Design of Pavements on Expansive Clay Subgrades

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Texas A&M University

Foundation Performance Association
Houston, Texas
December 12, 2012

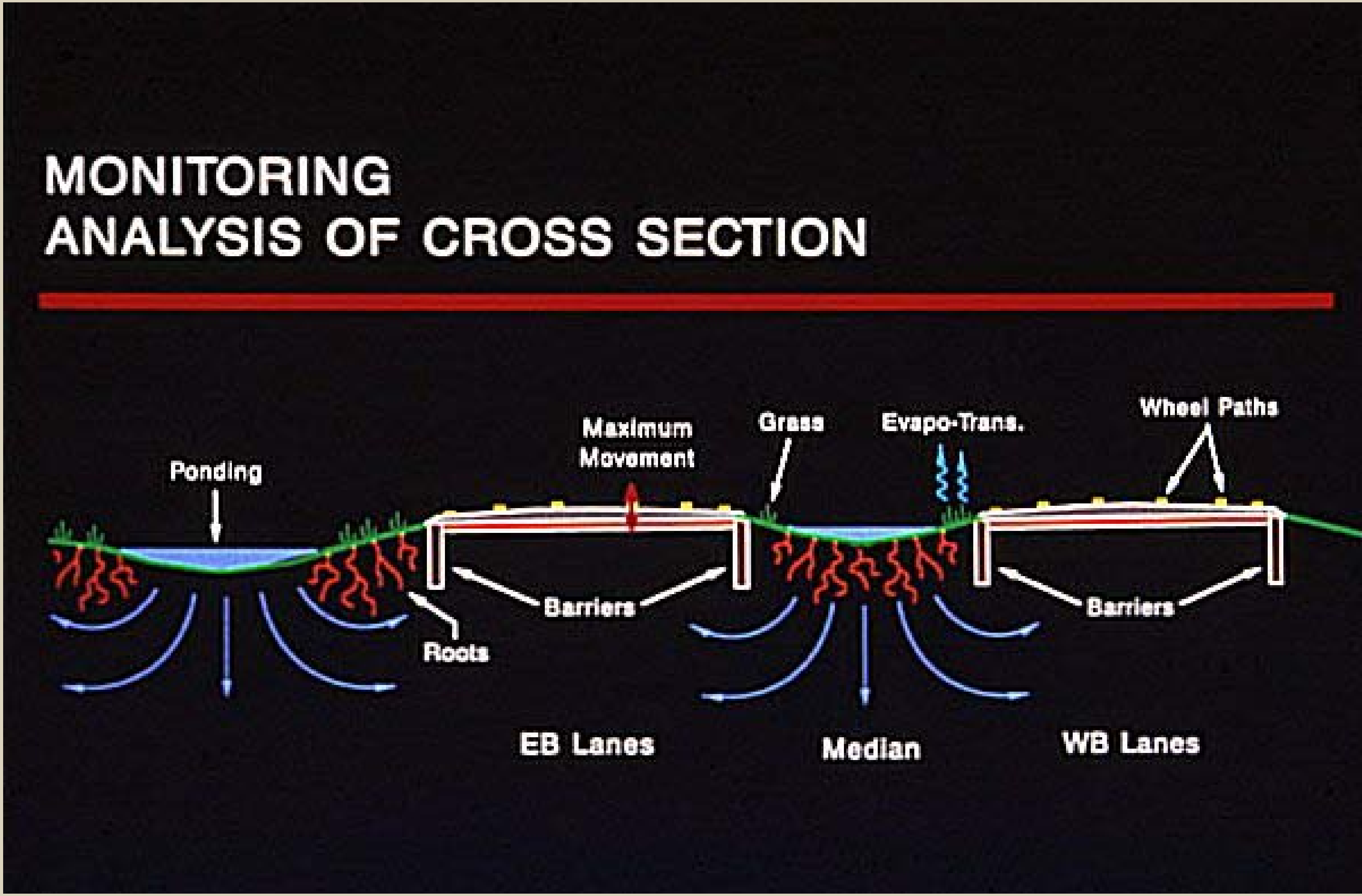
Outline

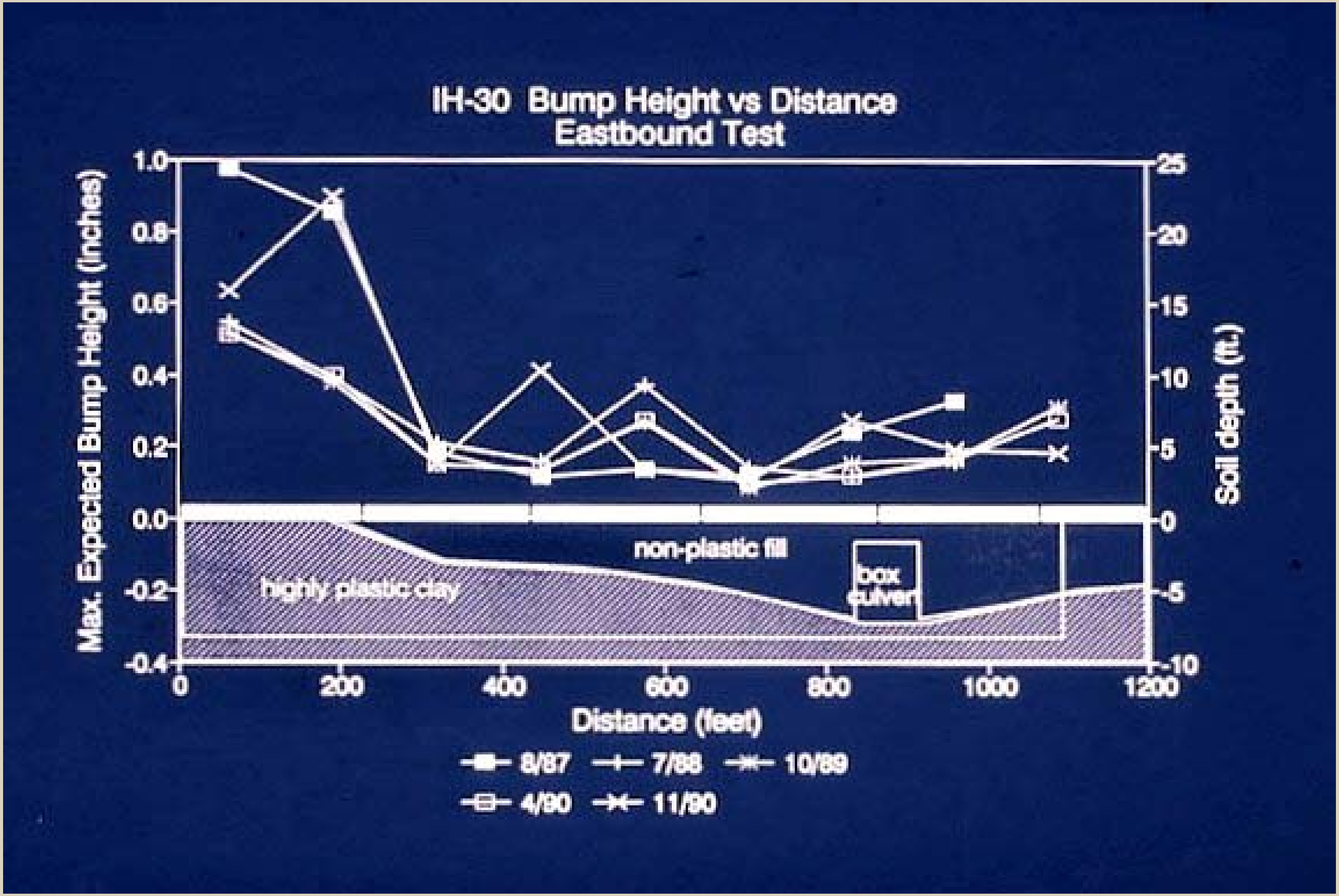
- Performance of pavements on expansive clays
  - Roughness
  - Cracking
- Pavement monitoring program
- Suction envelopes for design
- Prediction of movement
  - Edge of pavement
  - Wheel path

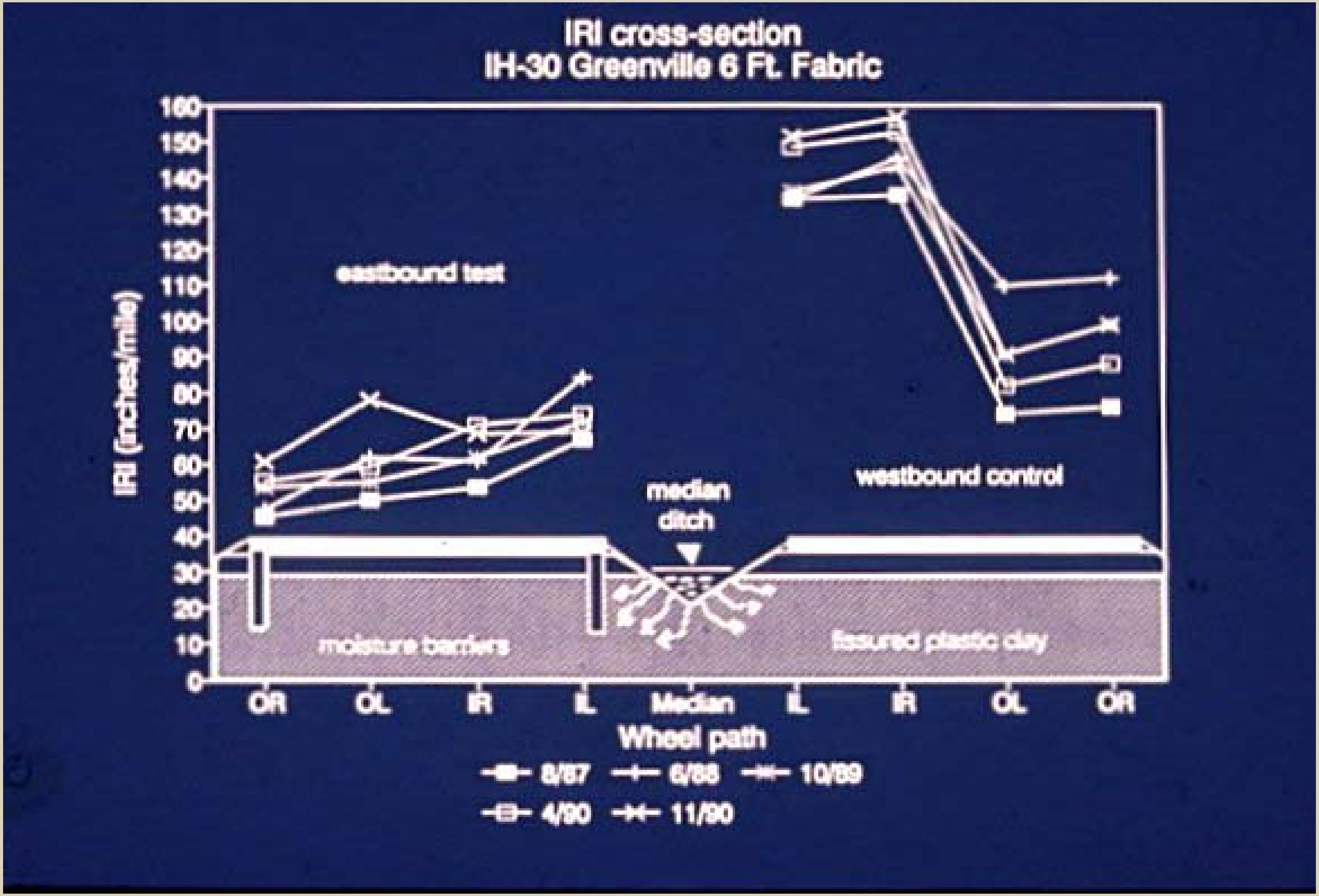
Outline, cont.

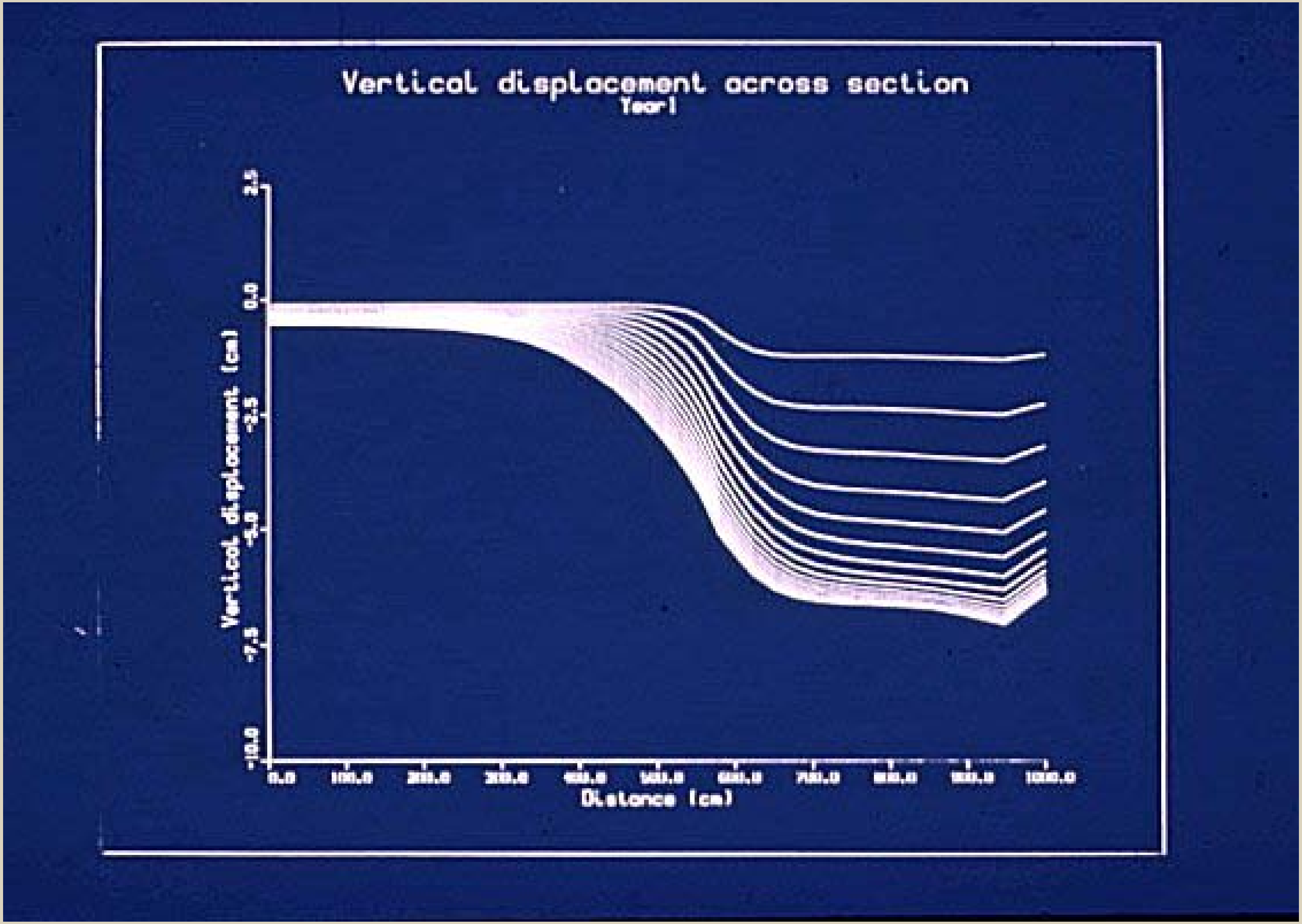
- Prediction of roughness
- Longitudinal cracking over expansive soils
  - Design countermeasures
  - Crack spacing
- Features of design program WinPRES
- WinPRES demonstration

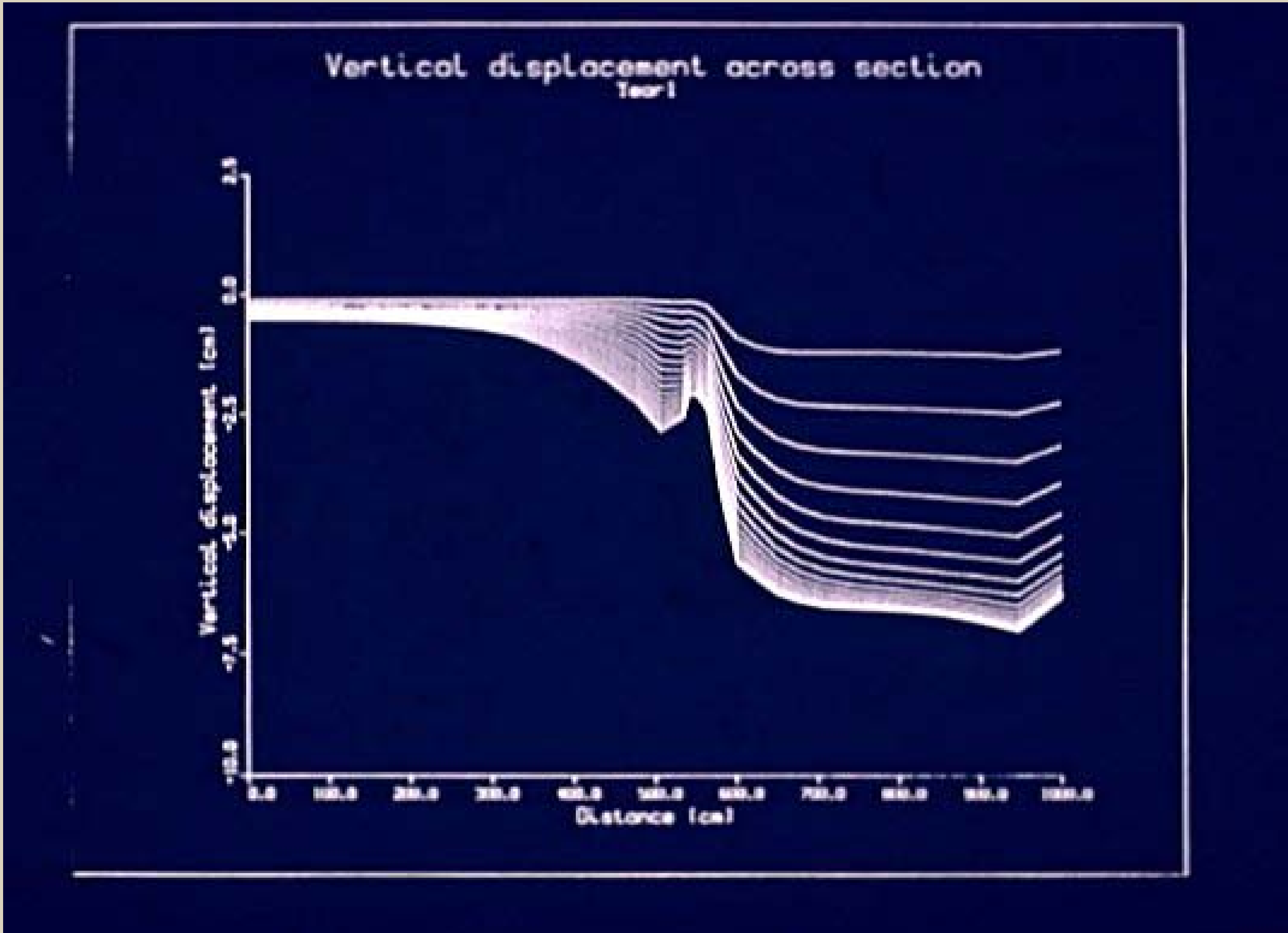
Guardrail between pavement lanes on expansive clay subgrade IH37, San Antonio, Texas (c. 1974)

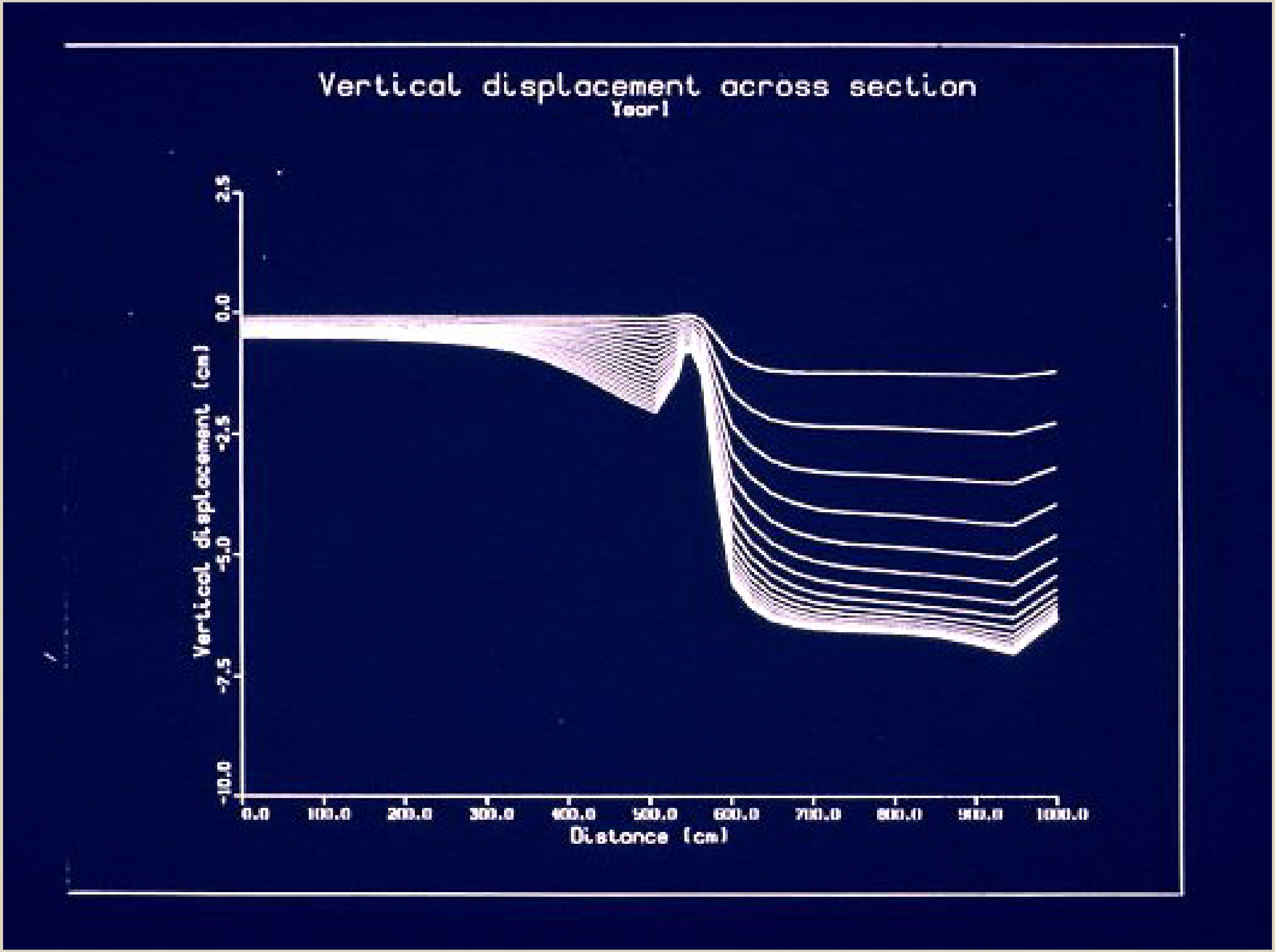

MONITORING
ANALYSIS OF CROSS SECTION
Ponding
Maximum Movement
Grass
Evapo-Trans.
Wheel Paths
Barriers
Barriers
Roots
EB Lanes
Median
WB Lanes

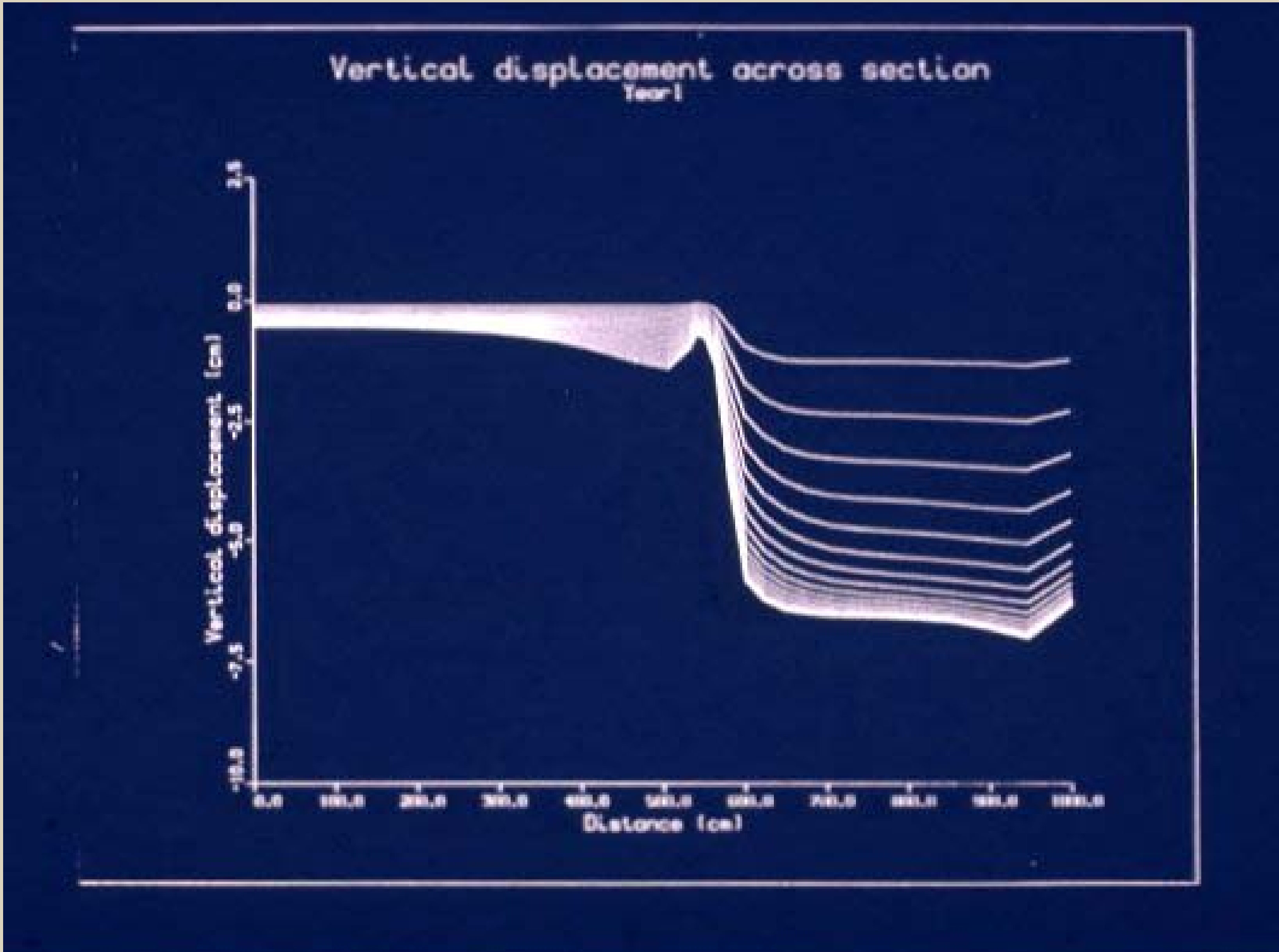

IH-30 Bump Height vs Distance
Eastbound Test
Max. Expected Bump Height (inches)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
Soil depth (ft.)
25
20
15
10
5
0
-5
-10
0
200
400
600
800
1000
1200
Distance (feet)
non-plastic fill
highly plastic clay
box culvert
8/87
7/88
10/89
4/90
11/90

