Louisiana DOTD Experience with CPT for Driven Pile Design

Mark J. Morvant, P.E.
Louisiana Transportation Research Center

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Louisiana CPT Systems

- Twenty-ton truck
  - LTRC - Research
  - DOTD - Production
    - 220’ max depth
- Minicone truck
  - LTRC - Research
    - 40’ max depth

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Available Cones:

- Friction
- Piezo

Available Cones:

- Friction
- Piezo
  - Single, U2
  - Dual, U1 & U3
- Seismic
- Conductivity

CPT Technology In Louisiana

- **Primary Uses**
  - **Load carrying capacity of piles**
    - **end-bearing piles (mid 80's to present)**
    - **friction piles (2000 to present)**
  - **Soil classification (stratification)**
  - **Soil improvement (relative density)**

- **Current Research Effort**
  - **Consolidation parameters**
  - **Subgrade Resilient modulus (mini-cone)**

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CPT Experience for Driven Piles

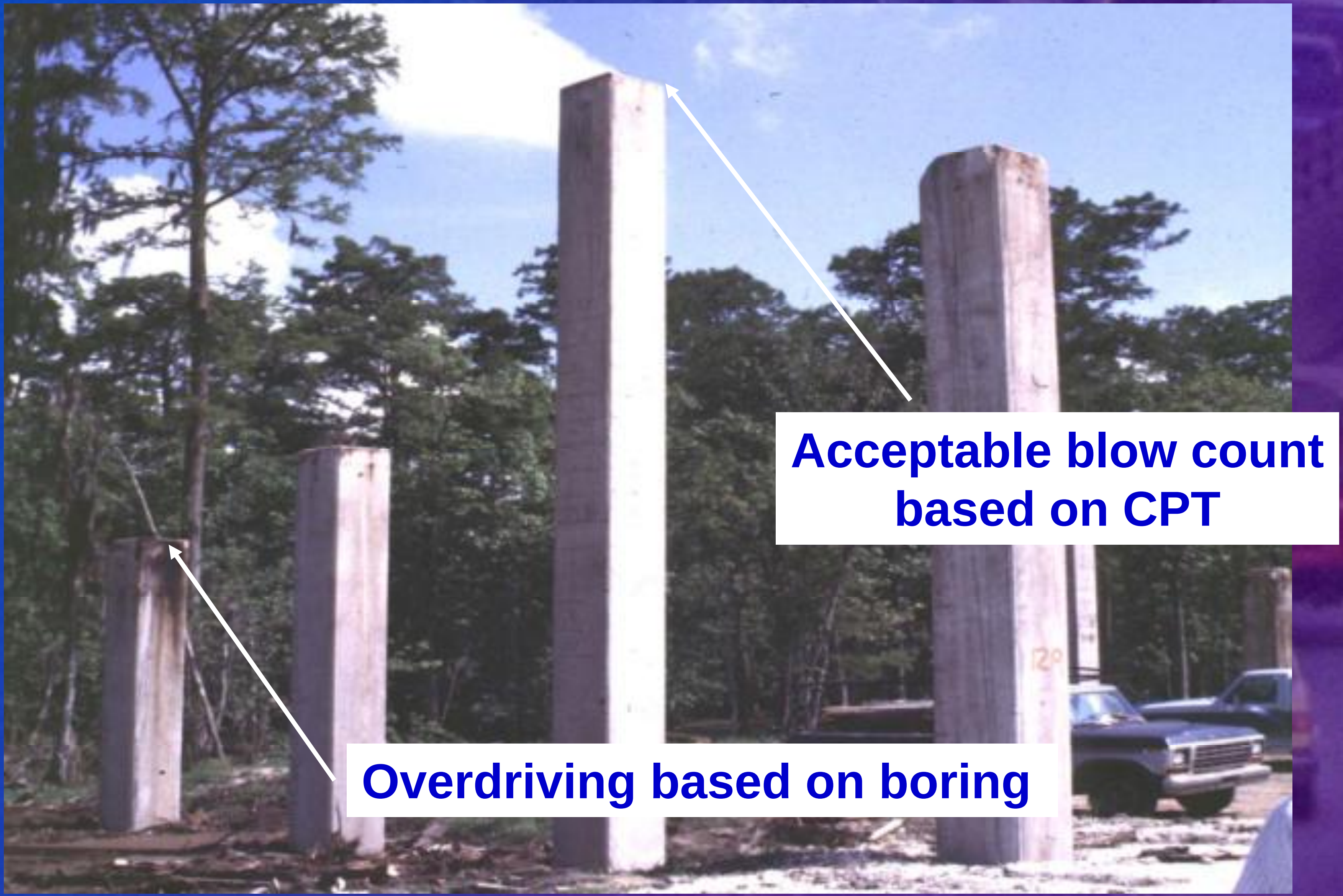
End-bearing Piles : Locating dense sand layers

Precast Concrete Piles

Timber Piles

Steel Pipe Piles

I-310 New Orleans



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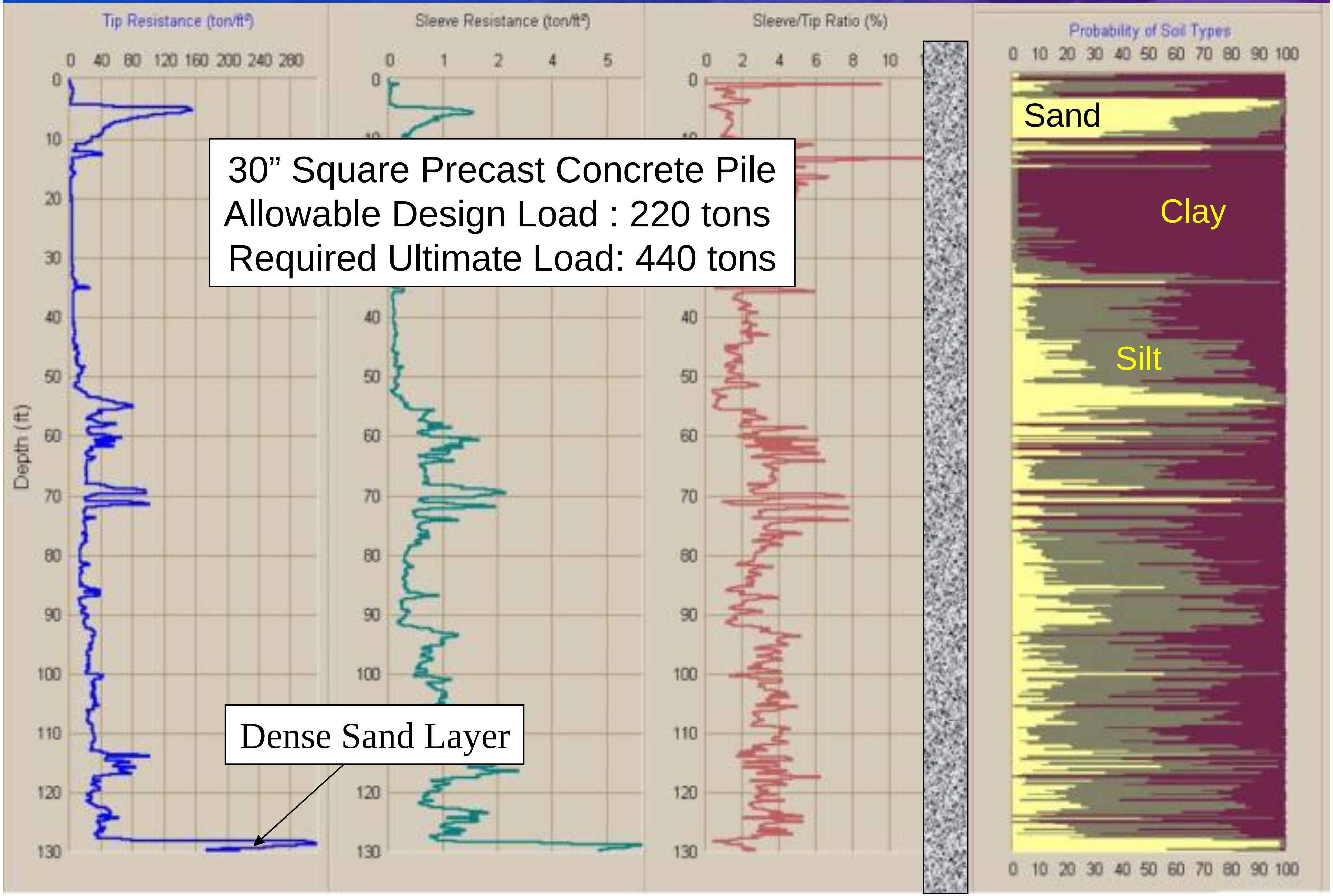
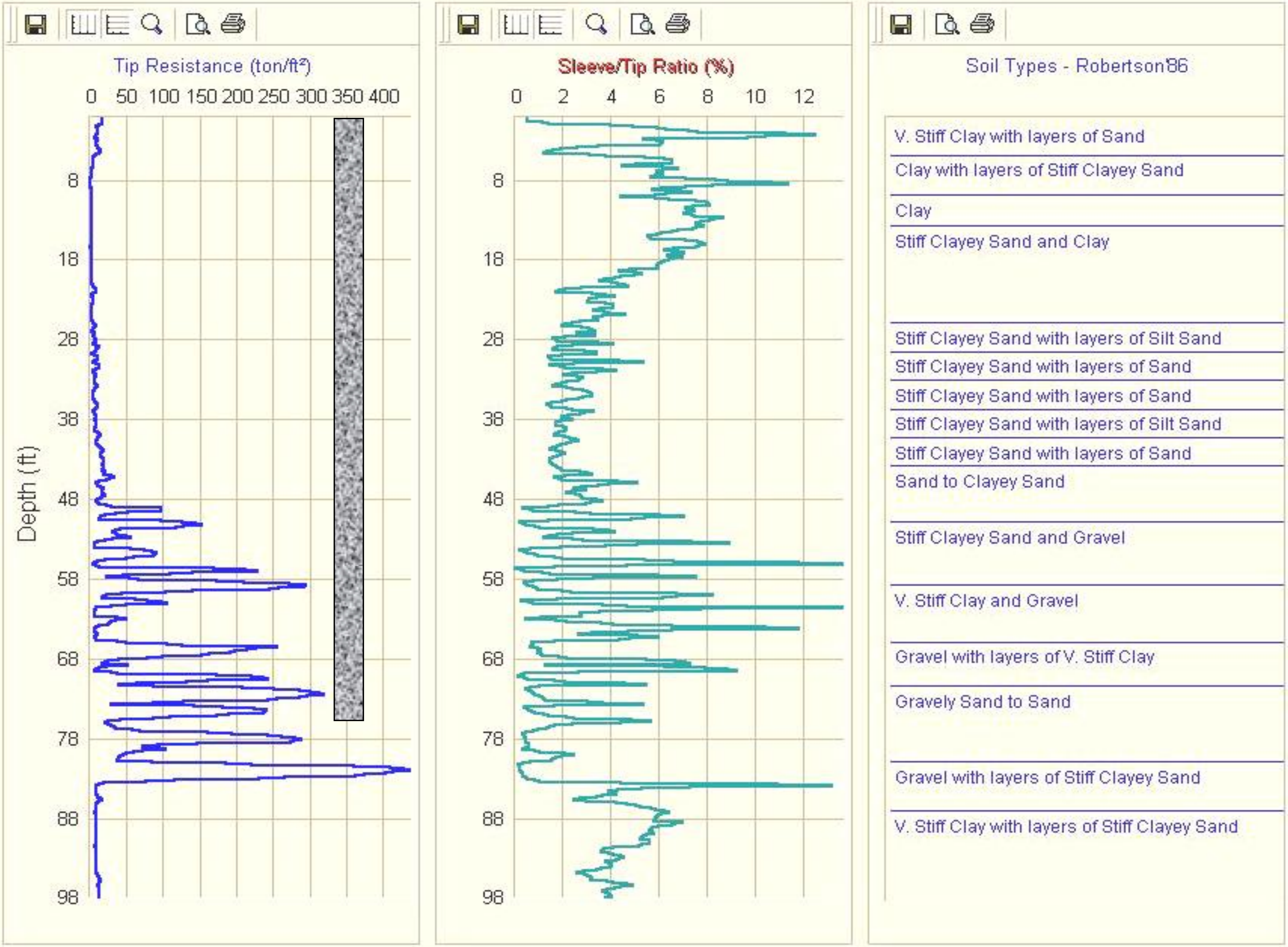
Typical South Louisiana CPT log





Tip Resistance (ton/ft²)
0 50 100 150 200 250 300 350 400
Depth (ft)
8
18
28
38
48
58
68
78
88
98
Sleeve/Tip Ratio (%)
0 2 4 6 8 10 12
Soil Types - Robertson'86
V. Stiff Clay with layers of Sand
Clay with layers of Stiff Clayey Sand
Clay
Stiff Clayey Sand and Clay
Stiff Clayey Sand with layers of Silt Sand
Stiff Clayey Sand with layers of Sand
Stiff Clayey Sand with layers of Sand
Stiff Clayey Sand with layers of Silt Sand
Stiff Clayey Sand with layers of Sand
Sand to Clayey Sand
Stiff Clayey Sand and Gravel
V. Stiff Clay and Gravel
Gravel with layers of V. Stiff Clay
Gravely Sand to Sand
Gravel with layers of Stiff Clayey Sand
V. Stiff Clay with layers of Stiff Clayey Sand

LTRC Research Project

Evaluation of Bearing Capacity of Piles From Cone Penetration Test Data
1998

Principal Investigator: Hani Titi, Ph.D, P.E.
Co-Principal Investigator: Murad Abufarsakh, Ph.D., P.E.
Project Manager: Mark Morvant, P.E.

