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APPENDIX A

Bore hole data

SITE	GROUND LEVEL	DEPTH OF BOREHOLE	BOREHOLE NO.
Prachinburi — Khao yai Road k.m. 12+658 — 12+765	99.98 m.	5.00 m.	DH1
LOCATION OF BOREHOLE	**BORING START**	**BORING COMPLETE**	
k.m. 12+755 offset ℄ 2.0 m.L	99.98 m.	94.98 m	

LOG	DEPTH m	DESCRIPTION OF STRATA	WATER CONTENT % (10, 20)	N - VALUES (10, 20)	AVERAGE VALUES
	0	Grayish white, loose to medium clayey sand with gravel and large angular cobbles and boulders of sandstone exceed 30%			Medium sand w = 17.5 % moist
	2				
	▽ 96.58				Loose sand w = 20.1 % wet to v. wet
	4				
	94.98				
	6				
	8				
	10				

Explanation

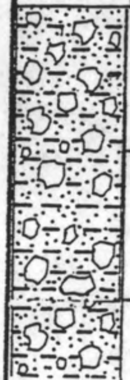
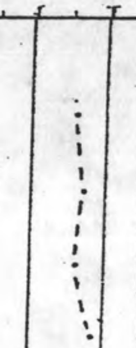
- Filled materials
- Filled materials, derived form colluvium
- Colluvium
- Residual soil

Remarks

- ground water level at first encountered
- artesian aquifer
- original ground surface

Date of boring	Scale
11/11/83	1:100

SITE	GROUND LEVEL	DEPTH OF BOREHOLE	BOREHOLE NO.
Prachinburi — Khao yai Road k.m. 12+658 — 12+765	99.94 m	5.00 m	**DH2**
LOCATION OF BOREHOLE	**BORING START**	**BORING COMPLETE**	
k.m. 12+738 offset ℄ 15 m. R	99.94 m	94.94 m	

LOG	DEPTH m	DESCRIPTION OF STRATA	WATER CONTENT % (10, 20)	N – VALUES (10, 20)	AVERAGE VALUES
	0 2 4 ▼ 95.94 94.94	Grayish white, loose to medium clayey sand with gravel and large angular cobbles and boulders of sandstone exceed 30%			Medium sand w = 15.6 % moist Loose sand w = 16.6 % moist Medium sand w = 19.8 % wet to v. wet
	6 8 10				

Explanation

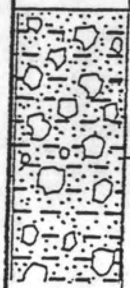
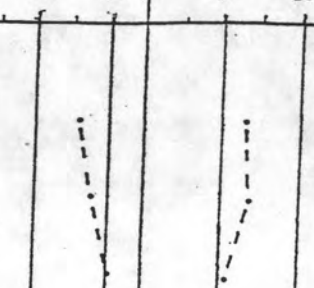
- Filled materials
- Filled materials, derived form colluvium
- Colluvium
- Residual soil

Remarks

- ▽ ground water level at first encountered
- ▼ artesian aquifer
- original ground surface

Date of boring	Scale
18/11/83	1:100

SITE	GROUND LEVEL	DEPTH OF BOREHOLE	BOREHOLE NO.
Prachinburi — Khao yai Road k.m. 12+658 — 12+765	99.94 m	3.60 m	**DH3**
LOCATION OF BOREHOLE	**BORING START**	**BORING COMPLETE**	
k.m. 12+723 offset ℄ 22.6 m R	99.94 m	96.34 m	

LOG	DEPTH m	DESCRIPTION OF STRATA	WATER CONTENT % (10, 20)	N - VALUES (10, 20)	AVERAGE VALUES
	0 2 96.94 96.34 4 6 8 10	Grayish white, loose to medium clayey sand with gravel and large angular cobbles and boulders of sandstone exceed 30%			Medium sand w = 15.8 % moist Medium sand w = 18.7 % moist

Explanation

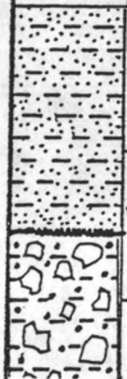
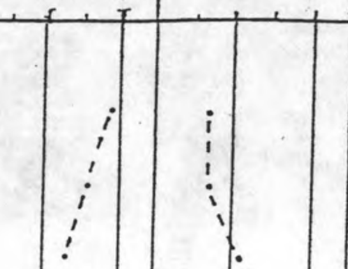
- Filled materials
- Filled materials, derived form colluvium
- Colluvium
- Residual soil

Remarks

- ▽ ground water level at first encountered
- ▼ artesian aquifer
- original ground surface

Date of boring	Scale
3/12/83	1:100

SITE	GROUND LEVEL	DEPTH OF BOREHOLE	BOREHOLE NO.
Prachinburi — Khao yai Road k.m. 12+658 — 12+765	97.39 m	5.00 m	DH4
LOCATION OF BOREHOLE	**BORING START**	**BORING COMPLETE**	
k.m. 12+733 offset ℄ 2.0 m R	97.39 m	92.39 m	

LOG	DEPTH m	DESCRIPTION OF STRATA	WATER CONTENT % (10, 20)	N – VALUES (10, 20)	AVERAGE VALUES
	0 – 94.39	Reddish brown, loose gravelly clayey sand with some rock fragments			Loose clayey sand w = 18.7 % moist
	94.39 – 92.39	Grayish white, medium clayey sand with gravel and large angular cobbles and boulders of sandstone exceed 30%			Loose to medium sand w = 14.5 % moist to wet.
	2, 4, 6, 8, 10				

Explanation

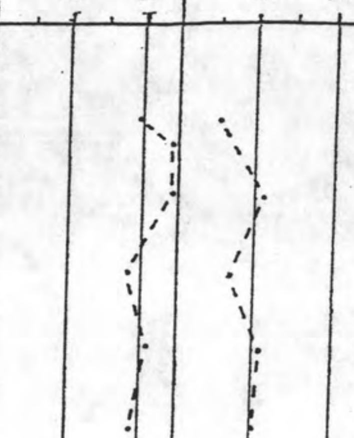
- Filled materials (Uppersoil layer)
- Filled materials, derived form colluvium (Lower soil layer)
- Colluvium
- Residual soil

Remarks

- ground water level at first encountered
- artesian aquifer
- original ground surface

Date of boring	Scale
21/11/83	1:100

SITE	GROUND LEVEL	DEPTH OF BOREHOLE	BOREHOLE NO.
Prachinburi — Khao yai Road k.m. 12+658 — 12+765	99.17 m	6.00 m	**DH5**
LOCATION OF BOREHOLE	**BORING START**	**BORING COMPLETE**	
k.m. 12+727 offset ℄ 6.5 m R	99.17 m	93.17 m	

LOG	DEPTH m	DESCRIPTION OF STRATA	WATER CONTENT % (10, 20)	N - VALUES (10, 20)	AVERAGE VALUES
	0 97.57 97.17 -2	Reddish brown, loose gravelly clayey sand with some rock fragments			Loose clayey sand w = 21.89 % moist to v. wet.
	96.17	Grayish white, loose to medium clayey sand with gravel and large angular cobbles and boulders of sandstone exceed 30%			Loose sand w = 21.00 % wet.
	-4				Medium sand w = 20.00 % wet
	93.17 -6				
	-8				
	-10				

Explanation

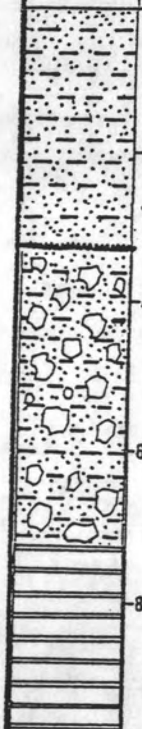
- Filled materials (Uppersoil layer)
- Filled materials, derived form colluvium (Lowersoil layer)
- Colluvium
- Residual soil

Remarks

- ▽ ground water level at first encountered
- ▼ artesian aquifer
- original ground surface

Date of boring	Scale
6/12/83	1:100

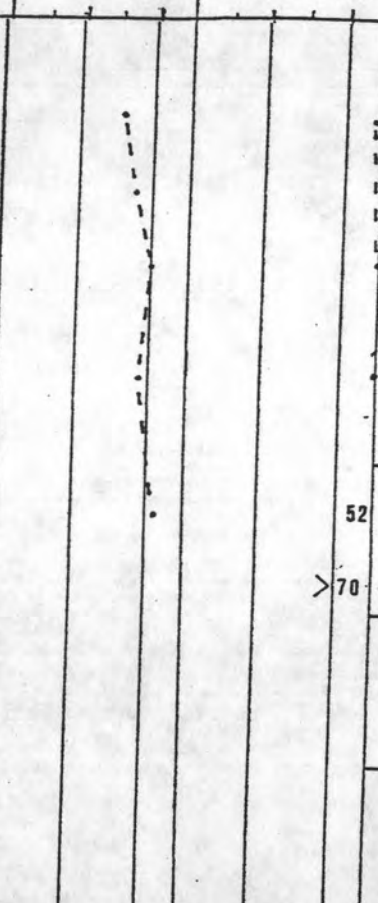
SITE	GROUND LEVEL	DEPTH OF BOREHOLE	BOREHOLE NO.
Prachinburi — Khao yai Road k.m. 12+658 — 12+765	95.00 m.	7.80 m.	**DH6**
LOCATION OF BOREHOLE	**BORING START**	**BORING COMPLETE**	
k.m. 12+706 offset ℄ 10.0 m R	95.00 m.	87.20 m.	



DEPTH m	DESCRIPTION OF STRATA	AVERAGE VALUES
0 – 93.00 / 91.80	Reddish brown, medium gravelly clayey sand with some rock fragments	Medium clayey sand w = 16.3 % moist; Medium. clayey sand w = 18.2 % moist to v. wet
91.80 – 87.80	Grayish white, medium clayey sand with gravel and large angular cobbles and boulders of sandstone exceed 30%	Medium sand w = 20.2 % wet to v. wet
87.80 / 87.20 –	Brownish red, hard mudstone, impervious layer	Medium sand hard mudstone w = 21.6 % wet, moist

Depth scale: 0, 2, 4, 6, 8, 10

WATER CONTENT % (10, 20) — N - VALUES (10, 20)



Explanation

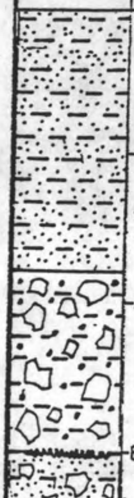
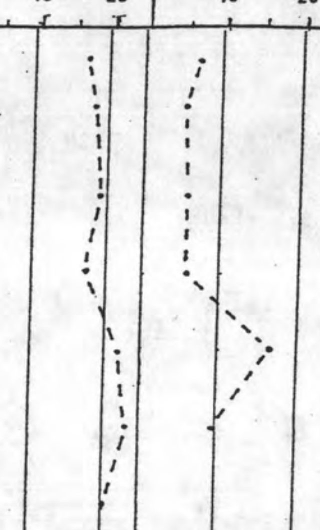
- Filled materials (Upper soil layer)
- Filled materials, derived form colluvium (Lower soil layer)
- Colluvium
- Residual soil

Remarks

- ▽ ground water level at first encountered
- ▼ artesian aquifer
- original ground surface

Date of boring	Scale
13/12/83	1:100

SITE	GROUND LEVEL	DEPTH OF BOREHOLE	BOREHOLE NO.
Prachinburi — Khao yai Road k.m. 12+658 — 12+765	97.02 m	6.60 m.	DH7
LOCATION OF BOREHOLE	**BORING START**	**BORING COMPLETE**	
k.m. 12+721 offset ℄ 5.0 m L	97.02 m	90.42 m.	

LOG	DEPTH m	DESCRIPTION OF STRATA	WATER CONTENT % (10, 20)	N - VALUES (10, 20)	AVERAGE VALUES
	0, 2, ▽ 94.02, 93.42	Reddish brown, loose gravelly clayey sand with some rock fragments			Loose clayey sand .w = 17.4 % moist to wet; Loose clayey sand .w = 18.2 % moist to wet
	4, 6 91.00, 90.42, 8, 10	Grayish white, loose to medium clayey sand with gravel and large angular cobbles and boulders of sandstone exceed 30%			Medium sand w = 22.5 % wet to v. wet

Explanation

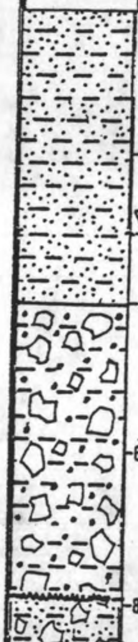
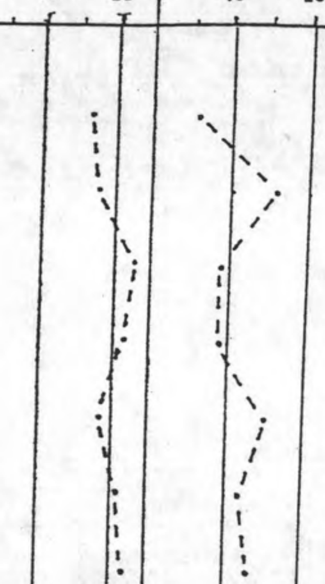
- Filled materials (Upper soil layer)
- Filled materials, derived form colluvium (Lower soil layer)
- Colluvium
- Residual soil

Remarks

- ▽ ground water level at first encountered
- ▼ artesian aquifer
- original ground surface

Date of boring	Scale
24/11/83	1:100

SITE	GROUND LEVEL	DEPTH OF BOREHOLE	BOREHOLE NO.
Prachinburi — Khao yai Road k.m. 12+658 — 12+765	97.00 m.	8.50 m.	**DH8**
LOCATION OF BOREHOLE	**BORING START**	**BORING COMPLETE**	
k.m. 12+718 offset ℄ 1.0 m L	97.00 m.	88.50 m.	

LOG	DEPTH m	DESCRIPTION OF STRATA	WATER CONTENT % (10, 20)	N – VALUES (10, 20)	AVERAGE VALUES
	0 – 94.00 – 93.00 (-4)	Reddish brown, loose gravelly clayey sand with some rock fragments			Loose clayey sand .w = 16.5 % .moist Loose clayey sand .w = 20.2 % .moist to v.wet
	93.00 – 89.10 – 88.50 (-8)	Grayish white, loose to medium clayey sand with gravel and large angular cobbles and boulders of sandstone exceed 30%			Loose to medium sand w = 20.0 % wet to v. wet Medium sand w = 21.3 % v. wet.
	-10				

Explanation

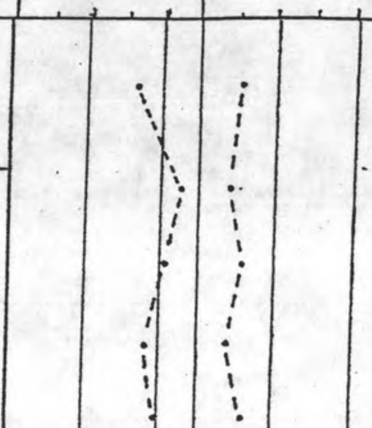
- Filled materials (Upper soil layer)
- Filled materials, derived form colluvium (Lower soil layer)
- Colluvium
- Residual soil

