Hatch Mott MacDonald

July 22, 2011

Richard A. Marsden, Jr., PE, PP, PLS, CME
Director of Engineering and DPW
8 Springfield Avenue
Cranford, New Jersey 07016

RE: Northeast Quadrant Flood Risk Mitigation Project, Phases 3&4 – Levee (Dike) Stability and Seepage Analysis

Dear Mr. Marsden:

Hatch Mott MacDonald (HMM) is pleased to provide this Report as authorized under our existing Professional Engineering Services Agreement for Phases 3 and 4 services. The Report summarizes findings on the stability of representative sections of the existing levees (a.k.a. dikes) located along the Rahway River in the Northeast Quadrant of the Township of Cranford.

The analyses described herein are based upon field data, including soil boring data, provided by the Army Corps of Engineers (ACOE), New York District. HMM wishes to acknowledge the cooperation of the ACOE.

The results of analyses indicate that for the levee sections where data is available, the slopes appear stable but the levees are potentially susceptible to erosion of the toe of slope due to seepage under the levee. After you have had an opportunity to review this Report, we would be pleased to meet with you to review the findings presented herein.

Very truly yours,

Hatch Mott MacDonald

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Township of Cranford NJ

Levee Reliability Study

SLOPE STABILITY AND SEEPAGE ANALYSIS REPORT

July 2011

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Levee Reliability Study

SLOPE STABILITY AND SEEPAGE ANALYSIS REPORT

Issue and Revision Record

Rev	Date	Originator	Checker	Approver	Description
0	July 22,2011	S. Kibby	J. Davies	J. Davies	Issued for Use

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APPENDICES

1.0 Introduction

Communications with the Corps in recent months have given rise to concern by the Township of Cranford with respect to the stability of the existing levees. The Corps has provided the Township with certain field data including logs of soil borings of the levees obtained by the Corps. The Corps has undertaken preliminary levee reliability analyses for the purposes of developing stage-damage relationships for economic evaluation of alternatives. However, the results of analyses are not available for public release at this time. In view of the Township's concerns with respect to the existing levees, the Township has expressed interest in undertaking an independent analysis of the stability of the levees.

The existing levees extend approximately 1,000 feet on the west side and 3,700 feet along the east side of the Rahway River in Cranford, generally between Springfield Avenue and Kenilworth Boulevard. The Corps has taken soil borings at 7 locations along the east levee and at 3 locations along the west levee. The borings indicate that the levees lack impervious cores within the levees or seepage cutoffs under the levees, which gives rise to concern with respect to instability due to seepage under or through the levees when the water level on the river side is at flood stage.

Seepage analysis can be undertaken in steady state conditions. Under steady state conditions, the water level on the river side of the dike remains constant for analysis purposes. This memo summarizes the results from the steady state analysis.

2.0 Analysis

Four sections through the levees were taken near the location of the borings. These sections were located based on the boring location and sections provided by the ACOE (See Figure 1). The sections were interpreted from the ACOE supplied survey which was done by Rogers Surveying PLLC in the spring of 2009. Dimensions of the sections are subject to some variation based on interpretation of contours and distances. The sections are labeled CR-33 (near borehole 2), CR-34 (near borehole 3), CR-36 (near borehole 4 on the east levee and borehole 5 on the west levee, designated CR-36W), and CR-38 (near borehole 6). Sections at these locations were analyzed on both the river and land side of the levee. Each slope stability analysis was done for both short term and long term conditions.

The reason both short and long term analysis were performed is because soil strength properties can change with time due to the changes in pore water pressures. The rate at which the properties change is related to the hydraulic conductivity and loading conditions of the soil.

3.0 Soil Parameters

The boring logs show the levees consist of red silt with some clay underlain by sandy silt. These materials have been labeled levee material and base material, respectively.

Soil parameters used for the short term analysis were the same ones utilized in the ACOE preliminary model and provided by the ACOE. The long term parameters have been based on empirical correlations using material descriptions and boring information (SPT n-values). The following table shows the parameters utilized in this analysis.

	Cohesion (c) (psf)	Friction angle (ϕ) (degrees)
Short Term Condition		
Levee material	2000	0
Base material	0	33
Long Term Condition		
Levee material	200	25
Base material	0	33

Section Location	Hydraulic conductivity (ft/s)
CR-33	0.00005
CR-34	0.000216
CR-36	0.000216
CR-38	0.000216

The friction angle can be considered the steepest angle of a slope relative to the horizontal when material on the face of the slope is on the verge of sliding. Cohesion is the component of soil shear strength independent of inter-particle friction. Hydraulic conductivity is the rate at which water migrates through a soil.

4.0 Methodology

The HMM analysis utilized SEEP/W and Slope/W programs to analyze the migration of flood water through the levees and the slope stability of the saturated levees. The analysis was set to only look at the levees for slope failure and excluded the potential for the river bank to fail. SEEP/W and Slope/W are commercially available programs by GEO SLOPE International Ltd.

Each location was analyzed in the steady state saturated condition. This means that the model assumes the flood water has filled behind the levee and fully saturated the levee material prior to the analysis taking place. This removes the time factor from the model and is generally considered to be a conservative approach in analyzing seepage and slope stability problems. The water level behind the levee is assumed to be at the top of the levee which does not correspond to a specific flood level. This was assumed because it presents the worst case water level prior to overtopping the levee. Once overtopping occurs failure of the levee would likely be due to erosion as opposed to slope stability or from piping induced erosion. The analysis performed looked at both short and long term stability.

The analysis was performed for both the water and landside slopes and used the results from the seepage analysis to determine water level and flow within the levee.

5.0 Results

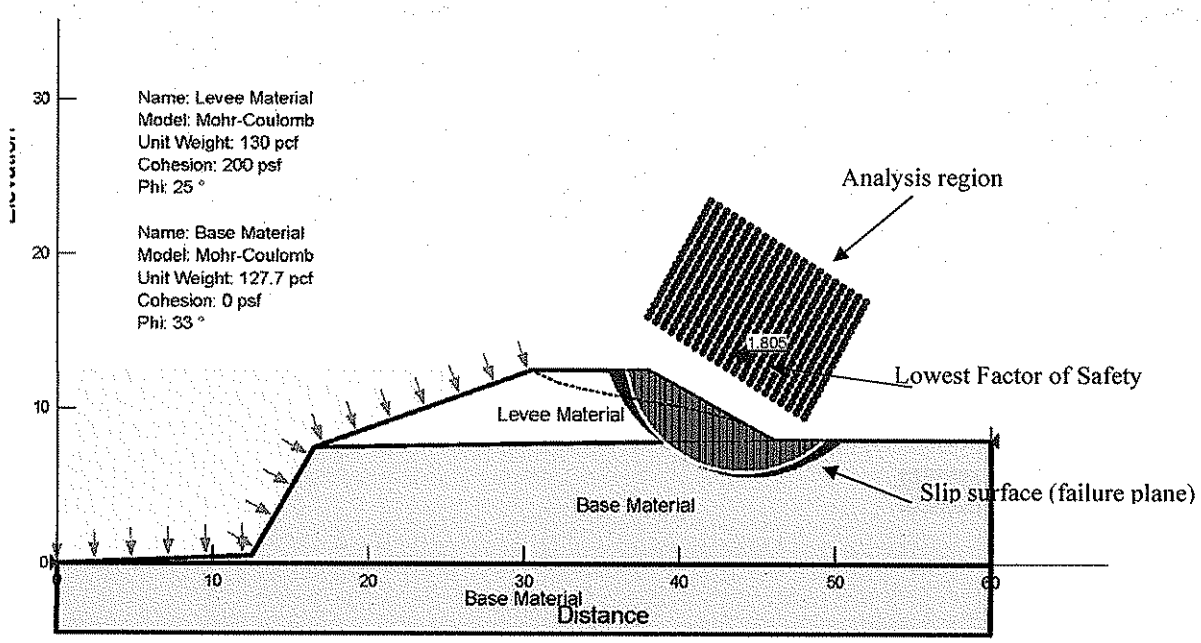
The following table summarizes the results of the analysis for each of the locations, both river and landside of the levee.

	Factor of Safety (FOS)				
	Short Term Conditions		Long Term Conditions		
	Landside	Riverside	Landside	Riverside	Exit Gradient
CR-33	13	17.8	1.8	1.8	0.57
CR-34	16.2	1.7	2	1.6	0.57
CR-36	18.3	1.51	2.3	1.5	0.56
CR-36W	n/a*	5.1	n/a*	3.6	n/a*
CR-38	17.9	17.1	1.6	2.8	0.85

* "levee" on west side is more of a river bank and the elevations behind the levee are approximately the same as the top of the levee

This analysis shows that the factor of safety for both sides of the levees are greater than the ACOE required Factor of Safety (FOS) of 1.4 per EM 1110-2-1913 under both short and long term conditions. The exit gradient exceeds the allowable gradient 0.5 in all sections. The exit gradient exceeding 0.5 indicates that under flood conditions with water at the top of the levee there is a potential for piping which could erode the landside toe of the levee. This erosion could cause the levee slopes to fail.

A sample output from Slope/W is shown below.



This figure shows the two materials, the water level and the slip circle with the lowest factor of safety. The grid of red dots shows the region where the potential failure circles were centered. The lowest factor of safety is shown as a brighter red dot with the value beside it.

6.0 Conclusions

The sections analyzed in this report appear to be stable under both short and long term conditions and exceed the ACOE required factor of safety. However, the levees could be susceptible to piping which could erode the toe of the landside slope and cause the slope to fail. To further investigate the rate at which the erosion might occur, a transient model would need to be developed. The development of a transient model would require substantial additional field, laboratory and survey information.