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DOTD Test Piles

- **Precast concrete piles with CPT data**
  - **60 piles identified**
- **Test loaded to failure**
  - **40 piles identified**
- **Skin friction is the major component**
  - **34 piles analyzed**
- **Implementation Phase (2001)**
  - **17 piles added to database**
  - **Total 51 test piles analyzed**

Load Capacity Methods

- **Load Test Results**
- **Traditional Static Analysis**
  - **Alpha method (Tomlinson)**
- **CPT Methods:**
  - **Schmertmann**
  - **de Ruiter and Beringen**
  - **Bustamante and Gianeselli (LCPC/LCP)**
  - **Tumay and Fakhroo**
  - **Aoki and De Alencar**
  - **Philipponnat**
  - **Price and Wardle**
  - **Penpile**

SOIL CLASSIFICATION
Soil-CPT Program

STATISTICAL APPROACH

1. Zhang, Z., and Tumay, M.T., "Statistical to Fuzzy Approach Toward CPT Soil Classification", JGE, ASCE, Vol. 125, No. 3, 1999.

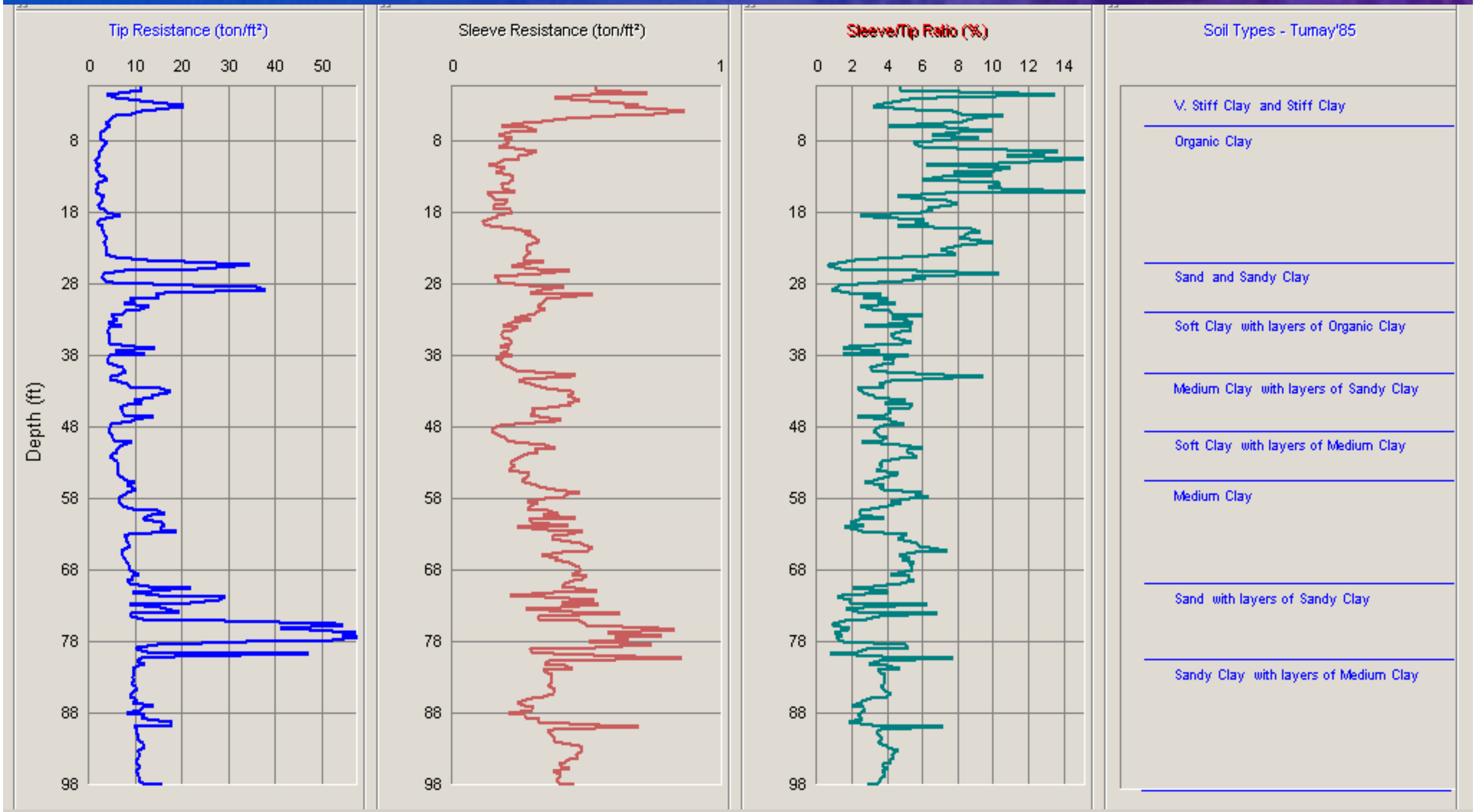
EXPERIMENTAL APPROACH

2. Tumay, M., Report No. FHWA/LA/LSU-GE85-02, LTRC, 1985

3. Robertson, P.K., Campanella, R.G., Gillespie, D., and Greig, J., "*Use of Piezometer Cone Data*", ASCE, 1986

Soil Classification: General Soil Type

Tumay, M.T (Modified Schmertmann)

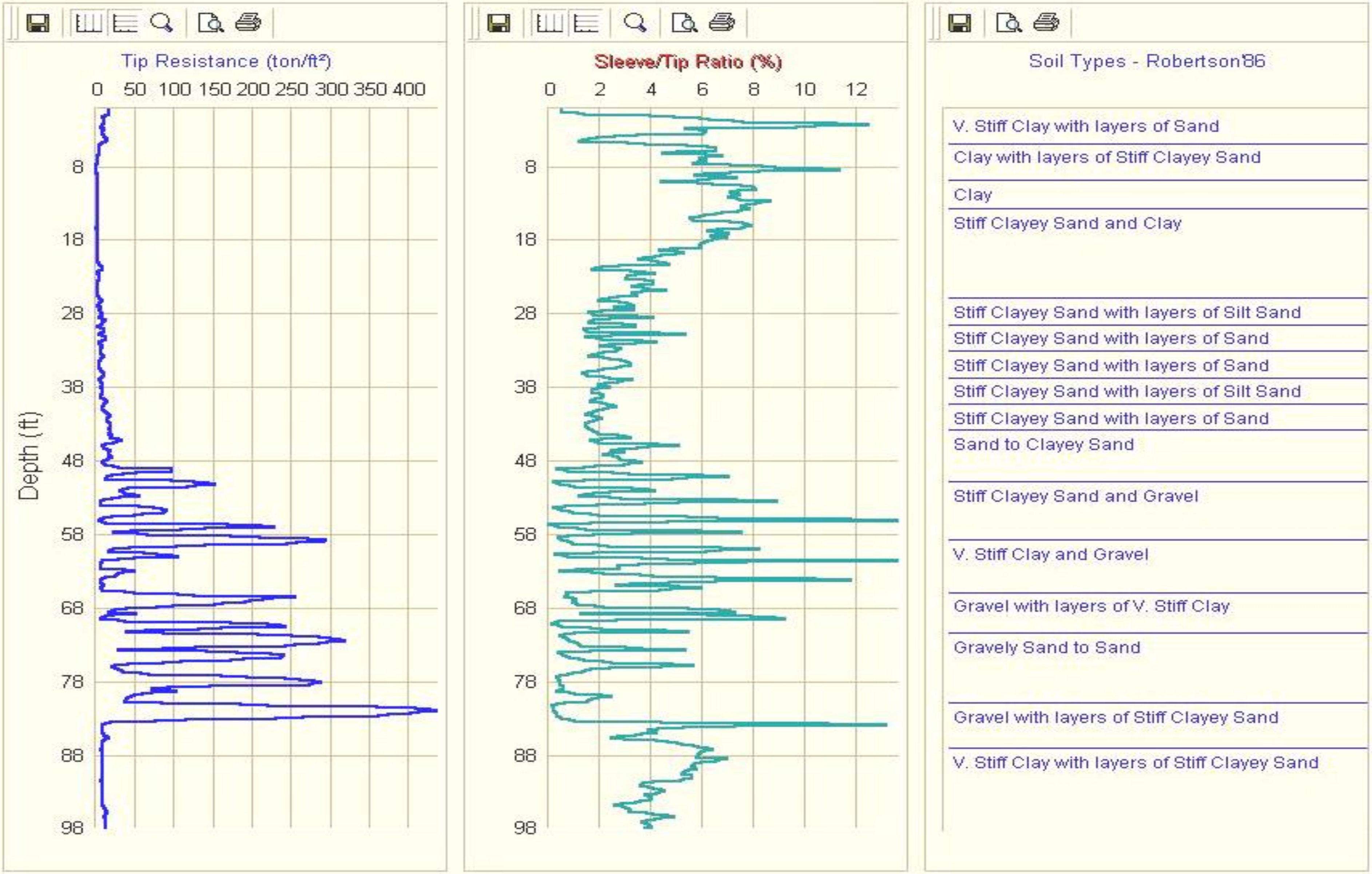


Project Number: 829-10-0013 Project Title: Bayou Lafourche Bridge @ Clotilda Station: 125+50 Offset: 35' rt

Elevation (ft): 15 Parish: Lafourche Date: 5/25/99 Latit.: Longit.:

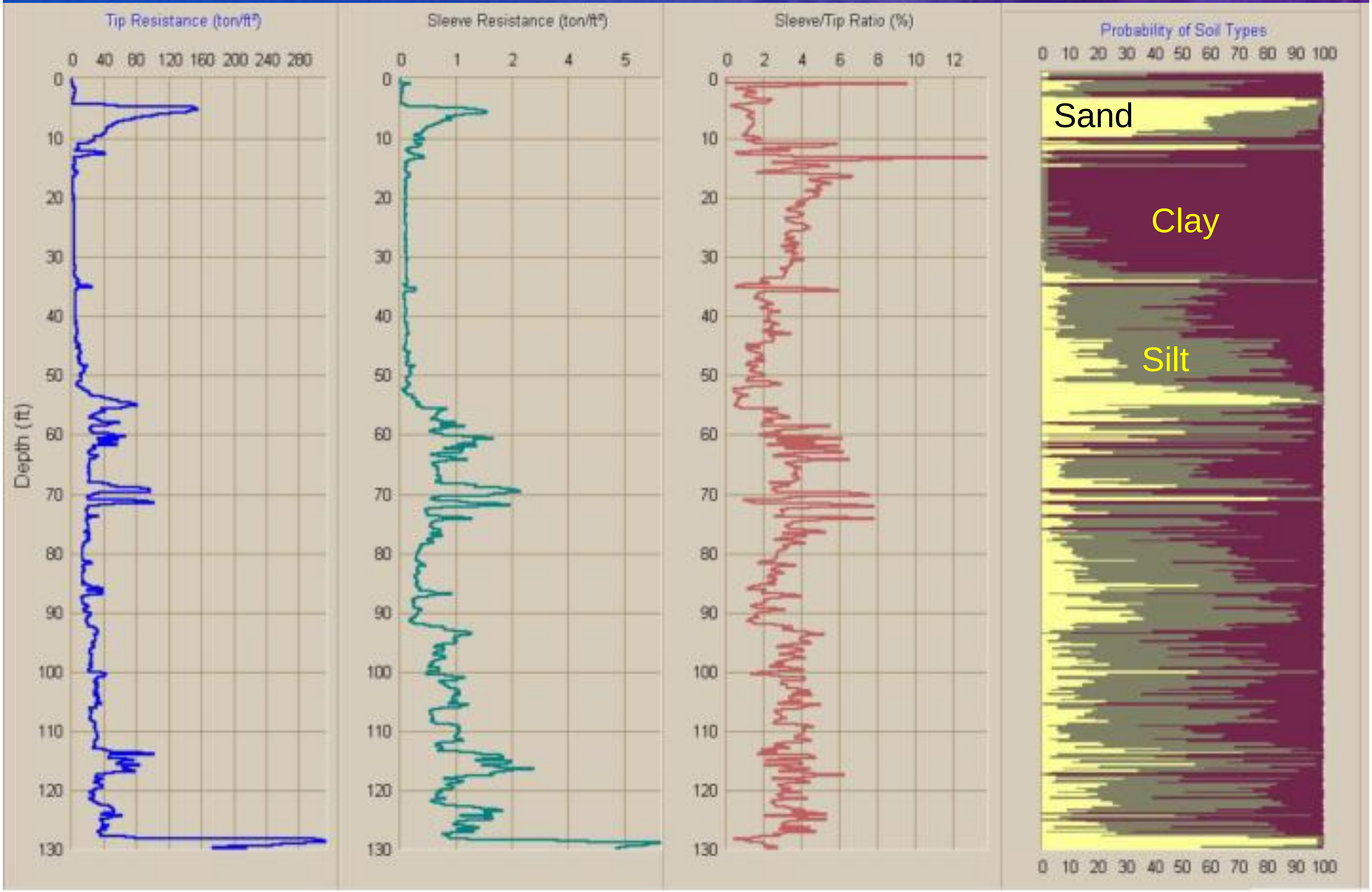
Soil Classification: General Soil Type

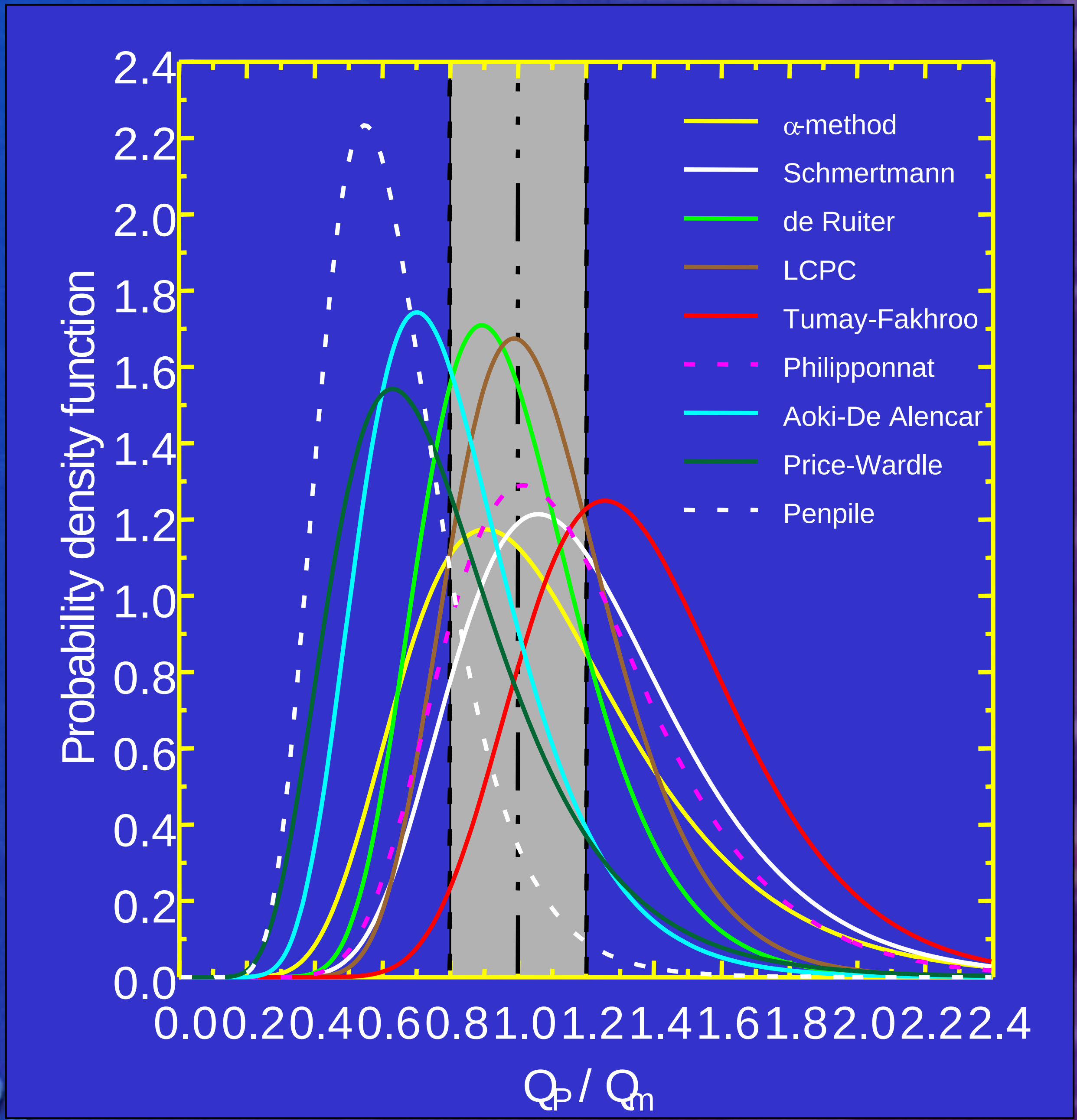
Robertson (no pore pressure)



Soil Classification: Statistical Method

Zhang, Z., and Tumay, M.T





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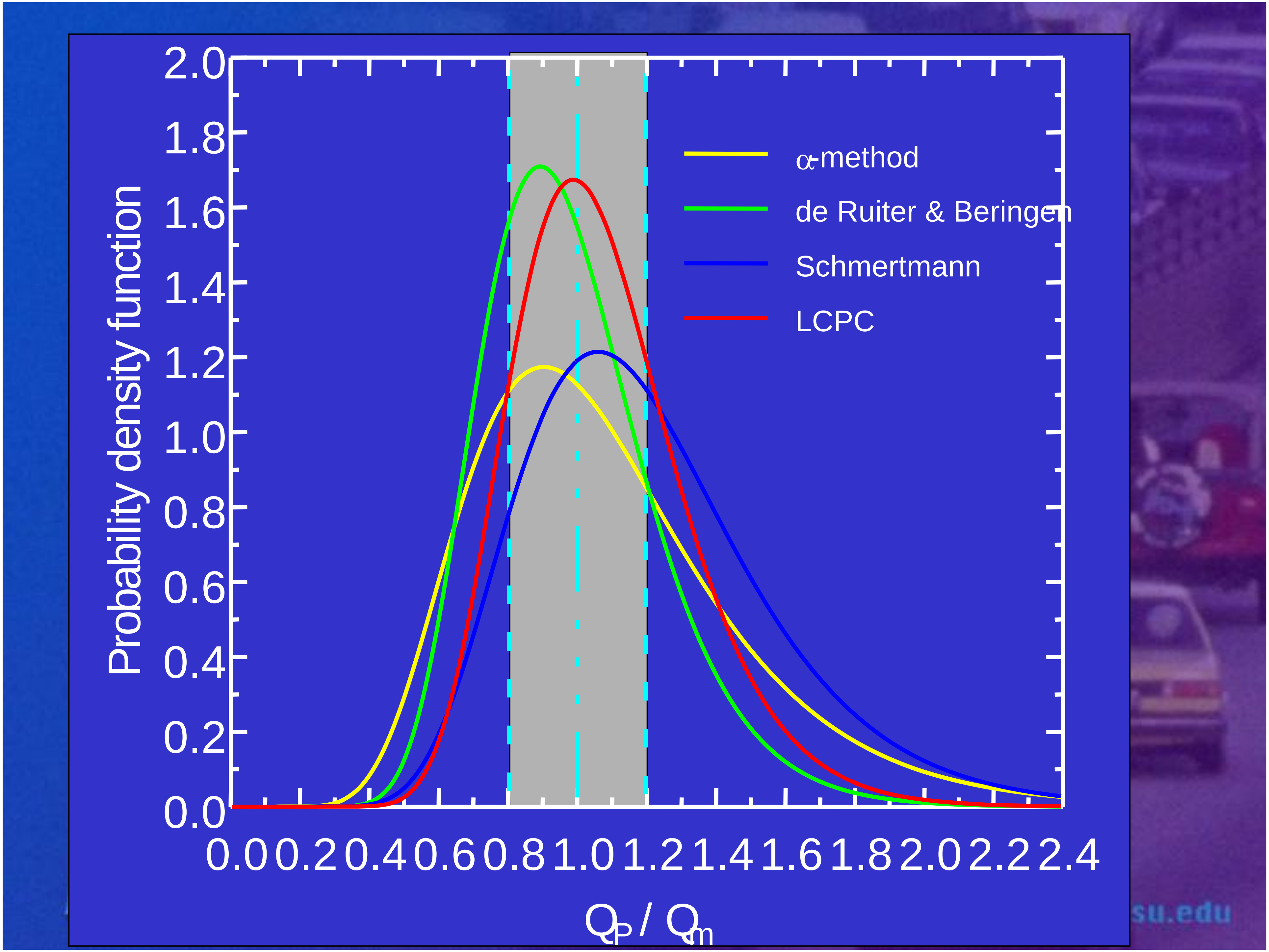
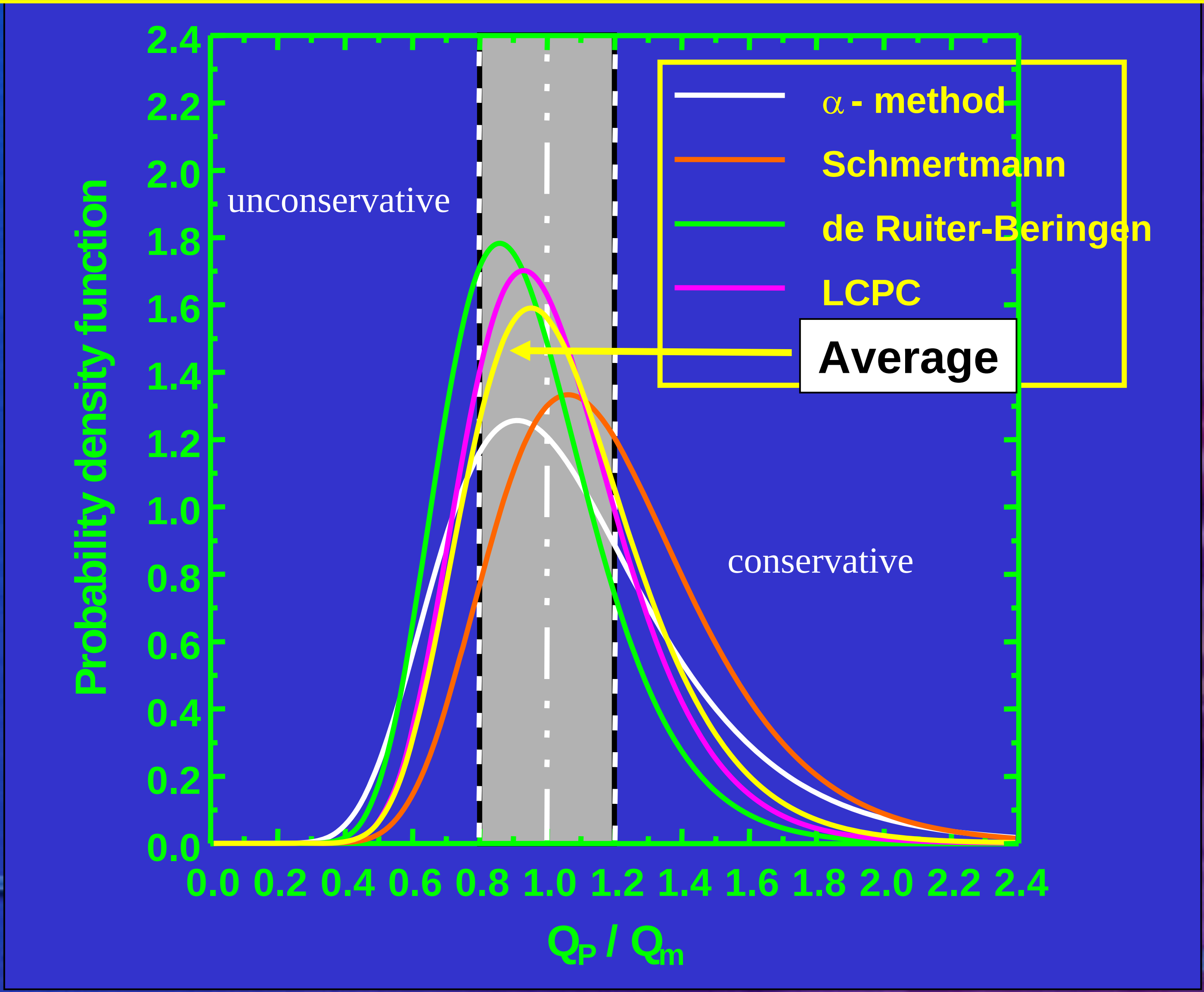
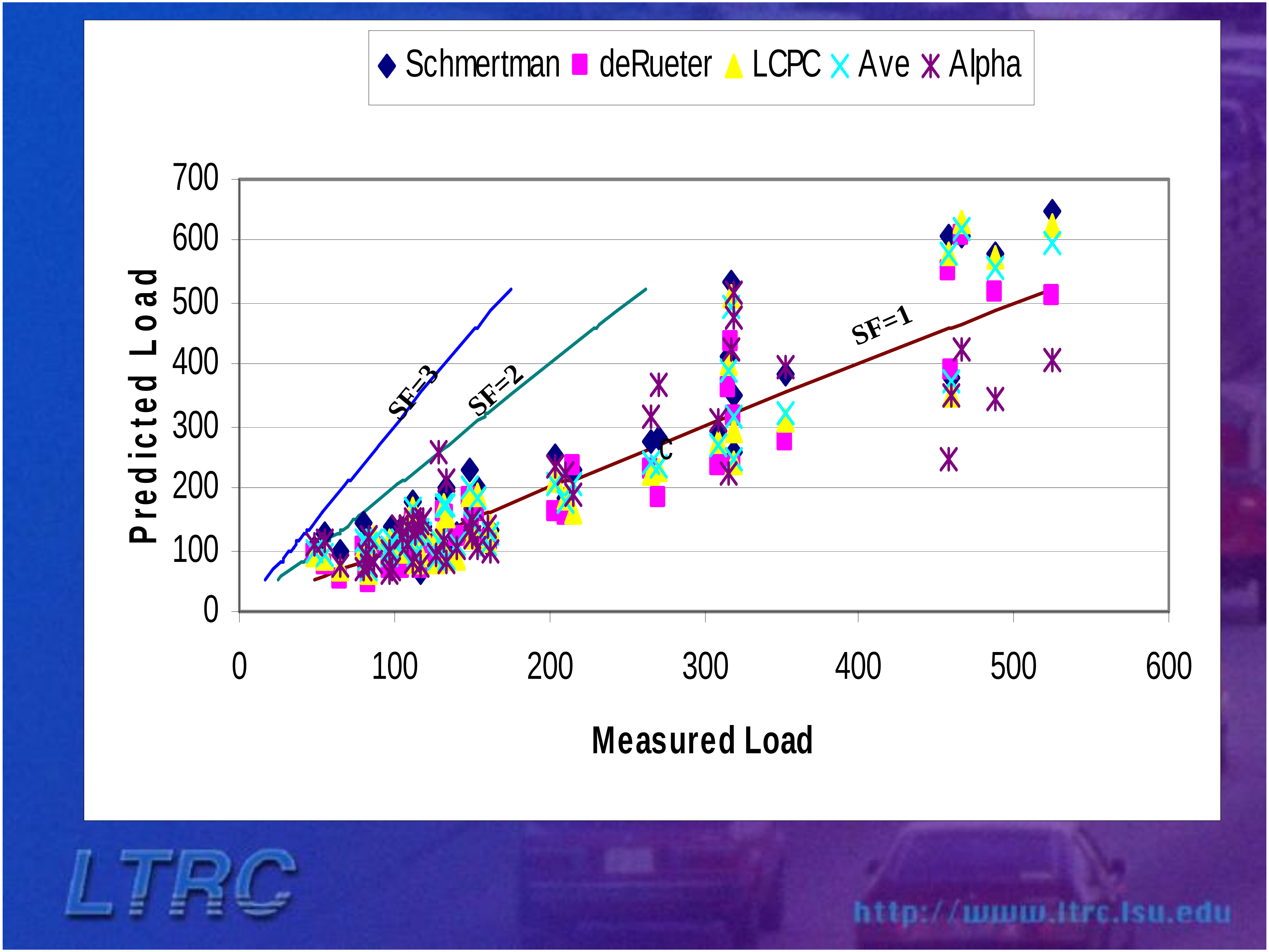


