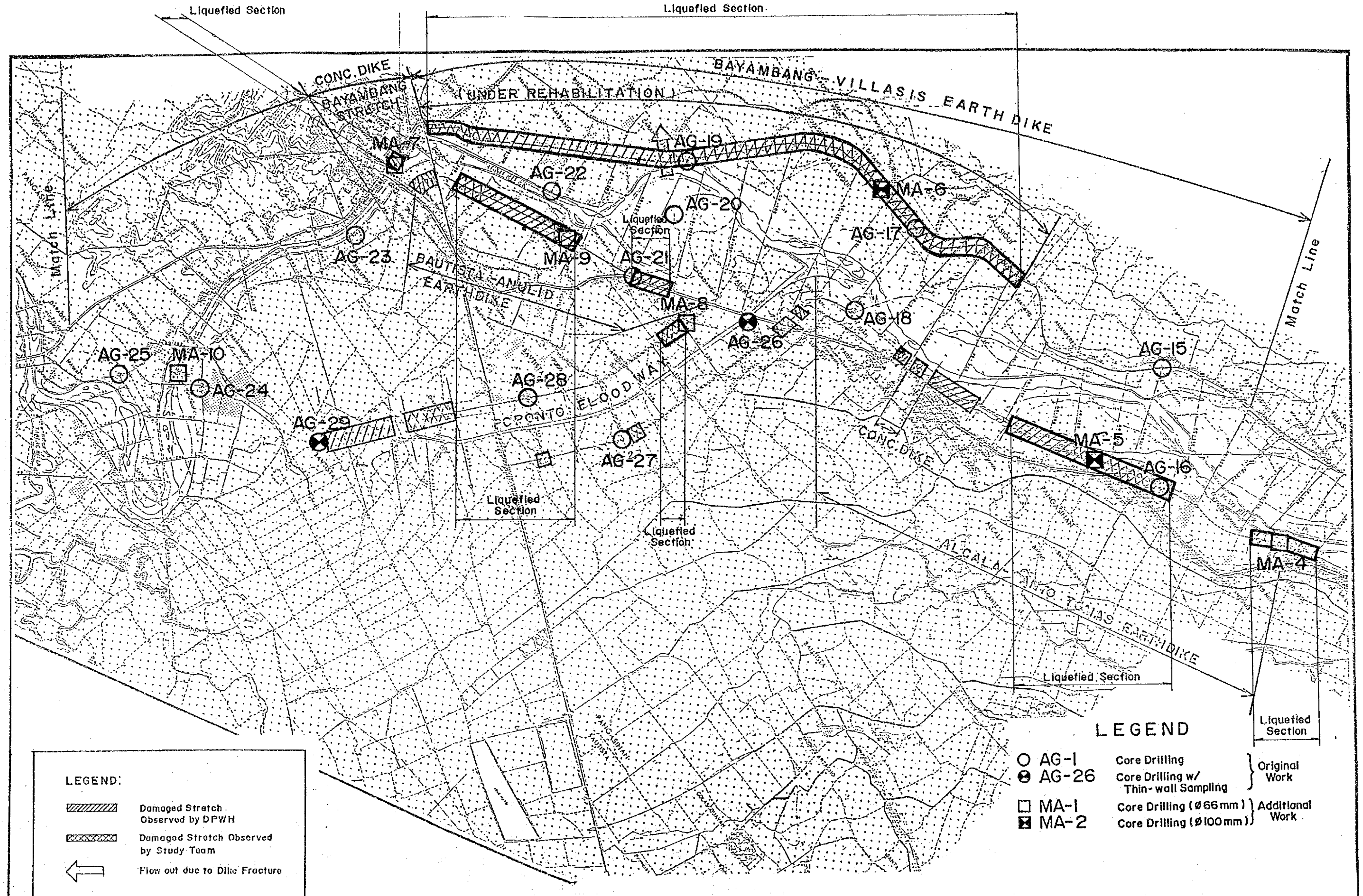


Fig. 10.1 LOCATION OF DAMAGE SITE AND LIQUEFIED AREA OF MAIN AGNO RIVER (1/3)

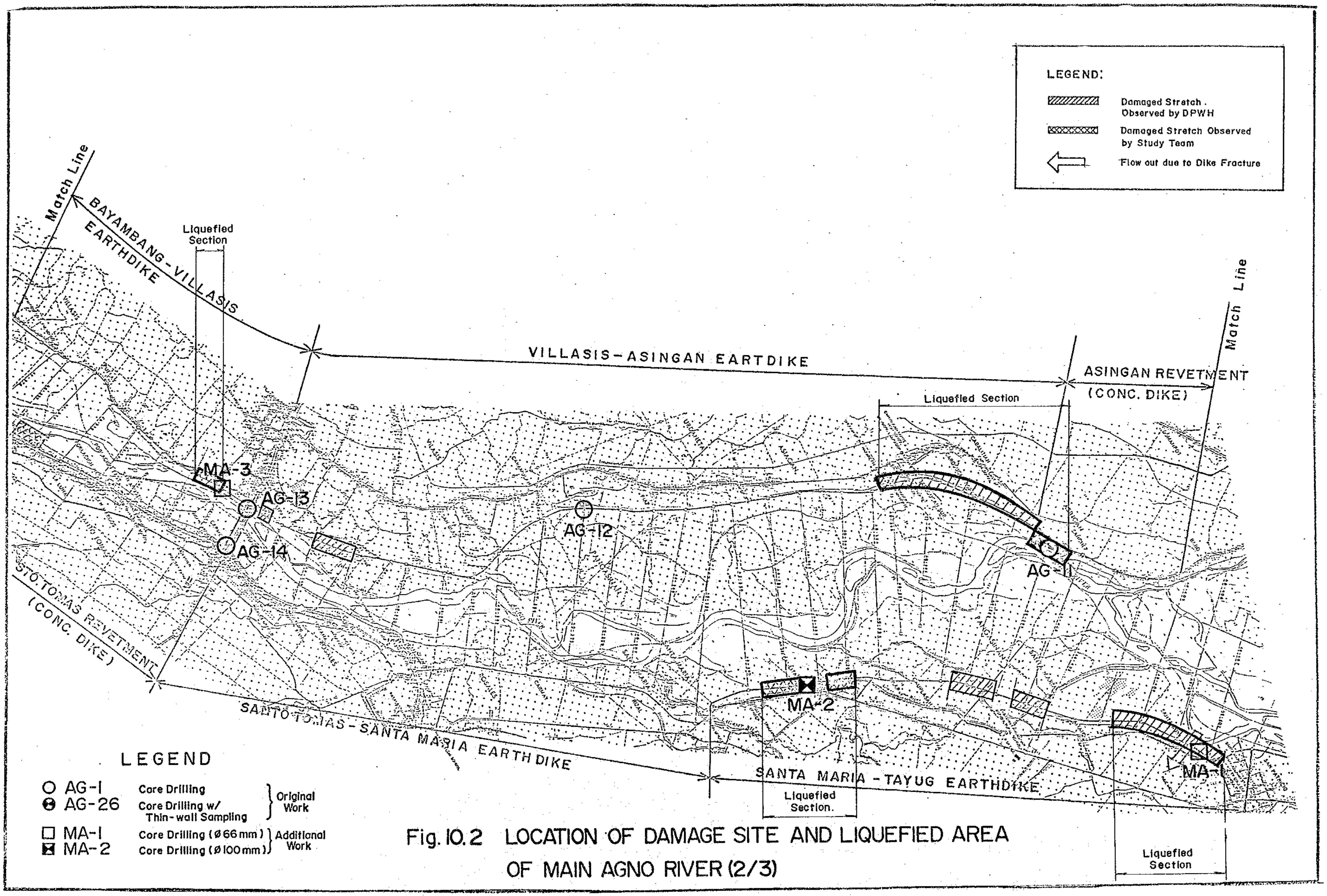


Fig. 10.2 LOCATION OF DAMAGE SITE AND LIQUEFIED AREA OF MAIN AGNO RIVER (2/3)

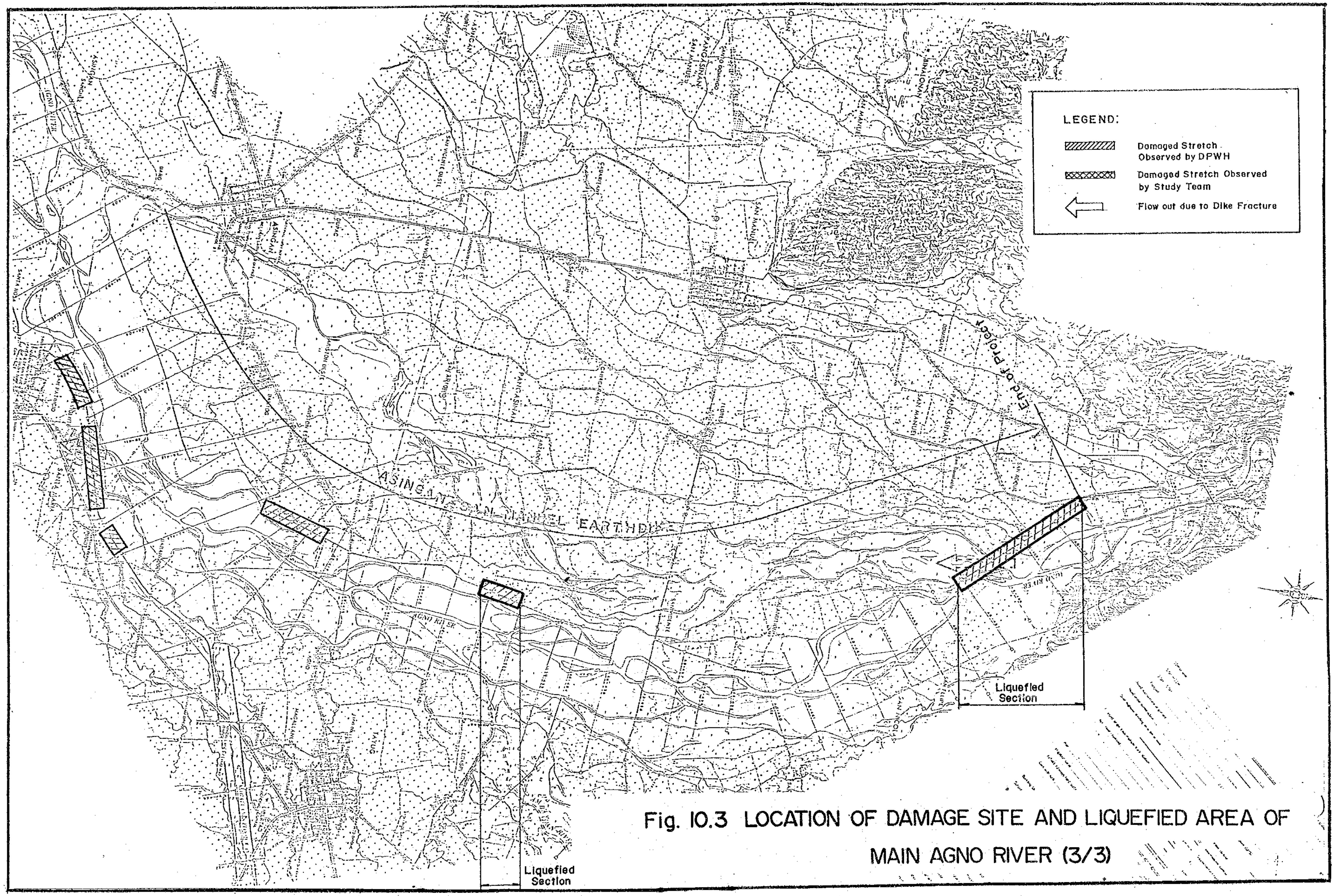


Fig. 10.3 LOCATION OF DAMAGE SITE AND LIQUEFIED AREA OF MAIN AGNO RIVER (3/3)

5. SR

5. SR

SEISMIC RESISTANCE STUDY

1. SUMMARY

(1) The Study Team estimated the return period of the July 16, 1990 Luzon Earthquake (hereafter referred to as Luzon Earthquake) having a magnitude of 7.7 to be about 80 years in the Study Area by the use of the historical earthquake data which have been recorded in the Philippine Institute of Volcanology and Seismology (PHIVOLCS).

(2) The expected value of maximum acceleration which has the same magnitude as Luzon Earthquake is estimated to be 187gal in the Study Area. Taking into account the regional condition and practice in Japan, the basic seismic coefficient for design in this study is determined to be 0.15. The basic seismic coefficient have to be converted into the design seismic coefficient on ground surface by being multiplied with the coefficient for ground type and the coefficient for regional significance.

(3) The simplified evaluation method, which was developed by the Public Works Research Institute Ministry of Construction of Japan, is applied to estimate liquefaction potential in the Upper Agno River and Dagupan City areas. It is found that liquefiable areas are distributed in the whole Study Area, and liquefiable sand layers exist within the depth of 10m from the ground surface with a thickness of 5m or less.

(4) Counterweight fills are adopted as the most suitable countermeasures against liquefaction for earthdikes. A series of stability analysis, in which the excess pore water pressure induced by liquefaction is considered, was carried out to obtain necessary length of the counterweight fills. As a result, it is estimated that a 5m high dike needs a length of 7.0 - 9.0m and a 3m high dike needs a length of 3.6 - 4.8m, depending on its side slope. For concrete revetments and other river structures a pile foundation is suitable.

SR: SEISMIC RESISTANCE STUDY

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1. OBJECTIVE

In the Agno River Basin and Dagupan City Area, many of river structures and buildings were heavily damaged by Luzon Earthquake. The main cause of the damages is supposed to be liquefaction. After the earthquake, the seismic resistance survey was conducted to achieve the following objectives.

(1) To analyze statistically the historical earthquake data in the Philippines and to determine basic and design seismic coefficients

(2) To determine the areas which require countermeasures against liquefaction

(3) To determine the optimum scale of countermeasures against liquefaction

2. SEISMIC ANALYSIS

2.1 Seismic Data in the Philippines

The Philippine islands are suffering from frequent occurrence of earthquakes because the Philippine Archipelago lies between two moving tectonic plates. The Philippine Fault extends through the entire archipelago. In historic time, large earthquakes occured along this fault. Historical earthquake data in the Philippines have been collected by Philippine Institute of Volcanology and Seismology (PHIVOLCS). The Study Area is illustrated in Figure 2.1. Figure 2.2 shows the distribution of epicentres of earthquake in the Philippines.

2.2 Statistic Analysis

A statistic analysis was carried out for the purpose of determining the design seismic coefficient for this study, on the basis of historical earthquake data of which magnitude are greater than 5.5 and epicenters are within radius of 300 kilometers from Dagupan City and Upper Agno River, prepared with PHIVOLCS for the period from 1907 to 190 (see Table 2.1, 2.2).

(1) Probable earthquake in the Study Area

The relationship between magnitude and frequency in the study area is shown in Figure 2.3. Abscissa of this figure corresponds to frequency and ordinate corresponds to magnitude. Inverse numbers of frequency denote return period of earthquakes. From this figure, the return period of Luzon Earthquake, which has a magnitude of 7.7, is obtained to be 83 years around the Study Area.

(2) Expectancy of maximum acceleration

The relationship between the maximum acceleration and frequency is obtained as shown in Figure 2.4, by using the attenuation equation for the ground of type III (see Figure 2.5) as shown below, which has been developed by the Public Works Research Institute of Ministry of Construction of Japan.

$$\alpha\ max = 403.8 \times 10^{0.265M} \times (\Delta + 30)^{-1.218}$$

where,

α max : Maximum ground acceleration (gal)

M : Magnitude of earthquake

Δ : Distance from epicenter (km)

From Figure 2.4 the expectancy of maximum acceleration in the Study Area is obtained to be 187gal at the same return period as Luzon Earthquake.