7.0 Limitations

This report is for informational purposes only. The results and conclusions of this analysis are limited to the sections identified here in and based on a limited amount of subsurface data supplied by others. The levees are likely not uniform, varying in composition, slope and construction. The analysis was performed utilizing generally accepted analytical procedures. Should additional information become available HMM should be given the opportunity to amend or revise our results and conclusions.

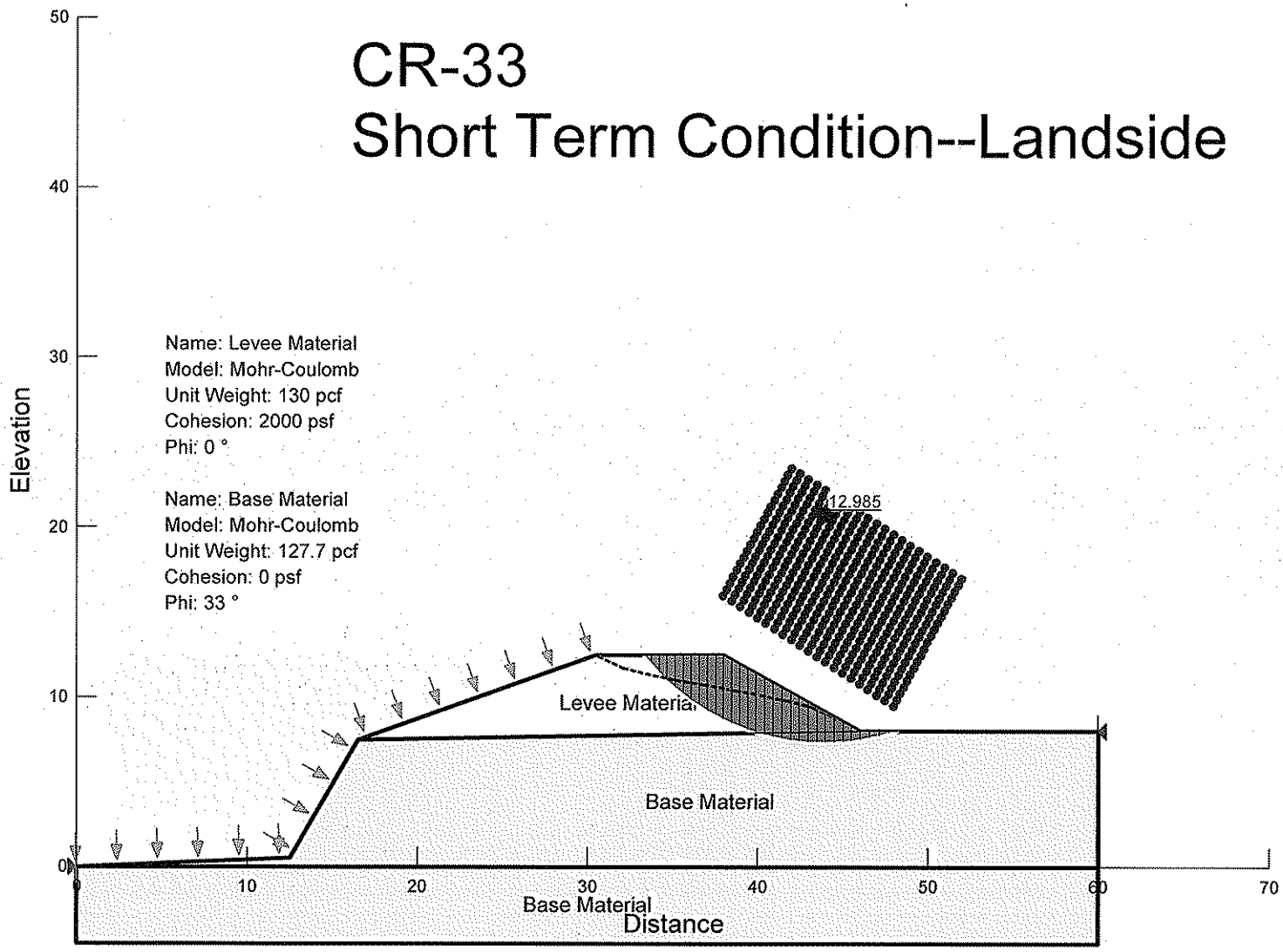
Figures

NOTE:
PROVIDED BY ARMY
CORPS OF ENGINEERS.

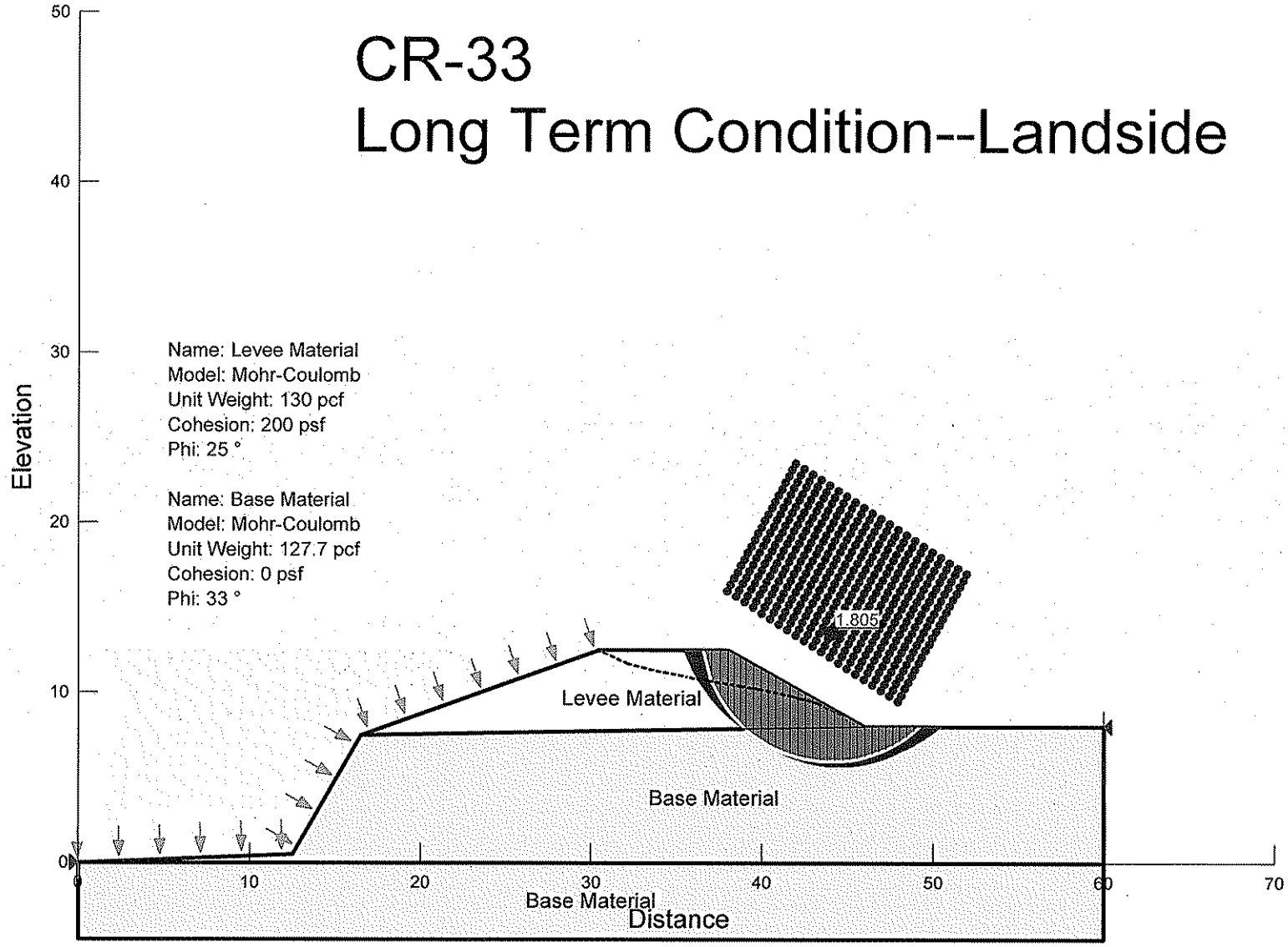
Hatch Mott MacDonald 400 BLUE HILL DRIVE SUITE 100, NORTH LOBBY WESTWOOD, MA. 02090	CRANFORD LEVEE ANALYSIS	BORING AND SECTION LOCATIONS	SCALE: NOT TO SCALE	DRAWN BY	DESIGN BY	CHECK BY	FIGURE: 1
			DATE: JULY 22, 2011	RAL			SHEET: 1 OF 1