2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Probability density function
α-method
de Ruiter & Beringen
Schmertmann
LCPC
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4
Q_P / Q_m
su.edu

Statistical Analysis: Including Average of Methods



LT... rc.lsu.edu


Schmertman
deRueter
LCPC
Ave
Alpha
Predicted Load
Measured Load
SF=3
SF=2
SF=1
0
100
200
300
400
500
600
700
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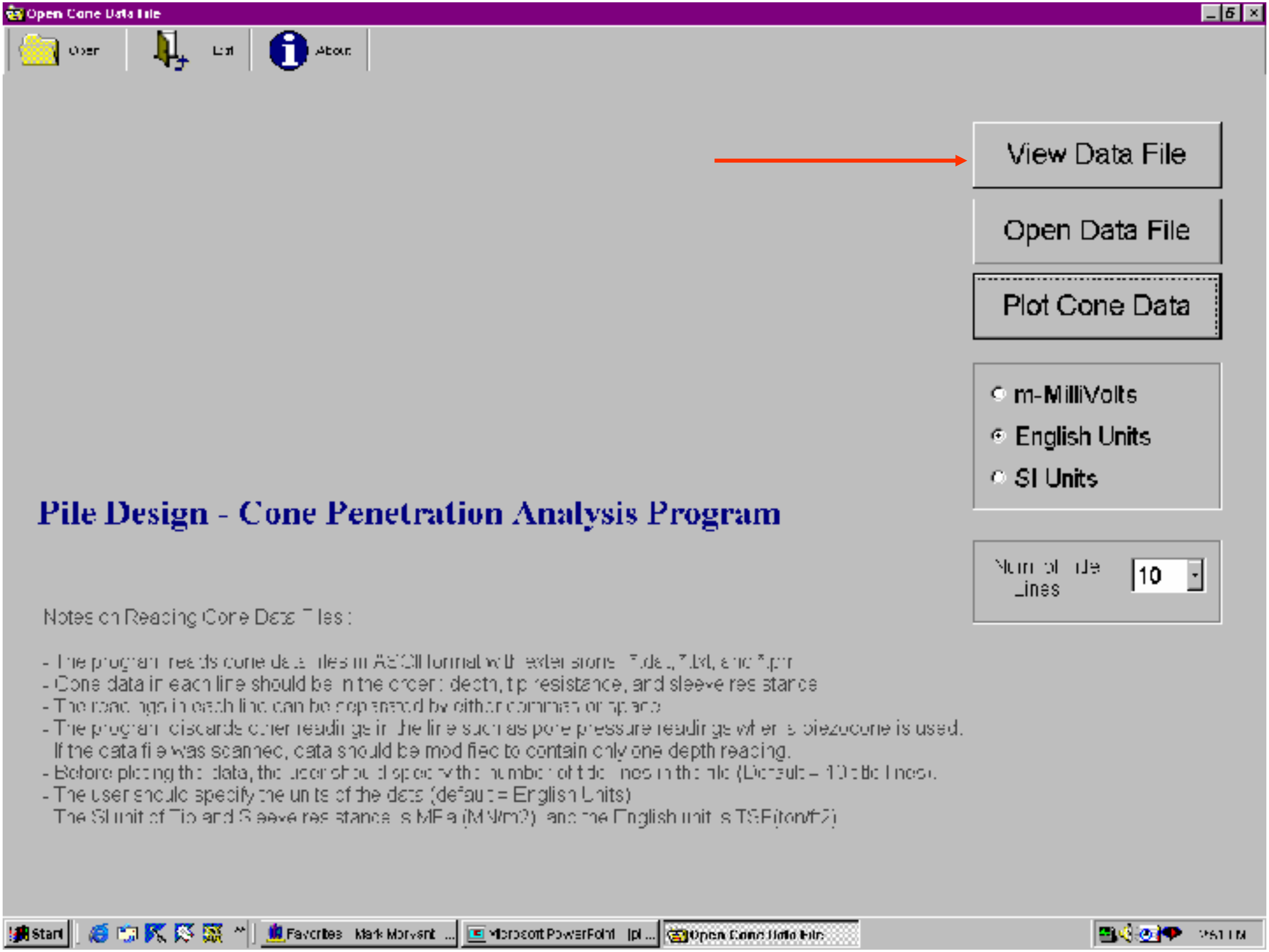
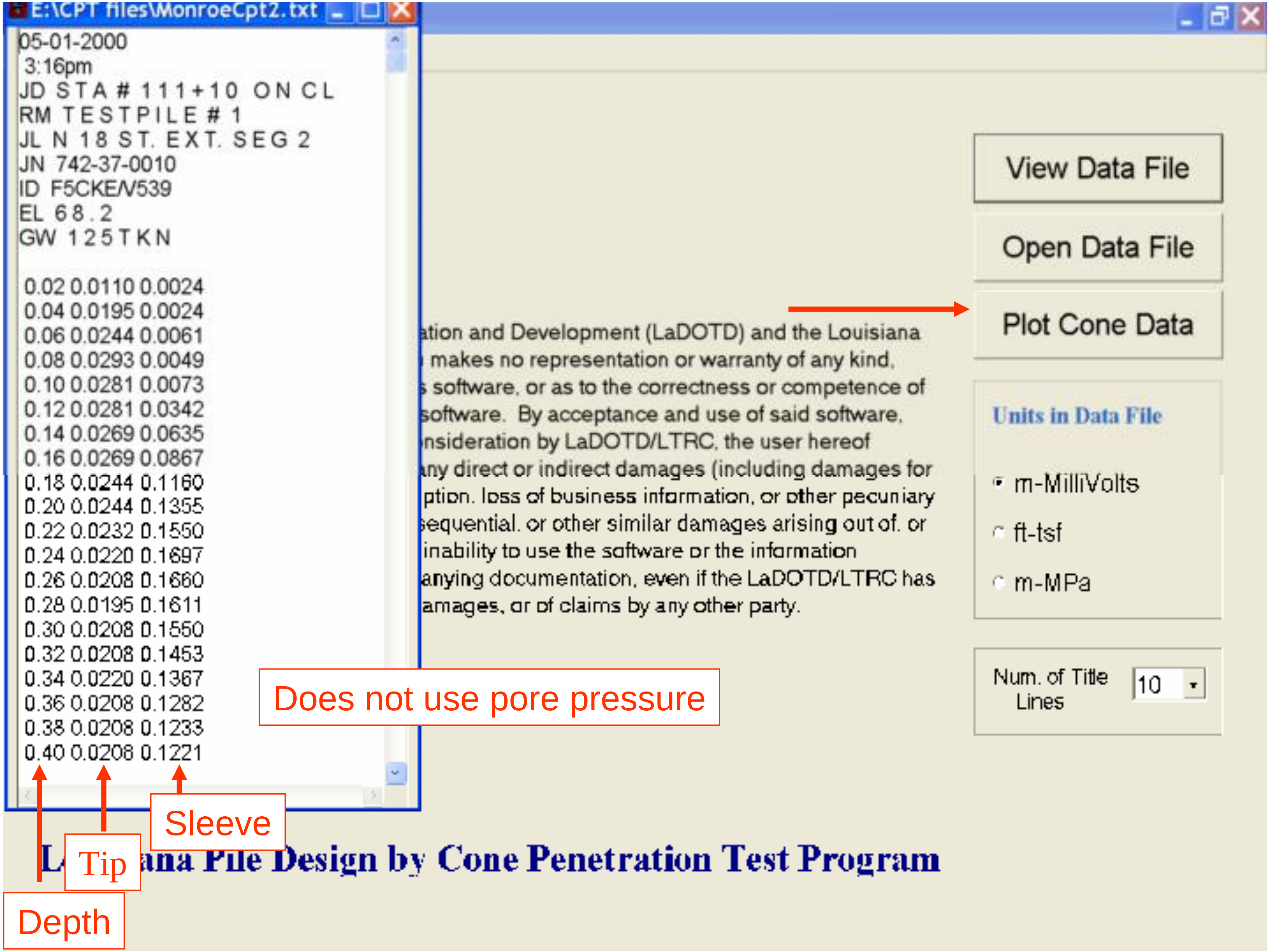
DOTD Design Policy for Piles