2.3 Seismic Coefficient for Design

In general, aseismatic design is applied to river structures such as dikes, gates, weirs on the basis of seismic intensity method, in which the design earthquake load is calculated by the following equation;

$$Ws = K_h \cdot W$$

where, Ws : design earthquake load

k_h : seismic intensity

W : dead load

The value kh in the above equation is taken to be less than max/g (g:gravity acceleration) because α max is the peak value of acceleration time history while the load Ws is applied to structures statically. It is appropriate that the value of 0.15, which is used in aseismatic design for earth structures in Japan, be employed as the basic seismic coefficient in this study taking into account the similarity of expectancy of maximum acceleration in the Philippines and Japan.

Design seismic coefficient has to be determined in consideration of a ground type where structures are founded as well as significance of the region which any damage to the structures may affect.

$$k_h = c_G \cdot c_I \cdot k_{ho}$$

where, K_h : Horizontal seismic coefficient for design

c_G : Coefficient for ground type

c_I : Coefficient for regional significance

K_{ho} : Basic seismic coefficient for design

Coefficient for ground type is shown in Table 2.3. To classify the ground type, Figure 2.5 is available. This figure is the result of a series of response analysis that was carried out for various ground conditions. As a result, ground types can be classified as shown in Figure 2.5. For example, if the thickness of alluvial strata is greater than 24m, it would be classified as type-III.

The Study Area is classified into three areas depending on the regional significance. The coefficient of each region is determined as shown in Table 2.4.

3. LIQUEFACTION ANALYSIS

3.1 Analysis Method

The liquefaction analysis was carried out using the simple prediction method which utilises SPT N value and gradation of soil. This method is commonly used in Japan to judge the possibility of liquefaction in soil deposits. Especially, the up-to-date specifications for Highway Bridges edited by Japan Road Association in 1990 will be the most advanced and widely used method in Japan. The flow of liquefaction analysis is shown in Figure 3.1.

In this method, the liquefaction resistant factor FL is defined by the following equation and value not exceeding 1.0 is judged to be liquefiable.

$$FL = R/L$$

where, R : Dynamic shear strength ratio

L : Cyclic shear stress ratio induced by earthquake

L is expressed by the following equation

$$L = \gamma d \cdot k_h \frac{\sigma v}{\sigma' v}$$

where,

γd : Reduction factor for depth ($=1.0-0.015z$)

z : Depth from ground surface (m)

k_h : Seismic coefficient at ground surface ($=c_I \cdot k_{ho}$)

c_I : Coefficient of regional significance

k_{ho} : Basic seismic coefficient (=0.15)

σv : Overburden pressure (kgf/cm^2) ($=\{\rho_t h + \rho_{sat}(z-h)\}/10$)

$\sigma'v$: Effective overburden pressure (kgf/cm^2)
$(=\{\rho_t h + (\rho_{sat} - 1.0)(z-h)\}/10)$

ρ_t : Wet density of soil (tf/m^3)

ρ_{sat} : saturated density of soil (tf/m^3)

h : Depth of ground water level (m)

R is eapressed by the following equation

$$R = R1 + R2 + R3$$

where, $R1 = 0.0882\sqrt{N/(\sigma'v + 0.7)}$

N : SPT N value

R2 :	0.19	$(0.02mm \le D50 \le 0.05mm)$
	0.225 log10 (0.35/D50)	$(0.05mm < D50 \le 0.6mm)$
	-0.05	$(0.6mm < D50 \le 2.0mm)$
R3 :	0.0	$(0\% \le FC \le 40\%)$
	0.04FC-0.16	$(40\% \le FC \le 100\%)$

FC : Fine Fracture content (%)

In these equations, R1 is expressed by the function of N value and effective overburden pressure $\sigma'v$, R2 is expressed by the function of mean particle size D50, and R3 is expressed by the function of fine content FC.

In this analysis, the basic conditions of calculation are as follows;

(1) The ground water level is assumed to be the same level of ground surface.

(2) D50 and FL obtained from laboratory test are used. If no labo test data exist, values in Table 3.1, which are taken as the averages of labo tests, are used.

(3) The density of each layer hasn't been measured. Therefore, the values in Table 3.1, which are referred to the Specification for Highway Bridges edited by Japan Road Association in 1990, are used.

3.2 Evaluation on Liquefaction Potential

A series of liquefaction analysis was carried out to evaluate liquefaction potential in the study area. The existing geotechnical data of the Agno River and the Pantal-Sinocalan River were used in this analysis. Surcharge Δ P was variable to know the effect of counterweight. An example of this method is shown in Figure 3.2.

Figure 3.3 - 3.5 show the distribution of liquefaction resistance factor FL. The following characteristics are seen in these figures.

(1) The depth of liquefiable sand layer, of which FL values are less than 1.0, is within 10m and the thickness of which layer is 5m or less except for a few calculated points.

(2) Surcharge is effective in improving liquefaction resistance in shallow area from ground surface but it is not effective in the area deeper than 5m.

(3) Even though surcharge is applied, there still remain a few points at which liquefaction potential is high.

Figure 3.6 shows the comparison between seismic coefficient kh = 0.18 and 0.1. It is seen that most calculated points are not liquefiable in the case of kh = 0.1.

Figure 3.7 shows the map of liquefaction possibility in the area of the Upper Agno River under the condition of surcharge Δ P=0. Observed damaged stretches induced by the Luzon Earthquake are also shown in this figure. There are some damaged dikes not due to liquefaction but due to earthquake motion (acceleration). Figure 3.8 shows the result under the condition of ΔP=4.0 tf/m2 which corresponds to 2m high counterweight. Some of the calculated points which are judged to be liquefiable in Figure 3.7 are adjusted to be not liquefiable taking into account the site conditions.

Figure 3.9, 3.10 show the distribution of liquefaction possibility of the Pantal-Sinocalan River area under the conditions of kh = 0.18 and kh = 0.10 respectively. It is seen that there are many points which are judged to be liquefiable in Figure 3.9. On the other hand, Figure 3.10 shows most calculated points are not liquefiable except for DG-7, AL-14, AL-15.

3.3 Area Requirement of Countermeasures

Taking into account the geological survey, liquefaction analysis and observation of damaged dikes, area requirement of countermeasures against liquefaction in the Study Area is determined as shown in Figure 3.11. Hatched areas indicate the areas which require liquefaction measures with the seismic coefficient of either 0.18 or 0.1, while areas delineated with a broken line indicate the areas which require no measures even with the seismic coefficient of 0.1.

4. COUNTERMEASURES

4.1 Stability Analysis for Dikes

In the liquefaction study (Supporting Report LF), comparison of effectiveness and cost on countermeasures against liquefaction for river structures was made. As a result, counterweight fill is proposed as the most suitable countermeasures method against liquefaction for the earthdike. Generally, counterweight fill work is considered to be effective to increase the overburden pressure of ground and protect dike slope during earthquake. This method will be the most economical one.

A series of stability analysis with due consideration of liquefaction was carried out to determine the scale of the counterweight fill.

Conventional slip circle method was employed to carry out stability analysis of dikes during earthquake. Safety factor was calculated in the following steps (see Table 4.1).

(1) <u>Before earthquake</u> (Case-1)
Neither seismic coefficient nor excess pore water pressure was considered in this stage.

(2) <u>Before peak acceleration during earthquake</u> (Case-2)
Horizontal shaking was considered in this stage. Excess pore water pressure was not considered.

(3) <u>After peak acceleration</u> (Case-3)
According to the past liquefaction study, excess pore water pressure rises after the main shock. Therefore excess pore water pressure was considered, but no seismic coefficient was considered in this stage.

Safety factor was calculated by the equation shown in Figure 4.1. Excess pore water pressure U in the equation was estimated by the following equation.

$$U = Lu \cdot \sigma'v$$

where, Lu : excess pore water pressure ratio ($=U/\sigma'v$)

$\sigma'v$: effective stress on slip circle

Figure 4.3 shows the condition of stability analysis. Loose sand layer was assumed to have a thickness of 10m and to be divided into some portions which have different Lu value. According to past study, the Lu value was supposed to change with liquefaction resistance factor FL. Figure 4.2 shows a FL-Lu relationship commonly used in Japan. Excess pore water ratio is determined as shown in Figure 4.3 by adopting this relationship to FL values in Table 4.2, values of which are average FL within 10m from the ground surface.

4.2 Result of Stability Analysis

Calculated cases and results are shown in Table 4.2. Figure 4.4 and 4.5 show examples of stability analysis without counterweight and with counterweight respectively. Figure 4.6 show safety factors against slip circle sliding of dikes of different cross sections.

TABLES

Table 2.1 EARTHQUAKE DATA
($\Delta \leqq$ 300 km from Middle Agno River, M $\geqq$ 5.5)

No.	DATE Year	Month	Day	Epicenter Latitude	Longitude	Depth (km)	Magunitude	Distance (km) from Site to Epicenter
1	1927	4	13	16.50N	120.50E	140.00	6.70	49
2	1927	4	13	16.10N	120.50E	140.00	6.30	12
3	1927	4	19	16.00N	120.00E	100.00	6.70	42
4	1928	8	5	16.10N	119.50E		6.30	95
5	1931	3	19	18.30N	120.20E		6.90	249
6	1931	10	28	17.50N	121.50E		6.30	198
7	1932	6	13	18.10N	119.30E		6.30	254
8	1932	6	14	18.30N	120.20E	80.00	6.50	249
9	1932	7	18	14.00N	120.00E	100.00	6.00	234
10	1932	8	24	16.50N	120.50E		6.30	49
11	1933	3	3	15.50N	120.10E	120.00	6.50	71
12	1933	6	6	14.00N	120.00E		6.30	234
13	1934	2	14	17.50N	119.10E		7.60	210
14	1934	7	31	15.10N	119.70E		5.60	131
15	1934	11	26	14.20N	120.20E		6.30	209
16	1937	3	16	18.00N	121.00E	100.00	6.50	224
17	1937	8	20	14.50N	121.50E		7.50	211
18	1938	5	23	18.20N	119.70E	80.00	7.00	248
19	1940	3	28	14.50N	120.10E	200.00	6.70	177
20	1942	4	8	13.50N	121.10E		7.70	296
21	1949	12	29	17.50N	121.50E		7.20	198
22	1950	1	3	18.10N	121.50E		6.50	255
23	1953	12	22	16.00N	119.00E		5.70	149
24	1956	7	19	15.10N	120.50E		5.70	109
25	1956	10	23	13.50N	120.50E	100.00	6.70	286
26	1957	6	11	18.10N	121.50E	44.00	6.70	255
27	1960	9	19	16.00N	120.00E	25.00	5.50	42
28	1961	2	26	15.50N	121.10E	32.00	6.10	99
29	1962	6	30	16.40N	122.30E		5.70	207
30	1963	2	25	15.58N	121.49E	61.00	5.50	130
31	1963	5	17	15.69N	120.13E	99.00	5.60	51
32	1966	1	7	16.60N	119.50E	47.00	7.70	112
33	1968	8	1	16.45N	122.55E	33.00	5.90	235
34	1968	8	3	16.45N	122.31E	52.00	6.10	209
35	1969	9	4	16.37N	119.56E	60.00	5.80	95
36	1969	10	6	14.99N	120.11E	66.00	5.60	124
37	1970	4	7	15.78N	121.71E	40.00	6.50	145
38	1970	4	7	15.68N	121.85E	22.00	5.50	162
39	1970	4	7	15.53N	121.86E	33.00	5.50	168
40	1970	4	8	15.40N	121.75E	7.00	5.70	164
41	1970	4	12	15.08N	122.01E	25.00	5.80	206
42	1970	11	21	15.01N	120.13E	53.00	5.50	121
43	1971	7	4	15.60N	121.87E	30.00	5.50	167
44	1971	7	4	15.60N	121.85E	50.00	5.50	165
45	1972	5	22	16.59N	122.29E	34.00	5.70	211
46	1974	2	9	16.20N	120.10E		5.50	34
47	1975	4	3	16.90N	120.50E		5.50	93
48	1975	6	18	15.00N	121.00E		5.90	136
49	1977	3	18	16.70N	122.31E	118.20	5.90	217
50	1987	4	25	15.87N	120.22E	106.00	5.50	29
51	1987	6	5	15.60N	121.00E	45.00	5.60	84
52	1990	7	16	16.50N	120.94E	33.00	5.70	76
53	1990	7	16	15.68N	121.26E	36.00	7.70	103
54	1990	7	16	16.46N	120.40E	33.00	5.70	43
55	1990	7	16	15.88N	121.13E	33.00	5.50	82
56	1990	7	16	16.41N	120.34E	33.00	5.50	38
57	1990	7	17	16.48N	120.83E	33.00	5.90	66
58	1990	7	17	16.39N	121.08E	33.00	6.50	82
59	1990	7	22	15.43N	121.16E	32.00	6.00	109
60	1990	7	16	16.07N	121.01E	33.00	5.50	66
61	1990	8	12	16.36N	120.16E	19.00	5.50	41
62	1990	8	19	16.17N	120.21E	1.00	5.50	22
63	1990	9	10	16.41N	120.28E	14.00	5.60	40

Table 2.2 EARTHQUAKE DATA
(Δ ≦ 300 km from Dugpan City, M ≧ 5.5)

