

REMARKS: _____

memorandum



To: D. Billings
Acting Head, Geotechnical Section
Central Region

From: Pavements and Foundations
Room 315, Central Building

Subject: South Approach Embankment, QEW SBL
Structure Over Welland River and N.Y.C. Railway
W.O. 93-11022
Site 34-65, District 6, Burlington

Date: 94 12 19

As requested, a field investigation was carried out for the fill movement at the above approach embankment location. The study has been completed and the results of the investigation together with our findings are summarized below.

The site is located on SBL of QEW just south of the Welland River crossing in the City of Niagara Falls, Regional Municipality of Niagara.

BACKGROUND

The SBLs of the QEW at this location were constructed in 1955 under Contract 55-25. The pavement in this area has a long history of distress due to settlements and possibly lateral movements. They were resurfaced under Contract 65-501 in 1965-66 and again in 1983 under Contract 83-43. However, movements continued to take place and cracks have reappeared.

The site was visited on 93 08 24 with Rob Kohlberger from your office. During the site visit, Two problem areas were identified and field investigation was planned for these areas. Area 1 is located around Sta. 10+310 with a longitudinal crack running near the edge of the SBL and curving towards the shoulder at both ends. The shape of the distress area suggests possible shear failure. Area 2 is located at the south abutment of the SBL structure. It consists of a crack that runs around a catchbasin in an arch shape at approximately Sta. 10+200 just south of the approach slab. Drg. No. 9311022-A attached indicates the location and extent of the distressed areas.

INVESTIGATION PROCEDURES

Soil data and inherent properties were obtained by insitu and laboratory testing. The procedures employed are discussed below.

Field -

The field work was carried out between 93 08 31 and 93 09 02 and consisted of four sampled boreholes taken down to 8.1 to 18.7 m depths. The boreholes were advanced by a track mounted augering machine with 82 mm I.D. hollow stem continuous augers.

The sampling program consisted of split spoon samples collected in the overburden. Disturbed subsoil samples were retrieved by a split spoon sampler in accordance with the Standard Penetration Test (ASTM D 1586). Relatively undisturbed samples were retrieved using thin walled shelby tube samplers in accordance with ASTM D1587. All the samples collected were used for identification and laboratory testing purposes. Vane shear tests were carried out in the cohesive strata to determine the shear strength of the material. A standard MTO 'N' vane was used. Piezometers were installed in BH 1, BH 2 and BH 2A to monitor the groundwater regime.

All subsoil samples were identified in the field and returned to the laboratory for further examination and appropriate testing. The ground water level was measured in open boreholes and monitored by piezometers installed. All the boreholes were backfilled upon completion of the fieldwork. Survey information related to the elevation of boreholes and cross-sectional profiles were provided by Central Region Survey and Plans Section.

Laboratory -

The laboratory testing program for selected soil samples consisted of:

- Atterberg Limit Test
- Grain Size Distribution
- Natural Moisture Content Determination
- Consolidation Test
- Unit Weight Determination
- Consolidated Undrained Shear Test
- Organic Content Determination

Laboratory test results are illustrated on the attached Record of Borehole sheets.

SUBSURFACE CONDITIONS

The attached plan and Record of Borehole sheets illustrate borehole locations and the subsurface conditions at the boreholes respectively. Figures 1 and 2 illustrates cross-sectional profiles at Areas 1 and 2 respectively.

In general, the native material in Area 1 consists predominantly of clayey silt to silty clay. Based on the results of the insitu vane tests, the shear strength of the material ranges from 40 \pm kPa to over 120 kPa, indicating firm to very stiff consistency. In BH1, a cohesive glacial till stratum was contacted at El. 160 m, underlying the above layer. The 'N' values recorded range from 33 to 4 and decreased with depth. The material becomes a silty clay below El. 155.7 m. In BH 2 and BH 2A, the embankment fill was penetrated at El. 173 \pm m and a layer of silty clay with organic inclusions was encountered. This layer was 2.3 m in BH 2 but the thickness was not explored in BH 2A. The 'N' values recorded in this layer range from 7 to 13 and insitu vane test performed indicate undrained shear strength of over 120 kPa. The material is therefore considered firm to very stiff.

