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STR. SITE No.

HWY. No. 17

LOCATION Hwy 17 Embankment Instability
(Orleans to Rockland)

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OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

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**foundation
investigation and
design report**

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WO 86-11007

DIST 9

HWY 17

STR SITE N/A

Embankment Instabilities
Orleans to Rockland

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FOUNDATION INVESTIGATION REPORT

For
Embankment Instabilities
W.O. 86-11007; Site N/A
Hwy. 17, District 9, Ottawa

INTRODUCTION

This report summarizes the foundation investigation for the remedial requirements for embankment instabilities at 5 locations along Hwy. 17, east of Ottawa, between Orleans and Rockland.

SITE DESCRIPTION

In this area, Hwy. 17 runs essentially east-west, parallel to the south bank of the Ottawa River. The distance between Orleans and Rockland is approximately 23 km.

The sites are distressed fill zones along Hwy. 17. These fills are 6 to 12 m high, and are characterized by surficial slips, washouts, and, at some locations, minor cracking at the crest.

The total distance along Hwy. 17, that has been identified for remedial treatment, is approximately 730 m. Chainages for the remedial treatments at the designated sites are as follows:

Site	Survey Chainage	
	Left	Right
1	NA	11+765 to 11+835
2	12+560 to 12+675	12+480 to 12+655
3	23+050 to 23+200	NA
4	12+295 to 12+365	(50 m on each side of culvert inlet)
5	NA	15+330 to 15+380

Approximate locations of the sites are illustrated in Figure 1. Typical sections are also appended (Figures 2A to 2E).

The sites are located in the physiographic area of Ottawa Valley Clay Plains (Chapman and Putnam, 1984). At these locations the surface slopes towards the Ottawa River.

INVESTIGATION PROCEDURES

The field work was carried out between 87 01 08 and 87 03 05 utilizing continuous flight auger machines equipped with 82 mm I.D. hollow stem augers and B-casings, and wash-boring drills equipped with B-casing.

The investigation consisted of 16 sampled boreholes accompanied by dynamic cone penetration tests. Boreholes/cone tests were advanced through the road shoulders and at the toe of slope, at critical sections, for depths ranging from 11.9 to 38.4 m. At some locations, cone tests were driven beyond the borehole depth in order to probe the extent of the overburden. Survey details of the borehole locations were provided by the Eastern Region Surveys and Plans Section.

A total of 182 samples were collected; 27 shelly tube samples, 153 split spoon samples, 2 chunk samples. The shelly tube samples provided relatively undisturbed samples for detailed laboratory evaluation of representative zones of the cohesive overburden. The split spoon samples provided Standard Penetration Test values for assessment of the insitu state of compaction of the non-cohesive materials and for an indication of shear strength of the cohesive materials. The split spoon samples and chunk samples provided material for identification purposes. The field work program also included 133 field vane tests to determine insitu shear strengths and sensitivity values of the cohesive material. Groundwater elevation measurements were attempted at each borehole, although stabilized levels were difficult to achieve because of the high plasticity of the overburden.

The laboratory testing consisted of:

- 40 grain size analyses and 40 water content/Atterberg Limit tests to identify the material

- 18 unconfined compression tests to determine shear strengths
- 18 unit weight tests
- 4 stage compression tests to determine effective stress parameters.

SUBSURFACE CONDITIONS

General

The Record of Borehole Sheets in the Appendix illustrate the subsurface conditions at the borehole locations. The boreholes are referenced as follows:

Site Reference Number	Borehole
1	1-1, 1-2
2	2-1, 2-2, 2-3
3	3-1, 3-2, 3-3, 3-4
4	4-1, 4-2, 4-3, 4-4
5	5-1, 5-2, 5-3

At the distressed sites, highway embankments are 6 to 12 m high. Typically, the upper 1.5 m of the fill is granular roadbed material, while the remainder is composed of clay of intermediate to high plasticity. The embankments are underlain by extensive deposits (20 + m) of sensitive marine clay.

Fills

Granular Base Coarse: Sand, some silt, trace clay

This non-cohesive material is the roadbed material. Its thickness at the borehole locations, is up to 1.7 m.

Based on results of Standard Penetration Tests, the insitu state of compaction of this material is loose to compact.

A typical grain size distribution is indicated below:

Gravel	0 %
Sand	83.0 - 88.0%
Silt	8.0 - 11.5%
Clay	4.0 - 5.5%

Main Embankment Fill: Clay (CI-CH), with silt, trace sand, trace gravel
This cohesive material is the main highway embankment fill. Its thickness is variable (up to 10.4 m at the BH locations) depending on local topography.

At some locations occasional sandy or gravelly zones were encountered within the fill.

Properties of the material, as determined by field and laboratory tests, are summarized as follows:

<u>Property</u>	<u>Range</u>	<u>Average</u>	<u>Median</u>
ATTERBERG LIMITS			
- moisture content (w)	26.0 - 38.0%	32.3%	32.0%
- liquid limit (w_L)	39.0 - 71.0%	54.5%	55.5%
- plastic limit (w_p)	17.5 - 25.5%	22.2%	22.5%
UNDRAINED SHEAR STRENGTH (cu)			
- from unconfined compression	73.6 - 99.3 kPa	82.4 kPa	74.3 kPa
- from MTC field vane	70 - 112+ kPa	NA	NA
- unit weight (γ)	17.5 - 19.2 kN/m ³	18.5 kN/m ³	18.7 kN/m ³

Figure 3 illustrates a typical grain size distribution for this material.

Based on the Atterberg Limits, the material is clay of intermediate to high plasticity.

Based on the results of the unconfined compression tests, field vanes and Standard Penetration Tests, the consistency of this material is firm to very stiff.

Toe Fill: Gravel, Sand, Organic Material and Boulders

This compact to very dense fill was encountered at the surface near the toe of the south side of the embankment at Site 4 where it apparently had been placed during construction of a Hydro access road.

Native Overburden Clay (CH), with silt, trace sand

This cohesive marine clay underlies the highway embankment fill at all sites. Its thickness (20 + m) was not fully investigated as boreholes were generally terminated within this deposit.

Properties of the material, as determined by field and laboratory tests, are summarized as follows:

<u>Property</u>	<u>Range</u>	<u>Average</u>	<u>Median</u>
ATTERBERG LIMITS			
- moisture content (w)	28.5 - 71.0%	46.6%	44.5%
- liquid limit (w_L)	35.5 - 80.0%	58.4%	60.0%
- plastic limit (w_p)	19.5 - 29.0%	23.4%	22.5%
UNDRAINED SHEAR STRENGTH (c_u)			
- from unconfined compression	22.9 - 96.1 kPa	52.0 kPa	55.2 kPa
EFFECTIVE STRESS PARAMETERS			
overconsolidated values			
- effective shear strength (c')	11.3 - 20.9 kPa	14.2 kPa	12.5 kPa
- effective friction angle (ϕ')	32.5 - 45.0°	36.1°	33.5°
normally consolidated values			
- effective shear strength (c')	0	0	0
- effective friction angle (ϕ')	35.0 - 44.0°	39.5°	39.5°
- Unit Weight (γ)	15.7 - 18.1 kN/m ³	16.6 kN/m ³	16.6 kN/m ³

Figure 4 illustrates a typical grain size distribution for this material.

Based on the Atterberg Limits, this material is clay of intermediate to high plasticity.

Figure 5 illustrates the typical relationship between shear strength and depth below native ground surface. The figure incorporates results from both laboratory unconfined compression tests and field vane tests. The native clay exhibits a 4 m thick crust of increased shear strength ranging from 80±kPa at the surface to 25+kPa at a depth of 4 m. Beyond the 4 m depth, the shear strength of this material increases linearly with depth, reaching 80±kPa at 20 m below the surface.

The results of remolded field vane tests illustrate the extremely high sensitivity of this material. Once disturbed its strength is drastically reduced.

The scattering of the effective stress results may be attributed to the non-uniformity and degree of disturbance of the samples and also to the presence of silt seams.

Based on the results of the unconfined compression tests, field vanes and Standard Penetration Tests, the consistency of this material is very soft to very stiff.

GROUNDWATER

Due to the high plasticity of the material, and consequently the long period of time required to establish a stabilized condition, the groundwater elevations have been largely inferred from field observations and natural water contents of the soil.

For stability calculation purposes, the groundwater elevation has been assumed to be at the toe of slope. However, based on previous investigations in this area, the actual water table may be some 3 m below ground surface. Groundwater seepage is expected to be in the direction of the Ottawa River.

Artesian groundwater conditions were encountered at 2 boreholes during the investigation.

At BH #3-3, an artesian condition (to elev. 47.9 m) was encountered on 87 02 19 at elevation 18.8 m, during driving of the dynamic cone (A-rod) from the bottom of the augered borehole (elev. 28.1 m). The artesian flow was contained within the augers on 87 02 19, and successfully sealed on 87 02 20 by installing the following sequence of plugs from the bottom of the augered borehole.

- 3.0 m of clay (CH)
- 1.5 m of peltonite
- 11.4 m of clay (CH)
- 1.5 m (0.2 m ϕ) log
- 1.5 m of peltonite
- 0.3 m of cement

At BH #4-3, an artesian condition (to elev. 42.9) was encountered on 87 02 24 at elevation 16.1 m, during driving of the dynamic cone (A-rod) from the bottom of the augered borehole (elev. 23.7 m). The artesian flow was contained within the augers on 87 02 24 and successfully sealed on the same day by installing the following sequence of plugs from the bottom of the augered borehole.

- 17.7 m of clay (CH)
- 1.2 m of peltonite
- 0.3 m of clay (CH)

DISCUSSION AND RECOMMENDATIONS

As requested by the Eastern Region Geotechnical Section on behalf of District 9 Maintenance, the Foundation Design Section carried out an investigation to determine appropriate remedial measures for 5 embankment instability sites along Hwy. 17 between Orleans and Rockland.

Stability Considerations

Detailed stability analyses, in terms of total and effective stresses have been carried out for 3 typical sections - 6, 9 and 12 m heights. These analyses were conducted with the aid of MTC's Bishop slope stability program.

Reference is made to the Foundation Investigation Report for W0 73-11053 for a rigorous assessment of the material properties as they relate to stability. Much of the experience from this previous investigation and construction has been incorporated into this report.

The shear strength parameters used for total stress analyses were based on consolidated undrained triaxial tests with pore pressure measurements, assuming $c' = 5$ kPa, $\phi' = 22^\circ$ for the fill and $c' = 10$ kPa, $\phi' = 22^\circ$ for the native material. These assumptions are consistent with C.B. Crawford's suggested reduction of measured effective stress parameters as discussed in his 1963 publication "Cohesion in an undisturbed sensitive clay". (Geotechnique, Vol. 13, pp 132-146).

Details of the assumptions and results of the stability analyses are provided in the following figures.

Embankment Height	Stability Analysis	
	Total Stress	Effective Stress
6	Fig. 6A	Fig. 6B
9	Fig. 7A	Fig. 7B
12	Fig. 8A	Fig. 8B

Remedial Recommendations

The instabilities at these sites are generally surficial failures characterized by slips and erosion. They are caused by the properties of the embankment material (clay) and the embankment geometry (relatively high embankments with relatively steep slopes).

The remedial recommendations for a typical instability are illustrated in Figure 9. Basically the slopes should be flattened to 2H:1V and covered with a 1 m thick blanket of rock fill or free-draining granular material.

Where embankments are over 6 m high, berms are required. The berms should be constructed at a height of 6 m below the embankment crest. The required berm widths for the range of embankment heights encountered are provided in Figure 10.

The slope blankets and berms may be graded into the existing topography, outside the remedial area, at slopes of 2H:1V.

Detailed descriptions and recommendations for each site are provided along with our recommended priorities based on geotechnical considerations.

SITE #: 1

LOCATION: 1.5 km east of ~~Chatelaine~~ ^{CHAMPLAIN} Street

EMBANKMENT

	LEFT (NORTH)	RIGHT (SOUTH)
HORIZONTAL EXTENT	NA	Sta. 11+765 to Sta. 11+835
EXISTING EMBANKMENT GEOMETRY (APPROXIMATE)		5.2 m high @ 1.5H:1V
PROBLEM DESCRIPTION		- surficial failures
REMEDIAL RECOMMENDATIONS		- flatten slope to 2H:1V - apply blanket
PRIORITY		Low

SITE #: 2

LOCATION: 2.5 km east of ~~Chatelaine~~ ^{Campbell} Street

EMBANKMENT

	LEFT (NORTH)	RIGHT (SOUTH)
HORIZONTAL EXTENT	Sta. 12+560 to Sta. 12+675	Sta. 12+480 to Sta. 12+655
EXISTING EMBANKMENT GEOMETRY (APPROXIMATE)	12.2 m high @ 2H:1V	6.4 m high @ 1.9H:1V
PROBLEM DESCRIPTION	<ul style="list-style-type: none"> - surficial failures - unacceptably low safety factor against deep-seated failure 	<ul style="list-style-type: none"> - surficial failures
REMEDIAL RECOMMENDATIONS	<ul style="list-style-type: none"> *REFER TO SITE #2 DETAILS - maintain maximum slope of 2H:1V - apply blanket - construct berm 	<ul style="list-style-type: none"> - flatten slope to 2H:1V - apply blanket
PRIORITY	High	Medium

SITE #: 3

LOCATION: 1 km east of Morin Road

EMBANKMENT

	LEFT (NORTH)	RIGHT (SOUTH)
HORIZONTAL EXTENT	Sta. 23+050 to Sta. 23+200	approx. same as left chainage
EXISTING EMBANKMENT GEOMETRY (APPROXIMATE)	8.5 m high @ 2.3H:1V	2.4 m high @ 1.4H:1V
PROBLEM DESCRIPTION	<ul style="list-style-type: none"> - surficial failures - undermining and erosion at culvert outlet - unstable existing gabion structure 	<ul style="list-style-type: none"> - surficial failures - space restrictions
REMEDIAL RECOMMENDATIONS	<p>*REFER TO SITE #3 DETAILS</p> <ul style="list-style-type: none"> - maintain maximum slope of 2H:1V - apply blanket - construct berm - realign outlet creek parallel to culvert - backfill existing meandering outlet creek <p>Option 1: extend culvert Option 2: build gabion outlet structure Option 3: construct culvert outlet with rockfill</p>	<p>Option 1 - maintain drainage with culvert pipe parallel to highway</p> <ul style="list-style-type: none"> - flatten slope by backfilling - apply blanket <p>Option 2 - continued inspection and repair as required by end dumping rockfill to flatten slope</p>
PRIORITY	High	Low

SITE #: 4

LOCATION: Laurier St. and Hwy. 17 approx. 60 m east of OPP Station

EMBANKMENT

	LEFT (NORTH)	RIGHT (SOUTH)
HORIZONTAL EXTENT	Sta. 12+295 to Sta. 12+365±	50± m on each side of culvert inlet
EXISTING EMBANKMENT GEOMETRY (APPROXIMATE)	6± m @ 1.5H:1V	3.3 m @ 1.8H:1V
PROBLEM DESCRIPTION	- surficial failures	- surficial failures - blockage of culvert inlet - steep slopes and restricted space
REMEDIAL RECOMMENDATIONS	- flatten slopes to 2H:1V - construct blanket	*REFER TO SITE #4 DETAILS - construct blanket and establish 2H:1V slopes by end dumping rockfill - construct gabion structure at culvert inlet to retain embankments
PRIORITY	Medium	Medium

SITE #: 5

LOCATION: East of Pigeon Street

EMBANKMENT

	LEFT (NORTH)	RIGHT (SOUTH)
HORIZONTAL EXTENT	NA	Sta. 15+330 to Sta. 15+380
EXISTING EMBANKMENT GEOMETRY (APPROXIMATE)		6 m high @ 2H:1V
PROBLEM DESCRIPTION		- surficial failures
REMEDIAL RECOMMENDATIONS		- establish slopes @ 2H:1V or flatter - construct blanket
PRIORITY		Low - except for Sta. 15+350 to Sta. 15+360 which is medium priority

Non-standard details for Sites #2, #3 and #4 are provided below:

Site #2 Details

The left (north) side at this site has an unacceptably low factor of safety against deep seated failure. This situation results from the relatively high embankment founded on the relatively weak deposit of marine clay. The risk of failure is more critical due to the extremely sensitive nature of the clay, with disturbed strengths less than 10% of undisturbed strengths.

However, it is our understanding that there is a limited budget for remedial work, and since there is tree cover along the lower portion of the embankment, a temporary measure could be considered to improve the surficial slope stability instead of the full scale berm option. This would involve removal of 1 m of the existing embankment, above the tree line, and replacement with either rock fill but preferably Granular A. This operation should be conducted in strips, not exceeding 5m in width. The strips should extend from the crest of the embankment to the treeline. Backfilling operations should be completed before excavation commences on subsequent strips. The existing tree cover and roots should not be disturbed. After the material has been replaced, the site should be periodically inspected, to ensure that the stability of the slope does not deteriorate. If any signs of distress are noted, this office should be notified immediately.

Site #3 Details

The main difficulty at this site will be the treatment at the culvert outlet. Three options have been proposed:

- 1) culvert extension
- 2) gabion outlet structure (refer to Figure 11)
- 3) rock fill outlet

Options 1 and 2 would lead to a more positive solution, but in view of budget limitations, Option 3 could be considered as an alternative, provided that the site is periodically monitored and any signs of distress are reported immediately.