No.	D A T E Year	Month	Day	Epicenter Latitude	Longitude	Depth (km)	Magunitude	Distance (km) from Site to Epicenter
1	1927	4	13	16.50N	120.50E	140.00	6.70	60
2	1927	4	13	16.10N	120.50E	140.00	6.30	25
3	1927	4	19	16.00N	120.00E	100.00	6.70	76
4	1928	8	5	16.10N	119.50E		6.30	130
5	1931	3	19	18.30N	120.20E		6.90	262
6	1931	10	28	17.50N	121.50E		6.30	187
7	1932	6	13	18.10N	119.30E		6.30	278
8	1932	6	14	18.30N	120.20E	80.00	6.50	262
9	1932	7	18	14.00N	120.00E	100.00	6.00	235
10	1932	8	24	16.50N	120.50E		6.30	60
11	1933	3	3	15.50N	120.10E	120.00	6.50	86
12	1933	6	6	14.00N	120.00E		6.30	235
13	1934	2	14	17.50N	119.10E		7.60	239
14	1934	7	31	15.10N	119.70E		5.60	148
15	1934	11	26	14.20N	120.20E		6.30	208
16	1937	3	16	18.00N	121.00E	100.00	6.50	225
17	1937	8	20	14.50N.	121.50E		7.50	187
18	1938	5	23	18.20N	119.70E	80.00	7.00	267
19	1939	5	6	13.50N	121.30E	110.00	6.50	285
20	1940	3	28	14.50N	120.10E	200.00	6.70	179
21	1942	4	8	13.50N	121.10E		7.70	281
22	1949	12	29	17.50N	121.50E		7.20	187
23	1950	1	3	18.10N	121.50E		6.50	248
24	1953	12	22	16.00N	119.00E		5.70	183
25	1956	7	19	15.10N	120.50E		5.70	103
26	1956	10	23	13.50N	120.50E	100.00	6.70	279
27	1957	6	11	18.10N	121.50E	44.00	6.70	248
28	1960	9	19	16.00N	120.00E	25.00	5.50	76
29	1961	2	26	15.50N	121.10E	32.00	6.10	70
30	1962	6	30	16.40N	122.30E		5.70	176
31	1963	2	25	15.58N	121.49E	61.00	5.50	96
32	1963	5	17	15.69N	120.13E	99.00	5.60	71
33	1966	1	7	16.60N	119.50E	47.00	7.70	145
34	1968	8	1	16.45N	122.55E	33.00	5.90	203
35	1968	8	3	16.45N	122.31E	52.00	6.10	178
36	1969	9	4	16.37N	119.56E	60.00	5.80	130
37	1969	10	6	14.99N	120.11E	66.00	5.60	130
38	1970	4	7	15.78N	121.71E	40.00	6.50	110
39	1970	4	7	15.68N	121.85E	22.00	5.50	127
40	1970	4	7	15.53N	121.86E	33.00	5.50	134
41	1970	4	8	15.40N	121.75E	7.00	5.70	130
42	1970	4	12	15.08N	122.01E	25.00	5.80	173
43	1970	4	12	15.21N	122.04E	18.00	5.50	167
44	1970	11	21	15.01N	120.13E	53.00	5.50	127
45	1971	7	4	15.60N	121.87E	30.00	5.50	132
46	1971	7	4	15.60N	121.85E	50.00	5.50	130
47	1972	4	25	13.37N	120.31E	50.00	7.20	296
48	1972	5	22	16.59N	122.29E	34.00	5.70	181
49	1974	2	9	16.20N	120.10E		5.50	69
50	1975	4	3	16.90N	120.50E	———	5.50	103
51	1975	6	18	15.00N	121.00E		5.90	116
52	1977	3	18	16.70N	122.31E	118.20	5.90	188
53	1987	4	25	15.87N	120.22E	106.00	5.50	54
54	1987	6	5	15.60N	121.00E	45.00	5.60	54
55	1990	7	16	16.50N	120.94E	33.00	5.70	61
56	1990	7	16	15.68N	121.26E	36.00	7.70	69
57	1990	7	16	16.46N	120.40E	33.00	5.70	61
58	1990	7	16	15.88N	121.13E	33.00	5.50	47
59	1990	7	16	16.41N	120.34E	33.00	5.50	60
60	1990	7	17	16.48N	120.83E	33.00	5.90	55
61	1990	7	17	16.39N	121.08E	33.00	6.50	59
62	1990	7	22	15.43N	121.16E	32.00	6.00	80
63	1990	7	16	16.07N	121.01E	33.00	5.50	33
64	1990	8	12	16.36N	120.16E	19.00	5.50	71
65	1990	8	19	16.17N	120.21E	1.00	5.50	57
66	1990	9	10	16.41N	120.28E	14.00	5.60	65

Table 2.3 COEFFICIENT FOR GROUND TYPE c_G

GROUND TYPE	I	II	III
c_G	0.8	1.0	1.2

Table 2.4 COEFFICIENT FOR REGIONAL SIGNIFICANCE c_I

c_I	R E A G I O N
1.0	Main stream of Agno river City and Urban Areas of the Pantal-Sinocalen River and its tributaries
0.8	Major tributaries of Aguno River
0.6	Minor tributaries of Agno River Rural areas along the main stream of Pantal-Sinocalen River and its tributaries

Table 3.1 ASSUMED VALUES OF DENSITY, MEAN PARTICLE SIZE AND FRACTURE CONTENT BY SOIL CLASSIFICATION

Soil Classification	Saturated Density ρ sat tf/m3	Wet Density ρ t tf/m3	Mean Particle Size D50 mm	Fracture Content FC %
Silty clay Sandy clay	1.70	1.50	0.00026	88
Clayey silt Silt Sandy silt	1.75	1.55	0.013	72
Silty sand Fine sand Fine to medium sand	1.95	1.75	0.165	22
Medium sand Medium to coase sand	2.0	1.80	0.376	13
coase sand gravelley sand	2.1	1.90		

Table 3.2 AVERAGE FL VALUES WITHIN 10m FROM FROUND SURFACE OF THE DRILLING HALLS WHICH ARE JUDGED TO BE LIQUEFIABLE BY SIMPLE PREDICTION METHOD

	— MIDDLE AGNO AREA —		
	$\Delta p = 0$	$\Delta p = 4\ tf/m^2$	$\Delta p = 10tf/m^2$
AG11-AG29	1.050	1.245	1.300
MA1 -MA11	0.964	1.234	1.264
	— DUGPAN CITY AREA —		
	$\Delta p = 0$	$\Delta p = 3\ tf/m^2$	$\Delta p = 6\ tf/m^2$
AL1 -AL26	1.088	1.403	1.411

Δ p:Surcharge

Table 4.1 STABILITY ANALYSIS CONDITIONS

Case No.	Seismic Coefficient Ks	Excess Pore Water Pressure
Case-1 (Normal)	0	No
Case-2 (Earthquake)	0.18	No
Case-3 (Liquefied)	0	Yes

Table 4.2 MINIMUM SAFETY FACTOR OF STABILITY ANALYSIS

Height of dike H (m)	Slope	ks	L=0m	3m	6m	9m	12m
5	1:2	0	1.483	1.610	1.856	2.172	2.382
		0.18	0.865	0.926	0.981	1.020	1.063
		0	0.650	0.765	0.878	1.005	1.137
	1:3	0	1.650	1.917	2.121	2.361	2.639
		0.18	0.944	0.977	1.024	1.060	1.088
		0	0.754	0.838	0.971	1.082	1.206
3	1:2	0	1.596	1.909	2.323	-	-
		0.18	0.930	1.008	1.074	-	-
		0	0.709	0.884	1.077	-	-
	1:3	0	1.732	2.148	2.588	-	-
		0.18	0.988	1.054	1.099	-	-
		0	0.767	0.950	1.142	-	-

Table 4.3 LENGTH OF COUNTERWEIGHT

Height of dike H (m)	slope	Length at Fs=1.0 L (m)
5	1:2	9.0
5	1:3	7.0
3	1:2	4.8
3	1:3	3.6