In Area 2, the native material encountered in BH 3 below El. 175 \pm m is a silty clay of intermediate plasticity. 'N' values recorded are 6 and 17 and the undrained shear strength determined by an insitu vane test is greater than 120 kPa. The material is considered firm to very stiff.

The thickness of the embankment fill material ranges from 8 \pm m in Area 1 to 9 \pm m in Area 2. The material is typically a silty clay of intermediate plasticity. 'N' values recorded in this stratum range from 2 to 11, indicating the erratic nature of the fill. Based on undrained shear strength values obtained from insitu vane tests which range from 50 kPa to over 120 kPa, the material is considered stiff to very stiff. However, variations are expected in the fill stratum. BH 3 was advanced from the paved shoulder of the highway and a 1.4 m thick layer of granular fill was encountered at the surface.

Groundwater level was measured in the open boreholes during the investigation. The boreholes were dry upon completion of drilling. Piezometers were installed in the native material close to the bottom of BH 1 and BH 2, and at the fill/native material interface in BH 2A. Initial piezometer readings right after installation are 12.5 m for BH 1 and dry for BH 2 and BH 2A. During a recent site visit on 94 10 25, piezometer readings were taken. The base groundwater table monitored by the piezometers installed in BH 1 and BH 2 had generally stabilized at El. 173 \pm m. In BH 2A, the groundwater level was measured to be at El. 178 \pm m, indicating that a perched water table apparently existed in the fill stratum.

DISCUSSION AND RECOMMENDATIONS

General -

The concerned areas in the current study have a long history of distress. In order to find out the cause or causes of the movements, a thorough desk study of the background information was carried out. Subsequent to the field investigation, laboratory tests were carried out on the soil samples which included consolidated undrained shear tests among other more routine tests. Based on the test results, the slopes were analyzed using effective stress parameters. The following summarizes the findings of the desk study and the results of the slope stability analyses.

Background information -

1. The NBL of QEW at this location was constructed prior to 1940. In 1955, the SBL was constructed under Cont. 55-25. The pavement design called for a sand filter media placed over the clay subgrade, with closely spaced French drains providing subgrade drainage into the ditch lines. When the NBLs were proposed for rehabilitation in 1961, there were concerns on the stability of the embankment. foundation recommendations were given in a report dated 61 07 26. Berms were constructed under Cont. 61-170 and the embankment has apparently been stable since then. In 1965-66, the SBLs were resurfaced under Contract 65-501. The pavement had rapidly deteriorated in this area and resurfacing was carried out under Cont. 83-43. The construction included laying of 100 mm perforated subdrains with geotextile along the shoulders. Since then, cracks reappeared and in particular, continuous cracks at Areas 1 and 2 suggest possible failure zones.
2. Air photographs available in this area over the past were reviewed. 1955 air photographs shows that NBLs were in place and SBLs were being constructed. In 1964, SBLs were completed and the culvert was in place. Apparently, some erosion gullies are visible on the embankment of the SBL just north of the culvert. In 1967, patches can be seen at both Area 1 and 2 locations. Erosion gullies can still be seen on slope. Air photographs taken in 1970s were from high elevations and cannot provide much information. In 1987, cracks have developed at both concerned locations.
3. Insitu vane tests generally indicate stiff to very stiff consistency within the fill embankment and firm to stiff consistency in the native foundation soils. Consolidated undrained shear test (with pore water pressure measurements) carried out on an undisturbed sample in the native cohesive deposit (BH 2, TW 12) gives effective stress parameters of $\phi = 27^\circ$ and $c = 0$ kPa. Consolidation tests carried

out in both the cohesive fill and native deposit indicate the materials are generally overconsolidated.

Discussion -

The embankment has been constructed for 40± years of time, it is believed that most of the consolidation settlements would have realized. Perched water table was detected in the piezometers installed at Area 1 location. It is possible that the subdrains are not working properly and infiltration has saturated the cohesive fill stratum. In Area 2 where the cracks wrap around a catchbasin, it is suspected that there is possible minor leakage from the manhole that has caused settlements in the fill.

Stability analyses were carried out on cross-sectional profiles at Areas 1 and 2 using effective stress parameters. In Area 1, perched water condition was assumed and the safety factor obtained was marginal for long term stability. A stabilizing berm is required to increase the factor of safety to acceptable levels. In Area 2, a back analysis was carried out assuming the current condition has a safety factor of 1.0. A berm was then added to raise the factor of safety to satisfactory levels.