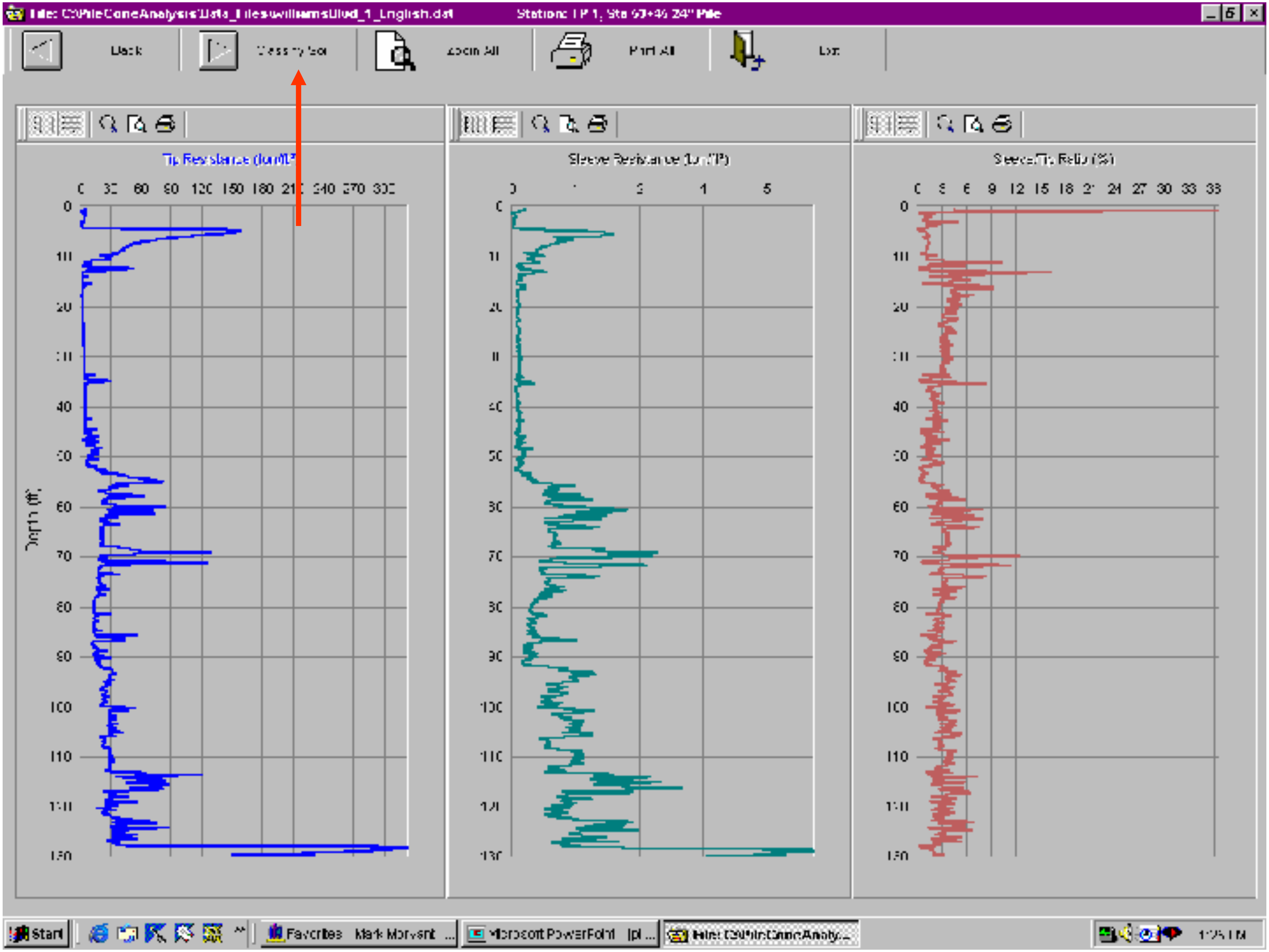
- AASHTO Design Codes
  - WSD (foundations)
  - LFD (structures)
  - LRFD (proposed)
- Safety Factor on Load Capacity (WSD)
  - 3.0 without test piles
  - 2.0 with test pile verification
- Current Policy: CPT for Design
  - CPT included into bid plans
    - Plan length determined by CPT Average of Methods
  - Boring Data Correlation
  - Test Pile Correlation

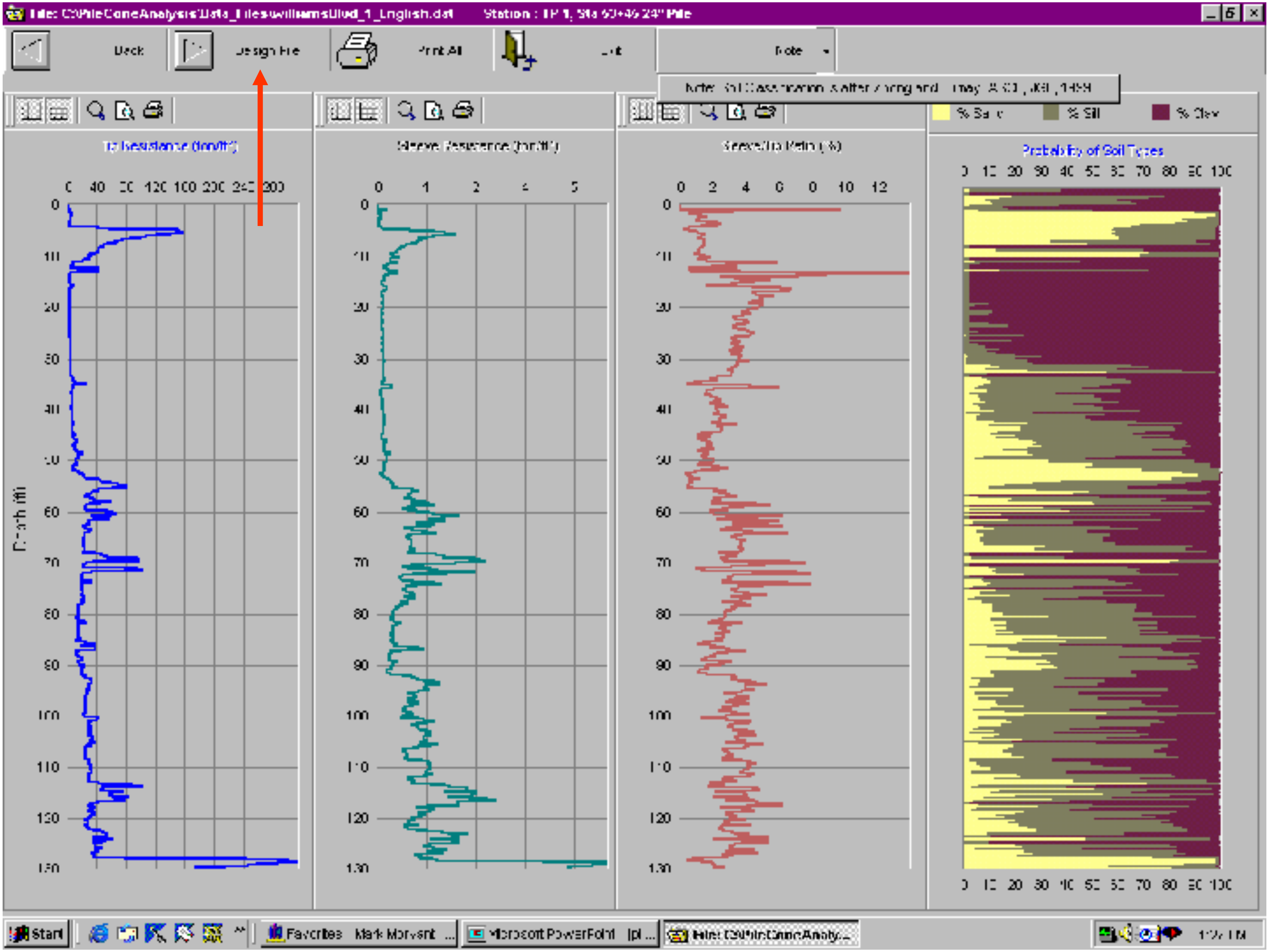
Pile Design Program

Available for download: www.ltrc.lsu.edu

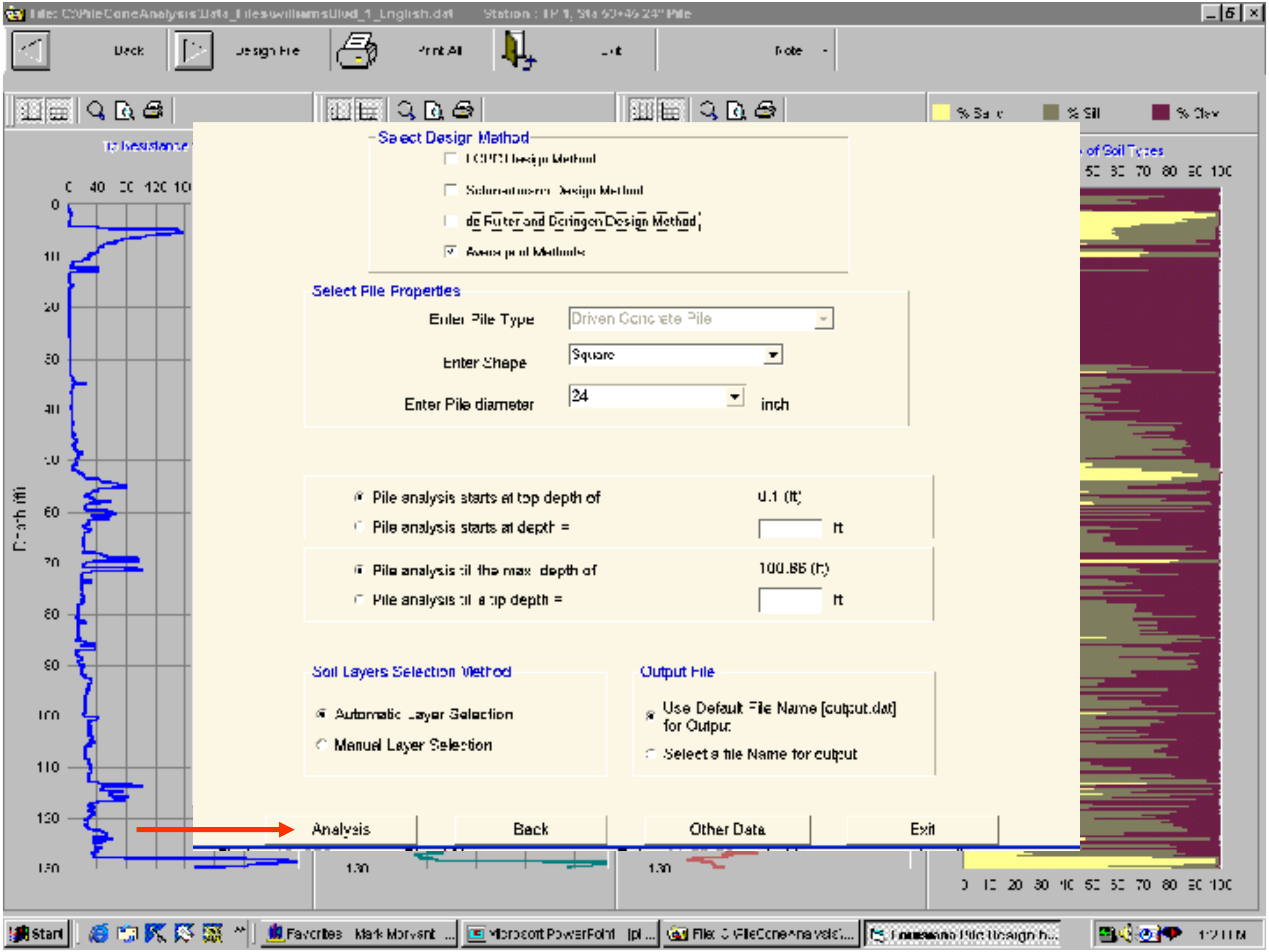

Open Cone Data File
View Data File
Open Data File
Plot Cone Data
m-MilliVolts
English Units
SI Units
10
Pile Design - Cone Penetration Analysis Program
Notes on Reading Cone Data Files :
- Cone data in each line should be in the order : depth, tip resistance, and sleeve resistance
- The program discards other readings in the line such as pore pressure readings when a piezocone is used.
If the data file was scanned, data should be modified to contain only one depth reading.
- The user should specify the units of the data (default = English Units)