FIGURES

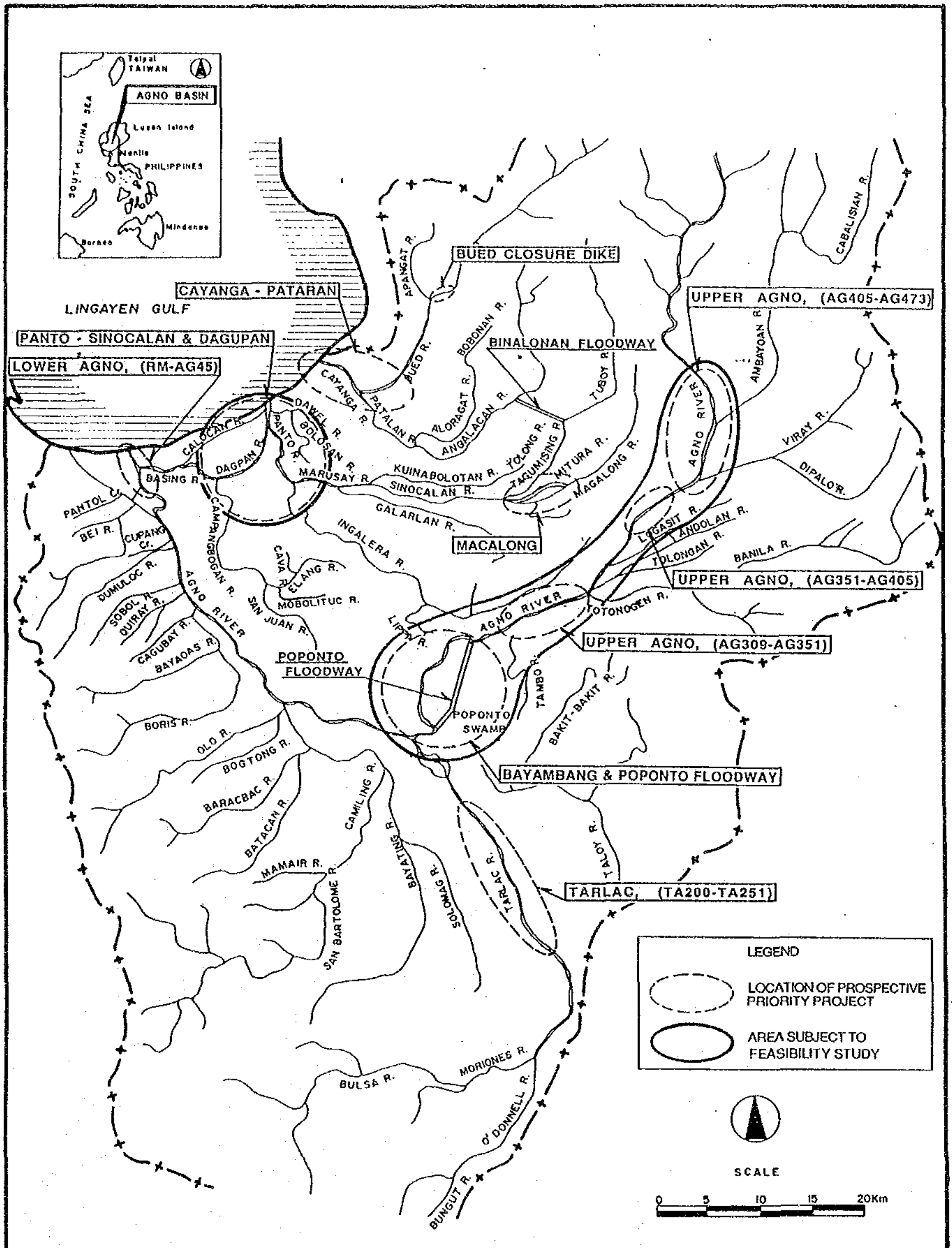


Fig. 2.1 LOCATION OF PROSPECTIVE PRIORITY AREAS FOR RIVER IMPROVEMENT WORKS

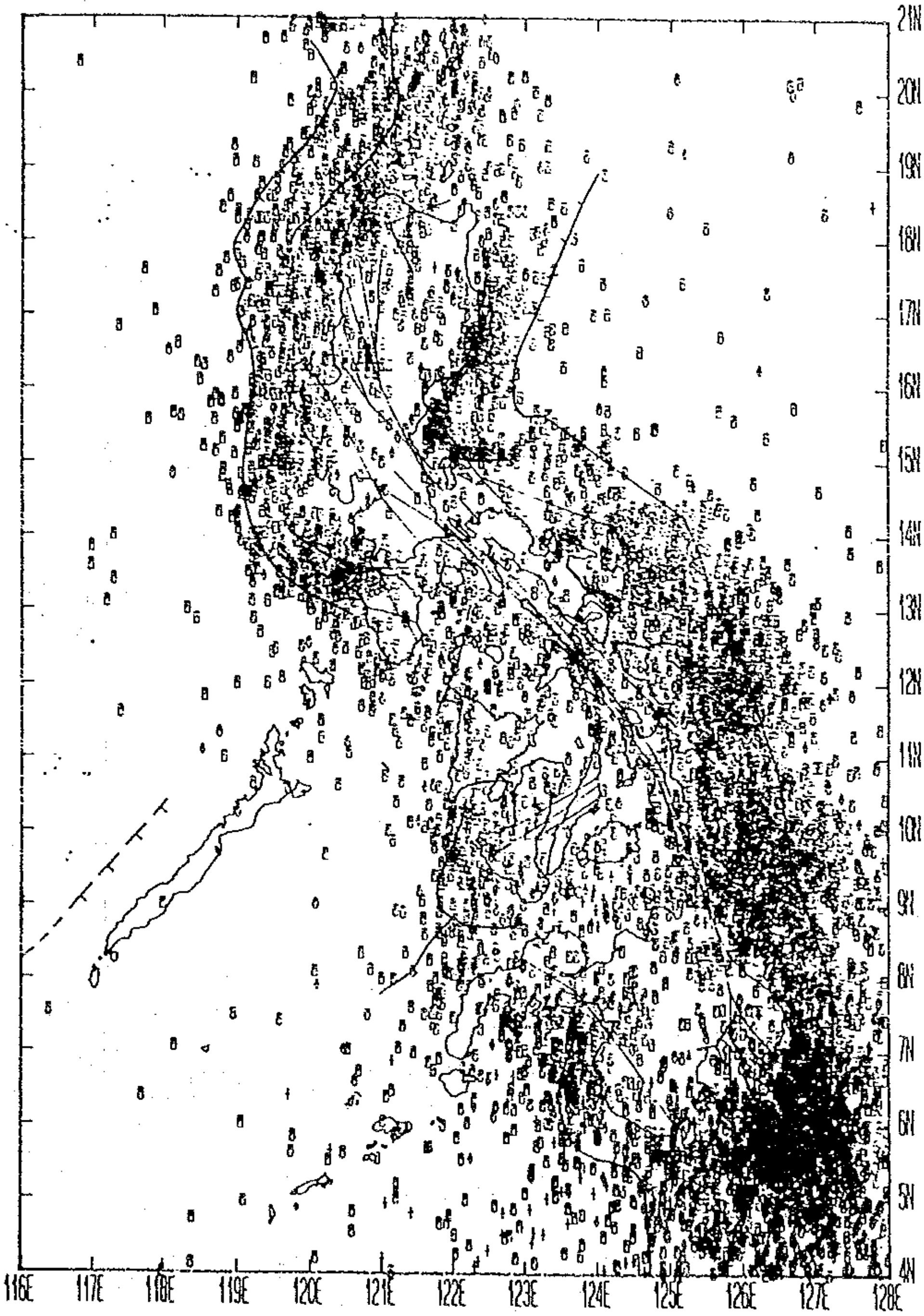


Fig. 2.2 LOCATION OF EPICENTERS OF EARTHQUAKES THAT OCCURED IN THE PHILIPPINES FROM 1960 TO 1988

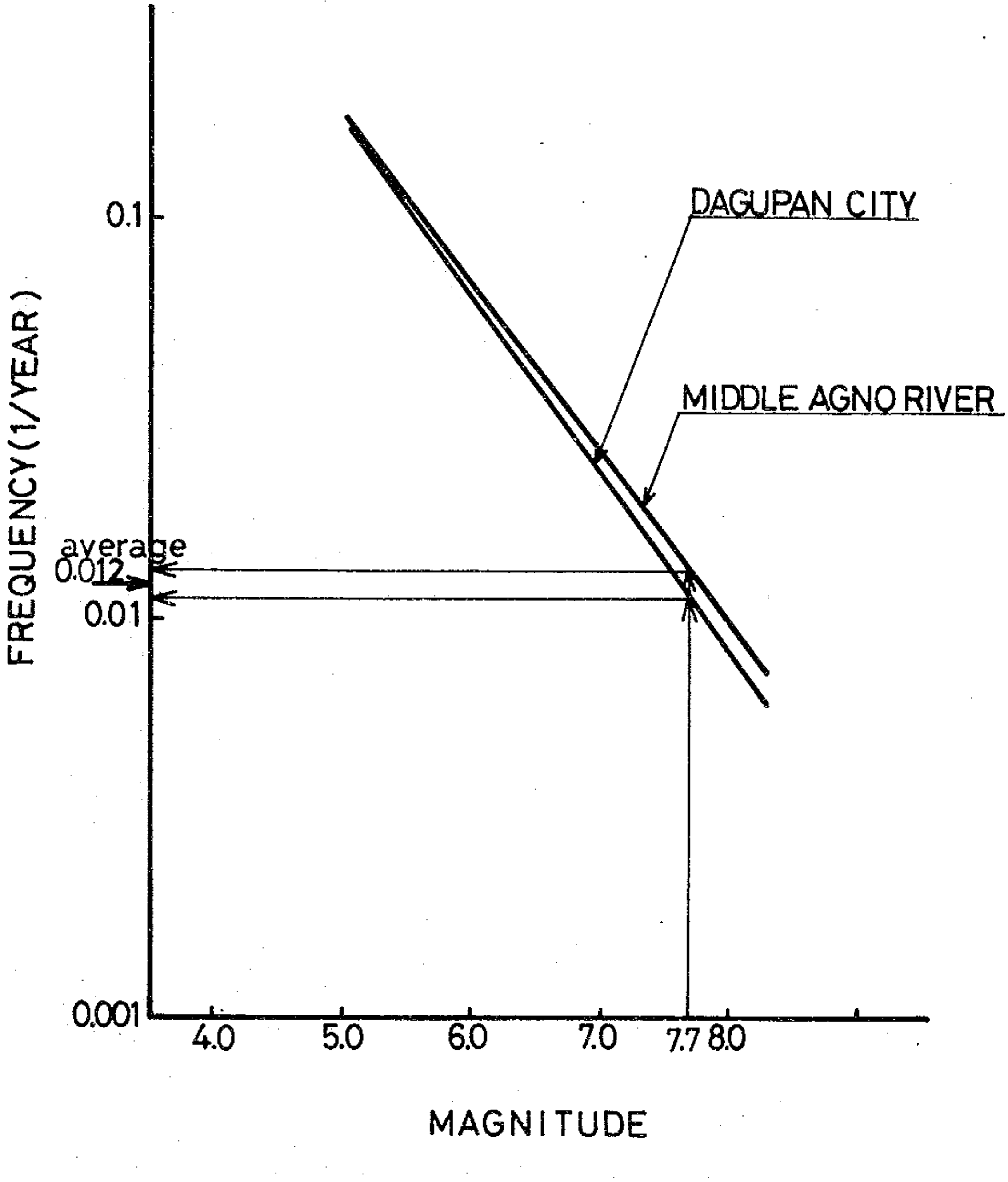


Fig. 2.3 FREQUENCY OF MAGNITUDE

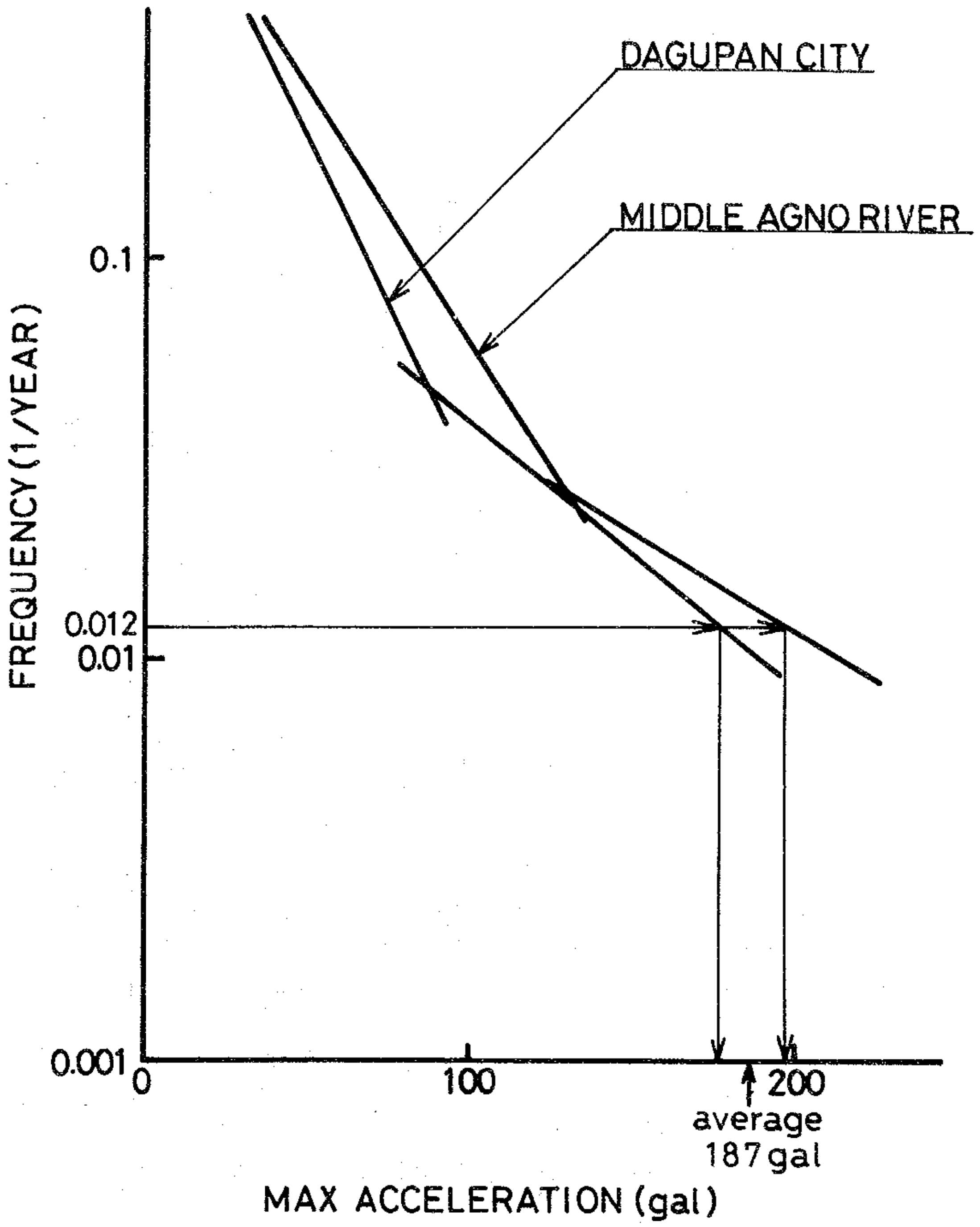
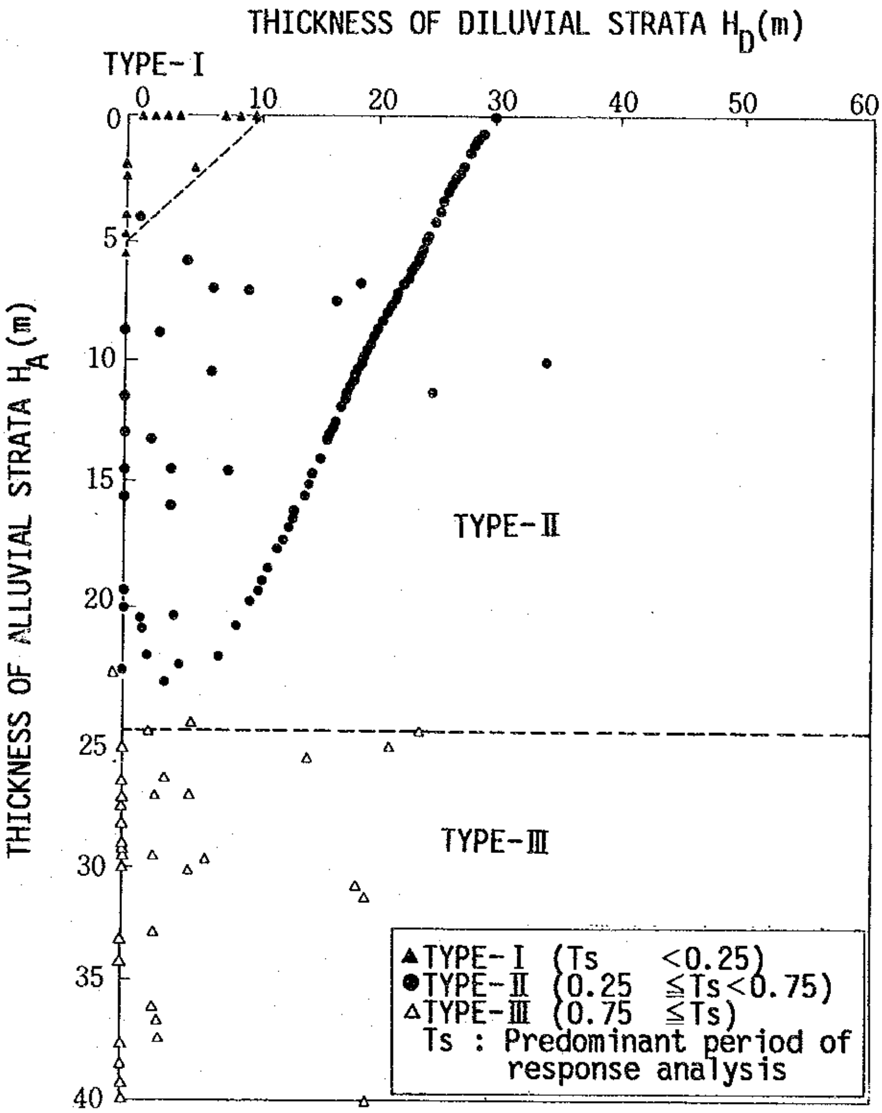


Fig. 2.4 FREQUENCY OF MAX ACCELERATION



(Specifications for Highway Bridges
edited in 1990, Japan Road Association)

Fig. 2.5 CLASSIFICATION OF GROUND TYPE BY USING H_A AND H_D

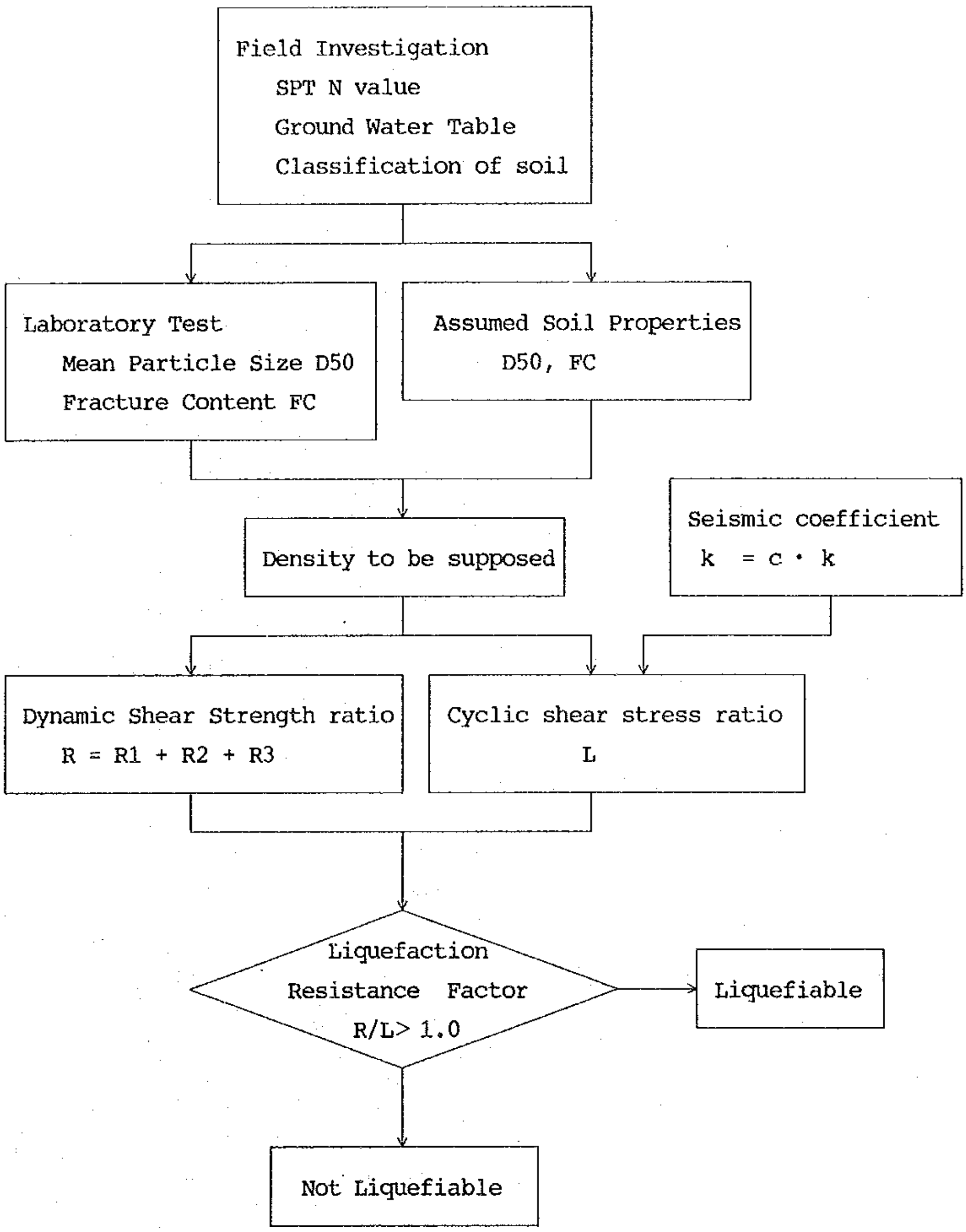


Fig. 3.1 FLOW OF LIQUEFACTION ANALYSIS

Bor. No. MA 1 Surcharge: Δp = 0.0 (tf/m²), Seismic Intencity: ks = 0.18

Z (m)	H (m)	Soil name
0.0		
0.80	0.80	SILTY SAND
1.80	1.00	SANDY CLAY
2.00	0.20	FINE SAND
8.00	6.00	FINE TO COARSE SAND
10.00	2.00	GRAVELLY SAND
15.45	5.45	MEDIUM TO COARSE SAND

N-value	Z (m)	γ (tf/m³)	σ_v' (tf/m²)	σ_v (tf/m²)	FC (%)	D_{50} (mm)	γ_d	τ_d (tf/m²)	R	L	F_L
2.0	1.30	1.80	1.04	2.34	65.0	0.05	1.0	0.41	0.429	0.397	1.081
17.0	2.30	1.80	1.93	4.23	3.0	0.81	1.0	0.74	0.335	0.381	0.879
15.0	3.30		2.93	6.23	3.0	0.81	1.0	1.07	0.293	0.364	0.805
17.0	5.30		4.93	10.23	7.0	0.52	0.9	1.70	0.294	0.344	0.856
28.0	7.30	2.00	6.93	14.23	7.0	0.52	0.9	2.28	0.357	0.329	1.084
28.0	10.30	2.10	10.13	20.43	4.0	0.67	0.8	3.11	0.307	0.307	0.999
28.0	12.30		12.13	24.43	4.0	0.67	0.8	3.59	0.287	0.296	0.972
26.0	15.30	2.00	15.13	30.43	4.0	0.67	0.8	4.22	0.252	0.279	0.905

