Reverse Battered Piles to Arrest Landslide Movement

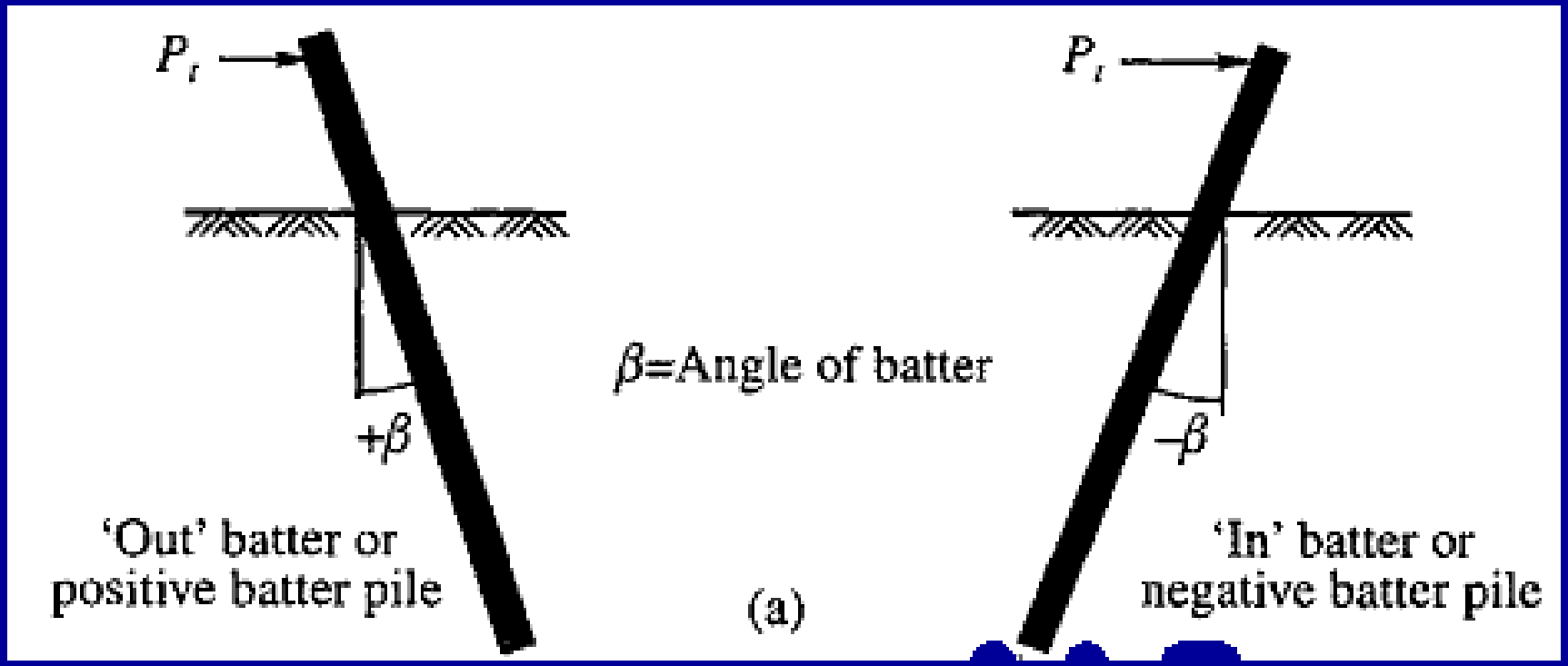
Joe Carte

TODAY'S PRESENTATION

- Introduction
- Discussion on Design
- Case History

Introduction

Introduction



Introduction

ANALYSIS OF STATIC LATERAL LOAD TEST OF BATTERED PILE GROUP AT I-10 TWIN SPAN BRIDGE

A Thesis

Submitted to the Graduate School of the
Louisiana State University and
Agriculture and Mechanical College
in partial fulfillment of the
requirements for the degree of
Mater of Science in Civil Engineering

in

The Department of Civil and Environment Engineering

By
Binay Pathak
B.Tech., National Institute of Technology, Rourkela, India (2004)
May, 2011

1953; Murthy 1964; and Prakash and Subramanyam,1965). Kim and Brungraber (1976) and Manoliu et al. (1977) also performed full-scale tests on battered piles. It was reported that negative batter piles offer more resistance than positive batter piles which was also agreed by Ranjan et al. (1980) based on their laboratory test result. Lu (1981) also supported the concept and explained that the soil reaction at ground level is zero for a positive batter pile and maximum for a negative batter pile, indicating that the upper layer soil support in a negative batter is enormous so the negative batter pile has larger lateral resistance.

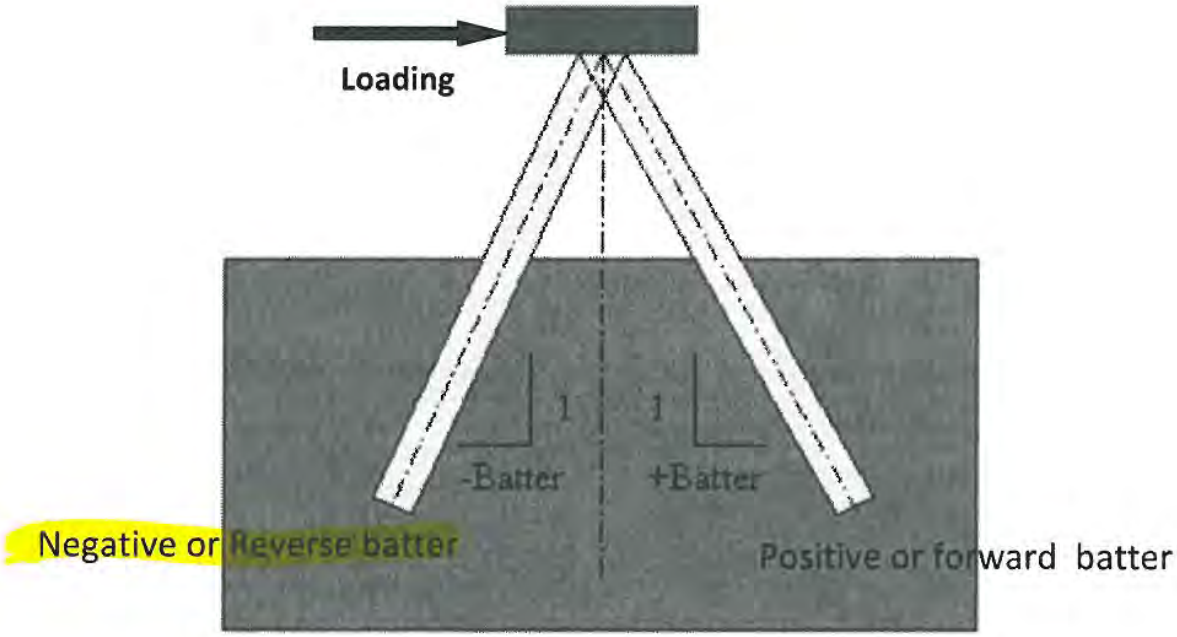
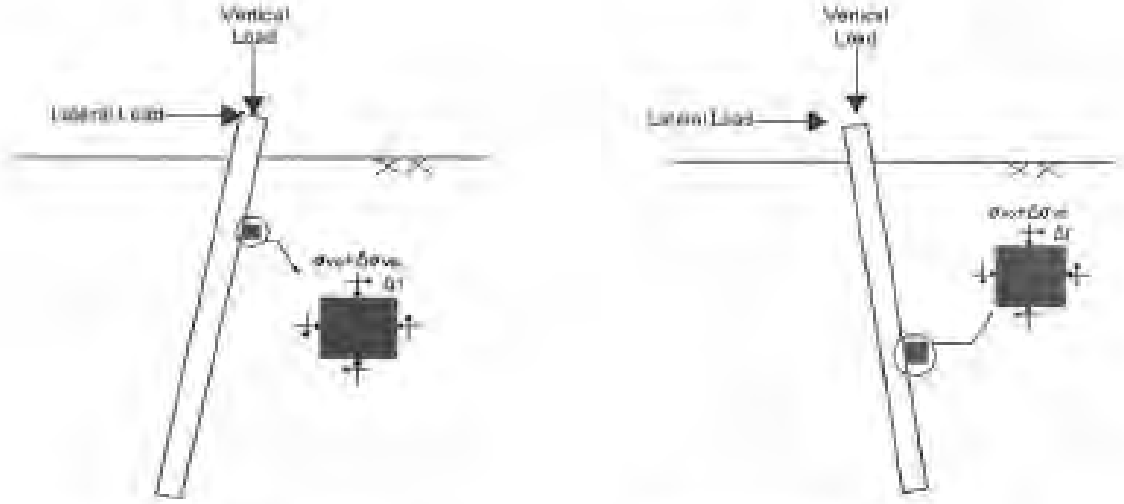