Remarks

- ▽ ground water level at first encountered
- ▼ artesian aquifer
- ~~~ original ground surface

Date of boring	Scale
23/11/83	1:100

SITE	GROUND LEVEL	DEPTH OF BOREHOLE	BOREHOLE NO.
Prachinburi — Khao yai Road k.m. 12+658 — 12+765	96.57 m.	6.30 m.	**DH9**
LOCATION OF BOREHOLE	**BORING START**	**BORING COMPLETE**	
k.m. 12+718 offset ℄ 5.5 m.R	96.57 m.	90.27 m.	

LOG	DEPTH m	DESCRIPTION OF STRATA	WATER CONTENT % (10, 20)	N - VALUES (10, 20)	AVERAGE VALUES
	0	Reddish brown, loose gravelly clayey sand with some rock fragments			Loose clayey sand w = 16.5 % moist
	2 94.57 93.97	Grayish white, v. loose to loose clayey sand with gravel and large angular cobbles and boulders of sandstone exceed 30%.			Very loose to loose sand w = 21.6 % wet to v. wet
	4				very loose Loose sand w = 19.0 % wet
	6 90.27				
	8				
	10				

Explanation

- Filled materials (Upper soil layer)
- Filled materials, derived form colluvium (Lower soil layer)
- Colluvium
- Residual soil

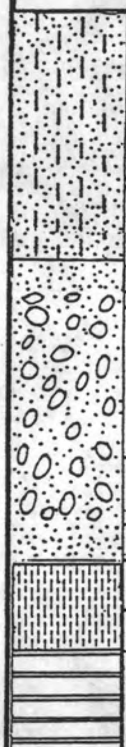
Remarks

- ground water level at first encountered
- artesian aquifer
- original ground surface

Date of boring	Scale
19/12/83	1:100

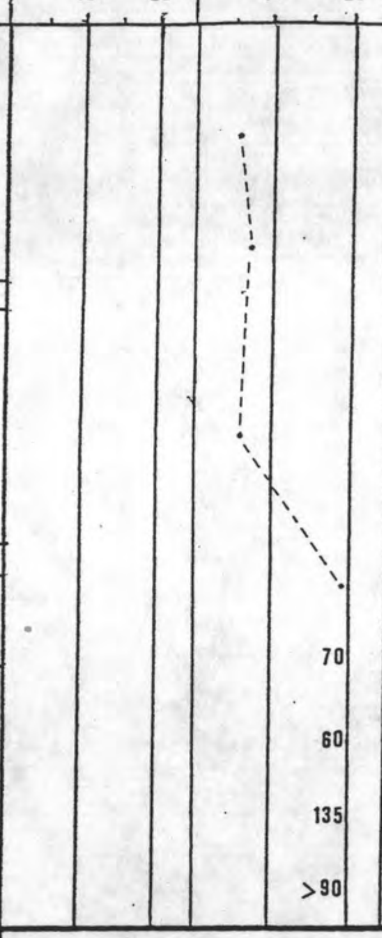
SITE	GROUND LEVEL	DEPTH OF BOREHOLE	BOREHOLE NO.
Prachinburi — Khao yai Road k.m. 12+658 — 12+765	96.20 m	12.20 m	**DH10**
LOCATION OF BOREHOLE	**BORING START**	**BORING COMPLETE**	
k.m. 12+717 offset ℄ 1.5 m L	96.20 m	84.00 m	

LOG



DEPTH m	DESCRIPTION OF STRATA	AVERAGE VALUES
0 – 92.75	Yellowish brown, Loose clayey silty fine sand with some rock fragments	Loose silty sand; Loose silty sand, sand
92.75 – 92.40	Coarse sand	
92.40 – 89.30 (ground water level 89.80)	Gravel, sand (gravel drain)	Loose gravel, sand
89.30 – 88.90	Coarse sand	Loose gravel, sand and very stiff mudstone
88.90 – 87.70	Brownish red, very stiff Shear zone, slickenside	Very stiff to hard mudstone
87.70 – 84.00	Brownish red, hard mudstone, impervious layer	Hard mudstone

WATER CONTENT % (10, 20) — N - VALUES (10, 20)



Explanation

- Filled materials
- Filled materials, derived form colluvium
- Colluvium
- Residual soil
- Gravel drain
- Fault material

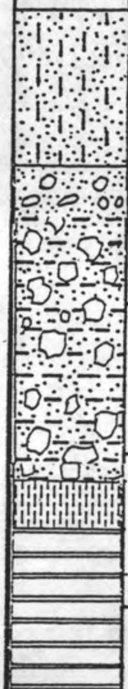
Remarks

- ▽ ground water level at first encountered
- ▼ artesian aquifer
- —— original ground surface

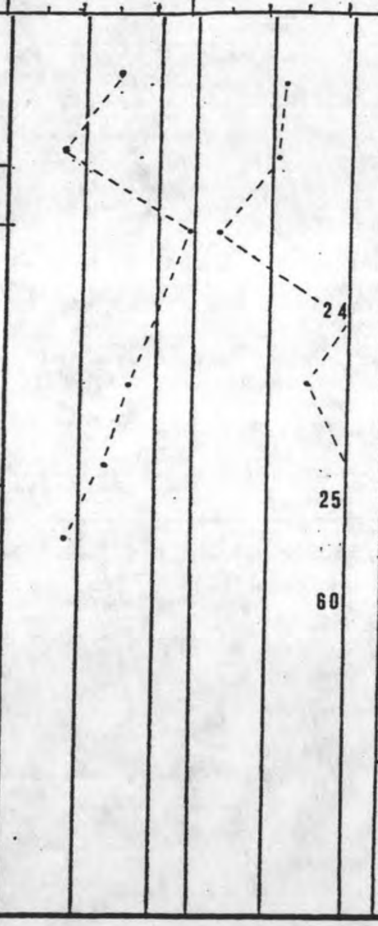
Date of boring	Scale
20/11/85	1:100

SITE	GROUND LEVEL	DEPTH OF BOREHOLE	BOREHOLE NO.
Prachinburi — Khao yai Road k.m. 12 + 658 — 12 + 765	97.56 m.	7.60 m.	**DH11**
LOCATION OF BOREHOLE	**BORING START**	**BORING COMPLETE**	
k.m. 12 + 736 offset ℄ 4.0 m R	97.56 m.	89.96 m.	

LOG	DEPTH m	DESCRIPTION OF STRATA	AVERAGE VALUES
	0	Yellowish brown, Medium clayey silty fine sand with some rock fragments	Medium silty sand w = 13 % moist
	2 — 95.46	Gravel, sand (drained layer)	very loose to loose gravel, sand wet
	94.71	Grayish white, v.loose to medium clayey sand with gravel and large angular cobbles and boulders of sandstone exceed 30%	Medium sand w = 15 % moist to wet
	6 — 91.21	Shear zone	Hard mudstone
	90.50		
	89.96	Brownish red, hard mudstone impervious layer	
	8		
	10		



WATER CONTENT % (10, 20) — N - VALUES (10, 20)



Explanation

- Filled materials
- Filled materials, derived form colluvium
- Colluvium
- Residual soil
- Gravel drain
- Fault materials

Remarks

- ▽ ground water level at first encountered
- ▼ artesian aquifer
- ——— original ground surface

Date of boring	Scale
8 / 12/85	1:100

APPENDIX B

Simple sounding penetration test's diagram

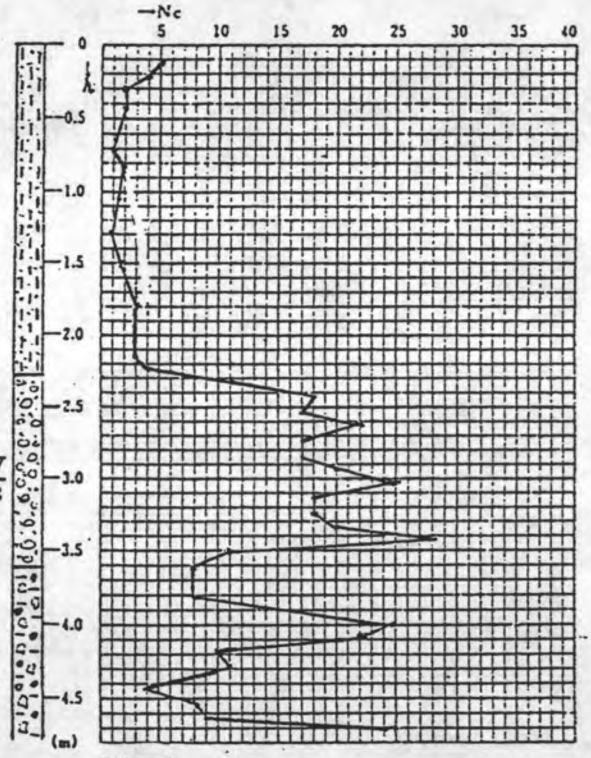
Recording Form of Simple Sounding Tester

Instrument No.

Station No.	B1	Test Location	K.M.12+722 offset ¢ 9m. Lt	Type of Soil		Testing Date	14/8/85

NOB N (Blows)	DOP h (cm)	AOP $d=h_n-h_{n-1}$	$N_c=\frac{N}{d}\times 10$
0	4		
4	12	8	5
4	21	9	4
2	30	9	2
2	42	12	2
4	61	19	2
1	71	10	1
2	82	11	2
4	108	26	2
2	130	22	1
4	153	23	2
5	166	13	4
4	179	13	3
5	200	21	2
4	213	13	3
4	224	11	4
10	233	9	11
20	244	11	18
15	255	9	17
20	264	9	22
20	273	12	17
20	285	12	17
20	295	10	20
20	303	8	25
20	314	11	18
20	325	11	18
20	335	10	20
20	342	7	28
10	351	9	11
8	361	10	8
8	371	10	8
8	381	10	8
20	392	11	18
20	400	8	3
20	409	9	22
11	419	10	11
10	428	9	11
6	442	14	4
10	454	12	8
8	463	9	9
20	471	8	25
16	480	9	18
22	488	8	28
20	495	6.5	31
20	500	5	40

Sounding diagram in the embankment



(Note) NOB ; Number of Blows
DOP ; Depth of Penetration
AOP ; Amount of Penetration

Filled materials

Upper soil layer

Gravel drain

Lower soil layer

Nc Conversion Table

N \ d	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0
1	20	10	7	5	4	3	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	40	20	13	10	8	7	6	5	4	4	4	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	1	1	1	1
3	~~60~~	30	20	15	12	10	9	8	7	6	5	5	5	4	4	4	4	3	3	3	3	3	3	2	2	2	2	2	2	2
4	~~80~~	40	27	20	16	13	11	10	9	8	7	7	6	6	5	5	5	4	4	4	4	4	3	3	3	3	3	2	3	3
5	~~100~~	50	33	25	20	17	14	13	11	10	9	8	8	7	7	6	6	6	5	5	5	5	4	4	4	4	4	3	3	3
6	~~120~~	~~60~~	40	30	24	20	17	15	13	12	11	10	9	9	8	8	7	7	6	6	6	5	5	5	5	5	4	4	4	4
8	~~160~~	~~80~~	~~53~~	40	32	27	23	20	18	16	15	13	12	11	11	10	9	9	8	8	8	7	7	7	6	6	6	6	6	5
10	~~200~~	~~100~~	~~67~~	50	40	33	29	25	22	20	18	17	15	14	13	13	12	11	11	10	10	9	9	8	8	8	7	7	7	7
15	~~300~~	~~150~~	~~100~~	~~75~~	~~60~~	50	43	38	33	30	27	25	23	21	20	19	18	17	16	15	14	14	13	12	12	12	11	11	10	10
20	~~400~~	~~200~~	~~133~~	~~100~~	~~80~~	~~67~~	~~57~~	50	44	40	36	33	31	28	27	25	24	22	21	20	19	18	17	17	16	15	15	14	14	13

How to use Nc Conversion Table:

Calculate Nc-Value when the amount of penetration is d cm by driving N number of blows

(Examle) when N is 5 number and d is 8 cm, Nc-value is 6.

Recording Form of Simple Sounding Tester

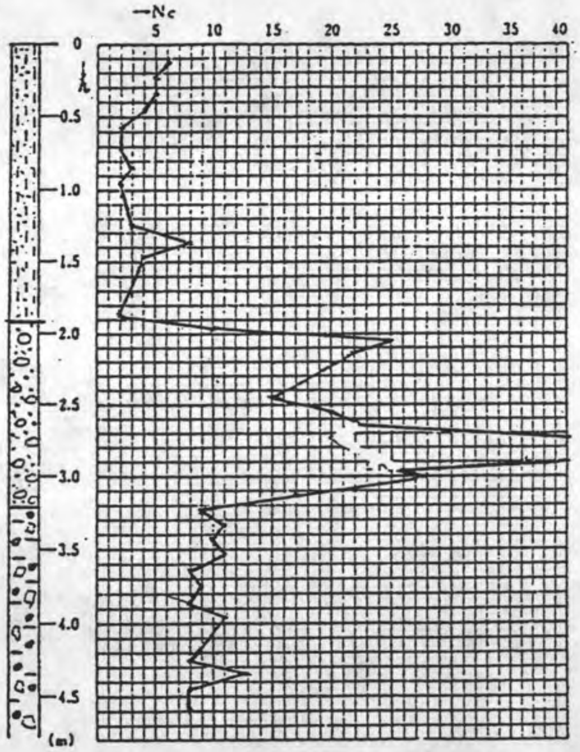
Instrument No

Station No	B-2	Test Location	K-M 13+728 offset 2M Lt	Type of Soil		Testing Date	14/8/85

NOB N (Blows)	DOP h (cm)	AOP $d = h_n - h_{n-1}$	$N_c = \frac{N}{d} \times 10$
0	4		
5	13	9	6
6	24	11	5
5	35	11	5
5	48	13	4
2	59	11	2
3	71	12	2
4	84	13	3
2	97	13	2
2	115	18	1
3	124	9	3
10	137	13	8
5	149	12	4
5	174	25	2
3	187	13	2
10	197	10	10
20	205	8	25
20	214	9	22
20	232	18	11
20	245	13	15
20	255	10	20
20	264	9	5
20	274	10	20
20	278	4	50
20	281	3	67
20	285	4	50
20	293	8	25
20	300	7	29
20	312	12	17
10	324	11	9
10	333	9	11
10	343	10	10
10	352	9	11
10	364	12	8
10	375	11	9
10	387	12	8
10	396	9	11

20	414	18	11
10	427	13	8
10	435	8	13
10	447	12	8
10	459	13	8
17	477	18	6
20	485	8	25
20	493	8	25
20	486	3	

Sounding diagram in the embankment



(Note) NOB ; Number of Blows
DOP ; Depth of Penetration
AOP ; Amount of Penetration

Filled materials — **Upper soil layer**; **Gravel drain**; **Lower soil layer**

Nc Conversion Table

N \ d	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5
1	20	10	7	5	4	3	3	3	2	2	2	2	2	1	1
2	40	20	13	10	8	7	6	5	4	4	4	3	3	3	3
3	~~60~~	30	20	15	12	10	9	8	7	6	5	5	5	4	4
4	~~80~~	40	27	20	16	13	11	10	9	8	7	7	6	6	5
5	~~100~~	50	33	25	20	17	14	13	11	10	9	8	8	7	7
6	~~120~~	~~60~~	40	30	24	20	17	15	13	12	11	10	9	9	8
8	~~160~~	~~80~~	~~53~~	40	32	27	23	20	18	16	15	13	12	11	11
10	~~200~~	~~100~~	~~67~~	50	40	33	29	25	22	20	18	17	15	14	13
15	~~300~~	~~150~~	~~100~~	~~75~~	~~60~~	50	43	38	33	30	27	25	23	21	20
20	~~400~~	~~200~~	~~133~~	~~100~~	~~80~~	~~67~~	~~57~~	50	44	40	36	33	31	28	27

N \ d	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	3	2	2	2	2	2	2	2	2	2	2	1	1	1	1
3	4	4	3	3	3	3	3	3	2	2	2	2	2	2	2
4	5	5	4	4	4	4	4	3	3	3	3	3	2	3	3
5	6	6	6	5	5	5	5	4	4	4	4	4	3	3	3
6	8	7	7	6	6	6	5	5	5	5	5	4	4	4	4
8	10	9	9	8	8	8	7	7	7	6	6	6	6	6	5
10	13	12	11	11	10	10	9	9	8	8	8	7	7	7	7
15	19	18	17	16	15	14	14	13	12	12	12	11	11	10	10
20	25	24	22	21	20	19	18	17	17	16	15	15	14	14	13

How to use Nc Conversion Table;

Calculate Nc−Value when the amount of penetration is d cm by driving N number of blows

(Examle) when N is 5 number and d is 8 cm, Nc-value is 6.

Recording Form of Simple Sounding Tester

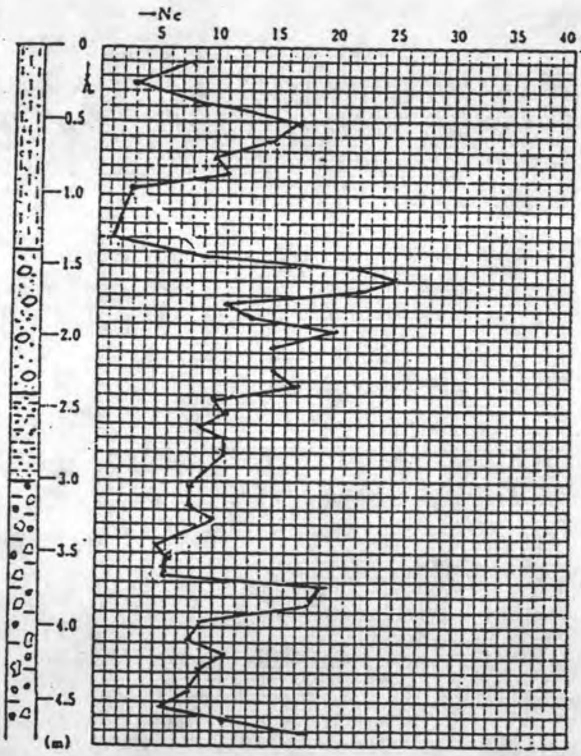
Instrument No.

Station No.	B3	Test Location	K.M.12+736 offset ¢ 5M Rt	Type of Soil		Testing Date	14/8/85