Fig. 3.2 AN EXAMPLE OF SIMPLE PREDICTION METHOD

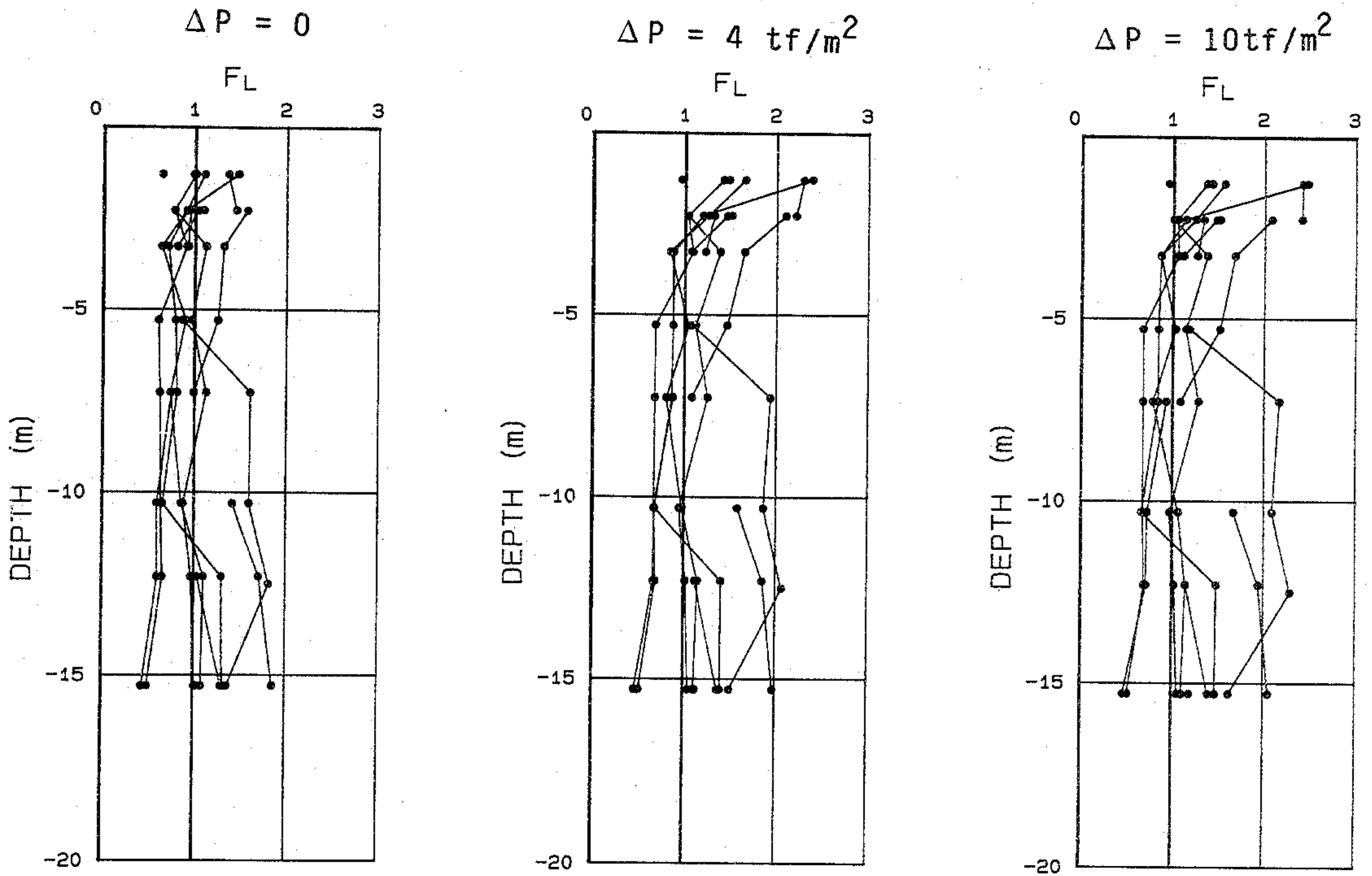


Fig. 3.3 DISTRIBUTION OF RESISTANCE FACTOR AGAINST LIQUEFACTION FL (AG11 - AG26) $k_h = 0.18$

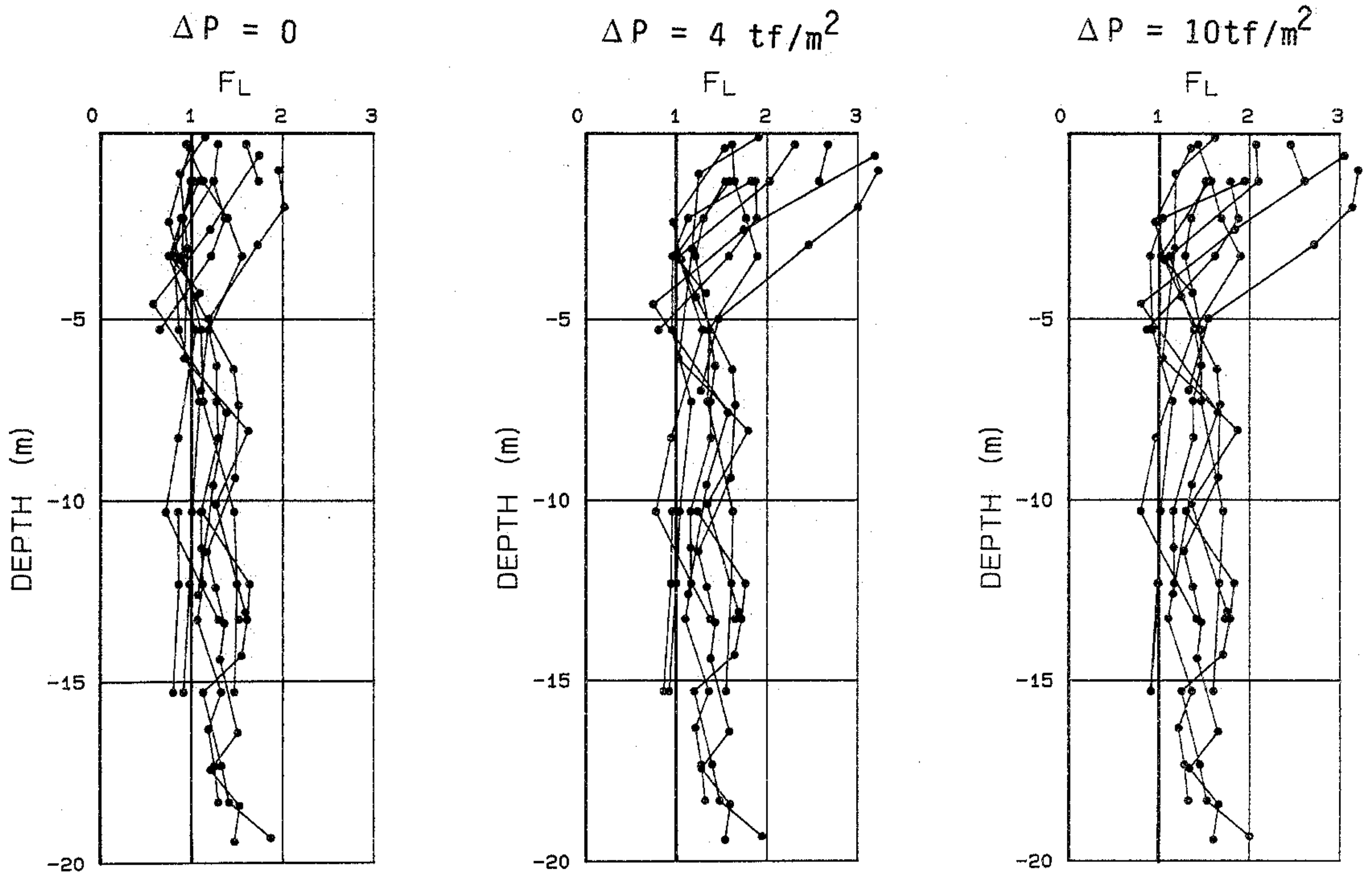


Fig. 3.4 DISTRIBUTION OF RESISTANCE FACTOR AGAINST LIQUEFACTION FL (MA1 - MA11) $k_h = 0.18$

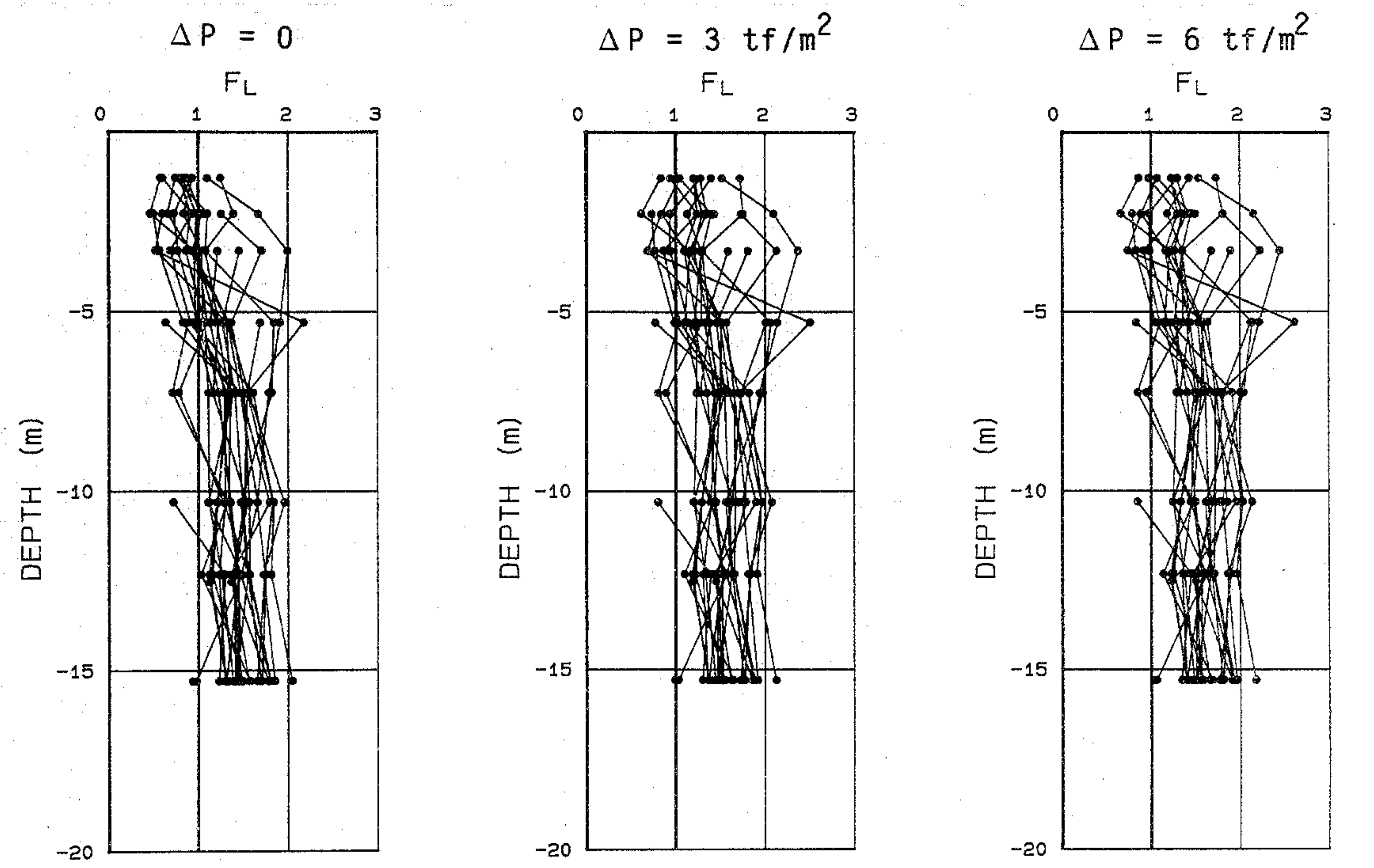


Fig. 3.5 DISTRIBUTION OF RESISTANCE FACTOR AGAINST LIQUEFACTION FL (AL1 - AL26) $k_h = 0.18$

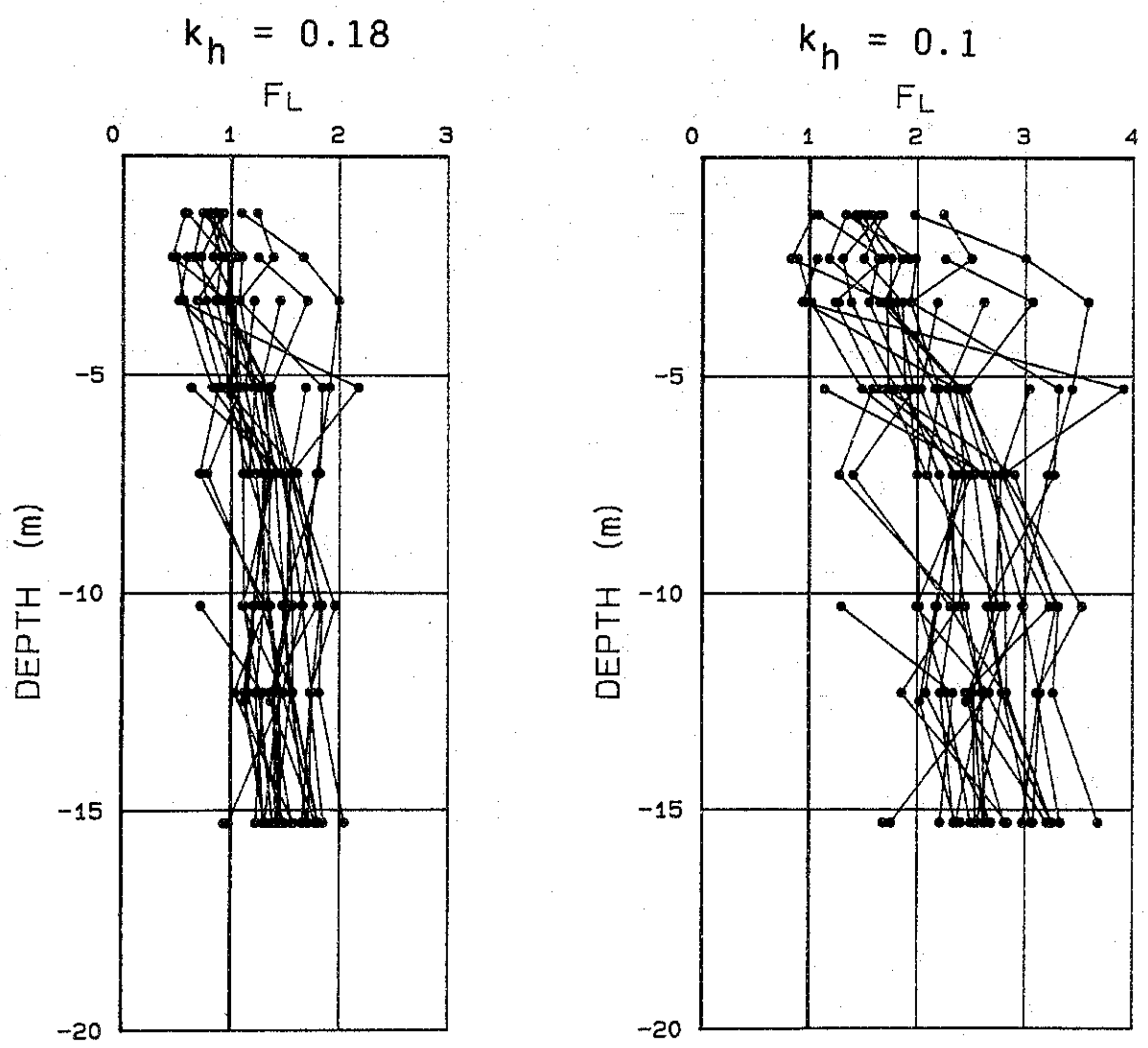


Fig. 3.6 DISTRIBUTION OF RESISTANCE FACTOR AGAINST LIQUEFACTION FL (AL1 - AL26) $\Delta P = 0$