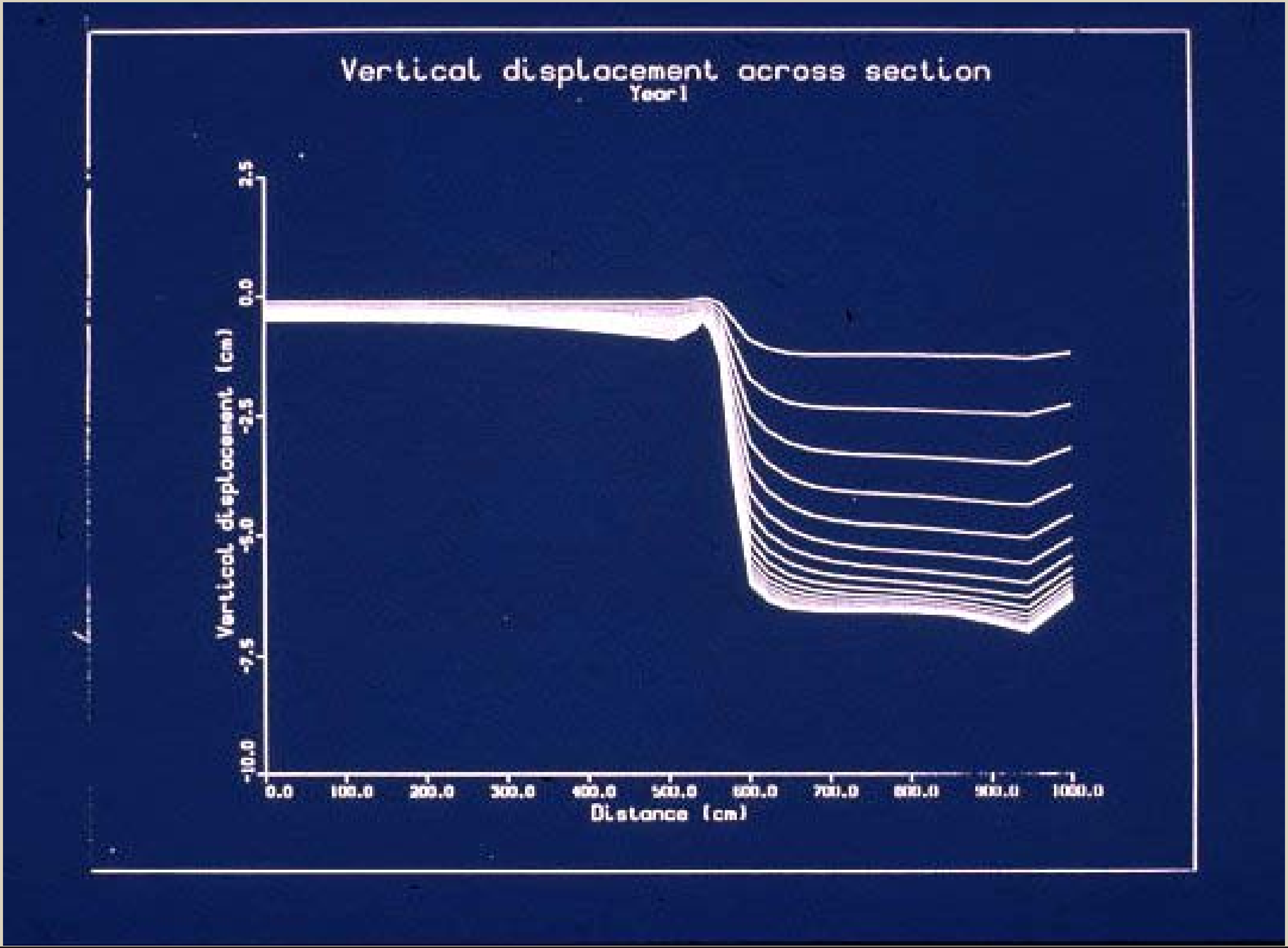

IRI cross-section
IH-30 Greenville 6 Ft. Fabric
IRI (inches/mile)
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
eastbound test
westbound control
median
ditch
moisture barriers
fissured plastic clay
OR
OL
IR
IL
Median
IL
IR
OL
OR
Wheel path
8/87
6/88
10/89
4/90
11/90

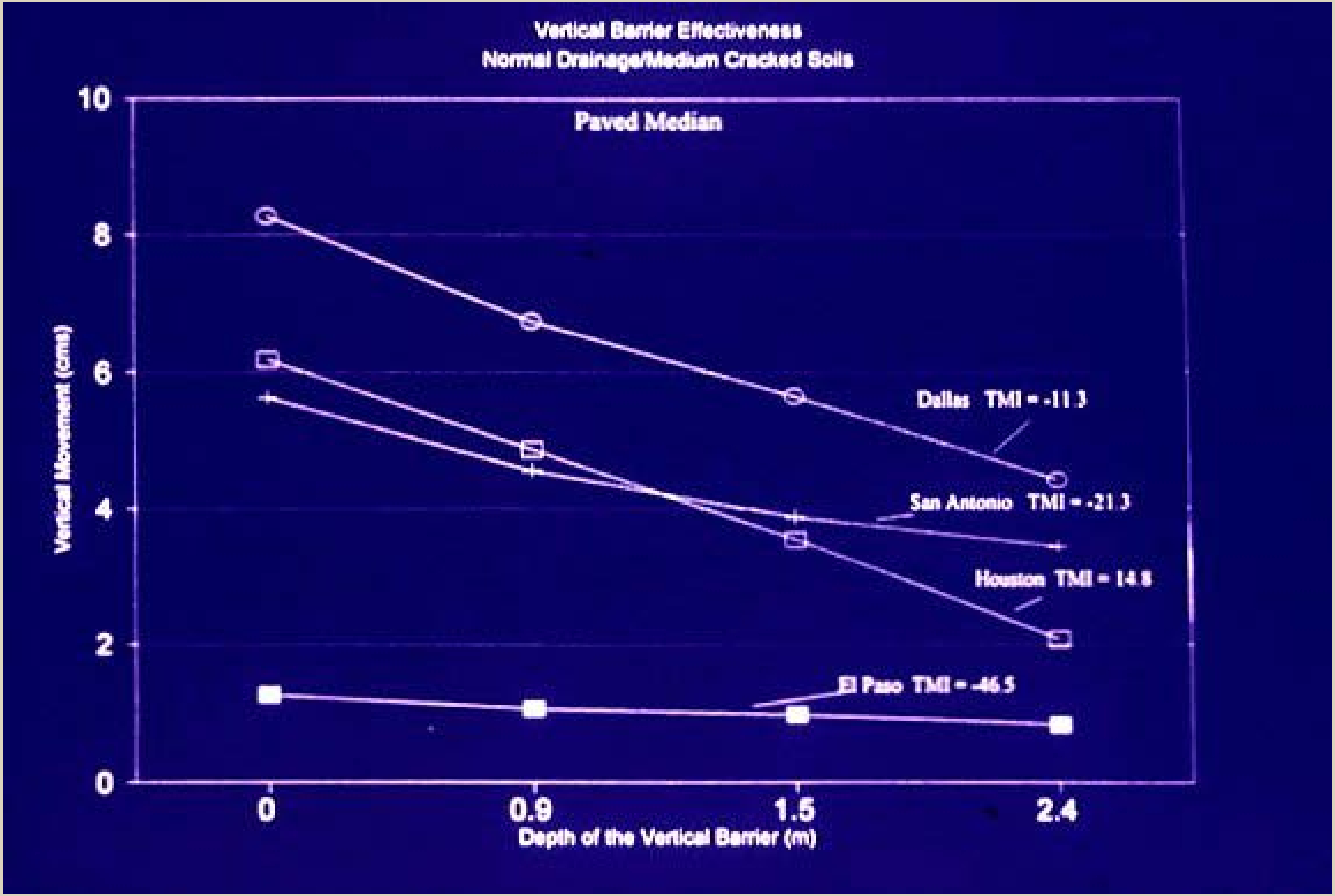

Vertical displacement across section
Year 1
Vertical displacement (cm)
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Distance (cm)
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
1000.0

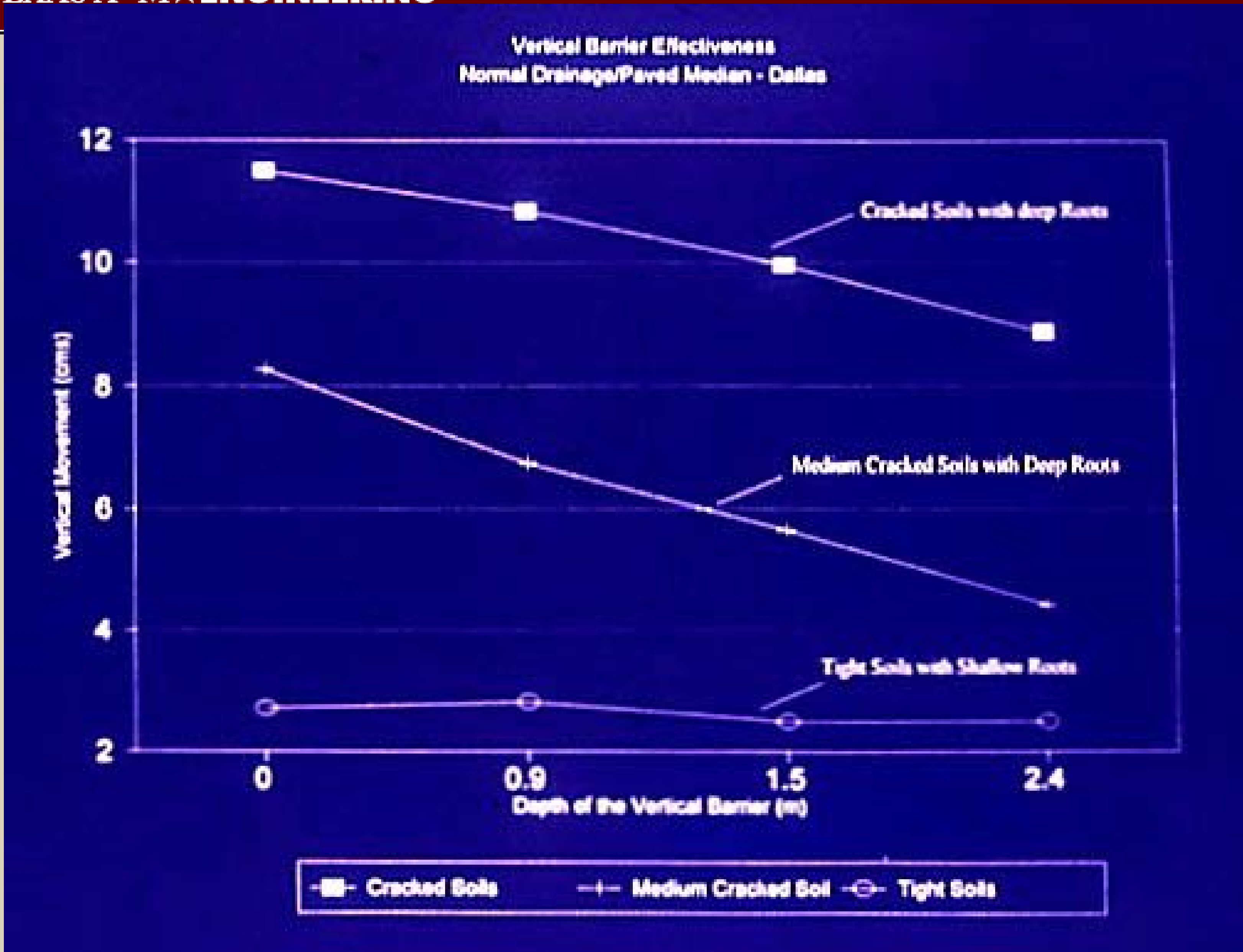

Vertical displacement across section
Vertical displacement (cm)
Distance (cm)

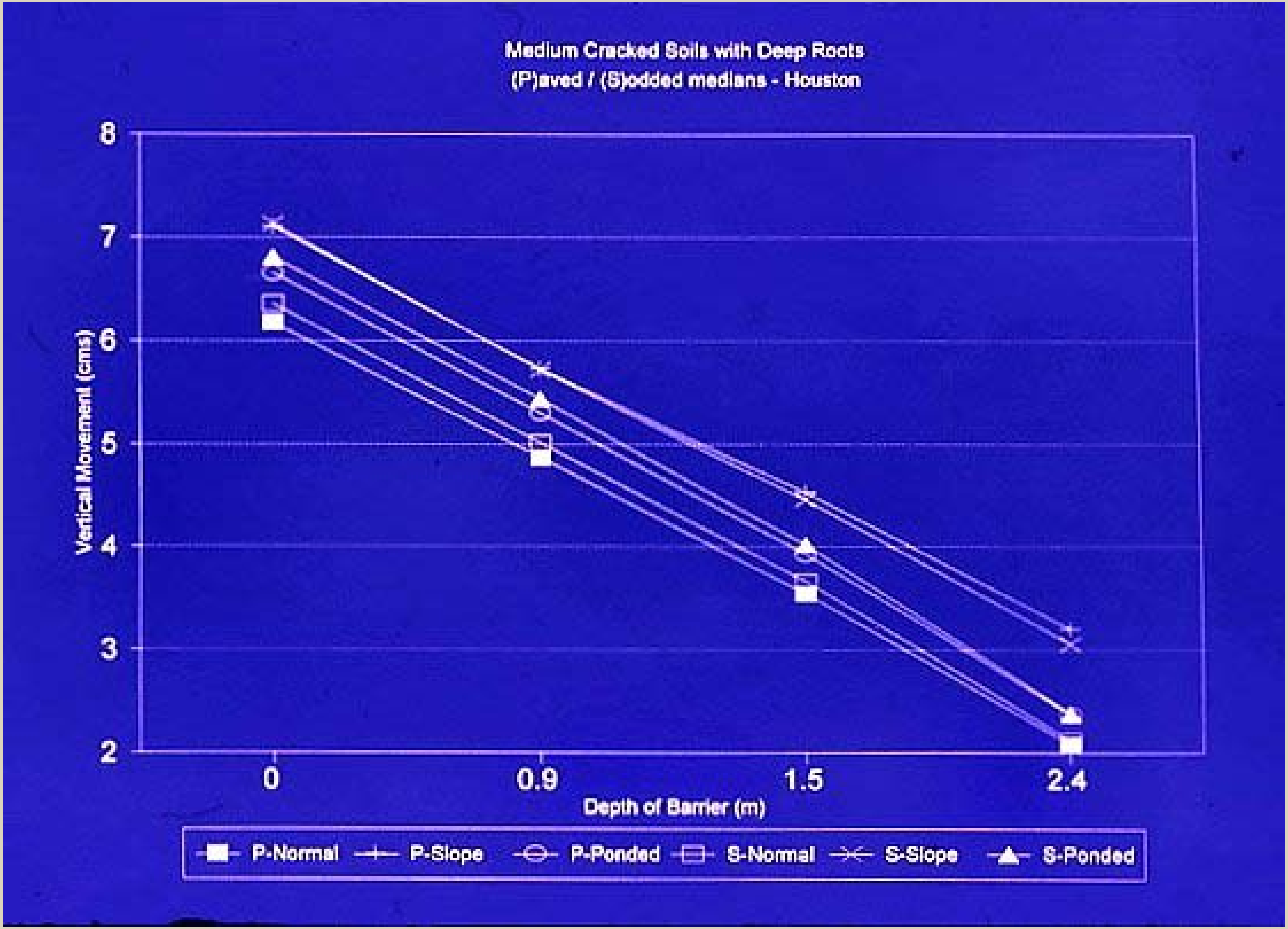

Vertical displacement across section
Year 1
Vertical displacement (cm)
2.5
0.0
-2.5
-5.0
-7.5
-10.0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
1000.0
Distance (cm)

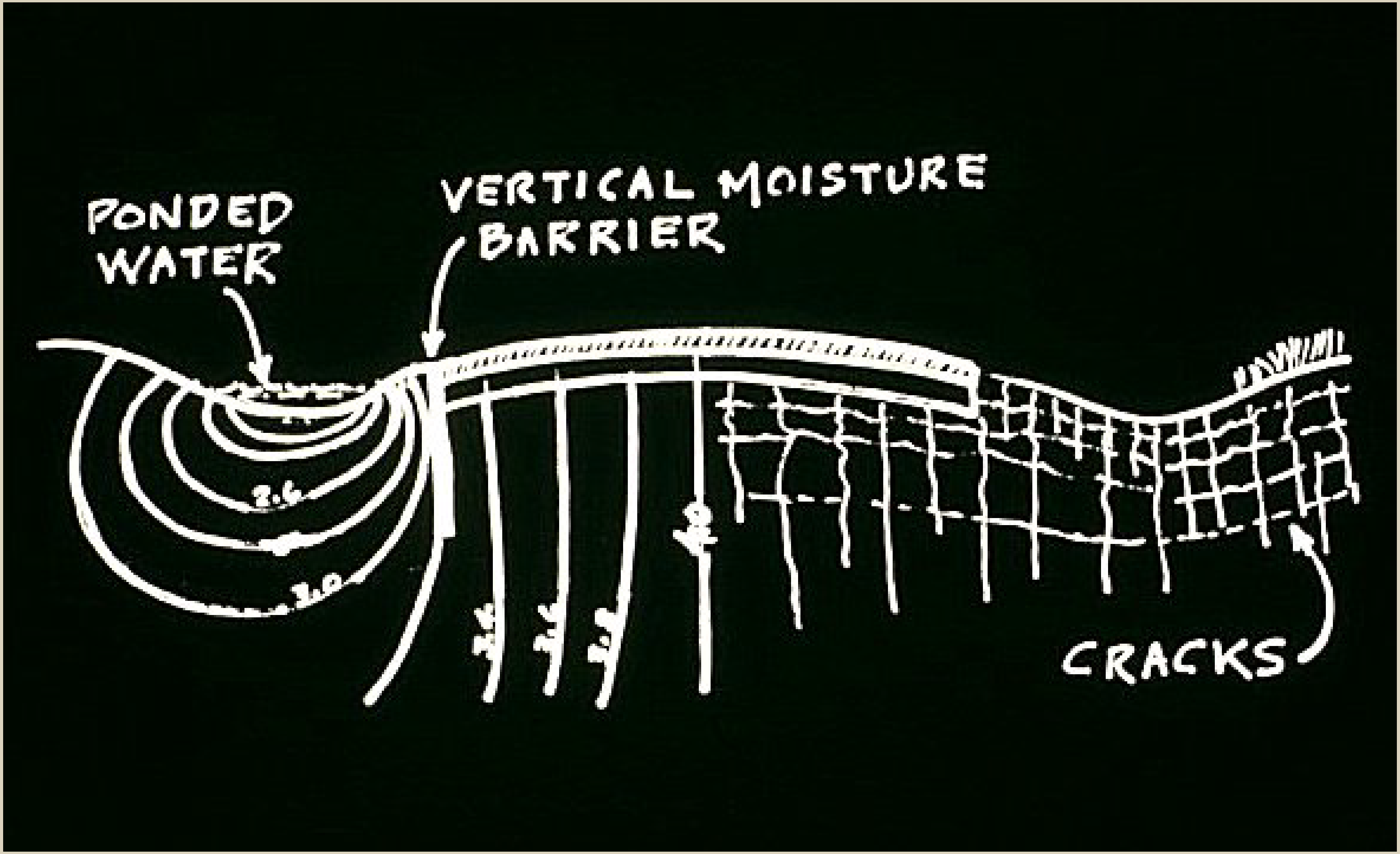

Vertical displacement across section
Vertical displacement (cm)
Distance (cm)
2.5
0.0
-2.5
-5.0
-7.5
-10.0

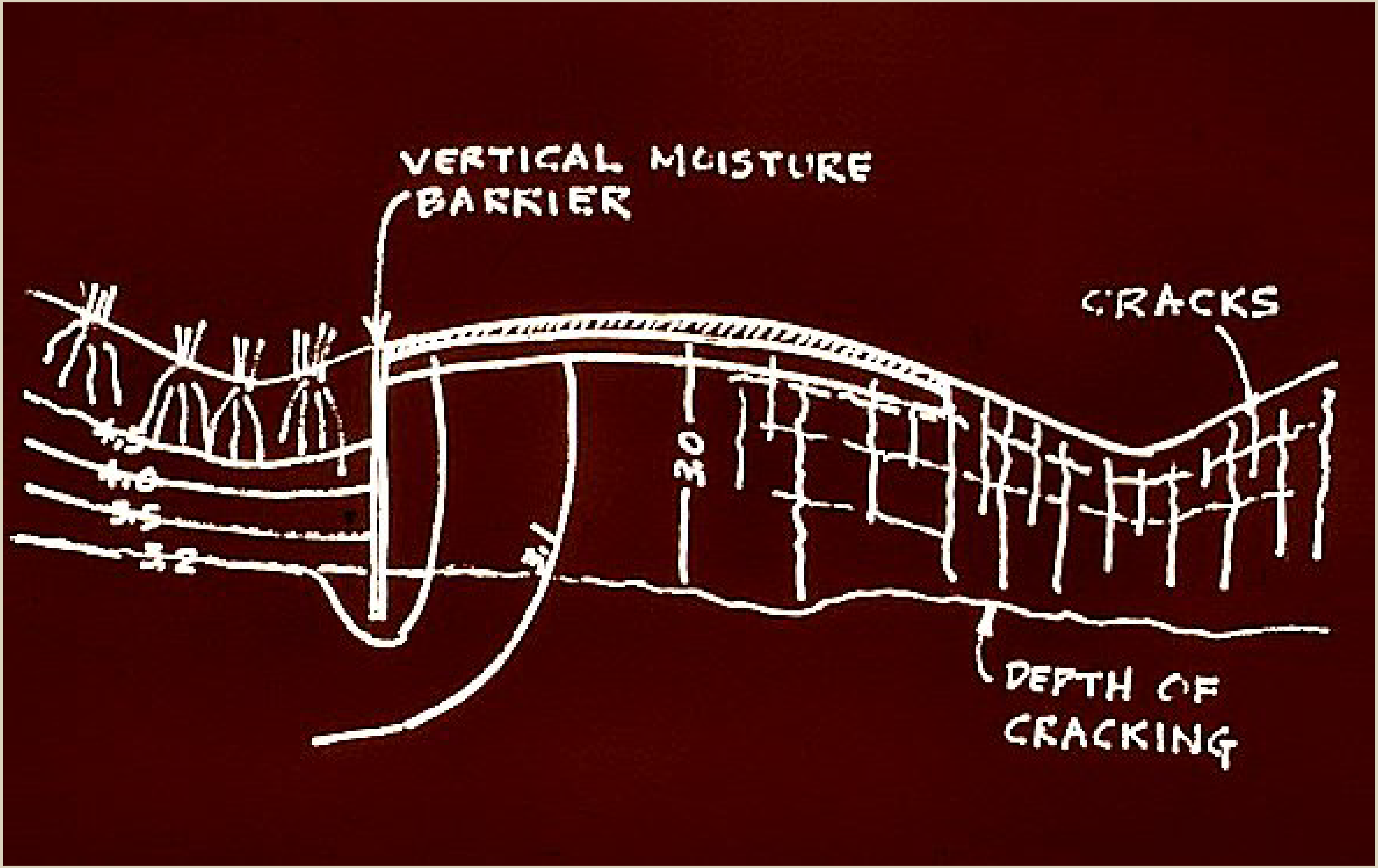

Vertical displacement across section
Year 1
Vertical displacement (cm)
2.5
0.0
-2.5
-5.0
-7.5
-10.0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
1000.0
Distance (cm)


Vertical Barrier Effectiveness
Normal Drainage/Medium Cracked Soils
Paved Median
Vertical Movement (cms)
Depth of the Vertical Barrier (m)
0
2
4
6
8
10
0
0.9
1.5
2.4
Dallas TMI = -11.3
San Antonio TMI = -21.3
Houston TMI = 14.8
El Paso TMI = -46.5


Vertical Barrier Effectiveness
Normal Drainage/Paved Median - Dallas
Vertical Movement (cms)
12
10
8
6
4
2
0
0.9
1.5
2.4
Depth of the Vertical Barrier (m)
Cracked Soils with deep Roots
Medium Cracked Soils with Deep Roots
Tight Soils with Shallow Roots
Cracked Soils
Medium Cracked Soil
Tight Soils

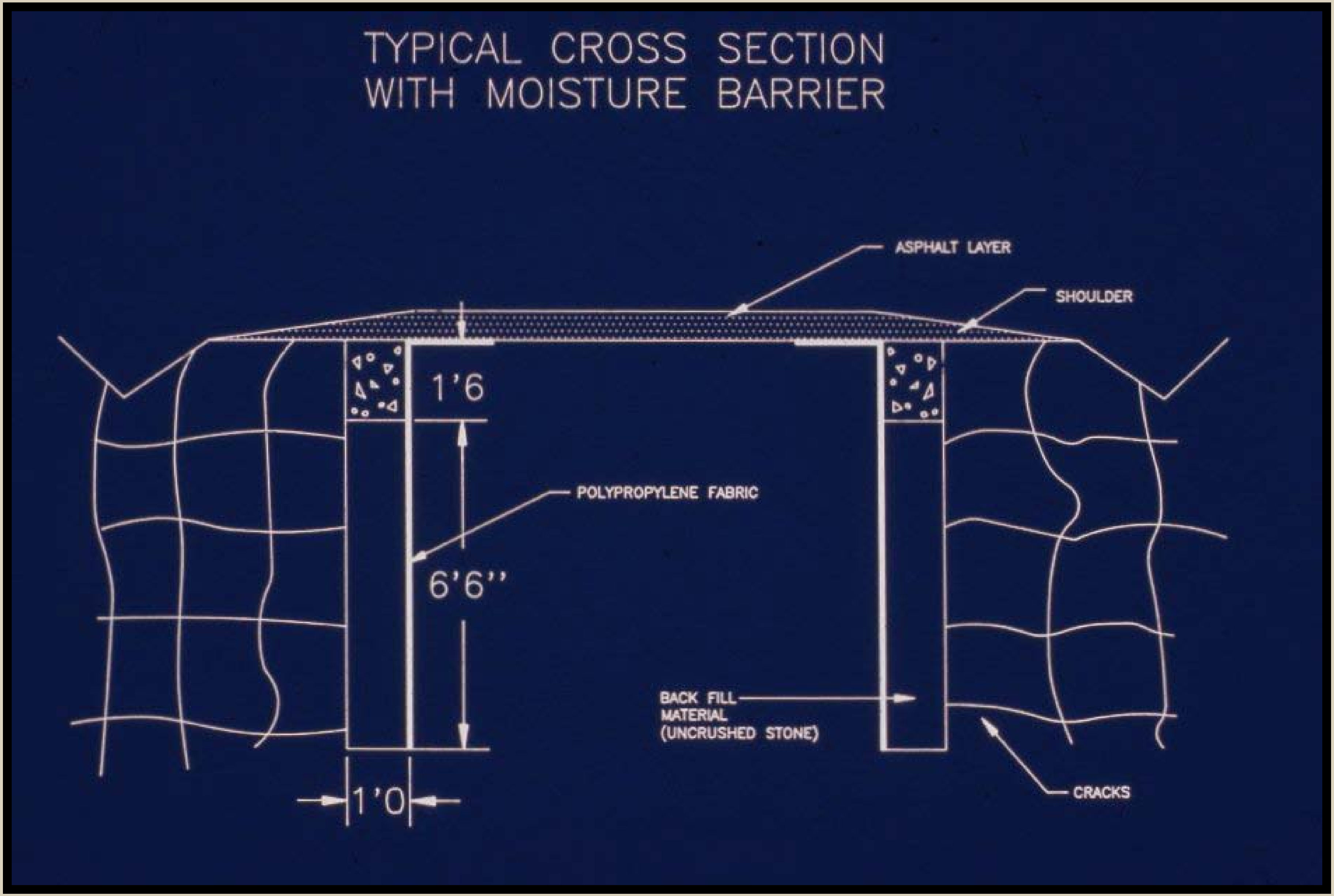

Medium Cracked Soils with Deep Roots
(P)aved / (S)odded medians - Houston
Vertical Movement (cms)
8
7
6
5
4
3
2
0
0.9
1.5
2.4
Depth of Barrier (m)
P-Normal
P-Slope
P-Ponded
S-Normal
S-Slope
S-Ponded