Recommendations -

As discussed above, it is recommended to construct some mid-height berms at Areas 1 and 2 to ensure adequate factor of safety for overall stability. In addition, it is recommended to bench the existing slope for the full height and reconstruct the slope face above the berm level with compacted granular fill. This will ensure the new fill key in well with the existing cohesive fill to prevent shallow slips within the fill material. Geometry and extent of the proposed works are shown in Figures 1 & 2 and Drg. No. 9311022A respectively. Figure 3 shows a schematic design of the proposed works. The finished slope should be properly protected with vegetation cover.

The current slope movement is slow and rapid failure is not envisaged due to the nature of the material. The existing cracks should be sealed and the proposed slope works be included in the upcoming contracts in the area. In the meantime, visual inspections should be carried out regularly to monitor the slope for any deteriorations.

We believe the above is sufficient for your purpose. If you need further information, please contact our office.

A handwritten signature in black ink, appearing to read 'David Kwok', is written over the typed name.

David Kwok, P. Eng.
Project Foundation Engineer
for
Paul Payer, P. Eng.
Senior Foundation Engineer

RECORD OF BOREHOLE No 1

1 OF 1

METRIC

W.O. 93-11022 LOCATION N 4 766897.9 E 335593.9 ORIGINATED BY DK
DIST 6 HWY QEW BOREHOLE TYPE H.S. Auger COMPILED BY DK
DATUM Geodetic DATE 93 08 31 - 93 09 01 CHECKED BY PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT		UNIT WEIGHT γ 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	20 40 60 80 100	W _P W W _L	WATER CONTENT (%)				
173.1	Ground Surface														
0.0	Silty Clay to Clayey Silt Occasional Silt Zones Firm to Stiff Greyish to Reddish Brown		1	CS	-								20.0		
			2	SS	13										
			3	SS	13										
			4	SS	8										
			5	TW	PH										
			6	TW	PH										
			7	TW	PH										
			8	SS	4										
			9	TW	PH										
			10	SS	6										
			11	SS	3										
160.0															
13.1	Heterogeneous Mixture of Silt, Clay and Gravel Occasional Boulders & Silt Zones Reddish Brown, Soft to Hard (Glacial Till)		12	SS	33								5 9 78 8		
			13	SS	11										
			14	SS	4										
155.7															
17.4	Silty Clay														
154.4	Reddish Brown and Grey, Soft		15	SS	3										
18.7	End of Borehole														
94 10 25 * GROUND WATER CONDITIONS															
PIEZO. NO.		GROUND WATER ELEVATION (Metres)													
1		172.4													