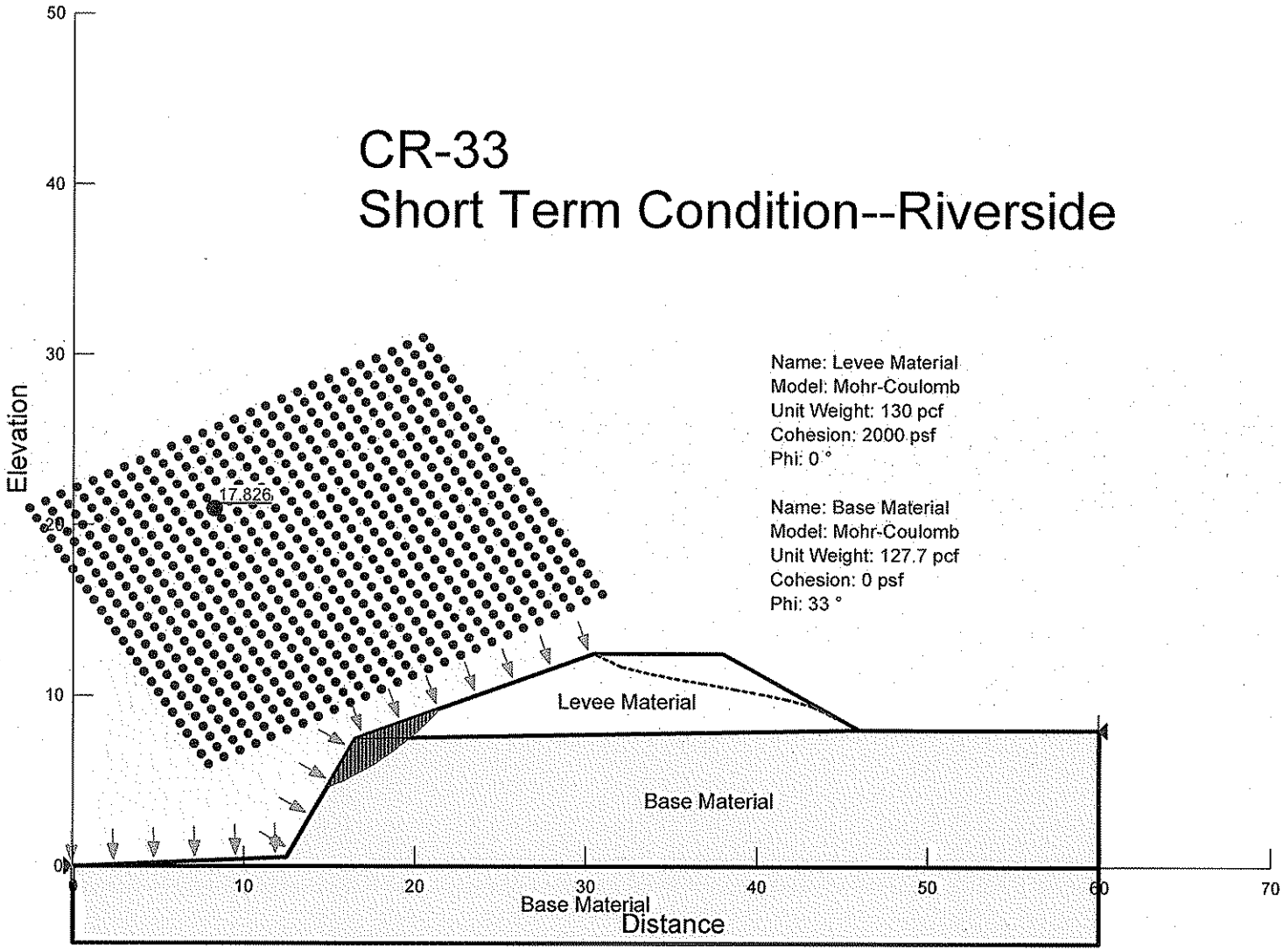
Slope/W Output

CR-33
Short Term Condition--Landside



CR-33
Long Term Condition--Landside

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Base Material
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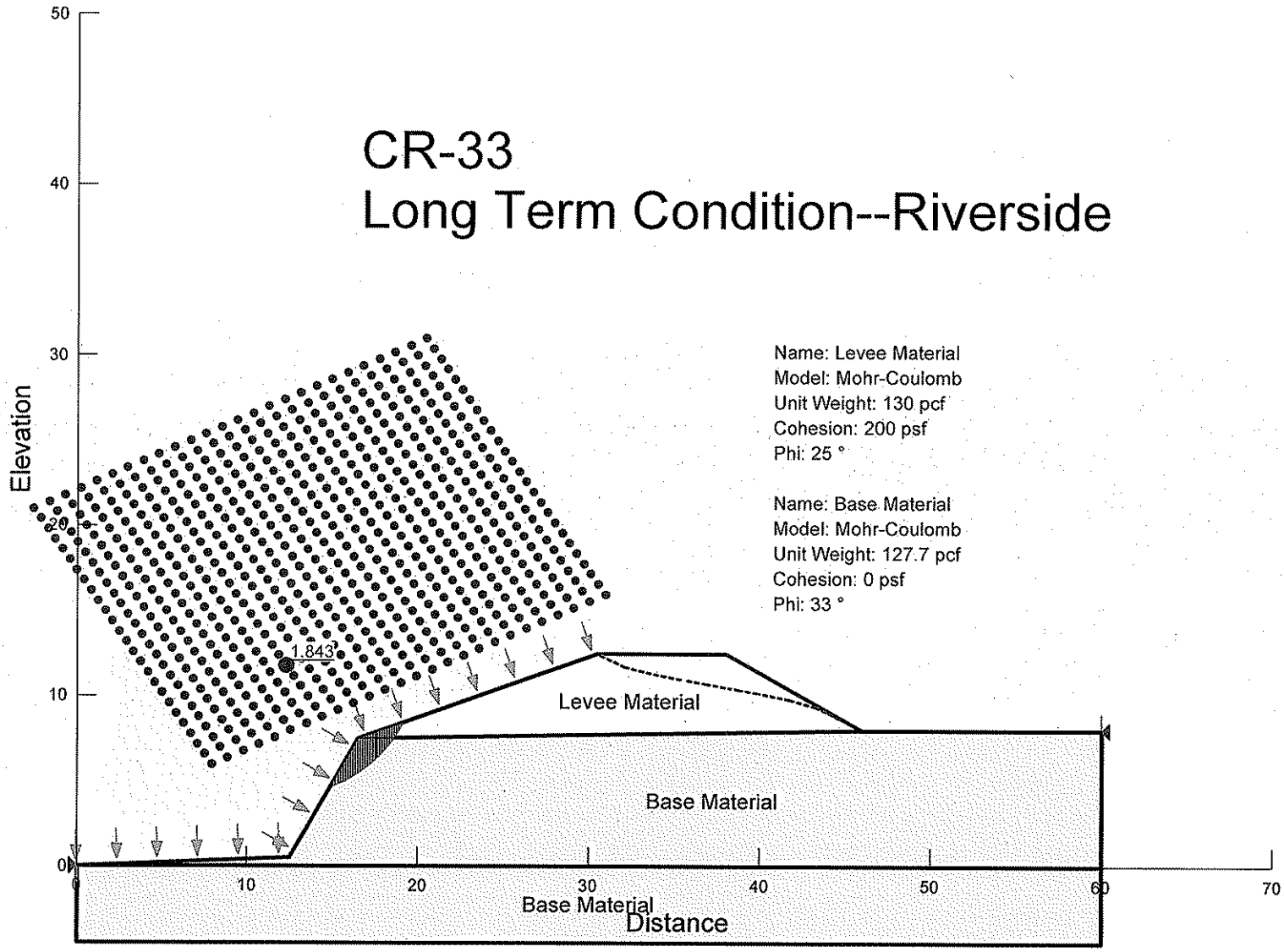
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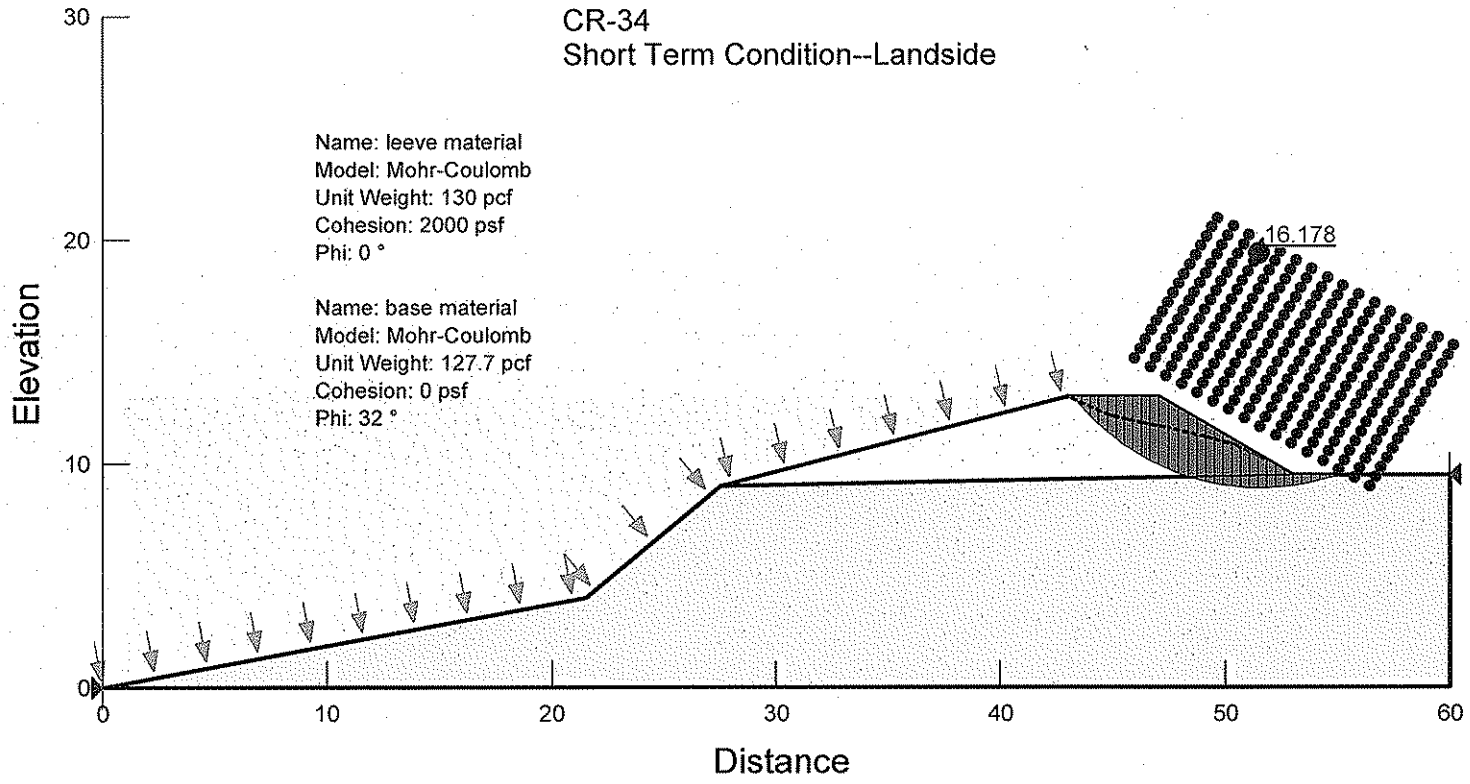
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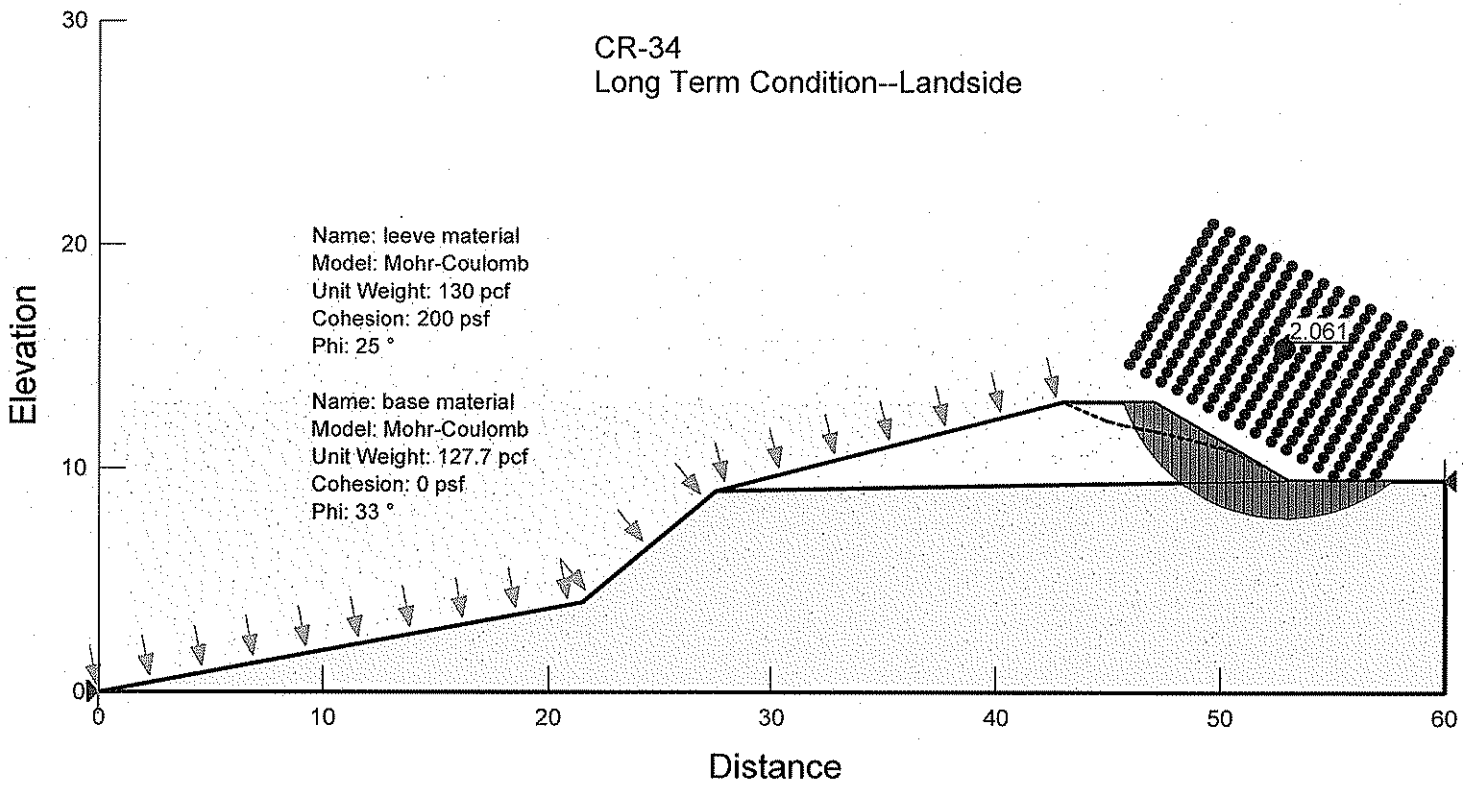