For Option 3, the outlet creek should be straightened to parallel the culvert, and protected with rock protection for a minimum of 10 m beyond the toe of slope. The existing outlet creek should be backfilled. The embankment and berm should be constructed as illustrated in Figures 9 and 10. In the immediate area of the culvert outlet, water is expected to run through the rock fill to the outlet creek.

Site #4 Details

The recommended treatment at the right (south) side of Site 4 is to end dump rock fill to construct stable 2H:1V slopes. The water in the ditch is expected to run through the rock fill. However, retaining structures will be required to maintain the embankments to the existing level of the culvert inlet. This can be accomplished by a gabion structure with a 0.5 m thick rock fill mat as illustrated in Figure 12.

MISCELLANEOUS

The field work for this project was carried out under the supervision of Mr. D. Liu, Student Engineer.

The equipment used was owned and operated by Marathon Drilling Co. Ltd.

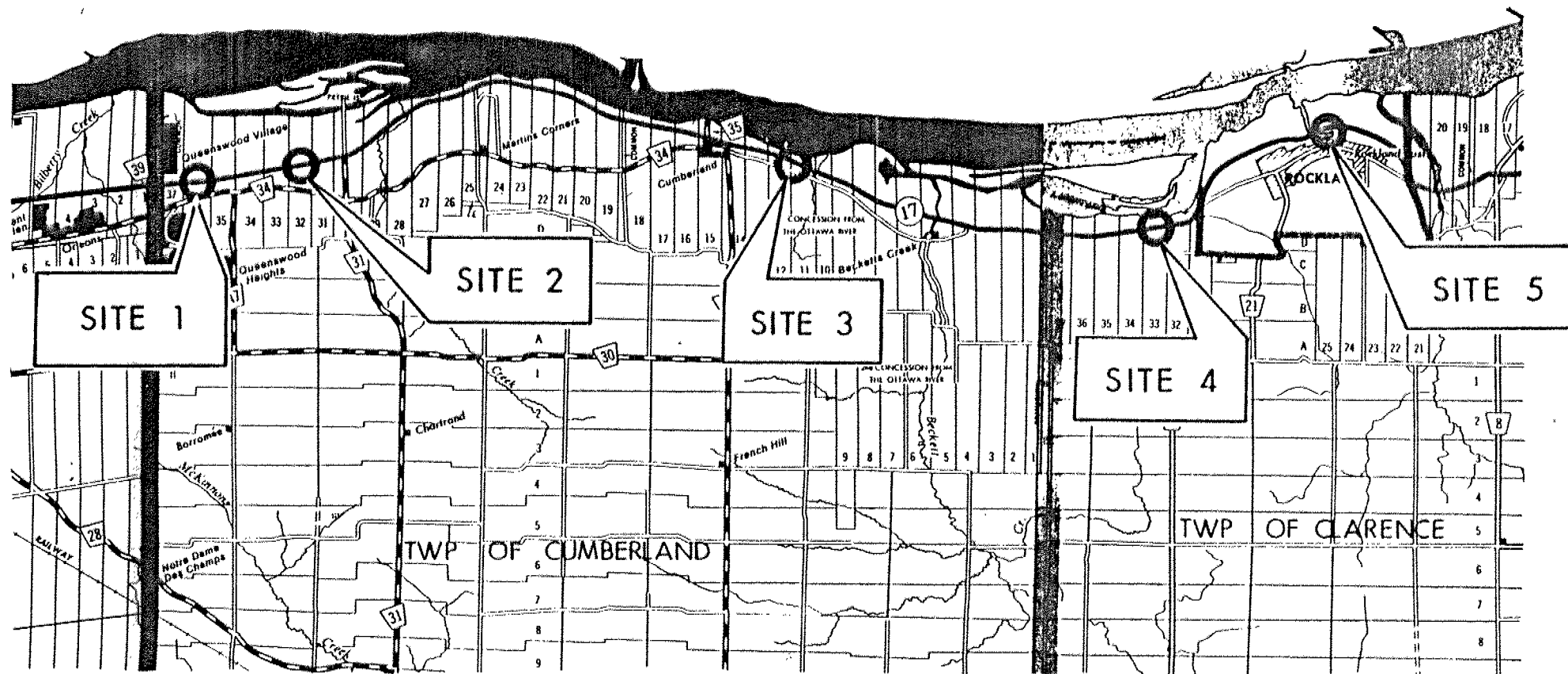
The report was written by Mr. D. Dundas, Senior Foundations Engineer and reviewed by Mr. M. Devata, Chief Foundations Engineer (East).



D. H. Dundas
D. H. Dundas, P.Eng.
Senior Foundations Engineer

M. Devata
M. Devata, P.Eng.
Chief Foundations Engineer (East)

APPENDIX



SITE PLAN SCALE: 1cm = 1km

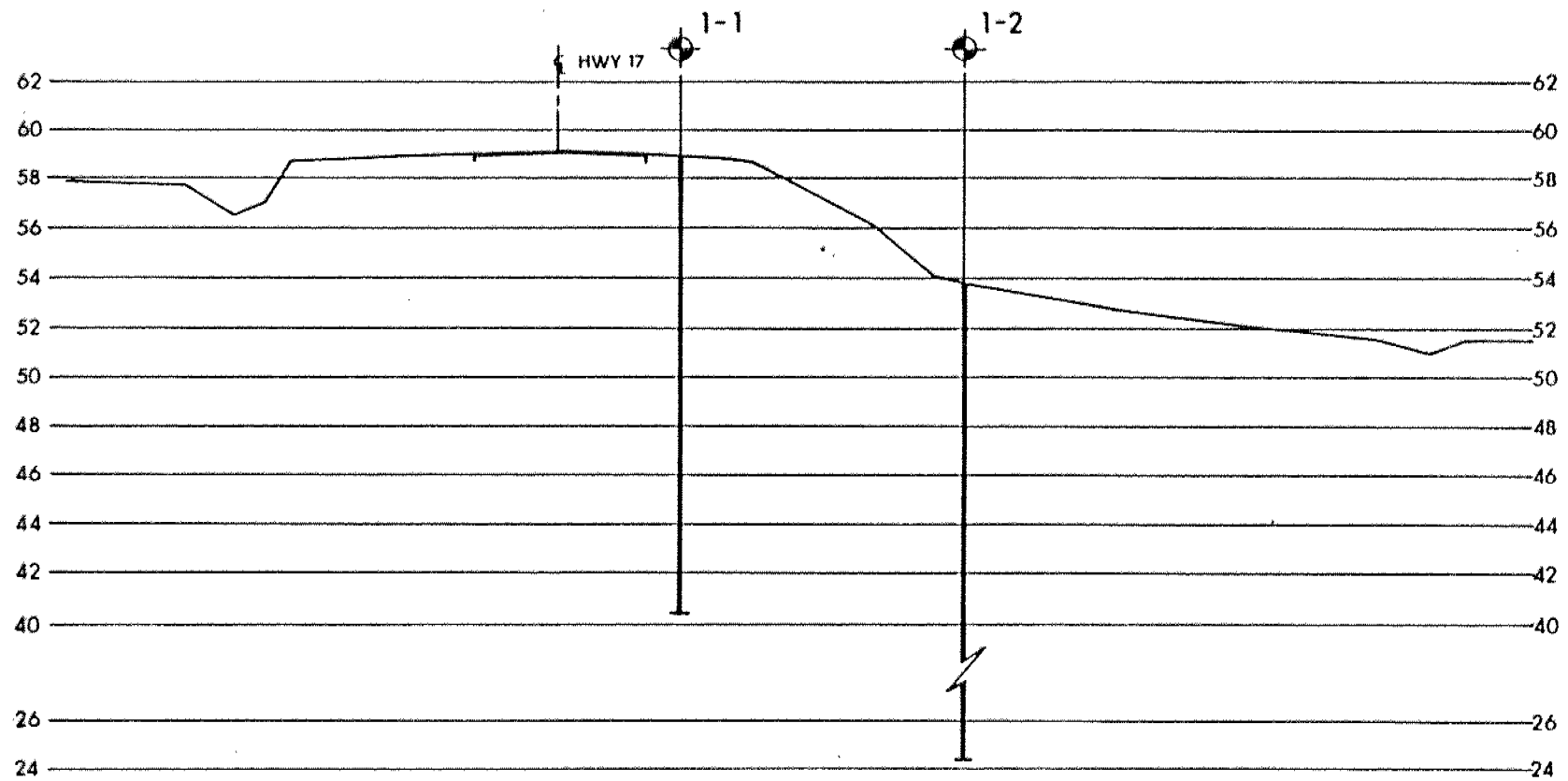
Site #1		
B.H.	Station	Offset
1-1	11 + 811.0	5.0 m Rt.
1-2	11 + 811.0	16.6 m Rt.

Site #2		
B.H.	Station	Offset
2-1	12 + 588.4	4.7 m Rt.
2-2	12 + 588.4	24.2 m Rt.
2-3	12 + 588.4	34.0 m Lt.

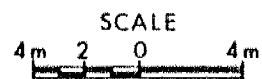
Site #3		
B.H.	Station	Offset
3-1	23 + 153.0	5.0 m Rt.
3-2	23 + 153.0	5.2 m Lt.
3-3	23 + 153.0	17.3 m Lt.
3-4	23 + 121.0	19.2 m Lt.

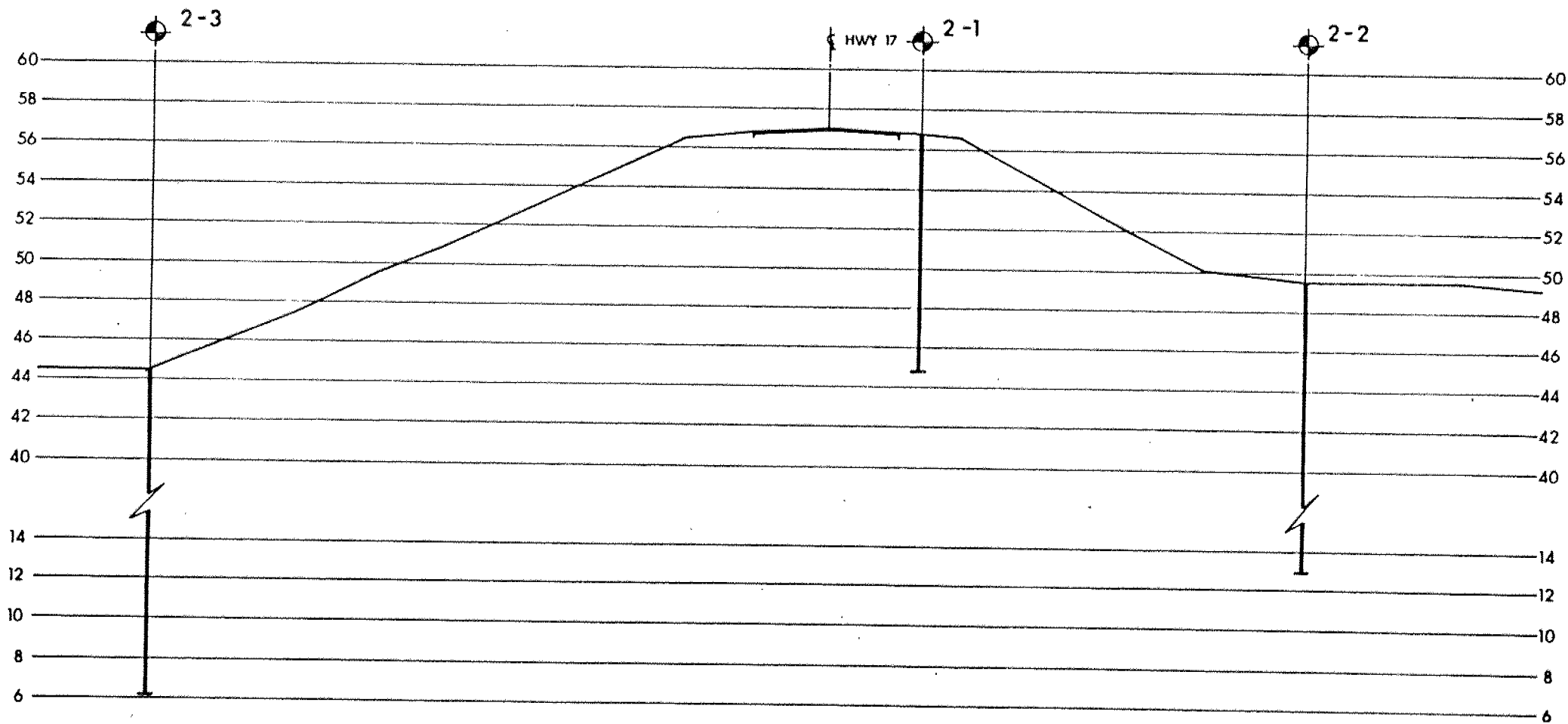
Site #4		
B.H.	Station	Offset
4-1	12 + 322.0	5.0 m Lt.
4-2	12 + 322.0	20.0 m Rt.
4-3	12 + 322.0	17.0 m Lt.
4-4	12 + 371.0	20.3 m Lt.

Site #5		
B.H.	Station	Offset
5-1	15 + 399.0	5.0 m Rt.
5-2	15 + 399.0	25.4 m Rt.
5-3	15 + 342.6	25.0 m Rt.

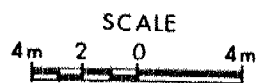


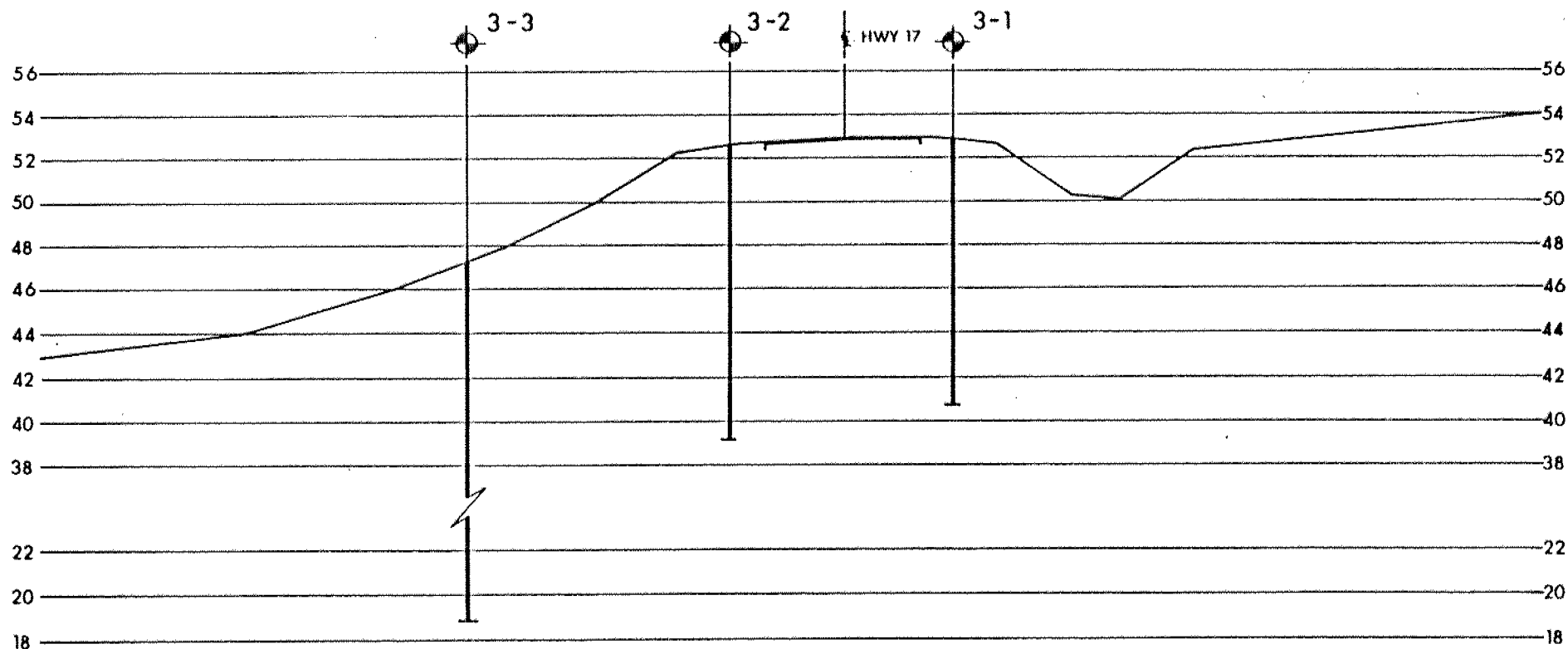
SECTION AT STA. 11+811.0
(SITE 1)