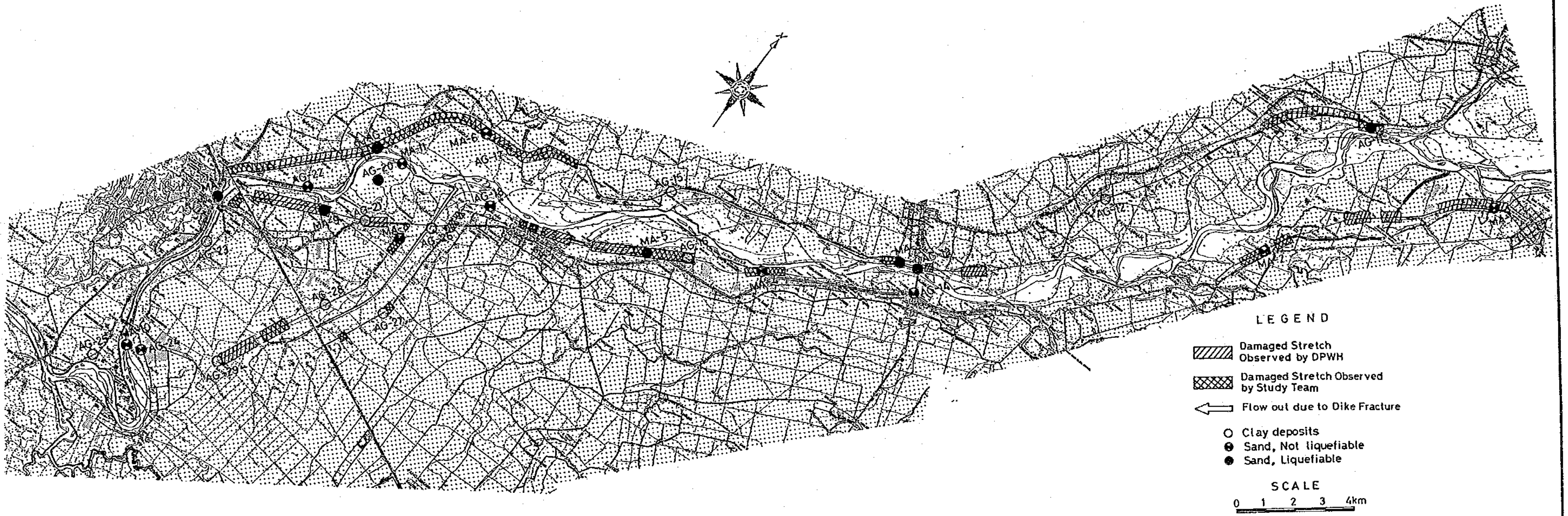


Fig. 3.7 LIQUEFACTION POSSIBILITY IN THE MIDDLE AGNO RIVER (k_h = 0.18, ΔP = 0)

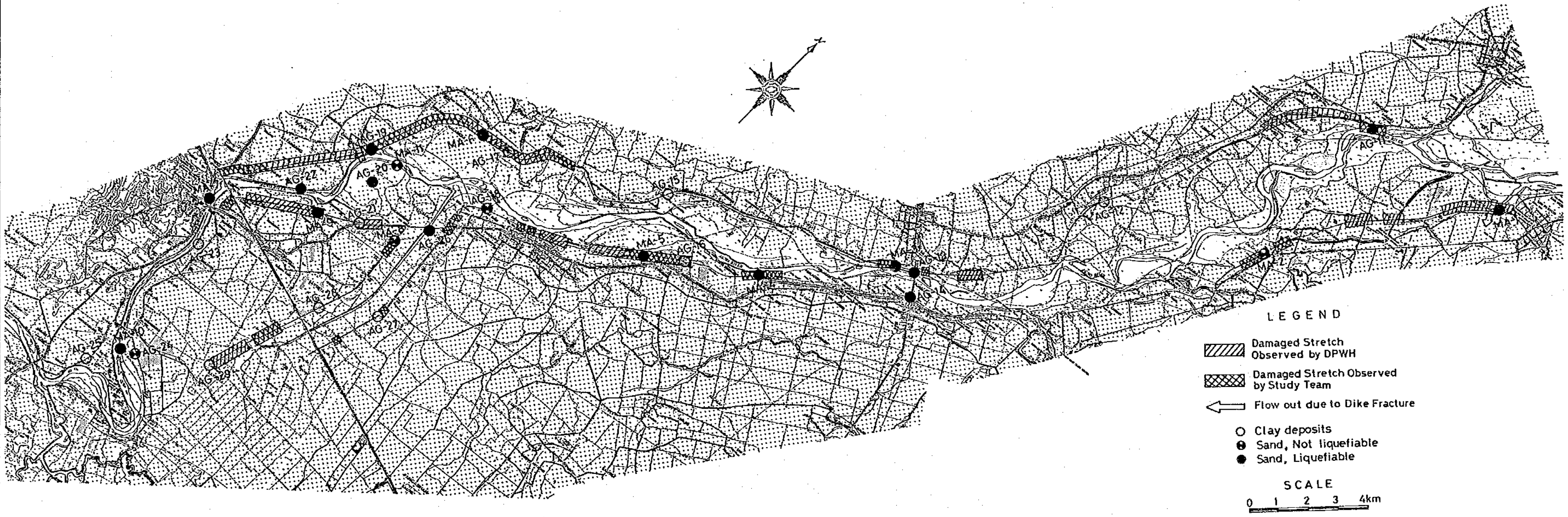


Fig. 3.8 LIQUEFACTION POSSIBILITY IN THE MIDDLE AGNO RIVER
(k_h = 0.18, ΔP = 4 tf/m2)

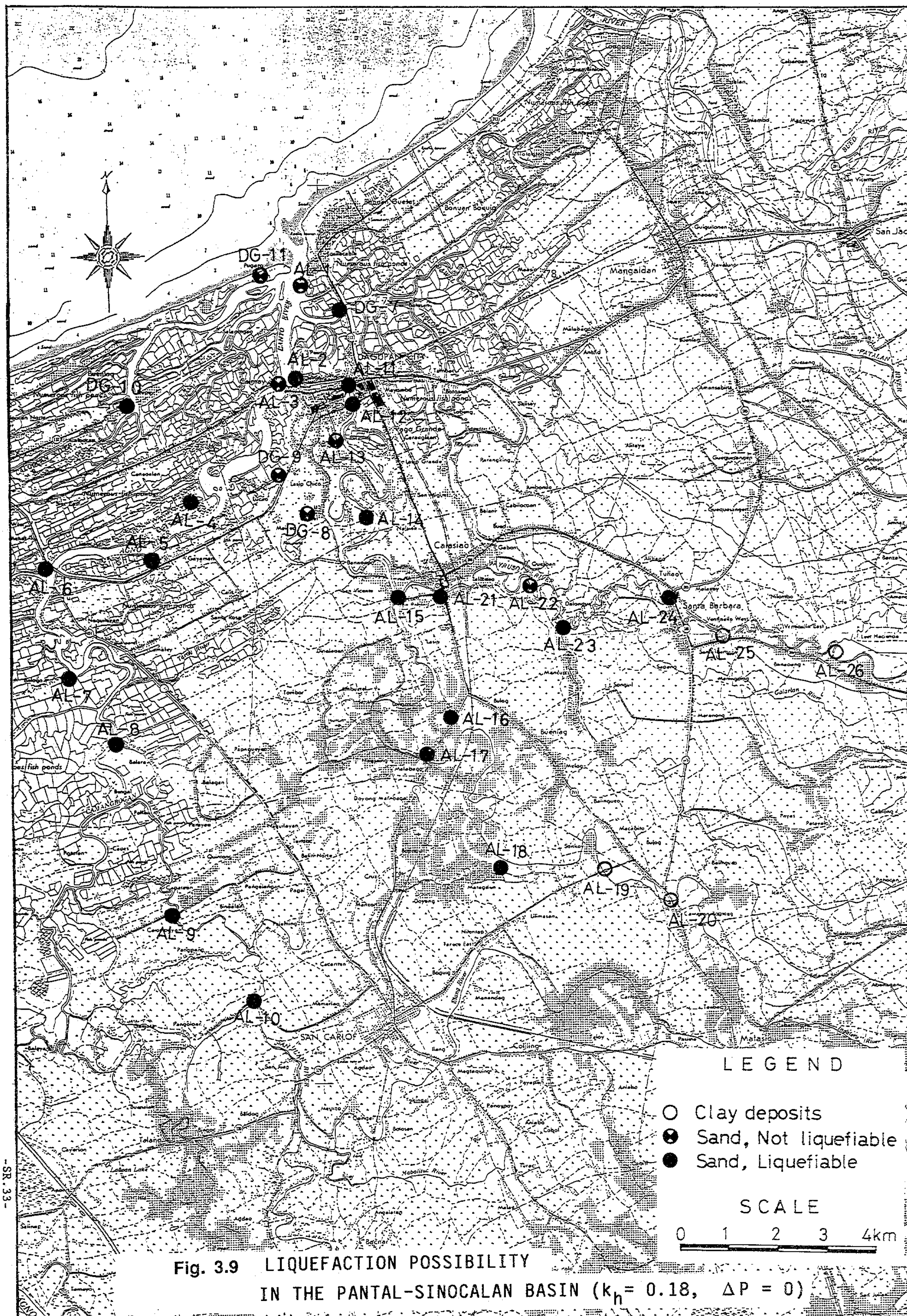


Fig. 3.9 LIQUEFACTION POSSIBILITY IN THE PANTAL-SINOCALAN BASIN ($k_h = 0.18$, $\Delta P = 0$)

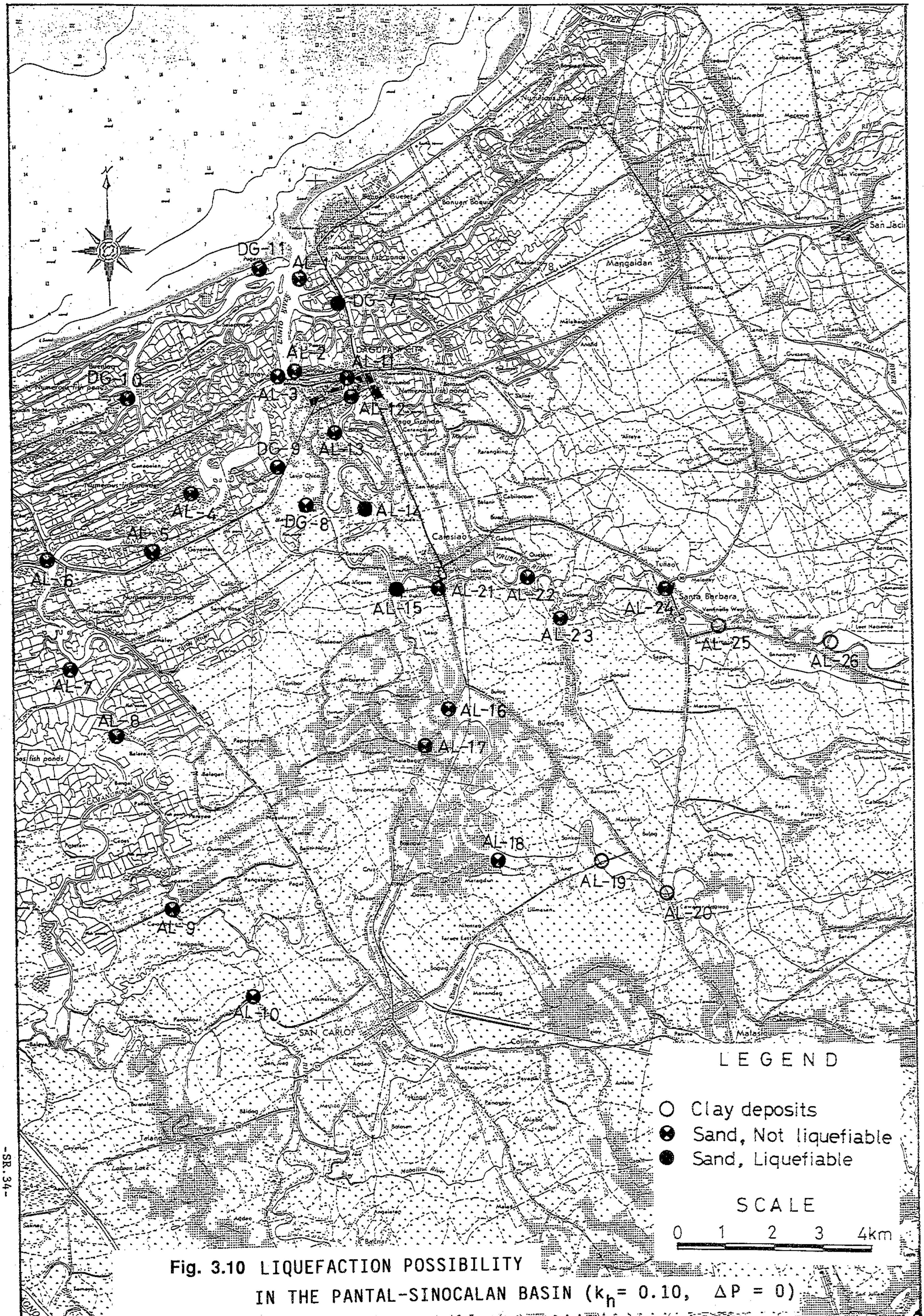


Fig. 3.10 LIQUEFACTION POSSIBILITY IN THE PANTAL-SINOCALAN BASIN ($k_h = 0.10$, $\Delta P = 0$)