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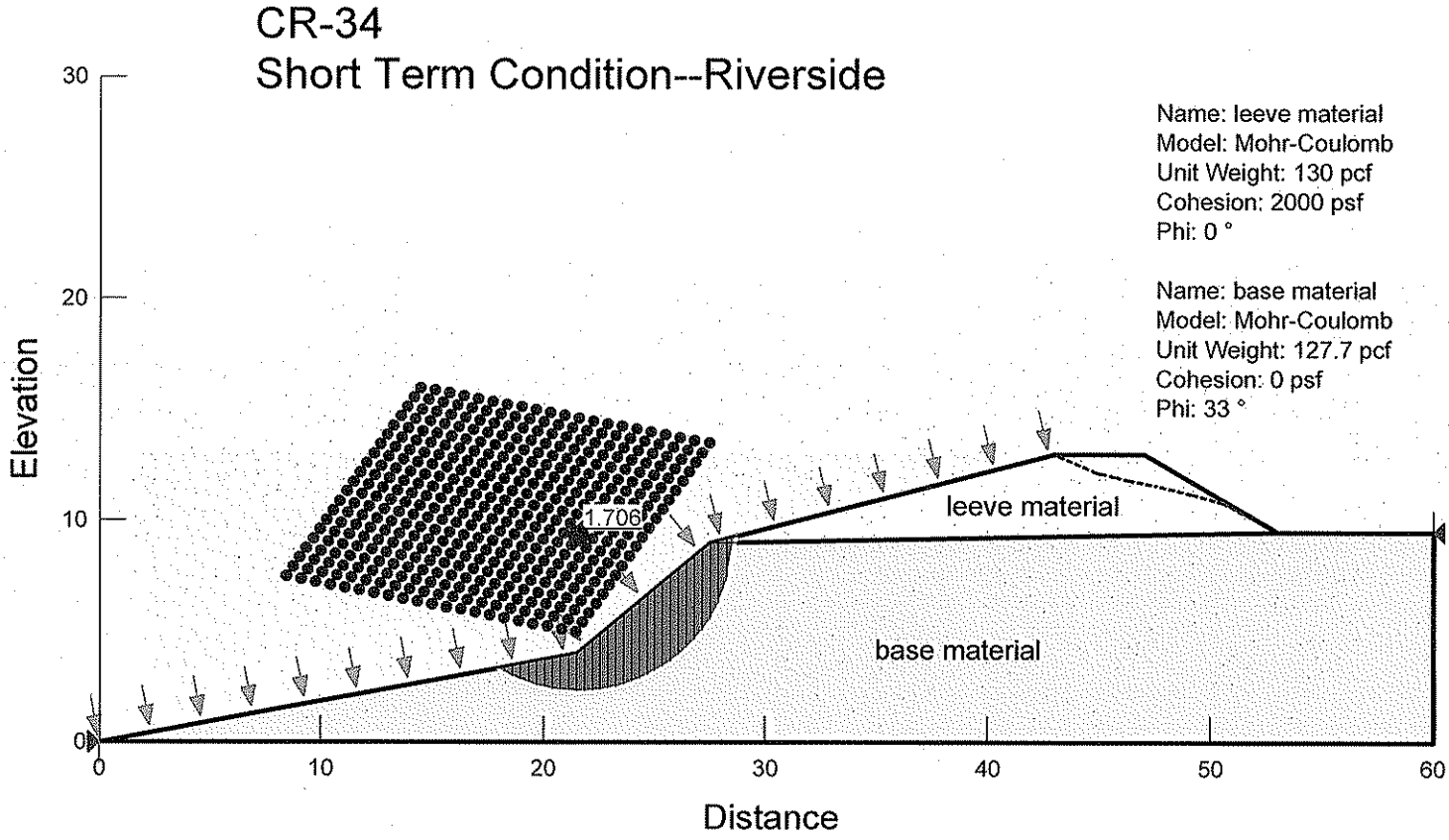
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base material
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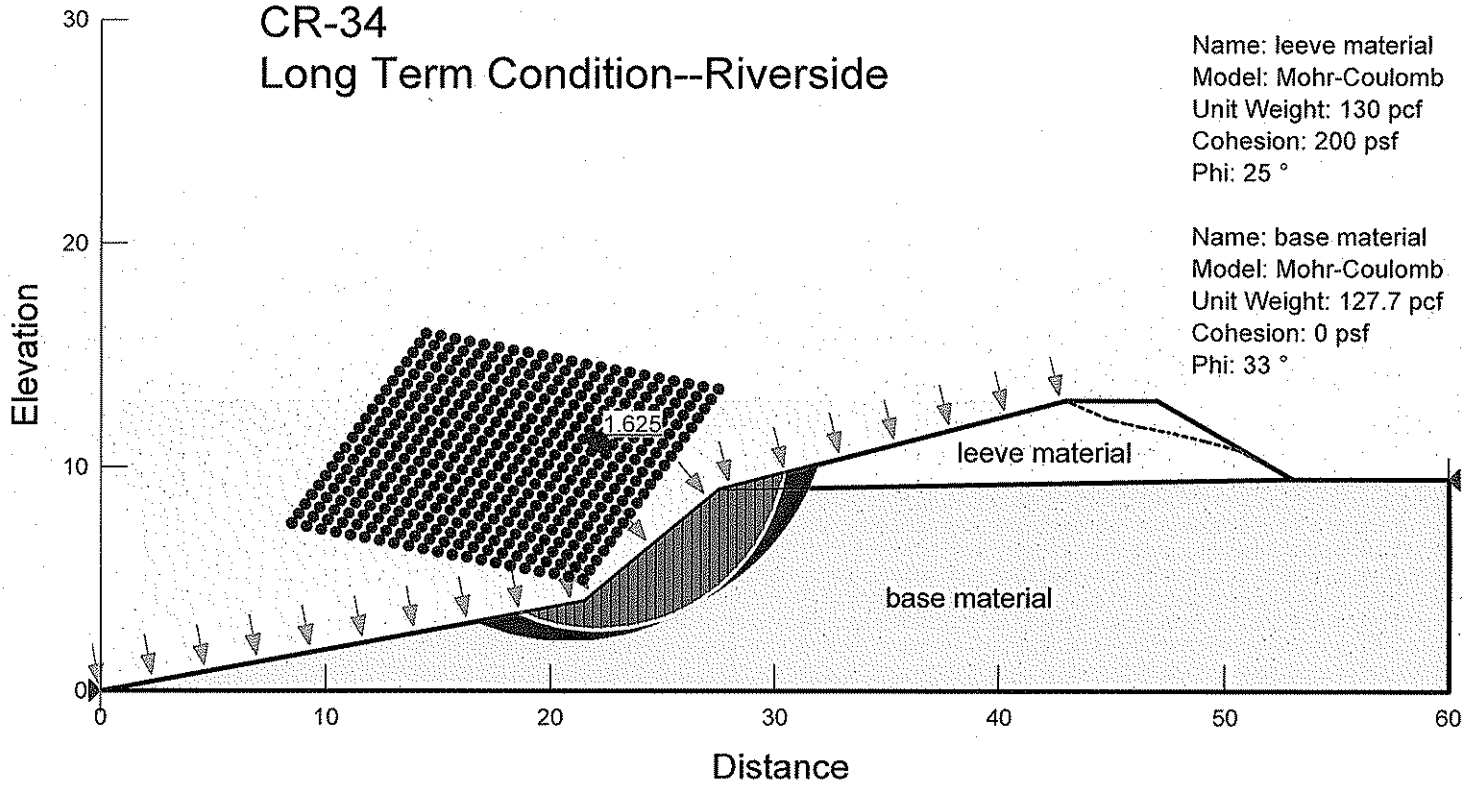
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base material
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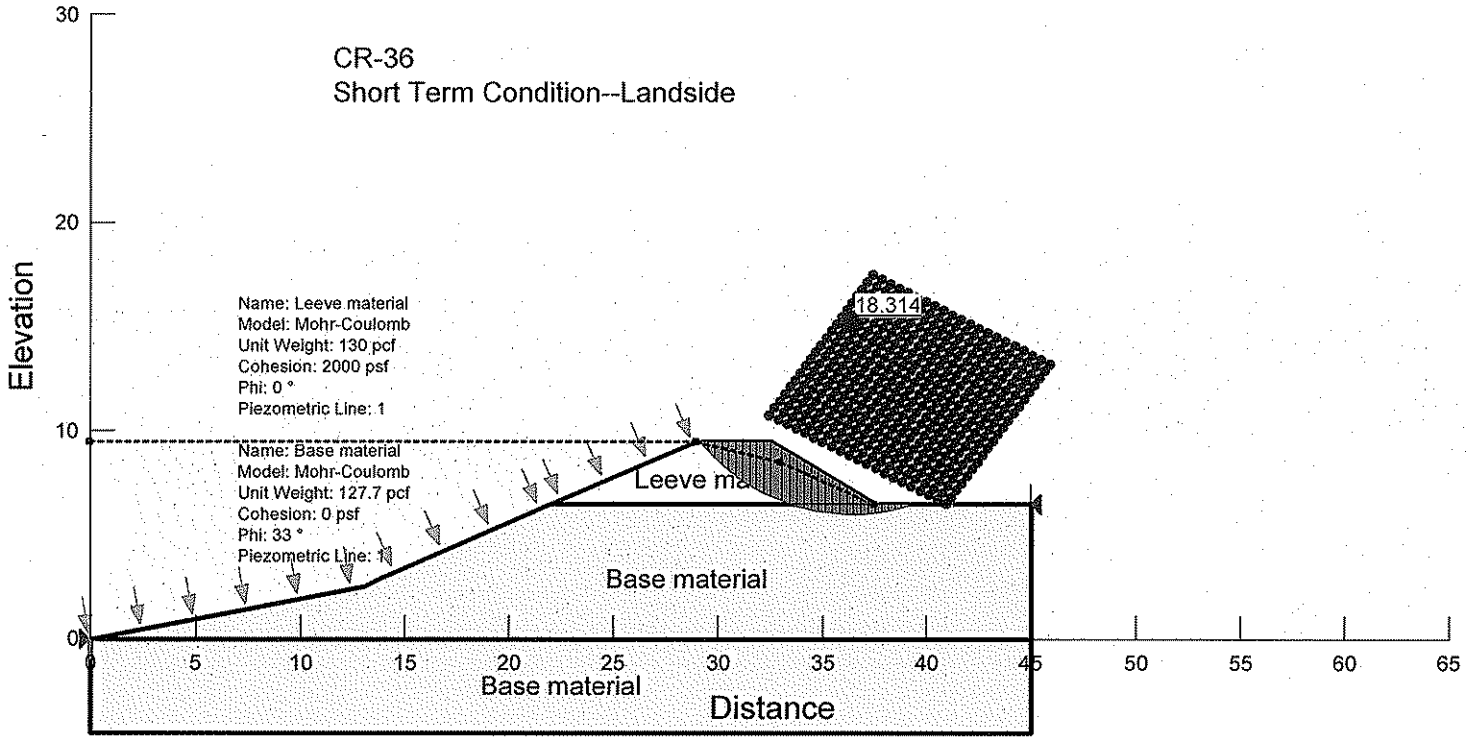