NOB N (Blows)	DOP h (cm)	AOP $d = h_n - h_{n-1}$	$N_c = \frac{N}{d} \times 10$
0	4		
10	17	13	8
3	26	9	3
10	39	13	8
20	51	12	17
20	64	13	15
10	75	11	9
10	84	9	11
3	95	11	3
3	131	36	1
10	142	11	9
20	151	9	22
20	159	8	25
20	168	9	22
10	177	9	11
10	185	8	13
20	195	10	20
20	208	13	15
20	221	13	15
20	233	12	17
10	243	10	10
10	252	9	11
10	263	11	9
10	272	9	11
10	281	9	11
10	292	11	9
10	304	12	8
10	316	12	8
10	326	10	10
10	346	20	5
5	355	9	6
6	366	11	6
15	374	8	19
20	385	11	18
10	396	11	9
10	409	13	8
10	418	9	11

10	430	11	9
10	442	12	8
7	452	10	7
10	461	9	11
20	472	11	18
20	486	14	14

Sounding diagram in the embankment



Filled materials — **Upper soil layer**

Gravel drain

Upper soil layer

Lower soil layer

(Note) NOB ; Number of Blows
DOP ; Depth of Penetration
AOP ; Amount of Penetration

Nc Conversion Table

	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0
1	20	10	7	5	4	3	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	40	20	13	10	8	7	6	5	4	4	4	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	1	1	1	1
3	~~60~~	30	20	15	12	10	9	8	7	6	5	5	5	4	4	4	4	3	3	3	3	3	3	2	2	2	2	2	2	2
4	~~80~~	40	27	20	16	13	11	10	9	8	7	7	6	6	5	5	5	4	4	4	4	4	3	3	3	3	3	2	3	3
5	~~100~~	50	33	25	20	17	14	13	11	10	9	8	8	7	7	6	6	6	5	5	5	5	4	4	4	4	4	3	3	3
6	~~120~~	~~60~~	40	30	24	20	17	15	13	12	11	10	9	9	8	8	7	7	6	6	6	5	5	5	5	5	4	4	4	4
8	~~160~~	~~80~~	~~53~~	40	32	27	23	20	18	16	15	13	12	11	11	10	9	9	8	8	8	7	7	7	6	6	6	6	6	5
10	~~200~~	~~100~~	~~67~~	50	40	33	29	25	22	20	18	17	15	14	13	13	12	11	11	10	10	9	9	8	8	8	7	7	7	7
15	~~300~~	~~150~~	~~100~~	~~75~~	~~60~~	50	43	38	33	30	27	25	23	21	20	19	18	17	16	15	14	14	13	12	12	12	11	11	10	10
20	~~400~~	~~200~~	~~133~~	~~100~~	~~80~~	~~67~~	~~57~~	50	44	40	36	33	31	28	27	25	24	22	21	20	19	18	17	17	16	15	15	14	14	13

How to use .Nc Conversion Table;

Calculate Nc−Value when the amount of penetration is d cm by driving N number of blows

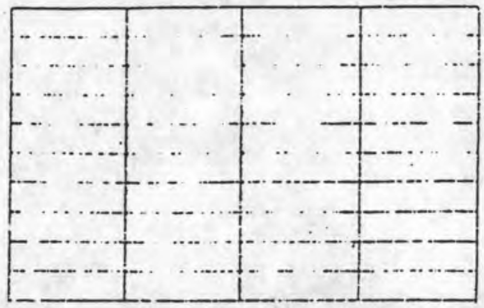
(Examle) when N is 5 number and d is 8 cm , Nc−value is 6.

Recording Form of Simple Sounding Tester

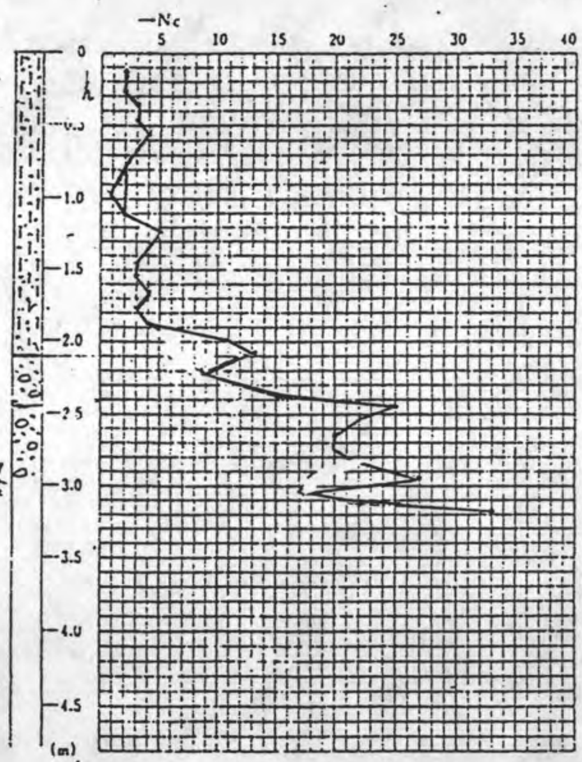
Instrument No.

Station No	B 5	Test Location	K.M. 12+714 offset of SMR	Type of Soil		Testing Date	14/8/85

NOB N (Blows)	DOP h (cm)	AOP $d = h_n - h_{n-1}$	$N_c = \frac{N}{d} \times 10$
0	4		
2	13	9	2
3	28	15	2
3	37	9	3
3	48	11	3
4	58	10	4
3	68	10	3
3	80	12	3
2	101	21	1
2	111	10	2
6	124	13	5
4	134	11	4
4	146	12	3
3	155	9	3
4	166	10	4
3	176	11	3
5	189	13	4
10	198	9	11
12	207	9	13
11	220	13	9
14	237	10	14
20	245	8	25
20	254	9	22
20	264	10	20
25	274	10	25
20	283	9	22
30	294	11	27
16	303	9	18
30	312	9	33
30	318	6	50



Sounding diagram in the embankment



(Note) NOB ; Number of Blows
DOP ; Depth of Penetration
AOP ; Amount of Penetration

Filled materials

Upper soil layer

Gravel drain

Nc Conversion Table

N \ d	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0
1	20	10	7	5	4	3	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	40	20	13	10	8	7	6	5	4	4	4	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	1	1	1	1
3	~~[illegible]~~	30	20	15	12	10	9	8	7	6	5	5	5	4	4	4	4	3	3	3	3	3	3	2	2	2	2	2	2	2
4	~~[illegible]~~	40	27	20	16	13	11	10	9	8	7	7	6	6	5	5	5	4	4	4	4	4	3	3	3	3	3	2	3	3
5	~~[illegible]~~	50	33	25	20	17	14	13	11	10	9	8	8	7	7	6	6	6	5	5	5	5	4	4	4	4	4	3	3	3
6	~~[illegible]~~	~~[illegible]~~	40	30	24	20	17	15	13	12	11	10	9	9	8	8	7	7	6	6	6	5	5	5	5	5	4	4	4	4
8	~~[illegible]~~	~~[illegible]~~	~~[illegible]~~	40	32	27	23	20	18	16	15	13	12	11	11	10	9	9	8	8	8	7	7	7	6	6	6	6	6	5
10	~~[illegible]~~	~~[illegible]~~	~~[illegible]~~	50	40	33	29	25	22	20	18	17	15	14	13	13	12	11	11	10	10	9	9	8	8	8	7	7	7	7
15	~~[illegible]~~	~~[illegible]~~	~~100~~	~~[illegible]~~	~~60~~	50	43	38	33	30	27	25	23	21	20	19	18	17	16	15	14	14	13	12	12	12	11	11	10	10
20	~~[illegible]~~	~~[illegible]~~	~~133~~	~~100~~	~~[illegible]~~	~~[illegible]~~	~~57~~	50	44	40	36	33	31	28	27	25	24	22	21	20	19	18	17	17	16	15	15	14	14	13

How to use Nc Conversion Table;

Calculate Nc−Value when the amount of penetration is d cm by driving N number of blows
(Examle) when N is 5 number and d is 8 cm , Nc−value is 6.

Recording Form of Simple Sounding Tester

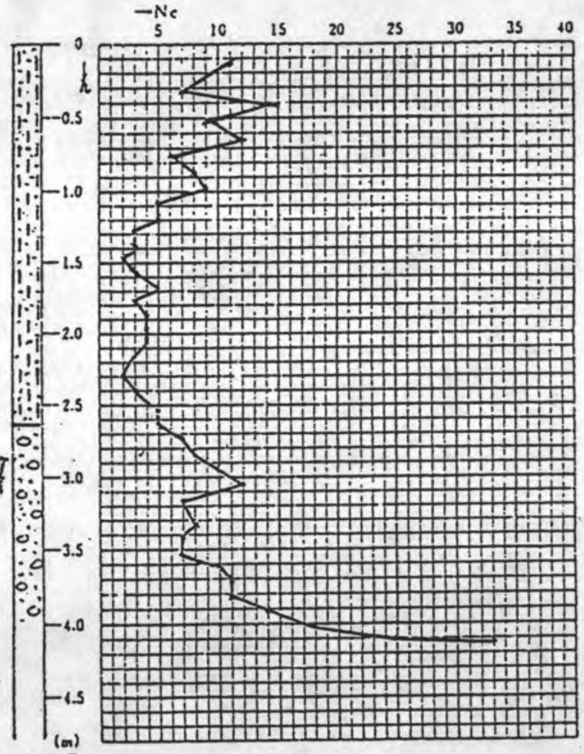
Instrument No.

Station No	B 6	Test Location	℄ K.M 12+714	Type of Soil		Testing Date	15/8/85

NOB N (Blows)	DOP h (cm)	AOP $d=h_n-h_{n-1}$	$N_c=\frac{N}{d}\times 10$
0	4		
10	13	9	11
12	31	18	7
15	41	10	15
10	52	11	11
15	65	13	12
6	75	10	6
10	88	13	8
8	99	11	7
5	109	10	5
5	120	11	5
3	129	9	3
3	139	10	3
2	148	9	2
3	159	11	3
5	169	10	5
3	178	9	3
4	187	9	4
4	197	10	4
4	207	10	4
3	218	11	3
3	230	12	2
3	240	10	3
6	252	12	5
5	263	11	5
6	272	9	7
10	285	13	8
10	295	10	10
15	307	12	12
8	319	12	7
10	332	13	8
8	383	11	7
8	354	11	7
10	364	10	10
10	373	9	11
10	382	9	11
15	393	11	14

20	A04	11	18
20	A12	8	25
10	A15	5	20
10	A17	2	50
10	A22	5	20

Sounding diagram in the embankment



(Note) NOB ; Number of Blows
DOP ; Depth of Penetration
AOP ; Amount of Penetration

Filled materials

Upper soil layer

Gravel drain

Nc Conversion Table

	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0
1	20	10	7	5	4	3	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	40	20	13	10	8	7	6	5	4	4	4	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	1	1	1	1
3	~~60~~	30	20	15	12	10	9	8	7	6	5	5	5	4	4	4	4	3	3	3	3	3	3	2	2	2	2	2	2	2
4	~~80~~	40	27	20	16	13	11	10	9	8	7	7	6	6	5	5	5	4	4	4	4	4	3	3	3	3	3	2	3	3
5	~~100~~	50	33	25	20	17	14	13	11	10	9	8	8	7	7	6	6	6	5	5	5	5	4	4	4	4	4	3	3	3
6	~~120~~	~~60~~	40	30	24	20	17	15	13	12	11	10	9	9	8	8	7	7	6	6	6	5	5	5	5	5	4	4	4	4
8	~~160~~	~~80~~	~~53~~	40	32	27	23	20	18	16	15	13	12	11	11	10	9	9	8	8	8	7	7	7	6	6	6	6	6	5
10	~~200~~	~~100~~	~~67~~	50	40	33	29	25	22	20	18	17	15	14	13	13	12	11	11	10	10	9	9	8	8	8	7	7	7	7
15	~~300~~	~~150~~	~~100~~	~~75~~	~~60~~	50	43	38	33	30	27	25	23	21	20	19	15	17	16	15	14	14	13	12	12	12	11	11	10	10
20	~~400~~	~~200~~	~~133~~	~~100~~	~~80~~	~~67~~	~~57~~	50	44	40	36	33	31	28	27	25	24	22	21	20	19	18	17	17	16	15	15	14	14	13

How to use Nc Conversion Table:

Calculate Nc-Value when the amount of penetration is d cm by driving N number of blows

(Examle) when N is 5 number and d is 8 cm , Nc-value is 6.

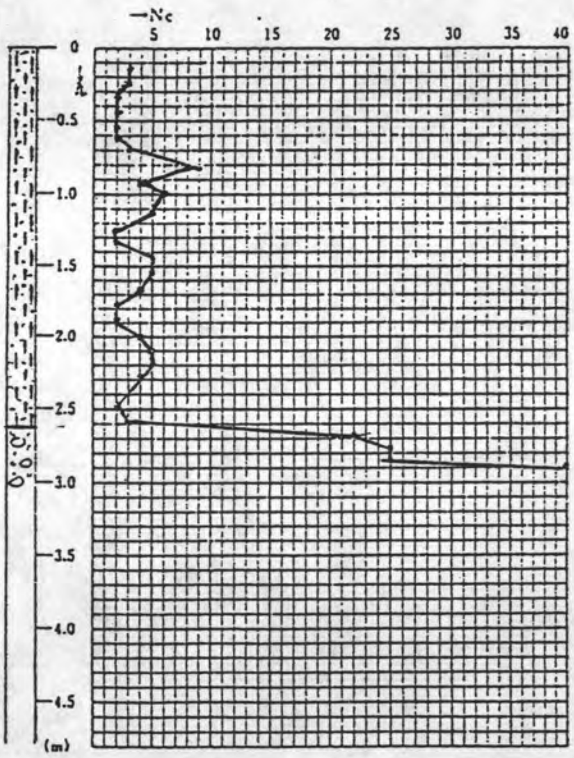
Recording Form of Simple Sounding Tester

Instrument No

Station No	B7	Test Location	K.M 12.714 offset ⊄ 3 m Lt	Type of Soil		Testing Date	15/8/85

NOB N (Blows)	DOP h (cm)	AOP $d = h_n - h_{n-1}$	$N_c = \frac{N}{d} \times 10$
0	4		
3	13	9	3
3	24	11	3
2	33	9	2
2	44	11	2
2	53	9	2
2	62	9	2
2	70	8	3
10	81	11	9
4	91	10	4
5	100	9	6
6	113	13	5
2	124	11	2
2	134	10	2
5	144	10	5
5	155	11	5
5	167	12	4
3	179	12	2
2	189	10	2
4	200	11	4
5	210	10	5
5	220	10	5
4	229	9	4
3	249	20	12
3	259	10	13
20	268	9	22
20	276	8	25
20	284	8	25
20	289	5	40

Sounding diagram in the embankment



(Note) NOB ; Number of Blows
DOP ; Depth of Penetration
AOP ; Amount of Penetration

Filled materials

Upper soil layer

Gravel drain

Nc Conversion Table

[illegible]	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0
1	20	10	7	5	4	3	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	40	20	13	10	8	7	6	5	4	4	4	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	1	1	1	1
3	~~[illegible]~~	30	20	15	12	10	9	8	7	6	5	5	5	4	4	4	4	3	3	3	3	3	3	2	2	2	2	2	2	2
4	~~40~~	40	27	20	16	13	11	10	9	8	7	7	6	6	5	5	5	4	4	4	4	4	3	3	3	3	3	2	3	3
5	~~[illegible]~~	50	33	25	20	17	14	13	11	10	9	8	8	7	7	6	6	6	5	5	5	5	4	4	4	4	4	3	3	3
6	~~[illegible]~~	~~[illegible]~~	40	30	24	20	17	15	13	12	11	10	9	9	8	8	7	7	6	6	6	5	5	5	5	5	4	4	4	4
8	~~100~~	~~[illegible]~~	~~53~~	40	32	27	23	20	18	16	15	13	12	11	11	10	9	9	8	8	8	7	7	7	6	6	6	5	6	5
10	~~200~~	~~100~~	~~67~~	50	40	33	29	25	22	20	18	17	15	14	13	13	12	11	11	10	10	9	9	8	8	8	7	7	7	7
15	~~300~~	~~150~~	~~100~~	~~76~~	~~60~~	50	43	38	33	30	27	25	23	21	20	19	18	17	16	15	14	14	13	12	12	12	11	11	10	10
20	~~400~~	~~200~~	~~133~~	~~100~~	~~80~~	~~67~~	~~57~~	50	44	40	36	33	31	28	27	25	24	22	21	20	19	18	17	17	16	15	15	14	14	13

How to use Nc Conversion Table:

Calculate Nc-Value when the amount of penetration is d cm by driving N number of blows

(Examle) when N is 5 number and d is 8 cm , Nc-value is 6.

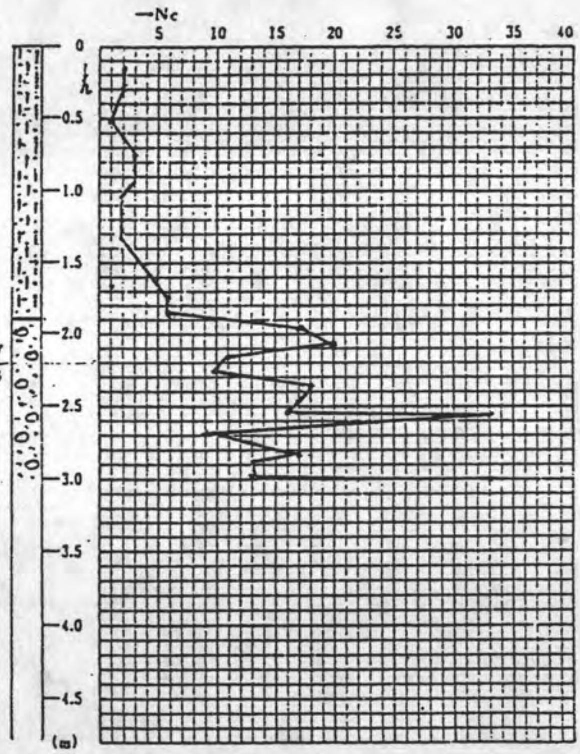
Recording Form of Simple Sounding Tester

Instrument No

Station No	B 8	Test Location	K.M 12.714 offset + 16 M Lt	Type of Soil		Testing Date	15/8/85

NOB N (Blows)	DOP h (cm)	AOP $d = h_n - h_{n-1}$	$N_c = \frac{N}{d} \times 10$
0	A		
2	17	13	2
2	30	13	2
1	51	21	1
2	60	13	2
3	75	11	3
3	85	10	3
3	94	9	3
2	104	10	2
2	116	12	2
3	136	20	2
2	166	30	1
6	176	10	6
6	186	10	6
20	198	12	17
20	208	10	20
10	217	9	11
8	225	8	10
20	236	11	18
20	248	12	17
8	253	5	16
10	256	3	33
10	267	11	9
10	275	8	13
10	281	6	17
10	289	8	13
10	297	8	13
10	300	3	33
10	302	2	50

Sounding diagram in the embankment



Filled materials

Upper soil layer

Gravel drain

(Note) NOB ; Number of Blows
DOP ; Depth of Penetration
AOP ; Amount of Penetration

Nc Conversion Table

N \ d	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0
1	20	10	7	5	4	3	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	40	20	13	10	8	7	6	5	4	4	4	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	1	1	1	1
3	~~[illegible]~~	30	20	15	12	10	9	8	7	6	5	5	5	4	4	4	4	3	3	3	3	3	3	2	2	2	2	2	2	2
4	~~[illegible]~~	40	27	20	16	13	11	10	9	8	7	7	6	6	5	5	5	4	4	4	4	4	3	3	3	3	3	2	3	3
5	~~[illegible]~~	50	33	25	20	17	[illegible]	13	11	10	9	8	8	7	7	6	6	6	5	5	5	5	4	4	4	4	4	3	3	3
6	~~[illegible]~~	~~[illegible]~~	40	30	24	20	17	15	13	12	11	10	9	9	8	8	7	7	6	6	6	5	5	5	5	5	4	4	4	4
8	~~[illegible]~~	~~[illegible]~~	~~53~~	40	32	27	23	20	18	16	15	13	12	11	11	10	9	9	8	8	8	7	7	7	6	6	6	6	6	5
10	~~200~~	~~100~~	~~67~~	50	40	33	29	25	22	20	18	17	15	14	13	13	12	11	11	10	10	9	9	8	8	8	7	7	7	7
15	~~300~~	~~150~~	~~100~~	~~75~~	~~60~~	50	43	38	33	30	27	25	23	21	20	19	18	17	16	15	14	14	13	12	12	12	11	11	10	10
20	~~400~~	~~200~~	~~133~~	~~100~~	~~80~~	~~67~~	~~57~~	50	44	40	36	33	31	28	27	25	24	22	21	20	19	18	17	17	16	15	15	14	14	13

How to use Nc Conversion Table:

Calculate Nc−Value when the amount of penetration is d cm by driving N number of blows

(Examle) when N is 5 number and d is 8 cm . Nc−value is 6.

APPENDIX C

Field electrical resistivity curves and its interpretation

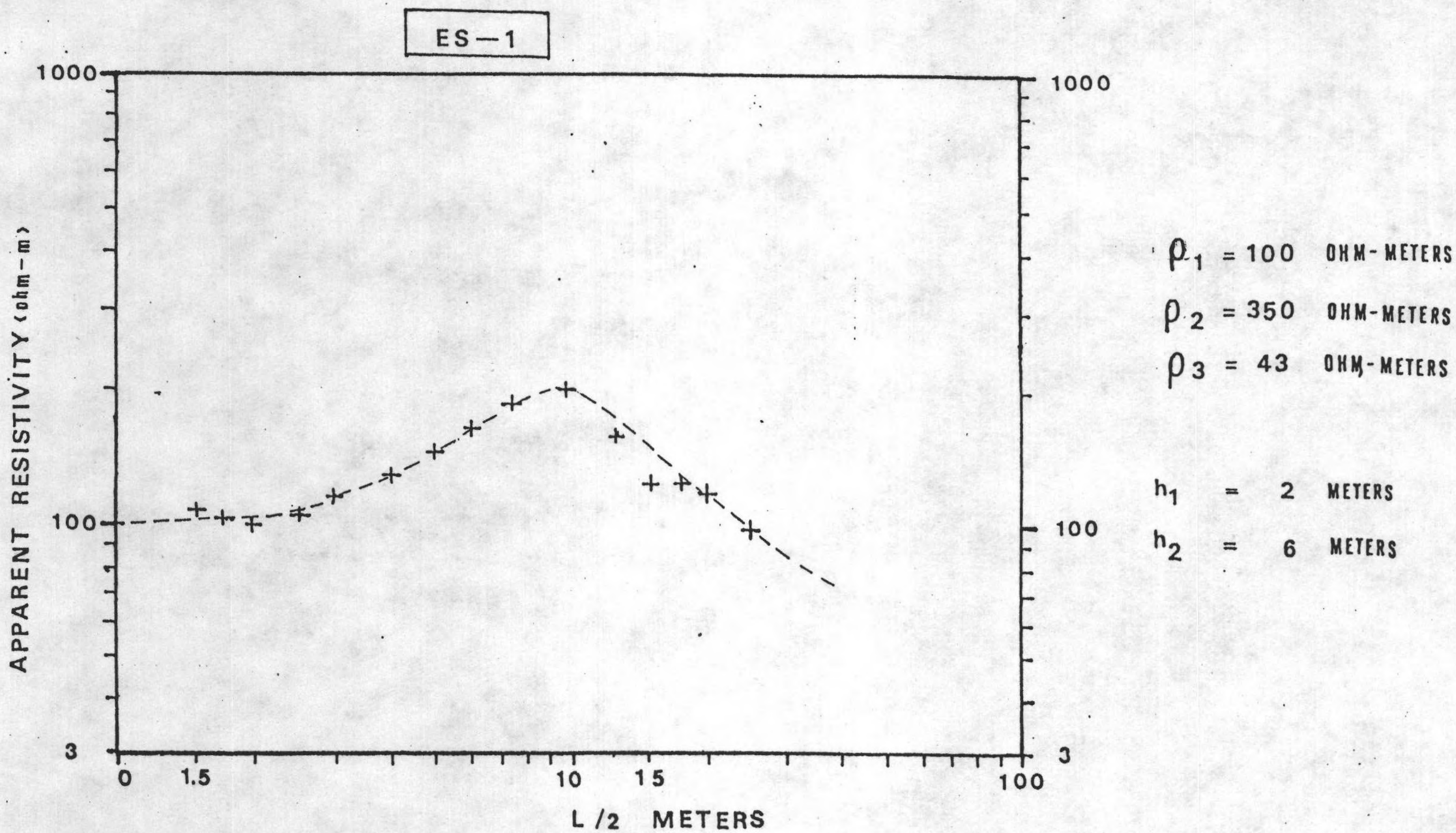
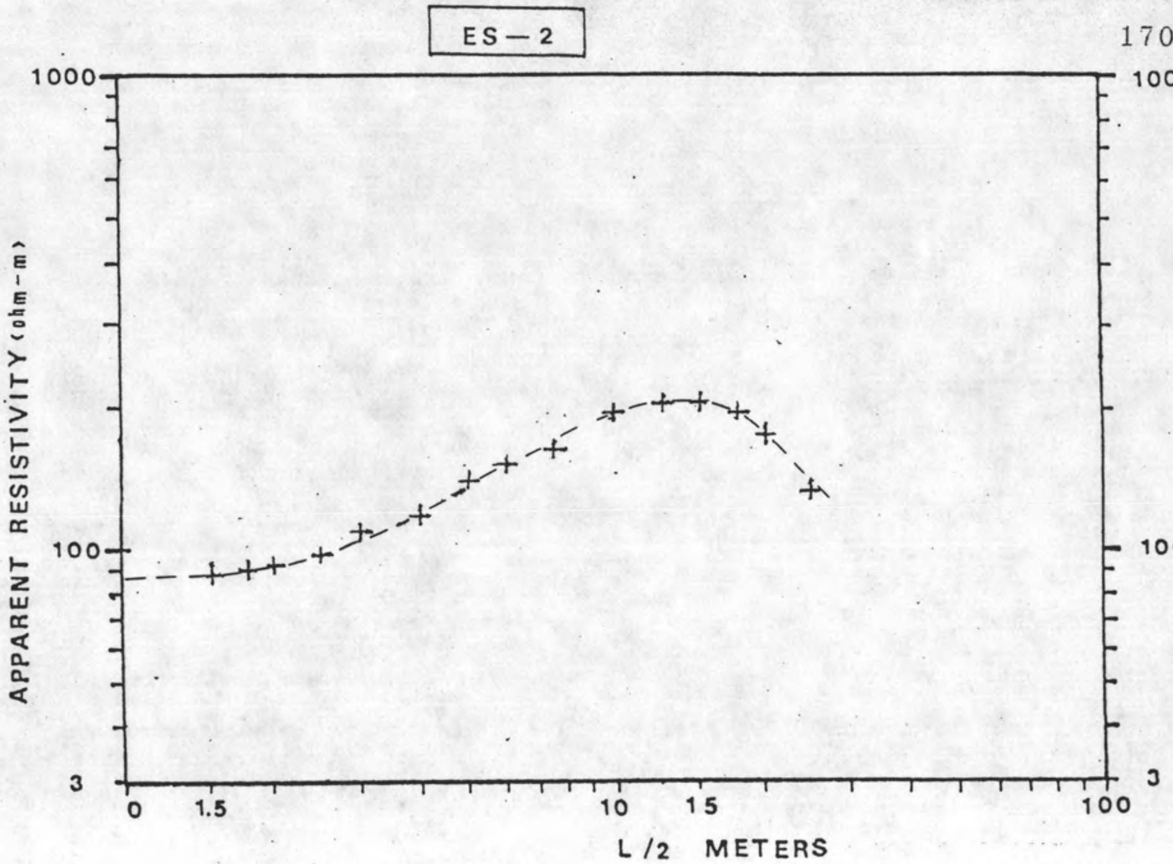


Figure C-1 Field electrical resistivity curves and its interpretation. The test site is at KM. 12.717 offset road centerline 2 meters Lt.

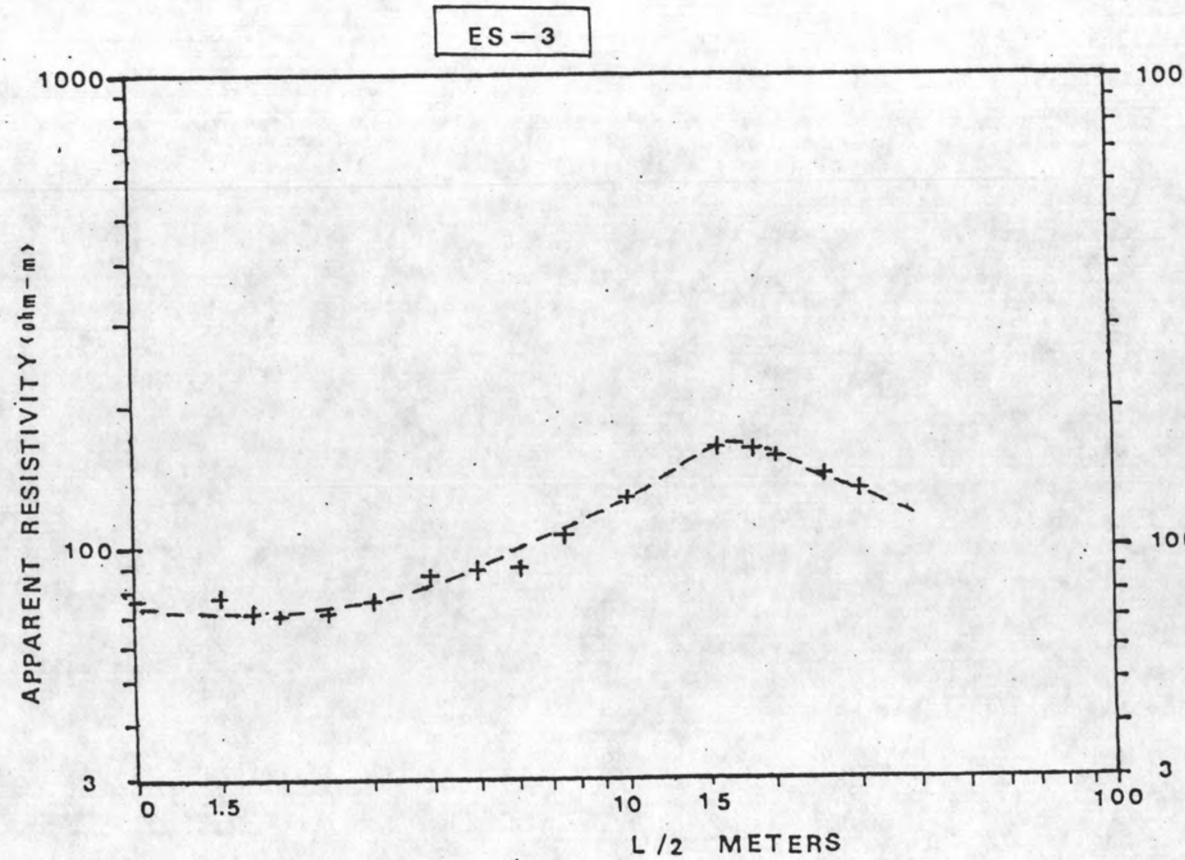


ρ_1 = 83 OHM-METERS

ρ_2 = 442 OHM-METERS

h_1 = 2.2 METERS

h_2 = 6.6 METERS



ρ_1 = 85 OHM-METERS

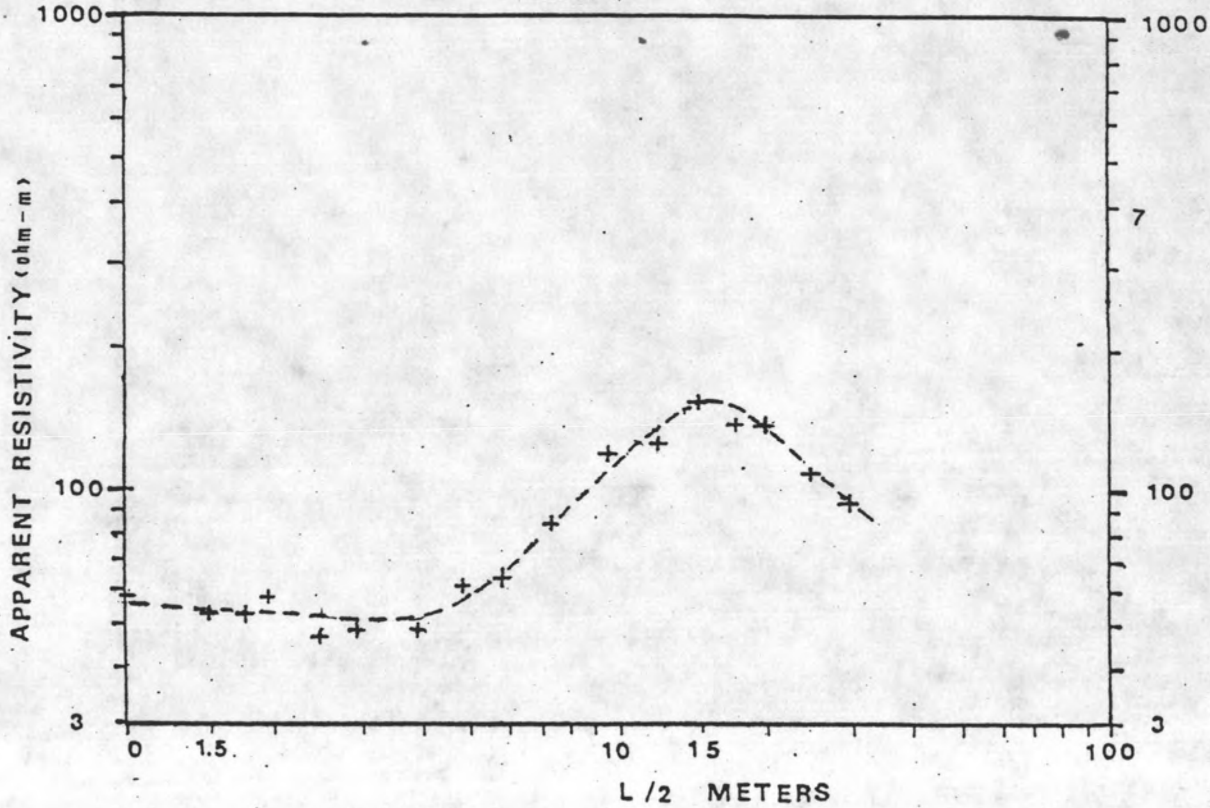
ρ_2 = 452 OHM-METERS

h_1 = 1.6 METERS

h_2 = 9.4 METERS

Figure C-1 (Cont.)

ES — 5



ρ_1 = 46 OHM-METERS

ρ_2 = 90 OHM-METERS

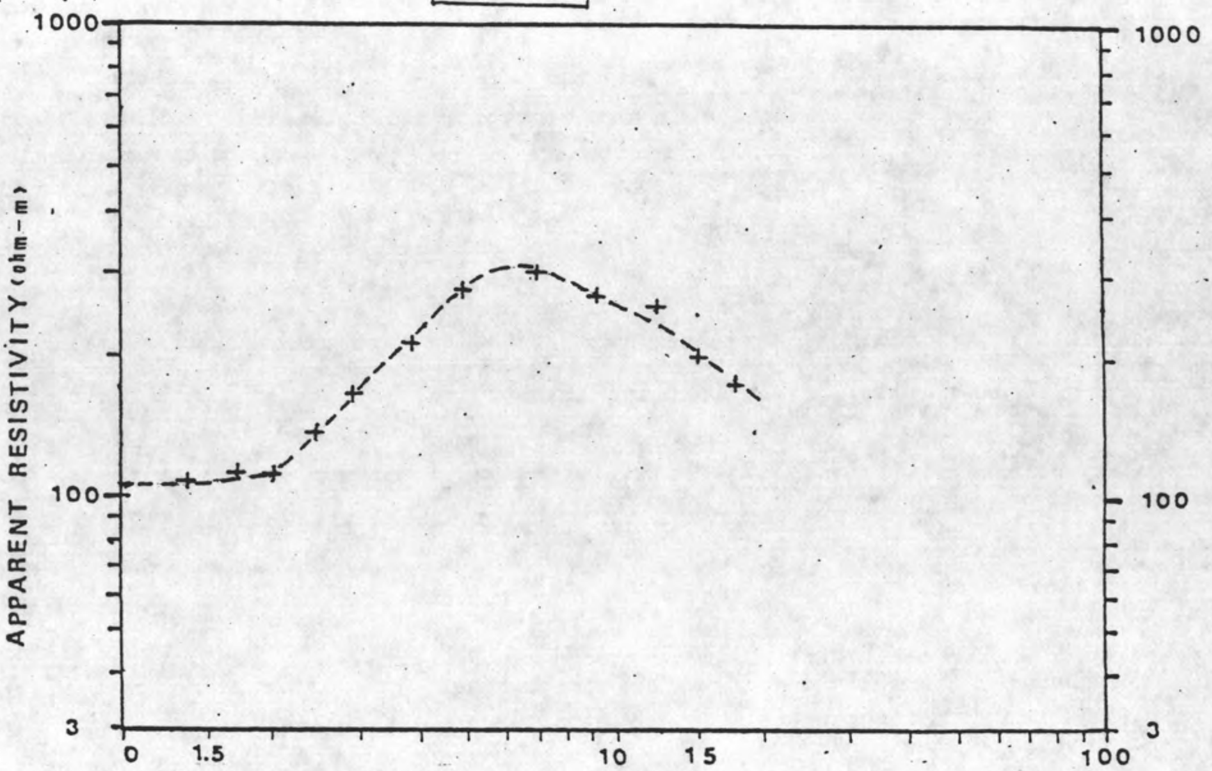
ρ_3 = 403 OHM-METERS

h_1 = 0.3 METERS

h_2 = 0.5 METERS

h_3 = 13.9 METERS

ES — 6



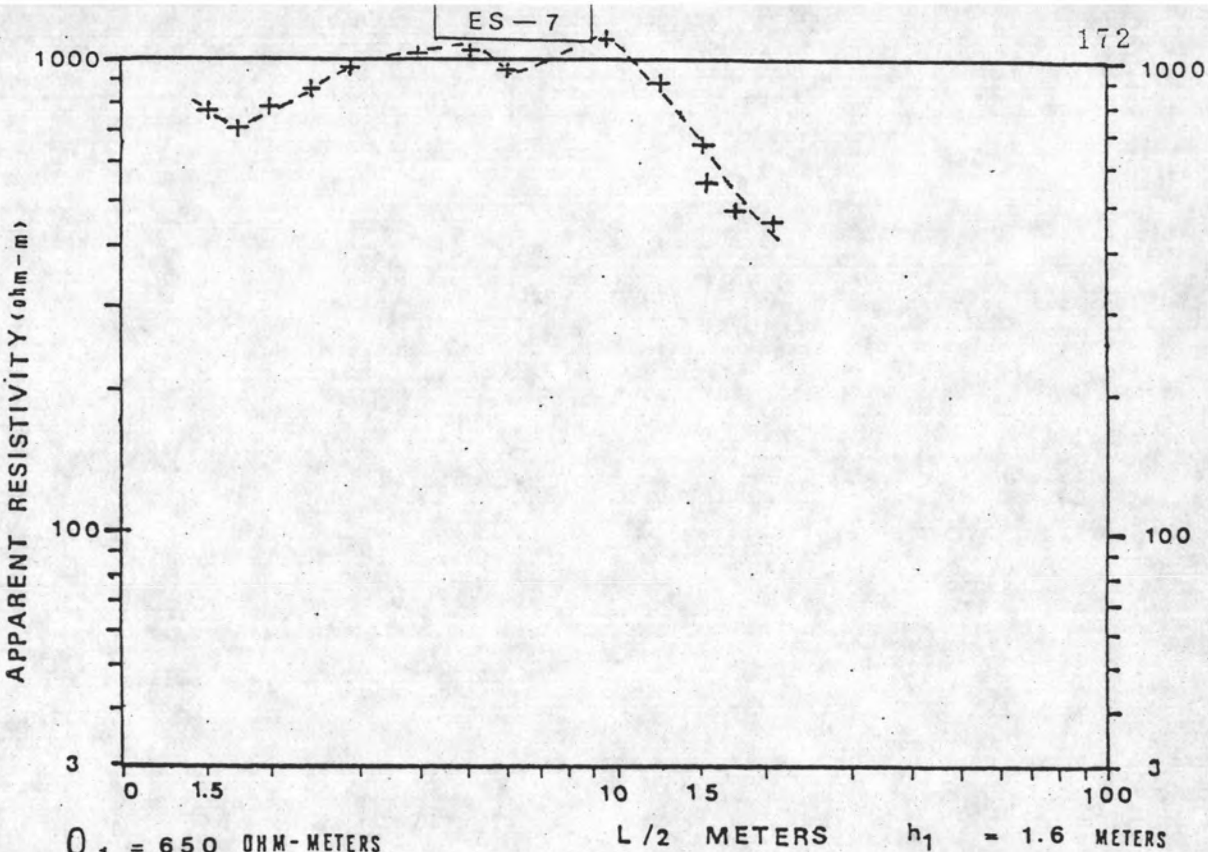
ρ_1 = 81 OHM-METERS

ρ_2 = 835 OHM-METERS

h_1 = 1.20 METERS

h_2 = 6.0 METERS

Figure C-1 (Cont.)



ρ_1 = 650 OHM-METERS

ρ_2 = 3,250 OHM-METERS

ρ_3 = 715 OHM-METERS

ρ_4 = 4,100 OHM-METERS

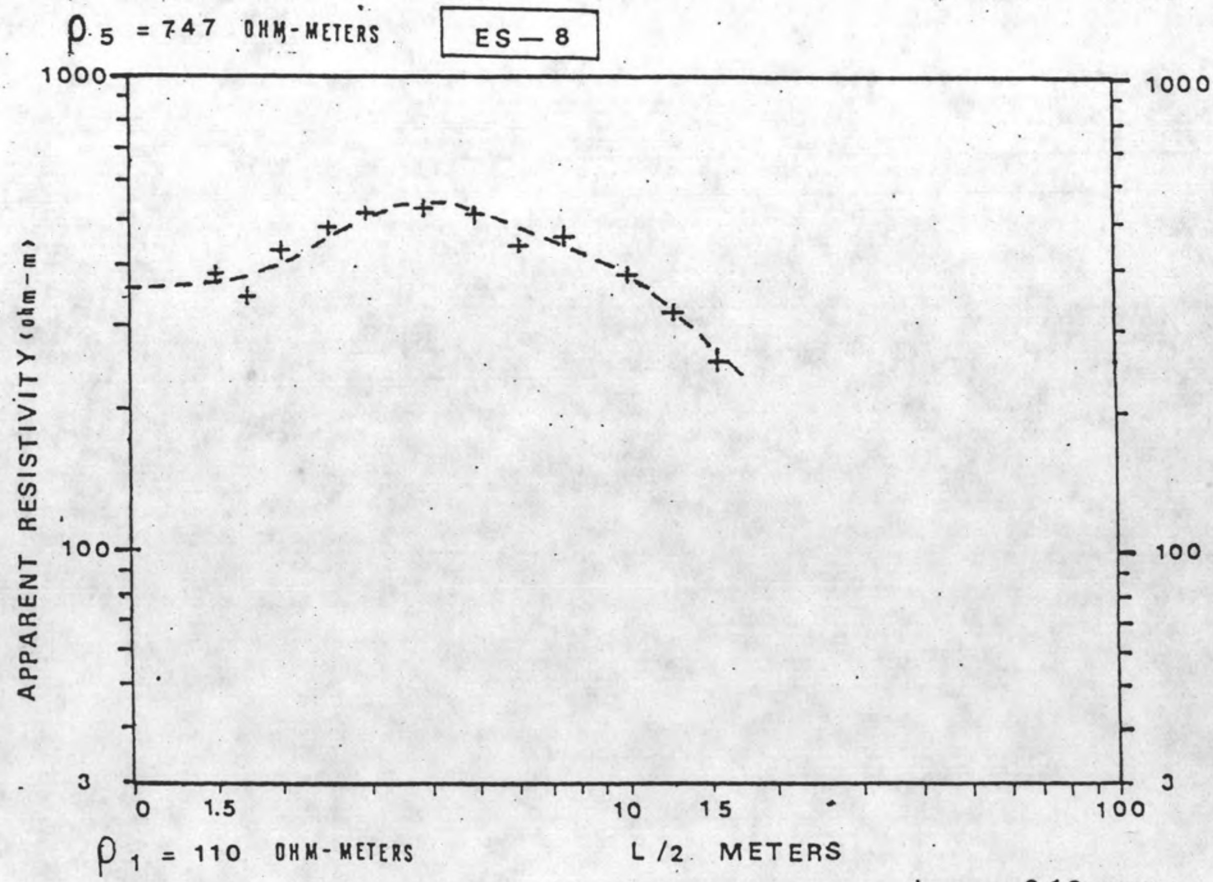
ρ_5 = 747 OHM-METERS

h_1 = 1.6 METERS

h_2 = 0.67 METERS

h_3 = 3.9 METERS

h_4 = 1.3 METERS



ρ_1 = 110 OHM-METERS

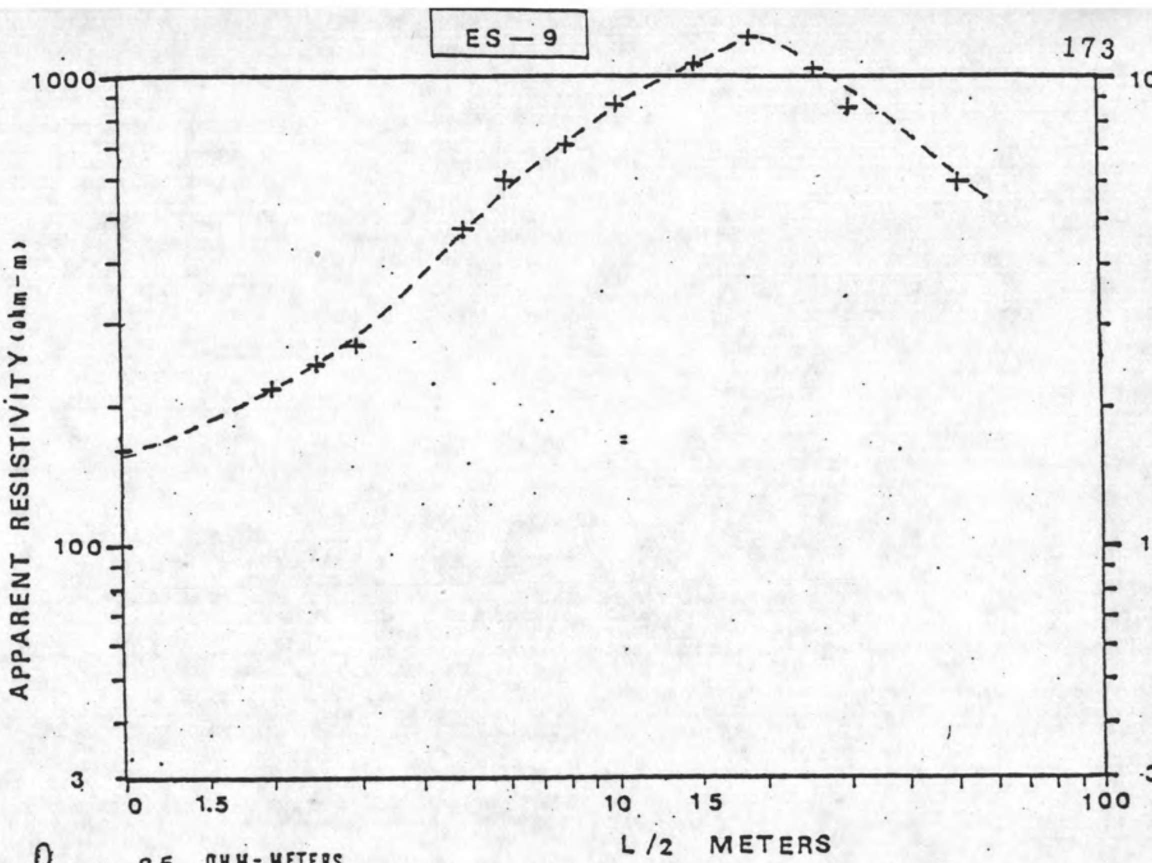
ρ_2 = 547 OHM-METERS

ρ_3 = 13 OHM-METERS

h_1 = 0.10 METERS

h_2 = 7.20 METERS

Figure C-1 (Cont.)



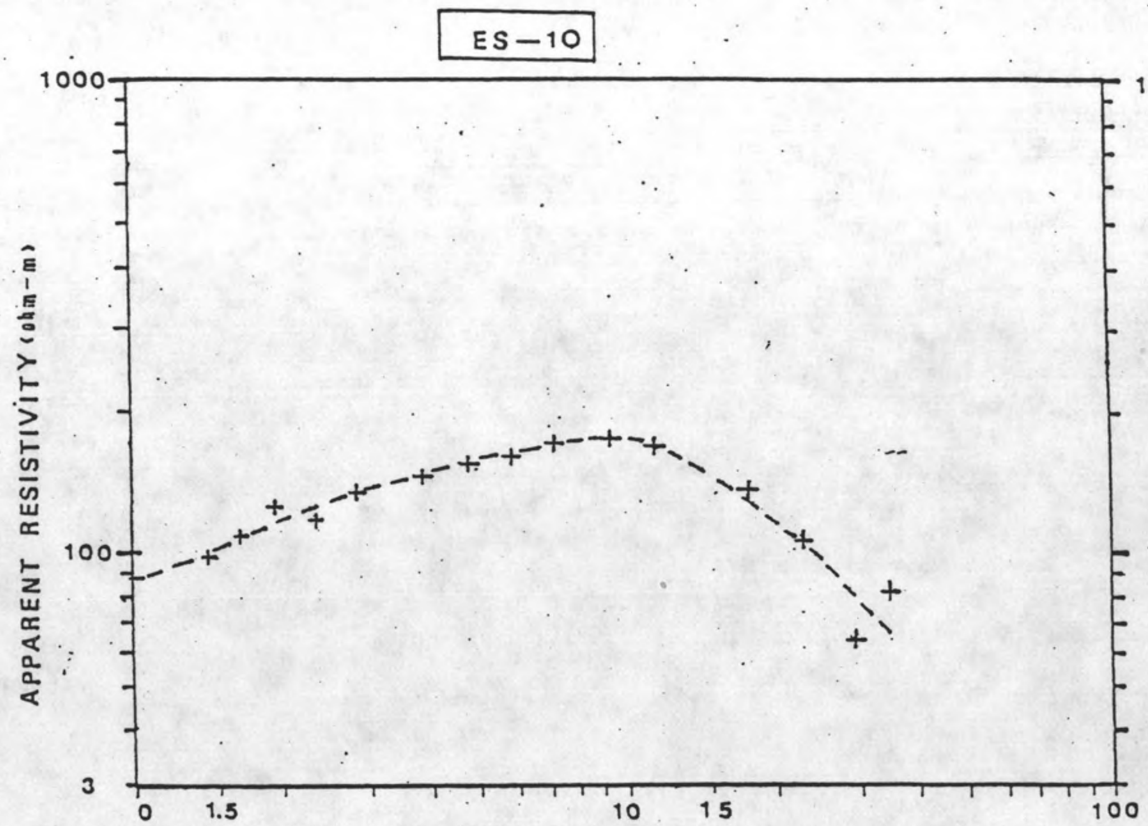
ρ_1 = 85 OHM-METERS

ρ_2 = 1,700 OHM-METERS

ρ_3 = 340 OHM-METERS

h_1 = 1.05 METERS

h_2 = 9.03 METERS



ρ_1 = 90 OHM-METERS

ρ_2 = 180 OHM-METERS

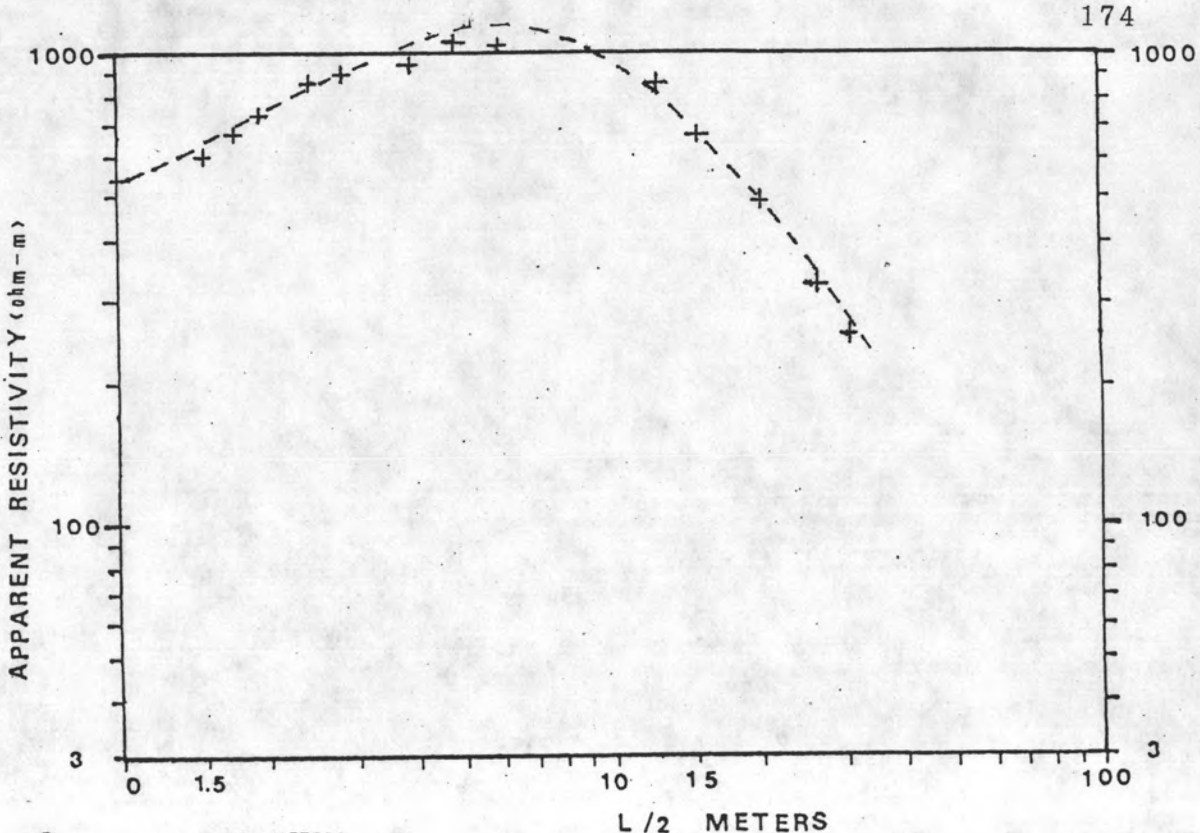
ρ_3 = 27 OHM-METERS

h_1 = 0.98 METERS

h_2 = 11.8 METERS

Figure C-1 (Cont.)

ES — 11



ρ_1 = 480 OHM-METERS

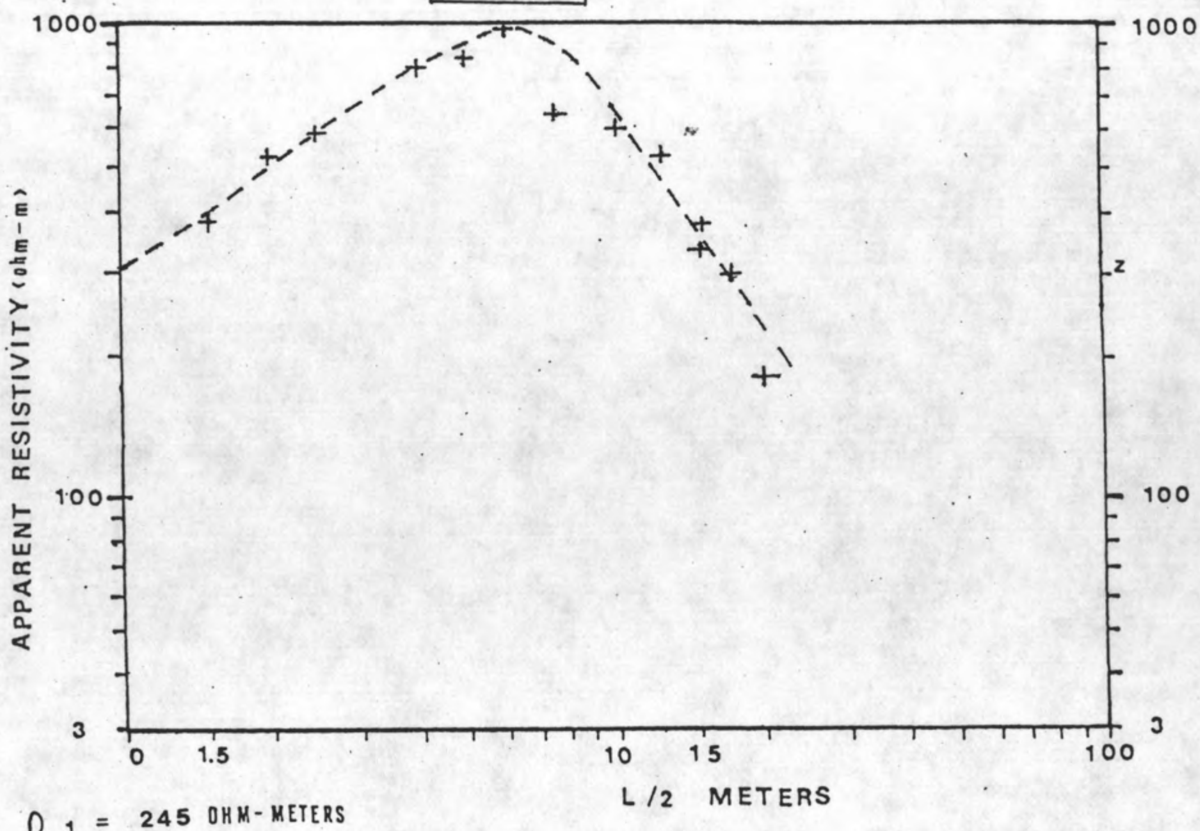
ρ_2 = 1,200 OHM-METERS

ρ_3 = 78.4 OHM-METERS

h_1 = 0.70 METERS

h_2 = 8.4 METERS

ES — 13



ρ_1 = 245 OHM-METERS

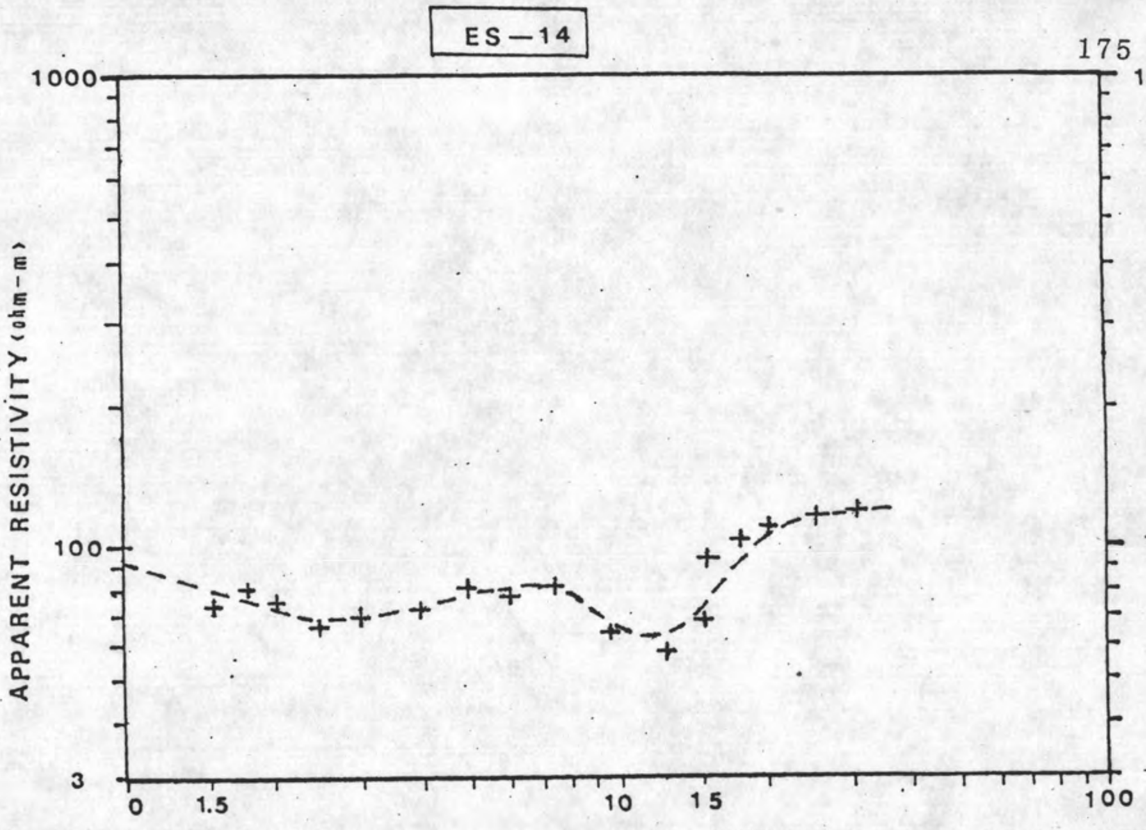
ρ_2 = 1,715 OHM-METERS

ρ_3 = 80 5 OHM-METERS

h_1 =0.76 METERS

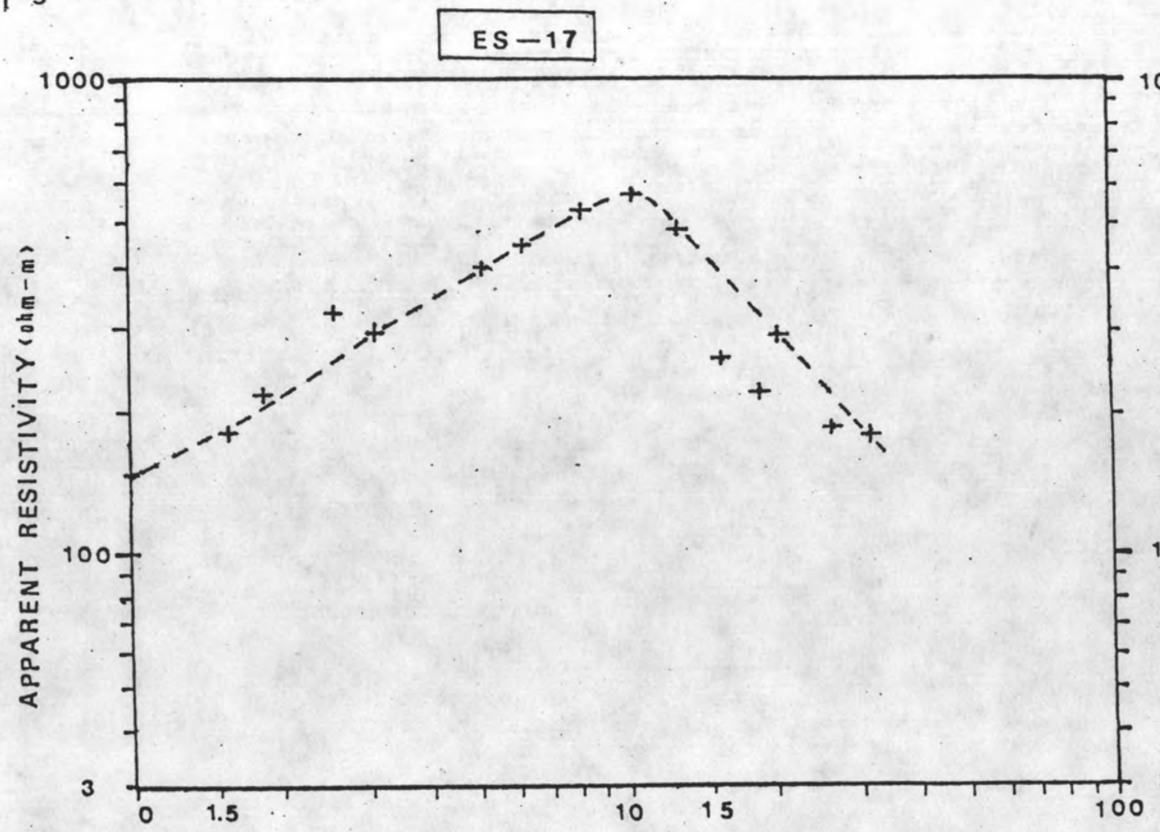
h_2 =3.8 METERS

Figure C-1 (Cont.)



ρ_1 = 100 OHM-METERS
ρ_2 = 50 OHM-METERS
ρ_3 = 124 OHM-METERS
ρ_4 = 36 OHM-METERS
ρ_5 = 550 OHM-METERS

h_1 = 1.0 METERS
h_2 = 1.7 METERS
h_3 = 3.37 METERS
h_4 = 5.36 METERS



ρ_1 = 112 OHM-METERS
ρ_2 =4,480 OHM-METERS
ρ_3 = 750 OHM-METERS
ρ_4 = 29 OHM-METERS

h_1 = 0.80 METERS
h_2 = 1.40 METERS
h_3 = 8.9 METERS

APPENDIX D

Tables of soil ratings for roads

TABLE D-1 Soil Ratings for Roads and Runways [ASSHO, 1962]

CBR No.	General Rating	Uses	Classification System: Unified	Classification System: AASHTO
0-3	Very poor	Subgrade	OH, CH, MH, OL	A5, A6, A7
3-7	Poor to fair	Subgrade	OH, CH, MH, OL	A4, A5, A6, A7
7-20	Fair	Subbase	OL, CL, ML, SC, SM, SP	A2, A4, A6, A7
20-50	Good	Base, subbase	GM, GC, SW, SM, SP, GP	A1*b*, A2-5, A3, A2-6
>50	Excellent	Base	GW, GM	A1*a*, A2-4, A3

TABLE D-2 General Guide to Selection of Soils on Basis of Anticipated Embankment Performance [Krebs et al., 1971 ; Gregg, 1960]

HRB Classification	*Visual Description*	*Maximum Dry-Weight Range (pcf)*	*Optimum Moisture Range (%)*	*Anticipated Embankment Performance*
A-1-a	Granular material	115-142	7-15	Good to excellent
A-1-b				
A-2-4	Granular material with soil	110-135	9-18	Fair to excellent
A-2-5				
A-2-6				
A-2-7				
A-3	Fine sand and sand	110-115	9-15	Fair to good
A-4	Sandy silts and silts	95-130	10-20	Poor to good
A-5	Elastic silts and clays	85-100	20-35	Unsatisfactory
A-6	Silt-clay	95-120	10-30	Poor to good
A-7-5	Elastic silty clay	85-100	20-35	Unsatisfactory
A-7-6	Clay	90-115	15-30	Poor to fair

TABLE D-3 Compaction Characteristics and Ratings of Unified Soil Classification Classes for Soil Construction [Krebs et al., 1971; U.S. Army Corps. of Engi., 1953]

Class	*Compaction Characteristics*	*Maximum Dry Density Standard AASHTO (pcf)*	*Compressibility and Expansion*	*Value as Embankment Material*	*Value as Subgrade Material*	*Value as Base Course*
GW	Good: tractor, rubber-tired, steel wheel, or vibratory roller	125-135	Almost none	Very stable	Excellent	Good
GP	Good: tractor, rubber-tired, steel wheel, or vibratory roller	115-125	Almost none	Reasonably stable	Excellent to good	Poor to fair
GM	Good: rubber-tired or light sheepsfoot roller	120-135	Slight	Reasonably stable	Excellent to good	Fair to poor
GC	Good to fair: rubber-tired or sheepsfoot roller	115-130	Slight	Reasonably stable	Good	Good to fair
SW	Good: tractor, rubber-tired, or vibratory roller	110-130	Almost none	Very stable	Good	Fair to poor
SP	Good: tractor, rubber-tired, or vibratory roller	100-120	Almost none	Reasonably stable when dense	Good to fair	Poor
SM	Good: rubber-tired or sheepsfoot roller	110-125	Slight	Reasonably stable when dense	Good to fair	Poor
SC	Good to fair: rubber-tired or sheepsfoot roller	105-125	Slight to medium	Reasonably stable	Good to fair	Fair to poor
ML	Good to poor: rubber-tired or sheepsfoot roller	95-120	Slight to medium	Poor stability, high density required	Fair to poor	Not suitable
CL	Good to fair: sheepsfoot or rubber-tired roller	95-120	Medium	Good stability	Fair to poor	Not suitable
OL	Fair to poor: sheepsfoot or rubber-tired roller	80-100	Medium to high	Unstable, should not be used	Poor	Not suitable
MH	Fair to poor: sheepsfoot or rubber-tired roller	70-95	High	Poor stability, should not be used	Poor	Not suitable
CH	Fair to poor: sheepsfoot roller	80-105	Very high	Fair stability, may soften on expansion	Poor to very poor	Not suitable
OH	Fair to poor: sheepsfoot roller	65-100	High	Unstable, should not be used	Very poor	Not suitable
PT	Not suitable	—	Very high	Should not be used	Not suitable	Not suitable

APPENDIX E

Review of methods of slope stability analysis

REVIEW OF METHODS OF SLOPE STABILITY ANALYSIS.

1. Methods of slope stability analysis Various analytical method of slopes stability of investigated slopes were performed. These methods of stability analysis are summarized as follows:

a) Bishop's method: Bishop (1955) proposed an effective stress method of stability analysis using a method of slice in which