Figure 2.15: Battered pile categorized into positive and negative battered pile

Introduction

Based on a centrifugal tests on laterally loaded single battered piles in sand with different relative density, Zhang et al. (1999) inferred that the effect of pile inclination on the lateral resistance is more effective in the dense sand and the lateral resistance of pile increases with the increment of the batterness of reversed or negative battered pile, whereas the lateral resistance decreases with the increment of batterness of forwarded or positive battered pile. Similarly, Rajashree and Sitharam (2001) performed a non-linear static analysis for both positive and negative batter piles at different angles (10°-30° inclination) and observed that the lateral deflection predicted at the ground line for a pile in positive batter is more than for vertical pile and less than for a negative batter pile, which agrees with Lu (1981) observation that there is zero lateral resistance for positive battered pile and maximum for negative battered pile at the ground line. Zhang et al. (2002) explained that the lateral resistance of the individual battered

Int



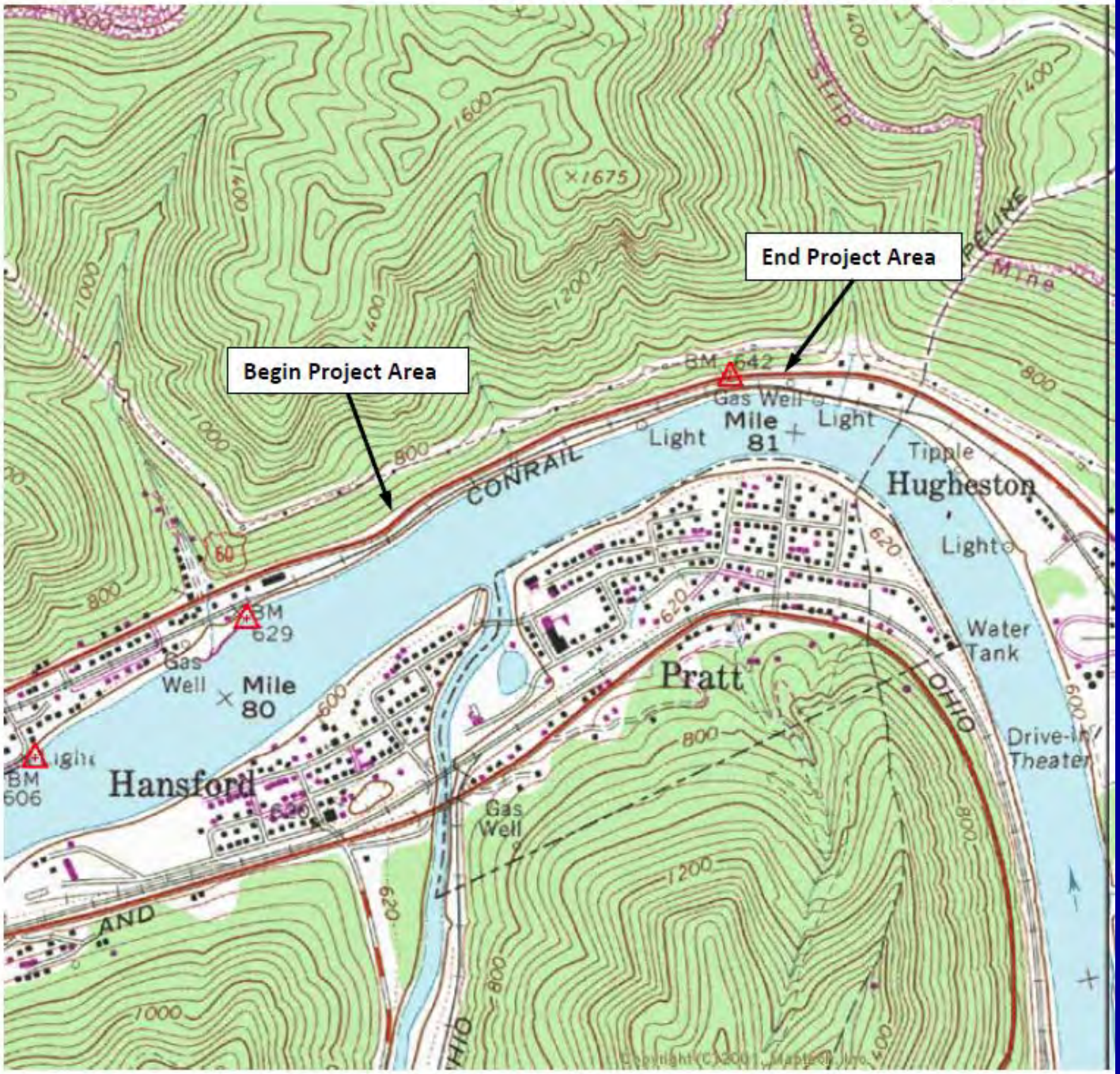
(a) For negative battered pile

(b) For positive battered pile

Figure 2.16: Movement of soil around battered pile (after Zhang et al., 1999)