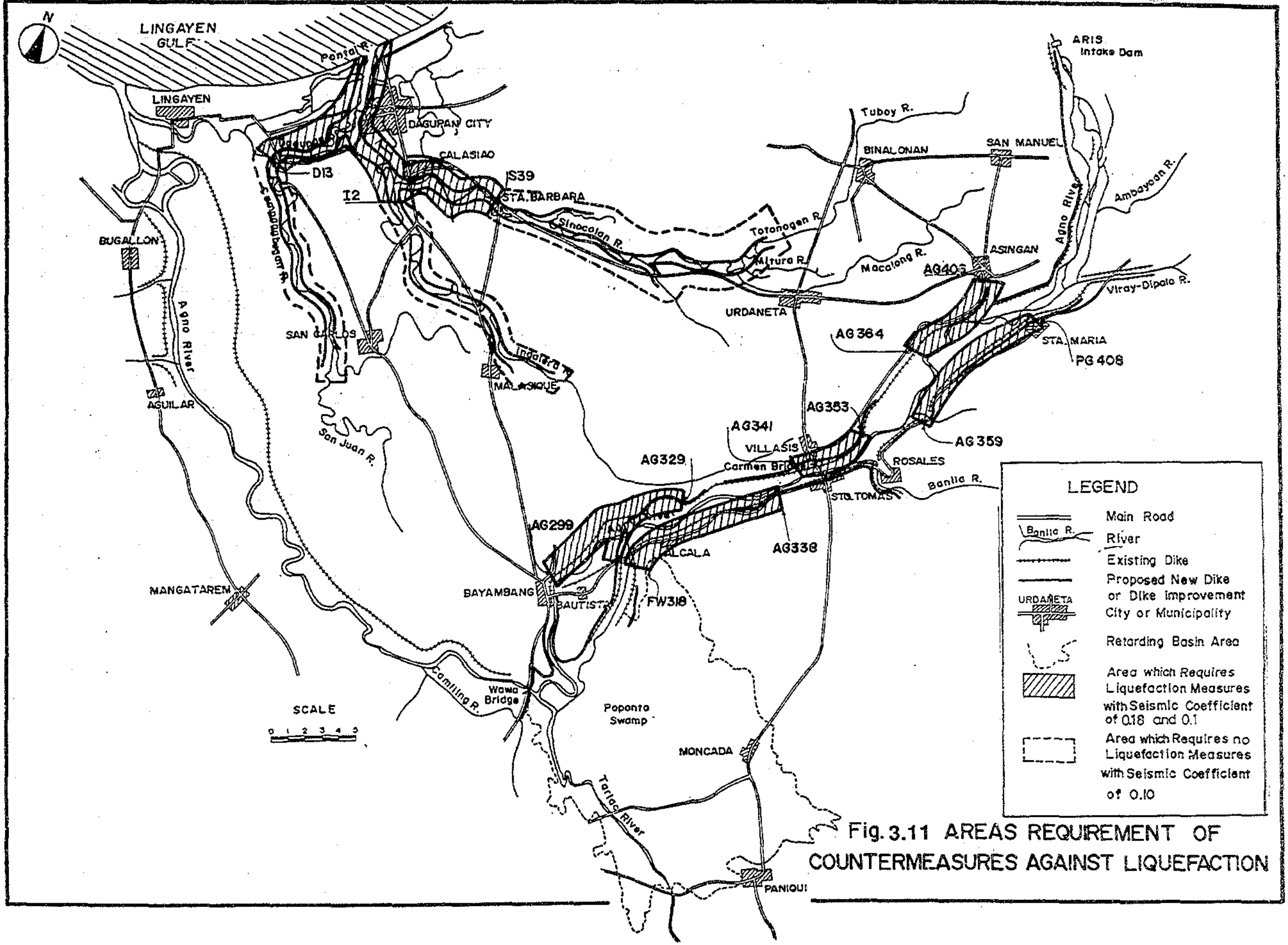
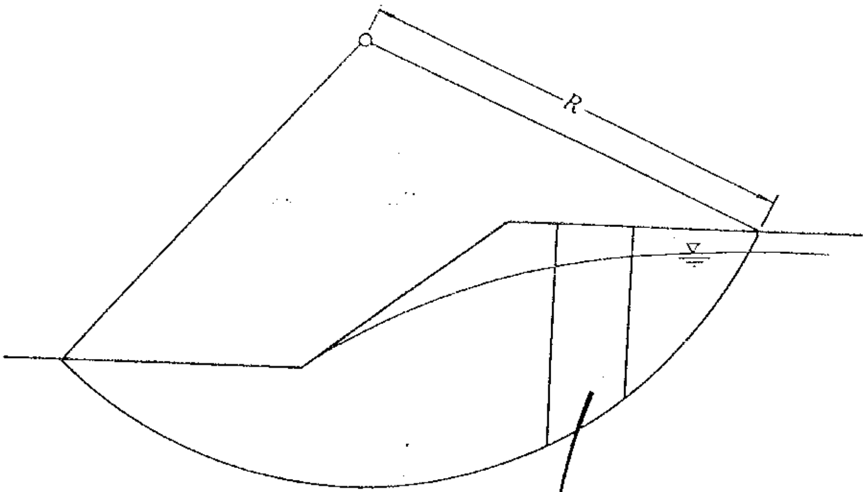
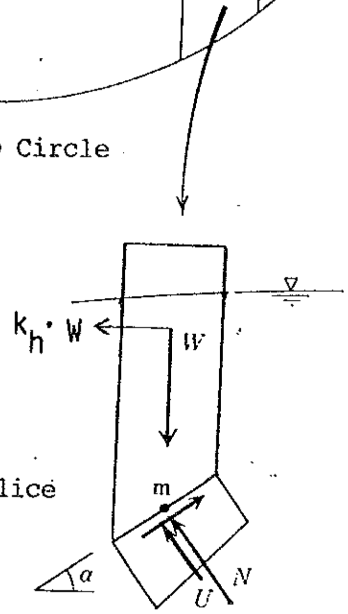


Fig. 3.11 AREAS REQUIREMENT OF COUNTERMEASURES AGAINST LIQUEFACTION



(a) Slip Circle

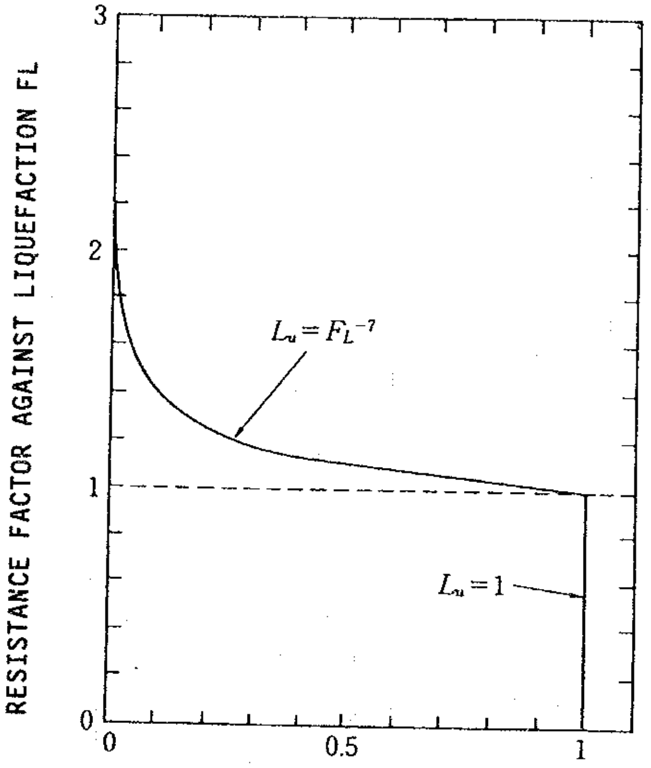


(b) Appling Forces on a Slice

$$Fs = \frac{\Sigma R(c \cdot l + ((W-(U1+U2) \cdot b)\cos\alpha - k_h \cdot W \cdot \sin\alpha)\tan\phi)}{\Sigma(R \cdot W\sin\alpha + k_h \cdot W \cdot y)}$$

Where
- Fs : Safty Factor
- R : Radius of Slip Circle
- W : Weight of Each Slice
- U1 : Hydrostatistic pressure
- U2 : Excess Pore Water Pressure on Slip Surface
- k_h : Design Seismic Coefficient
- b : Width of Each Slice
- y : Vertical Distance from the Center of Slip Circle to the Centroid of Each Slice
- l : Length of Slip Circle
- c : Cohesion of soil
- ϕ : Internal Friction of soil

Fig. 4.1 STABILITY ANALYSIS METHOD



EXCESS PORE WATER PRESSURE RATIO $Lu = \frac{\Delta u}{\sigma ' v}$

(Specifications for Highway Bridges
edited in 1990, Japan Road Association)

Fig. 4.2 FL - Lu RELATION

Material No.	Density (t/m³)	C (tf/m²)	ϕ (degree)	Excess Pore Water Pressure Ratio After Liquefaction
0	2.00	0	35	0
1	1.95	0	25	0.5
2	1.95	0	25	0.3
3	1.95	0	25	0.5
4	1.95	0	25	0.8
5	2.00	1	30	0

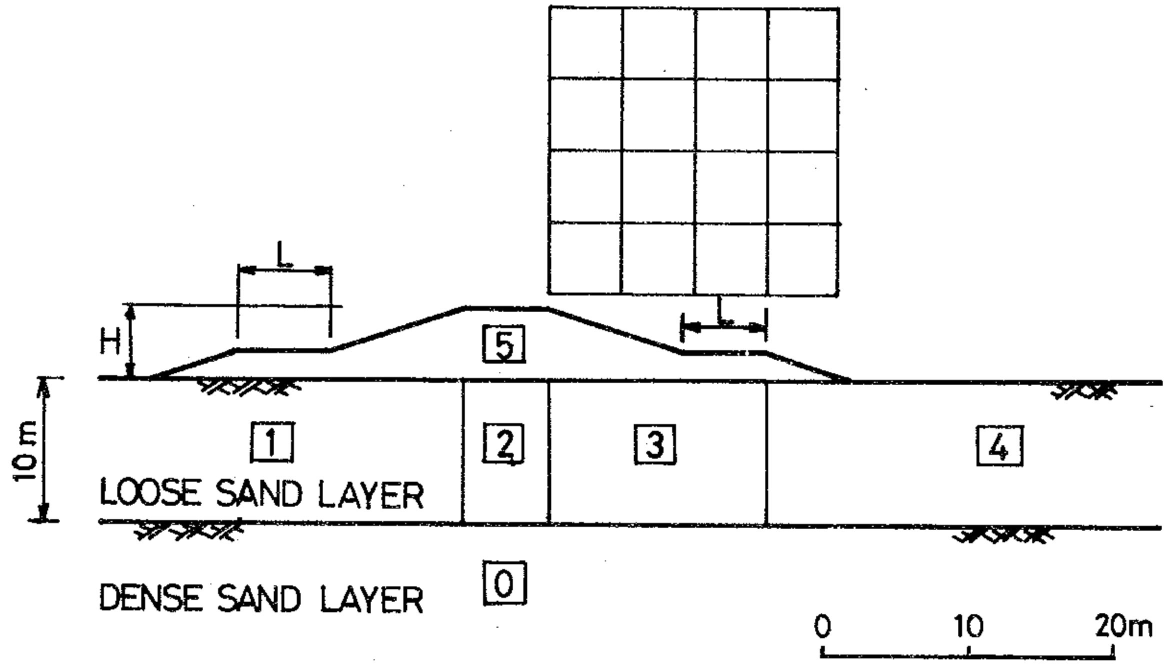


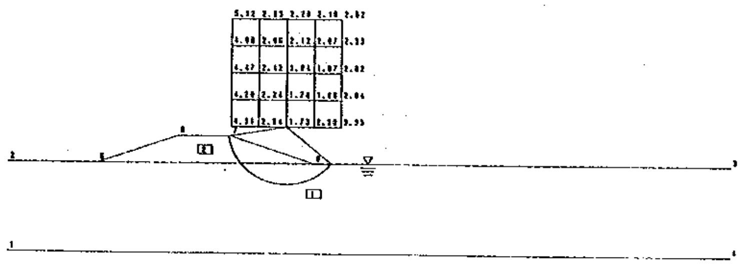
Fig. 4.3 CONDITION OF STABILITY ANALYSIS

Case: MA-H3-CO-NON

Scale: 1 / 400

Fs min = 1.73
Mr = 126.02 (T*M)
Mo = 72.78 (T*M)

Layer No.	γ_{sat} (tf/m³)	γ_t (tf/m³)	Seismic intensity	C (tf/m²)	ϕ (degree)
1	1.95	1.95	0.000	0.0	25.0
2	2.00	2.00	0.000	1.0	30.0

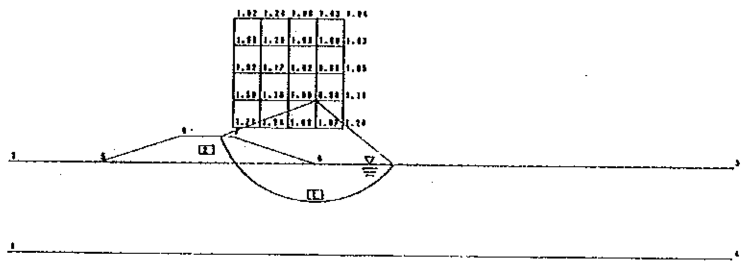


Case: MA-H3-CO-NON

Scale: 1 / 400

Fs min = 0.98
Mr = 378.60 (T*M)
Mo = 383.03 (T*M)

Layer No.	γ_{sat} (tf/m³)	γ_t (tf/m³)	Seismic intensity	C (tf/m²)	ϕ (degree)
1	1.95	1.95	0.180	0.0	25.0
2	2.00	2.00	0.180	1.0	30.0



Case: MA-H3-CO-LIQ

Scale: 1 / 400

Fs min = 0.76
Mr = 120.53 (T*M)
Mo = 157.12 (T*M)

Layer No.	γ_{sat} (tf/m³)	γ_t (tf/m³)	Seismic intensity	C (tf/m²)	ϕ (degree)
1	1.95	1.95	0.000	0.0	13.1
2	1.95	1.95	0.000	0.0	18.1
3	1.95	1.95	0.000	0.0	13.1
4	1.95	1.95	0.000	0.0	5.3
5	2.00	2.00	0.000	1.0	30.0

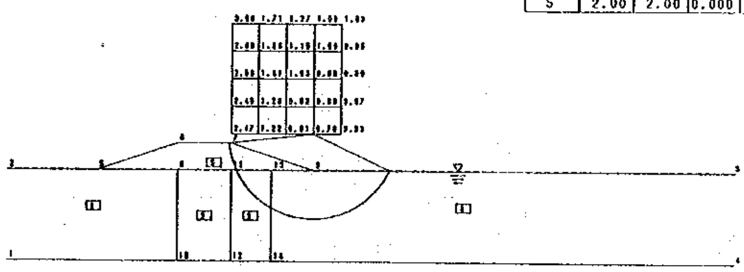


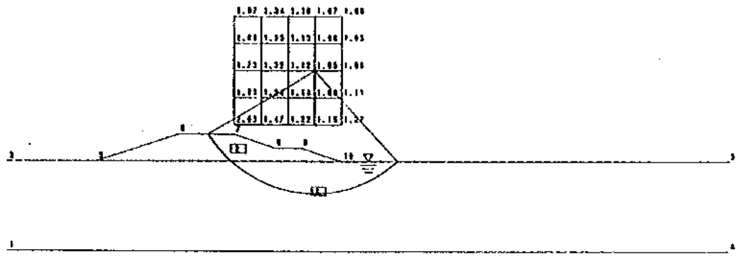
Fig. 4.4 AN EXAMPLE OF STABILITY ANALYSIS (WITHOUT COUNTERWEIGHT)

Case: MA-H3-C3-NON

Scale: 1 / 400

Fs MIN = 1.05
MR = 551.25 (T*M)
MO = 522.77 (T*M)

Layer No.	γ_{sat} (tf/m³)	γ_t (tf/m³)	Seismic Intensity	C (tf/m²)	φ (degree)
1	1.95	1.95	0.180	0.0	25.0
2	2.00	2.00	0.180	1.0	30.0

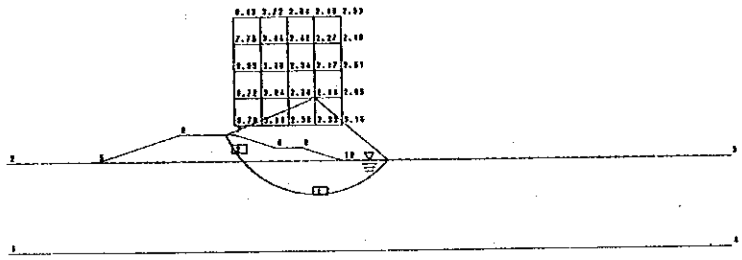


Case: MA-H3-C3-NON

Scale: 1 / 400

Fs MIN = 2.14
MR = 378.44 (T*M)
MO = 176.21 (T*M)

Layer No.	γ_{sat} (tf/m³)	γ_t (tf/m³)	Seismic Intensity	C (tf/m²)	φ (degree)
1	1.95	1.95	0.000	0.0	25.0
2	2.00	2.00	0.000	1.0	30.0



Case: MA-H3-C3-LIQ

Scale: 1 / 400

Fs MIN = 0.94
MR = 158.35 (T*M)
MO = 166.74 (T*M)

Layer No.	γ_{sat} (tf/m³)	γ_t (tf/m³)	Seismic Intensity	C (tf/m²)	φ (degree)
1	1.95	1.95	0.000	0.0	13.1
2	1.95	1.95	0.000	0.0	18.1
3	1.95	1.95	0.000	0.0	13.1
4	1.95	1.95	0.000	0.0	5.3
5	2.00	2.00	0.000	1.0	30.0