+3, x5: Numbers refer to
Sensitivity

20
15-5 (%) STRAIN AT FAILURE
10

METRIC

+3, x⁵: Numbers refer to Sensitivity

METRIC

20
15-5 (%) STRAIN AT FAILURE
10

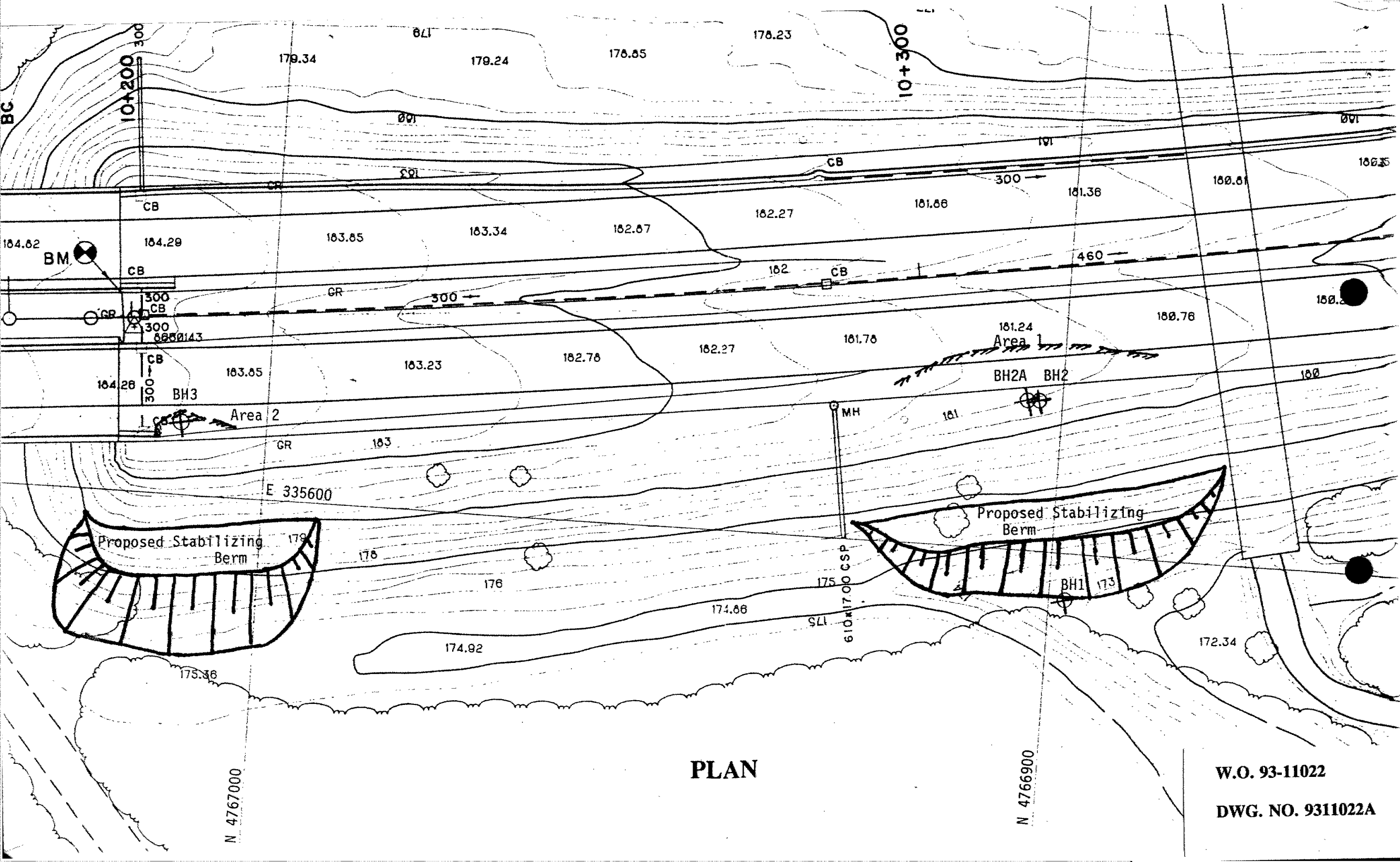
RECORD OF BOREHOLE No 3

1 OF 1

METRIC

W.O. 93-11022 LOCATION N 4 767011.1 E 335609.0 ORIGINATED BY DK
 DIST 6 HWY QEW BOREHOLE TYPE H.S. Auger COMPILED BY DK
 DATUM Geodetic DATE 93 09 02 CHECKED BY PP

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					
184.0	Ground Surface																
0.0	Granular Fill		1	CS	-	DRY											
182.6	Grey, Compact		2	SS	13												
1.4	Silty Clay		3	SS	4		182										
	Trace Gravel and Organics		4	SS	6												
	Greyish Brown		5	TW	PH		180										
	Very Stiff		6	SS	10		178										
	(Fill)																
174.9							176										
9.1	Silty Clay		7	TW	PH												
	Firm to Very Stiff		8	SS	17		174										
	Reddish Brown and Grey		9	SS	6		172										
169.8							170										
14.2	End of Borehole																
	* 93 09 02 Hole dry upon completion																