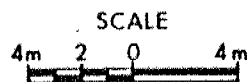


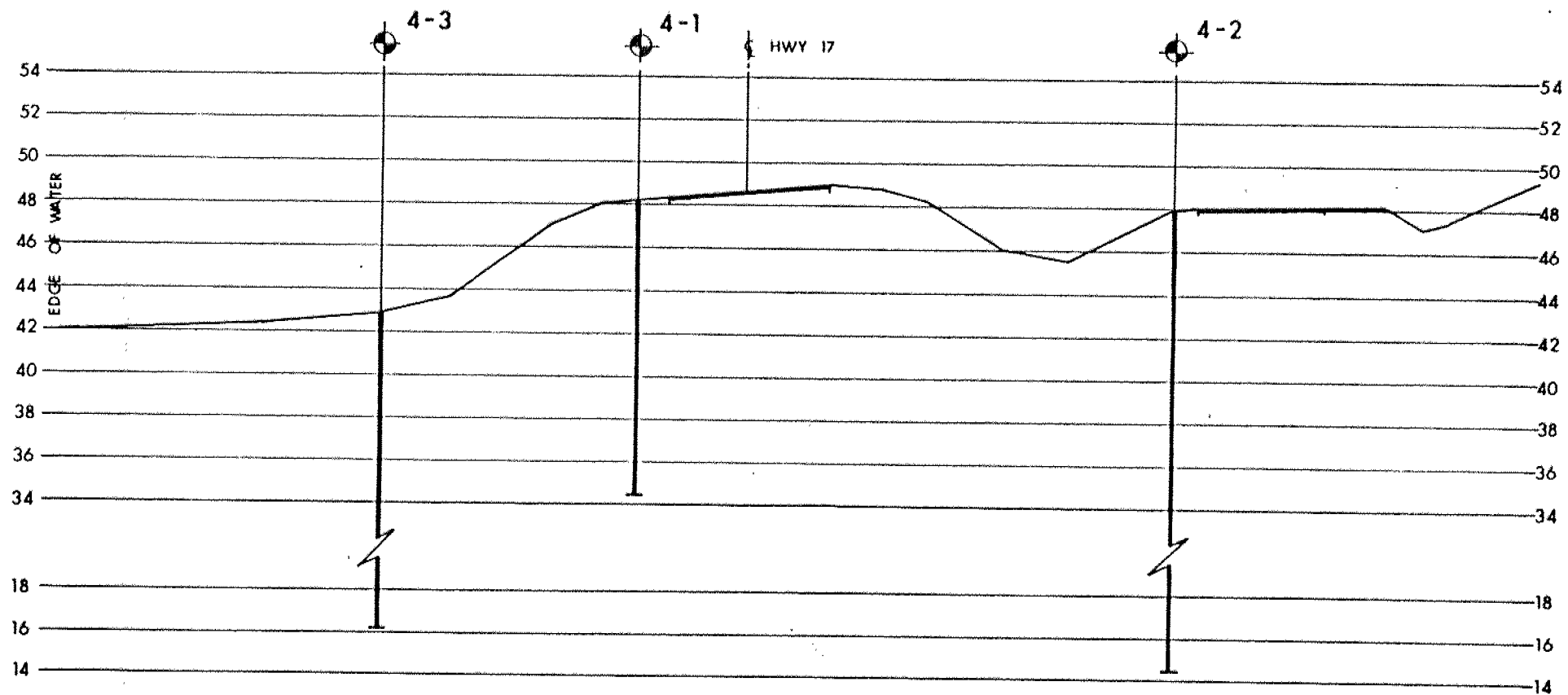
SECTION AT STA. 12+588.4
(SITE 2)

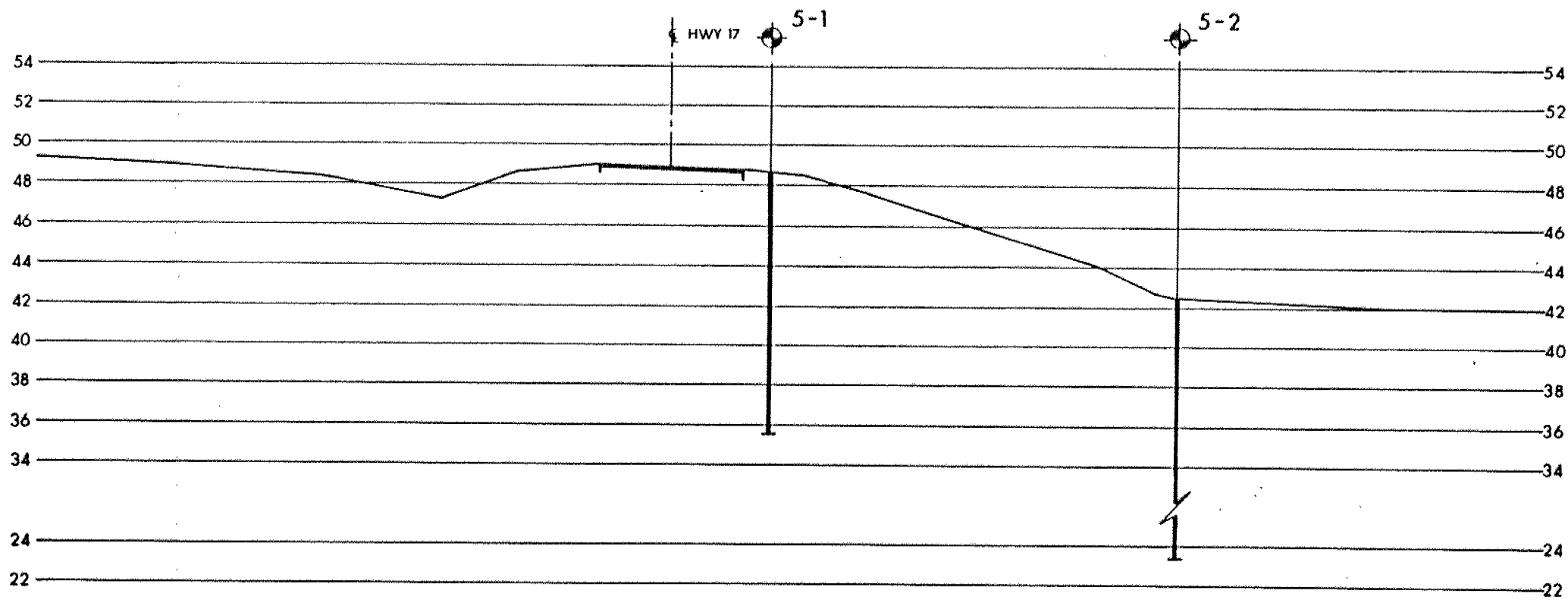




SECTION AT STA. 23+153.0
(SITE 3)



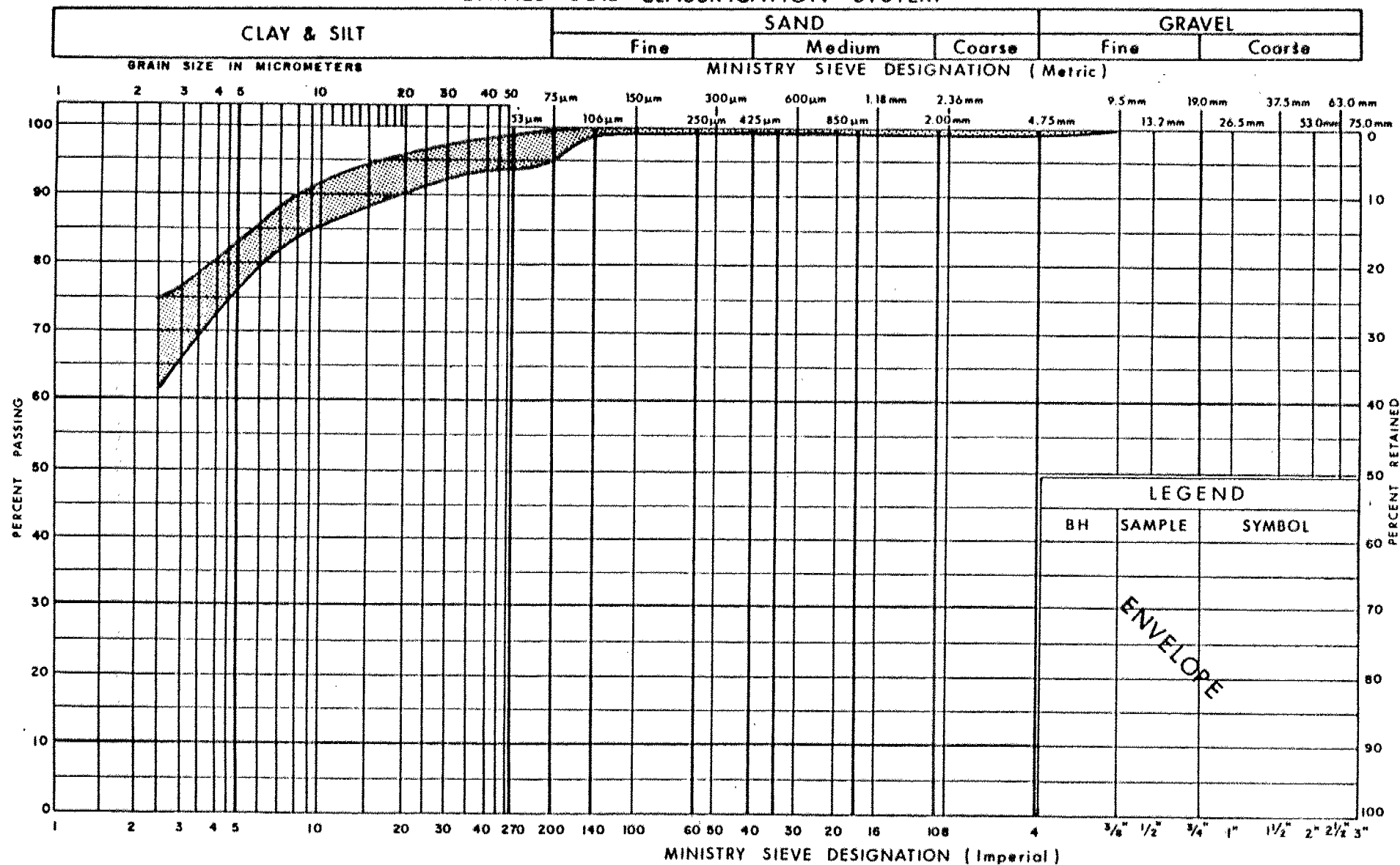




SECTION AT STA. 15+399.0
(SITE 5)



UNIFIED SOIL CLASSIFICATION SYSTEM



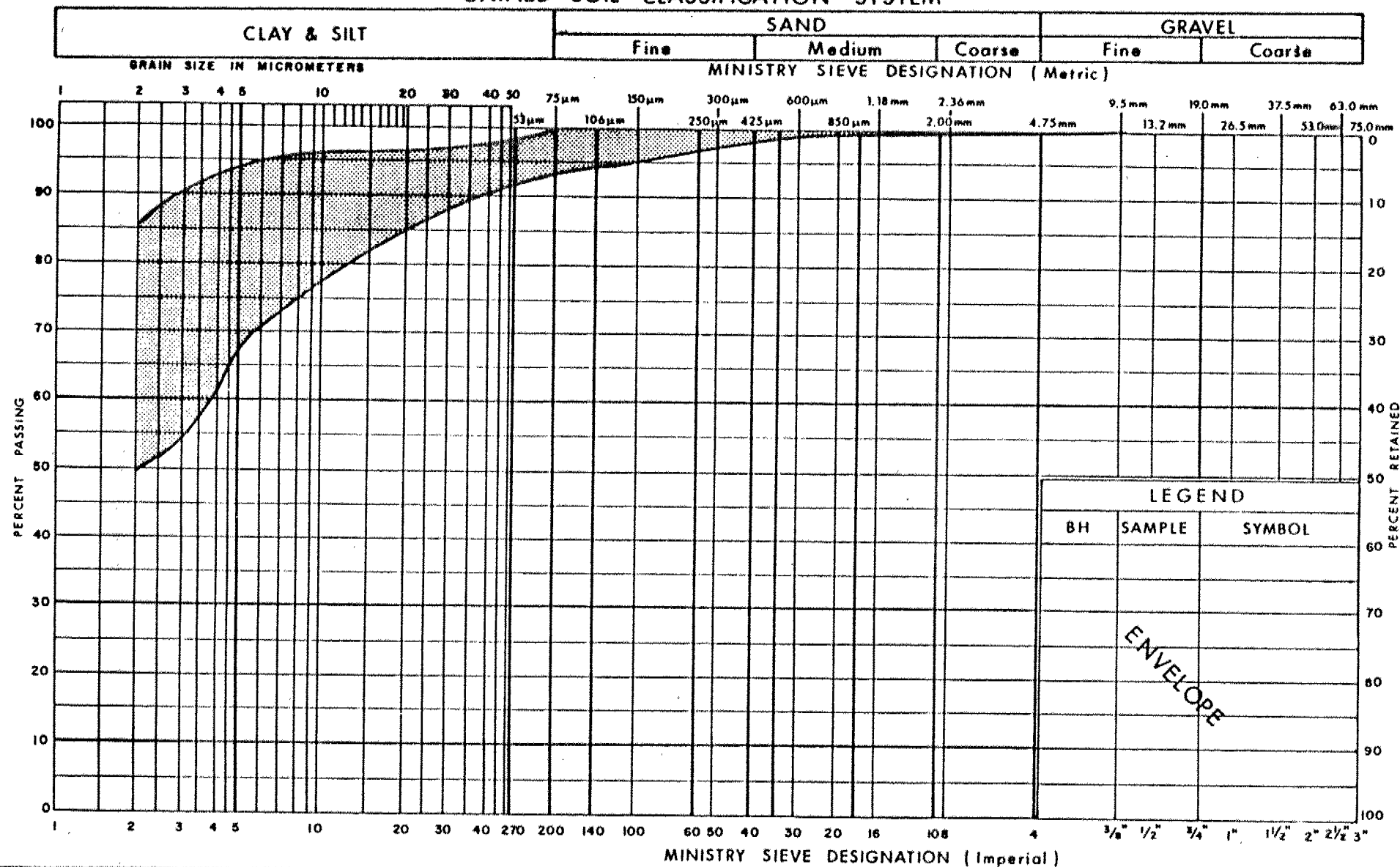
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GRAIN SIZE DISTRIBUTION
CLAY WITH SILT, TRACE SAND, TRACE GRAVEL
(FILL)

FIG No 3

WO 86-11007

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
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Communications

GRAIN SIZE DISTRIBUTION
CLAY WITH SILT, TRACE SAND
(MARINE)