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Piezometric Line: 1
Name: Base material
Model: Mohr-Coulomb
Unit Weight: 127.7 pcf
Cohesion: 0 psf
Phi: 33 °
Piezometric Line: 1
18.314
Leeve ma
Base material
Base material
Elevation
Distance
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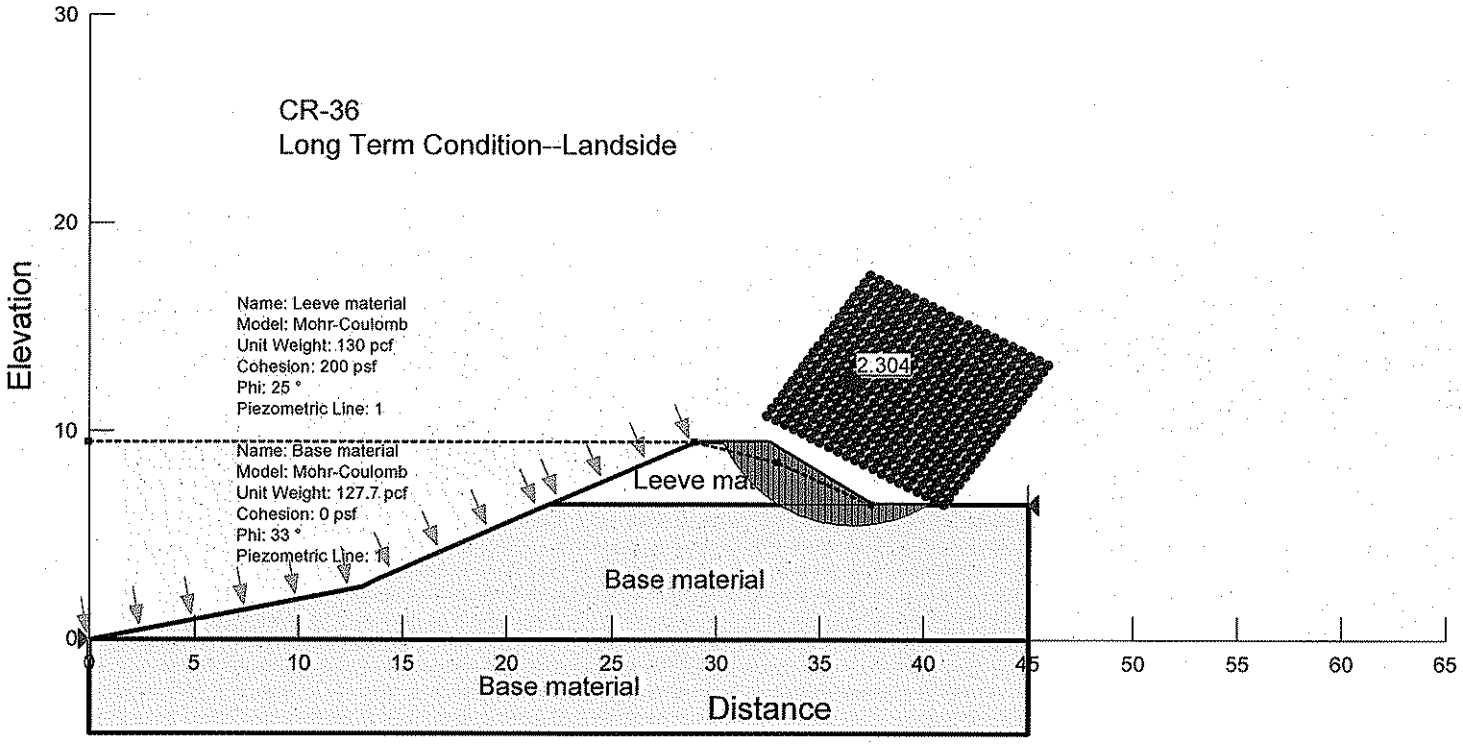
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Cohesion: 0 psf
Phi: 33 °
Piezometric Line: 1