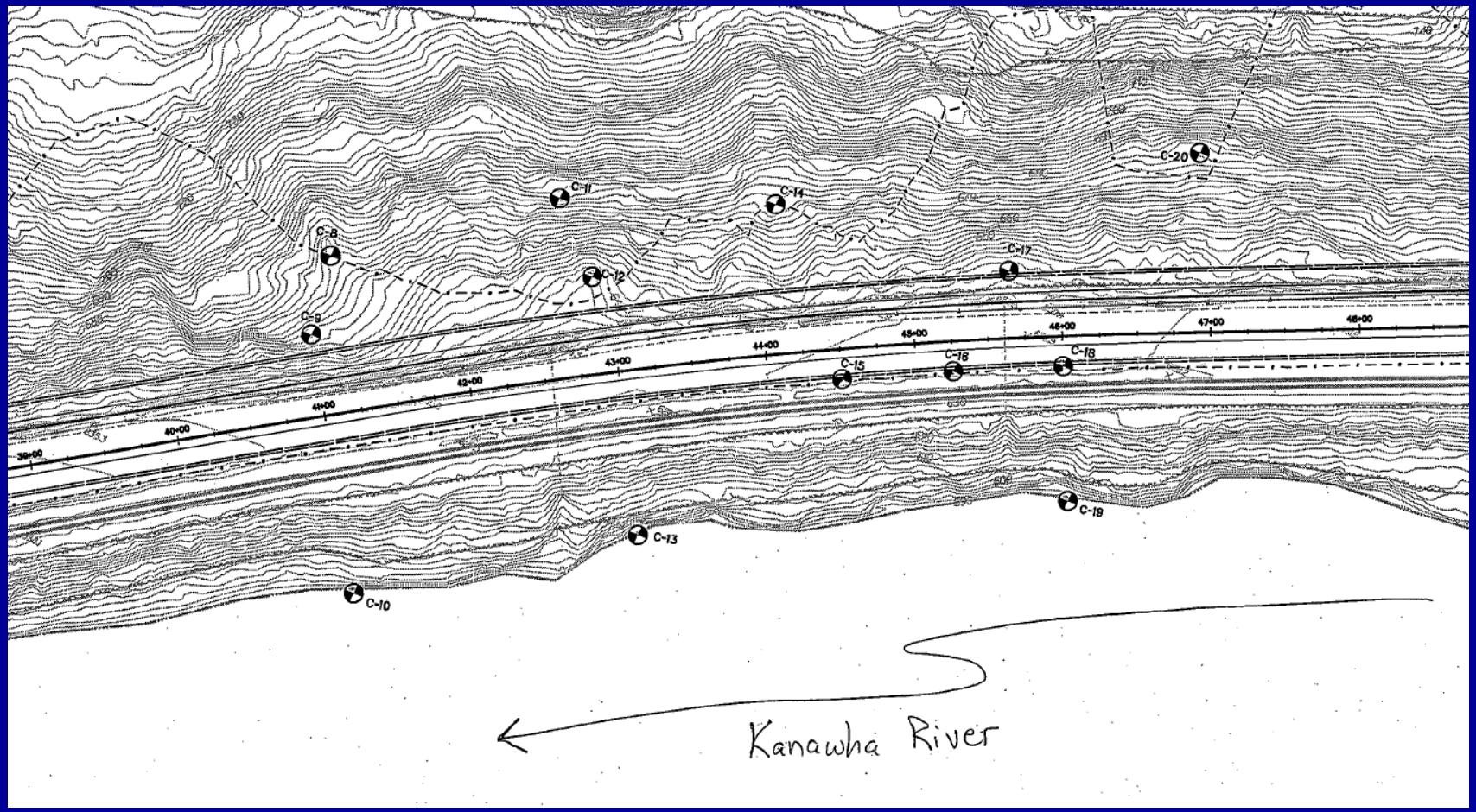
To the contrary, the lateral movement of the positive battered pile will cause an upward movement of soil which will reduce the vertical stress and hence the lateral resistance of the positive battered pile will be smaller than the vertical load. In comparison, the lateral resistance of negative battered pile will have a higher lateral resistance, followed by the vertical pile and positive battered pile will have the least lateral resistance. However, when the vertical load is applied, the lateral resistance of the negative battered pile reduced because of the bending moment by the vertical load component causes an additional lateral defection, whereas the lateral resistance of the positive battered pile since the bending moment caused by the vertical load negates the effect of the lateral load component.