PONDED WATER
VERTICAL MOISTURE BARRIER
CRACKS
2.6
3.0


VERTICAL MOISTURE BARRIER
CRACKS
DEPTH OF CRACKING
3.0

Guardrail between pavement lanes
on expansive clay subgrade
IH37, San Antonio, Texas (c. 1974)


CEM. STAB. BACKFILL
GRAVEL BACKFILL
VERTICAL MOISTURE SEAL
PROPOSED
TYPICAL MAINLANE PAVEMENT SECTION


TYPICAL CROSS SECTION
WITH MOISTURE BARRIER
ASPHALT LAYER
SHOULDER
1'6
POLYPROPYLENE FABRIC
6'6''
BACK FILL
MATERIAL
(UNCRUSHED STONE)
CRACKS
1'0

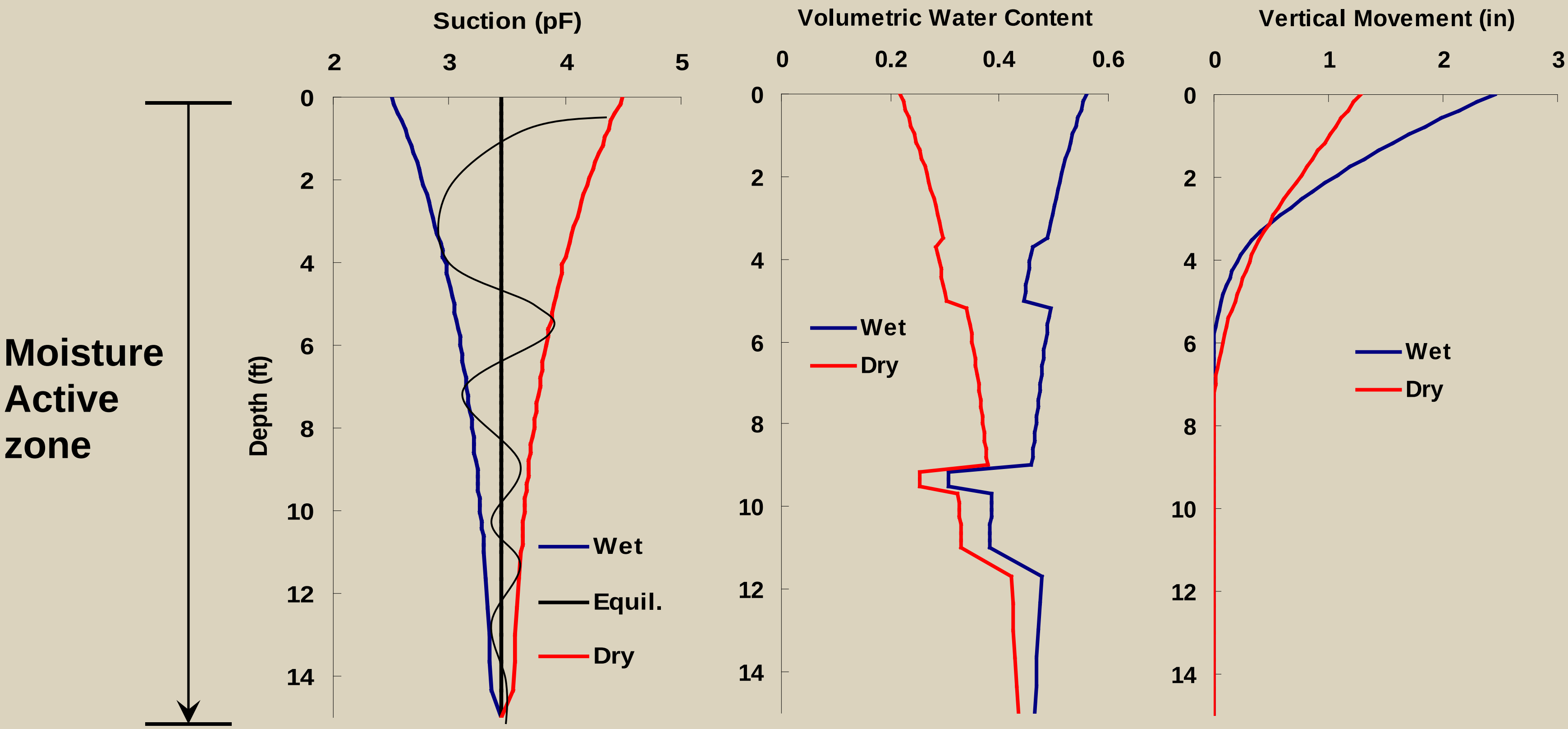
Exponential Suction Profile for Extreme Wetting and Drying Condition

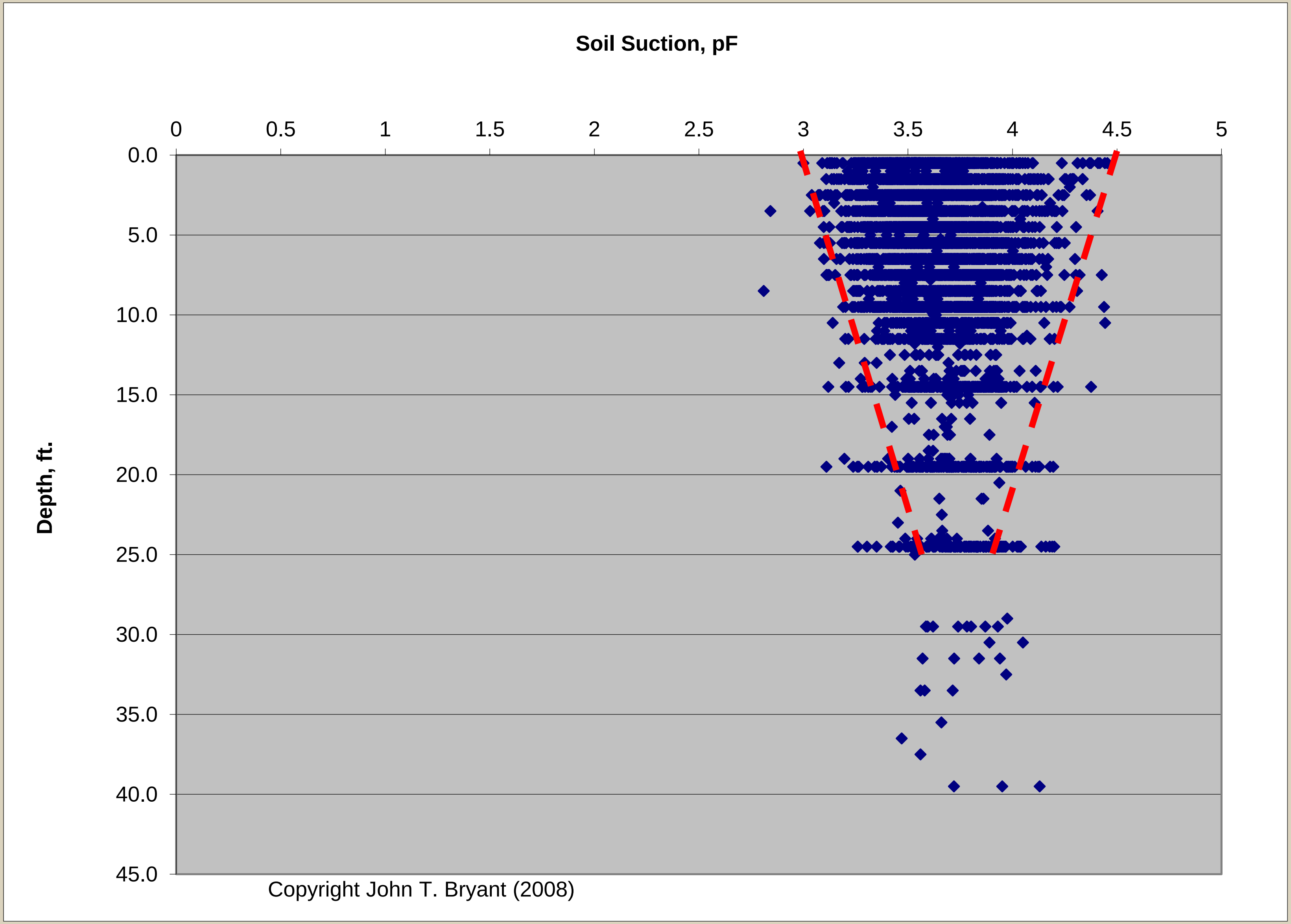
$$U(Z,t) = U_e + U_o \exp\left(-\sqrt{\frac{n\pi}{\alpha}} Z\right) \cos\left(2\pi n t - \sqrt{\frac{n\pi}{\alpha}} Z\right)$$

Mitchell (1979)

$$U(Z) = U_e + U_o \exp\left(-\sqrt{\frac{n\pi}{\alpha}} Z\right)$$

Fort Worth Interstate 820




Soil Suction, pF
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Depth, ft.
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0

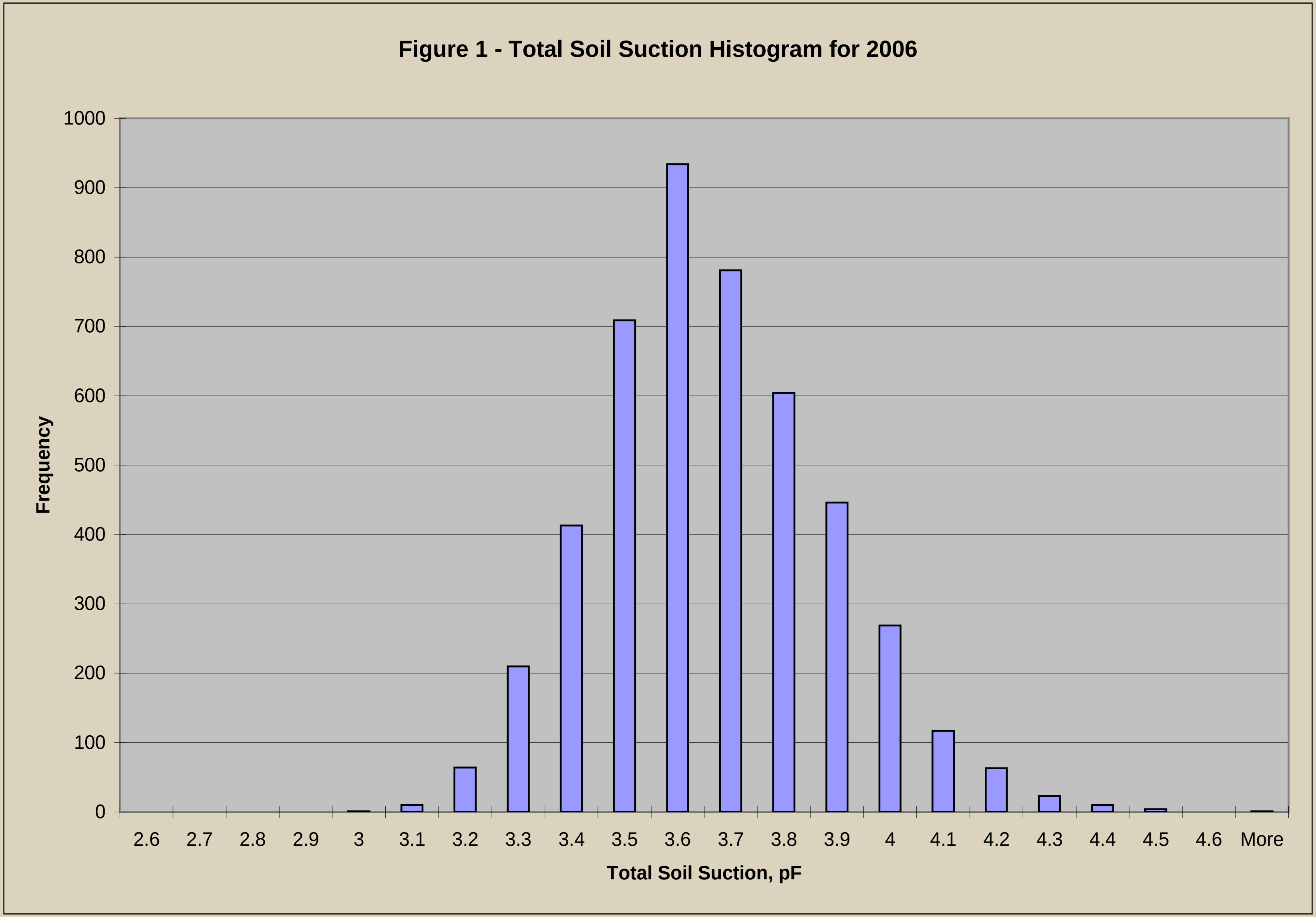
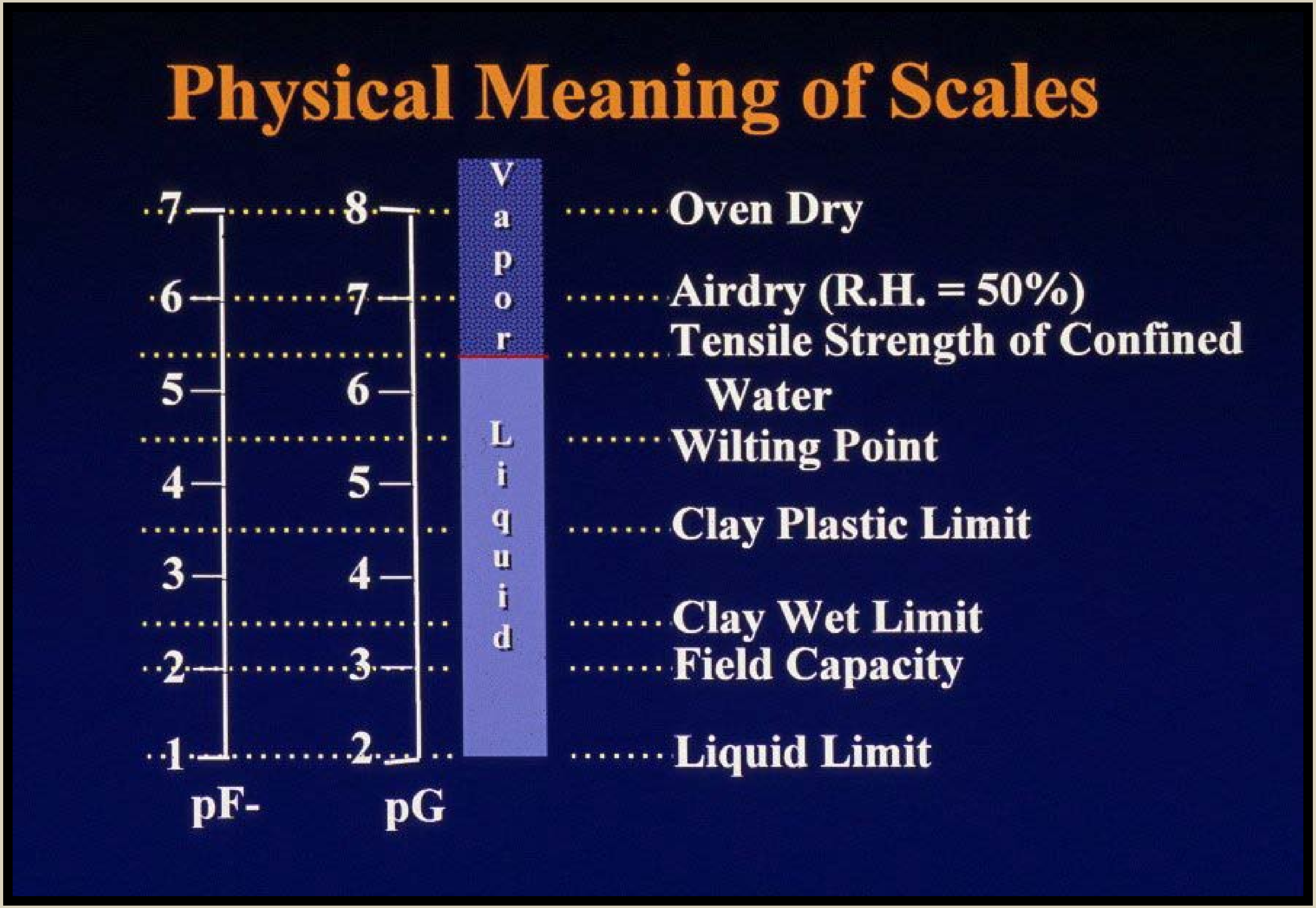


Figure 1 - Total Soil Suction Histogram for 2006
Frequency
1000
900
800
700
600
500
400
300
200
100
0
2.6
2.7
2.8
2.9
3
3.1
3.2
3.3
3.4
3.5
3.6
3.7
3.8
3.9
4
4.1
4.2
4.3
4.4
4.5
4.6
More
Total Soil Suction, pF


Physical Meaning of Scales
7
6
5
4
3
2
1
pF-
8
7
6
5
4
3
2
pG
Vapor
Liquid
Oven Dry
Airdry (R.H. = 50%)
Tensile Strength of Confined Water
Wilting Point
Clay Plastic Limit
Clay Wet Limit
Field Capacity
Liquid Limit

Performance Criteria for Engineering Structures

Engineering Structure	Performance Criteria
Foundations	• Differential movement: vertical and lateral and allowable stresses • Differential movement and allowable stresses • Total vertical and lateral movement; lateral pressure; allowable stresses
Pavements	• Roughness spectrum, International Roughness Index, Longitudinal cracking • Roughness spectrum, Pilot and Passenger acceleration
Retaining Walls	• Lateral pressure and movement, allowable stresses

Performance Criteria for Engineering Structures, cont.

Engineering Structure	Performance Criteria
Pipelines	• Roughness spectrum, allowable stress, fatigue criteria, corrosion
Slopes	• Downhill movement, shallow slope failure, slope stability
Canals	• Combination of the performance criteria of retaining walls, pipelines, and slopes; thermal and shrinkage cracking; permeability of the cracks and joints
Moisture Barriers	• Reduction of the movement of water in the soil and of total vertical movement
Land Fill Covers and Liners	• Moisture and leachate transmission (including the effects of cracks)

The Design Problem

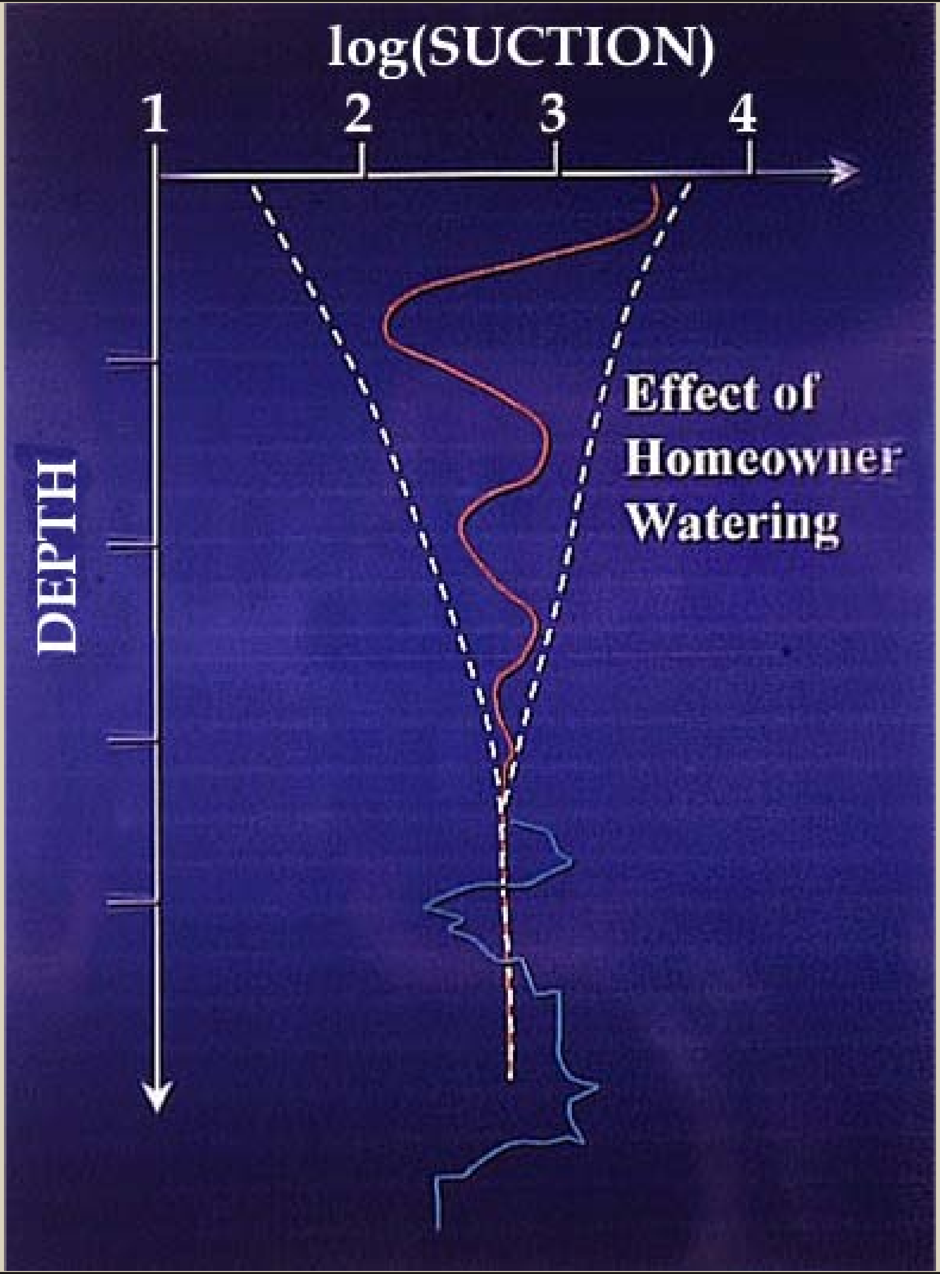
How do you design a foundation to perform successfully when you have poor site conditions?

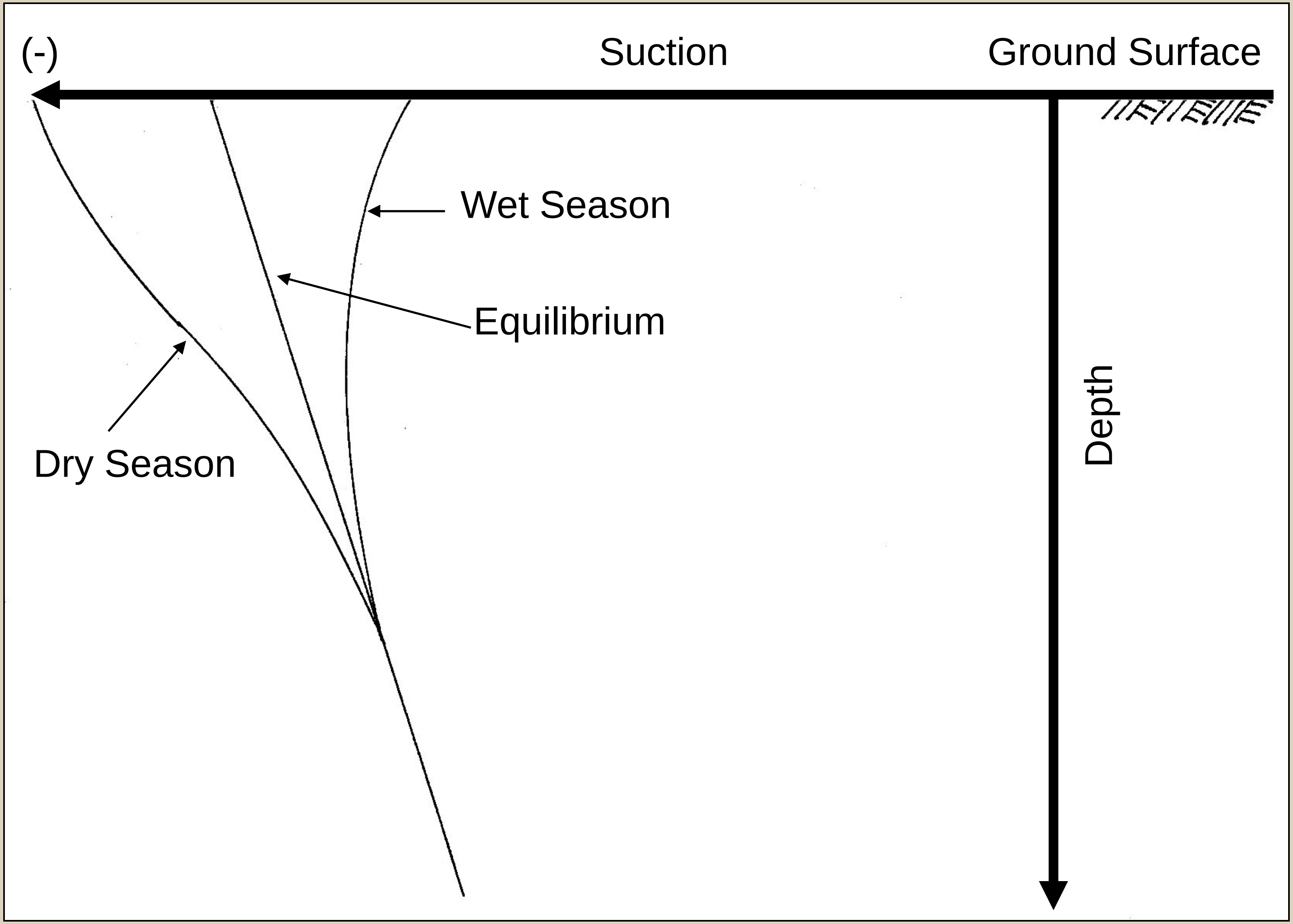
- Vegetation
- Drainage
- Slopes

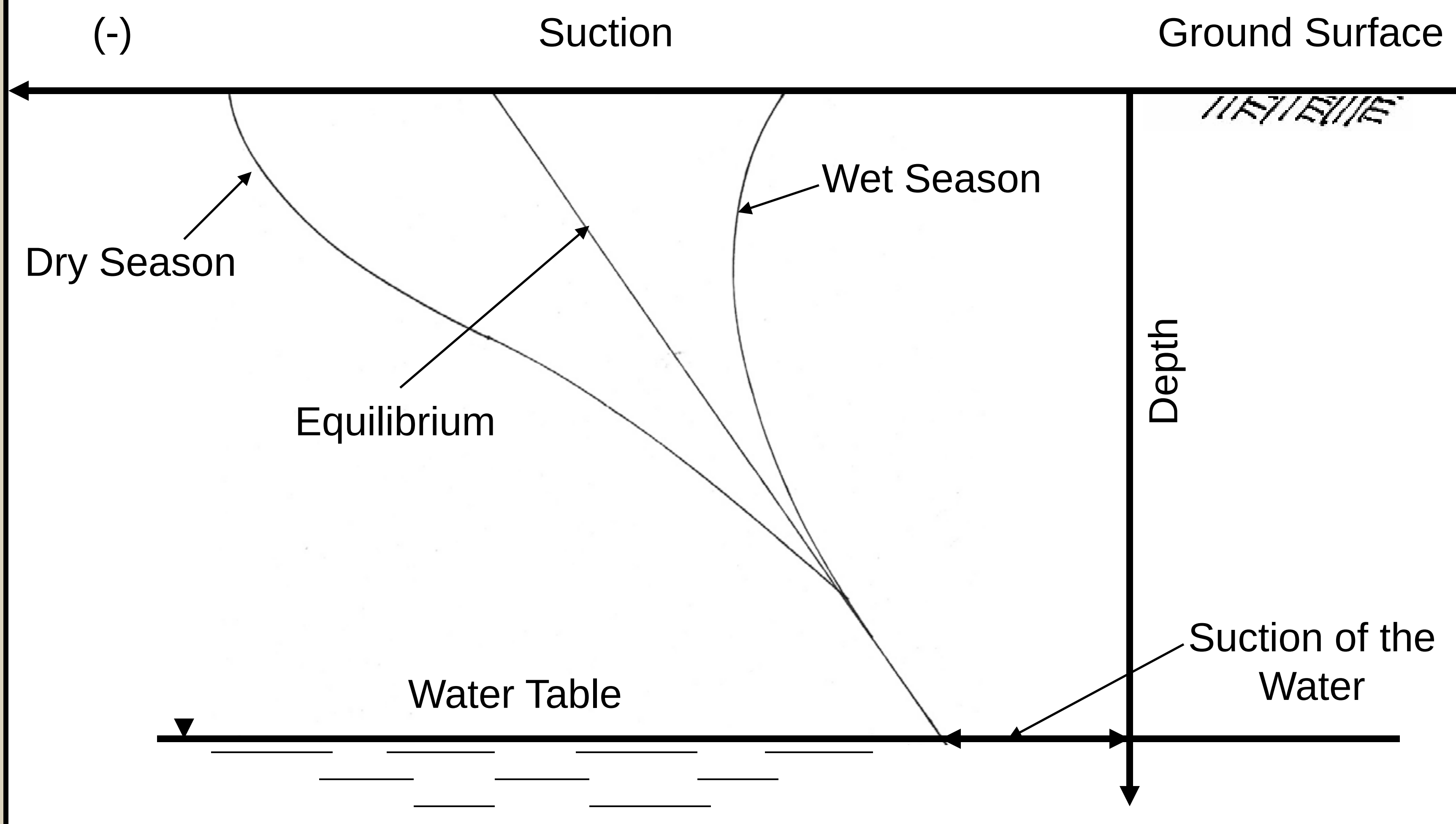
Answer: Design for the worst that they can do