(1) The force acting on a typical slice are as shown in Figure E-1;

(2) The slip surface is assumed to be an arc of circle;

(3) The interslice force are taken into consideration.

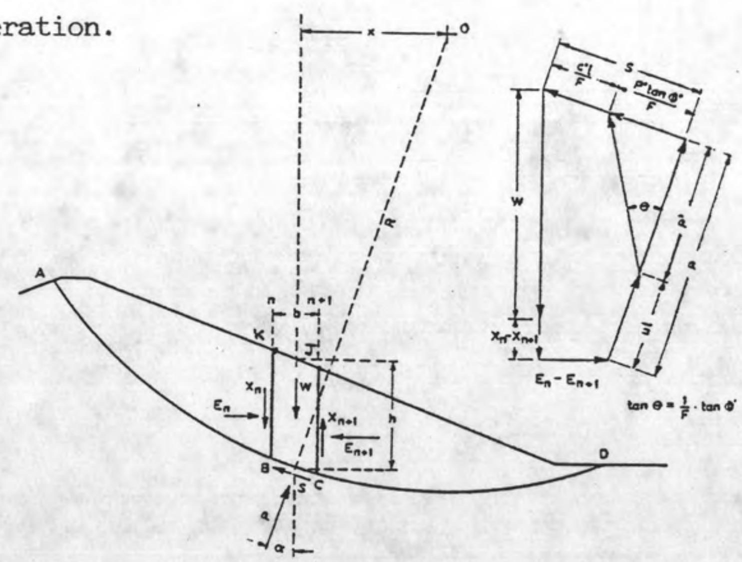


Figure E-1 Forces involved in effective stress slip circle analysis.

Considering the equilibrium of the mass of soil bounded by the circular arc ABCD and a typical slice B C J K, and.

O = center of the circle;

R = radius;

h = height of the slice;

b = width of the slice;

P = total normal force acting on the base of slice;

W = total weight of the slice;

S = total shear force along the base;

X_n, X_{n+1} = vertical shear force on interfaces B K and C J;

E_n, E_{n+1} = normal forces on interface.

The mobilized shear strength to satisfy the condition of limiting equilibrium is given by an equation

$$S = \frac{1}{F}\left[C' + \frac{(P - U)}{l} \tan \text{Ø}'\right] \qquad (6.1)$$

where; S = mobilized shear strength;

F = factor of safety;

C'= cohesion;

Ø'= angle of shearing resistance;

Δ l = length of the base of slice;

P/l = total normal stress;

U = pore water pressure.

Moment equilibrium about the center of rotation gives:

$$Wx = SR = slR \qquad (6.2)$$

Substituting of S in Eq. 6.1.1a, we can get:

$$F = \frac{R}{\sum Wx} \cdot \sum [C'l + (P-Ul) \tan \text{Ø}'] \qquad (6.3)$$

From force polygon in Figure E-1.

By summing up the forces on the slice in the vertical direction, we obtain

$$P' = \frac{W+[X_n-X_{n+1}]-l[C'\sin\alpha/_F+U\cos\alpha]}{\cos\alpha+\tan\phi'\sin\alpha/_F} \quad (6.4)$$

Substituting Eq. (6.4) into Eq. (6.3) and using $l = b\sec\alpha$, $X = \sin\alpha$ and $\bar{B} = Ub/W$, we find

$$F = \frac{1}{\sum W\sin\alpha}\sum[\,bc'+\tan\phi'\{W(1-\bar{B})+X_n-X_{n+1}\}\;\frac{\sec\alpha}{1+\tan\alpha\tan/_F} \quad (6.5)$$

Let $m = \sec\alpha/\,[\,1+(\tan\alpha\tan\phi'/F)]$

And substituting m in Eq.6.5, we obtain

$$F = \frac{1}{\sum W\sin\alpha}.\sum[bc'+\tan\phi'\{W(1-\bar{B})+X_n-X_{n+1}\}m\,] \quad (6.6)$$

Supposing there is no horizontal external forces, then

$$(E_n + E_{n+1}) = 0$$

Summing the forces on the slice in the tangential direction, we get

$$(W+X_n-X_{n+1})\sin\alpha+(E_n-E_{n+1})\cos\alpha = S$$

or

$$(E_n-E_{n+1}) = S\sec\alpha-(W+X_n-X_{n+1})\tan\alpha \quad (6.7)$$

If Eq. (6.5) is written as

$$F = \frac{1}{\sum W\sin\alpha}.\sum[m],$$

then $S = m/F$; and substituting this into Eq.(6.7), we obtain

$$\sum(E_n-E_{n+1}) = \sum[\,m/F\sec\alpha-(W+X_n-X_{n+1})\tan\alpha\,]$$

Since $(E_n - E_{n+1}) = 0$,

thus $\sum[m/F\sec\alpha-(W+X_n-X_{n+1})\tan\alpha] = 0$ (6.8)

For a practical purpose, we only consider the vertical equilibrium. Hence, Eq. (6.6) can be simplified by assuming $X_n - X_{n+1} = 0$.

The simplified solution is thus given as

$$F = \frac{1}{\sum w \sin\alpha} \cdot \sum [bC' + \tan\phi' \{W(1-\bar{\bar{B}})\} m] \qquad (6.9)$$

Eq.(6.9) is simplified Bishop equation and minimum factor of safety can be solved by iteration from Eq.'s (6.6) and (6.9).

b) Wedge method or Sliding block method.: Lambe and Whitman (1979); Chowdhury (1982); Patton et al.,(1974) proposed the procedure of calculated factor of safety using wedge method. In this method, the sliding mass above the slip surface is divided by vertical lines into two or three wedges or slices as shown in Figure E-2 in which

i) Failure surface is not likely to be circular and consisting of two or three planes;

ii) With assume F.S.and interwedge friction angles α_1 and α_2 the condition of horizontal and Vertical force equilibrium of each wedge are considers to determined effective force E_{12}, E_{23} between wedges;

iii) If equilibrium of the last wedge is not satisfied, assumed new value of F until equilibrium of all wedges is satisfied;

iv) Can be performed in a graphical or numerical procedure.

Wedge or Sliding block failure often arise, when failure occurs through a weak layer underlying a strong layer in foundation of an embankment or an earth dam, and when failure occurs predominantly along discontinuities such as joints and faults in natural or cut slopes (Chowdhury, 1982).

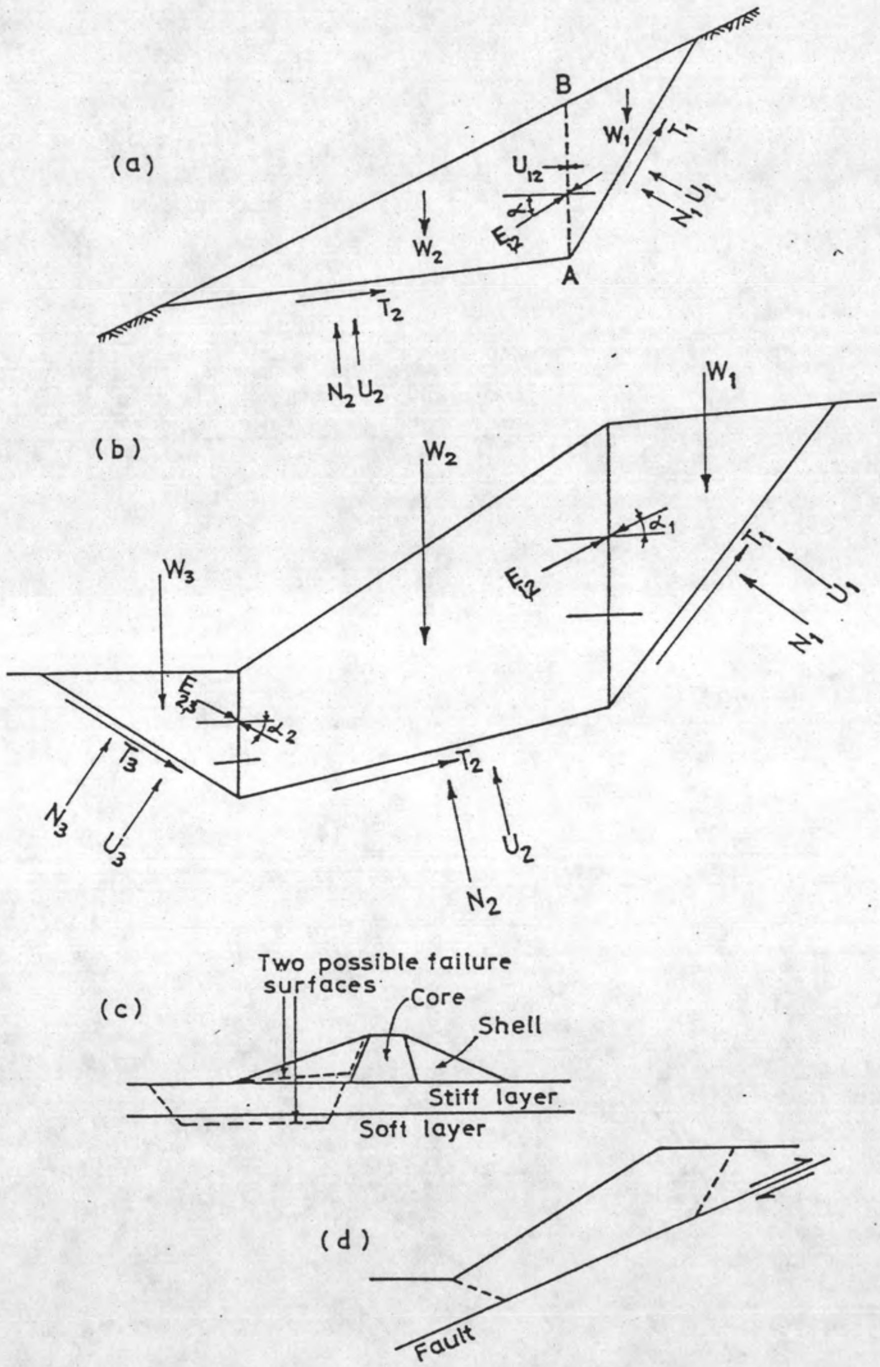


Figure E-2 Sliding block or wedge method showing forces in

(a) Bi-planar

(b) Triplanar cases, and typical triplanar failure surfaces in

(c) Earth dam and

(d) Cut slope (From Chowdhury, 1982).

Duncan and Buchignani (1975) proposed a convenient approximate procedure for calculating factor of safety both in graphic and numeric version. The basic assumption in this wedge method is that the side forces between wedges (E_{12}, E_{23}) are assumed to be horizontal, the error due to this assumption is no more than 15%.

C) Morgenstern and Price's method:- Morgenstern .and Price (1965) developed a method of analysis the stability for slip surfaces of arbitrary shape. It is believed that this method satisfies all the equilibrium condition provided an assumption is made to make the problem statistically determinate. The potential sliding mass, coordinate axes, and the forces on a slice are shown in Figure E-3.

where
- the equation of the assumed slip surface is $y = y(x)$
- the equation of the surface of the slope, taken as known $y = z(x)$
- the equation of the position of action of the effective horizontal thrust is $y = y_t'(x)$ and is unknown
- the line of thrust of the internal water pressure is $y = h(x)$

The forces acting on an infinitesimal slice of width dx of the potential sliding mass are shown in Figure E - 3b. In this Figure:

E' = horizontal lateral thrust on the side of the slice in termsof effective stress

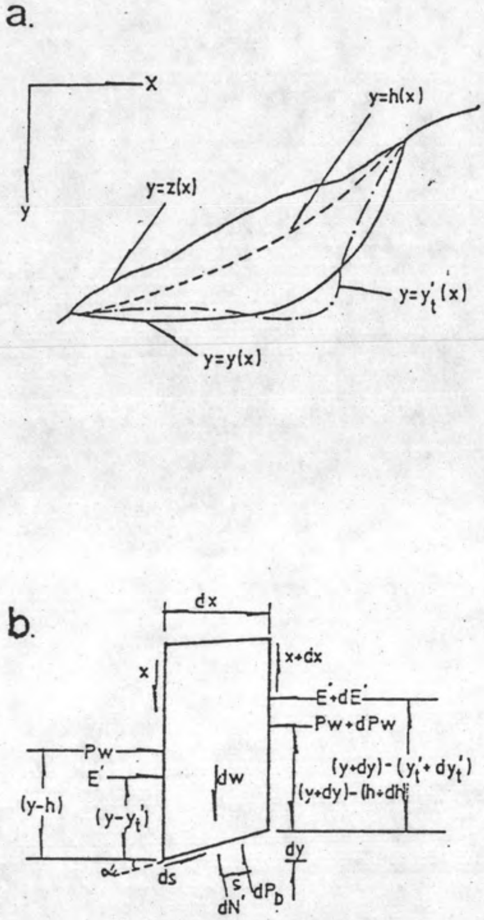


Figure E-3 Morgenstern and Price Method.

(a) Potential sliding mass.

(b) Forces acting on an infinitesimal slice.

X = vertical shear force on the side of the slice

dW = weight of slice

Pw = resultant water pressure acting on the side of the slice

dP_b = water pressure on the base of the slice

dN' = effective normal pressure

dS = shear force acting along the base of the slice

α = inclination of the base of the slice with respect to the horizontal

The condition that there be no rotation of the slice is satisfied if the sum of the moments about the center of the base of the slice is equal to zero. By taking moments about the midpoint of the base of the slice, simplifying and proceeding to the limit as dx approaches zero, it can be shown that:

$$X = \frac{d}{dx}(E'.Y'_t) - y\frac{dE'}{dx} + \frac{d}{dx}(Pw.h) - y\frac{dPw}{dx} \qquad (6.10)$$

For equilibrium in the direction normal to the base of slice (the N direction), we find

$$dN' + dP_b = dW\cos\alpha - dX\cos\alpha - dE'\sin\alpha - dPW\sin\alpha \qquad (6.11)$$

For equilibrium in the direction tangential to the base of slice (the S direction), we find

$$dS = dE'\cos\alpha + dP\cos\alpha - dX\sin\alpha + dW\sin\alpha \qquad (6.12)$$

The Coulomb-Mohr failure criterion in terms of effective stresses may be expressed as

$$dS = \frac{1}{F}\,[C'dX \sec\alpha + (dN')\tan\phi']$$

Where C',Ø', represent effective strength parameters, and F denotes the factor of safety.

Substituting for dS, Eqs.(6.10), (6.11), (6.12) can be reduced to two governing differential equations:

$$X = \frac{d}{dx}(E'.Y'_t) - Y\frac{dE'}{dx} + \frac{d}{dx}(PW.h) - Y\frac{dPW}{dx} \quad (6.13)$$

$$\frac{dE}{dx}\left[1-\frac{\tan\phi'}{F}\frac{dy}{dx}\right] + \frac{dx}{dx}\left[\frac{\tan\phi'}{F} + \frac{dy}{dx}\right] = \frac{C'}{F}\left[1+\left(\frac{dy}{dx}\right)^2\right] +$$

$$\frac{dPw}{dx}\left[\frac{\tan\phi'}{F}\frac{dy}{dx} - 1\right] + \frac{dW}{dx}\left\{\frac{\tan\phi'}{F} + \frac{dy}{dx} - r_u\left[1+\left(\frac{dy}{dx}\right)^2\right]\frac{\tan\phi'}{F}\right\} \quad (6.14)$$

Where r_u is the pore pressure ratio.

If y is specified as some function of x, we have, in general, a statistically indeterminate problem involving unknowns F, E', X and Y'_t.

Assume the relation between E' and X as.