Hughes Creek Landslide Project #: S320- 60/- 38.87 SEC 00



Design

Design


C-8
C-9
C-10
C-11
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C-14
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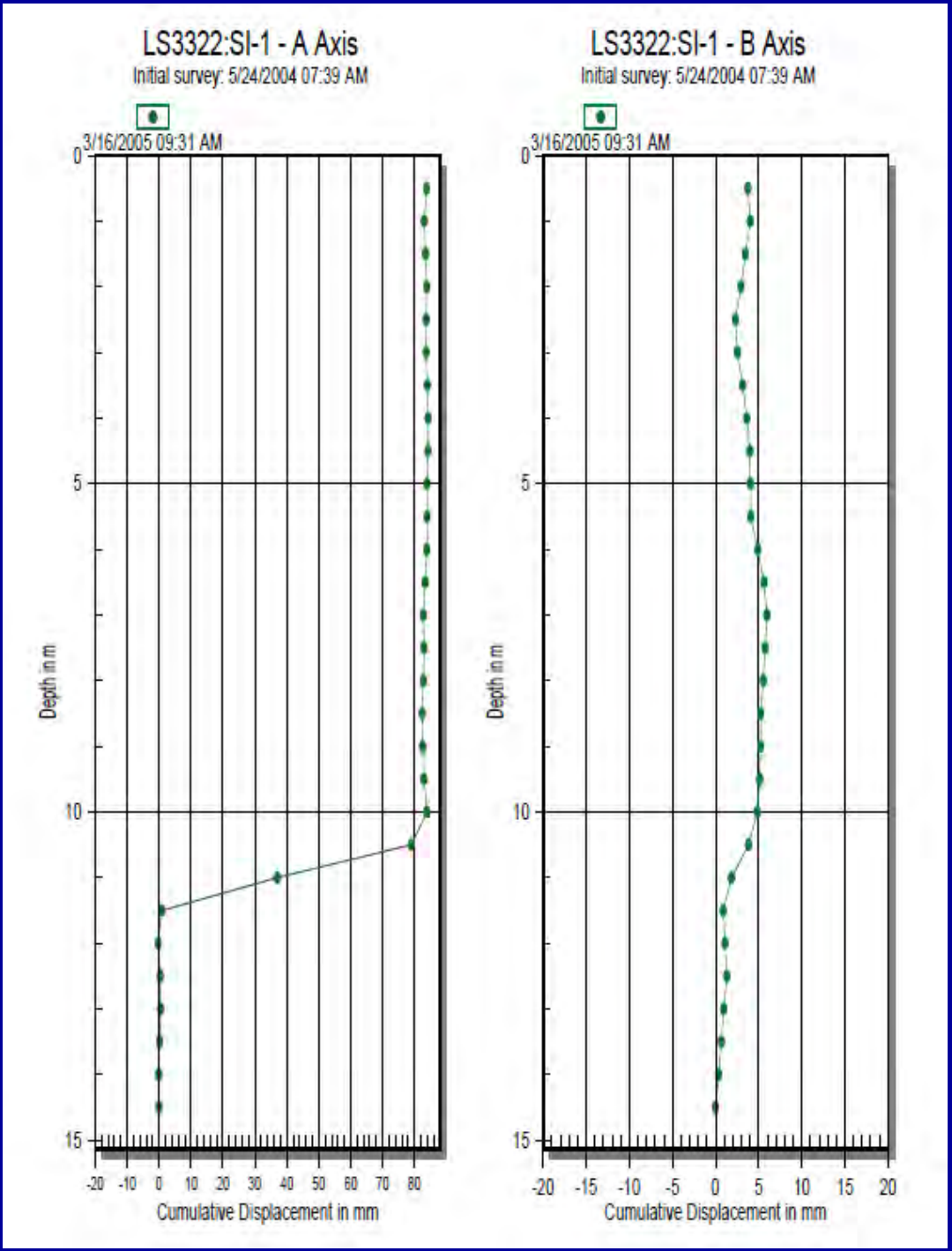
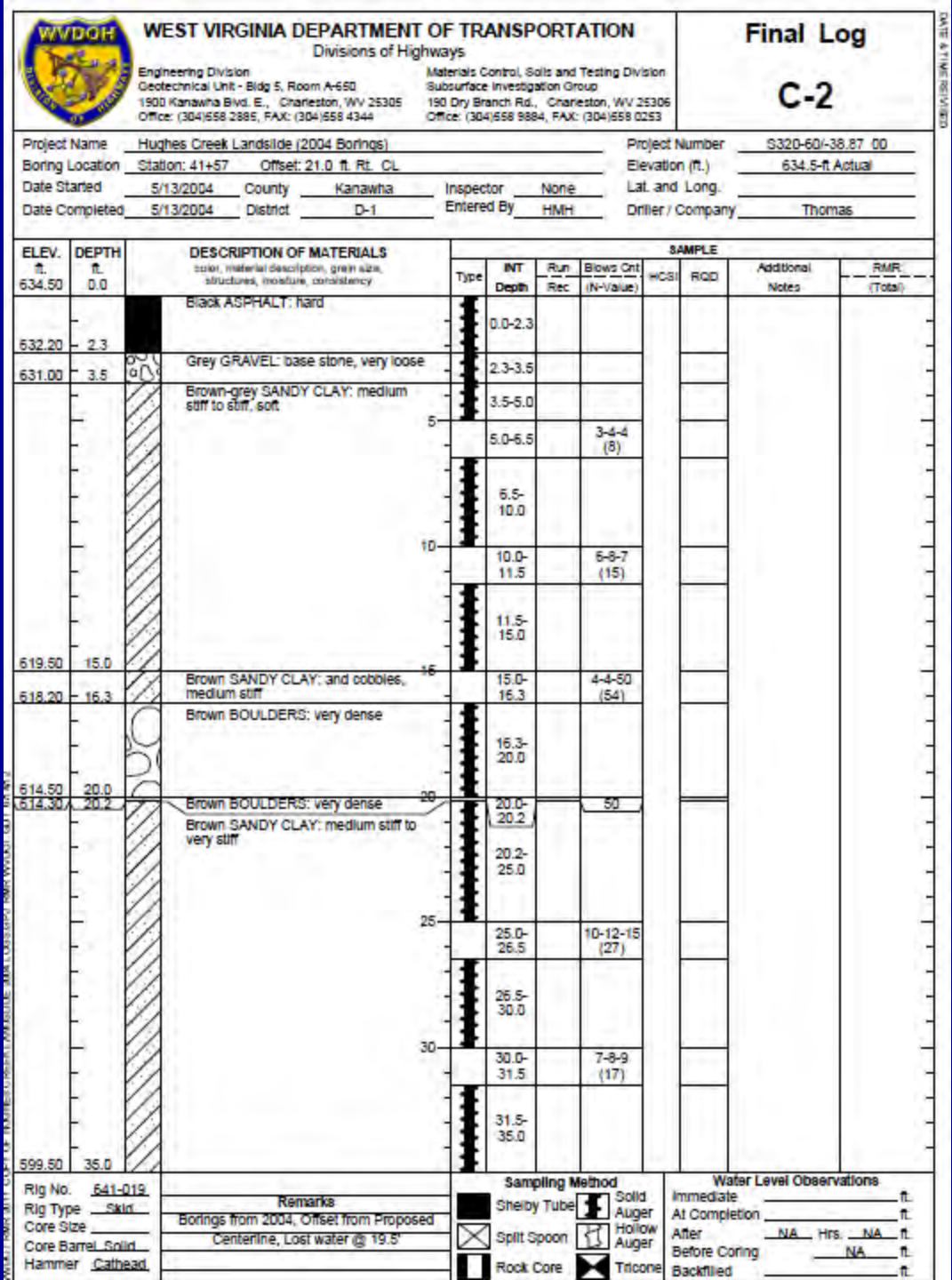
C-16
C-17
C-18
C-19
C-20
39+00
40+00
41+00
42+00
43+00
44+00
45+00
46+00
47+00
48+00
Kanawha River

Design


LS3322:SI-1 - A Axis
Initial survey: 5/24/2004 07:39 AM
3/16/2005 09:31 AM
Depth in m
0
5
10
15
-20 -10 0 10 20 30 40 50 60 70 80
Cumulative Displacement in mm
LS3322:SI-1 - B Axis
Initial survey: 5/24/2004 07:39 AM
3/16/2005 09:31 AM
Depth in m
0
5
10
15
-20 -15 -10 -5 0 5 10 15 20
Cumulative Displacement in mm

Design



WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
Divisions of Highways

Engineering Division
Geotechnical Unit - Bldg 5, Room A-650
1900 Kanawha Blvd. E., Charleston, WV 25305
Office: (304)558 2885, FAX: (304)558 4344

Materials Control, Soils and Testing Division
Subsurface Investigation Group
190 Dry Branch Rd., Charleston, WV 25306
Office: (304)558 9884, FAX: (304)558 0253

Final Log

C-2

Project Name: Hughes Creek Landslide (2004 Borings)
Project Number: S320-60/-38.87 00
Boring Location: Station: 41+57 Offset: 21.0 ft. Rt. CL
Elevation (ft.): 634.5-ft Actual
Date Started: 5/13/2004 County: Kanawha Inspector: None
Lat. and Long.:
Date Completed: 5/13/2004 District: D-1 Entered By: HMH
Driller / Company: Thomas

ELEV. ft.	DEPTH ft.	DESCRIPTION OF MATERIALS (color, material description, grain size, structures, moisture, consistency)	SAMPLE Type	INT Depth	Run Rec	Blows Cnt (N-Value)	HCSI	RQD	Additional Notes	RMR (Total)
634.50	0.0									
		Black ASPHALT: hard		0.0-2.3						
632.20	2.3									
		Grey GRAVEL: base stone, very loose		2.3-3.5						
631.00	3.5									
		Brown-grey SANDY CLAY: medium stiff to stiff, soft		3.5-5.0						
				5.0-6.5		3-4-4 (8)				
				6.5-10.0						
				10.0-11.5		5-8-7 (15)				
				11.5-15.0						
619.50	15.0									
		Brown SANDY CLAY: and cobbles, medium stiff		15.0-16.3		4-4-50 (54)				
618.20	16.3									
		Brown BOULDERS: very dense		16.3-20.0						
614.50	20.0									
614.30	20.2	Brown BOULDERS: very dense		20.0-20.2		50				
		Brown SANDY CLAY: medium stiff to very stiff		20.2-25.0						
				25.0-26.5		10-12-15 (27)				
				26.5-30.0						
				30.0-31.5		7-8-9 (17)				
				31.5-35.0						
599.50	35.0									