FIG No 4

WO 86 - 11007

SHEAR STRENGTH vs DEPTH MARINE CLAY

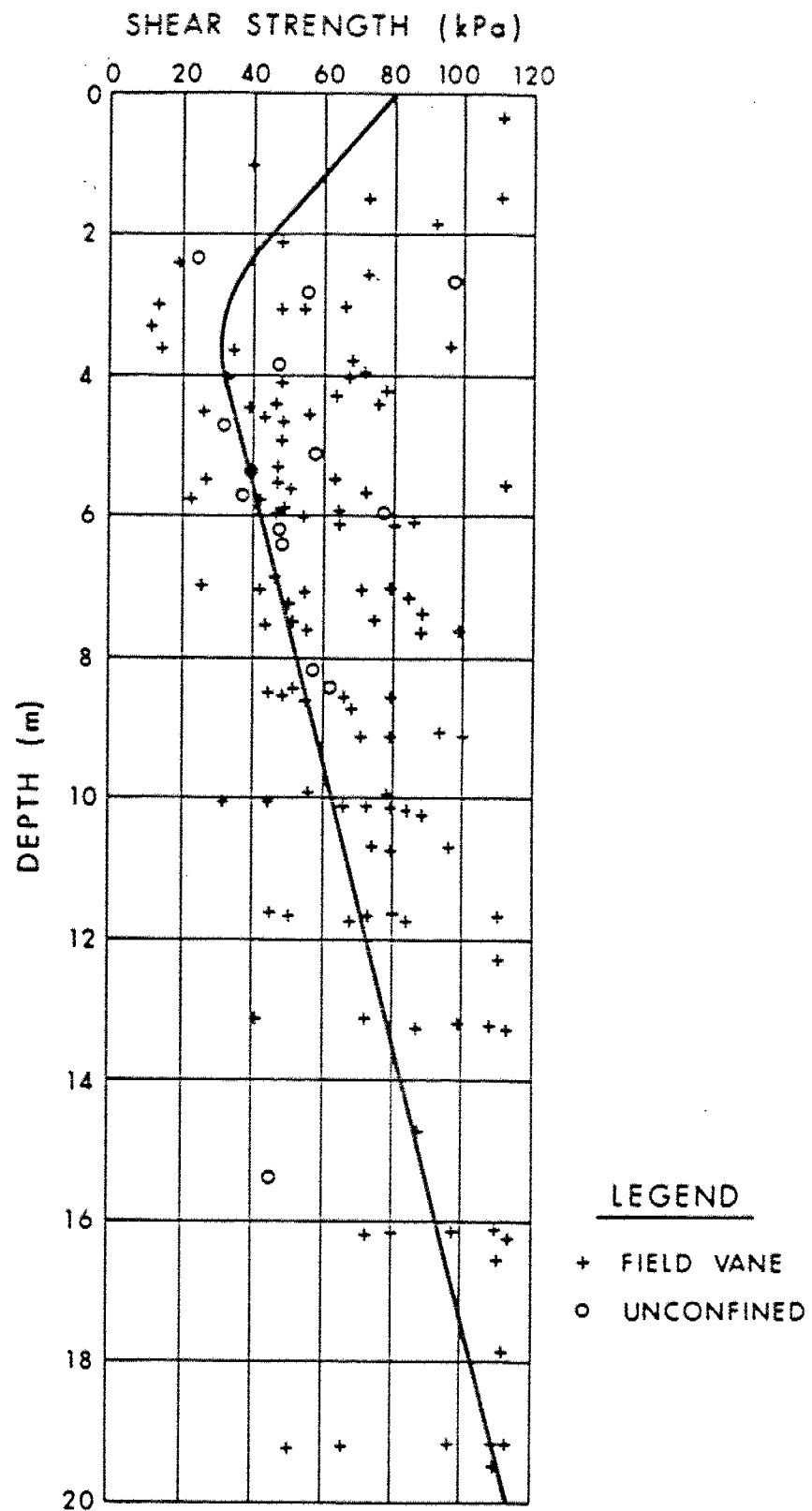


FIG 5

6m EMBANKMENT
DEEP-SEATED STABILITY
TOTAL STRESS

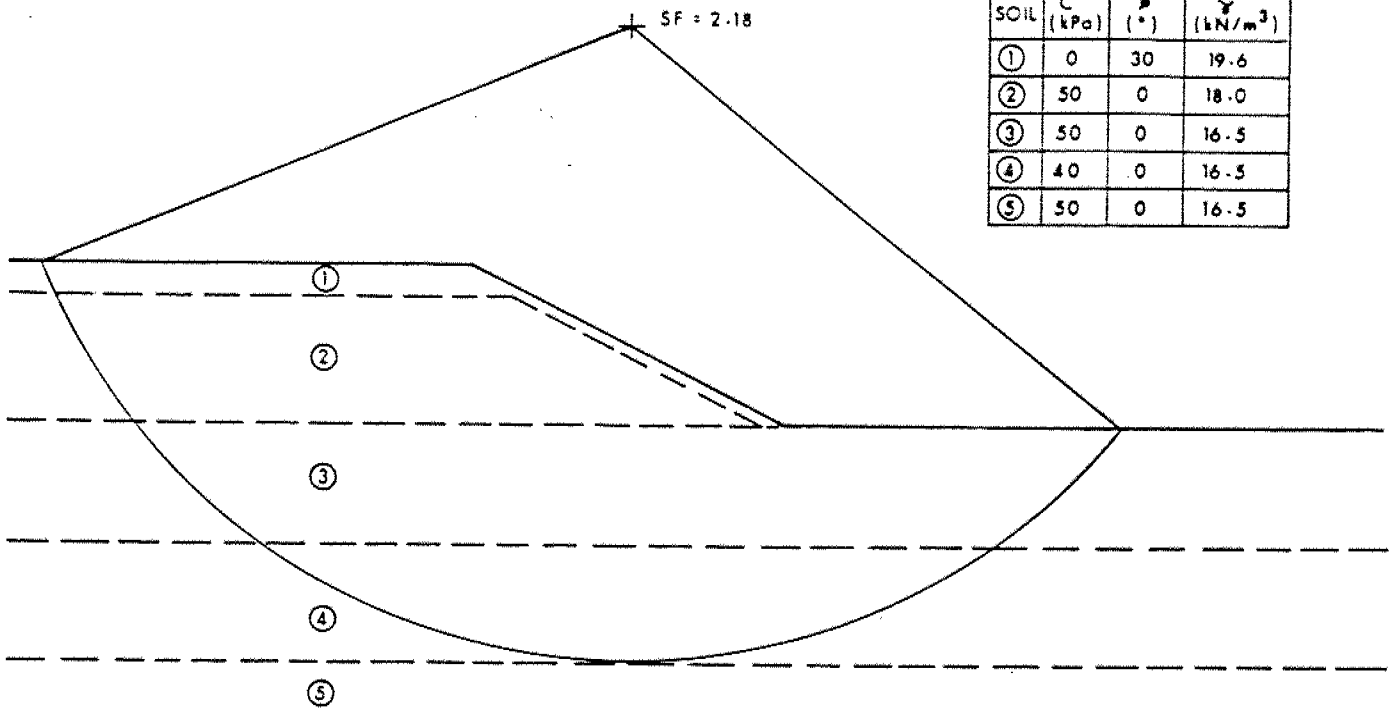


Figure 6A

6m EMBANKMENT
SURFICIAL STABILITY
EFFECTIVE STRESS

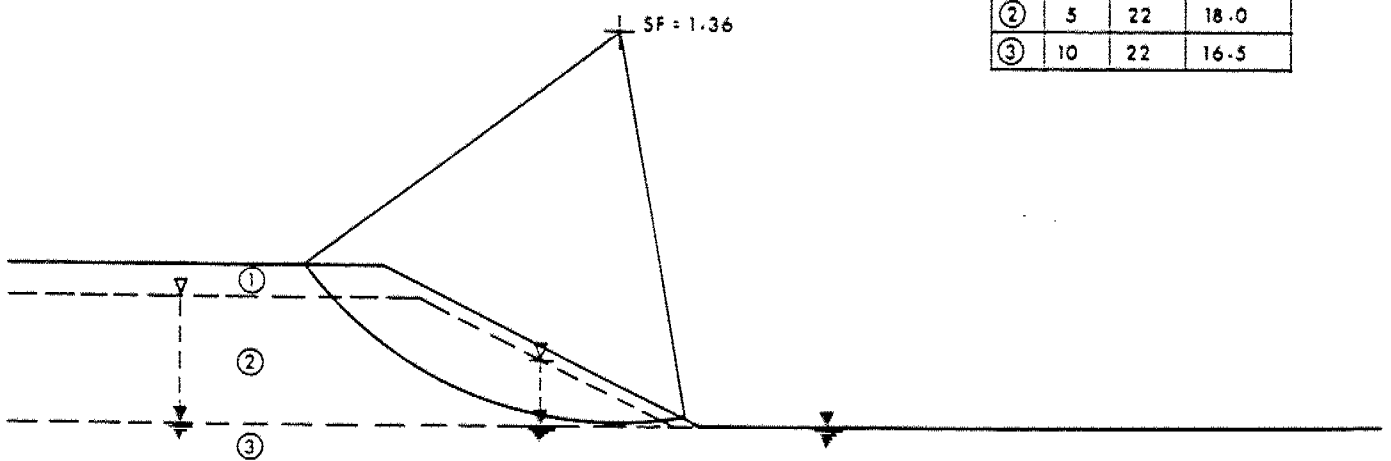


Figure 6B

9m EMBANKMENT
DEEP-SEATED STABILITY
TOTAL STRESS

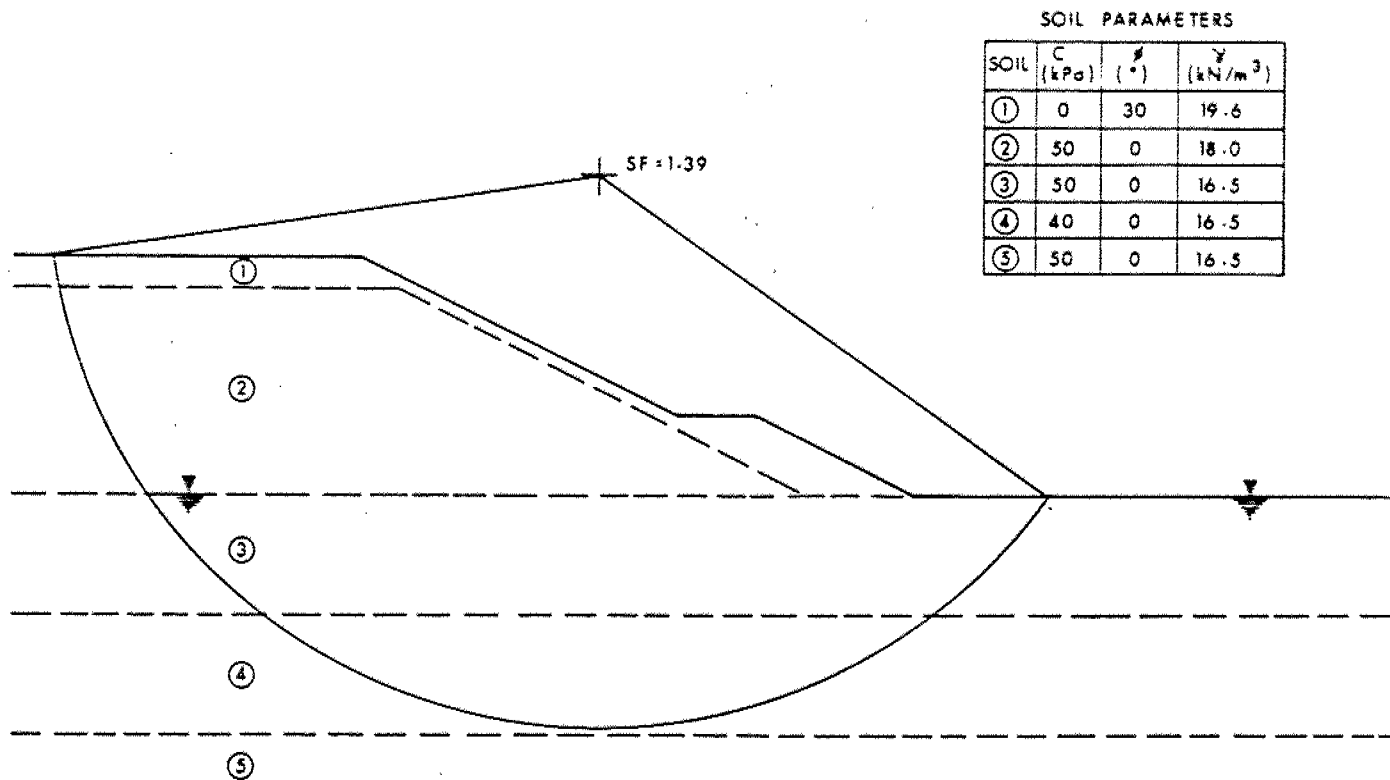


Figure 7A

9m EMBANKMENT
SURFICIAL STABILITY
EFFECTIVE STRESS

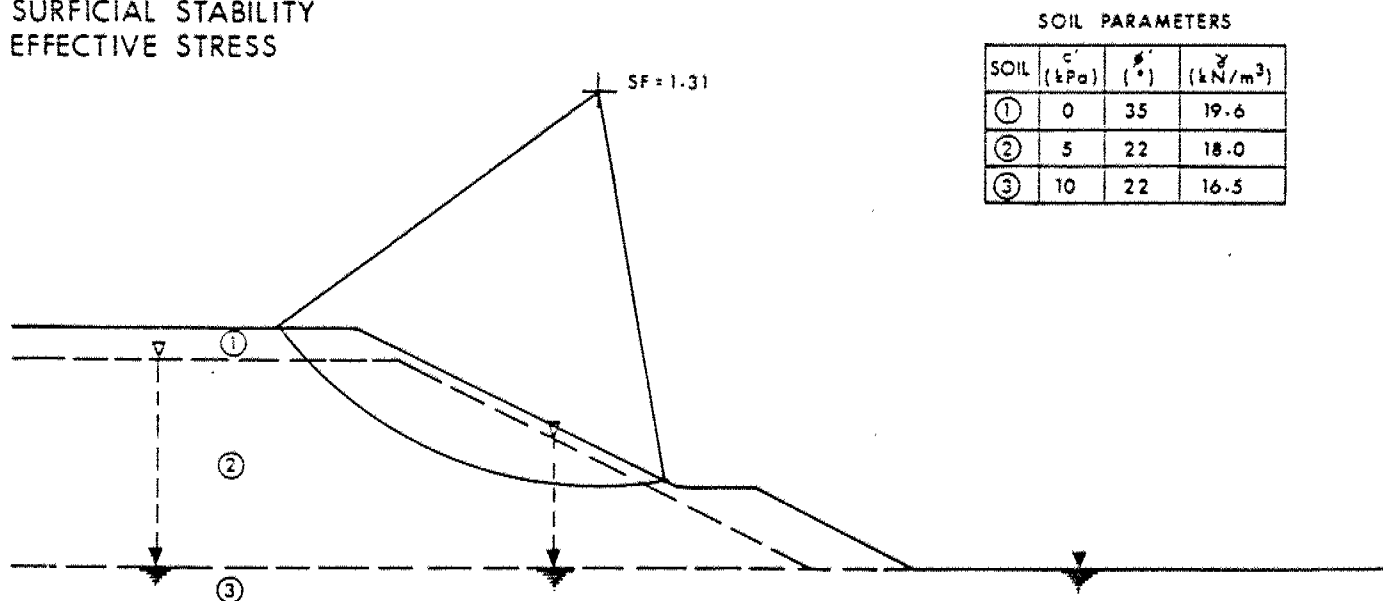


Figure 7B

12m EMBANKMENT
DEEP-SEATED STABILITY
TOTAL STRESS

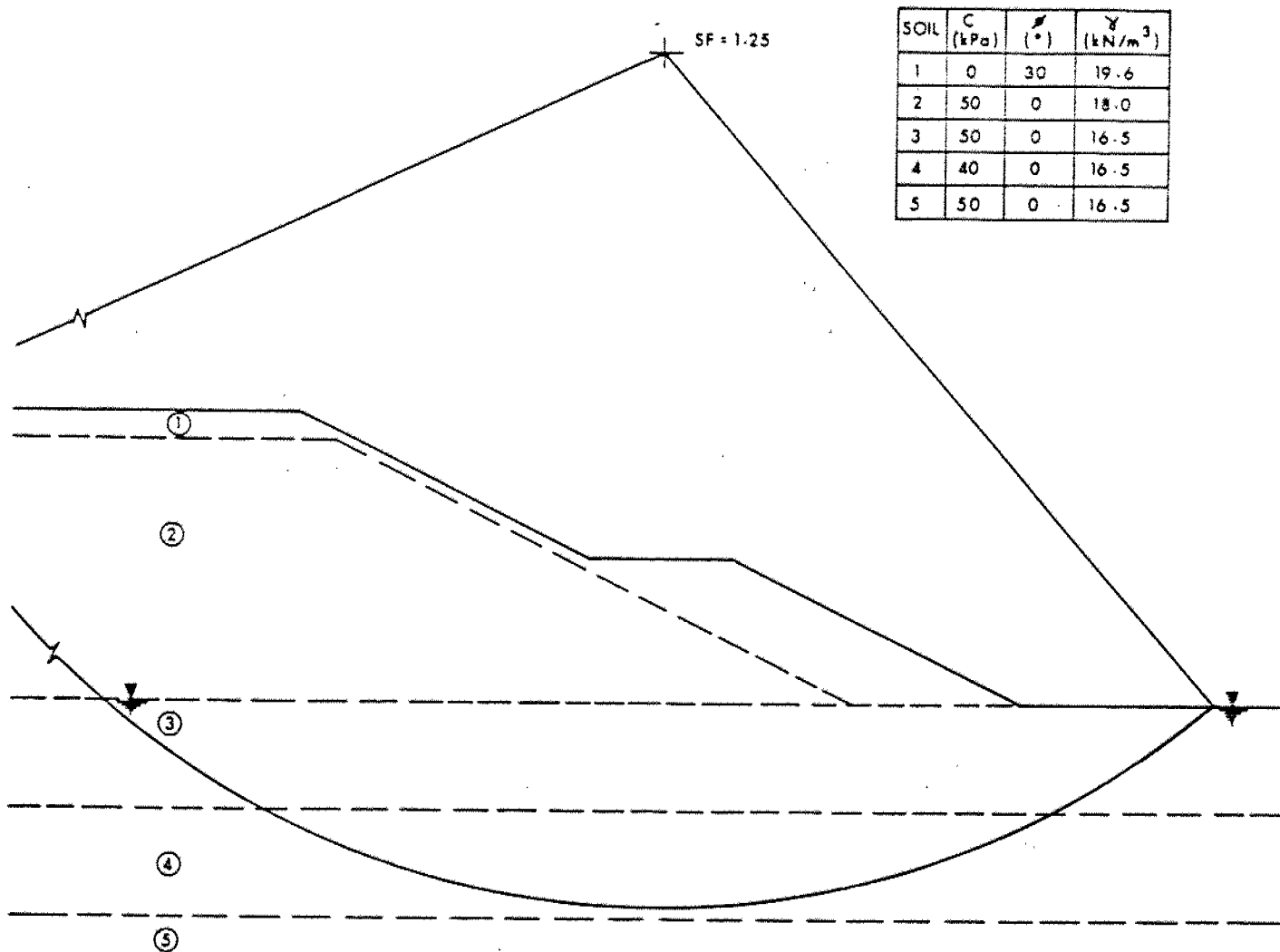


Figure 8A

12m EMBANKMENT
SURFICIAL STABILITY
EFFECTIVE STRESS

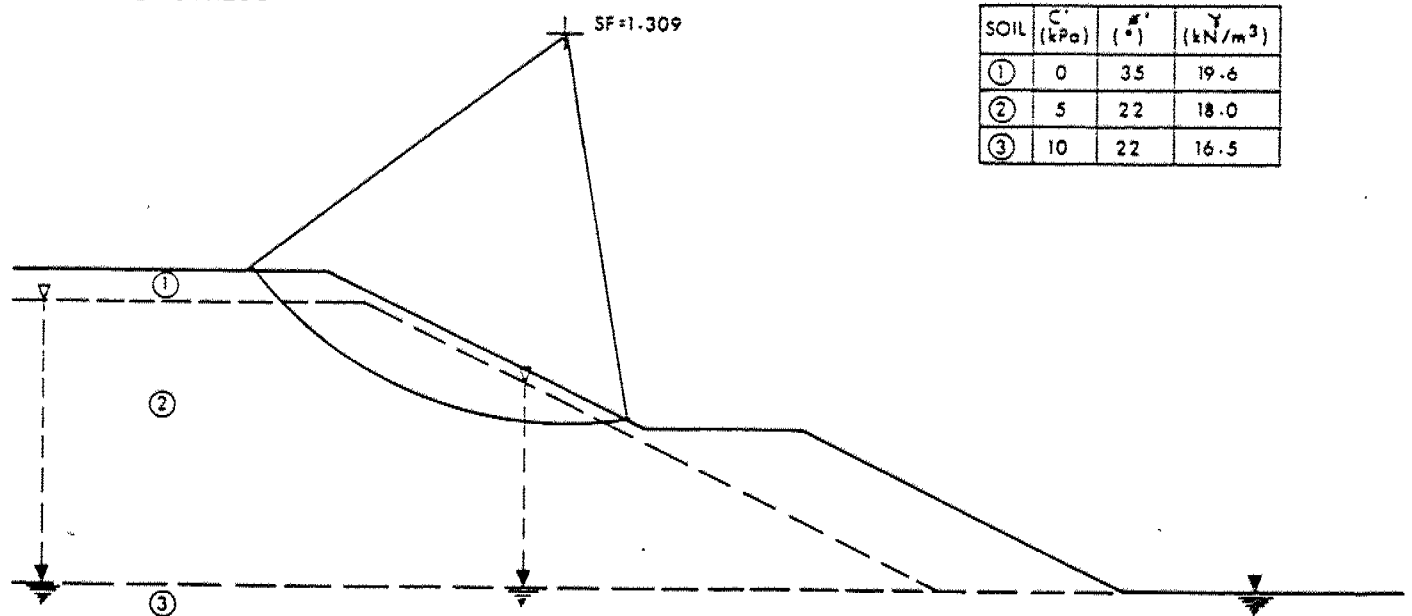
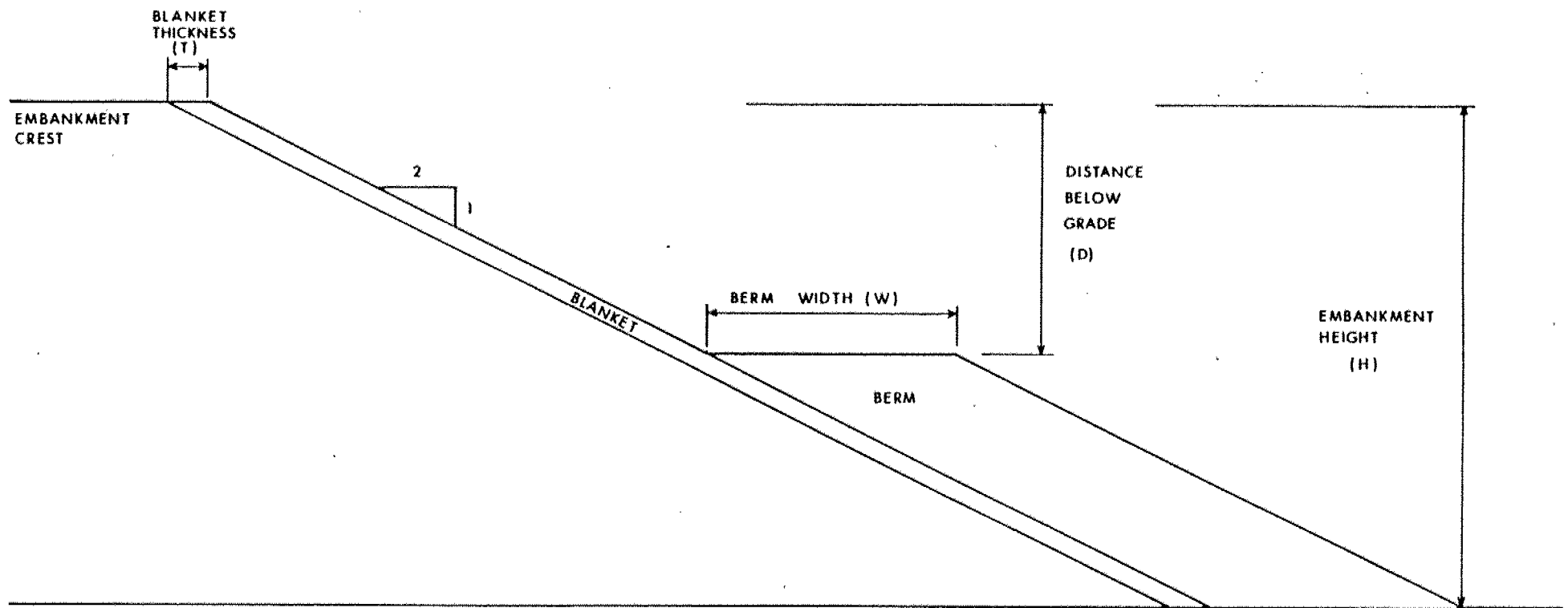


Figure 8B



RECOMMENDED EMBANKMENT GEOMETRY

Figure -9

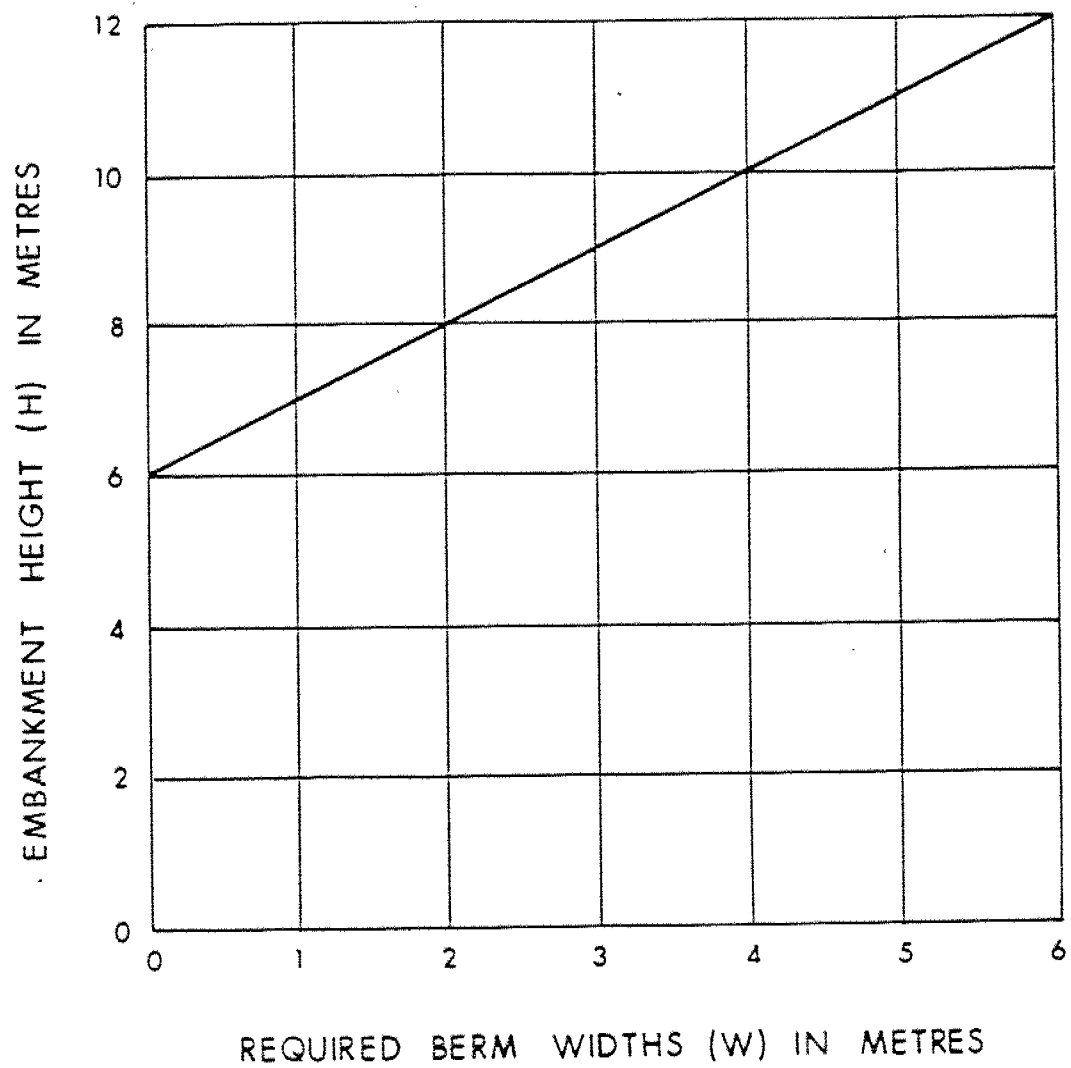
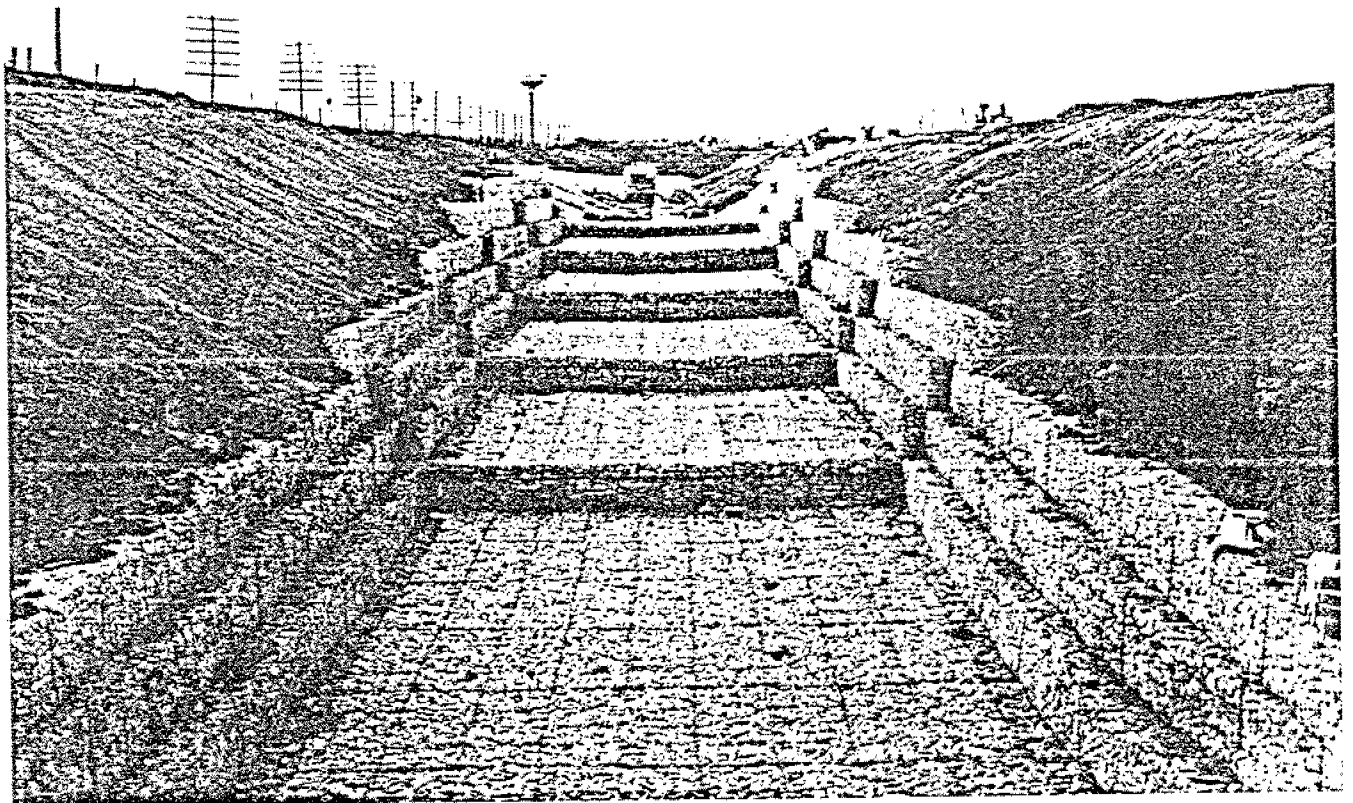


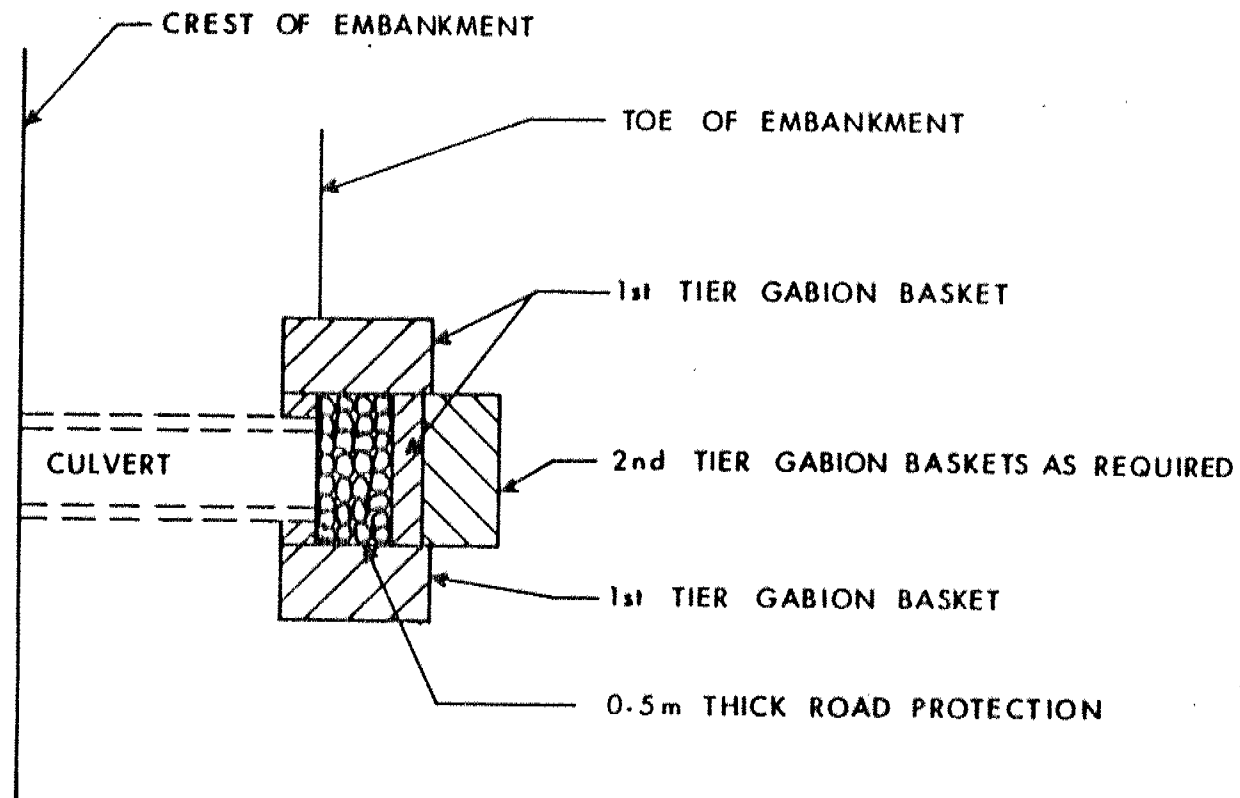
FIG 10



GABION STRUCTURE FOR CULVERT OUTLET

Fig 11

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PLAN VIEW - NTS

SCHEMATIC OF GABION STRUCTURE AT CULVERT INLET

Figure 12

WO 86-11007



RECORD OF BOREHOLE No 1-1

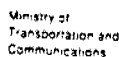
METRIC

W O 86-11007 LOCATION Sta. 11 + 811.0: O/S 5.0 m Rt. of Hwy. 17 $\frac{1}{4}$ ORIGINATED BY DL