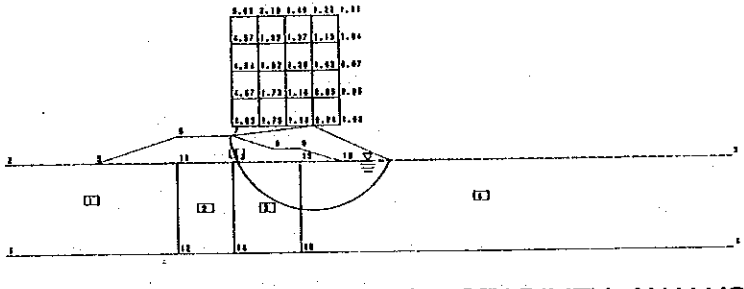


Fig. 4.5 AN EXAMPLE OF STABILITY ANALYSIS (WITH COUNTERWEIGHT)

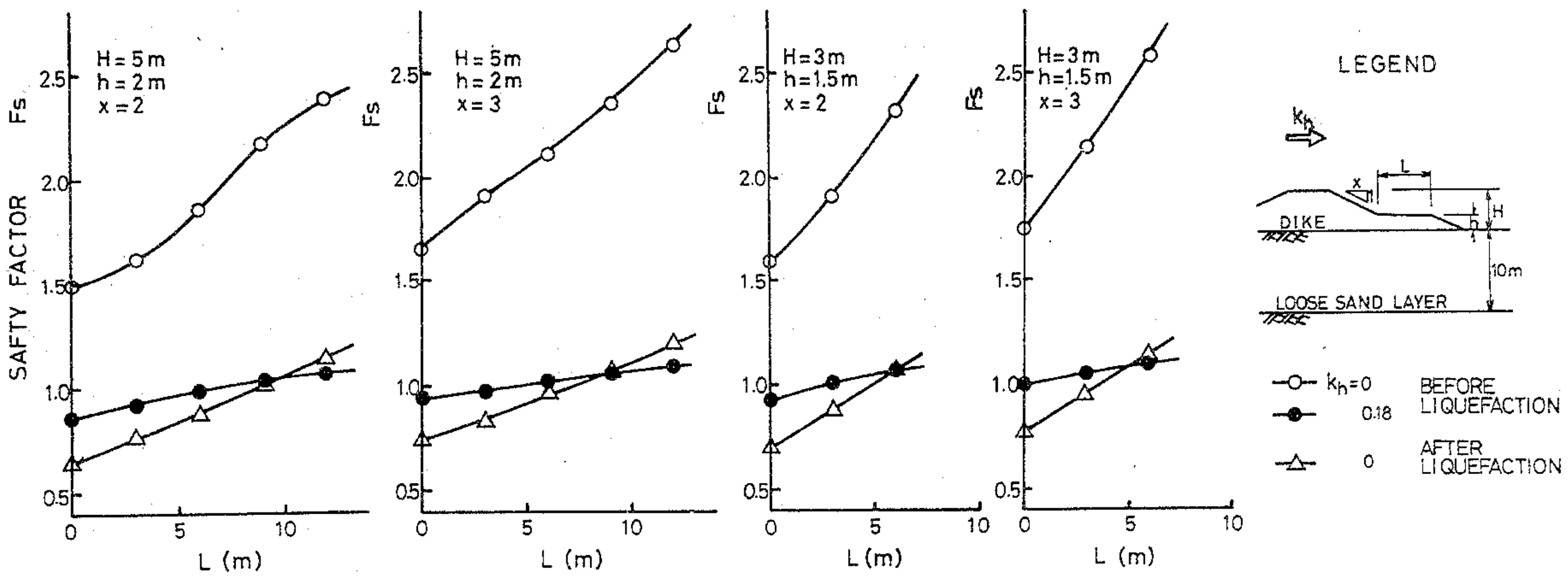


Fig. 4.6 FS - LENGTH OF COUNTERMEASURE RERATION

6. SV

6. SV SURVEY

SV : SURVEY

TABLE OF CONTENTS

1. INTRODUCTION

Additional topographic mapping was carried out by the aerial photogrammetric method using the aerial photographs taken in 1989.

The materials of aerial photography for the mapping are under the control of Armed Forces of Philippines, after the second mapping work which was executed in Japan in 1990 (fiscal year).

Any application of aerial photography is impossible without security clearance by G.H.Q. and without the presence of security officer(s).

Thus this mapping work was executed in Philippine by the local surveyor, F.F. CRUZ & Co. Inc. entrusted by JICA in accordance with the contract dated on May 16, 1991.

2. SCOPE OF WORKS

The quantity of topographic mapping is as follows:

(1) Mapping area

. Upper Agno River area	10.5 Km^2
- right bank area of Asingan-San Manuel stretch	
- left bank area of San Vicente stretch	
. Pantal-Sinocalan River area	1.5 Km^2
- Dagupan by-pass area	
Total	12.0 Km^2

(2) Original drawing sheets : 14 sheets

3. SURVEY PROCESSES

The topographic mapping consists of following processes:

(1) Plotting
(2) Editing
(3) Drawing

Necessary data and source materials for the mapping were prepared by the Study Team as follows:

(1)	Results of the aerial triangulation	1 set
(2)	Contact photographs on which control points, pass points, tieing points or the others are indicated	1 set
(3)	Positive films for plotting	1 set
(4)	Results of control survey	1 set
(5)	Plotting sheets	1 set
(6)	Editing sheets	1 set
(7)	Original drawing sheets	1 set

The materials mentioned above, contact photographs, positive films and results of control survey are under the control of the Government of Philippines. The necessary procedures for the permission of usage in mapping, were cleared by the Study Team with the cooperation of Department of Public Works and Highways.

3.1 Plotting

Mapping scale	1/5,000
Control interval	1.0 meter
Equipment	ZEISS PLANICOMP-100

Plotting accuracy

- planimetry	0.4 mm in maximum on sheet
- spot height	0.5 m in maximum

3.2 Editing

The editing was executed without field checking.

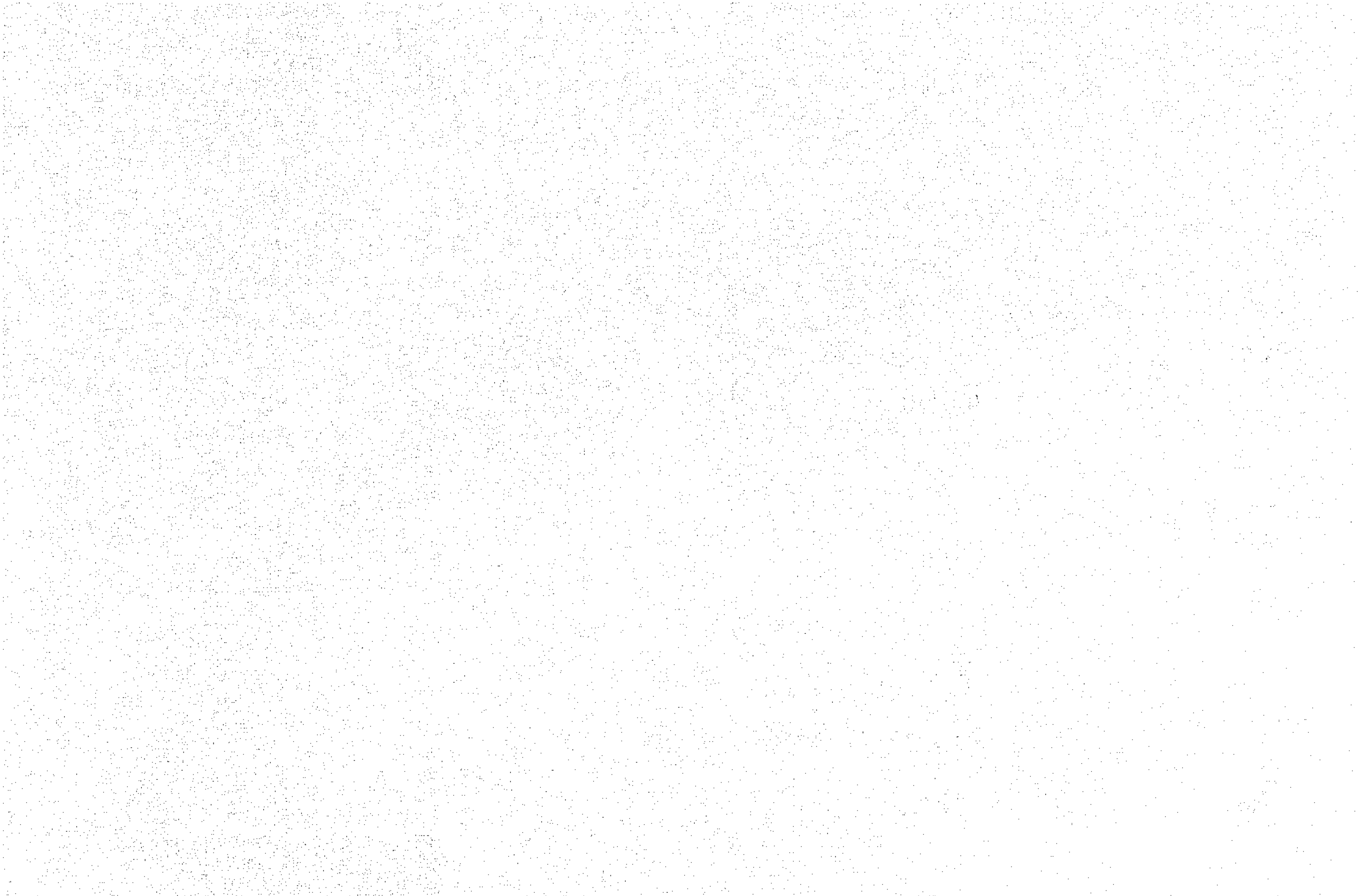
3.3 Drawing

Drawing was executed according to the legend and the symbols as same as the mapping works by JICA in 1989 and 1990.

4. SURVEY MATERIALS TO BE SUBMITTED

The following survey materials are to be submitted:

(1)	Original Drawing Map (polyester base)	1 set
(2)	Duplicated Drawing Map (polyester base)	1 set
(3)	Blue print	3 sets
(4)	Plotting sheet	1 set
(5)	Editing sheet	1 set
(6)	Orientation record	1 set
(7)	The materials to be returned to the Government of Republic Philippines	
	- Contact photographs	1 set
	- Positive films for plotting	1 set



7. FD

7. FD
FLOOD DAMAGE

SUMMARY

The flood damage analysis in this stage was conducted focussing on the maximum inundation areas of priority projects for the Feasibility Study which were identified in the Master Plan Study, namely, the Upper Agno Project and the Pantal-Sinocalan Project.

The objectives of the flood damage analysis were the additional study on the actual flooding condition in the Pantal-Sinocalan River Basin as well as the estimation of the annual average flood damage under the condition without project as the basis for the planning and the evaluation of flood control measures for two (2) projects mentioned above.

The applied procedures were the same as those used in the previous study stage which was conducted with the same purposes covering all the study area, namely all the Agno River Basin and the Allied River Basin which consists of the Pantal-Sinocalan River Basin and the Cayanga-Patalan River Basin.

The following summarizes the procedure for estimating flood damage as well as the results of this study.

(1) The flooding condition of the 1989 September flooding which occurred in the Pantal-Sinocalan River Basin due to heavy rainfall of some 5-year return period was studied as the basis to formulate the flood control measures for the Pantal-Sinocalan River.

(2) The maximum inundation area related to the Upper Agno Project has 1,264 Km^2 and extends in thirty (30) municipalities and two (2) cities, while that of the Pantal-Sinocalan Project has 879 km^2 and includes fifteen (15) municipalities and two (2) cities.

(3) Flood damage is classified into two: direct damage and indirect damage. Direct damage is the damage directly inflicted on vulnerable assets, while indirect damage is the loss due to the suspension of economic activities, additional transportation cost in taking alternative traffic routes, and costs for rescue and relief activities due to the flood.

(4) Mesh method with a size of 1 km square was applied to estimate the flood damage in the maximum inundation areas for the two (2) priority projects. The distribution of assets was estimated by counting the number and acreage of various assets using the new maps which were prepared for the Feasibility Study. The number and acreage were adjusted based on the statistical data published by the related agencies.

(5) The unit value of each asset used in this study is the same as that applied in the previous study except for those of houses/buildings in Dagupan City and Calasiao in which their unit value is judged higher than the average in the Study Area due to wider floor space.

(6) The damage rate which shows the relationship among the degree of asset damage, depth and duration of flooding is the same as that used in the previous study, which is mainly based on similar past studies in the country.

(7) Probable damage of assets for floods with seven (7) different return periods was estimated as the product of the area/number of assets, the damageable values and the damage rate. The affected people by a 10-year return period flood are estimated at 793 thousand and 745 thousand in the maximum inundation areas for the Upper Agno Project and for the Pantal-Sinocalan Project, respectively and the damage amounts are 1,196 million Pesos and 985 million Pesos at the price level of 1989.

(8) The annual average flood damage including the indirect damage in the maximum inundation area for both the priority projects was calculated based on the probable flood damage mentioned above. The annual flood damage was estimated at about

457.7 million pesos for the area of the Upper Agno Project and 504.4 million Pesos for the area of the Pantal-Sinocalan Project at the price level of 1989.

SECTORAL REPORT OF FEASIBILITY STUDY

FD: FLOOD DAMAGE ANALYSIS

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ABBREVIATIONS

1. PHILIPPINE GOVERNMENT AGENCIES

AFCS	Agno River Flood Control
ARIS	Agno River Irrigation System
BAS	Bureau of Agricultural Statistics
BFAR	Bureau of Fishery and Aquatic Resources
BSWM	Bureau of Soils and Water Management
DA	Department of Agriculture
DENR	Department of Environment and Natural Resources
DND	Department of National Defense
DOTC	Department of Transportation and Communications
DPWH	Department of Public Works and Highways
DPWH-PMO	DPWH Project Management Office
GOP	Government of the Philippines
LATRIS	Lower Agno and Totonogen River Irrigation System
LWUA	Local Water Utilities Administration
NAPOCOR	National Power Corporation
NAMRIA	National Mapping and Resource Information Authority
NEDA	National Economic Development Authority
NIA	National Irrigation Administration
OCD	Office of Civil Defense
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PENRO	Provincial Environment and Natural Resources Office
PNRC	Philippine National Red Cross
PNR	Philippine National Railways
SMORIS	San Miguel - O'Donnell River Irrigation System

2. JAPANESE GOVERNMENT AGENCIES AND OTHER ORGANIZATIONS

GOJ	Government of Japan
JICA	Japan International Cooperation Agency
MOC	Ministry of Construction, Japan
OECF	Overseas Economic Cooperation Fund, Japan
UN	United Nations

3. UNITS OF MEASUREMENT

(Length)

mm	millimeter(s)
cm	centimeter(s)
m	meter(s)
km	kilometer(s)

(Weight)

gr(grs)	gramme(s)
kg(kgs)	kilogramme(s)
ton(s)	ton(s), eq'vt to 1,000 kg

(Area)

mm^2	square millimeter(s)
cm^2	square centimeter(s)
m^2	square meter(s)
km^2	square kilometer(s)
ha(has)	hectare(s)

(Time)

sec	second(s)
min	minute(s)
hr(hrs)	hour(s)
dy(dys)	day(s)
mth(mths)	month(s)
yr(yrs)	year(s)

(Volume)

cm^3	cubic centimeter(s)
m^3	cubic meter(s)
ltr	liter(s)