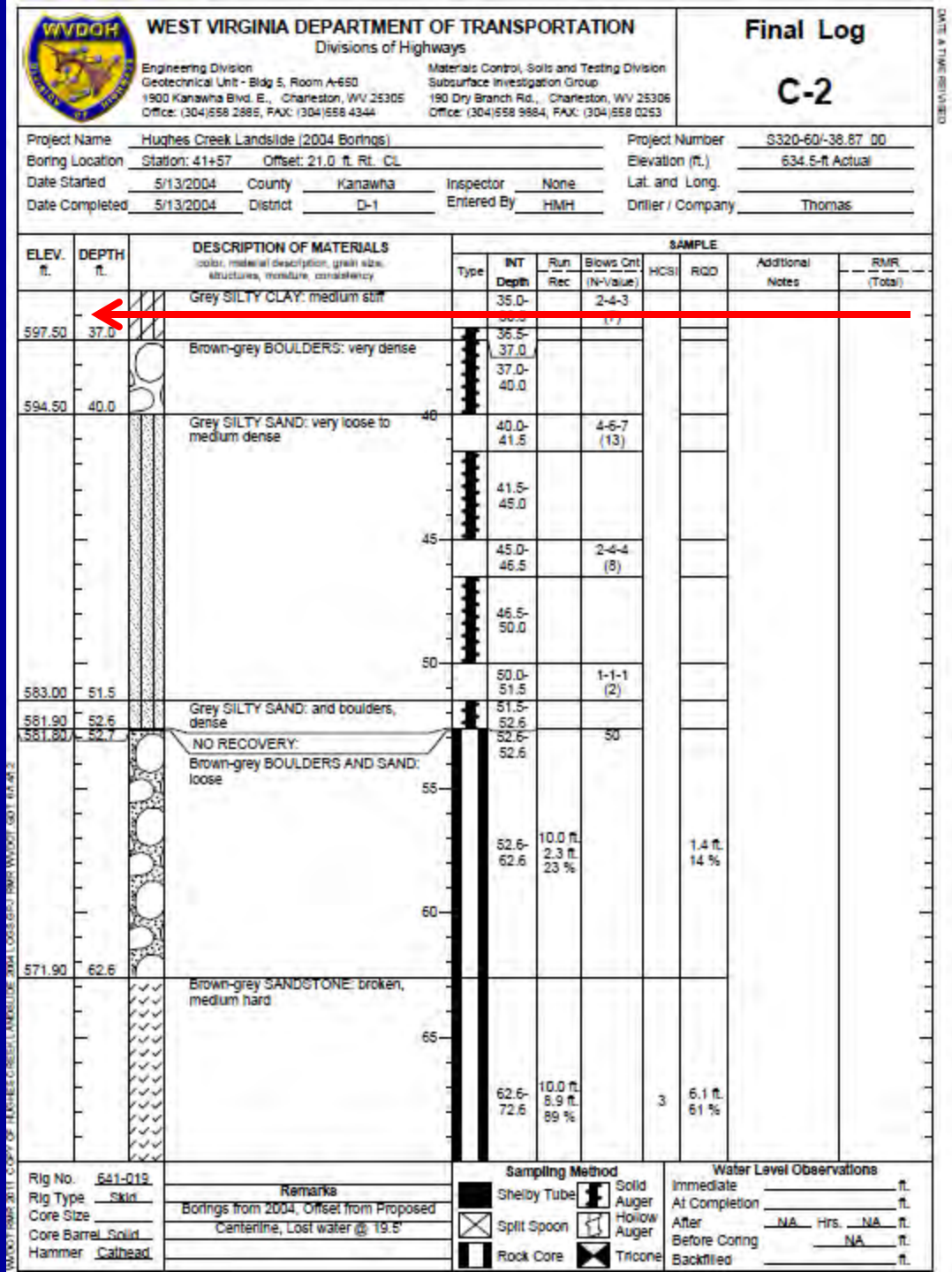
Rig No. 641-019
Rig Type Skid
Core Size
Core Barrel Solid
Hammer Cathead

Remarks
Borings from 2004, Offset from Proposed Centerline, Lost water @ 19.5'

Sampling Method
Shelby Tube
Split Spoon
Rock Core
Solid Auger
Hollow Auger
Tricone

Water Level Observations
Immediate ft.
At Completion ft.
After NA Hrs. NA ft.
Before Coring NA ft.
Backfilled ft.

Design



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Final Log

C-2

DATE & TIME REVISED

Project Name	Hughes Creek Landslide (2004 Borings)			Project Number	S320-60/-38.87 00
Boring Location	Station: 41+57 Offset: 21.0 ft. Rt. CL			Elevation (ft.)	634.5-ft Actual
Date Started	5/13/2004	County	Kanawha	Inspector	None
Date Completed	5/13/2004	District	D-1	Entered By	HMH
Lat. and Long.					
Driller / Company	Thomas				

ELEV. ft.	DEPTH ft.	DESCRIPTION OF MATERIALS (color, material description, grain size, structures, moisture, consistency)	Type	INT Depth	Run / Rec	Blows Cnt (N-Value)	HCSI	RQD	Additional Notes	RMR (Total)
		Grey SILTY CLAY: medium stiff		35.0-36.5		2-4-3 (7)				
597.50	37.0			36.5-37.0						
		Brown-grey BOULDERS: very dense		37.0-40.0						
594.50	40.0									
		Grey SILTY SAND: very loose to medium dense		40.0-41.5		4-6-7 (13)				
				41.5-45.0						
				45.0-46.5		2-4-4 (8)				
				46.5-50.0						
				50.0-51.5		1-1-1 (2)				
583.00	51.5									
		Grey SILTY SAND: and boulders, dense		51.5-52.6						
581.90	52.6									
581.80	52.7	NO RECOVERY:		52.6-52.6		50				
		Brown-grey BOULDERS AND SAND: loose		52.6-62.6	10.0 ft. 2.3 ft. 23 %			1.4 ft. 14 %		
571.90	62.6									
		Brown-grey SANDSTONE: broken, medium hard		62.6-72.6	10.0 ft. 8.9 ft. 89 %		3	6.1 ft. 61 %		

Depth scale: 40, 45, 50, 55, 60, 65

Rig No.	641-019
Rig Type	Skid
Core Size	
Core Barrel	Solid
Hammer	Cathead

Remarks
Borings from 2004, Offset from Proposed Centerline, Lost water @ 19.5'

Sampling Method
Shelby Tube; Solid Auger; Split Spoon; Hollow Auger; Rock Core; Tricone

Water Level Observations
Immediate ____ ft.
At Completion ____ ft.
After NA Hrs. NA ft.
Before Coring NA ft.
Backfilled ____ ft.