DIST 9 HWY 17 BOREHOLE TYPE Cone Test, Hollow Stem Auger COMPILED BY DL
DATUM Geodetic DATE 87 01 09 CHECKED BY DD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ KN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH KPa							WATER CONTENT (%)			
								20 40 60 80 100								20 40 60		
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE											
							20 40 60 80 100					20 40 60						
59.0	Ground Surface																	
0.0	Sand, Some Silt					*												
57.9	Trace Clay, Loose (Fill)																	
1.1	Clay (CH) With Silt Trace Sand Firm to Very Stiff (Fill)		1	SS	8													
			2	SS	5													
			3	TW	PH													
		4	SS	9														
		5	SS	10														
53.2	Clay (CH) With Silt Trace Sand Very Soft to Stiff (Marine)		6	SS	2													
5.8			7	SS	2													
			8	SS	2													
			9	TW	PH													
			10	SS	1													
			11	SS	2													
			12	SS	2													
40.4	End of Borehole																	
18.6	* Stabilized groundwater elevation not established																	

+3, x5: Numbers refer to
Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10



METRIC

WO 86-11007 LOCATION Sta. 11 + 811.0; O/S 16.6 m Rt. of Hwy. 17 4 ORIGINATED BY DL
DIST 9 HWY 17 BOREHOLE TYPE Cone Test, NX Casing COMPILED BY DL
DATUM Geodetic DATE 87 01 15 to 97 01 17 CHECKED BY DD