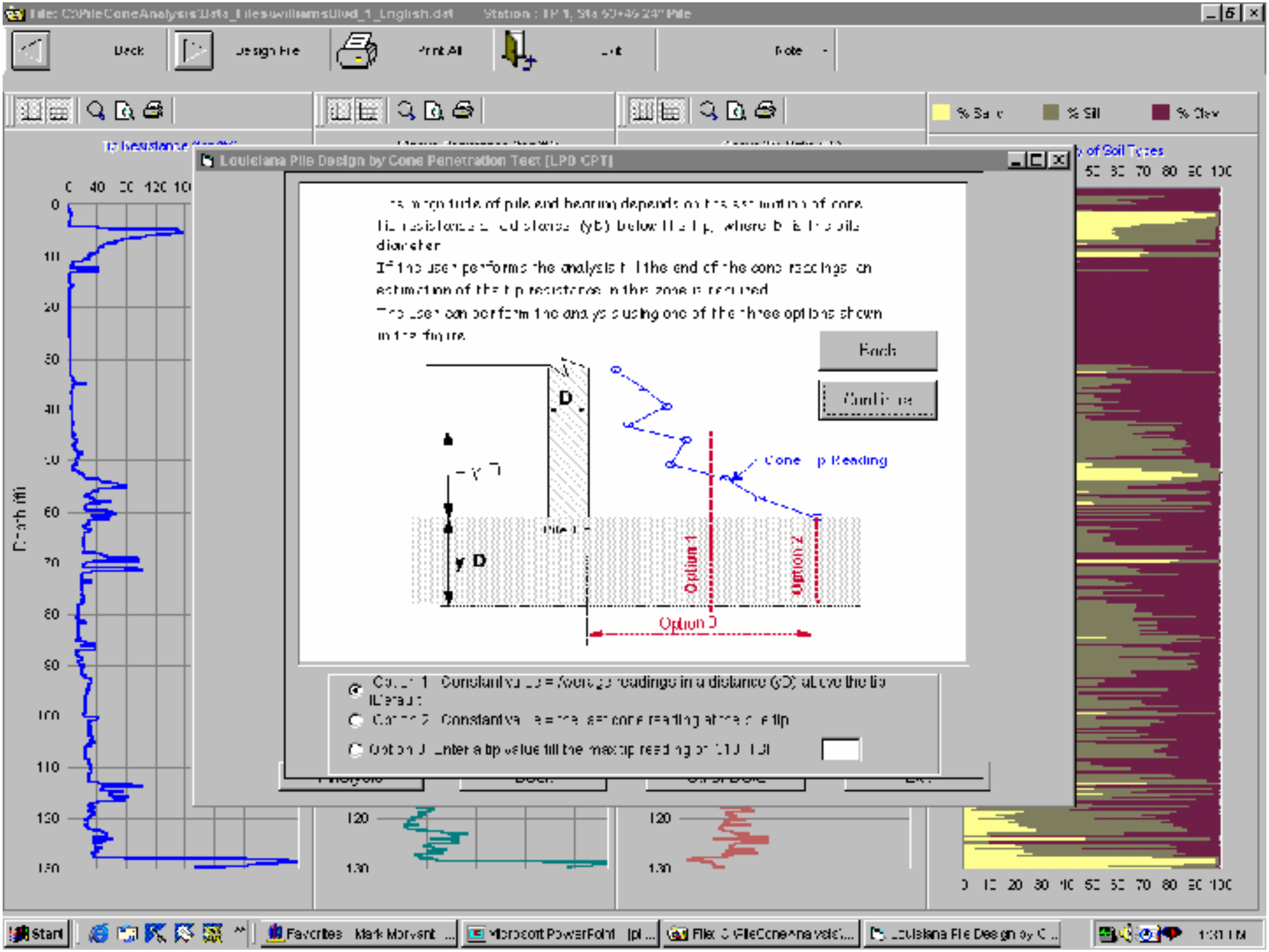

E:\CPT files\MonroeCpt2.txt
05-01-2000
3:16pm
JD STA # 111+10 ON CL
RM TESTPILE # 1
JL N 18 ST. EXT. SEG 2
JN 742-37-0010
ID F5CKE/V539
EL 68.2
GW 125TKN
0.02 0.0110 0.0024
0.04 0.0195 0.0024
0.06 0.0244 0.0061
0.08 0.0293 0.0049
0.10 0.0281 0.0073
0.12 0.0281 0.0342
0.14 0.0269 0.0635
0.16 0.0269 0.0867
0.18 0.0244 0.1160
0.20 0.0244 0.1355
0.22 0.0232 0.1550
0.24 0.0220 0.1697
0.26 0.0208 0.1660
0.28 0.0195 0.1611
0.30 0.0208 0.1550
0.32 0.0208 0.1453
0.34 0.0220 0.1367
0.36 0.0208 0.1282
0.38 0.0208 0.1233
0.40 0.0208 0.1221
View Data File
Open Data File
Plot Cone Data
ation and Development (LaDOTD) and the Louisiana
makes no representation or warranty of any kind,
software, or as to the correctness or competence of
software. By acceptance and use of said software,
nsideration by LaDOTD/LTRC, the user hereof
any direct or indirect damages (including damages for
ption, loss of business information, or other pecuniary
sequential, or other similar damages arising out of, or
inability to use the software or the information
anying documentation, even if the LaDOTD/LTRC has
amages, or of claims by any other party.
Units in Data File
m-MilliVolts
ft-tsf
m-MPa
Num. of Title Lines
10
Does not use pore pressure
Sleeve
Tip
Depth
ana Pile Design by Cone Penetration Test Program

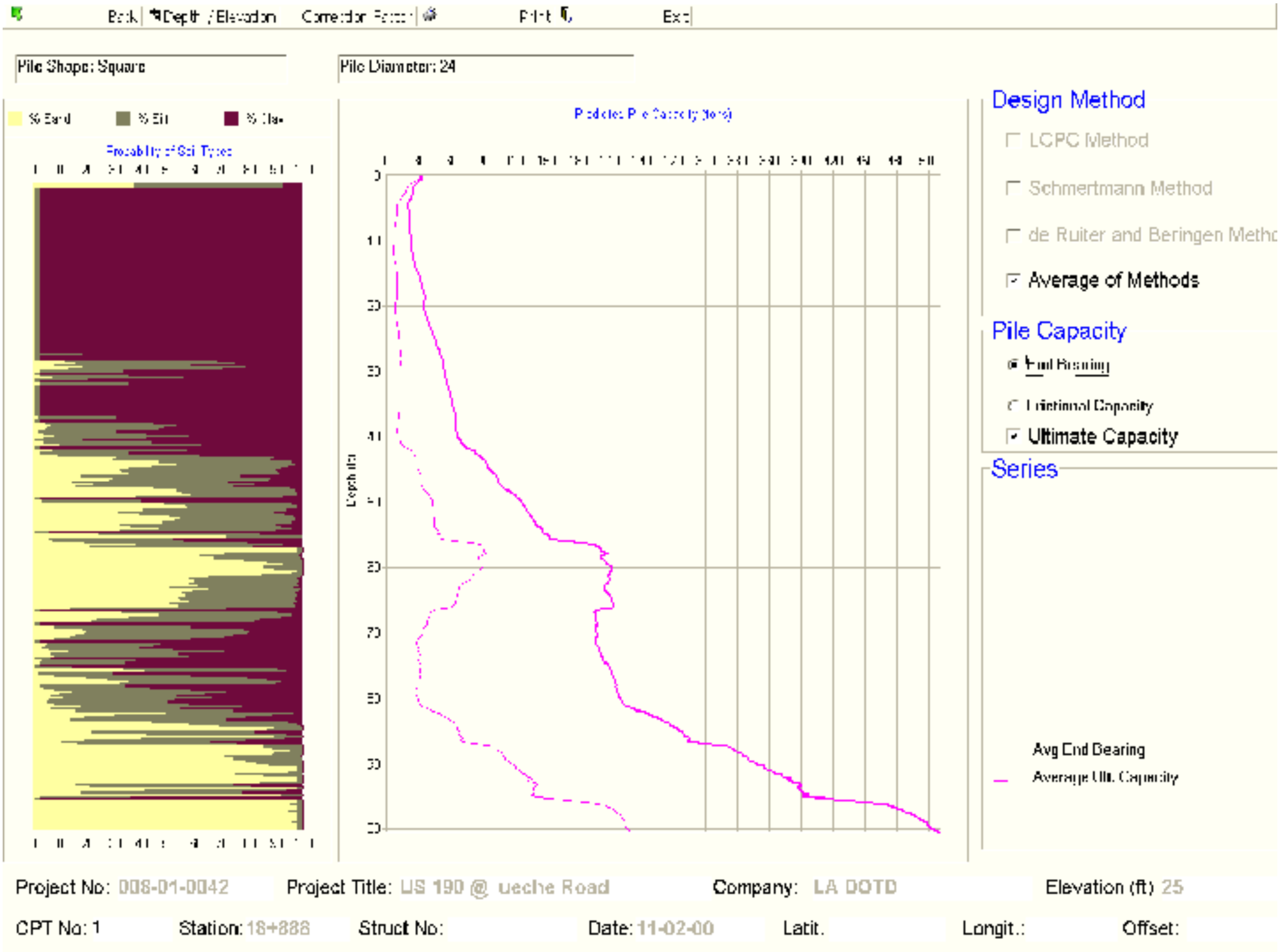

Back
Zoom All
Print All
Exit
Tip Resistance (ton/ft²)
Sleeve Resistance (ton/ft²)
Sleeve/Tip Ratio (%)
Depth (ft)
Start



Design File
Print All
Note
Sleeve Resistance (ton/ft²)
Probability of Soil Types
% Silt
Start
Favorites


Back
Design File
Print All
Exit
Select Design Method
LCPC Design Method
Schmertmann Design Method
de Ruiter and Beringen Design Method
Average of Methods
Select Pile Properties
Enter Pile Type
Driven Concrete Pile
Enter Shape
Square
Enter Pile diameter
24
inch
Pile analysis starts at top depth of
0.1 (ft)
Pile analysis starts at depth =
ft
Pile analysis til the max. depth of
100.86 (ft)
Pile analysis til a tip depth =
ft
Soil Layers Selection Method
Automatic Layer Selection
Manual Layer Selection
Output File
Use Default File Name [output.dat] for Output
Select a file Name for output
Analysis
Back
Other Data
Exit
% Sand
% Silt
% Clay
of Soil Types
Depth (ft)
Start


Louisiana Pile Design by Cone Penetration Test [LPD CPT]
Print All
Back
Continue
Cone Tip Reading
D
y D
Option 1
Option 2
Option 3
% Silt
Start


Back
Depth / Elevation
Correlation Factor
Print
Exit
Pile Shape: Square
Pile Diameter: 24
% Sand
% Silt
% Clay
Probability of Soil Types
Predicted Pile Capacity (tons)
Depth (ft)
Design Method
LCPC Method
Schmertmann Method
de Ruiter and Beringen Metho
Average of Methods
Pile Capacity
End Bearing
Frictional Capacity
Ultimate Capacity
Series
Avg End Bearing
Average Ult. Capacity
Project No: 008-01-0042
Project Title: US 190 @ ueche Road
Company: LA DOTD
Elevation (ft) 25
CPT No: 1
Station: 18+888
Struct No:
Date: 11-02-00
Latit.
Longit.:
Offset:

Bayou Lafourche Bridge at Clotilda
Mathews, LA
Lafourche Parish

Foundation:	24 " Test Pile	16" Test Pile
Required Load:	105.6 Tons	102.2 Tons
Tip Elevation:	-41.5	-62.2
Load Results:	66 Tons	> 154 Tons (Did not fail)