WVDOT RMR 2011 COPY OF HUGHES CREEK LANDSLIDE 2004 LOGS.GPJ RMR WVDOT GDT 6/14/12

Design

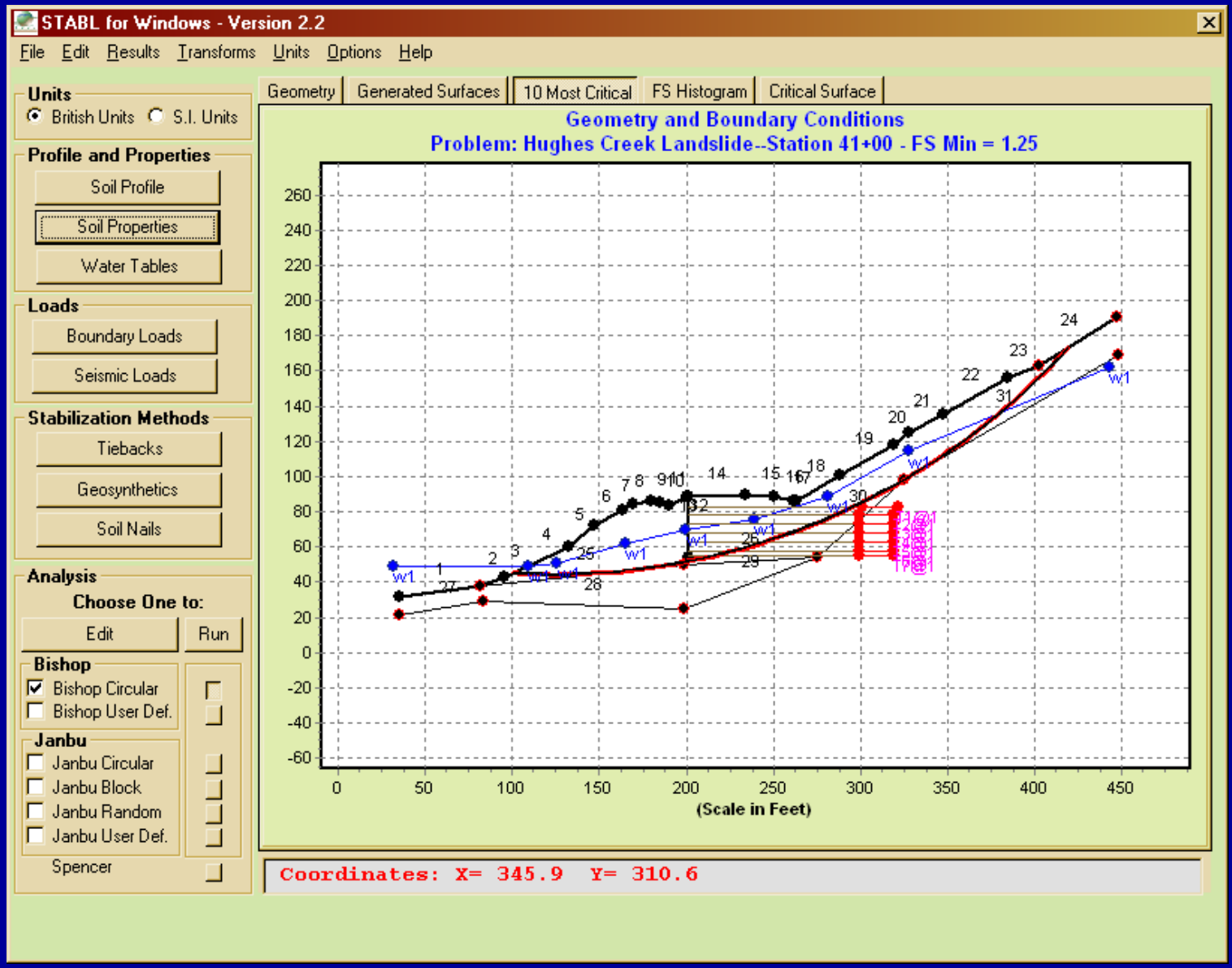
Design

- Due to the depth of the slip surface and the depth to rock our original design concept was to install large anchor blocks (14’x14’x3’ block w/ 27 strand cable 130’ deep).

- However due to the inconsistent bearing capacity of the RR fill, we abandoned this concept since differential settlement could break strands

- We revisited massive pile wall designs

Design


STABL for Windows - Version 2.2
File Edit Results Transforms Units Options Help
Units
British Units
S.I. Units
Profile and Properties
Soil Profile
Soil Properties
Water Tables
Loads
Boundary Loads
Seismic Loads
Stabilization Methods
Tiebacks
Geosynthetics
Soil Nails
Analysis
Choose One to:
Edit
Run
Bishop
Bishop Circular
Bishop User Def.
Janbu
Janbu Circular
Janbu Block
Janbu Random
Janbu User Def.
Spencer
Geometry
Generated Surfaces
10 Most Critical
FS Histogram
Critical Surface
Geometry and Boundary Conditions
Problem: Hughes Creek Landslide--Station 41+00 - FS Min = 1.25
(Scale in Feet)
Coordinates: X= 345.9 Y= 310.6

Design

- W24x250

Section Type, Dimensions, and Cross-section Properties

Section 1, Top

Number of Defined Sections = 1

Total Length = 65.00 ft

Section Type | Dimensions and Properties

Elevation Dimensions

Length of Section (ft) 65

Elastic Section Properties:

Structural Shape: H-Pile Strong Axis

•W24x250

	At Top	At Bottom
H-Pile Flange Wid., (in)	13.185	13.185
H-Pile Depth (in)	26.34	26.34
Area (in^2)	73.3017	73.3017
Mom. of Inertia (in^4)	8458.45652691	8458.45652691
Plas. Mom. Cap. (in-lbs)	33480000	33480000
Shear Capacity (lbs)	0	0

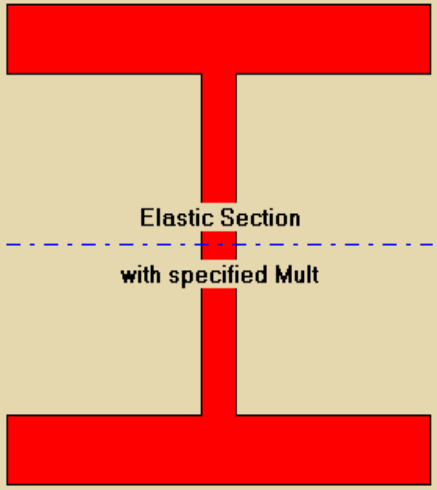
Elastic Pile w/Mom. Cap. Section Dimensions:

Section Diameter (in)	36
Section Depth (in)	0
Corner Chamfer (in)	0
Casing Wall Thickness (in)	0
Core Void Diameter (in)	0
Core Wall Thickness (in)	0
Flange Thickness (in)	1.89
Web Thickness (in)	1.04
Elastic Mod. (lbs/in^2)	29000000