Site condition	Problem	Limiting Condition
Vegetation	Drying shrinkage	Wilting point pF=4.5
Poor drainage	Swelling	Clay wet limit pF>2.5
Slopes	Downhill creep, shallow slides	Uphill offsets, drainage control

Answer: use suction envelopes to determine the worst that they can do

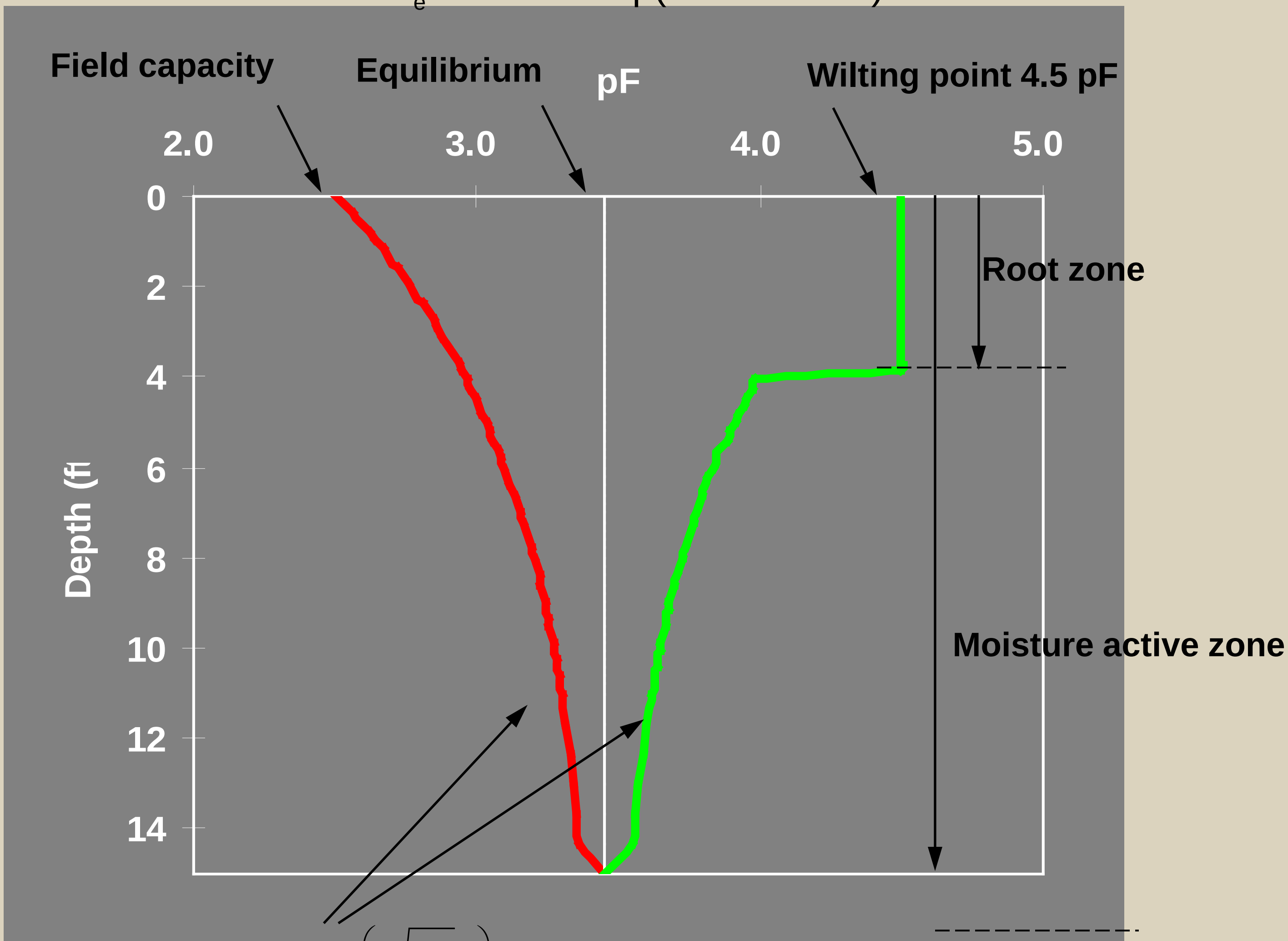

log(SUCTION)
1
2
3
4
DEPTH
Effect of
Homeowner
Watering


(-)
Suction
Ground Surface
Wet Season
Equilibrium
Dry Season
Depth

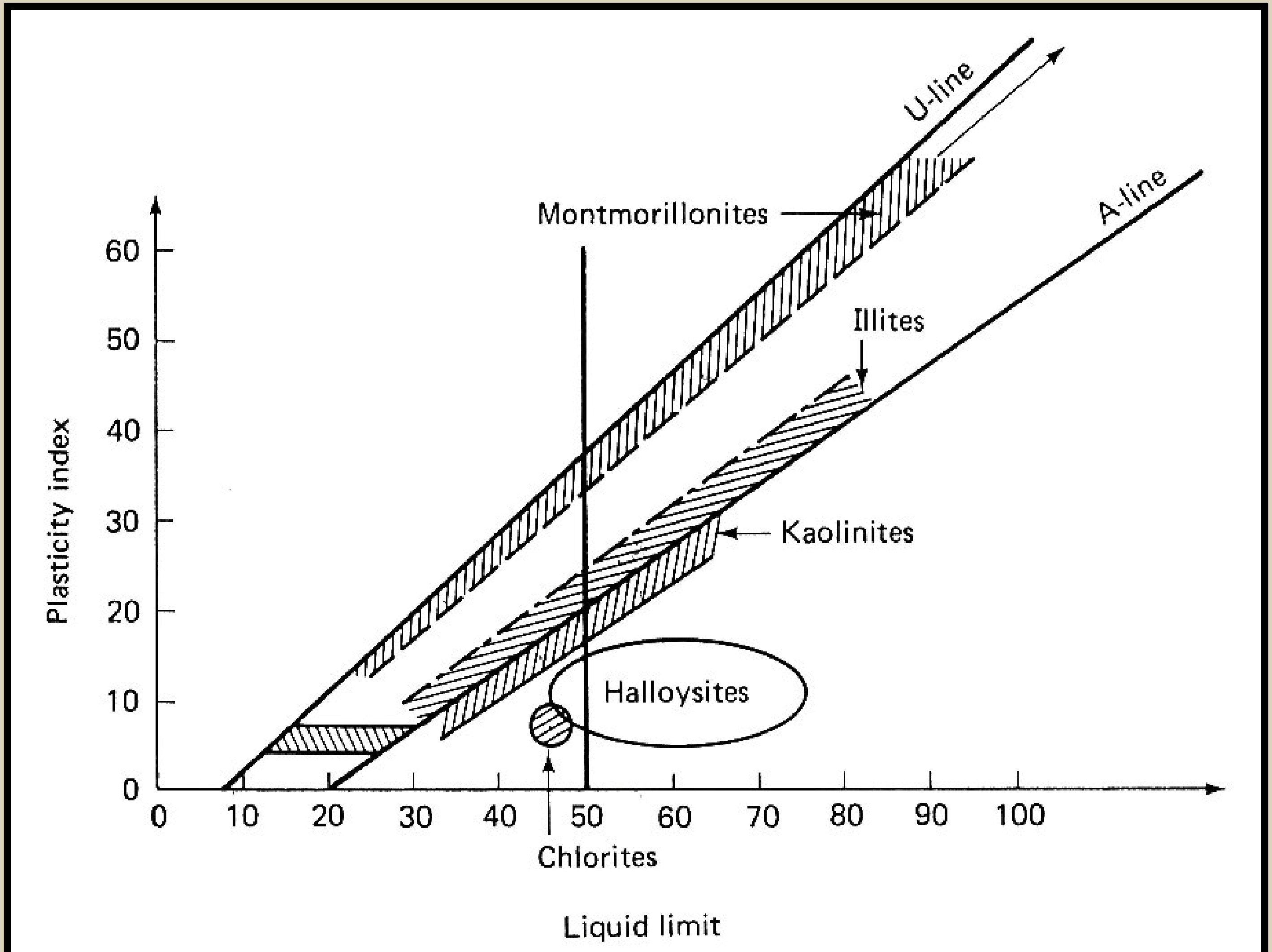

(-)
Suction
Ground Surface
Wet Season
Dry Season
Depth
Equilibrium
Suction of the Water
Water Table

Field Conditions

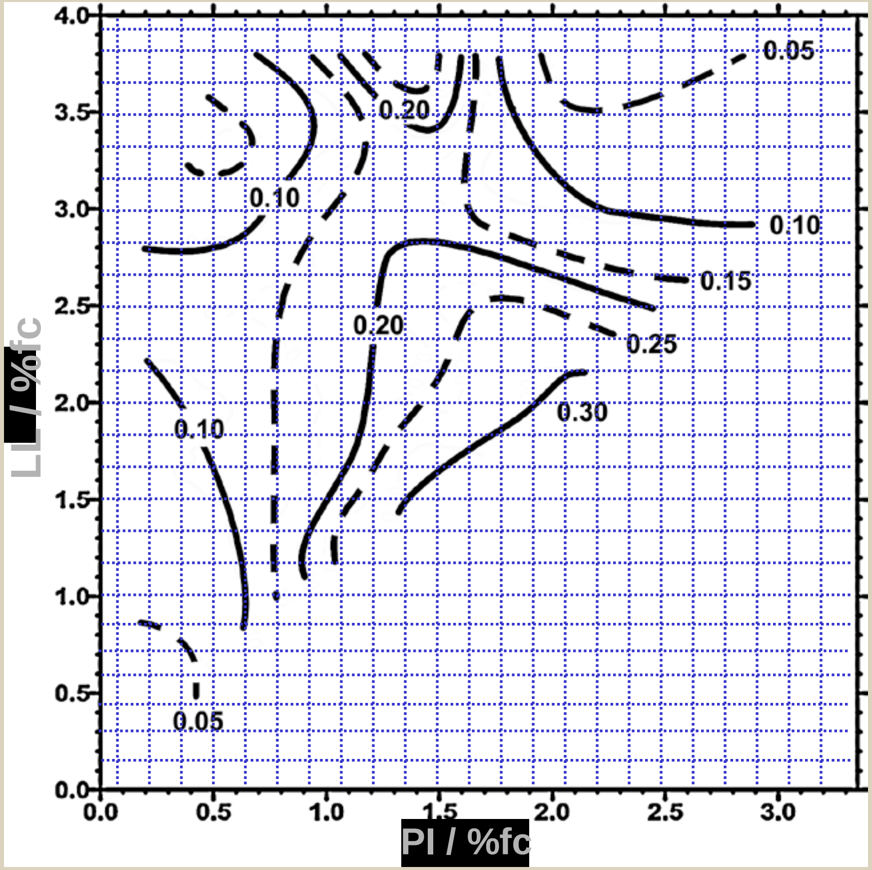
$$U_e = 3.5633\exp(-0.0051\mathrm{TMI})$$



$$U(Z) = U_e \pm U_0 \exp\left(-\sqrt{\frac{n\pi}{\alpha}}Z\right)$$


U-line
A-line
Montmorillonites
Illites
Kaolinites
Halloysites
Chlorites
Plasticity index
Liquid limit
0
10
20
30
40
50
60
70
80
90
100

Volume Change



Zone III (Covar and Lytton, 2001)

$$\%fc = \frac{\% - 2\,\mu m}{\% - No.200\,sieve}$$

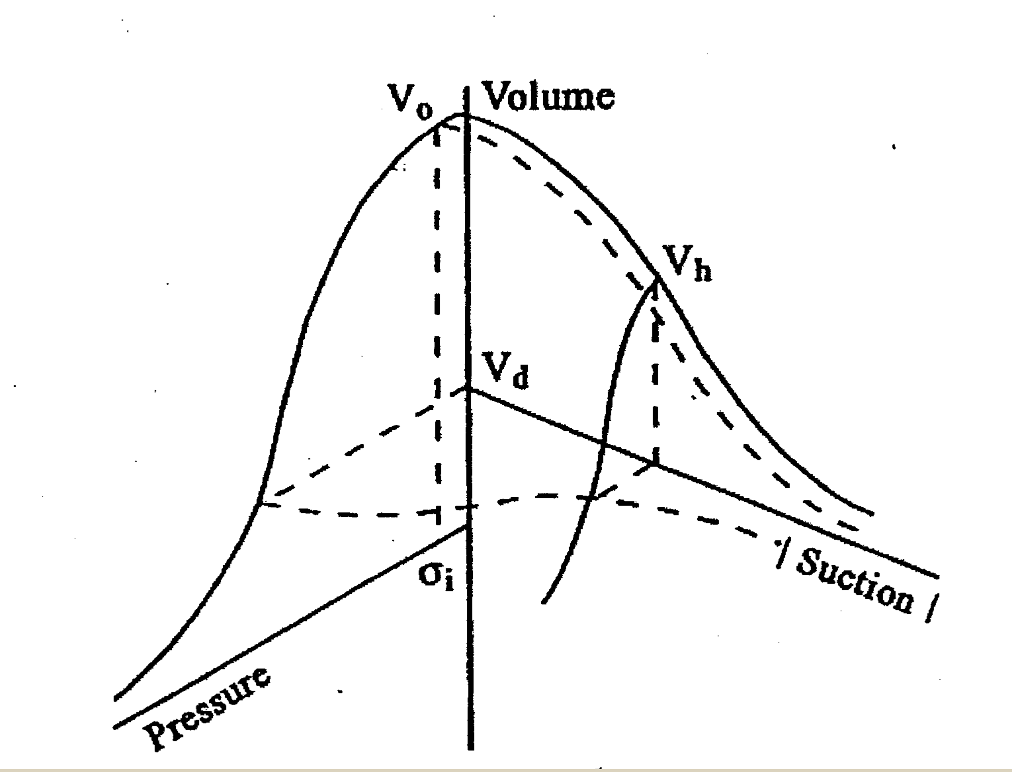
$$\gamma_h = \gamma_0 \times \left[\frac{\% - 2\,\mu m}{\% - No.200\,sieve} \right]$$

$$\gamma_\sigma = \gamma_h \frac{1}{1 + \dfrac{h}{\theta\left(\dfrac{\partial h}{\partial \theta}\right)}}$$

(Lytton, 1994)

Volume Change

$$\frac{\Delta V}{V} = -\gamma_h \log_{10}\left(\frac{h_f}{h_i}\right) - \gamma_\sigma \log_{10}\left(\frac{\sigma_f}{\sigma_i}\right)$$ **(Lytton, 1977)**



$$\frac{\Delta H}{H} = f\left(\frac{\Delta V}{V}\right)$$

$$f = 0.67 - 0.33\Delta pF$$

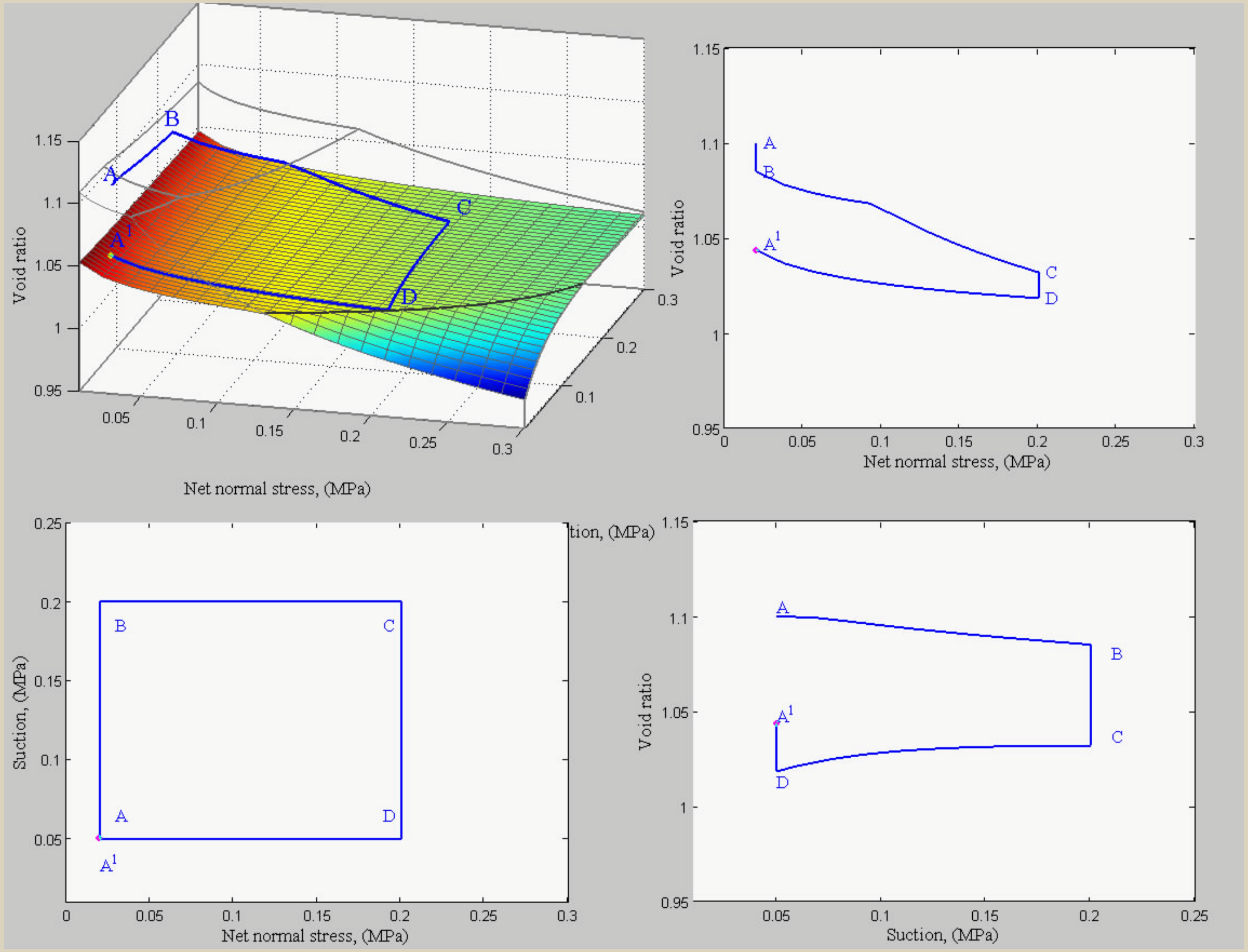
$$\begin{pmatrix} f = 0.5 \text{ when drying}; \\ f = 0.8 \text{ when wetting} \end{pmatrix}$$

$$\Delta = \sum_{i=1}^{n} f_i \left[\frac{\Delta V}{V}\right]_i \cdot \Delta Z_i$$

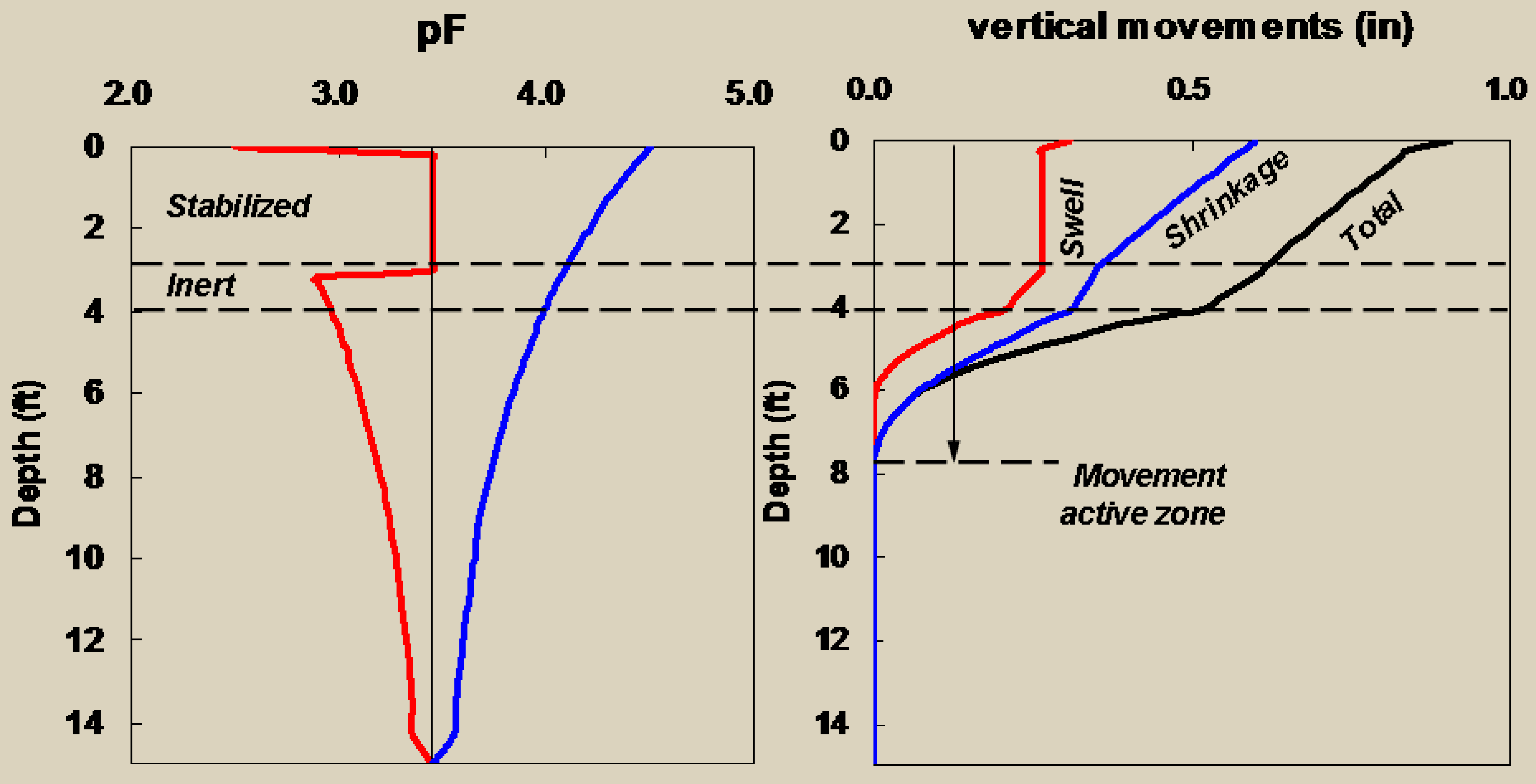
Volume–Mean Principle Stress-Suction surface