CPT Application: Correlate with load test to determine pile order lengths

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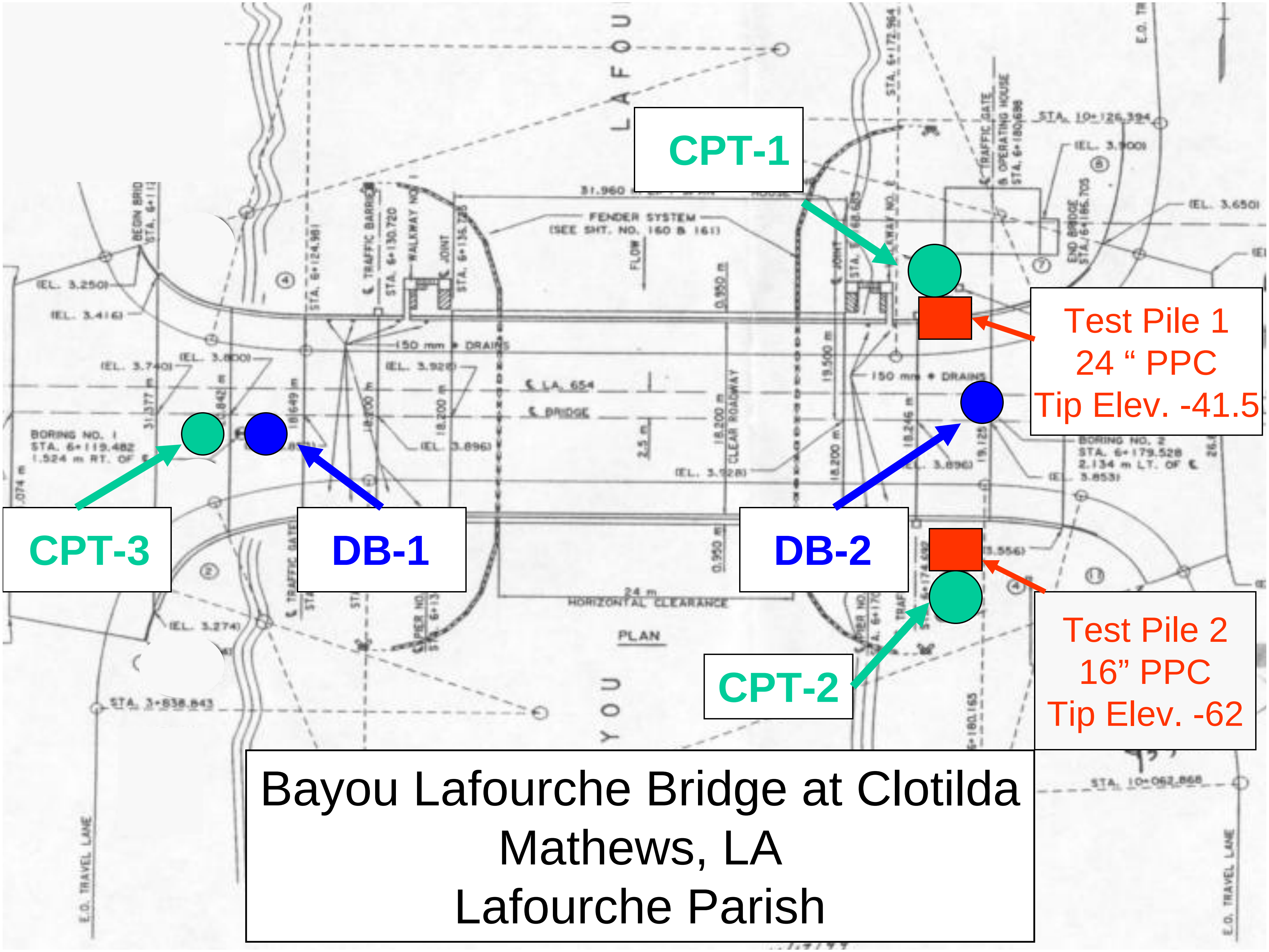
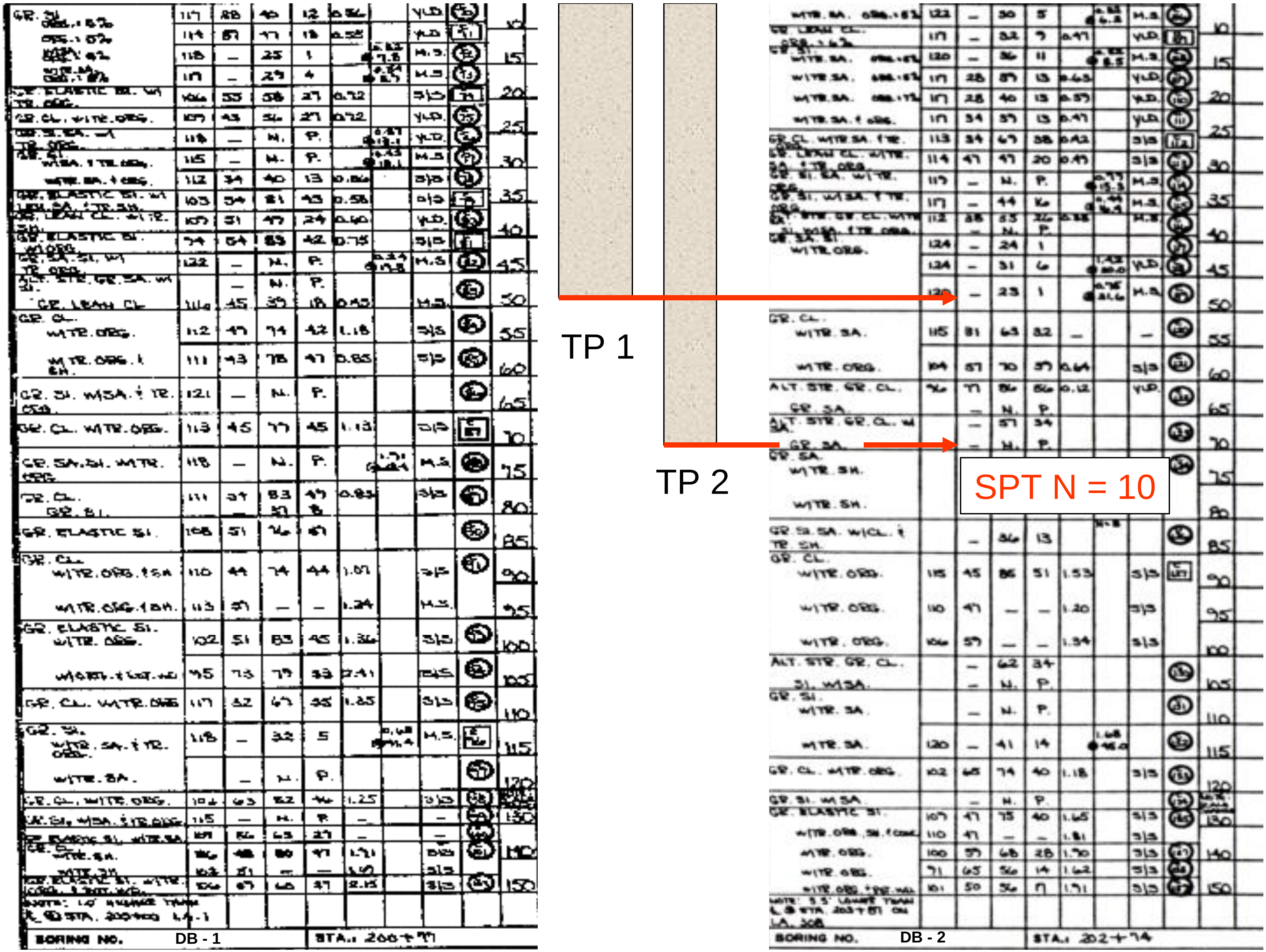
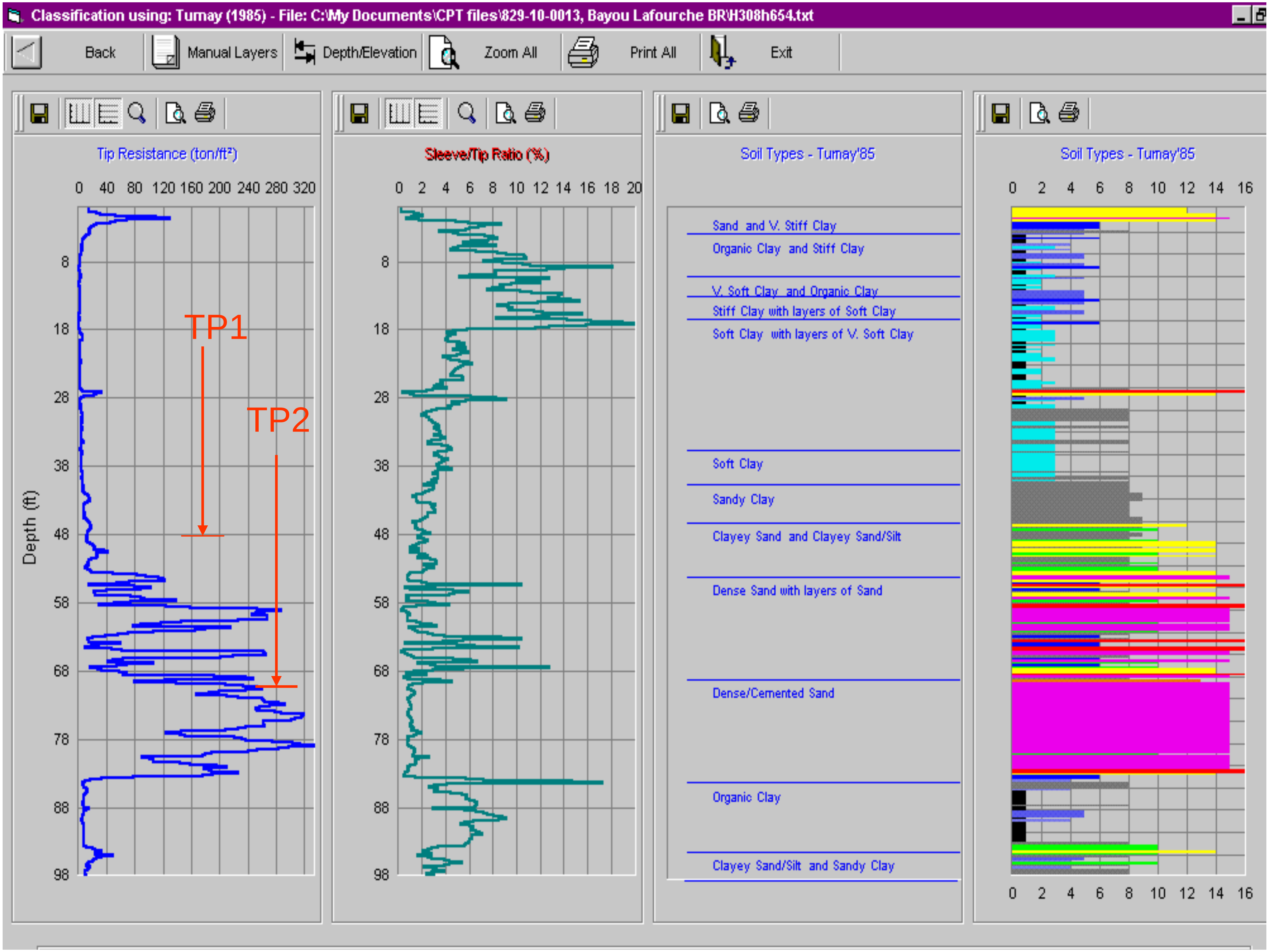
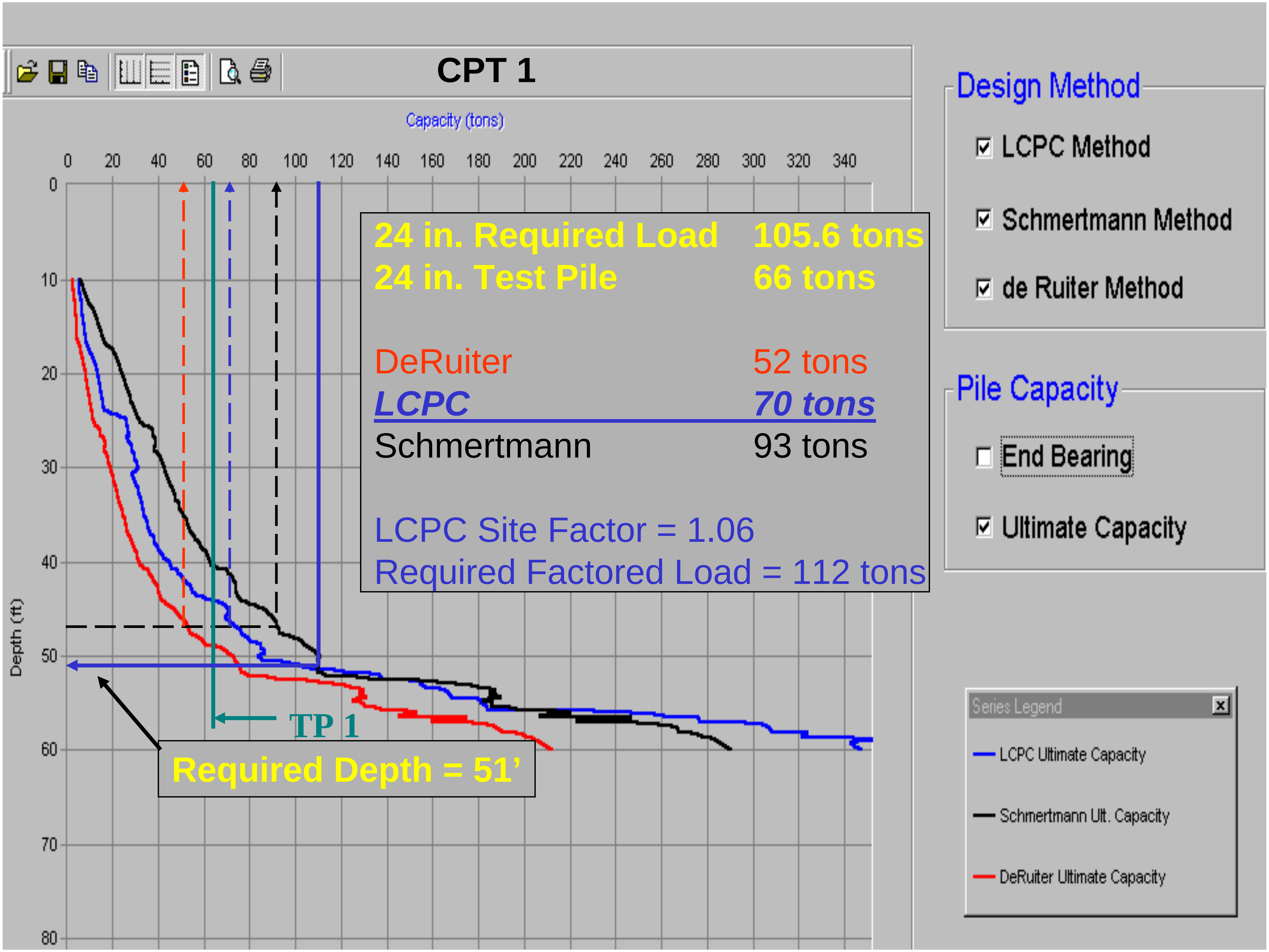