Compute Mom. of Inertia and Areas and Draw Section

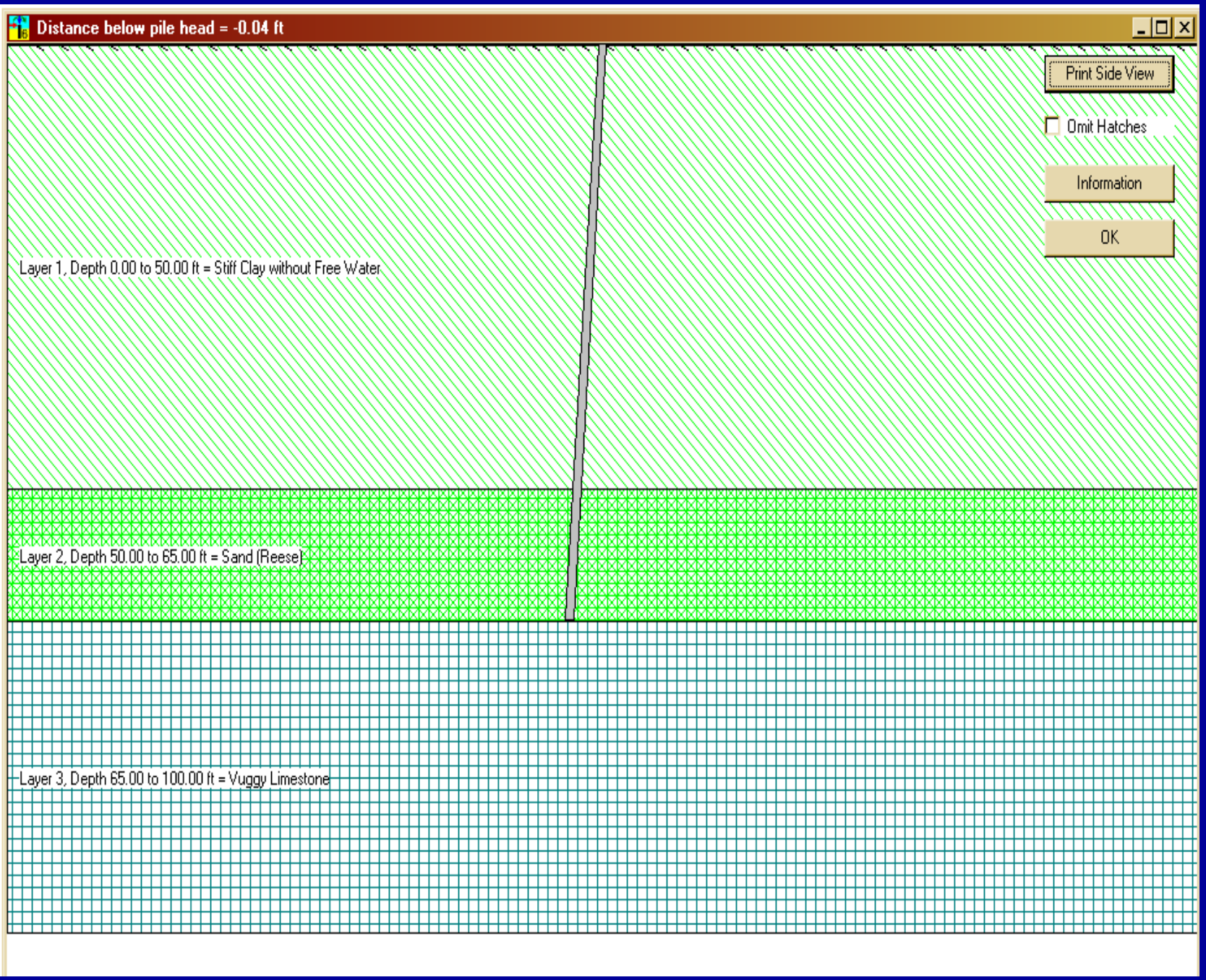
Copy Top Properties to Bottom

Show: (•) Section ( ) Profile



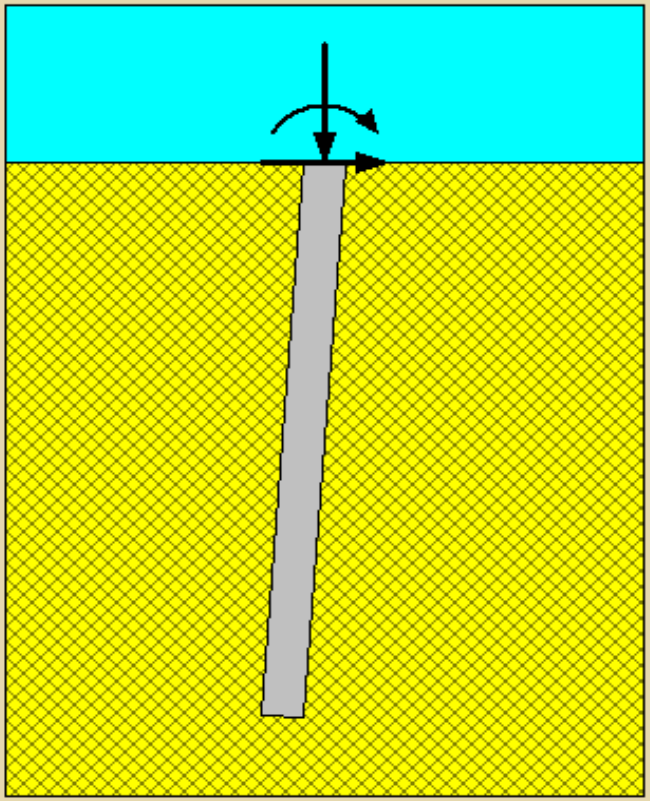
The strong H-pile elastic-plastic section shape with specified moment capacity allows the user to analyze an H-pile defined only by its structural dimensions and specified moment capacity. The cross-sectional area, and moment of inertia can be computed by pressing the button above or the user may enter values from a design handbook for area and moment of inertia of the cross-section. This shape models a pile with nonlinear bending properties. The user should check the compact section requirements for the H-pile when computing the specified moment capacity to determine if the flanges can buckle at stresses lower than the yield stress of steel.

Add Section | Insert Section | Delete Section | View Properties | Cancel | OK


Distance below pile head = -0.04 ft
Print Side View
Omit Hatches
Information
OK
Layer 1, Depth 0.00 to 50.00 ft = Stiff Clay without Free Water
Layer 2, Depth 50.00 to 65.00 ft = Sand (Reese)
Layer 3, Depth 65.00 to 100.00 ft = Vuggy Limestone

Ground Slope and Batter

Drawing is not to scale



Ground Slope
- (•) Flat
- ( ) Inclined

Batter
- ( ) Vertical
- (•) Battered

Ground Slope Angle, deg. 0

Pile Batter Angle, deg. 4

Pile-head elevation = 0.000 ft

Pile embedment is determined from the soil layering coordinates.

The origin of the soil layering coordinate system is located at the pile head.

Enter positive values for pile embedment if the pile head is above the ground surface and negative values if the pile head is below the ground surface.

This value should also be entered as the upper elevation of the topmost soil layer.

In conventional analyses, the axial loading acts along the axis of the pile and the shear load acts perperdicular to the axis of the pile.

In LRFD analysis, the applied pile-head forces are horizontal and vertical. LPile transforms these forces into their axial and transverse components prior to analysis.