$$X = \lambda f(x) E'$$

If f(x) is specified, the problem become determinate and correct λ and F may be found from a solution of the two governing differential equations which satisfy the appropriate boundary conditions.

d) Janbu's method.: A method of slope stability analysis proposed by Janbu (1954, 1957, 1973) is suitable for slip of surface of arbitrary shape. He named this method as the "Generalized Procedure of Slices" The sliding mass, forces acting on the sliding mass and boundaries of slice are shown in Figure E-4 in which

P,Q and q are external loads or surcharge

ab is any arbitrary shear surface

T_a and T_b are vertical components of resultant at a and b respectively

E_a and E_b are horizontal components of resultant at a and b respectively

In Figure E-4b shows an enlarged scale of typical slice, in which;

E and T are the resultants of the total inter-slice forces in the horizontal and vertical directions, respectively

Δl is the length of the shear surface

Δx is the width of the slice

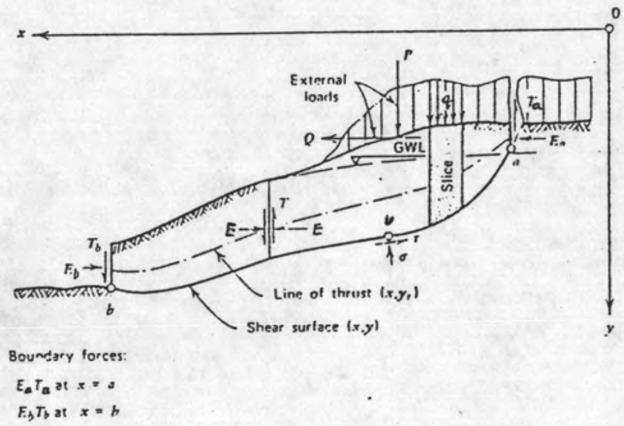
Z is the height of the slice

α is the angle between the base and the horizontal

$\Delta S, \Delta N$ are the resultants of the shear stress and total normal stress, respectively, acting over the length Δl

$\Delta E, \Delta T$ are the infinitesimal changes of the total interslice forces in the horizontal and vertical directions, respectively

ΔQ is the external horizontal force in each a



b

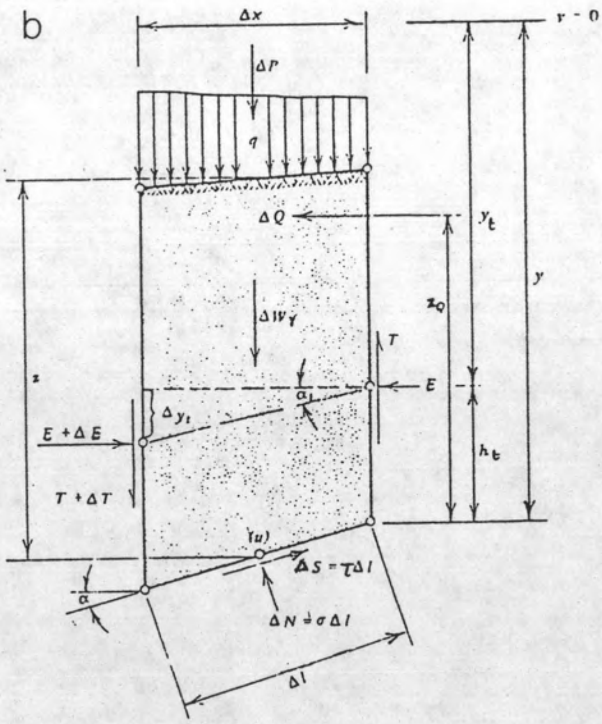


Figure E-4 Janbu's method.

a) Definitions and notations used for the generalized procedure of slices.

b) Forces acting on the boundaries of a single slice.

slice

Z_q is the distance that Q acts above the assumed shear surface

α_t is the angle between the line of thrust and the horizontal

h_t is the distance between the shear surface and the line of thrust

$\Delta P, q$ are the external line load and surcharge respectively

$\Delta W\gamma$ is the weight of the slice due to the soil only

Basic assumptions: The following basic assumptions are used for the general case.

a) The equilibrium shear stress along the shear surface is given by the equation

$$\tau = \frac{\tau_f}{F} = \frac{C'}{F} + \frac{\sigma' \tan\phi'}{F} \qquad (6.15)$$

b) The total resultant N is assumed to act where $\Delta W = \Delta W\gamma + q\Delta x + \Delta P$ intersects the base

c) The position of the line of thrust for the total side force E is assumed to be know. Generally it is assumed to act at the lower third point but a little higher in the compression zone and lower in the tension zone.

By use of equilibrium condition, we can obtain the following equations which must be satisfied simultaneously. For the state of limit equilibrium.

$$\tau = C' + (\sigma - U) \tan\phi' \quad (6.16)$$

For vertical equilibrium of each slice

$$\sigma = p + t - \tau \tan\alpha \quad (6.17)$$

Where; $p = \gamma Z + q + P/X$

γ = bulk unit weight of soil

Z = height of the slice

For a combination of horizontal and vertical equilibrium for each slice, we obtain.

$$\Delta E = \Delta Q + (p + t)\Delta x \tan\alpha - \tau \Delta x\,(1 + \tan^2\alpha) \quad (6.18)$$

Where; $t = \Delta T/\Delta x$

For moment equilibrium for a slice of infinitesimal width, we get.

$$T = -E \tan\alpha_t + h_t \frac{dE}{dx} - Z_q \frac{dQ}{dx} \quad (6.19)$$

For overall horizontal equilibrium, we get.

$$\sum_a^b \Delta E = E_b - E_a \quad (6.20)$$

Insert Eq. (6.18) into Eq (6.20) and obtain

$$E_b - E_a = \sum_a^b [\Delta Q + (p+t)\Delta x \tan\alpha] - \sum_a^b \tau \Delta x\,(1+\tan^2\alpha) \quad (6.21)$$

Since $\tau = \frac{\tau_f}{F}$, then

$$F = \frac{\sum_a^b \tau_f \Delta x\,(1+\tan^2\alpha)}{E_a - E_b + \sum_a^b [\Delta Q + (p+t) \tan\alpha \Delta x]} \quad (6.22)$$

and since

$$\tau_f = C' + (\sigma - U) \tan\phi'$$

$$\tau_f = C' + (p+t-U-\tau \tan\alpha) \tan\phi'$$

$$= C' + (p+t-U \frac{\tau_f}{F} \tan\alpha) \tan\phi'$$

$$\tau_f = \frac{C' + (p+t+U) \tan\phi'}{1 + 1/F \tan\phi' \tan\alpha} \quad (6.23)$$

Insert Eq.(6.23) in to Eq.(6.22), this yields.

$$F = \frac{\sum_a^b \frac{c' + (p+t-u)\tan\phi' \;\; \Delta x(1+\tan^2\alpha)}{1 + 1/F \tan\phi' \tan\alpha}}{E_a - E_b + \sum_a^b [\Delta Q + (p+t)\tan\alpha \Delta x]} \qquad (6.24)$$

Values of F can be obtained by trial and error solution.

Janbu, Bjerrum, and Kjaernsli (1956) proposed a conveniently approximate method of analysis suitable for hand calculations and sufficiently accurate. This method which inter-slice forces are ignored is called Janbu's Routine Method.

$$F = f_o \frac{\sum[c' + (p-u) \tan\phi'] \Delta x / n_\alpha}{Q + \sum \Delta W \tan\alpha}$$

When

$$n_\alpha = \frac{1 + (\tan\phi' / F)\tan\alpha}{1 + \tan^2\alpha}$$

f_0 is a correction factor for the role of the inter-slice forces, is a function of the curvature of the slip surface and the type of soil n_α is geometry function.

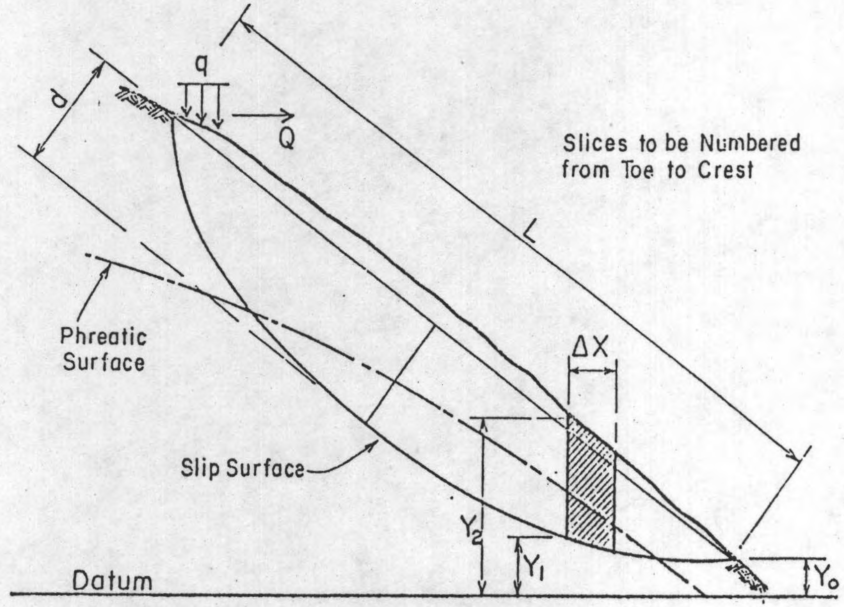
To calculate factor of safety, f_o and n_α function are presented in graphical forms and are shown in Figure E-5

2. Comparison of slope Stability Analysis Methods.

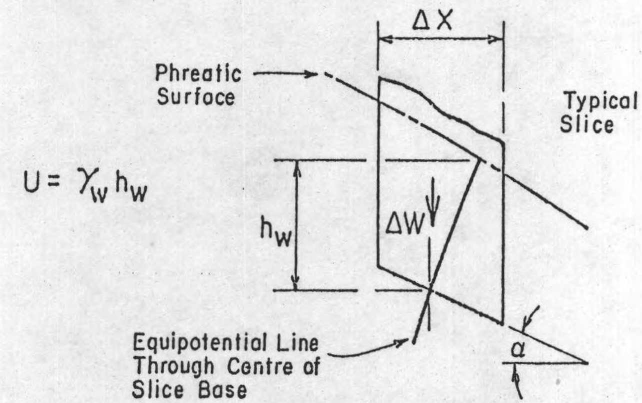
a) Bishop's and Bishop Simplified methods.

These method are suitable for both total and effective stress analysis of circular failure surfaces in soil and soft rock. In Bishop simplified the inter - slice force ignored. The difference between the simplified and rigorous method is not more than 1%

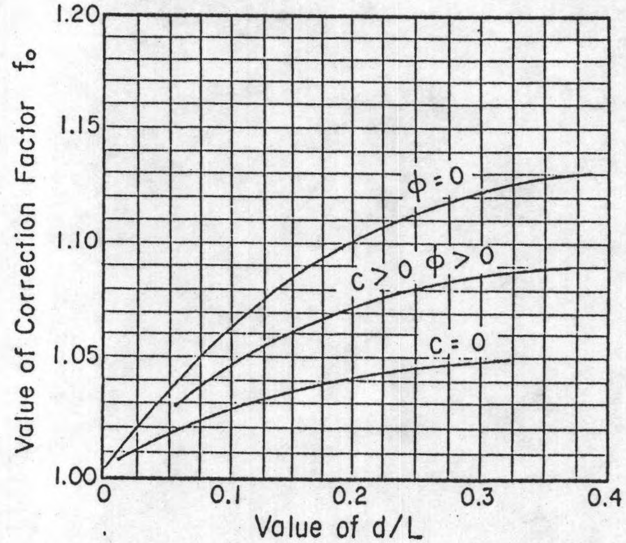
b) Wedge method or sliding block method.: This method satisfies both horizontal and vertical force equilibrium. The analysis can be performed either graphically or numerically. The



(i) Typical Slip Surface



(ii) Calculation of Average Water Pressure u on Base of Slice



(iii) Correction Factor f_o as Function of Curvature Ratio d/L and Type of Soil

$$F = f_o \frac{\sum \left[c' + (p-u) \tan \phi' \right] \frac{\Delta X}{n_\alpha}}{Q + \sum \Delta W . \tan \alpha}$$

where $$n_\alpha = \frac{1 + (\tan \phi' / F) \tan \alpha}{1 + \tan^2 \alpha}$$

FIG.E-5 a STABILITY ANALYSIS BY JANBU ROUTINE METHOD

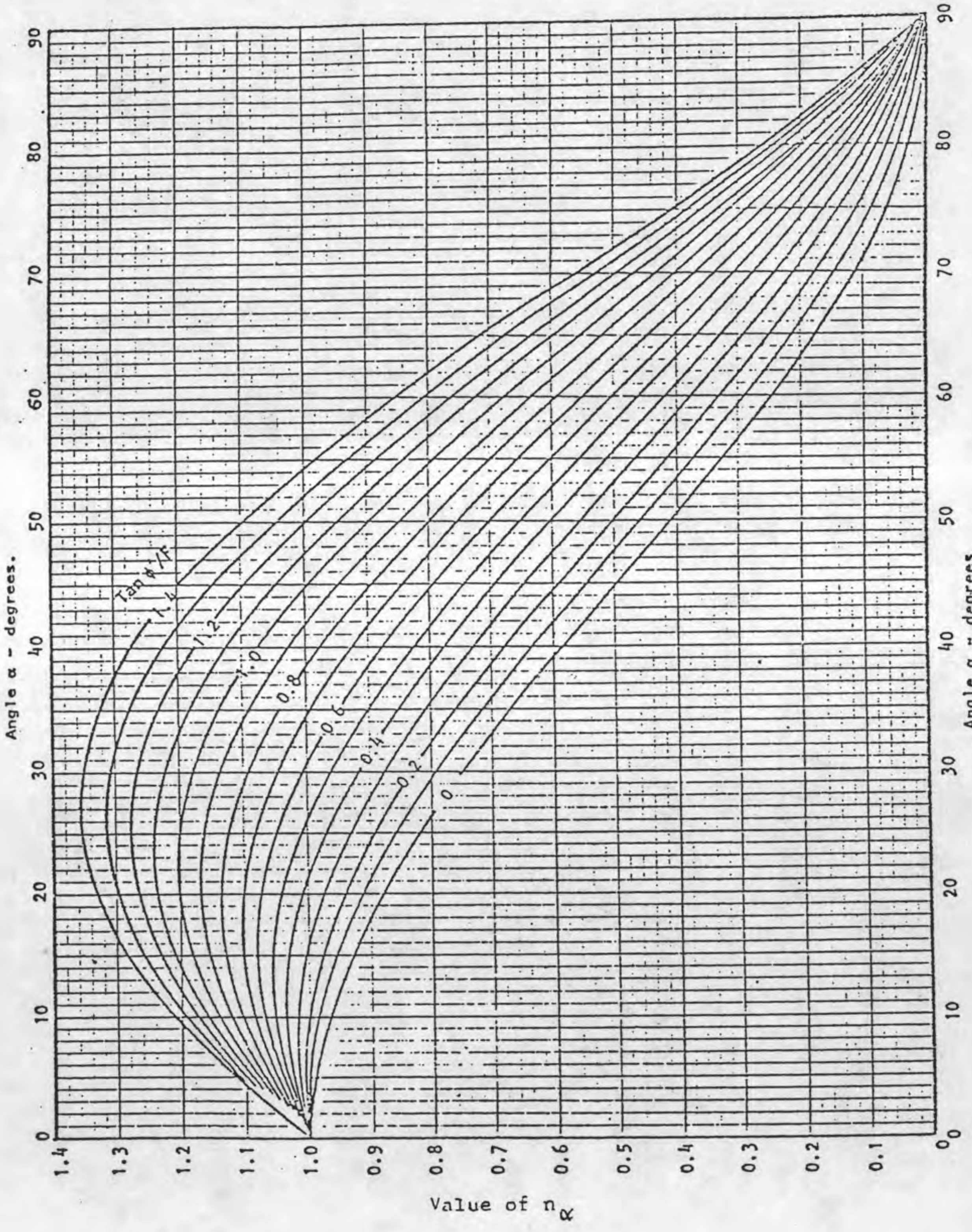


Figure E-5b Determination of value of n_α for positive angles. (Note that α is positive when the slope of the base of the slice is in the same quadrant as the ground slope).

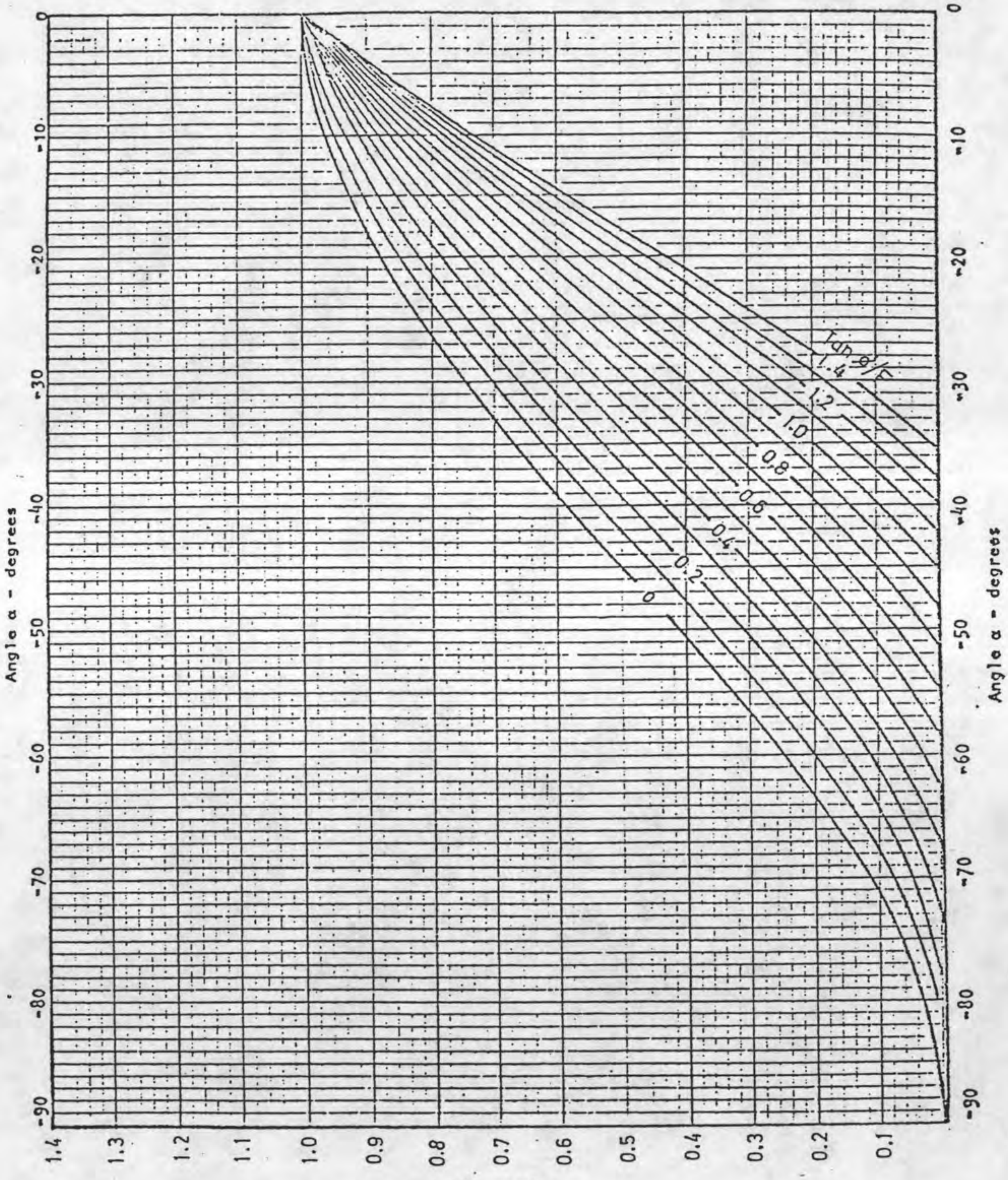


Figure E-5c Determination of value of n_α for negative angles. (Note that α is negative when the slope of the base of the slice is in different quadrant from the ground slope).

method most appropriate for condition where failure surface is not likely to be circular and failure occurs through a weak layer underlying a strong layer, and when failure occur predominantly along faults and joint in natural or cut slope. Care should be exercised in selecting inclination of interwedge forces. Suitable to many rock slopes and some soil slopes problems.

c) Morgenstern and Price's method.: Suitable for failure surface of arbitrary shape of soil and rock slopes but computer is essential. The method satisfies both force and moment equilibrium and accounts for inter-slice forces which must be assumed. Side force inclinations assumed to vary linearly across each slice. It is considered to be the most correct solution instability analysis too rigorous and too cumbersome for practical use.

d) Janbu's method: Requires assumption of inter-slice forces. Iteration made with successive sets of inter-slice forces till convergence reach. This method is the most commonly used for non - circular slip surface or slip surface of arbitrary shape of soil and rock slopes. It is sufficiently accurate for most practical purposes and simple enough to permit the solution of problems by hand calculation.

e) Janbu Simplified method: No need to account for inter-slice forces ignored. Use of correction factors necessary. Suitable for slip surface of arbitrary shape in soils and rocks.

APPENDIX F