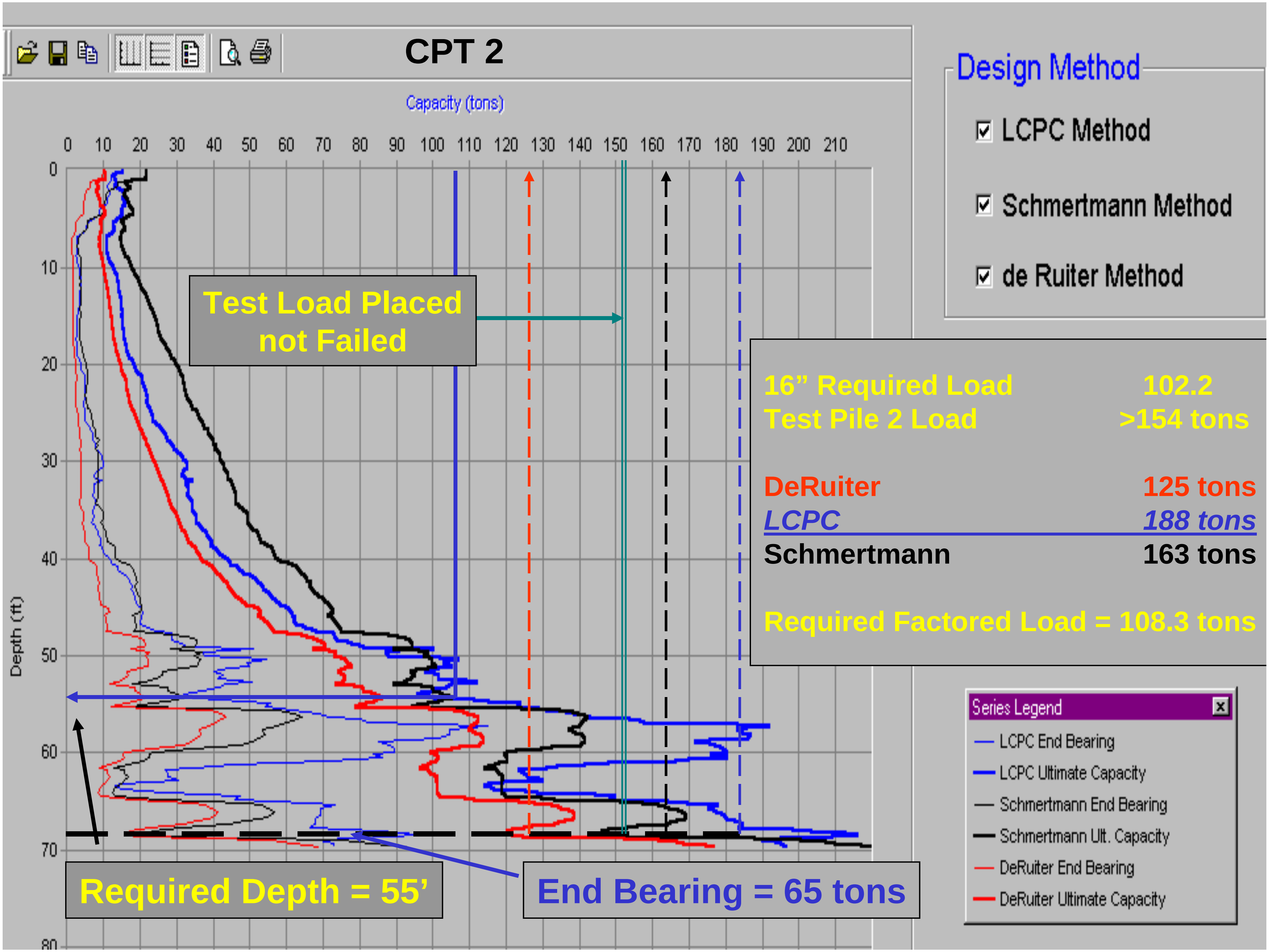
Bayou Lafourche Bridge at Clotilda
Mathews, LA
Lafourche Parish


TP 1
TP 2
SPT N = 10
BORING NO. DB - 1
BORING NO. DB - 2

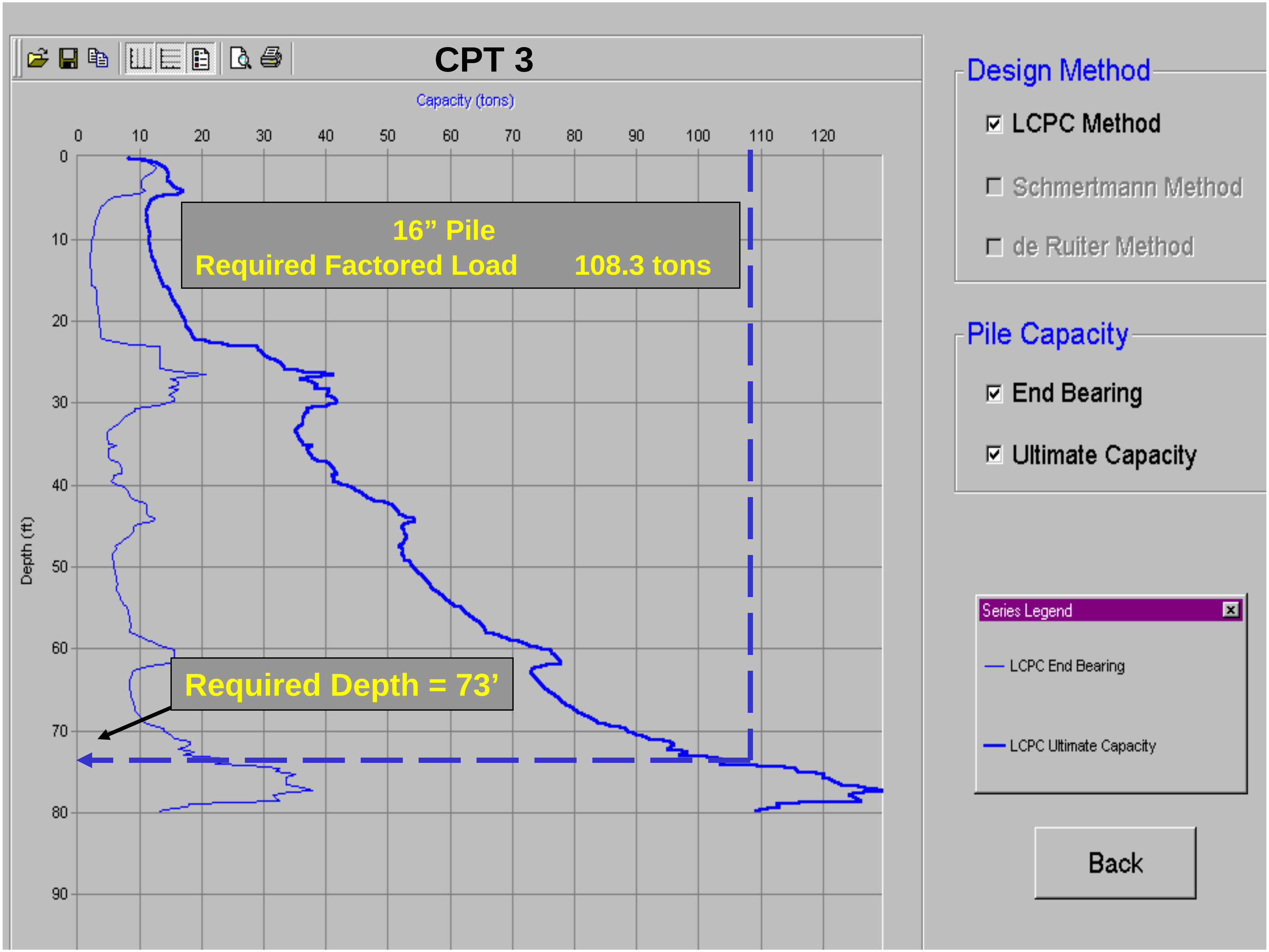

Classification using: Tumay (1985) - File: C:\My Documents\CPT files\829-10-0013, Bayou Lafourche BR\H308h654.txt
Back
Manual Layers
Depth/Elevation
Zoom All
Print All
Exit
Tip Resistance (ton/ft²)
0 40 80 120 160 200 240 280 320
Depth (ft)
8 18 28 38 48 58 68 78 88 98
TP1
TP2
Sleeve/Tip Ratio (%)
0 2 4 6 8 10 12 14 16 18 20
Soil Types - Tumay'85
Sand and V. Stiff Clay
Organic Clay and Stiff Clay
V. Soft Clay and Organic Clay
Stiff Clay with layers of Soft Clay
Soft Clay with layers of V. Soft Clay
Soft Clay
Sandy Clay
Clayey Sand and Clayey Sand/Silt
Dense Sand with layers of Sand
Dense/Cemented Sand
Organic Clay
Clayey Sand/Silt and Sandy Clay
Soil Types - Tumay'85
0 2 4 6 8 10 12 14 16



CPT 1
Capacity (tons)
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340
Depth (ft)
0 10 20 30 40 50 60 70 80
24 in. Required Load 105.6 tons
24 in. Test Pile 66 tons
DeRuiter 52 tons
LCPC 70 tons
Schmertmann 93 tons
LCPC Site Factor = 1.06
Required Factored Load = 112 tons
TP 1
Required Depth = 51'
Design Method
LCPC Method
Schmertmann Method
de Ruiter Method
Pile Capacity
End Bearing
Ultimate Capacity
Series Legend
LCPC Ultimate Capacity
Schmertmann Ult. Capacity
DeRuiter Ultimate Capacity



CPT 2
Capacity (tons)
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210
Depth (ft)
0 10 20 30 40 50 60 70 80
Test Load Placed not Failed
Required Depth = 55'
End Bearing = 65 tons
Design Method
LCPC Method
Schmertmann Method
de Ruiter Method
16" Required Load 102.2
Test Pile 2 Load >154 tons
DeRuiter 125 tons
LCPC 188 tons
Schmertmann 163 tons
Required Factored Load = 108.3 tons
Series Legend
LCPC End Bearing
LCPC Ultimate Capacity
Schmertmann End Bearing
Schmertmann Ult. Capacity
DeRuiter End Bearing
DeRuiter Ultimate Capacity


CPT 3
Capacity (tons)
Depth (ft)
16” Pile
Required Factored Load 108.3 tons
Required Depth = 73’
Design Method
LCPC Method
Schmertmann Method
de Ruiter Method
Pile Capacity
End Bearing
Ultimate Capacity
Series Legend
LCPC End Bearing
LCPC Ultimate Capacity
Back

CPT vs. Conventional Drilling Method

Deep Foundations

	Conventional Soil Exploration	CPT
Manpower	Crew: 4-5	Crew: 2-4
Time	Field: 6-8 / week Lab: 2-4 weeks	6-8 / day
Equipment	Drilling rig 3 support vehicles Lab equipment	CPT truck 1 support vehicle

CPT vs. Conventional Drilling Method
(1998)

	Typical Cost	
	Conventional Soil Exploration	CPT
DOTD	$45/ft - $50/ft	$14/ft
Consultant	$50/ft - $60/ft	$28/ft

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CPT Benefits

- **Cost Savings**
  - **Field exploration costs savings**
  - **Laboratory costs savings**
- **Time Savings**
- **Better subsurface stratification**
  - **Finer Detail**
  - **More locations**
- **Accuracy**
  - **Reduced number of test piles**
  - **Shorter pile lengths**


Questions ?
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