2.304
Leeve ma
Base material
Base material
Elevation
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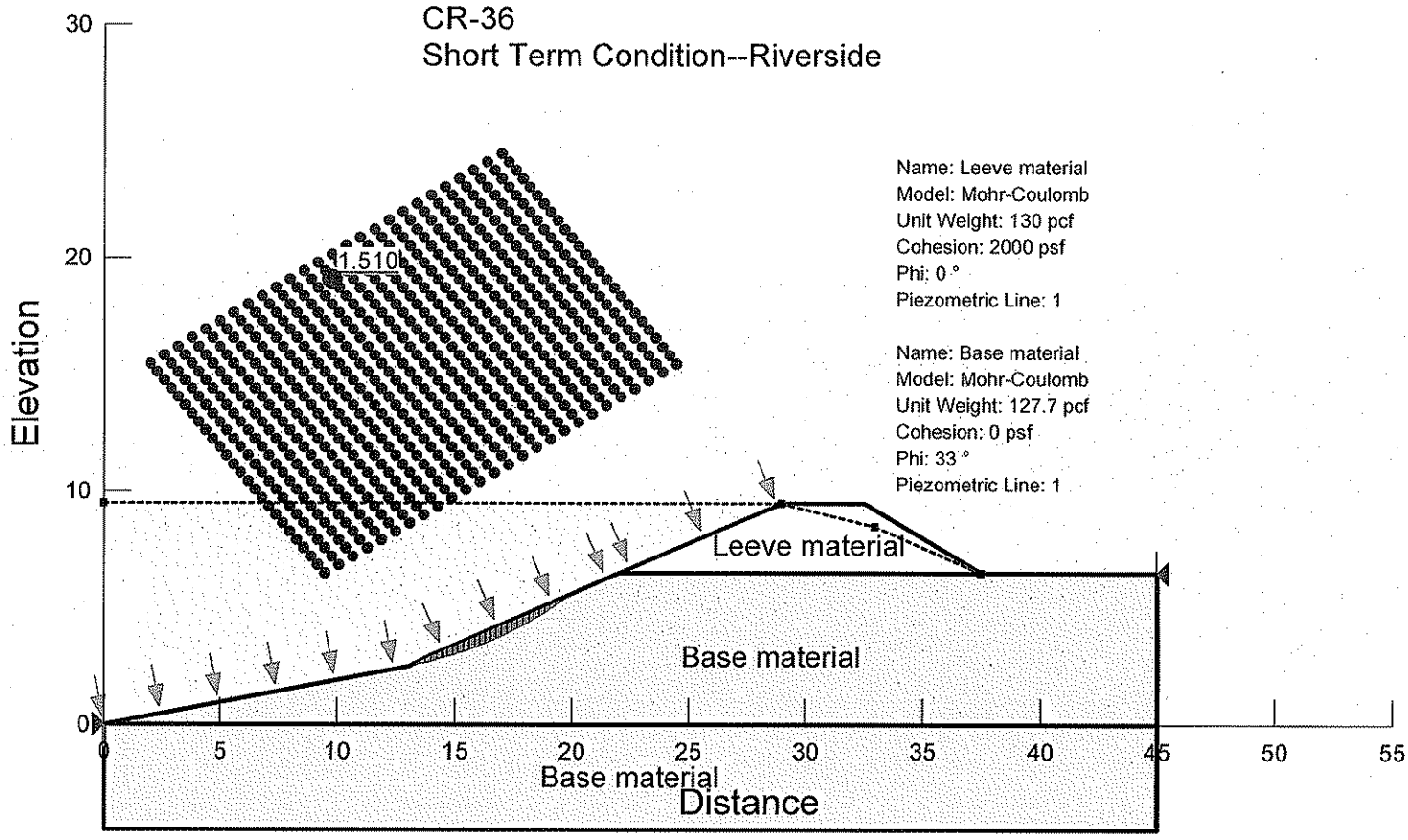
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Unit Weight: 127.7 pcf
Cohesion: 0 psf
Phi: 33 °
Piezometric Line: 1
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Leeve material
Base material
Base material
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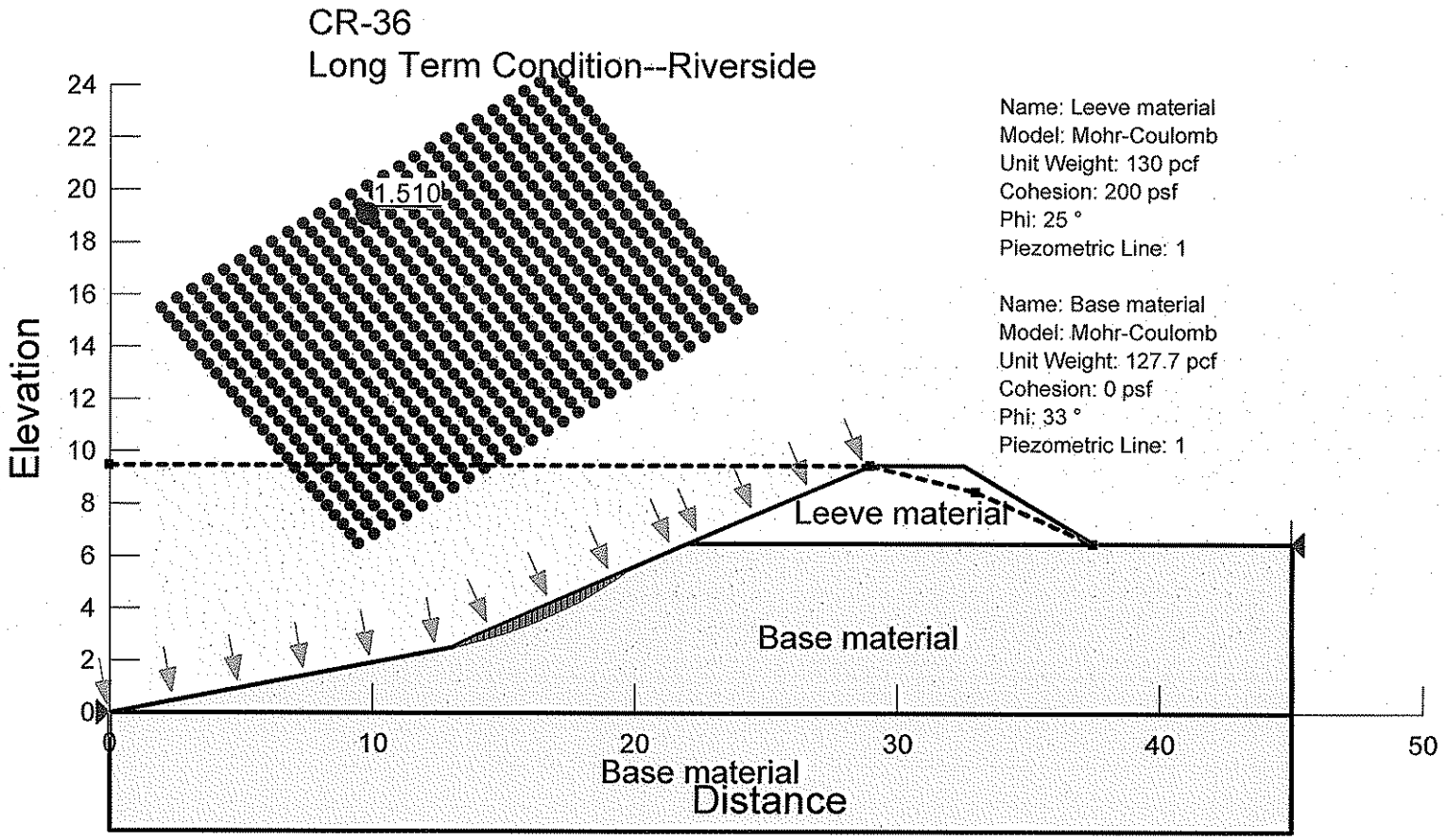