PLAN

W.O. 93-11022

DWG. NO. 9311022A

Elev. (m)
190

± QEW

180

El. 177m

5m

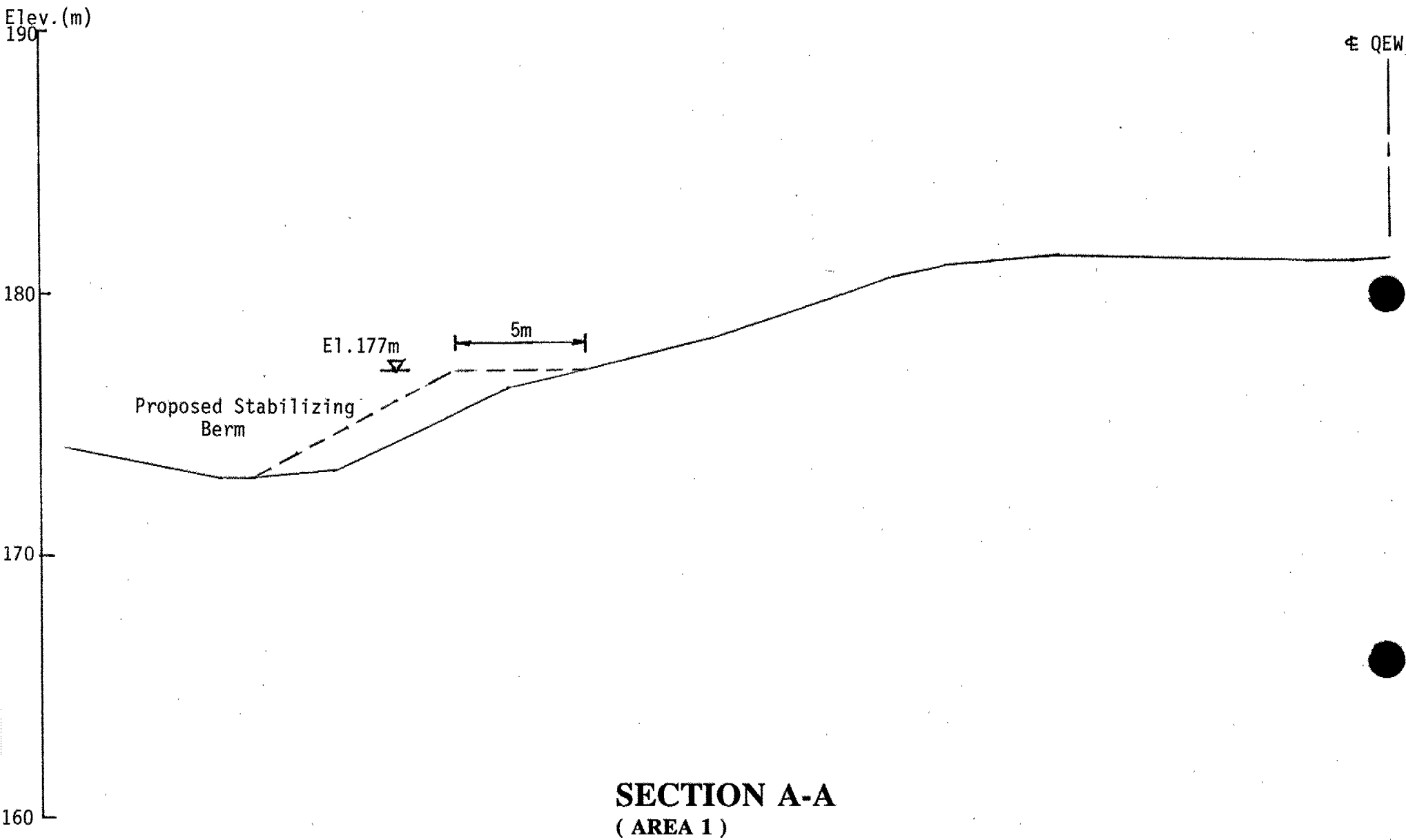
Proposed Stabilizing
Berm

170

160

SECTION A-A
(AREA 1)

W.O. 93-11022
Figure 1



Elev. (m)