[illegible]

Probable Bedrock
* Stabilized groundwater
elevation not established

+3, x5: Numbers refer to Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 2-1

METRIC

WO 85-11007 LOCATION Sta. 12 + 588.4; 9% 4.7 m Rt. of Hwy. 17 E
DIST 9 HWY 17 BOREHOLE TYPE Cone Test, Hollow Stem Auger ORIGINATED BY DL & DD
DATUM Geodetic DATE 87 01 08 COMPILED BY DL
CHECKED BY DD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100					
56.7	Ground Surface													
0.0	Sand					**	56	Augered						
55.2	Some Silt, Trace Clay Compact, Fill		1	SS	12									
1.5	Clay With Silt Trace Sand Firm to Very Stiff (Fill)		2	SS	10								19.2	1 13 36 50
			3	SS	9									
			4	TW	PH									0 5 37 58
			5	SS	6									
	CH		6	SS	8									0 8 29 63
			7	SS	13									
	Occ. Sand Pockets		8	SS	13									
44.8			9	SS	9									0 72 13 15
11.9	End of Borehole													
	* Shear Strength greater than 112 kPa													
	** Stabilized groundwater elevation not established													

OFFICE REPORT ON SOIL EXPLORATION

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 2-2 (1 of 2) METRIC

WO 86-11007 LOCATION Sta. 12 + 588.4; O/S 24.2 m Rt. of Hwy. 17 E ORIGINATED BY DL
DIST 9 HWY 17 BOREHOLE TYPE Cone Test, Hollow Stem Auger COMPILED BY DL
DATUM Geodetic DATE 87 02 03 to 87 02 05 CHECKED BY

SOIL PROFILE			SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE 20 40 60 80 100	PLASTIC LIMIT W _p NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE						
49.5	Ground Surface									
0.0			1	SS	8					
			2	SS	5					
			3	SS	7					
			4	SS	5					
			5	TW	PH					
			6	SS	5					
			7	SS	5					
			8	SS	6					
			9	TW	PH					
			10	CS	NA					
			11	SS	4					
			12	SS	9					
			13	CS	NA					
26.2			14	SS	18					
23.3	End of Borehole Probable Clay (CH) * Not a stabilized groundwater elevation									
19.3										
30.2										

Continued

+3, x5: Numbers refer to
Sensitivity

20
15
10
5 (%) STRAIN AT FAILURE

Continued



RECORD OF BOREHOLE No 2-2 (2 of 2) METRIC

WO 86-11007 LOCATION Sta. 12 + 588.4; O/S 24.2 m Rt. of Hwy. 17 E ORIGINATED BY DL
DIST 9 HWY 17 BOREHOLE TYPE Cone Test, Hollow Stem Auger COMPILED BY DL
DATUM Geodetic DATE 87 02 03 to 87 02 05 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE	PLASTIC LIMIT Wp	NATURAL MOISTURE CONTENT W	LIQUID LIMIT Wl	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES								
19.3	Continued												
30.2	Probable Clay (CH)												
12.9													
36.6	End of Cone Test												

+3, x5: Numbers refer to
Sensitivity

20
15
10
5 (%) STRAIN AT FAILURE



RECORD OF BOREHOLE No 2-3 (1 of 2) METRIC

WO 86-11007 LOCATION Sta. 12 + 588.4; O/S 34.0 m Lt. of Hwy. 17 # ORIGINATED BY DL
DIST 9 HWY 17 BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY DL
DATUM Geodetic DATE 87 02 17 CHECKED BY DD

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT Y KN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	20	40	60	80			100	W _p	W	W _L		
								SHEAR STRENGTH kPa						WATER CONTENT (%)					
								O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE											
44.5	Ground Surface																		
0.0	CI With/Some Sand		1	SS	7		44								0 33 37 30 0 21 29 50				
			2	SS	5														
			3	SS	2		42												
			4	SS	2		40												
			5	TW	PH		38							15.7	0 0 14 86				
			6	SS	2		36												
			7	SS	2		34												
	Clay (CH) With Silt Trace Clay Very Soft to Stiff Marine		8	SS	2		32												
			9	SS	2		30												
			10	SS	3		28												
			11	TW	PH		26												
			12	SS	1		24												
			13	SS	3		22												
19.2	End of Borehole						20												
25.3	Probable Clay (CH)						18												
	NOTE At some field vane tests soil remolded to such an extent that recorded sensitivity values extremely high						16												
14.3																			

Continued

* Stabilized groundwater
elevation not established

+3, x5: Numbers refer to
Sensitivity

20
15 \diamond 5 (%) STRAIN AT FAILURE
10

Continued



RECORD OF BOREHOLE No 2-3 (2 of 2) METRIC

W O 86-11007 LOCATION Sta. 12 + 588.4; O/S 34.0 m Lt. of Hwy. 17 E ORIGINATED BY DL
DIST 9 HWY 17 BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY DL
DATUM Geodetic DATE 87 02 17 CHECKED BY DD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE	PLASTIC LIMIT W _p NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
14.3	Continued										
30.2	Probable Clay (CH)										
6.1											
38.4	End of Cone Test										

+3, x⁵: Numbers refer to
Sensitivity

20
15 - 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 3-1

METRIC

WO 86-11007 LOCATION Sta. 23 + 153.0; O/S 5.0 m Rt. of Hwy. 17 ORIGINATED BY DL
DIST 9 HWY 17 BOREHOLE TYPE Cone Test, Hollow Stem Auger COMPILED BY DL
DATUM Geodetic DATE 87 01 13 CHECKED BY DD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ KN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa		Wp	W	Wl		
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE x LAB VANE	WATER CONTENT (%)				
53.0	Ground Surface							20 40 60 80 100	20 40 60					
0.0	Sand Some Silt, Trace Clay Compact, Fill		1	SS	22	**	52	Augered						
51.3			2	SS	20		50						0 7 37 56	
1.7			3	SS	12		48							
	--- CI ---		4	SS	7		46							
			5	TW	PH		44							
	Clay (CH) With Silt Trace Sand Very Soft to Very Stiff Marine		6	SS	5		42							
			7	SS	1									
			8	SS	1									
			9	TW	PH									
			10	SS	1									
40.7														
12.3	End of Borehole													
	* Shear Strength greater than 112 kPa													
	** Stabilized groundwater elevation not established													
	NOTE At some field vane tests soil remolded to such an extent that recorded sensitivity values extremely high													



RECORD OF BOREHOLE No 3-2

METRIC

W.O. 86-11007 LOCATION Sta. 23 + 153.0; O/S 5.2 m Lt. of Hwy. 17 E ORIGINATED BY DL
DIST 9 HWY 17 BOREHOLE TYPE Cone Test, Hollow Stem Auger COMPILED BY DL
DATUM Geodetic DATE 87 01 19 CHECKED BY DD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ KN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
52.7	Ground Surface													
0.0	Sand Some Silt, Trace Clay					**								
51.2	Compact, Fill													
1.5	Clay (CI-CH) With Silt Trace Sand Trace Gravel Firm to Very Stiff Fill		1	SS	7								1 10 34 55	
			2	SS	6								0 0 38 62	
48.4			3	SS	8									
4.3			4	SS	7									
			5	SS	5									
	Clay (CH) With Silt Trace Sand Very Soft to Stiff Marine		6	TW	PH								17.4	0 0 22 78 c'=12 kPa ϕ' =32.5°
			7	SS	2									
			8	SS	2									
			9	SS	1									
			10	TW	PH								16.0	0 0 26 74
			11	SS	2									
39.1														
13.6	End of Borehole													
	* Shear Strength greater than 112 kPa													
	** Stabilized groundwater elevation not established													

+3, x5: Numbers refer to
Sensitivity

20
15
10
5 (%) STRAIN AT FAILURE



RECORD OF BOREHOLE No 3-3

METRIC

W O 86-11007 LOCATION Sta. 23 + 153.0; O/S 17.3 m LT. of Hwy. 17 E ORIGINATED BY DL
DIST 9 HWY 17 BOREHOLE TYPE Cone Test, Hollow Stem Auger COMPILED BY DL
DATUM Geodetic DATE 87 02 19 to 87 02 20 CHECKED BY DD

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE 20 40 60 80 100	PLASTIC LIMIT W _p NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L WATER CONTENT (%) 20 40 60	UNIT WEIGHT Y KN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE						
47.3	Ground Surface									
0.0										
			1	SS		39				
			2	SS		16				
			3	SS		5				
			4	TW		PH				
			5	SS		4				
			6	SS		5				
			7	SS		5				
			8	SS		5				
			9	SS		6				
			10	SS		6				
			11	TW		PH				
			12	TW		5				
28.1										
19.2	End of Borehole Probable Clay (CH)									
	NOTE At some field vane tests soil remolded to such an extent that recorded sensitivity values extremely high									
18.8										
28.5	End of Cone Test * Shear strength greater than 112 kPa									

RECORD OF BOREHOLE No 3-4

METRIC

WO 86-11007 LOCATION Sta. 23 + 121.0: 0/S 19.2 m Lt. of Hwy. 17 4
DIST 9 HWY 17 BOREHOLE TYPE Hollow Stem Auger, Cone Test
DATUM Geodetic DATE 87 02 20
ORIGINATED BY DL
COMPILED BY DL
CHECKED BY DD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100					
46.3	Ground Surface													
0.0	Clay (CH) With Silt Trace Sand Soft to Very Stiff Marine		1	SS	28	*	46							
			2	SS	28		44							
			3	SS	7		42							
			4	SS	2		40							
			5	SS	3		38							
			6	SS	4		36							
			7	SS	2		34							
			8	SS	3									
			9	SS	4									
			10	SS	6									
33.2	End of Borehole													
	* Stabilized groundwater elevation not established													
	NOTE: At some field vane tests soil remolded to such an extent that recorded sensitivity values extremely high													

RECORD OF BOREHOLE No 4-1

METRIC

WO 86-11007 LOCATION Sta. 12 + 322.0; O/S S.O. m Lt. of Hwy. 17 E ORIGINATED BY DL
DIST 9 HWY 17 BOREHOLE TYPE Cone Test, Hollow Stem Auger COMPILED BY DL
DATUM Geodetic DATE 87 01 20 CHECKED BY DD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100					
48.2	Ground Surface													
0.0	Sand Some Silt, Trace Clay Compact, Fill					**	48	Augered						
46.7							46							
1.5	Clay (CI-CH) With Silt Trace/Some Sand Trace Gravel Firm to Very Stiff Fill		1	SS	7		46						19.2	1 5 38 56
			2	SS	4									
			3	TW	PH									
43.6							44							
4.6			4	SS	10		42							
			5	SS	4									
			6	SS	2		40							0 1 32 67
	Clay (CH) With Silt Trace Sand Very Soft to Stiff Marine		7	SS	1									
			8	TW	PH		38						16.2	0 0 23 77 c'=13 kPa φ'=33.5°
			9	SS	2									
			10	SS	3		36							
34.4														
13.3	End of Borehole													
	* Shear Strength greater than 112 kPa													
	** Stabilized groundwater elevation not established													

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 4-2 (1 of 2)

METRIC

WO 86-11007 LOCATION Sta. 12 + 322.0; O/S 20.0 m Rt. of Hwy. 17 4 ORIGINATED BY DL
 DIST 9 HWY 17 BOREHOLE TYPE Cone Test, Hollow Stem Auger COMPILED BY DL
 DATUM Geodetic DATE 87 01 21 CHECKED BY _____

[illegible]

Continued

*Stabilized groundwater elevation not established

+3, x5; Numbers refer to Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10

Continued



RECORD OF BOREHOLE No 4-2 (2 of 2) METRIC

W O 86-11007 LOCATION Sta. 12 + 322.0; O/S 20.0 m Rt. of Hwy. 17 \leftarrow ORIGINATED BY DL
DIST 9 HWY 17 BOREHOLE TYPE Cone Test COMPILED BY DL
DATUM Geodetic DATE 87 01 21 CHECKED BY DD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
17.7	Continued																
30.2	Probable Clay (CH)																
14.4																	
33.5	End of Cone Test																

+3, x⁵: Numbers refer to
Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 4-3

METRIC

WO 86-11007 LOCATION Sta. 12 + 322.0; O/S 17.0 m Lt. of Hwy. 17 E ORIGINATED BY DL
DIST 9 HWY 17 BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY DL
DATUM Geodetic DATE 87 02 23 to 87 02 24 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100					
42.9	Ground Surface													
0.0														
			1	SS	12									0 4 36 60
			2	SS	13									0 4 42 54
			3	SS	12									0 0 44 56
			4	SS	6									
			5	SS	2									
			6	TW	PH								16.5	0 0 20 80
	Clay (CH) With Silt Trace Sand Very Soft to Very Stiff Marine		7	SS	2									
			8	SS	4									
			9	SS	5									
			10	SS	5									
			11	TW	PH									
			12	SS	8									
23.7														
19.2	End of Borehole Probable Clay (CH)													
16.1														
26.8	End of Cone Test * Artesian groundwater to elevation 42.9 (sealed with bentonite plug) ** Shear Strength greater than 112 kPa													

+3, x5: Numbers refer to
Sensitivity

20
15
10

5 (%) STRAIN AT FAILURE



RECORD OF BOREHOLE No 4-4

METRIC

WO 86-11007 LOCATION Sta. 12 + 371.0; O/S 20.3 m Lt. of Hwy. 17 E ORIGINATED BY DL
DIST 9 HWY 17 BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY DL
DATUM Geodetic DATE 87 02 24 CHECKED BY DD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE 20 40 60 80 100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT. PROF.	NUMBER	TYPE	'N' VALUES								
42.4	Ground Surface												
0.0	Gravel, Sand, Organic Material and Boulders Compact to Very Dense Fill					*	42	Augered					
40.3							40						
2.1	Clay (CH) With Silt Trace Sand Very Soft to Very Stiff Marine		1	SS	14		38	+21					
			2	SS	4		36	+25					
			3	SS	2		34	+10					
			4	SS	3		32	+35					
			5	SS	2		30	+23					
			6	SS	3			+44					
			7	SS	2			+19					
			8	SS	6								
29.3													
13.1	End of Borehole												
	* Stabilized groundwater elevation not established												
	NOTE At some field vane tests soil remolded to such an extent that recorded sensitivity values extremely high												

+3, x5: Numbers refer to Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 5-1

METRIC

W O 86-11007 LOCATION Sta. 15 + 399.0; O/S 5.0 m Rt. of Hwy. 17 E ORIGINATED BY DL
DIST 9 HWY 17 BOREHOLE TYPE Cone Test, Hollow Stem Auger COMPILED BY DL
DATUM Geodetic DATE 87 01 26 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT Y KN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
48.6	Ground Surface																
0.0	Sand, Some Silt Trace Clay, Loose (Fill)		1	SS	9	*	48										0 88 8 4
47.3			2	SS	13												
1.3	Clay (CH) With Silt Trace Sand Stiff to Very Stiff (Fill)		3	SS	13												
			4	SS	11												
			5	TW	PH											17.5	0 0 28 72
43.1			6	SS	4												
5.5	Clay (CH) With Silt Trace Sand Very Soft to Stiff (Marine)		7	SS	1												
			8	SS	2												
			9	TW	PH											16.8	0 1 26 73
			10	SS	1												
35.5																	
13.1	End of Borehole																
	* Stabilized groundwater elevation not established																
	** Shear Strength greater than 112 kPa																

+3, x⁵: Numbers refer to 20
Sensitivity 15 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 5-2

METRIC

WO 86-11007 LOCATION Sta. 15 + 399.0; O/S 25.4 m Rt. of Hwy. 17 4
DIST 9 HWY 17 BOREHOLE TYPE NX Casing, Cone Test ORIGINATED BY DL
DATUM Geodetic DATE 87 03 05 COMPILED BY DL
CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100					
42.5	Ground Surface													
0.0														
			1	SS	13		42							0 4 31 65
			2	SS	7									0 0 38 62
			3	SS	2		40							
			4	SS	1									
			5	TW	PM		38							
			6	SS	1								18.1	0 0 54 46
			7	SS	1		36							
			8	SS	1		34							
			9	SS	1		32							
			10	SS	1		30							
			11	TW	PM		28							
			12	SS	1		26						16.8	0 0 35 65
23.3							24							
19.2	End of Borehole													
	* Stabilized groundwater elevation not established													
	NOTE At some field vane tests soil remolded to such an extent that recorded sensitivity values extremely high													

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 5-3

METRIC

WO 86-11007 LOCATION Sta. 15 + 342.6; O/S 25.0 m Rt. of Hwy. 17 E ORIGINATED BY DL
DIST 9 HWY 17 BOREHOLE TYPE NX Casing, Cone Test COMPILED BY DL
DATUM Geodetic DATE 87 03 03 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE 20 40 60 80 100	PLASTIC LIMIT W _p NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
42.5 0.0	Ground Surface										
	Clay (CH) With Silt Trace Sand Very Soft to Stiff (Marine)		1	SS	12		42				
			2	SS	3						
			3	SS	1		40				
			4	TW	PH						
			5	SS	1		38				
			6	SS	1						
			7	SS	1		36				
			8	SS	1						
			9	SS	2		34				
			10	SS	1						
			11	TW	PH		32				
			12	SS	1		30				
23.3	End of Borehole						28				
19.2	* Stabilized groundwater elevation not established						26				
	NOTE At some field vane tests soil remolded to such an extent that recorded sensitivity values extremely high						24				

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10

memorandum



To: T.W. Murphy
Head, Geotechnical Section
Eastern Region

Date: 1987 06 08

Attention: D. McLay

From: Foundation Design Section

Re: Embankment Instabilities
F.D.S. Reference WO 86-11007
Hwy. 17, District 9, Ottawa

This memo is a follow-up to our preliminary recommendation memo dated 87 05 25. It incorporates refinements developed during our site visit of 87 05 26 and discussed in our subsequent telephone conversations. The recommendations are intended to be sufficient for design and construction of remedial treatments to proceed. If further detailing is required please contact this office. A complete Foundation Report will be submitted when drafting has been completed.