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Piezometric Line: 1
Name: Base material
Model: Mohr-Coulomb
Unit Weight: 127.7 pcf
Cohesion: 0 psf
Phi: 33 °
Piezometric Line: 1
Leeve material
Base material
Base material
Elevation
Distance
0
2
4
6
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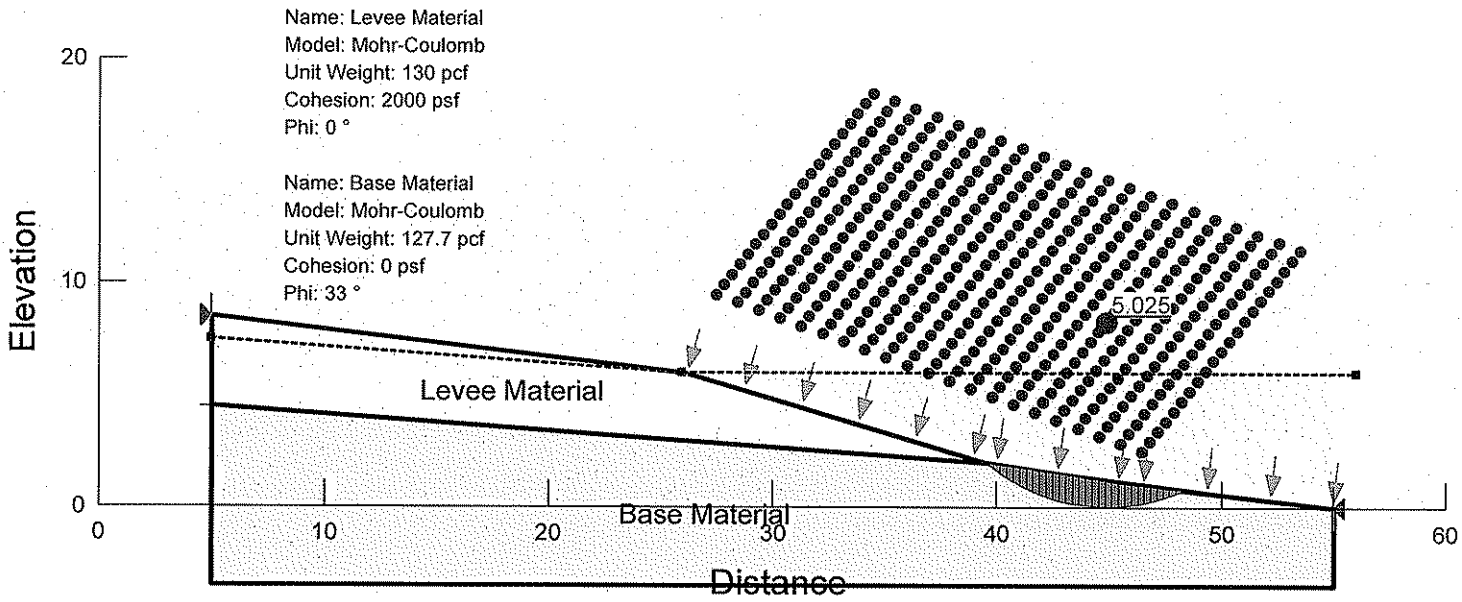
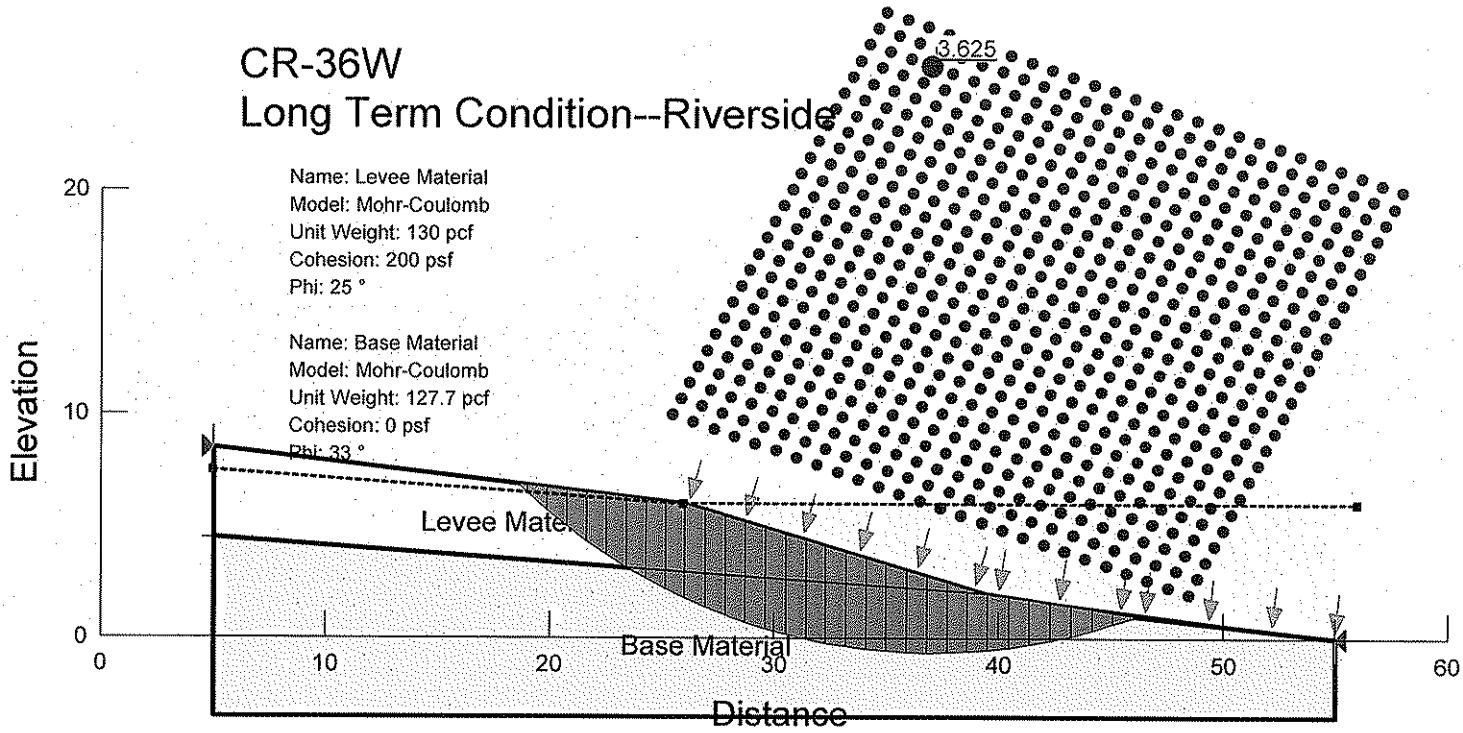
CR-36W
Short Term Condition--Riverside