Suction vs. Pressure vs. Volume Surface

Formation of Suction vs. Pressure vs. Volume Surface

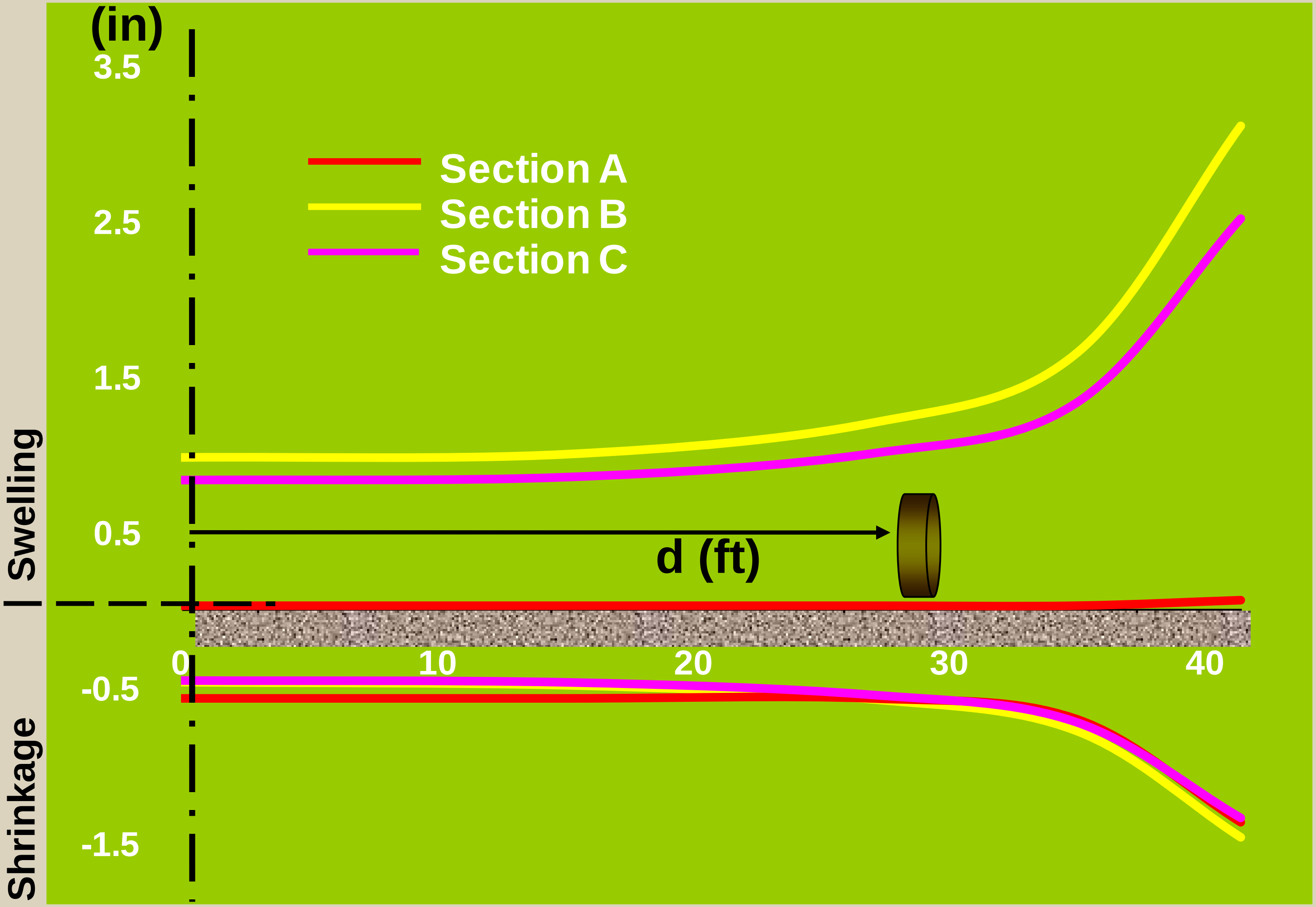


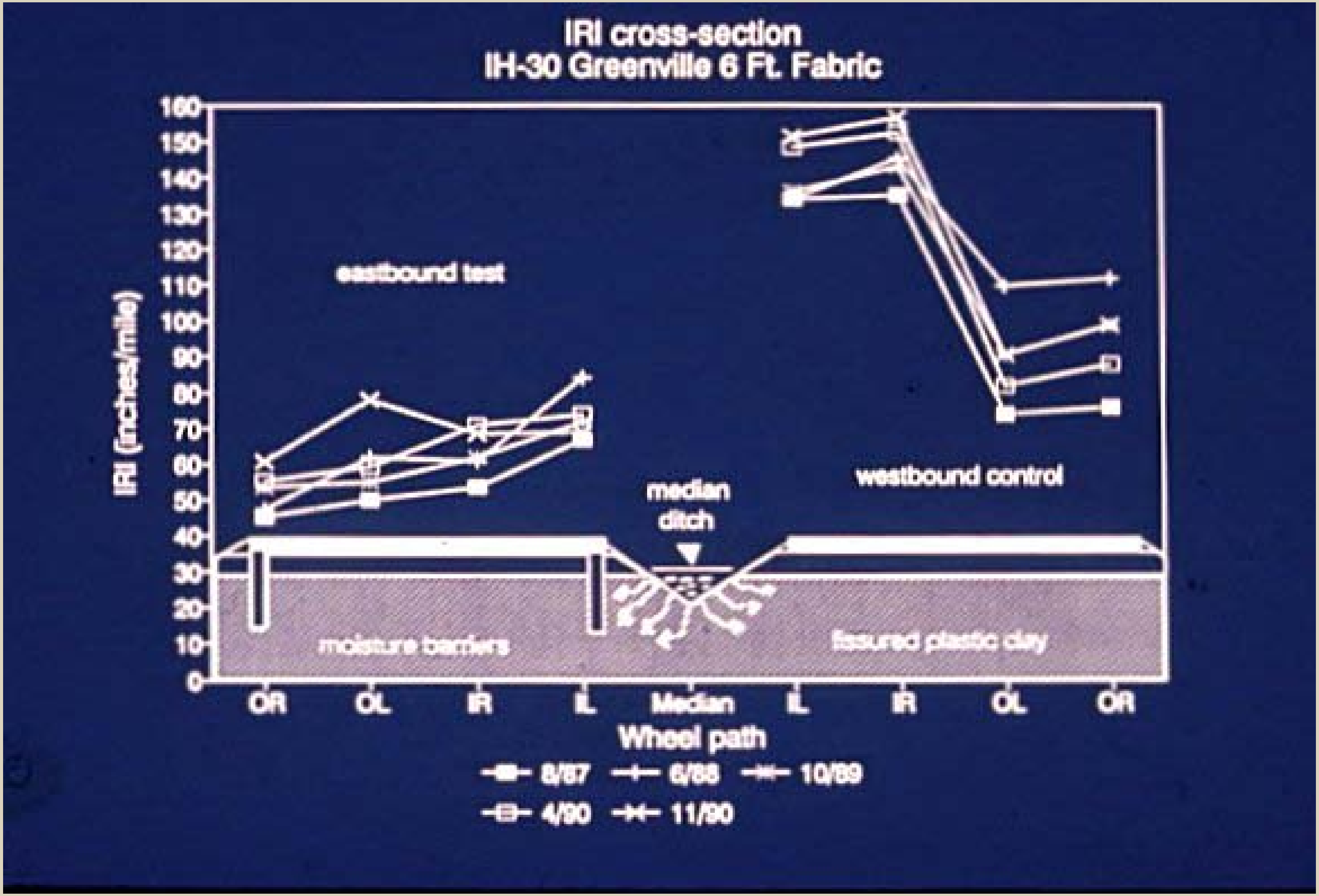
Calculated Vertical Movement



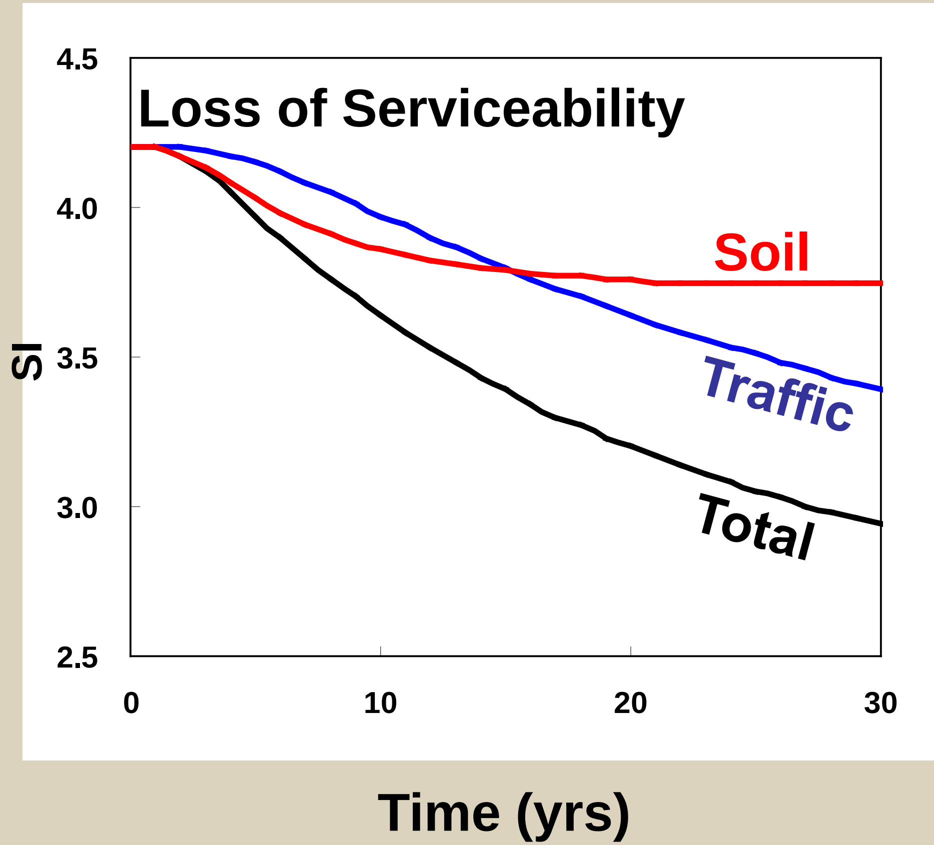
Fort Worth Interstate 820 B

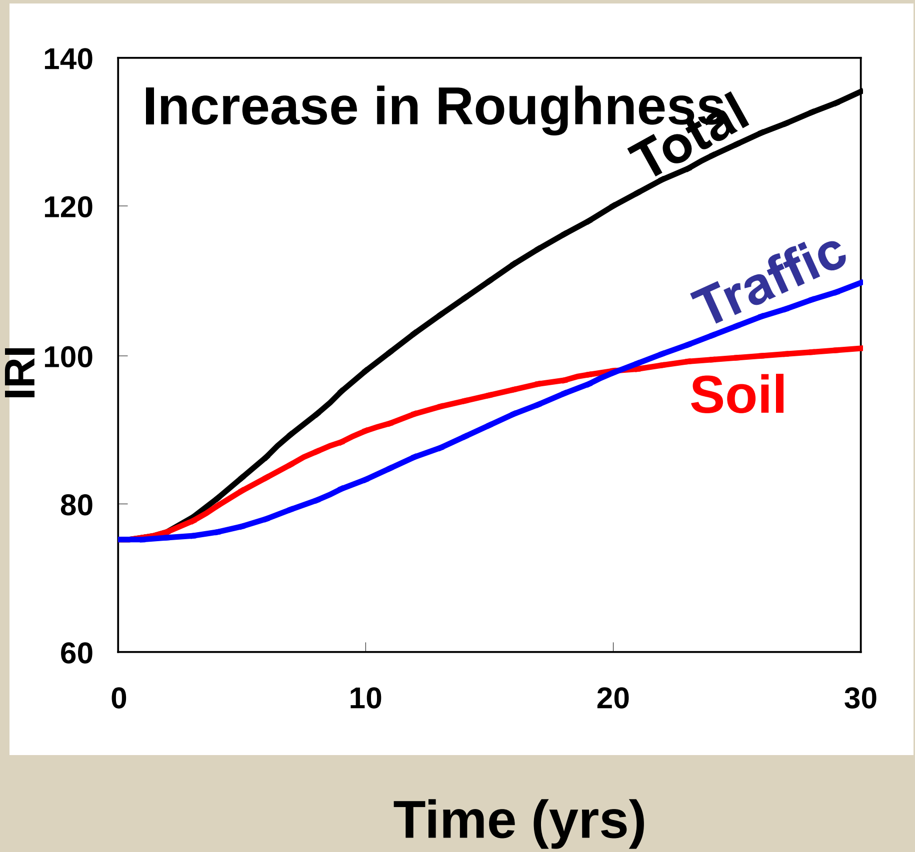
Transverse Distribution of Vertical Movements




IRI cross-section
IH-30 Greenville 6 Ft. Fabric
IRI (inches/mile)
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
eastbound test
westbound control
median
ditch
moisture barriers
fissured plastic clay
OR
OL
IR
IL
Median
IL
IR
OL
OR
Wheel path
8/87
6/88
10/89
4/90
11/90

Predicted Roughness vs. Time; Fort Worth I-820 B





Predicting Changes in IRI (R)

$$\frac{dR}{dt} = \beta_1(\Delta H) + \beta_2$$

- Pavement categories:
  - Moisture barriers with paved medians

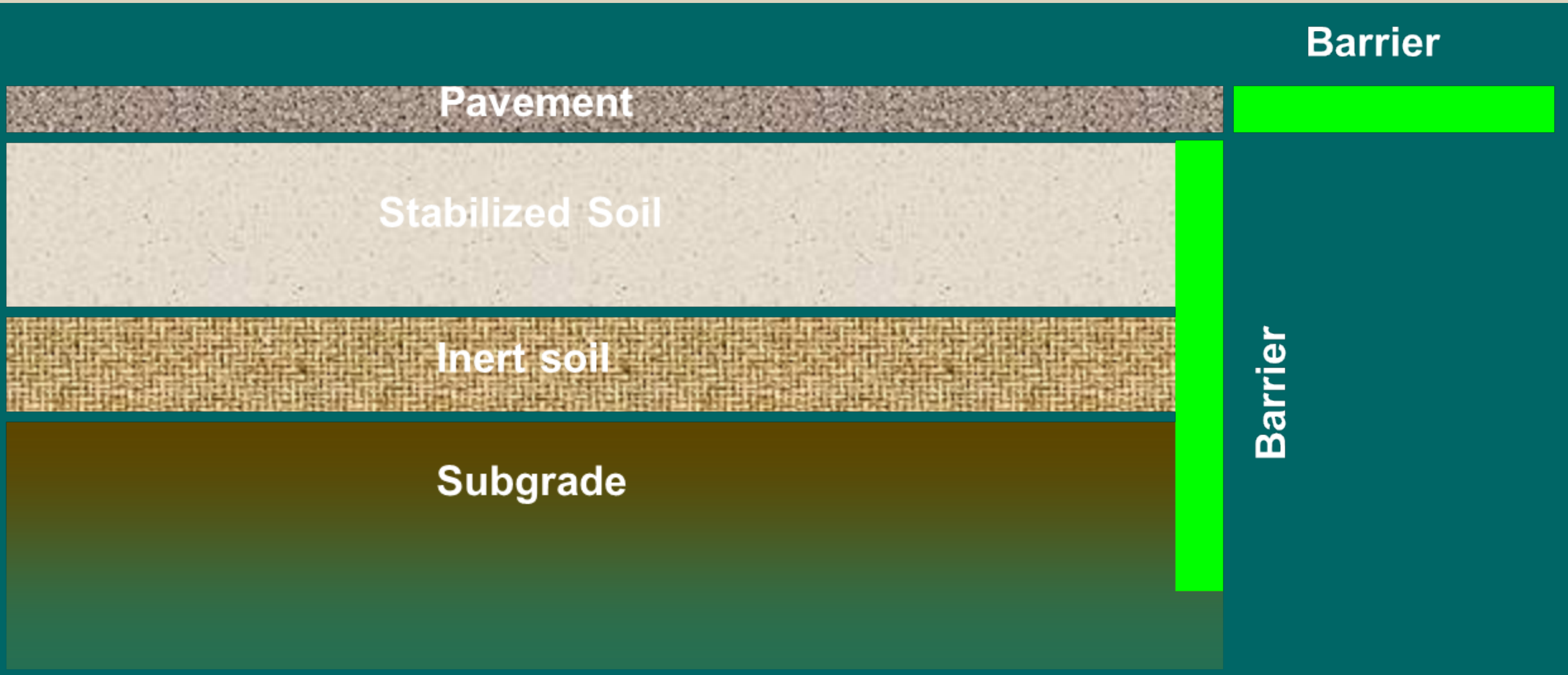
    $\beta_1 = 0.619$, $\beta_2 = 1.295$
  - Moisture barriers with sodded medians

    $\beta_1 = 1.583$, $\beta_2 = 2.011$
  - Control section with and without medians

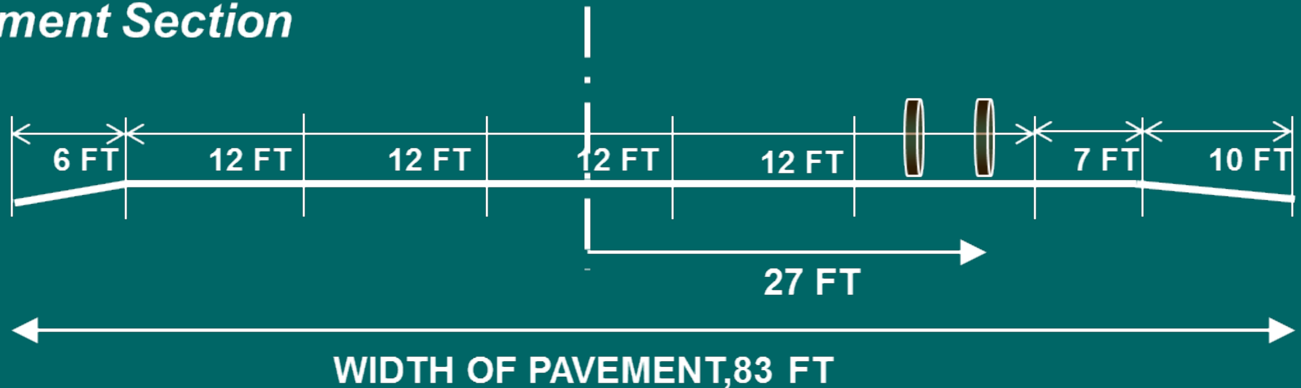
    $\beta_1 = 2.701$, $\beta_2 = 4.015$

IRI vs. PSI

International Roughness Index		Serviceability Index
(m/km)	(in/mile)	
0.95	60	4.68
1.03	65	4.51
1.10	70	4.35
1.18	75	4.21
1.26	80	4.07
1.34	85	3.94
1.42	90	3.82
1.50	95	3.70
1.58	100	3.59
1.66	105	3.48
1.74	110	3.39
1.82	115	3.29
1.89	120	3.20
1.97	125	3.11
2.05	130	3.03
2.13	135	2.95
2.21	140	2.87
2.29	145	2.79
2.37	150	2.72
2.45	155	2.65

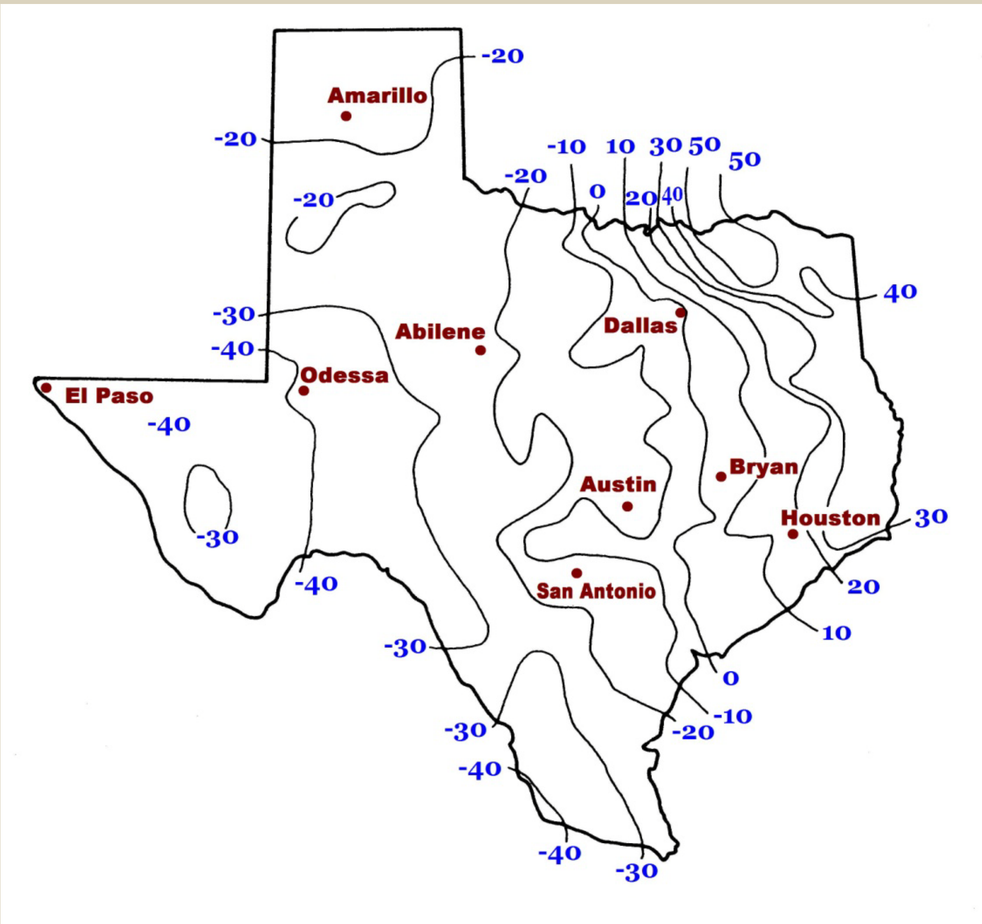


Pavement Section



Climatic Conditions

Thornthwaite Moisture Index (TMI, 1948)



$$TMI = \frac{100R - 60DEF}{E_p}$$

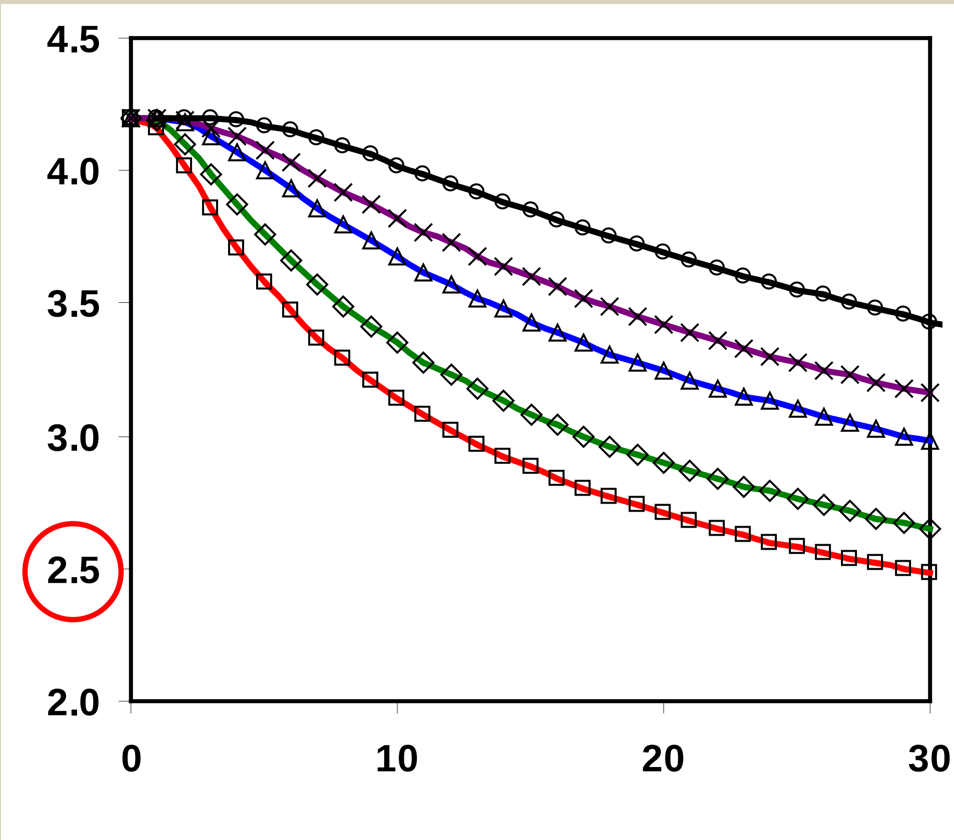
R = runoff moisture depth
DEF = deficit moisture depth
E_p = evapotranspiration

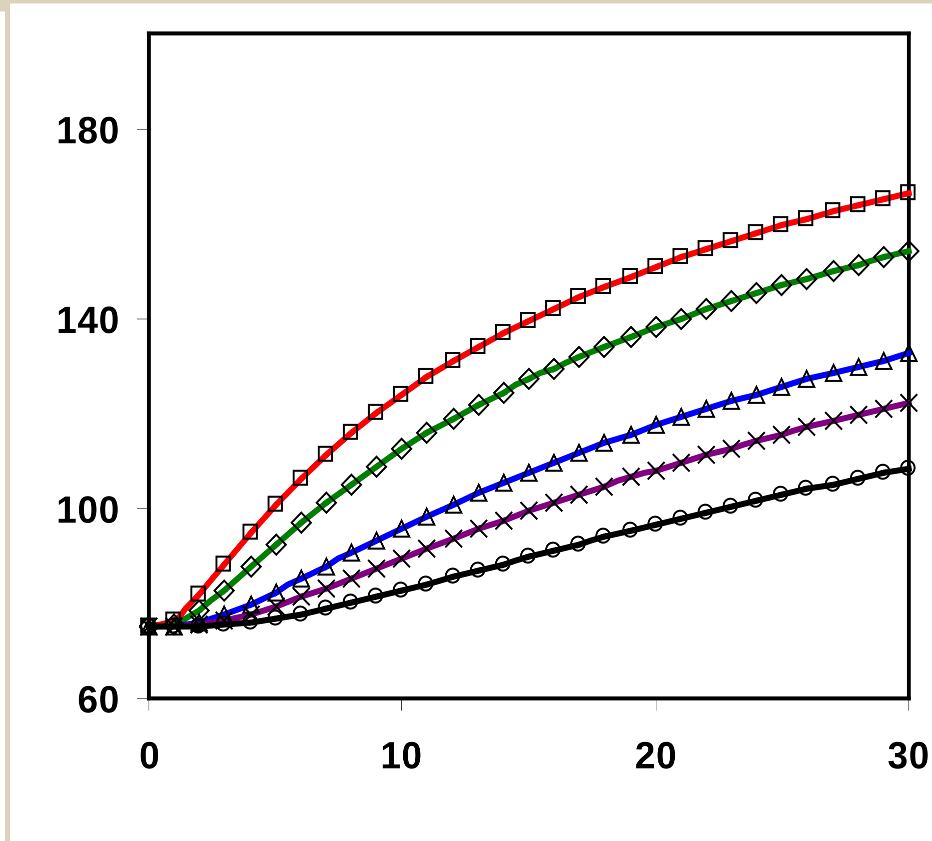
Roadside Drainage Conditions

Longitudinal Drainage

Lateral Slope	Hill	Slope	Valley
Cut	2.3 pF	2.0 pF	2.0 pF
Flat	2.5 pF	2.2 pF	2.2 pF
Fill	2.6 pF	2.3 pF	2.3 pF