Concept of slope failure and stability analysis of colluvial slope

CONCEPT OF SLOPE FAILURE AND STABILITY ANALYSIS OF COLLUVIAL SLOPES.

1. Slope in Colluvium.

a) Steepness of colluvial slope.: Dalrymple (1968) proposed landsurface model of region with a humid temperate climate into nine units. Transportation of material by mass movement are dominate geomorphic processes in transportation midslope and colluvial footslope units. Gray(1971) studied the stability of colluvial slopes and concluded that the maximum stable slope angles are 20 and 11 degrees for dry and saturated condition respectively. The maximum stable slopes angle that the shear strength are reduced to its residual value decrease to about 7 degrees.

b) Typical profiles.: Colluvium is frequently encountered beneath cliffs and very steep slopes and on hillsides that rise above drowned coastal topography and aggrading rivers covering the pre-slide ground surface and weathering profile. Colluvium consists of poorly sorted mixture of angular rock fragments and fine grained materials (Costa and Baker, 1981). The mixture is extremely variable in composition, grading, density (Huntley et al., 1981). Its composition varies greatly from a collection of matrixless boulders at one extreme to fine slope-wash material at the other (Brand, 1984). But the most common form consists of boulders and cobbles set in a fine grained matrix. According to Deere et al., (1971) the colluvial profiles are classified into:

i) Single layer of colluvium;

ii) Multiple layers of colluvium.

c) <u>Groundwater condition.</u>: Colluvium consists of large grain size unconsolidated materials. This results in high value of permeability, may cause a perched aquifers watertable to form at the body base during high rainfall. This groundwater flows parallel to the slope just above the underlying basement layer.

The locally lower-permeability zone within the colluvium caused by dessication or consolidation by weight of succeeding layers, the buried weathering profile between each colluvium layer, and reformation at the top of each layer or within an individual layer are generally found in multiple layers of colluvium. This lower-permeability zone affords artesian aquifer at the base of colluvium (Deere et al.,1971).

2. <u>Slope failure in colluvium</u>.:

Colluvial soils frequently contain weak planes developed during creep or slide movement. The weak, slickensided planes may occur at several levels with in the colluvium but there is always one locate at or adjacent colluvium-residual soil or rock interface. (Hunt, 1982; Deere et al., 1971)

a) <u>Slides in Colluvium</u>.: Based on the thickness of colluvial soil. Deere et al. (1971) classified slide in colluvium into 2 types (Figure F-1) as follow.

i) Ravelling of thin colluvium layer;

ii) Deep - seated slides.

b) <u>Shape of failure surface</u>.: The failure surface of arbitrary shape or non-circular failure surface are the most common

(Brand, 1981).

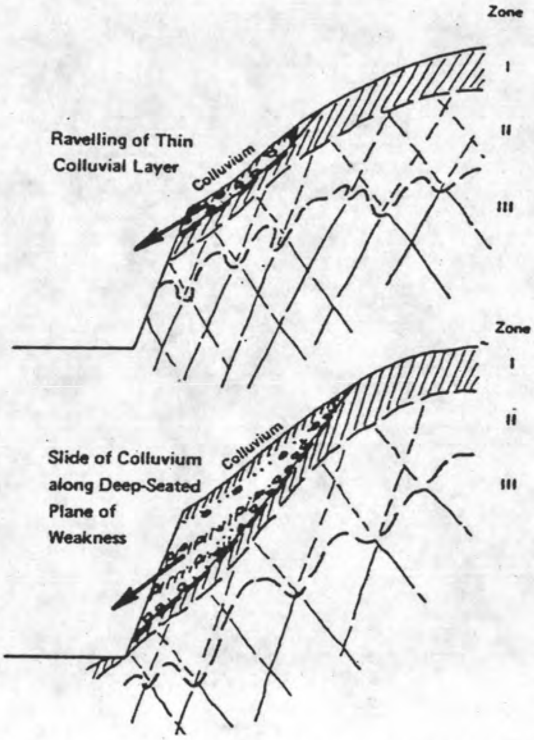


Figure F-1 Common types of slides in colluvium
(From Deere et al., 1971).

3. <u>Shear strength parameters</u>.:

Stability computation must be made in term of effective stress. The laboratory strength tests are usually carried out on the matrix materials of colluvium.

During the geology development of a colluvial slopes, the shear stress which exist at the base of a colluvial mass will have exceeded the peak shearing strength of the slide plane material resulting in a stability failure, probably in the form of creep movement. The strain movements associated with creep failure reduce the available shearing strength of the slide plane material to its residual value (Gray et al.,1971). The residual shear strength parameters are recommended for the stability computation when the failure surface occurs at the base of colluvium, or slickenside is found.

4. Method of stability analysis.:

The method of stability analysis of slopes in which the failure surface is non-circular or arbitrary shape, especially Janbu's (1954, 1973) and Morgenstern & Price's (1965) methods are most suitable.

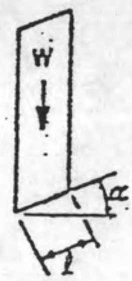
APPENDIX G

The calculation of the stability of slope for minimum F.S.

$$\Delta E = \frac{N_4 - N_1 - N_2 + N_3}{N_5}$$

Slice No.	W	α	l (m)	C (KN/m²)	ϕ	u (KN/m²)	N_1: $\frac{Cl}{\cos\alpha}$	N_2: $W\tan\phi$	N_3: $\frac{ul\tan\phi}{\cos\alpha}$
1	474.23	50°	11.50	12.60	25°	29.43	225.42	221.14	245.52
2	9389.14	14°	53.00	9.16	21°	78.48	500.34	3604.15	1645.54
3	816.10	-16	11.50	12.60	25	61.80	150.74	380.55	344.76

Trial	F	Slice No.	N_4: $FW\tan\alpha$	N_5: $F + \tan\phi\tan\alpha$	ΔE	$\Sigma\Delta E$
1	1.00	1	565.17	1.556	+234.02	-359.23
		2	2340.98	1.096	-107.64	
		3	-234.01	0.866	-485.61	
2	1.20	1	678.19	1.756	+271.73	+103.56
		2	2809.18	1.296	+270.24	
		3	-280.81	1.066	-438.41	
3	1.14	1	644.29	1.696	+261.35	-19.54
		2	2668.71	1.236	+169.72	
		3	-266.77	1.006	-450.60	
4	1.15	1	649.85	1.706	263.14	+1.82
		2	2692.13	1.246	187.14	
		3	-269.11	1.016	-448.4	



C = cohesion intercept
ϕ = friction angle
u = pore pressure at base of slice

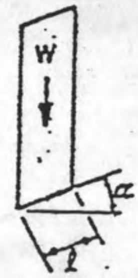
F.S 1.15

Figure G-1 Tabular form for calculating factor of safety by wedge method for preconstruction condition.

$$\Delta E = \frac{N_4 - N_1 - N_2 + N_3}{N_5}$$

Slice No.	W	α	l (m)	C (KN/m²)	ϕ	u (KN/m²)	N_1: $\frac{Cl}{\cos\alpha}$	N_2: $W \tan\phi$	N_3: $\frac{ul \tan\phi}{\cos\alpha}$
1	629.71	60°	12.50	12.60	25°	49.00	315	293.64	571.29
2	9203.89	14°	41.00	9.16	21°	83.39	387.06	3533.04	1352.61
3	1042.50	−18°	14.25	12.60	25°	49.05	188.79	486.13	342.70

Trial	F	Slice No.	N_4: $FW \tan\alpha$	N_5: $F + \tan\phi \tan\alpha$	ΔE	$\Sigma\Delta E$
1.	1.00	1	1090.69	1.808	+582.57	−457.45
		2	2294.79	1.096	−248.81	
		3	−338.73	0.848	−791.21	
2	1.22					+116.08
		1	1330.64	2.028	+637.68	
		2	2799.64	1.316	+176.41	
		3	−413.25	1.068	−698.01	
3	1.17					+3.33
		1	1276.11	1.978	+626.22	
		2	2684.90	1.266	+92.74	
		3	−396.31	1.018	−715.65	



C = cohesion intercept
ϕ = friction angle
u = pore pressure at base of slice

F.S. 1.17

Figure G-2 Tabular form for calculating factor of safety by wedge method for failure in 1983.

$$\Delta E = \frac{N_4 - N_1 - N_2 + N_3}{N_5}$$

Slice No.	W	α	ℓ (m)	C (kN/m²)	ϕ	u	N_1: $\frac{C\ell}{\cos\alpha}$	N_2: $W\tan\phi$	N_3: $\frac{u\ell\tan\phi}{\cos\alpha}$
1	397.76	63°	11.32	12.60	25	35.93	314.17	185.48	417.76
2	10331.80	14	48.62	9.16	21	98.00	458.99	3966.01	1885.01
3	1756.97	−12	23.64	12.60	25	65.88	304.52	819.29	742.45

Trial	F	Slice No.	N_4: $FW\tan\alpha$	N_5: $F + \tan\phi\tan\alpha$	ΔE	$\Sigma\Delta E$
1	1.00	1	780.65	1.915	+364.89	−440
		2	2576.01	1.096	+32.86	
		3	−373.46	0.901	−837.75	
2	1.14	1	889.94	2.055	+393.21	−61.18
		2	2936.65	1.236	+320.92	
		3	−425.74	1.041	−775.31	
3	1.16	1	905.55	2.075	+396.94	−13.97
		2	2988.17	1.256	+356.83	
		3	−433.21	1.061	−767.74	

C = cohesion intercept
ϕ = friction angle
u = pore pressure at base of slice

F.S. 1.16

Figure G-3 Tabular form for calculating factor of safety by wedge method for failure in 1985 - 1986.

Preconstruction Stage

1983

Non-circular surface No. 5B

PT	X	Y
1	6	24.5
2	20	20.5
3	25.5	22
4	32	24
5	44	25
6	47.5	24.5
7	59	28
8	64	30
9	73	32.5
10	81	42

JANBU METHOD

NUMBER OF SLICES= 25

SLICE	C	PHI	ALPHA	GAMA*H	PORE P
1	12.6	24.99	-15.95	10.16838	8.079317
2	12.6	24.99	-15.95	44.46081	32.6855
3	12.6	24.99	-15.95	97.9631	67.0853
4	12.6	24.99	-15.95	148.921	99.88413
5	9.16	20.99	-5.69	185.6008	119.3877
6	9.16	20.99	15.25	201.3861	129.1864
7	9.16	20.99	16.18	196.9069	127.4742
8	9.16	20.99	17.1	186.1875	123.469
9	9.16	20.99	13.11	177.4274	119.5166
10	9.16	20.99	4.76	175.8249	119.5567
11	9.16	20.99	4.76	177.0278	123.1679
12	9.16	20.99	4.76	182.2347	126.779
13	9.16	20.99	.45	187.8967	132.1999
14	9.16	20.99	-3.91	198.3661	141.2225
15	9.16	20.99	16.92	199.3275	143.2963
16	9.16	20.99	16.92	188.4309	136.8745
17	9.16	20.99	16.92	177.4274	130.6676
18	9.16	20.99	18.58	165.902	123.7495