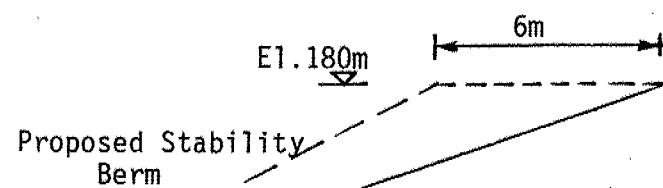
190

180

170

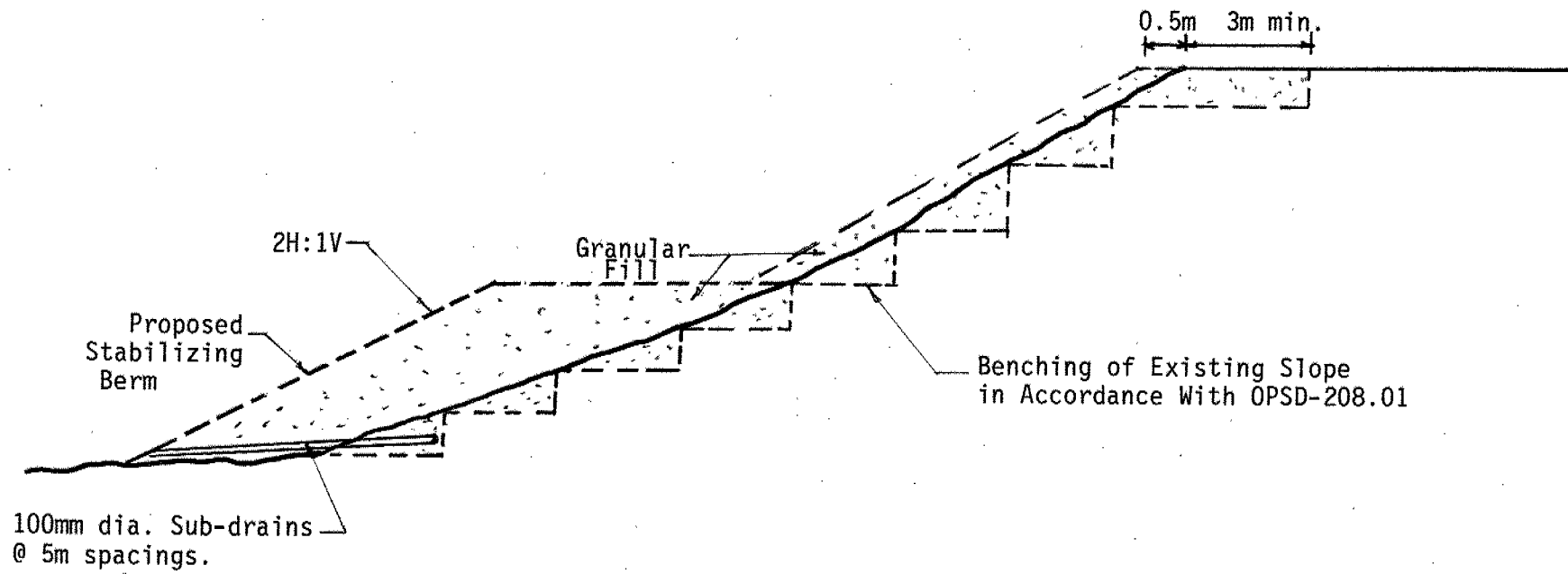
160

± QEW



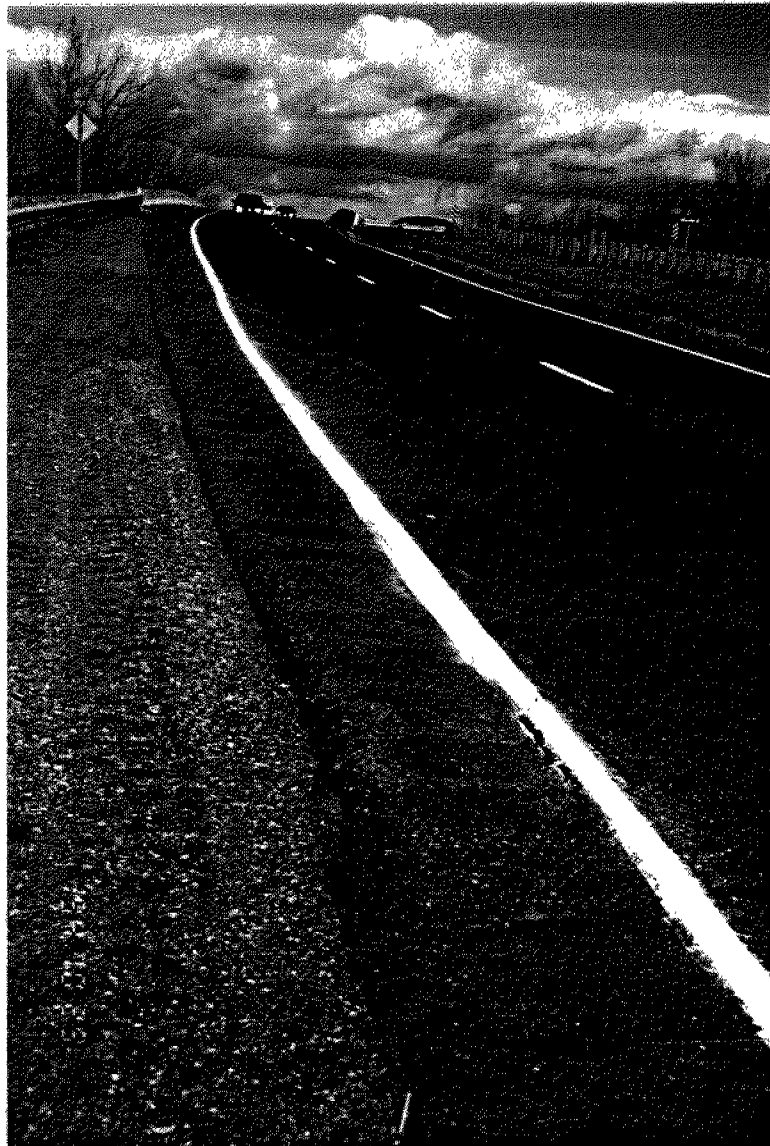
SECTION B-B
(AREA 2)