Acceptable Predicted Performance



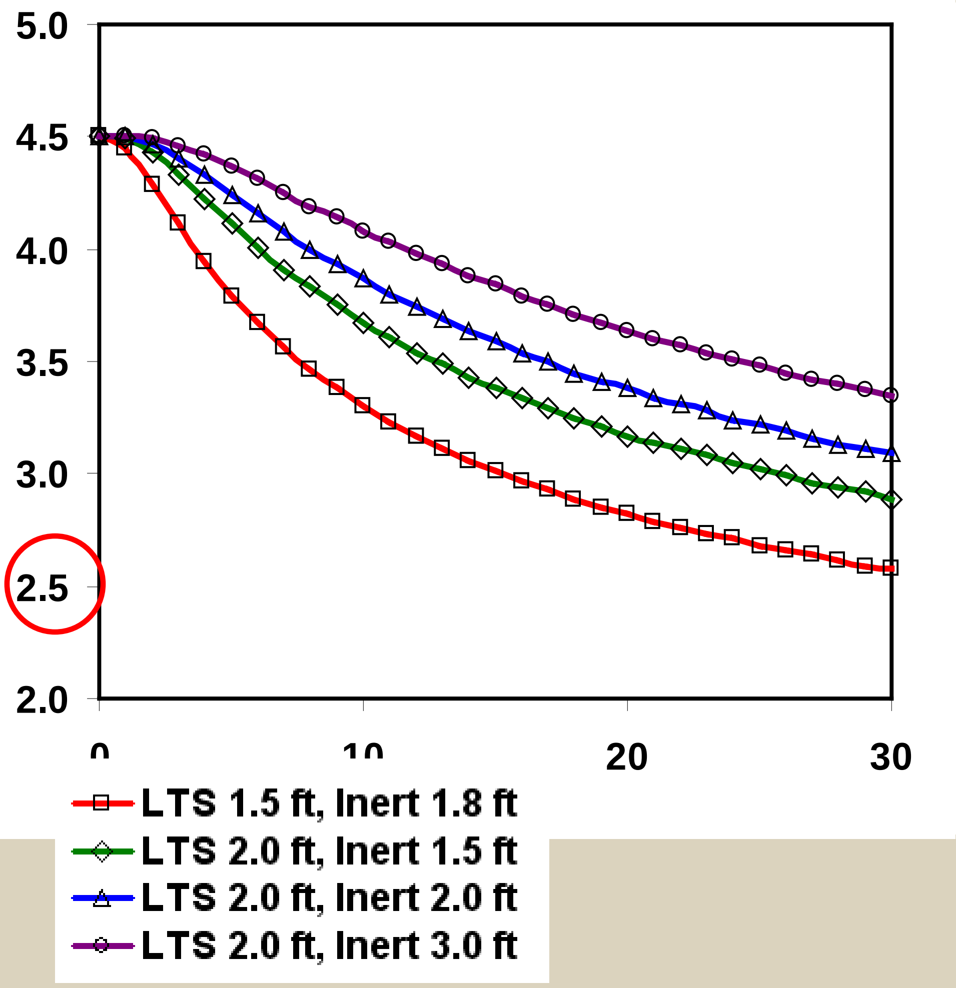


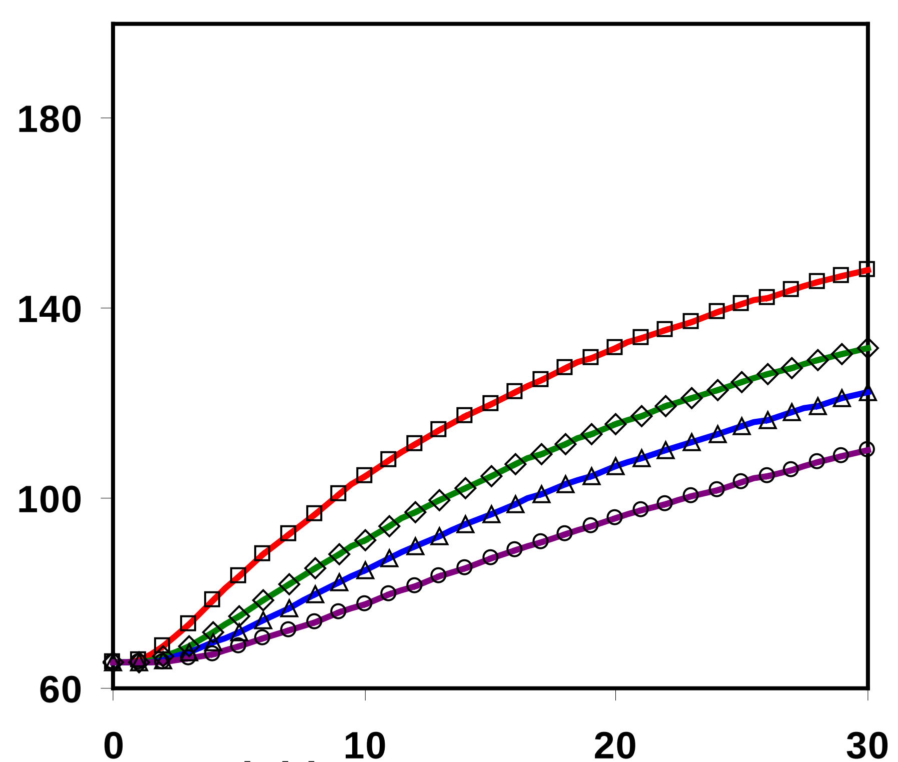
- LTS 2.8 ft
- LTS 2.8 ft and Inert 2.0 ft
- LTS 3.0 ft and Inert 2.0 ft
- LTS 3.2 ft
- LTS 3.5 ft

Flexible Pavement

Fort Worth I-820 A

Acceptable Predicted Performance





Rigid Pavement

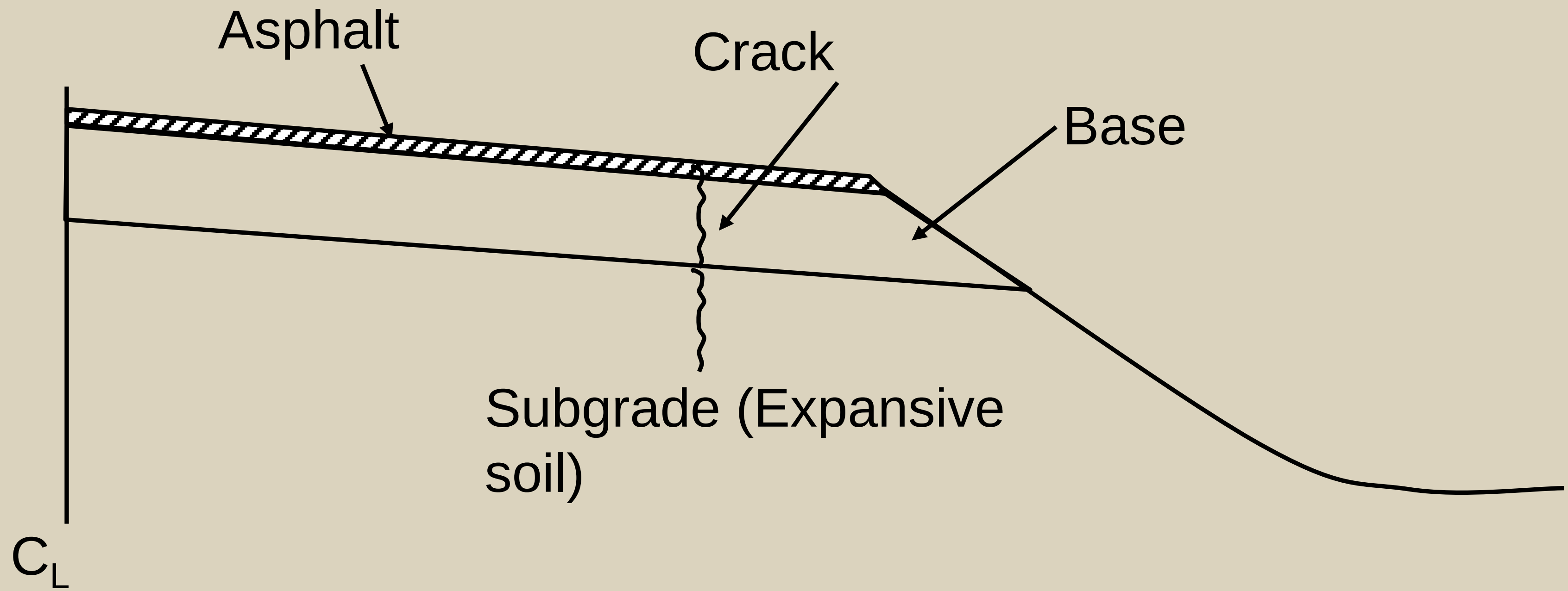
Austin SR-1

Longitudinal Cracking over Expansive Soil

- Expansive soil
  - Experiences volumetric change when subjected to moisture variation
- Longitudinal crack
  - Initiates in shrinking expansive subgrade
  - Propagates to pavement surface

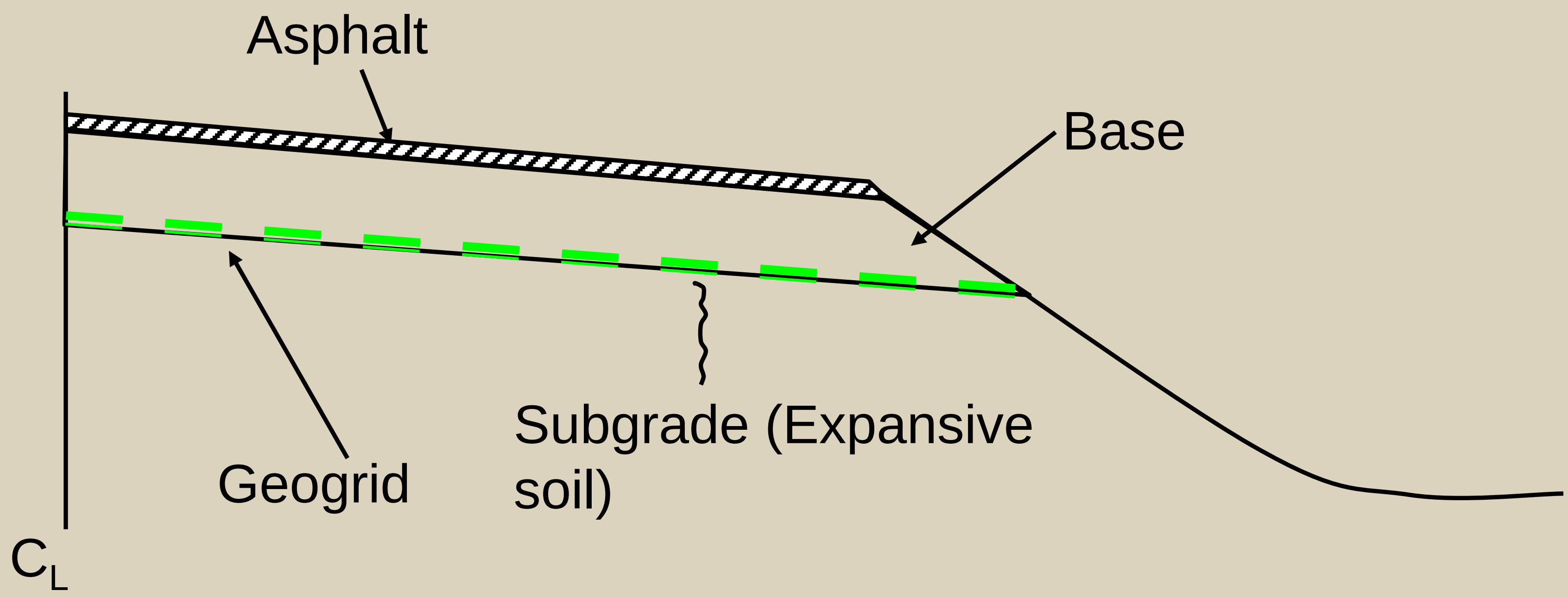
Practice of Lime Treatment

Without Geogrid Reinforcement…

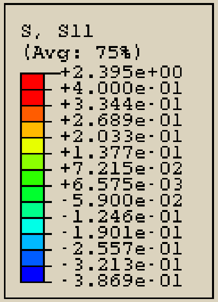


* Rong Luo, Texas A&M University

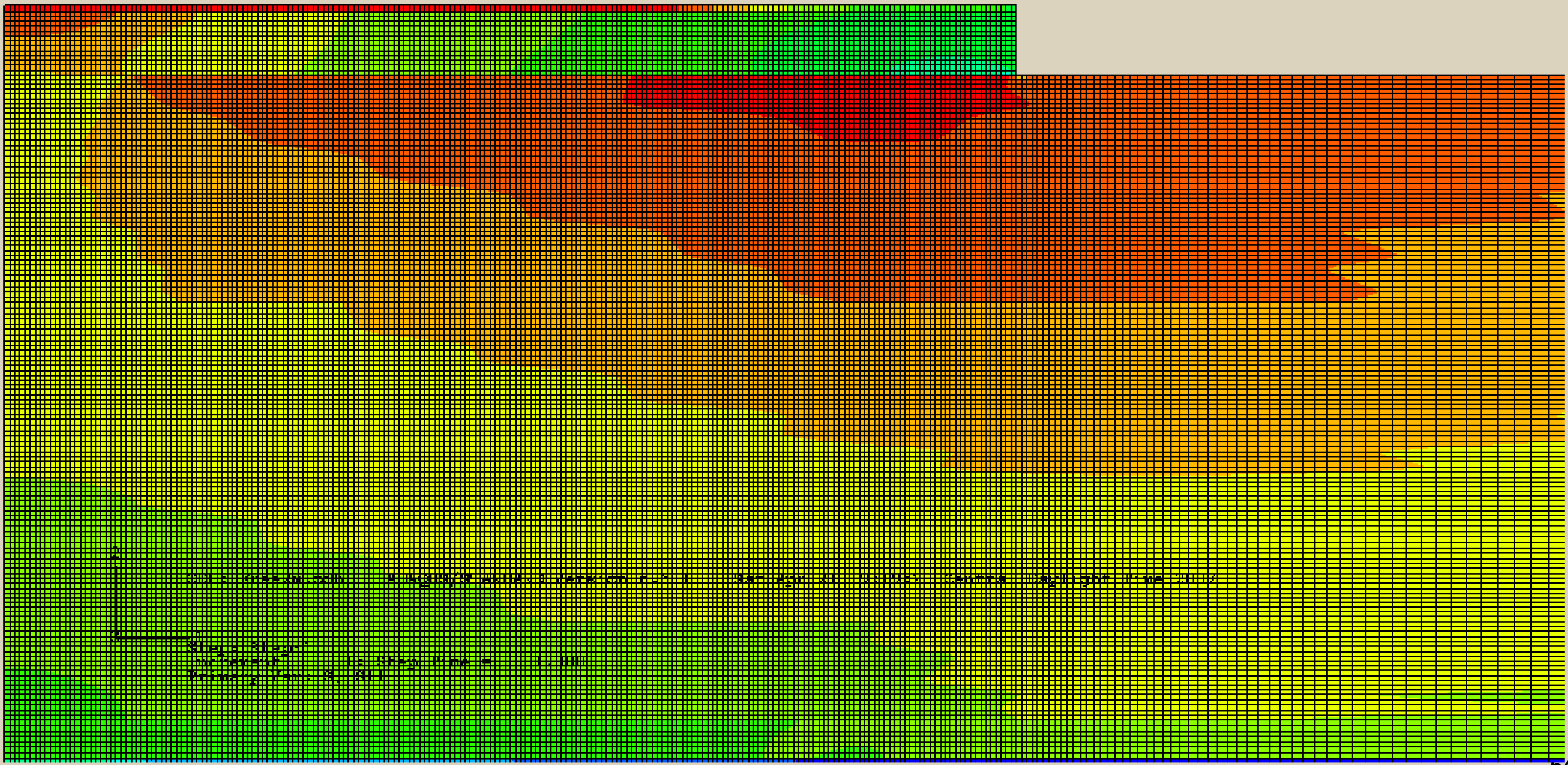
With Geogrid Reinforcement…

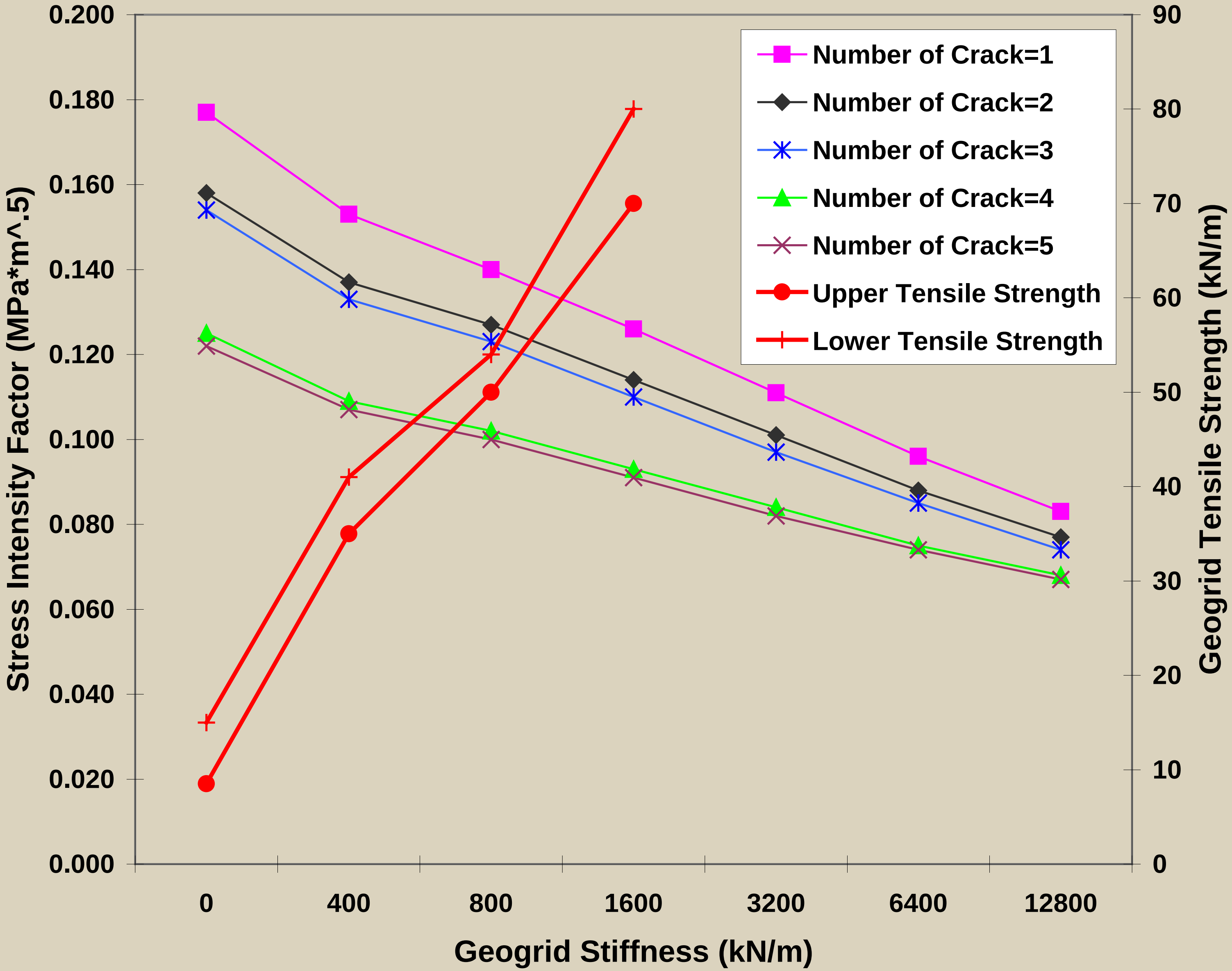


TEXAS A&M ENGINEERING



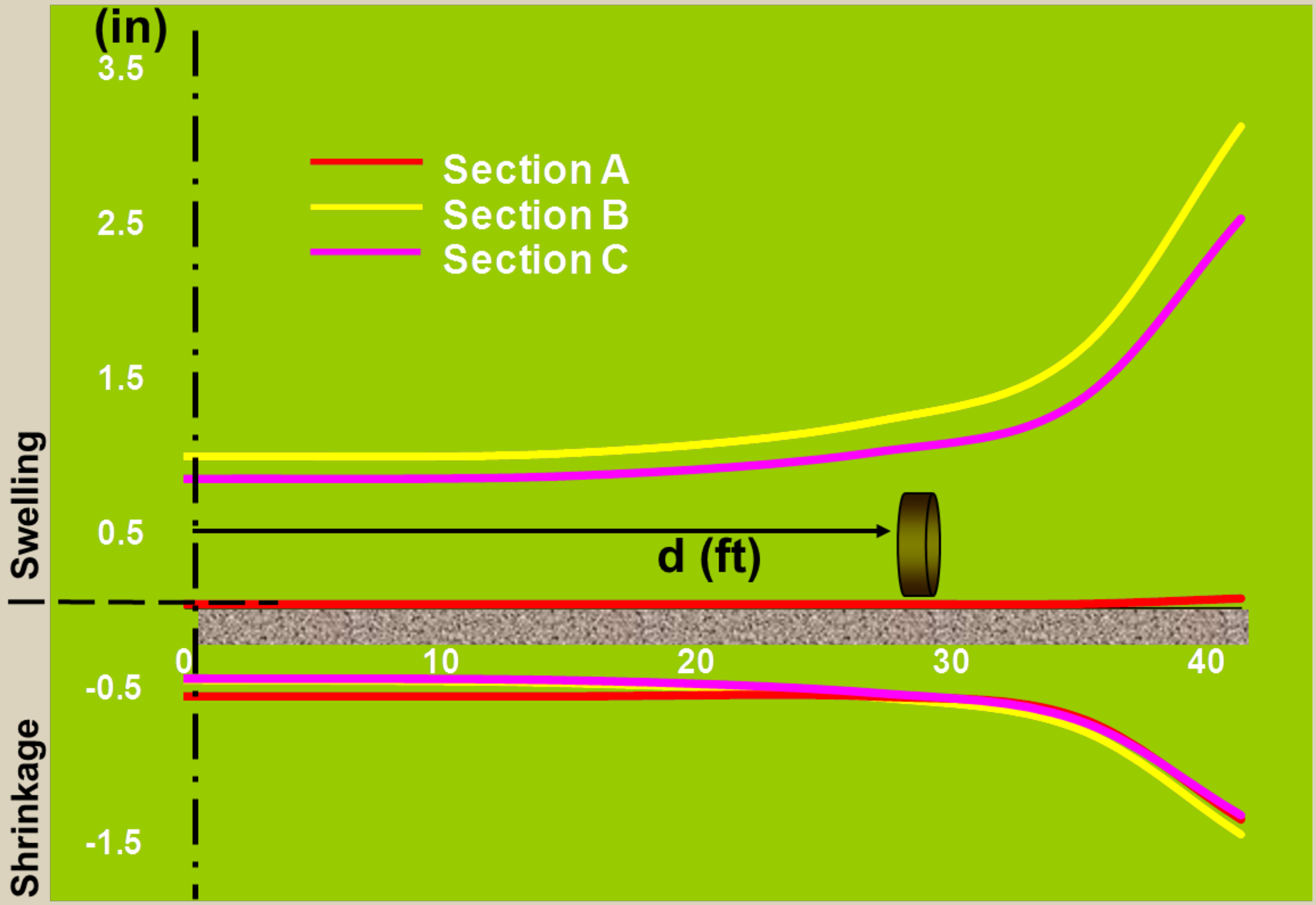
Transverse Stress Distribution in Pavement (Crack at Edge of Shoulder)



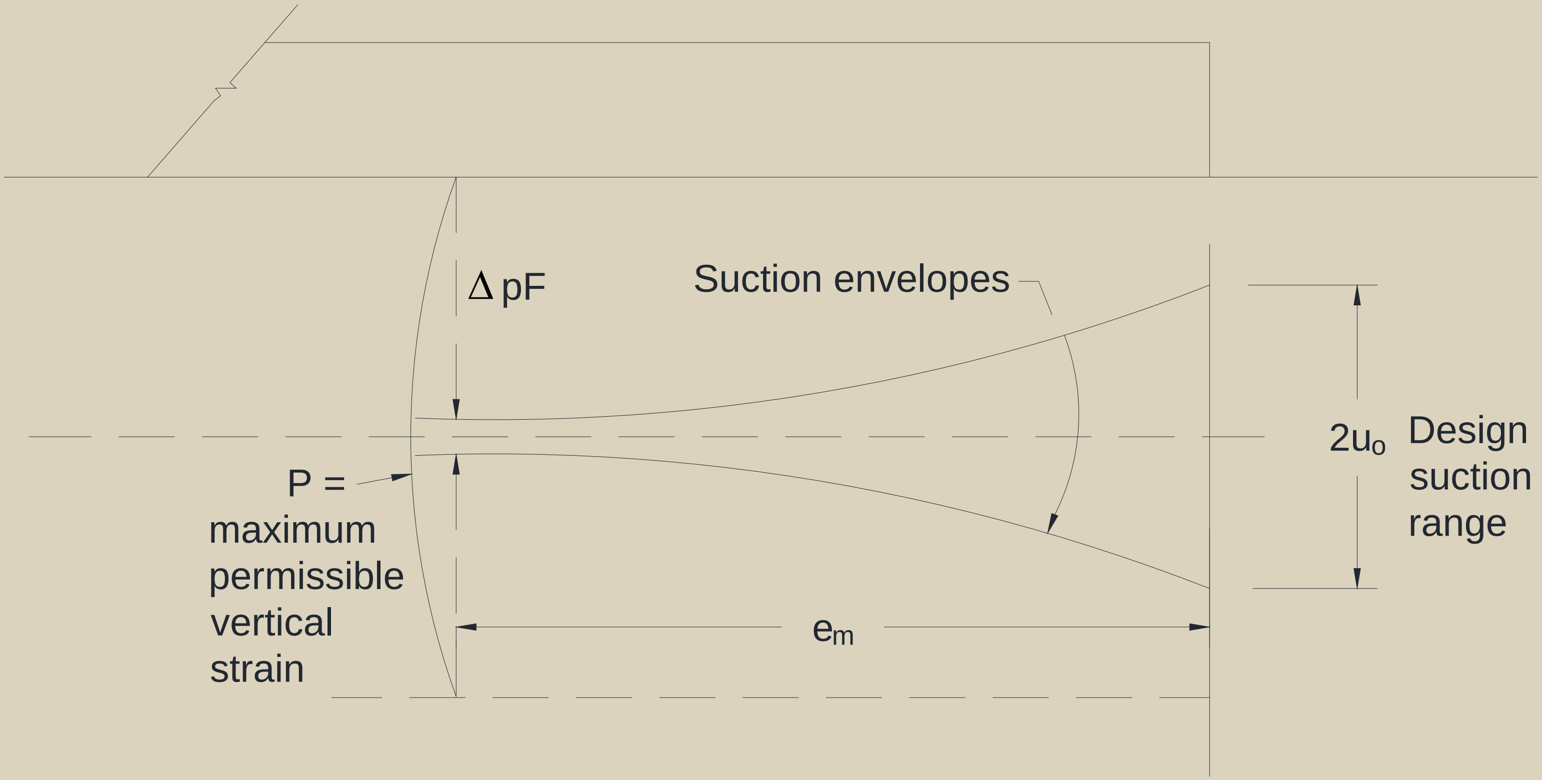


Number of Crack=1
Number of Crack=2
Number of Crack=3
Number of Crack=4
Number of Crack=5
Upper Tensile Strength
Lower Tensile Strength
Stress Intensity Factor (MPa*m^.5)
Geogrid Tensile Strength (kN/m)
Geogrid Stiffness (kN/m)
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
90
80
70
60
50
40
30
20
10
0
0
400
800
1600
3200
6400
12800