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Levee Mate
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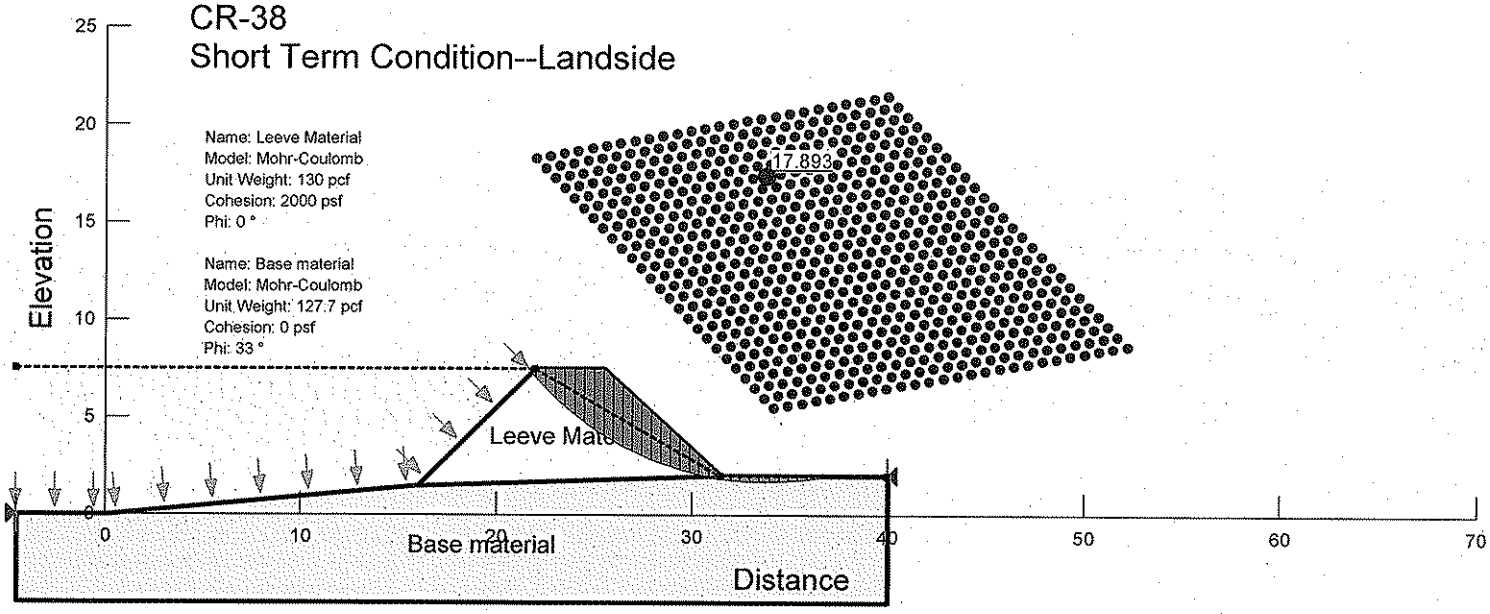
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Phi: 33 °
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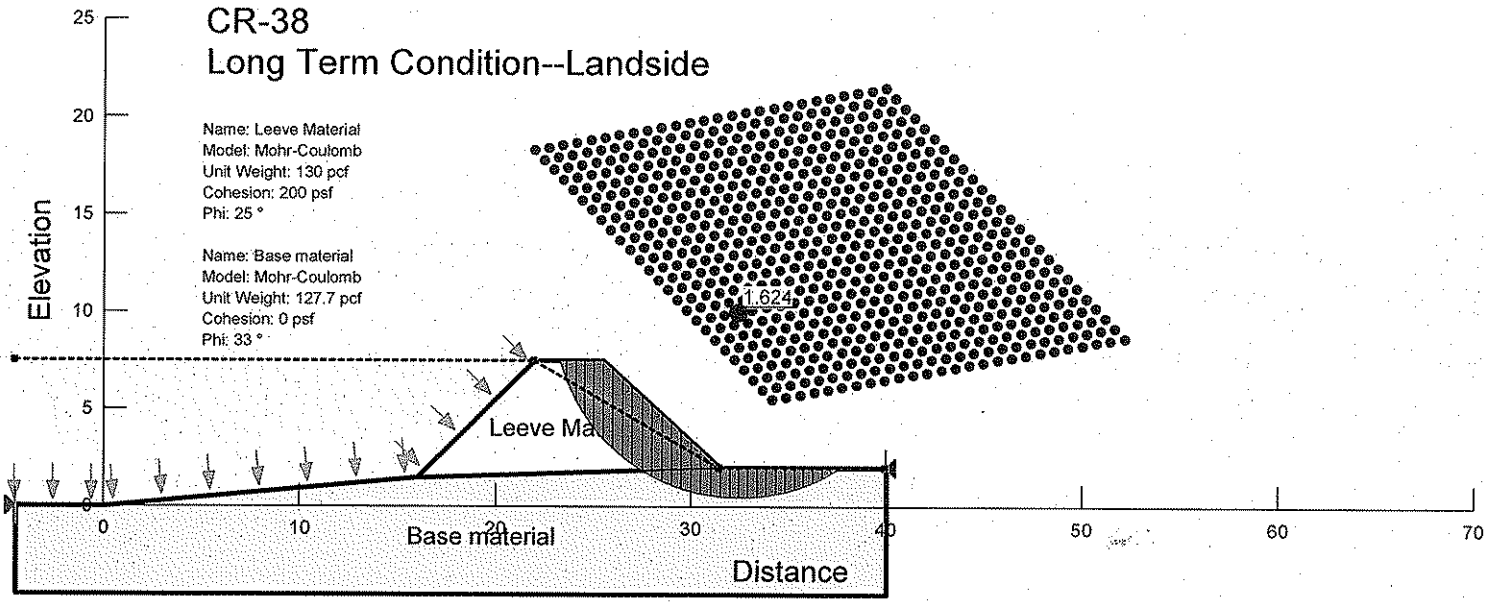
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Phi: 33 °
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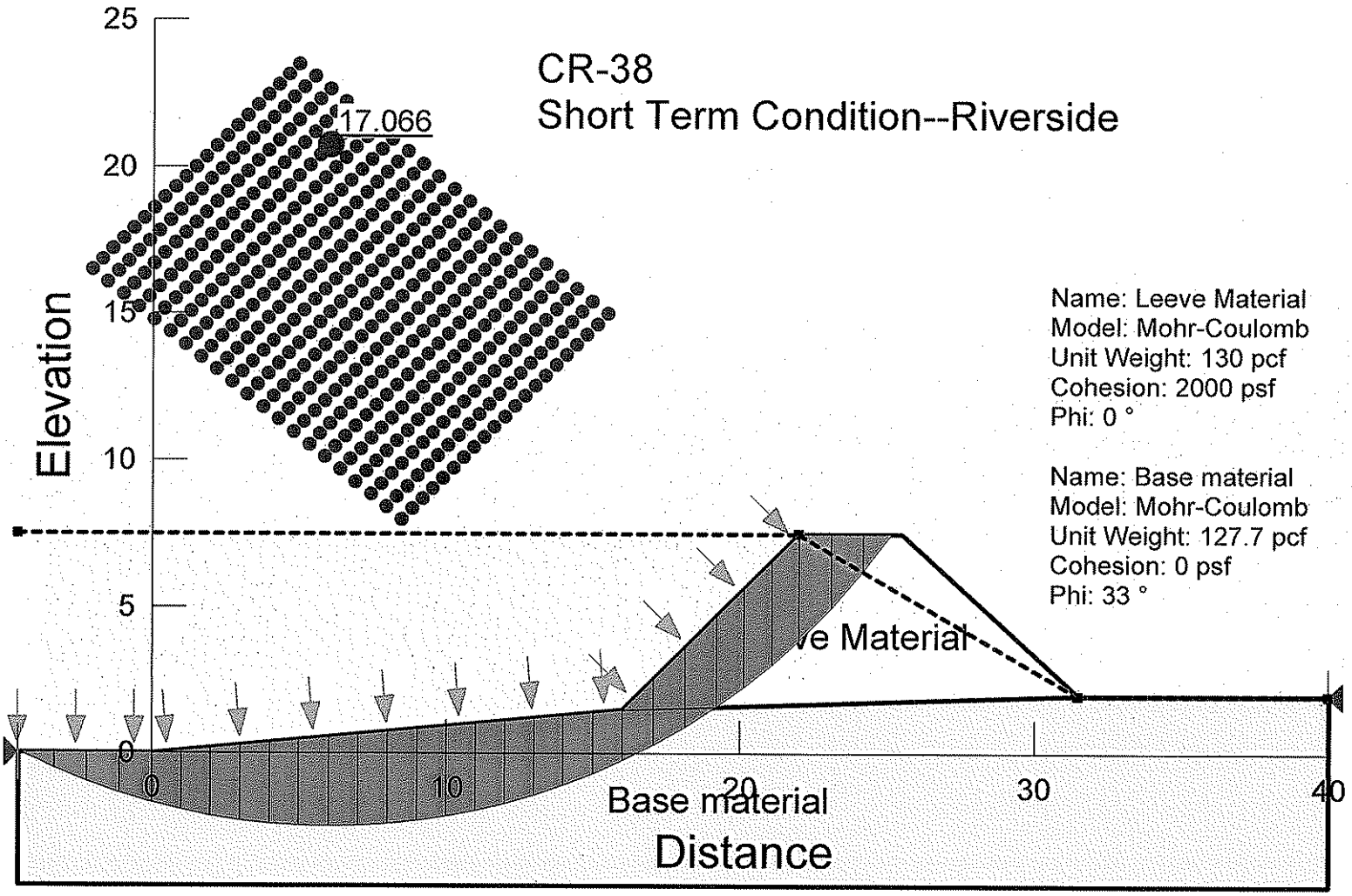
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Elevation
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20
30
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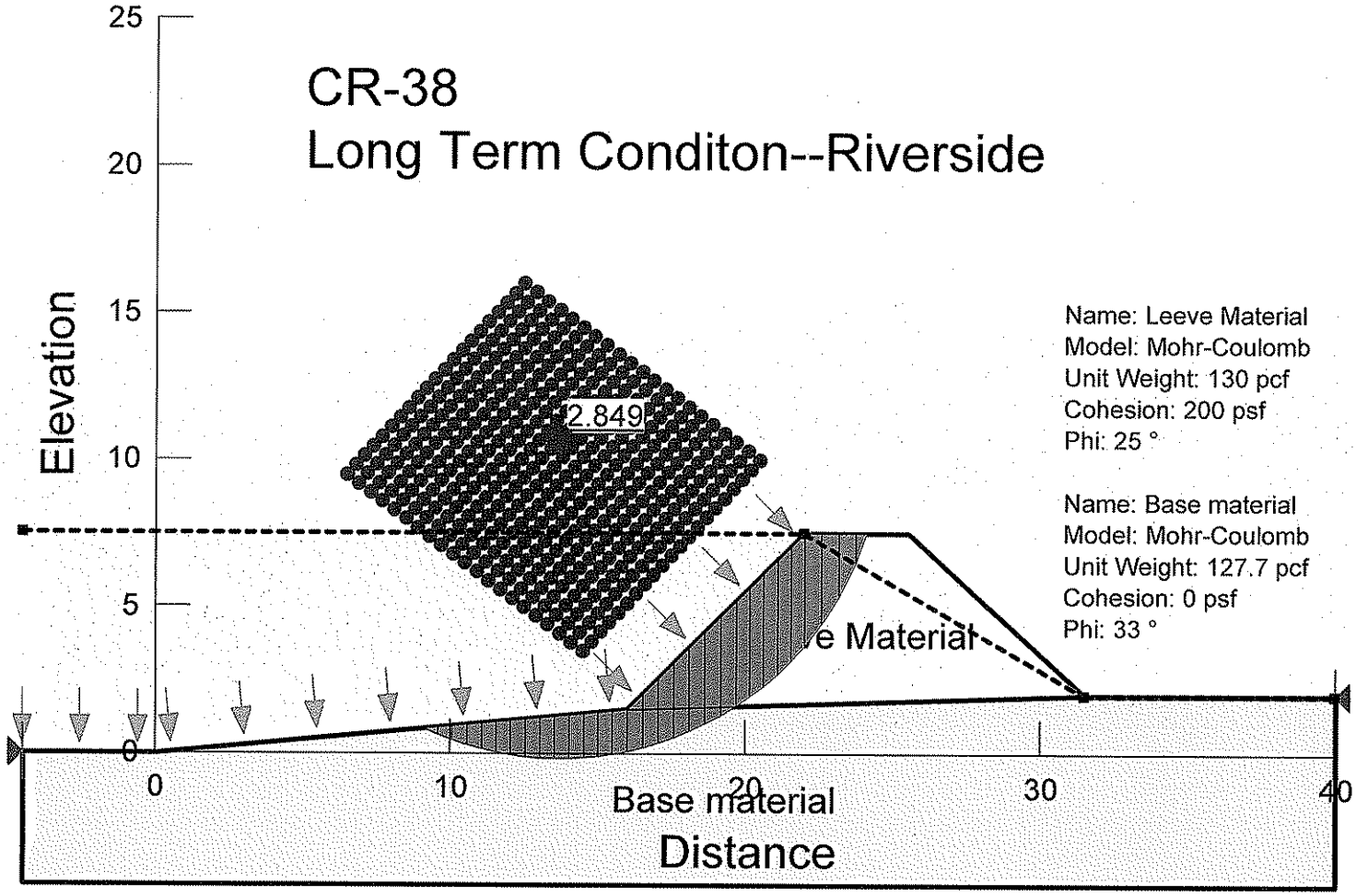
Base material
Distance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Elevation
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30
40
Distance
Base material
2.849
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Cohesion: 200 psf
Phi: 25 °
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Model: Mohr-Coulomb
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Cohesion: 0 psf
Phi: 33 °