The instabilities at these sites are generally surficial failures characterized by slips and erosion. They are caused by the properties of the embankment material (clay) and the embankment geometry (relatively high embankments with relatively steep slopes). However, at Site 2 there are concerns that the present embankment geometry is near the deep-seated failure threshold.

The remedial recommendations for this typical instability are illustrated in Figure 1. Basically the slopes should be flattened to 2H:1V and covered with a 1 m thick blanket of rock fill or free-draining granular material.

Where embankments are over 6 m high, berms are required. The berms should be constructed at a height of 6 m below the embankment crest. The required berm widths for the range of embankment heights encountered are provided in Figure 2.

The slope blankets and berms may be graded into the existing topography, outside the remedial area, at slopes of 2H:1V.

Detailed descriptions and recommendations for each site are attached, along with our recommended priorities based on geotechnical considerations.

If there are any questions, please contact this office.

D.H. Dundas
D.H. Dundas, P. Eng.
Sr. Foundations Engineer

Site #2 Details

The left (north) side at this site has an unacceptably low factor of safety against deep seated failure. This situation results from the relatively high embankment founded on the relatively weak deposit of marine clay. The risk of failure is more critical due to the extremely sensitive nature of the clay, with disturbed strengths less than 10% of undisturbed strengths.

However, it is our understanding that there is a limited budget for remedial work, and since there is tree cover along the lower portion of the embankment, a temporary measure could be considered to improve the surficial slope stability instead of the full scale berm option. This would involve removal of 1 m of the existing embankment, above the tree line, and replacement with either rock fill but preferably Granular A. This operation should be conducted in strips, not exceeding 5 m in width.* Backfilling operations should be completed before excavation commences on subsequent strips. The existing tree cover and roots should not be disturbed. After the material has been replaced, the site should be periodically inspected, to ensure that the stability of the slope does not deteriorate. If any signs of distress are noted, this office should be notified immediately.

* The strips should extend from the crest of the embankment to the treeline.

Site #3 Details

The main difficulty at this site will be the treatment at the culvert outlet. Three options have been proposed:

- 1) Culvert extension
- 2) gabion outlet structure (refer to Figure 3)
- 3) rock fill outlet

Options 1 and 2 would lead to a more positive solution, but in view of budget limitations, Option 3 could be considered as an alternative, provided that the site is periodically monitored and any signs of distress are reported immediately.

For Option 3, the outlet creek should be straightened, to parallel the culvert, and protected with rock protection for a minimum of 10 m beyond the toe of slope. The existing outlet creek should be back-filled. The embankment and berm should be constructed as illustrated in Figures 1 and 2. In the immediate area of the culvert outlet, water is expected to run through the rock fill to the outlet creek.

Site #4 Details

The recommended treatment at the right (south) side of Site 4 is to end dump rock fill to construct stable 2H:1V slopes. The water in the ditch is expected to run through the rock fill. However, retaining structures will be required to maintain the embankments to the existing level of the culvert inlet. This can be accomplished by a gabion structure with a 0.5 m thick rock fill mat as illustrated in Figure 4.

SITE #: 1

LOCATION: 1.5 km east of Chatelaine Street

	EMBANKMENT	
	LEFT (NORTH)	RIGHT (SOUTH)
HORIZONTAL EXTENT	NA	Sta. 10 +765 to Sta.11+835
EXISTING EMBANKMENT GEOMETRY (APPROXIMATE)		5.2 m high @ 1.5H:1V
PROBLEM DESCRIPTION		-surficial failures
REMEDIAL RECOMMENDATIONS		-flatten slope to 2H:1V -apply blanket
PRIORITY		Low

SITE #: 2

LOCATION: 2.5 km east of Chatelaine Street

	EMBANKMENT	
	LEFT (NORTH)	RIGHT (SOUTH)
HORIZONTAL EXTENT	Sta. 12+560 to Sta. 12+675	Sta. 12+480 to Sta. 12+650
EXISTING EMBANKMENT GEOMETRY (APPROXIMATE)	12.2 m high @ 2H:1V	6.4 m high @ 1.9H:1V
PROBLEM DESCRIPTION	<ul style="list-style-type: none">-surficial failures-unacceptably low safety factor against deep-seated failure	<ul style="list-style-type: none">-surficial failures
REMEDIAL RECOMMENDATIONS	<ul style="list-style-type: none">*REFER TO MEMO FOR DETAILS-maintain maximum slope of 2H:1V-apply blanket-construct berm	<ul style="list-style-type: none">-flatten slope to 2H:1V-apply blanket
PRIORITY	High	Medium

SITE #: 3

LOCATION: 1 km east of Morin Road

	EMBANKMENT	
	LEFT (NORTH)	RIGHT (SOUTH)
HORIZONTAL EXTENT	Sta. 23+050 to Sta. 23+200	approx. same as left chainage
EXISTING EMBANKMENT GEOMETRY (APPROXIMATE)	8.5 m high @ 2.3H:1V	2.4 m high @ 1.4H:1V
PROBLEM DESCRIPTION	<ul style="list-style-type: none">-surficial failures-undermining and erosion at culvert outlet-unstable existing gabion structure	<ul style="list-style-type: none">-surficial failures-space restrictions
REMEDIAL RECOMMENDATIONS	<p>*REFER TO MEMO FOR DETAILS</p> <ul style="list-style-type: none">-maintain maximum slope of 2H:1V-apply blanket-construct berm-realign outlet creek parallel to culvert-backfill existing meandering outlet creek <p>Option 1: extend culvert Option 2: build gabion outlet structure Option 3: construct culvert outlet with rockfill</p>	<p>Option 1:-maintain drainage with culvert pipe parallel to highway</p> <ul style="list-style-type: none">-flatten slope by backfilling-apply blanket <p>Option 2:-continued inspection and repair as required by end dumping rockfill to flatten slope</p>
PRIORITY	High	Low

SITE #: 4

LOCATION: Laurier St. and Hwy. 17 approx. 60 m east of OPP Station

	EMBANKMENT	
	LEFT (NORTH)	RIGHT (SOUTH)
HORIZONTAL EXTENT	Sta.12+295 to Sta.12+365±	50± m on each side of culvert inlet
EXISTING EMBANKMENT GEOMETRY (APPROXIMATE)	6± m @ 1.5H:1V	3.3 m @ 1.8H:1V
PROBLEM DESCRIPTION	-surficial failures	-surficial failures -blockage of culvert inlet -steep slopes and restricted space
REMEDIAL RECOMMENDATIONS	-flatten slopes to 2H:1V -construct blanket	*REFER TO MEMO FOR DETAILS -construct blanket and establish 2H:1V slopes by end dumping rockfill -construct gabion structure at culvert inlet to retain embankments
PRIORITY	Medium	Medium

SITE #: 5

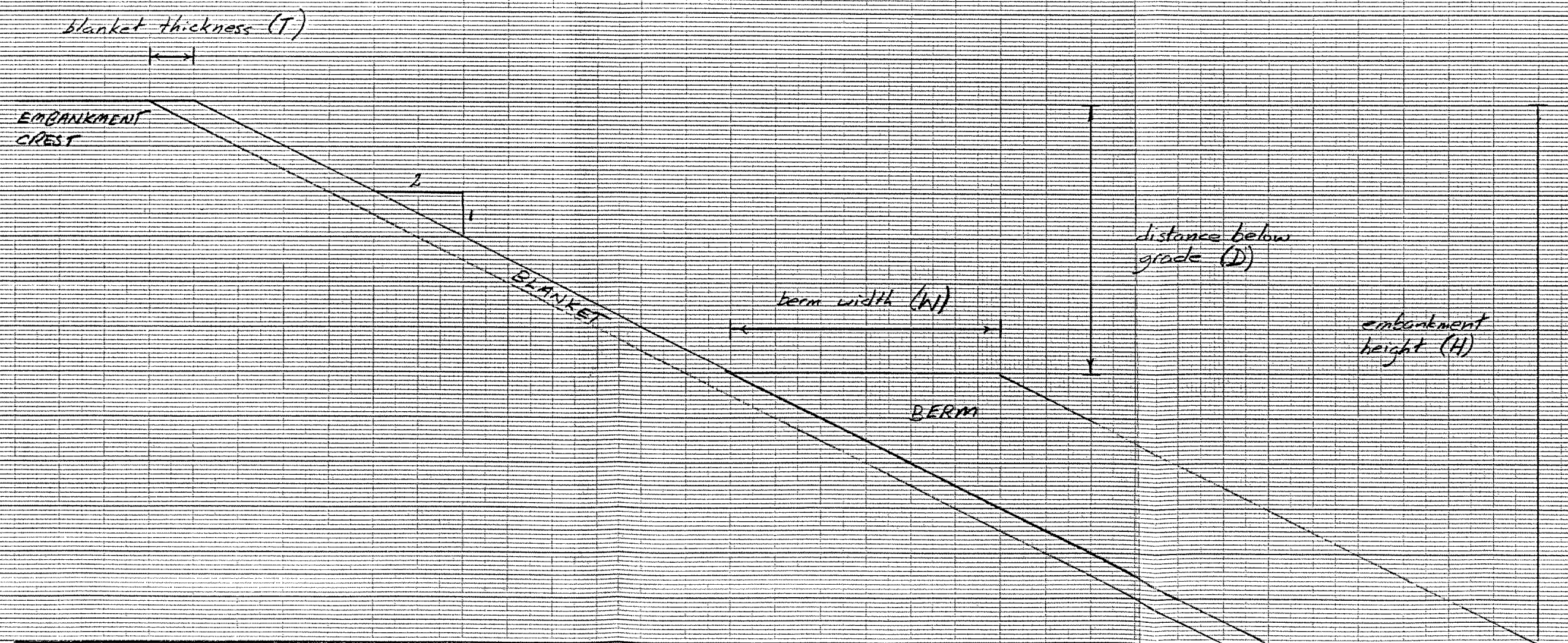
LOCATION: East of Pigeon Street

	EMBANKMENT	
	LEFT (NORTH)	RIGHT (SOUTH)
HORIZONTAL EXTENT	NA	Sta.15+330 to Sta.15+380
EXISTING EMBANKMENT GEOMETRY (APPROXIMATE)		6 m high @ 2H:1V
PROBLEM DESCRIPTION		-surficial failures
REMEDIAL RECOMMENDATIONS		-establish slopes @ 2H:1V or flatter -construct blanket
PRIORITY		Low -except for Sta. 15+350 to Sta. 15+360 which is medium priority