Transverse Distribution of Vertical Movements

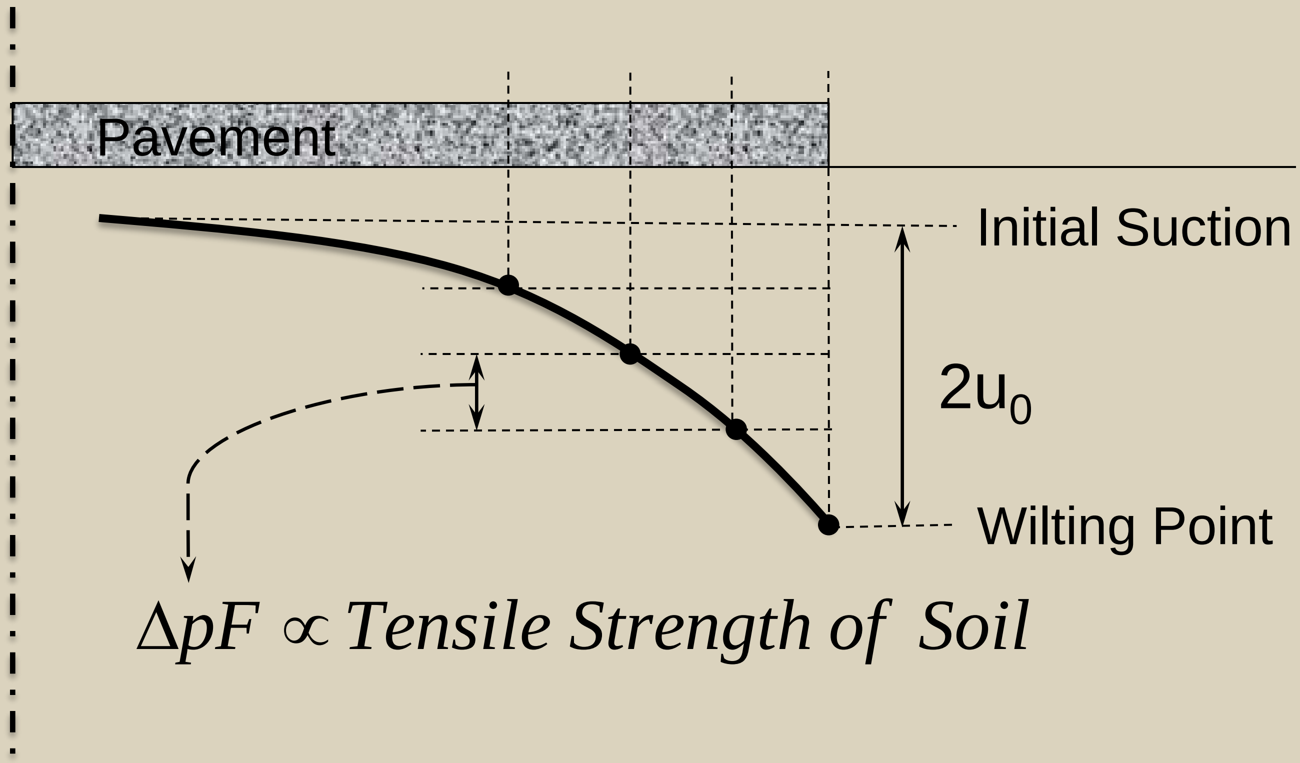


Edge Moisture Variation Distance, e_m



$$e_m = \sqrt{\frac{\alpha T}{\pi}} \ln\left(\frac{2u_0}{\Delta pF}\right) \qquad \Delta pF = 1 - \sqrt{1 + \frac{3p}{\gamma_h}}$$

Longitudinal Crack Spacing



$$\Delta pF \propto Tensile\ Strength\ of\ Soil$$

Shrinkage Strain

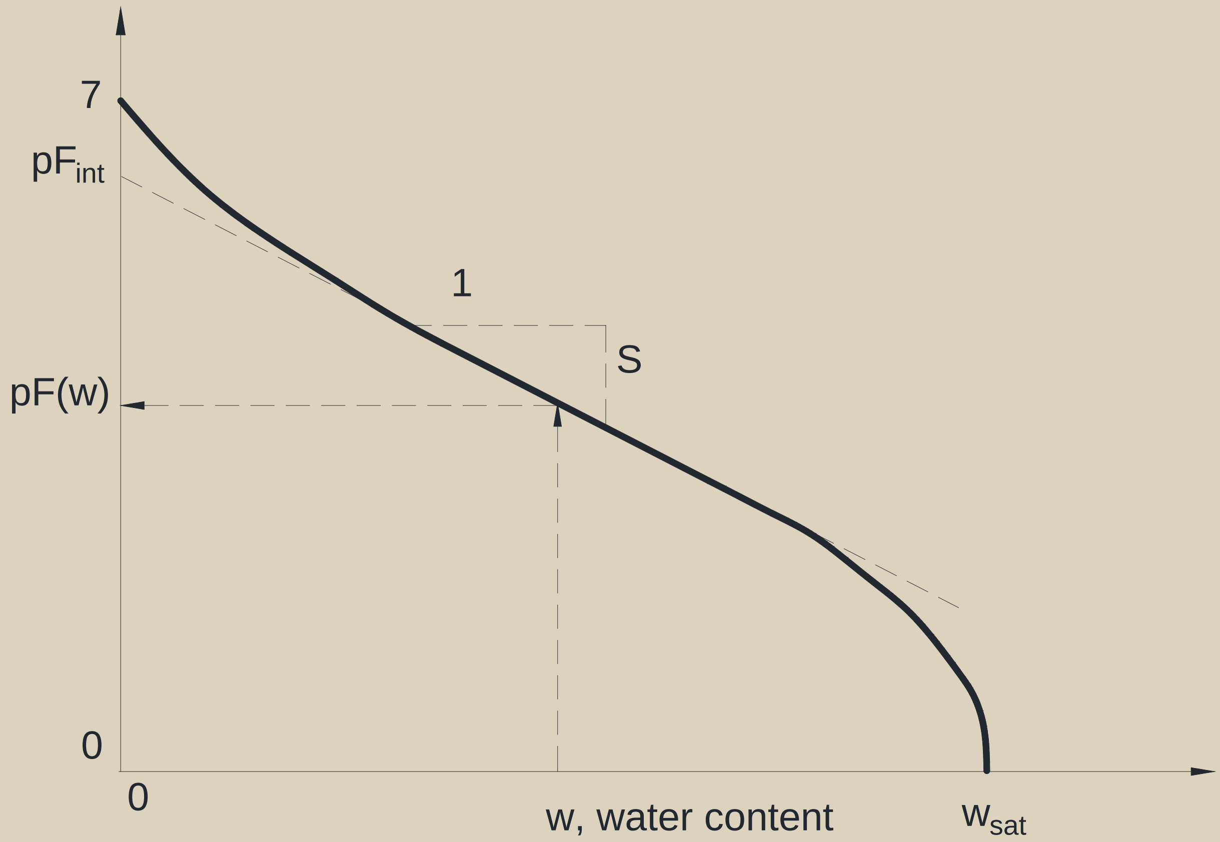
$$\varepsilon_s = \frac{1}{6}(1+\Delta pF)\left[-\gamma_h(\Delta pF)\right]$$

Distance to First Shrinkage Crack

$$x_1 = \sqrt{\frac{\alpha T}{\pi}} \ln\left(\frac{2u_0}{2u_0 - \Delta p F}\right)$$

Diffusivity

$$\alpha\left(\frac{m^2}{\sec}\right)=\left[0.0029-0.000162(S)-0.0122(\gamma_h)\right]\times 10^{-4}$$



$$Sw = pF(w) - pF_{\text{intercept}}$$

$$pF_{\text{intercept}} = 5.622 - 0.0041(\%\text{fine clay})$$

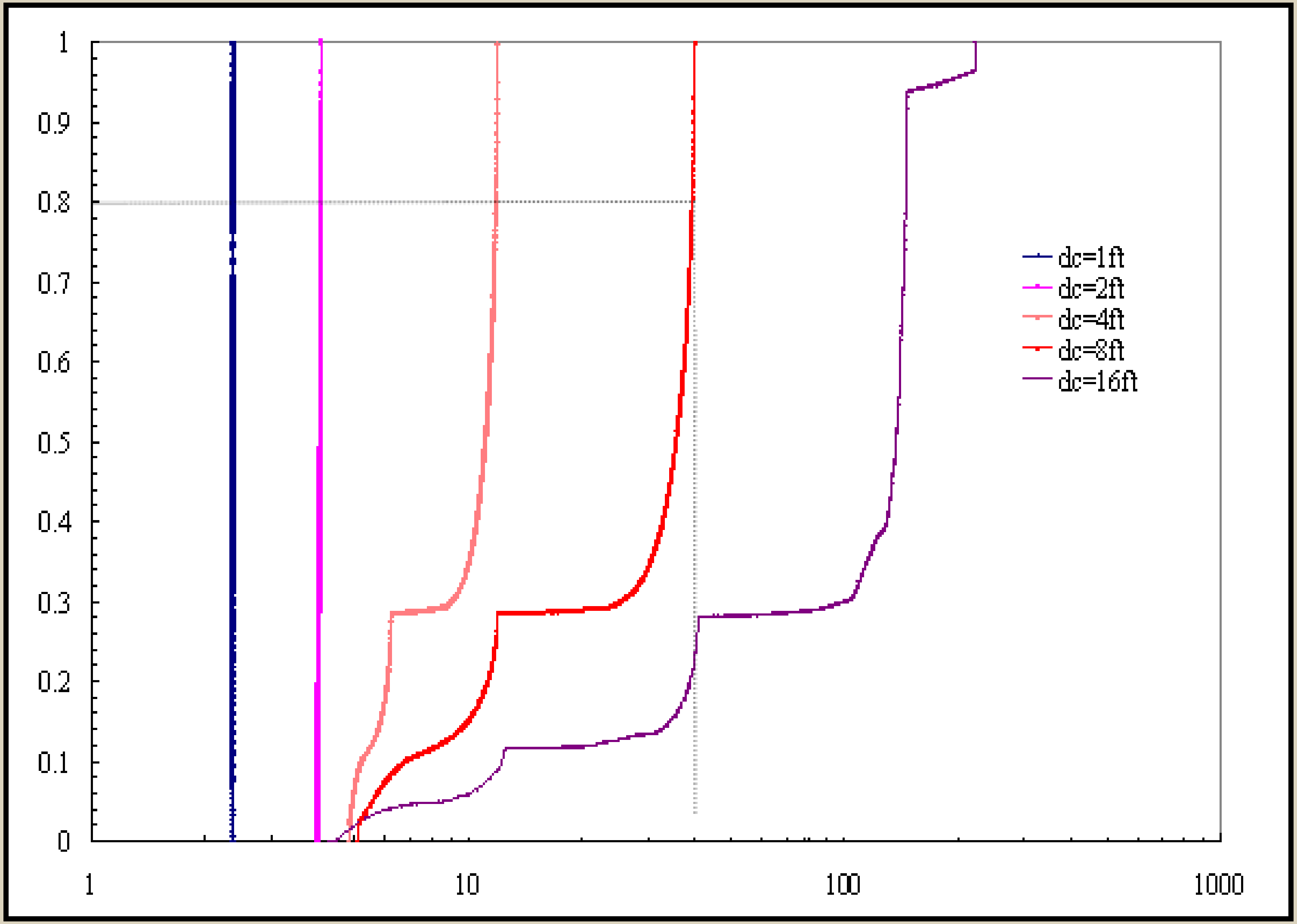
Alternative

- Use built-in empirical expression:

$$\alpha = 0.0029 - 0.000162\, S - 0.0122\, \gamma_h$$

- where:
  - S = −20.3 – 0.155 (LL) – 0.117 (PI) + 0.068 (%−No. 200)
  - $\gamma_h = \gamma_0 \times \left[\dfrac{\%\text{-}2\mu m}{\%\text{-No.}\,200\ \text{sieve}} \right]$