19	9.16	20.99	21.8	155.583	115.861
20	9.16	20.99	17.66	150.4819	109.8133
21	9.16	20.99	15.52	150.2331	107.3444
22	9.16	20.99	15.52	151.1434	106.7864
23	12.6	24.99	41.48	133.1428	96.39912
24	12.6	24.99	49.89	85.99815	58.29748
25	12.6	24.99	49.89	28.63044	17.54102

SLICE WIDTH= 3
WATER FORCE= 0
TOTAL WT= 11268.17

SAFETY FACTOR= .98
CRITICAL ACCELERATION,Kc= 0

********************SLOPE STABILITY********************

PROJECT :FAILURE IN 1983, FAILURE SURFACE NO.3D
Non-circular surface

PT	X	Y
1	6	24.5
2	20	20
3	25.5	22
4	32	24
5	44	25
6	47.5	24.5
7	59	28
8	64.5	37.5
9	66	40

JANBU METHOD

NUMBER OF SLICES= 27

SLICE	C	PHI	ALPHA	GAMA*H	PORE P
1	12.6	25	-17.82	10.56132	6.666895
2	12.6	25	-17.82	33.49752	24.00544
3	12.6	25	-17.82	65.39485	47.60023
4	12.6	25	-17.82	104.333	73.4129
5	12.6	25	-17.82	143.2712	98.88042
6	9.16	20.99	-17.82	181.9329	118.4395
7	9.16	20.99	8.979999	208.5487	133.6184
8	9.16	20.99	19.98	217.1062	136.1835
9	9.16	20.99	19.34	215.463	133.7385
10	9.16	20.99	17.1	210.7776	131.0362
11	9.16	20.99	17.1	206.9255	128.8442
12	9.16	20.99	13.51	205.0785	126.9581
13	9.16	20.99	4.76	208.3437	128.1751
14	9.16	20.99	4.76	214.7864	132.0096
15	9.16	20.99	4.76	221.3359	135.8746
16	9.16	20.99	4.76	227.8853	139.7395
17	9.16	20.99	4.76	234.4246	143.6015
18	9.16	20.99	-6.86	245.9922	151.1155
19	9.16	20.99	:14	259.5146	160.0679
20	9.16	20.99	16.92	263.0191	161.5918
21	9.16	20.99	16.92	259.3761	158.0607
22	9.16	20.99	16.92	255.6264	154.7173
23	9.16	20.99	16.92	251.9834	151.4042
24	9.16	20.99	27.37	243.8105	144.4737
25	12.6	25	59.93	198.4767	117.3967
26	12.6	25	59.93	118.5871	58.93691
27	12.6	25	59.33	38.81325	14.69353

SLICE WIDTH= 2.222222
WATER FORCE= 0
TOTAL WT= 11210.81

SAFETY FACTOR= .98
Kc=-.01

Non-circular surface No. 5C

PT	X	Y
1	36	21.2
2	46	18.4
3	62	17.2
4	74.4	20
5	80	21.2
6	86	21.2
7	92	21.6
8	108.8	26.4
9	116	32.8
10	118.8	36.4

JANBU METHOD

NUMBER OF SLICES= 35

SLICE	C	PHI	ALPHA	GAMA*H	PORE P
1	12.6	25	-15.65	24.9364	15.92967
2	12.6	25	-15.65	61.774	42.60101
3	12.6	25	-15.65	85.67641	64.12413
4	12.6	25	-15.65	109.6788	85.68704
5	12.6	25	-6.94	129.5274	103.758
6	12.6	25	-4.29	144.262	117.4149
7	12.6	25	-4.29	157.7233	129.825
8	12.6	25	-4.29	170.2714	141.0269
9	12.6	25	-4.29	183.1272	151.7065
10	12.6	25	-4.29	196.5838	162.6252
11	9.16	20.99	-4.13	209.2723	165.2522
12	9.16	20.99	12.72	218.0346	170.4454
13	9.16	20.99	12.72	224.9372	171.5123
14	9.16	20.99	12.72	233.6865	173.2441
15	9.16	20.99	12.72	242.8284	175.1171
16	9.16	20.99	12.72	252.1215	177.0447
17	9.16	20.99	12.24	254.803	176.6947
18	9.16	20.99	12.09	250.6798	174.0287
19	9.16	20.99	7.31	248.3022	173.0192
20	9.16	20.99	0	250.7543	176.2348
21	9.16	20.99	0	256.2044	182.0193
22	9.16	20.99	3.29	259.986	186.5539
23	9.16	20.99	3.81	261.7524	189.6121
24	9.16	20.99	7.89	261.7129	191.0836
25	9.16	20.99	15.94	256.5058	188.1531
26	9.16	20.99	15.94	247.7003	182.2203
27	9.16	20.99	15.94	239.1015	176.3619
28	9.16	20.99	15.94	230.4993	170.5023
29	9.16	20.99	15.94	221.7777	164.3026
30	9.16	20.99	15.94	213.022	156.9302
31	9.16	20.99	22.91	201.0436	145.9453
32	12.6	25	41.63	187.932	138.9107
33	12.6	25	41.63	176.7573	122.2445
34	12.6	25	43.88	130.0314	86.23874
35	19.61	33	52.12	73.27764	11.98554

SLICE WIDTH= 2.365714
WATER FORCE= 0
TOTAL WT= 16243.67

SAFETY FACTOR= .95
Kc= .01

***********************SLOPE STABILITY*********************

PROJECT :FAILURE IN 1985-1986, SECTION D-D' FAILURE SURFACE NO.4C
Non-circular surface

PT	X	Y
1	38	33.2
2	50	28.8
3	61.2	27.2
4	73.48	30.4
5	78	31.2
6	89.2	32.8
7	102	35.6
8	108	37.2
9	114	49.2

JANBU METHOD

NUMBER OF SLICES= 22

SLICE	C	PHI	ALPHA	GAMA*H	PORE P
1	12.6	25	-20.14	5.12064	4.416194
2	12.6	25	-20.14	29.337	25.18716
3	12.6	25	-20.14	67.42176	57.85425
4	12.6	25	-13.98	101.1326	86.78458
5	12.6	25	-8.14	138.364	117.9389
6	12.6	25	-8.14	183.9163	155.48
7	9.16	20.99	1.62	225.0549	181.026
8	9.16	20.99	14.6	247.126	199.8603
9	9.16	20.99	14.6	257.5078	207.7337
10	9.16	20.99	14.6	270.2207	210.5582
11	9.16	20.99	11.28	278.1589	208.6682
12	9.16	20.99	9.229999	277.4166	205.3132
13	9.16	20.99	8.13	273.7366	201.8623
14	9.16	20.99	8.13	271.0243	199.0946
15	9.16	20.99	8.89	267.6484	196.1452
16	9.16	20.99	12.33	261.3208	191.3933
17	9.16	20.99	12.33	252.6082	184.9855
18	9.16	20.99	12.33	241.2926	177.6407
19	9.16	20.99	13.57	226.4981	168.6588
20	9.16	20.99	14.93	210.701	159.5891
21	12.6	25	57.06	162.1208	126.2453
22	19.61	33	63.43	105.1947	20.53409

SLICE WIDTH= 3.454546
WATER FORCE= 0
TOTAL WT= 15037.37

SAFETY FACTOR= .79

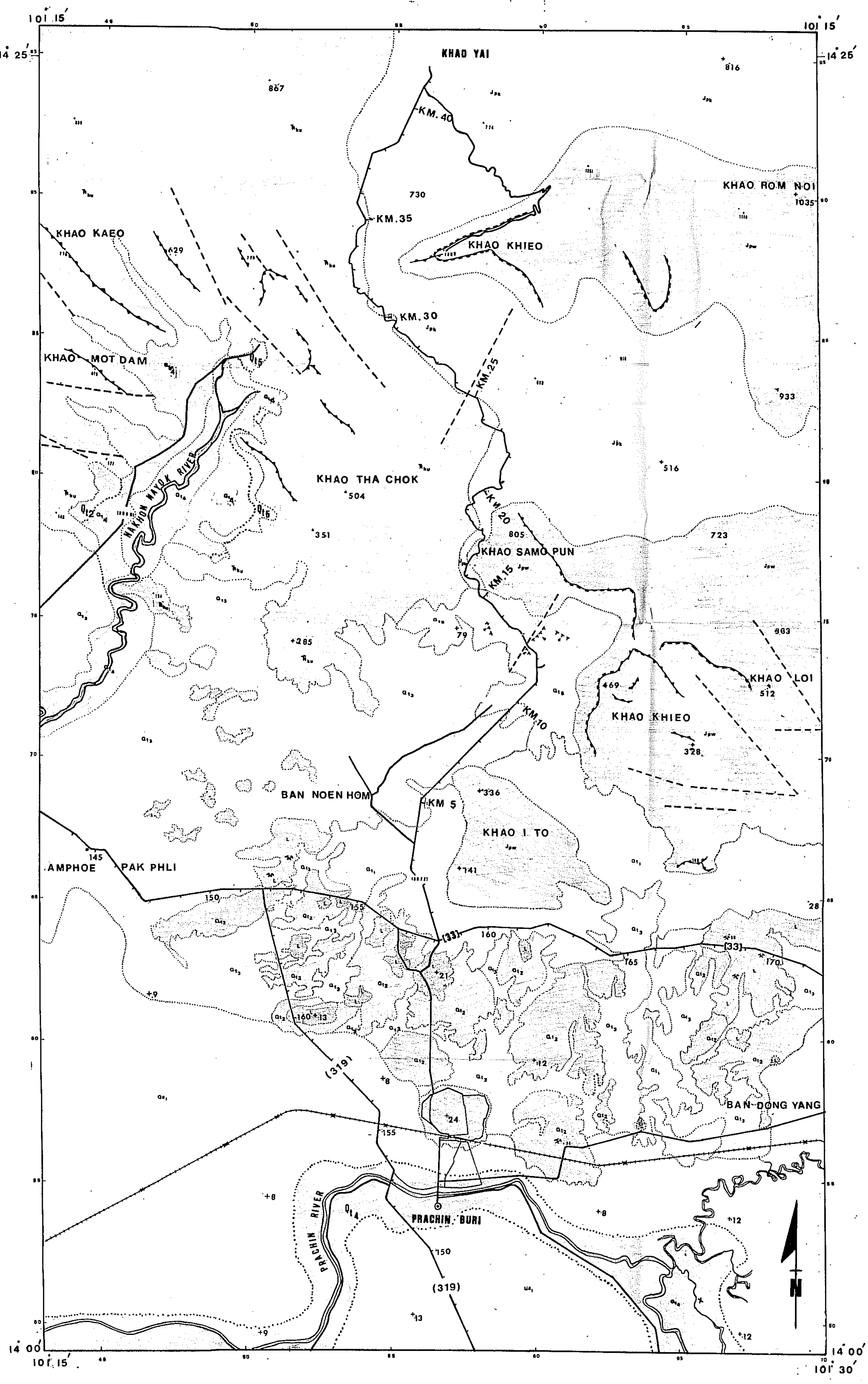
Kc=-.04

BIOGRAPHY

Mr. Surapol SANGUANKEO was born on JUNE 3, 1954 in Changwat Chiangmai, northern part of Thailand. In 1976, he graduated from Chiangmai University in geology. He has spent a period working as an engineering geologist for Material and Research Division, Highways Department, where he works in the geotechnical group of highways. In 1986, he returned to study for M.Sc. (Geology) at the Graduate School of Chulalongkorn University. He is now responsible for a variety of projects but specializing in landslide investigation.

PLATE 6.1

GEOTECHNICAL MAP OF PRACHINBURI–KHAO YAI AREA



EXPLANATION

Surficial Deposits

Qa_1	Dark grey to black clay
Qt_1	Brown to yellowish brown silty fine sand, non-plastic, the depth to bed rocks is 7–15 m.
Qt_2	Brown to pale brown, greyish brown clayey silty find sand and silty clayey fine sand, non-plastic(VL) to slightly plastic(SL) the depthto bed rocks is 5–15 m.
Qt_3	Brown to greyish brown silty clay or clayey find sand, slightly (SL) to medium plastic (M) the depth to bed rocks is 7–20 m.
Qt_4	Undifferentiated Alluvium, Recent Alluvium.
Qt_5	Colluvium is greyish white, consists of large rock fragments in gravelly clayey fine sand matrix, slightly plastic (SL)
L	Lateritic soil in middle and high terrace, clayey sandy gravel or clayey gravelly sand, gravel 35-55%, slightly (SL)– medium plastic(M) thickness is > 1.50 m locally 5-9 m

Rock Units

J_{pw}	White, yellowish brown, thick bedded Sandstone, moderately to well cement, moderately strong rock 50–60 MN/m^2
J_{pk}	Reddish brown, purplish red, stiff soil to moderately weak Mudstone and Siltstone locally interbedded with strong to very strong Siltstone 100– 250 MN/m^2 the lower part of the unit is completely to highly weathered basal conglomerale
Tr_{ku}	Slightly to completely weathered (thickness > 12 m) Rhyolite, Tuff, agglomerate locally is moderately strong to strong rock 60–175 MN/m^2

Structure

- Faults
- Boundary between units

Morphology

- Cliff
- Sharp ridges

Slope movement

- Slump

Railroad

Province

SCALE 1:112,360

1 3 5 km.

1) Compiled and Drawn by

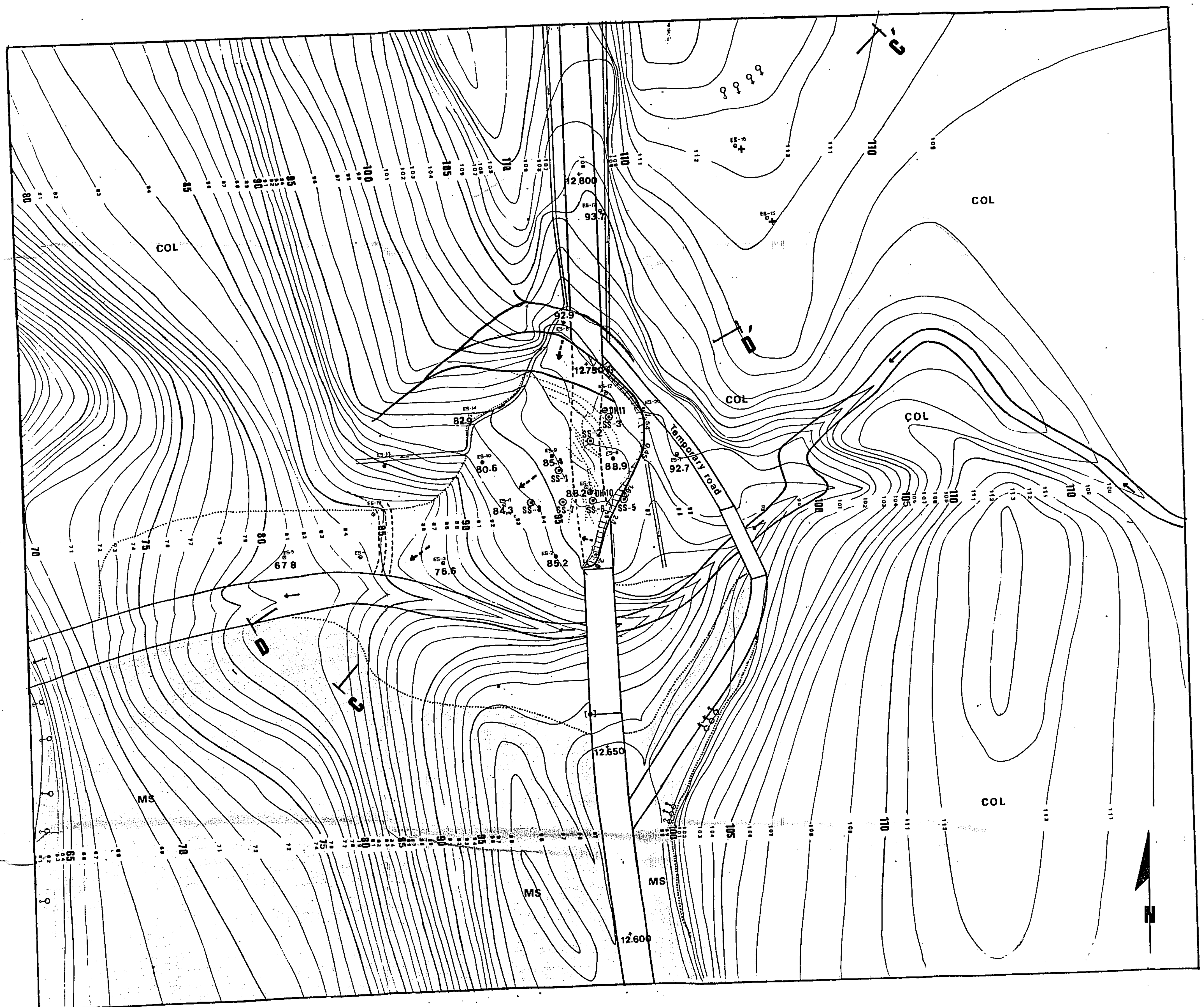
SURAPOL SANGUANKEO, 1988

2) This map is based on drilling logs, aerial photograph interpretation and field observations

PLATE 6.2

ENGINEERING GEOLOGICAL MAP OF LANDSLIDE AREA (1985—1986)

K M. 12.658 TO 12.765 PRACHINBURI TO KHAO YAI HIGHWAY



SCALE 1:800

0 16 32 m.

S. SANGUANKEO. 1988

EXPLANATION

(blank box)	Filled material consist of yellowish brown silty sand, loose to medium (N-values = 5-12), non-plastic soil poor to fair subgrade (CBR). The thickness varies from 2-3.5 m.
COL	Grayish white colluvium, consists of a lot of large subangular- subround of moderately - slightly weathered rock fragments and sandstone boulders in loose - medium, slightly plastic of gravelly clayey sand matrix. The thickness varies from 4-12 m.
MS	Reddish brown mudstone & siltstone, hard to very hard, impermeable.
....	Approximate geologic boundary
1.65	Major crack of failure in 1985 & landslide scarp showing height (1.65) in metres
	Major cracks
	Tension cracks
	Stream
????	Seepage
	Side ditch & drained chute
ES-5 ⊙ 67.8	Electrical resistivity sounding points with depth to top of bedrock
⊕DH11, ⊙, +	Boreholes with installed piezometers, Simple sounding penetration tests, Observation wells.
	Movement direction of slide
D—D'	Geological cross-section lines
85	Contour line (metre)
[•]	Reference bench mark (98.00 M.)