W.O. 93-11022
Figure 2

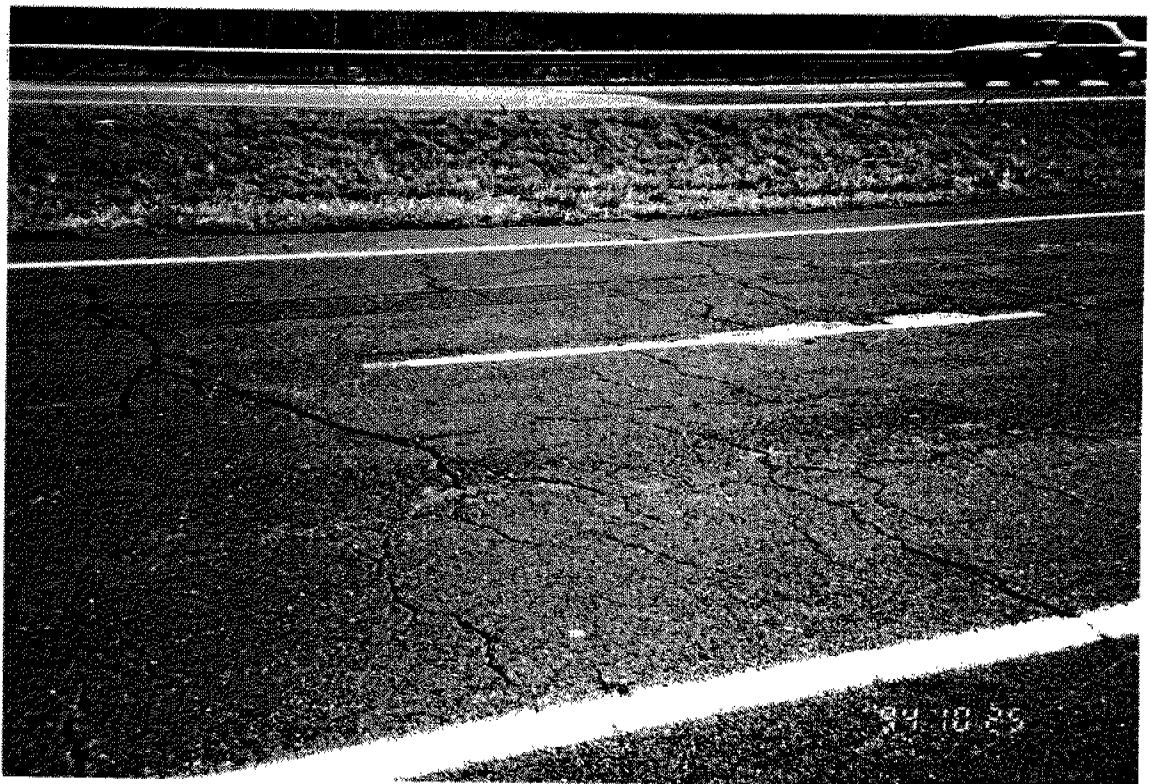


SCHEMATIC DESIGN OF SLOPE WORKS

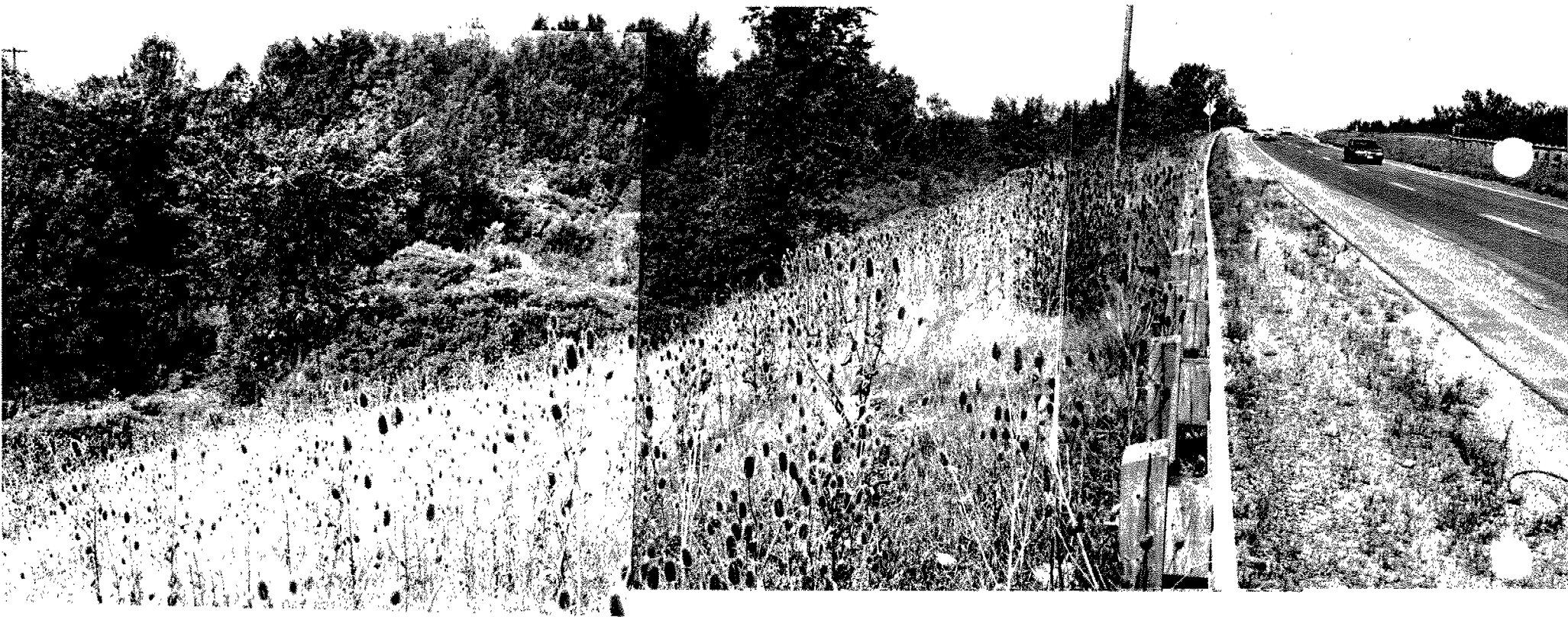
W.O. 93-11022
Figure 3



















From: Betty Bennett
To: MTOCR.DOWNSVCR.Vanbiesb
Subject: QEW and Welland River - Slope Instability

Jim

I visited the above site yesterday. Based on the subsurface data gathered in 1993 and the observations at the site, no foundation investigation along the QEW NB embankment is required.

As described this morning, the slopes along the NB lanes of the QEW in the vicinity of the pavement cracking appear stable. The cracking occurs in the proximity of the concrete culvert. What was noticeable was the amount of seepage from the toe of the slope over the crown of the culvert. It is possible that the seepage is creating a loss of fines in the embankment resulting in some distress of the pavement.

A perched water table was identified in the fill during the investigation carried out in 1993 (BH 2A - El. 178.2). Water within the fill appears to be an ongoing problem. As we discussed, any improvements to surface drainage would alleviate the build-up of hydrostatic pressures within the fill. This is likely the most practical solution at this time

Betty

P.S. I stopped by the Highway 140 site as well... nice crabgrass.

CC: MTOCR.DOWNSVCR.Tannous, MTOCR.DOWNSVCR.Kohlberg