Field to Laboratory Diffusion Coefficient Ratio

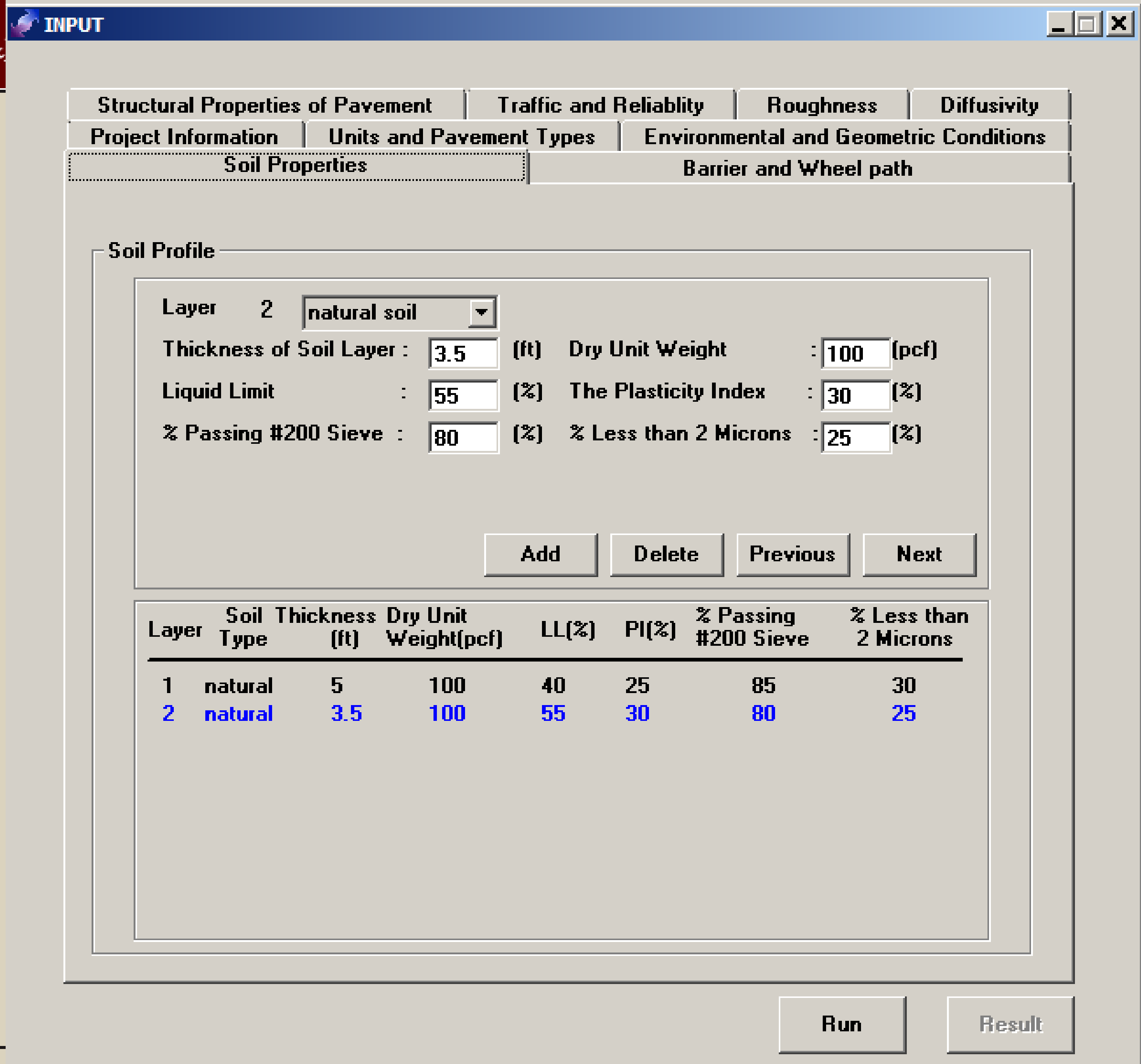


Field α/laboratory α_0

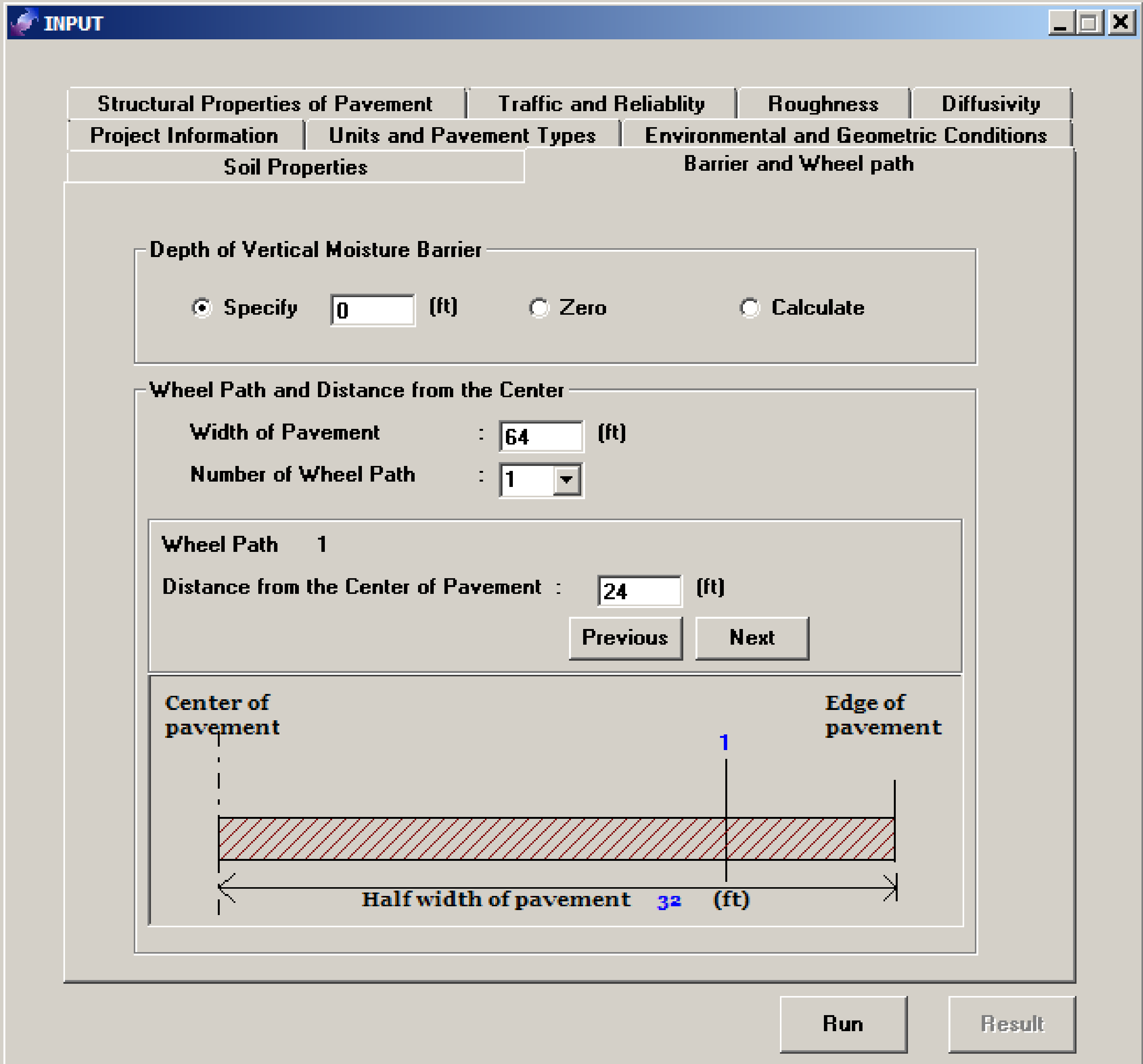
Program WinPRES

TEXAS A&

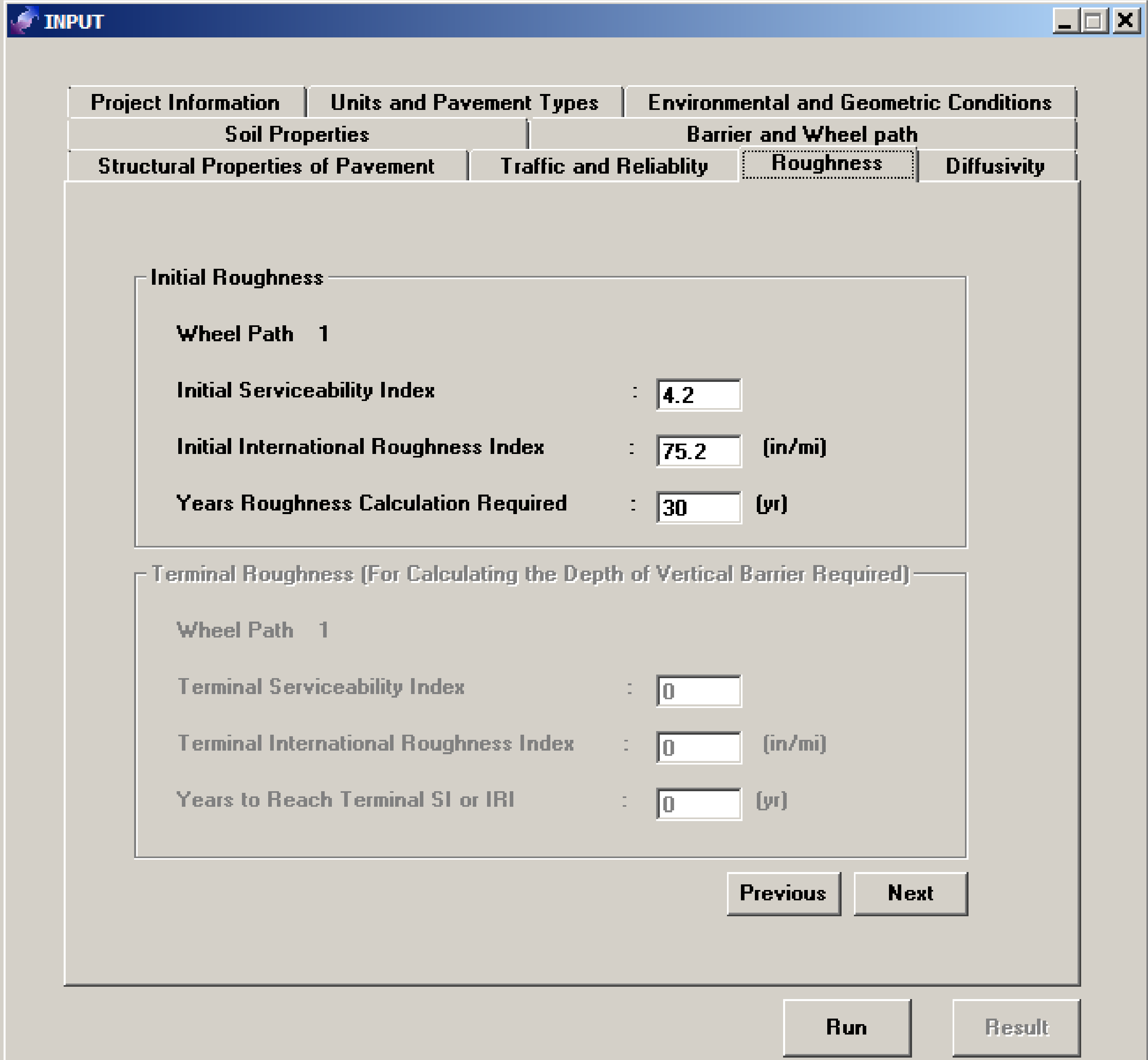
Soil Properties



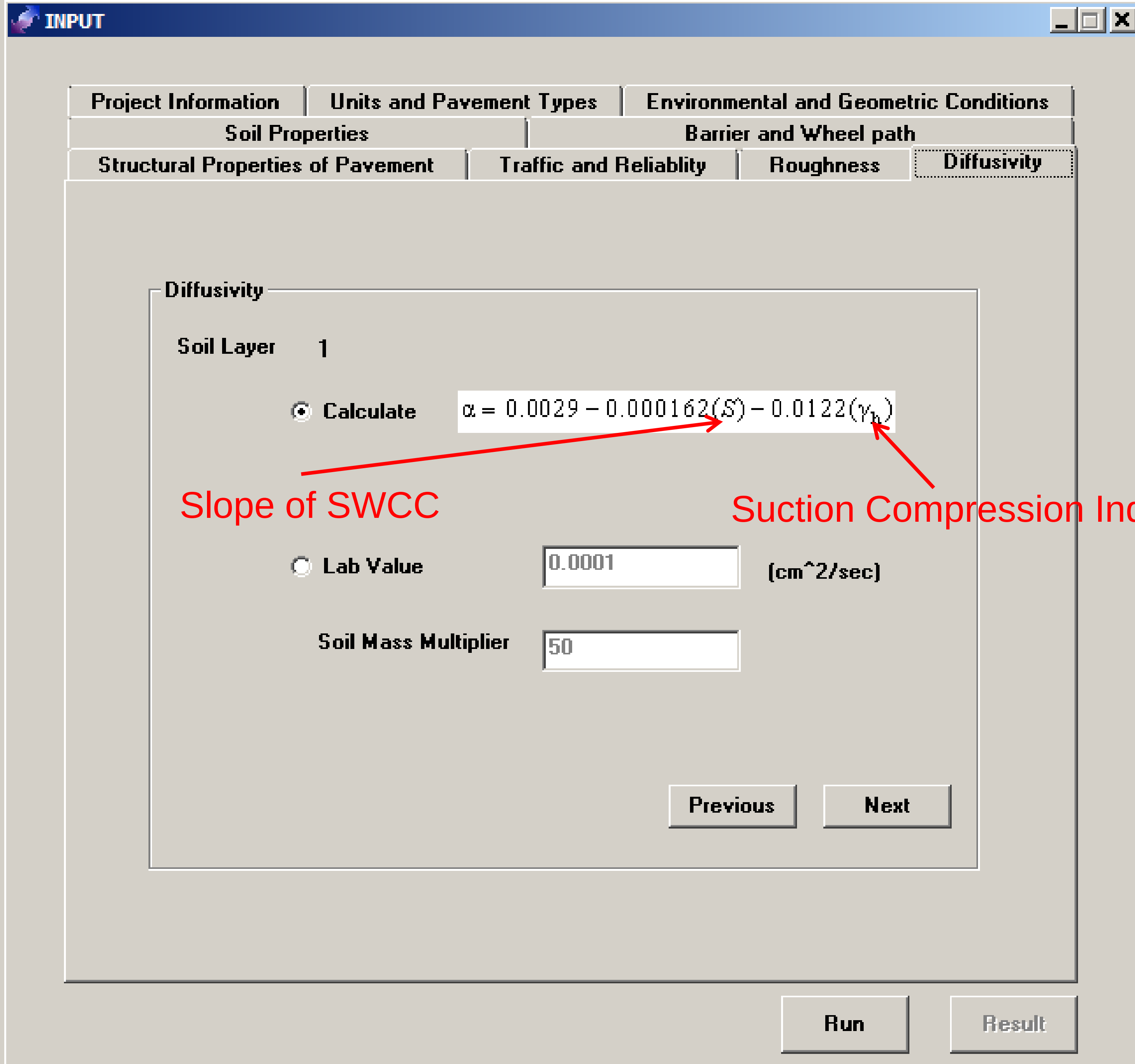
Lane/Barrier configuration



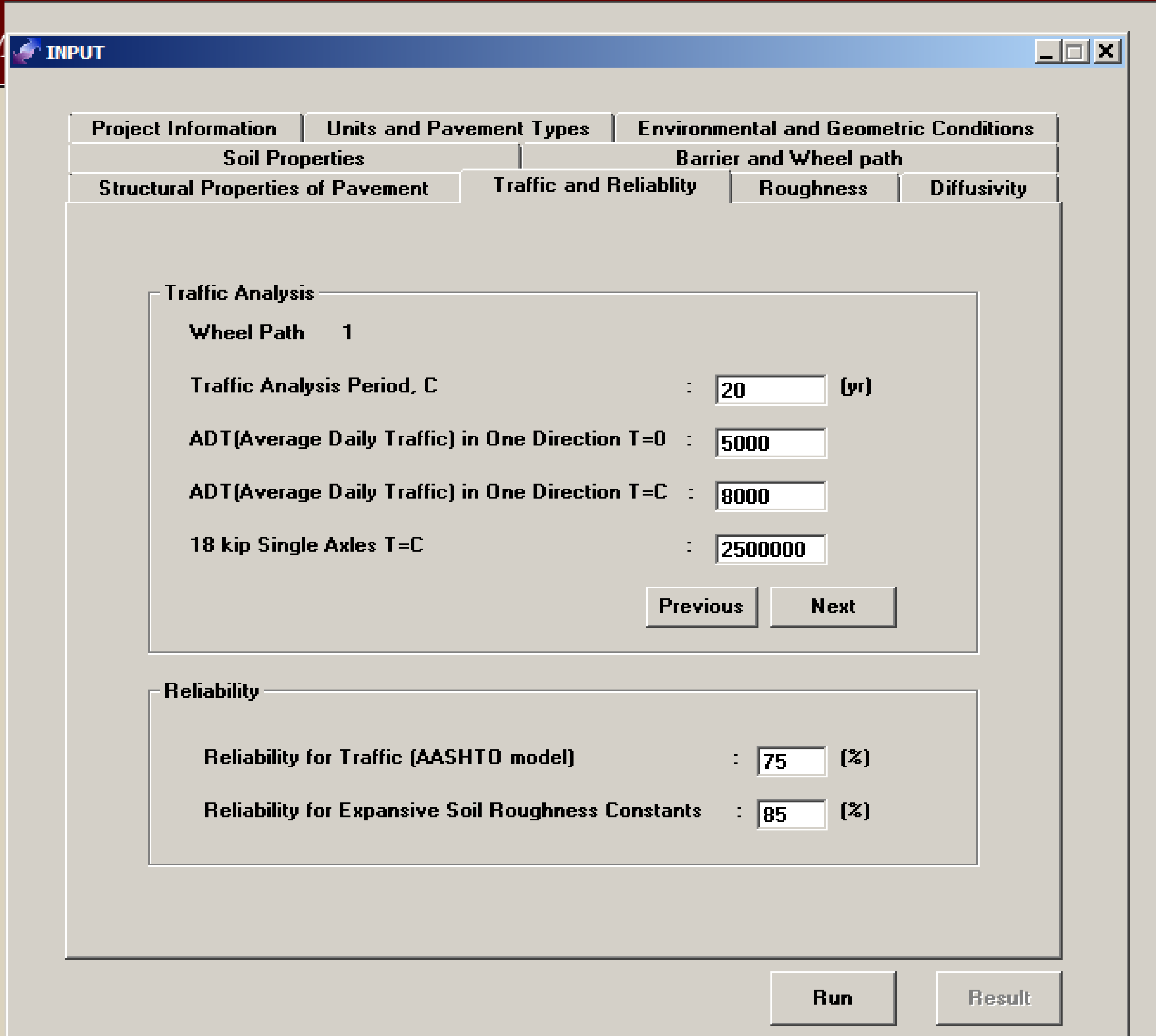
Initial Serviceability



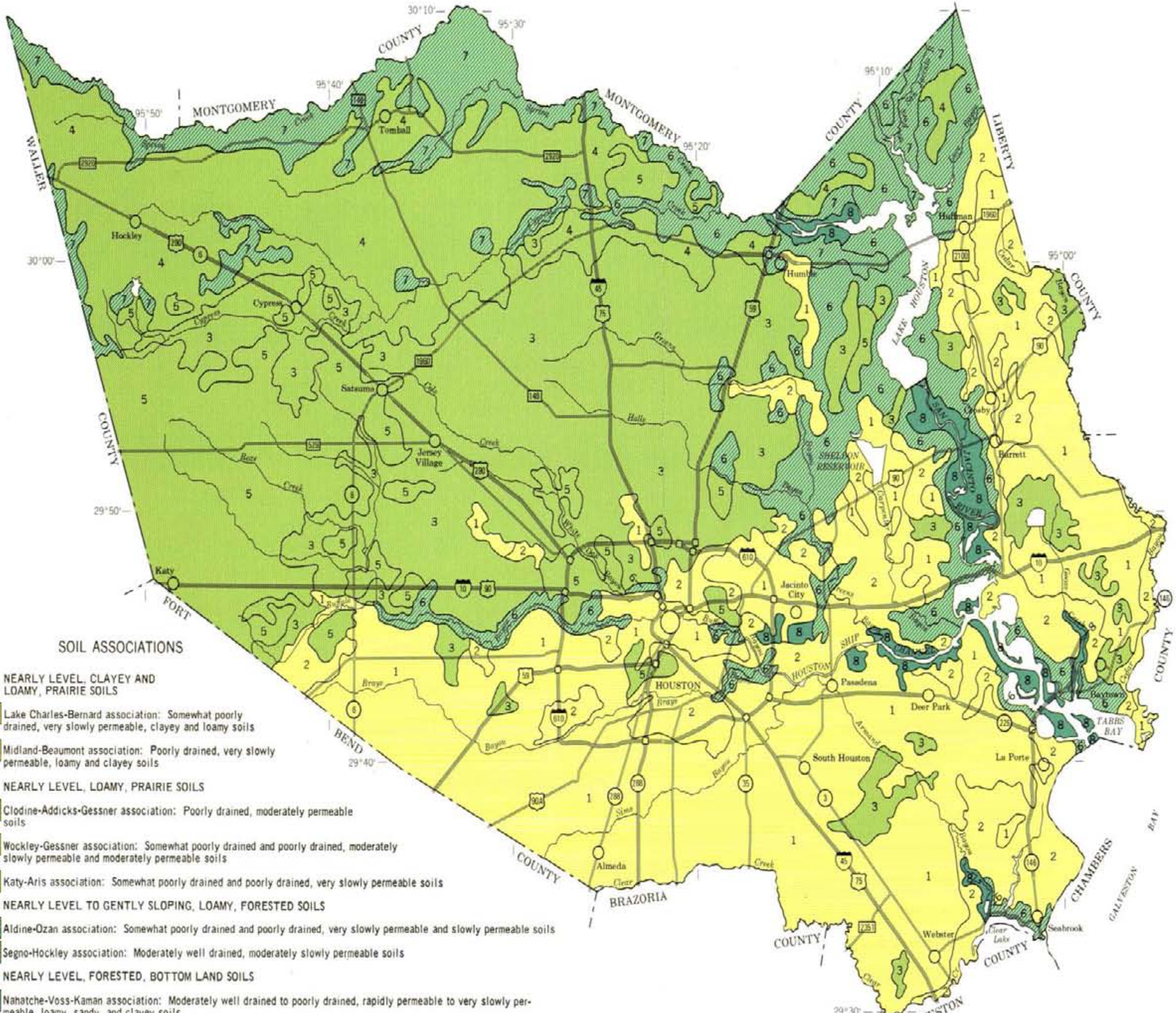
Diffusivity



Traffic/Reliability



WinPRES Demo



Each area outlined on this map consists of more than one kind of soil. The map is thus meant for general planning rather than a basis for decisions on the use of specific tracts.

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
TEXAS AGRICULTURAL EXPERIMENT STATION
AND
HARRIS COUNTY FLOOD CONTROL DISTRICT

SOIL ASSOCIATIONS

NEARLY LEVEL, CLAYEY AND LOAMY, PRAIRIE SOILS

1 Lake Charles-Bernard association: Somewhat poorly drained, very slowly permeable, clayey and loamy soils

2 Midland-Beaumont association: Poorly drained, very slowly permeable, loamy and clayey soils

NEARLY LEVEL, LOAMY, PRAIRIE SOILS

3 Clodine-Addicks-Gessner association: Poorly drained, moderately permeable soils

4 Wockley-Gessner association: Somewhat poorly drained and poorly drained, moderately slowly permeable and moderately permeable soils

5 Katy-Aris association: Somewhat poorly drained and poorly drained, very slowly permeable soils

NEARLY LEVEL TO GENTLY SLOPING, LOAMY, FORESTED SOILS

6 Aldine-Ozan association: Somewhat poorly drained and poorly drained, very slowly permeable and slowly permeable soils

7 Segno-Hockley association: Moderately well drained, moderately slowly permeable soils

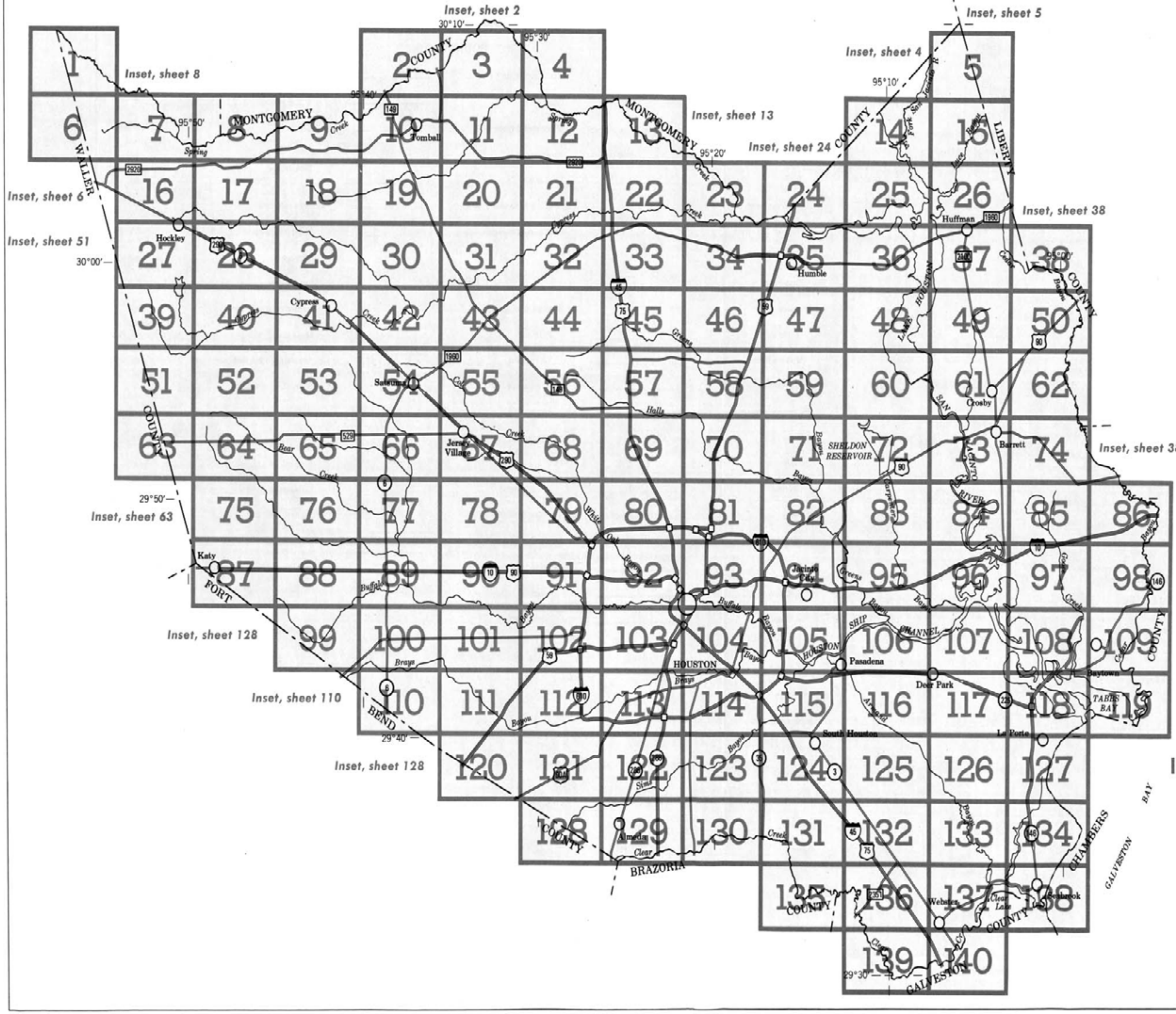
NEARLY LEVEL, FORESTED, BOTTOM LAND SOILS

8 Nahatche-Voss-Kaman association: Moderately well drained to poorly drained, rapidly permeable to very slowly permeable, loamy, sandy, and clayey soils

Compiled 1975

GENERAL SOIL MAP
HARRIS COUNTY, TEXAS

Scale 1:316,800
1 0 1 2 3 4 5 Miles

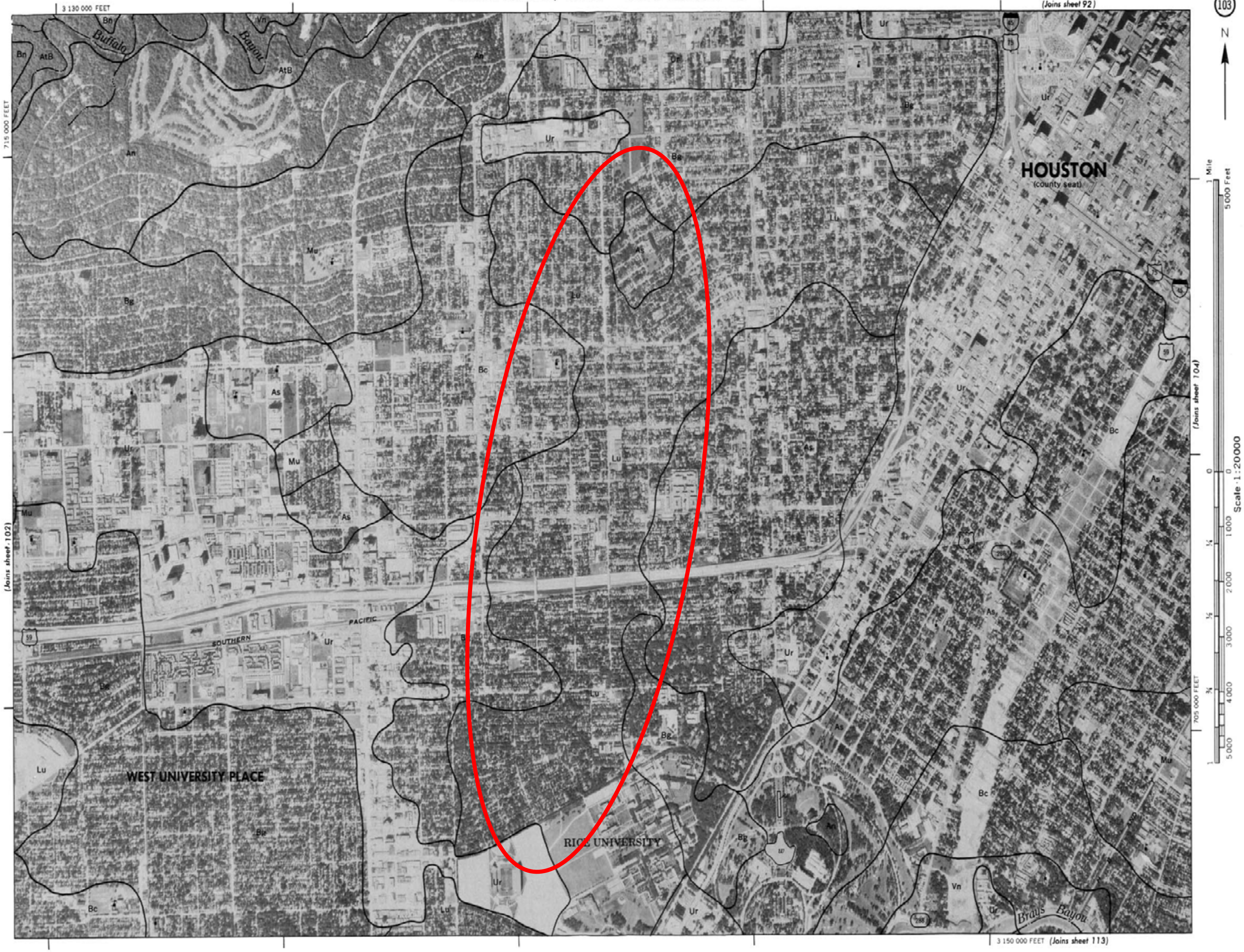


INDEX TO MAP SHEETS
HARRIS COUNTY, TEXAS

Scale 1:316,800

1 0 1 2 3 4 5 Miles

HARRIS COUNTY, TEXAS — SHEET NUMBER 103



Soil Survey of Harris County, Texas

- Lake Charles series

B22t—50 to 65 inches; prominently mottled light gray (10YR 6/1), strong brown (7.5YR 5/6), and red (2.5YR 4/6) clay loam; few medium distinct gray (10YR 5/1) mottles; moderate coarse prismatic structure parting to moderate coarse blocky; extremely hard, very firm; few fine roots mostly between ped faces; continuous dark gray (10YR 4/1) clay films mainly on faces of blocks; fine sandy loam coatings 1 to 5 millimeters thick on prism faces; slightly acid.

The A horizon is 18 to 30 inches thick. It is slightly acid or medium acid. The Ap horizon is dark grayish brown, grayish brown, or brown. The A2 horizon is brown, pale brown, very pale brown, yellowish brown, or light yellowish brown. Mottles of yellowish brown and gray are in the A2 horizon in some places. The B2t horizon is prominently mottled gray, grayish brown or light brownish gray, yellowish brown or strong brown, and red or yellowish red. The dark red centers of some red mottles in the lower part of the B2t horizon are plinthite. The amount of plinthite ranges from 0 to about 3 percent. Some ped faces are coated with very dark gray or dark gray in most profiles. The B2t horizon is clay loam, sandy clay loam, or clay. Clay makes up 25 to 35 percent of the control section. The B2t horizon is strongly acid through neutral. Some profiles are moderately alkaline below a depth of 50 inches.

Kenney series

The Kenney series consists of deep, acid, nearly level to gently sloping, sandy soils on forested uplands. These soils have a thick sandy layer underlain by a reddish loamy layer (fig. 14). They formed in thick beds of unconsolidated sediment of loamy sand, sandy loam, and sandy clay loam.

places. The B2t horizon is fine sandy loam, sandy clay loam, or clay loam. It is very strongly acid to slightly acid. In a few places, plinthite is in the upper part of the B2t horizon and the plinthite makes up less than 4 percent of the soil.

Lake Charles series

The Lake Charles series consists of deep, neutral, nearly level to gently sloping, clayey soils on upland prairies. These soils are clayey throughout the profile and have wide deep cracks and intersecting slickensides (fig. 15). They formed in alkaline marine clay.

Undisturbed areas of these soils have gilgai microrelief, in which the microknolls are 6 to 12 inches higher than the microdepressions. When these soils are dry, deep, wide cracks form on the surface. Water enters the cracks rapidly, but when the soils are wet and the cracks are sealed, water enters very slowly. These soils are somewhat poorly drained. Surface runoff is very slow or medium. Internal drainage is very slow. Permeability is very slow, and the available water capacity is high.

These soils are used mainly for rice and pasture. Some are in urban uses.

Representative profile of Lake Charles clay, 0 to 1 percent slopes, at the center of a microdepression, in pasture, from the intersection of Cook Road and Alief Road in

Lake Charles series, cont.

Alief, 1.11 miles west along Alief Road, 1.37 miles north on Synott Road, and 75 feet west:

Ap—0 to 22 inches; black (10YR 2/1) clay, very dark gray (10YR 3/1) dry; moderate fine blocky structure; very hard, very firm, very sticky and plastic; many fine roots; few fine iron-manganese concretions; shiny pressure faces; neutral; diffuse wavy boundary.

A12—22 to 36 inches; very dark gray (10YR 3/1) clay, dark gray (10YR 4/1) dry; moderate fine blocky and subangular blocky structure in upper 12 inches and breaking to moderate fine and medium blocky in the lower part; the lower part contains common large wedge-shaped peds having long axes tilted 10 to 60 degrees from the horizontal and bordered by intersecting slickensides; extremely hard, very firm, very sticky and plastic; aggregates have shiny pressure faces; few fine iron-manganese and calcium carbonate concretions; mildly alkaline; diffuse wavy boundary.

AC1g—36 to 52 inches; dark gray (10YR 4/1) clay, gray (10YR 5/1) dry; common fine and medium distinct mottles of olive (5Y 4/3) and few fine distinct mottles of yellowish brown (10YR 5/4); common large wedge-shaped peds having long axes tilted 10 to 60 degrees from the horizontal and bordered by intersecting slickensides, peds break to moderate medium and coarse blocky structure; extremely hard, very firm, very sticky and plastic; few fine roots; aggregates have shiny pressure faces; few fine iron-manganese concretions; few calcium carbonate concretions as much as 1 centimeter in diameter; mildly alkaline; diffuse wavy boundary.

AC2g—52 to 74 inches; gray (5Y 5/1) clay, gray (5Y 6/1) dry; common fine and medium distinct mottles of light olive brown (2.5Y 5/4) and few fine distinct mottles of yellowish brown (10YR 5/6); weak fine angular blocky structure; extremely hard, very firm, very sticky and plastic; few fine iron-manganese concretions; few intersecting slickensides; few irregularly shaped pitted calcium carbonate concretions generally less than 3 centimeters in size; mildly alkaline.

In undisturbed areas, gilgai microknolls are 6 to 12 inches higher than microdepressions. The center of the microknolls is about 4 to 16 feet from the center of the microdepressions. When the soils are dry, cracks 1 to 2 inches wide form on the surface and extend into the ACg horizon. Intersecting slickensides begin at a depth of about 20 to 30 inches. The A horizon is black or very dark gray. It ranges from slightly acid through mildly alkaline. The ACg horizon is very dark gray, dark gray, or gray. Mottles in the ACg horizon are olive, yellowish brown, light olive brown, strong brown, yellow, or red. The ACg horizon is clay or silty clay. It ranges from neutral through moderately alkaline. In some places it is calcareous in the lower part.

Soil Survey of Harris County, Texas

- Engineering properties and classifications

TABLE 16.--ENGINEERING PROPERTIES AND CLASSIFICATIONS--Continued

Soil name and map symbol	Depth	USDA texture	Classification		Percentage passing sieve number--				Liquid limit	Plas-ticity index
			Unified	AASHTO	4	10	40	200		
Lake Charles:										
LcA, LcB----------	0-22	Clay------------	CH	A-7	100	99-100	80-100	75-100	64-80	40-55
	22-74	Clay------------	CH	A-7	98-100	98-100	80-100	75-100	54-90	37-60
[1]Lu:										
Lake Charles part	0-22	Clay------------	CH	A-7	100	99-100	80-100	75-100	64-80	40-55
	22-74	Clay------------	CH	A-7	98-100	98-100	80-100	75-100	54-90	37-60

Soil Survey of Harris County, Texas

- Engineering test data

TABLE 19.--ENGINEERING TEST DATA--Continued

Soil name and location	Depth from surface	Shrinkage				Mechanical analysis[1]								Liquid limit[2]	Plasticity index	Classification	
		Linear	Limit[2]	Ratio	Volumetric	Percentage passing sieve--				Percentage smaller than--						AASHTO[3]	Unified[4]
						No. 4	No. 10	No. 40	No. 200	0.05 mm	0.02 mm	0.005 mm	0.002 mm				
	Depth																
Kenney loamy fine sand: From Spring, 3.75 miles west on Spring-Stuebner Road to Rothwood Road, 1.8 miles north on Rothwood Road and 40 feet west in timber (modal). Texas report no. 1271L-347, 348.	9-56	1.7	18.3	1.83	5.2		100	99	21	4	1	0	0	21	7	A-2-4(0)	SM-SC
	56-80	3.5	18.6	1.71	10.4			100	34	24	15	12	12	25	9	A-2-4(0)	SC
Lake Charles clay: From Alief, 1.11 miles west on Alief Road to Synott Road, then 1.37 miles north on Synott Road and 75 feet west in pasture (modal). Texas report no. 1271L-198, 199, 200.	0-22	26.2	12.5	2.02	60.0			100	96	67	64	57	56	87	60	A-7-6(20)	CH
	36-52	29.9	6.0	2.23	65.7	99	99	98	92	86	79	61	56	92	66	A-7-6(20)	CH
	52-74	29.0	6.3	2.14	64.6	95	94	93	90	87	84	71	66	91	64	A-7-6(20)	CH

Soil Survey of Harris County, Texas

- Profile of Lake Charles clay

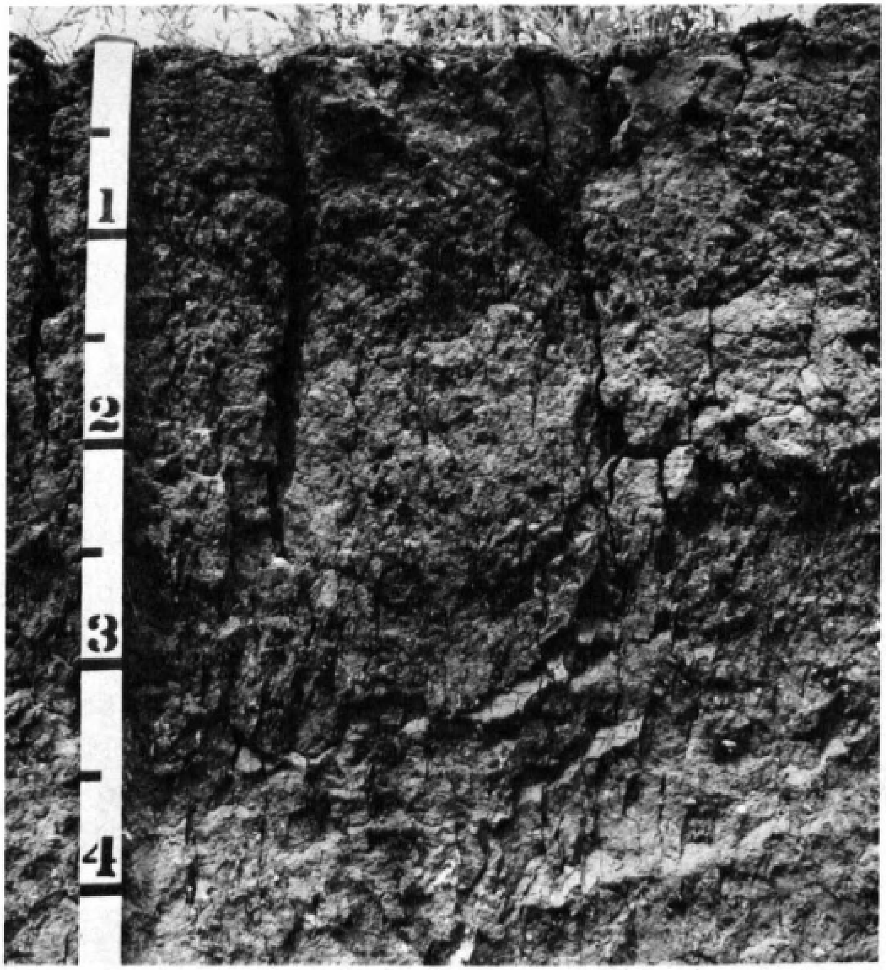


Figure 15. —Profile of Lake Charles clay, 0 to 1 percent slopes. Wide, deep cracks are in the upper layers, and intersecting slickensides are in the lower layers.

WinPRES Demo