FIGURE 1

RECOMMENDED EMBANKMENT GEOMETRY

NO 86-11007



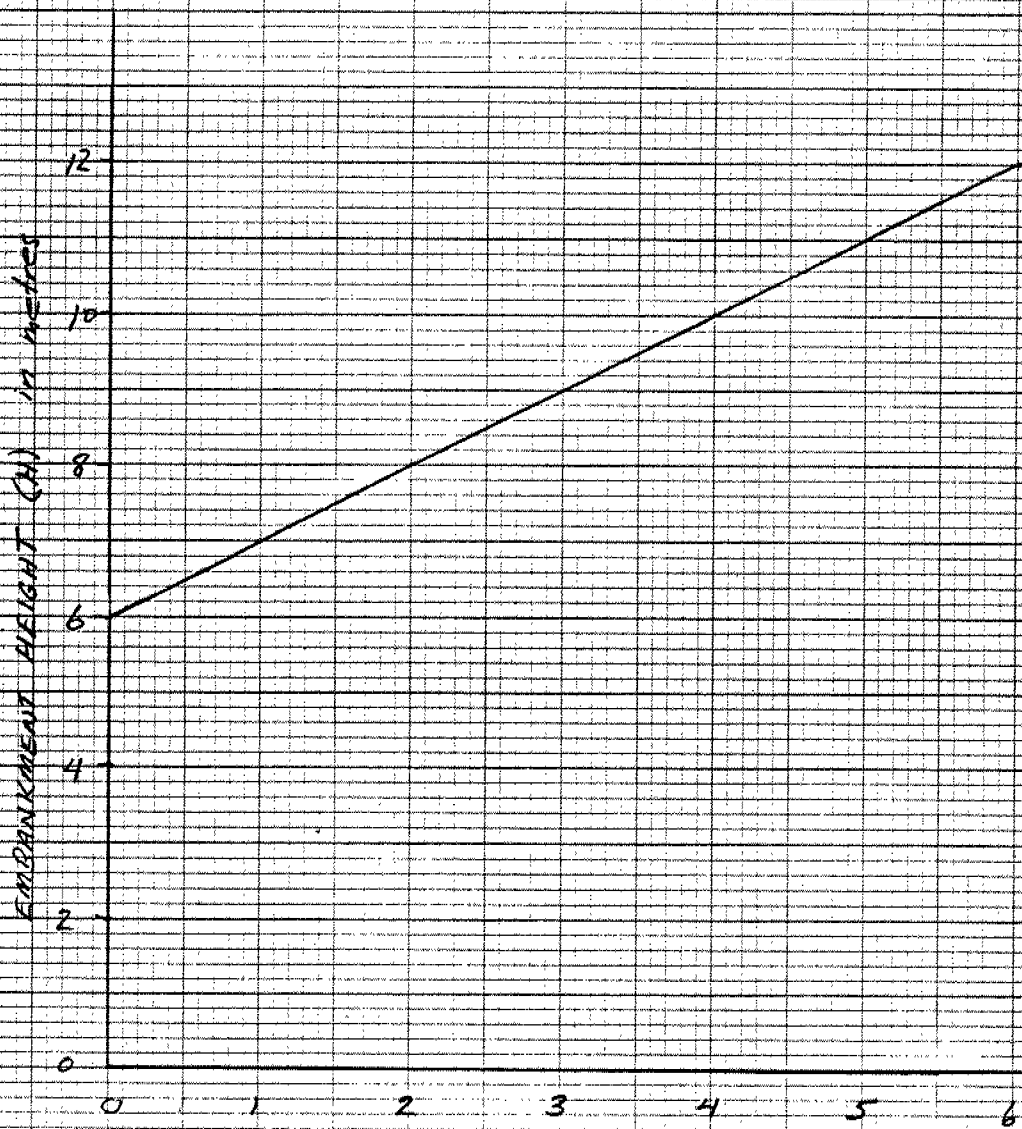


FIGURE 2 REQUIRED BERM WIDTHS (W)
in metres

Figure 3 Gabion Structure for Culvert Outlet WO 86-11007

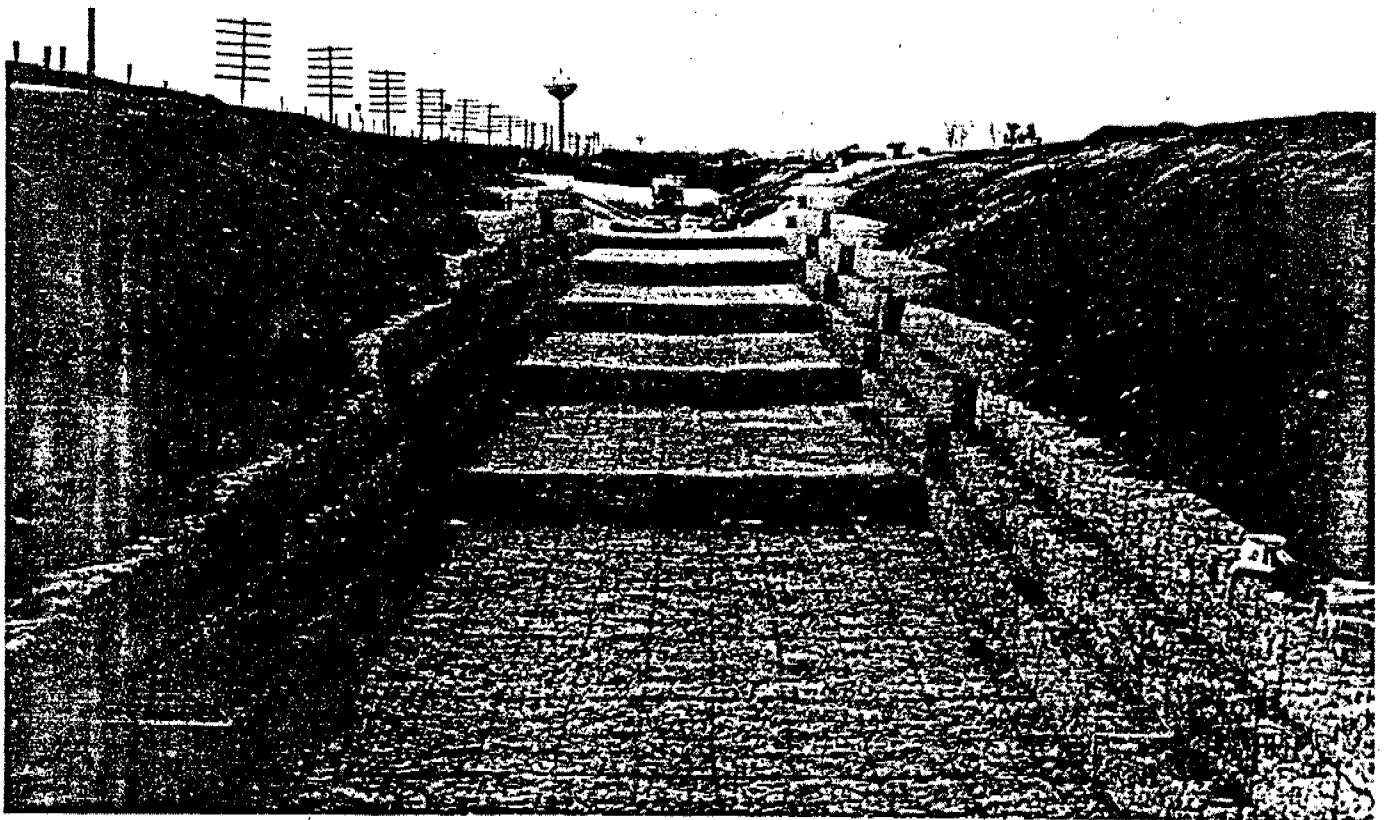
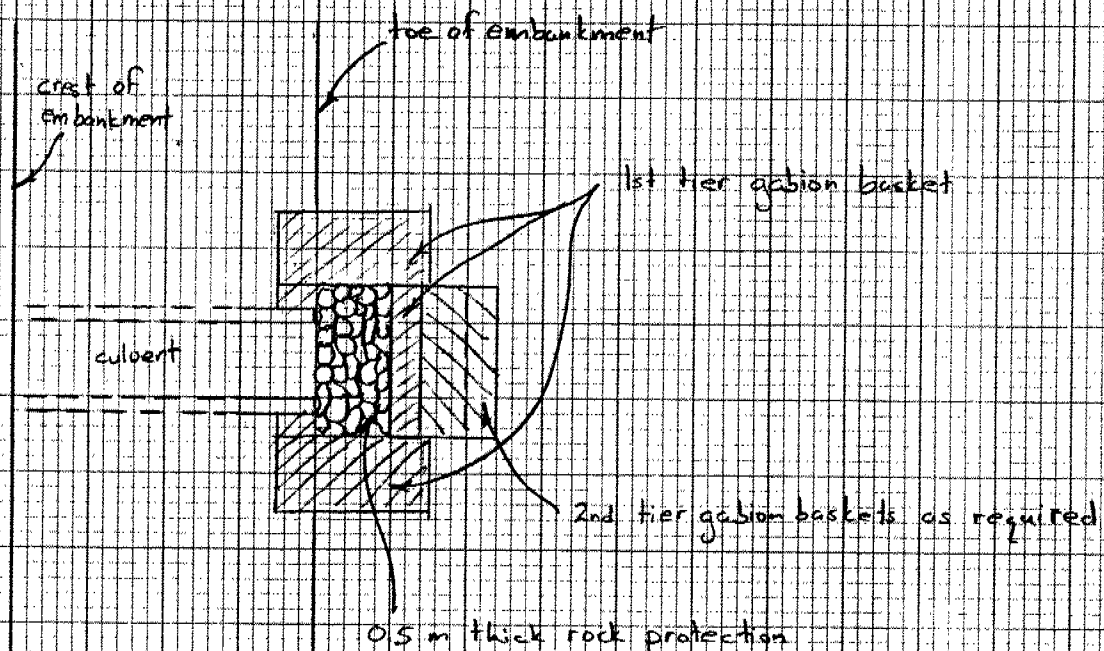


FIGURE 4

PLAN VIEW

WD 86-11007

SCHEMATIC OF STRUCTURE AT CULVERT INLET



NTS

memorandum



To: T.W. Murphy
Head, Geotechnical Section
Eastern Region

ATT: D. McLay

From: Foundation Design Section
Room 315, Central Building
Downsview, Ontario

Re: Embankment Instabilities
F.D.S. Reference WO 86-11007
Hwy. 17, District 9, Ottawa

Date: 1987 05 25

As per your request, we have investigated embankment instabilities at 5 sites along Hwy. 17 between Ottawa and Rockland. More specific location details are provided in the detailed descriptions for each site.

This memo provides preliminary recommendations that are intended to be sufficient for design and construction of remedial treatments to proceed. No major revisions are anticipated although minor modifications and detailing may be required. This office will be available to assist with these modifications as required. A complete Foundation Report will be submitted when drafting has been finalized.

General remedial recommendations applicable to all 5 sites are provided followed by specific details for each site.

If there are any quesstions, please contact this office.

A handwritten signature in dark ink, appearing to read "D.H. Dundas".

D.H. Dundas, P. Eng.
Sr. Foundations Engineer

DHD/ep

GENERAL REMEDIAL RECOMMENDATIONS

Descriptions and remedial recommendations for 3 typical problems are presented below:

PROBLEM TYPE 1

- relatively high embankments with relatively steep slopes

RECOMMENDATIONS

- refer to Figure 1 for a schematic illustration of recommended remedial treatments
- the slope should be established at 2H:1V or flatter
- a blanket with minimum thickness of 1 m should be placed on slope
- for embankments greater than 6 m high berms are required
- the berms should be constructed at a height of 6 m below the embankment crest
- required berm widths for the range of embankment height are provided in Figure 2
- the blanket and berm should be constructed integrally from the same material
- either rock fill or free-draining granular material is acceptable
- the slope treatment should be graded into the existing topography at 2H:1V

PROBLEM TYPE 2

- erosion and undermining of culvert outlets

RECOMMENDATIONS

- extend culvert as required to permit stable embankment geometry
- consideration should be given to a sloping extension if the outlet is not at toe of slope
- steel culverts have been used for such extensions previously
- all existing undermining should be backfilled
- the outlet should be controlled to prevent erosion
- channelling with gabioin baskets, energy dissipation with gabion wiers and erosion control with gabion mats may be required.

PROBLEM TYPE 3

- relatively low embankments with steep slopes due to space restrictions

RECOMMENDATIONS

- maintain drainage with a pipe and backfill to establish stable slope

Please refer to the specific details for each site for further explanations, and suggested priorities from a geotechnical perspective.

SITE #: 1

LOCATION: 1.5 km east of Champlain Street (Sta. 11+811.0)

	EMBANKMENT	
	LEFT (NORTH)	RIGHT (SOUTH)
HORIZONTAL EXTENT	NA	
EXISTING EMBANKMENT GEOMETRY (APPROXIMATE)		5.2 m high @ 1.5:1
PROBLEM DESCRIPTION		- surficial failures
REMEDIAL RECOMMENDATIONS		- flatten slope to 2H:1V - apply blanket
PRIORITY		MEDIUM

SITE #: 2

LOCATION: 2.5 km east of Champlain Street (Sta. 12+528.4)

	EMBANKMENT	
	LEFT (NORTH)	RIGHT (SOUTH)
HORIZONTAL EXTENT		
EXISTING EMBANKMENT GEOMETRY (APPROXIMATE)	6.4 m high @ 1.9:1	12.2 m high @ 2.1:1
PROBLEM DESCRIPTION	- surficial failures	- surficial failures - unacceptably low safety factor against deep-seated failure
REMEDIAL RECOMMENDATIONS	- flatten slope to 2H:1V - apply blanket	- maintain max 2H:1V slope - apply blanket - construct berm - culvert extension as required
PRIORITY	MEDIUM	HIGH

SITE #: 3

LOCATION: 1 km east of Morin Road (Sta. 23+153.0)

	EMBANKMENT	
	LEFT (NORTH)	RIGHT (SOUTH)
HORIZONTAL EXTENT		
EXISTING EMBANKMENT GEOMETRY (APPROXIMATE)	8.5 m high @ 2.3:1	2.4 m high @ 1.4:1
PROBLEM DESCRIPTION	<ul style="list-style-type: none">- surficial failures- undermining and erosion at culvert outlet- floating gabion structure	<ul style="list-style-type: none">- surficial failures- space restrictions
REMEDIAL RECOMMENDATIONS	<ul style="list-style-type: none">- extend culvert. A flexible pipe angled to toe of slope should be considered- provide outlet control for culvert- treat slope with blanket and berm	<ul style="list-style-type: none">- maintain drainage with pipe- flatten slope by backfilling- apply blanket
PRIORITY	- high	- low

SITE #:

4

LOCATION: Laurier St. & Hwy 17 60 m east of OPP (Sta. 12+322.0)

EMBANKMENT

LEFT (NORTH)

RIGHT (SOUTH)

HORIZONTAL EXTENT

EXISTING EMBANKMENT
GEOMETRY (APPROXIMATE)

6± m @ 1.5H:1V

3.3 m @ 1.8H:1V

PROBLEM DESCRIPTION

- surficial failures

- surficial failures
- blockage of culvert
inlet
- steep slopes and
restricted space

REMEDIAL RECOMMENDATIONS

- flatten slopes to 2:1
- construct blanket
- modify culvert outlet
as required

- clean up ditch
and culvert inlet
- maintain drainage
with pipe
- establish stable
slope by backfilling
to 2H:1V or flatter
OR
- construct gabion retain-
structure to permit
flattening of embankment
slope

PRIORITY

MEDIUM

MEDIUM

SITE #: 5

LOCATION: East of Pigeon Street (Sta. 15+399.0)

EMBANKMENT

LEFT (NORTH)

RIGHT (SOUTH)

HORIZONTAL EXTENT

NA

EXISTING EMBANKMENT
GEOMETRY (APPROXIMATE)

6m high @ 2+ : 1
varies

PROBLEM DESCRIPTION

- superficial failures

REMEDIAL RECOMMENDATIONS

- establish slopes to
2H:1V or flatter
- construct blanket

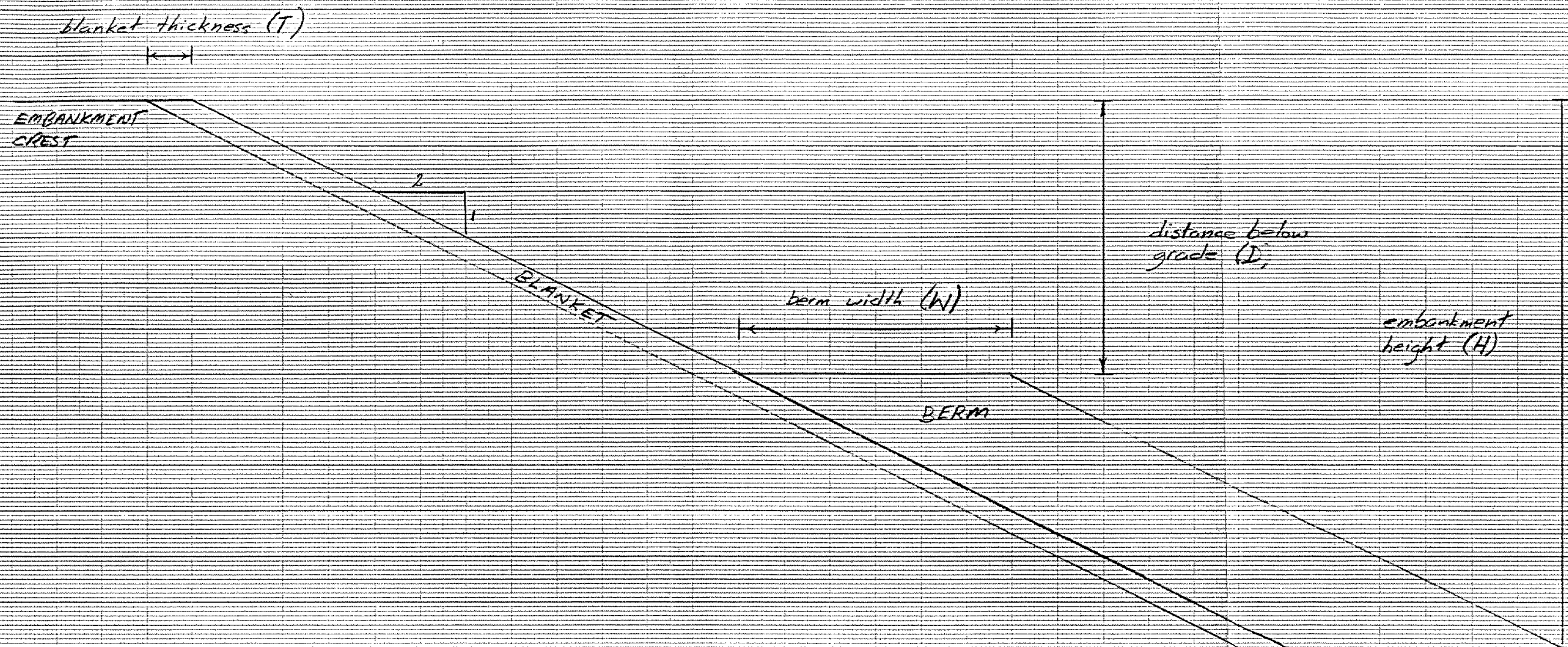
PRIORITY

LOW

FIGURE 1

RECOMMENDED EMBANKMENT GEOMETRY

WD 86-11007



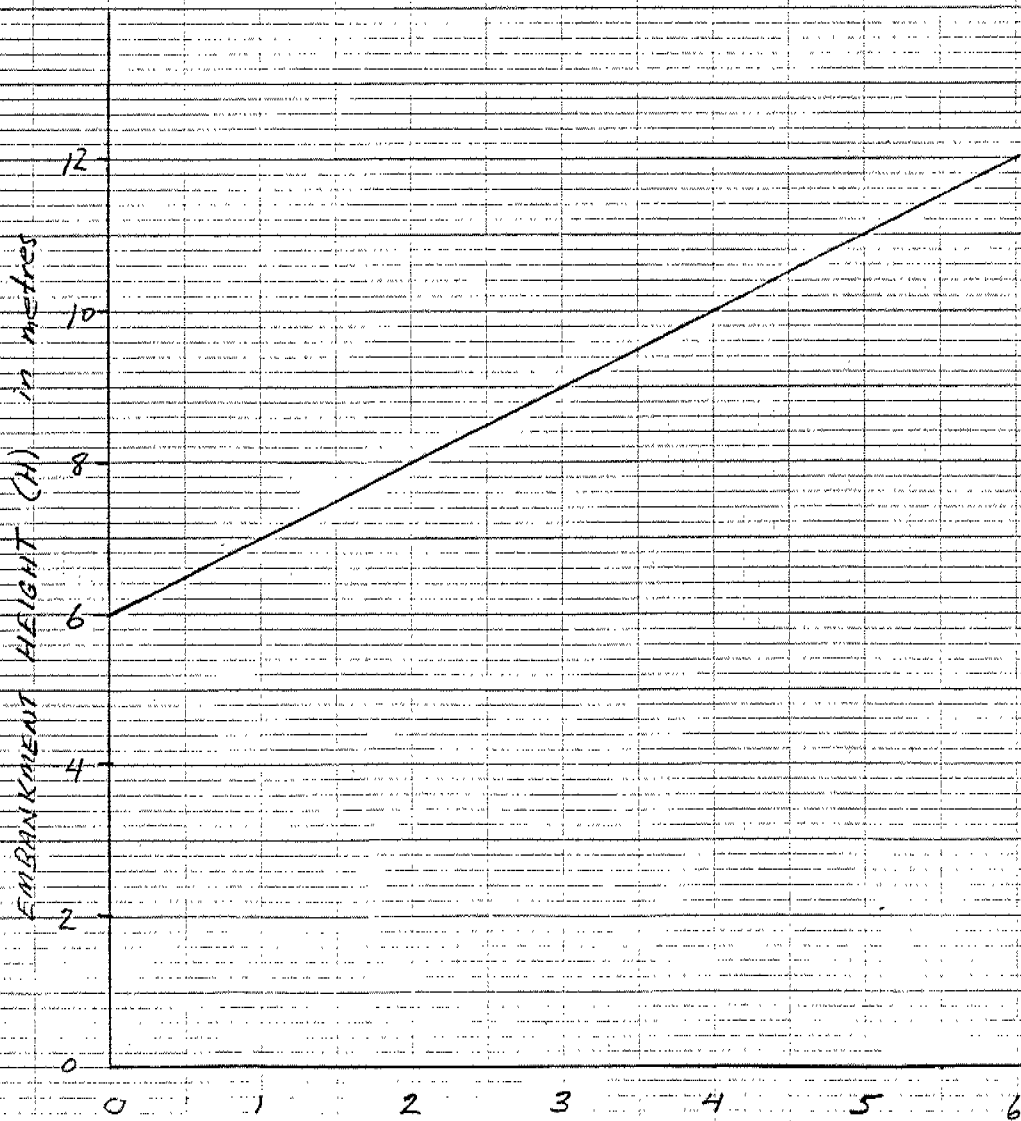


FIGURE 2 REQUIRED BERM WIDTHS (W)
in metres