Cancel OK

•Minimum Batter = 4 degrees

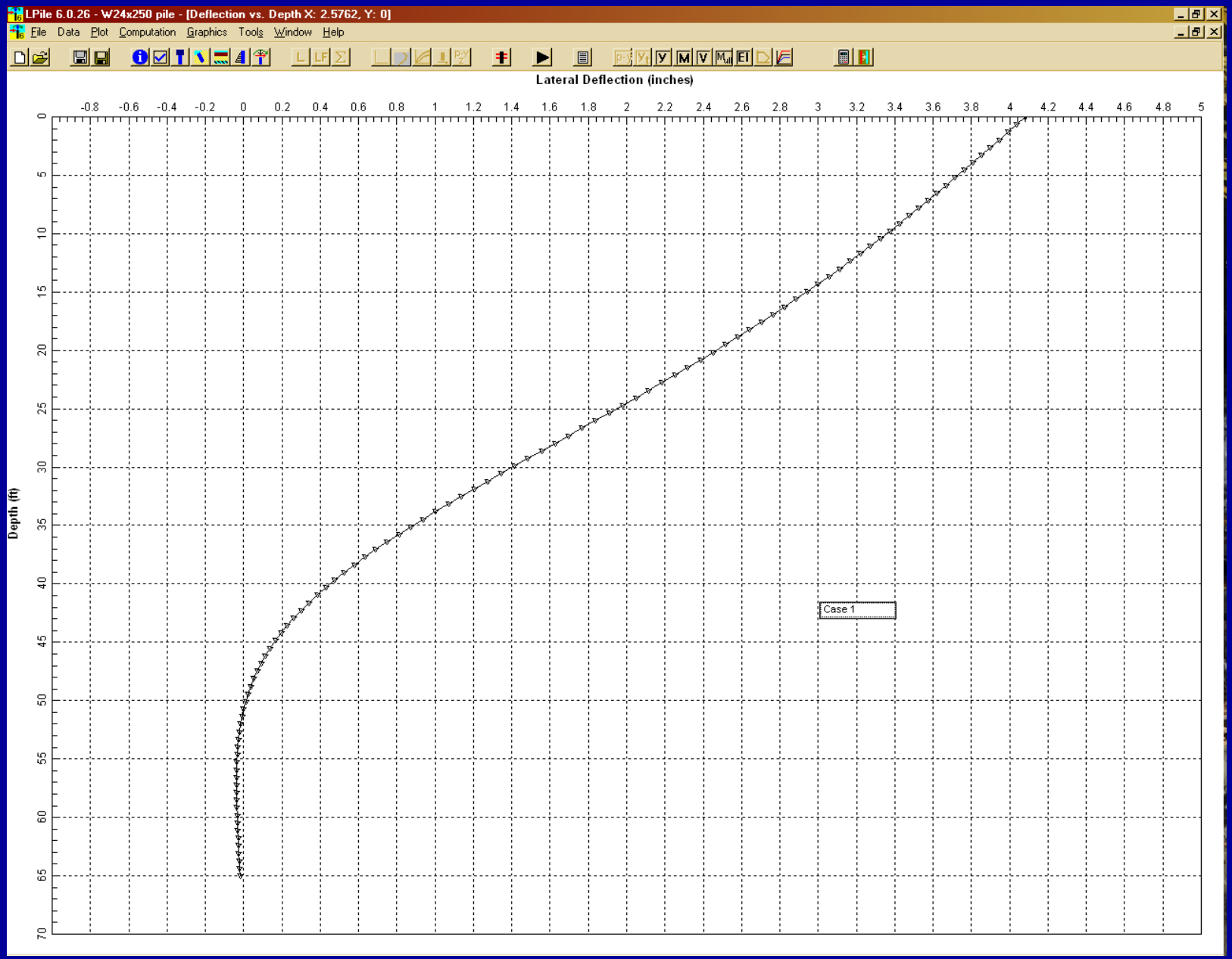
Distributed Lateral Loads

Depth Point	Distance Below Pile Head (in)	Lateral Load Intensity (lbs/in)
1	60	1920
2	120	1920
3	180	1920
4	240	1920
5	300	1920
6	360	1920
7	420	1920

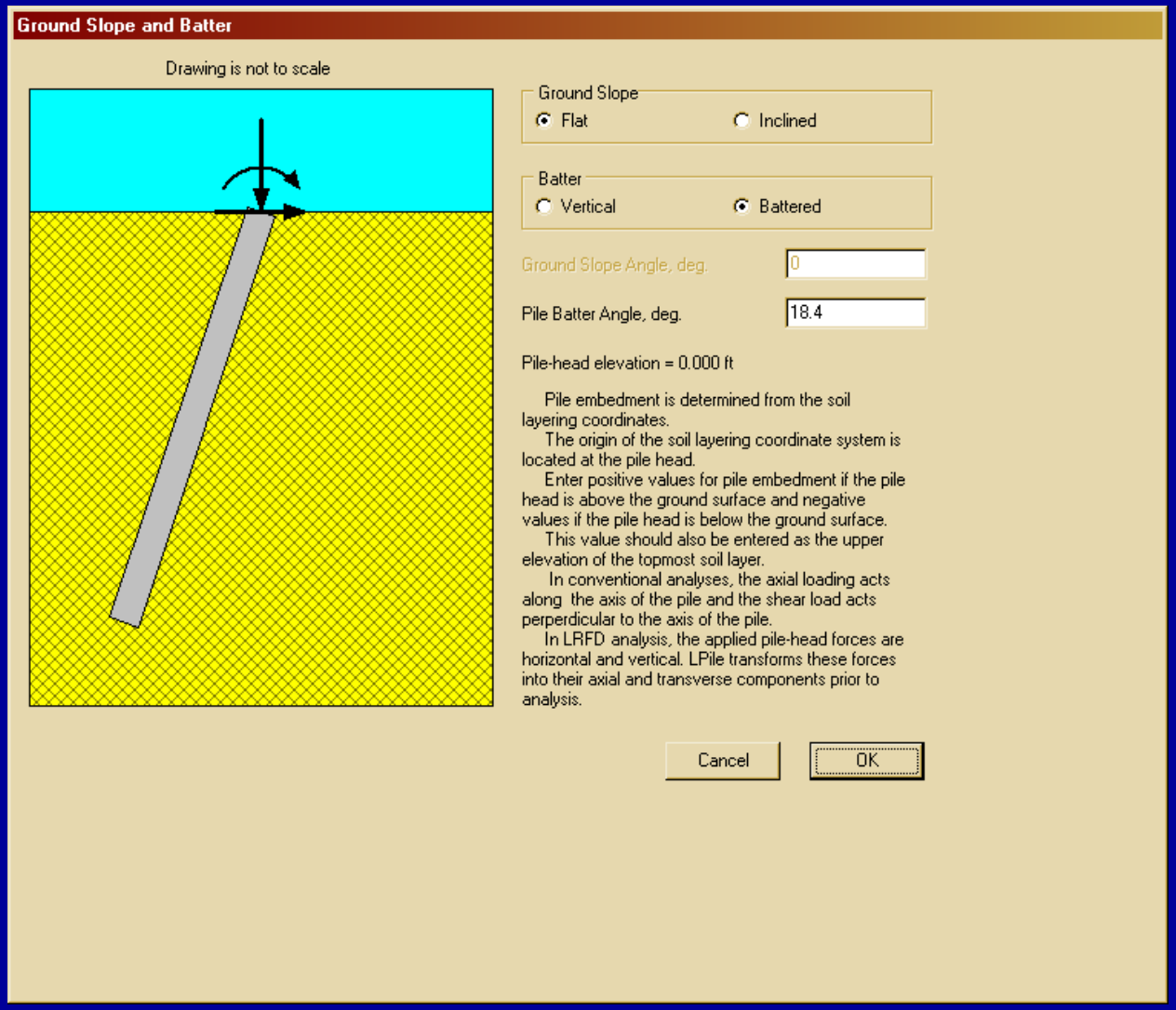
Add Row | Insert Row | Delete Row

Values of distributed lateral load are input as values versus distance from the pile head.
Distributed lateral loads are applied perpendicular to the axis of the pile.

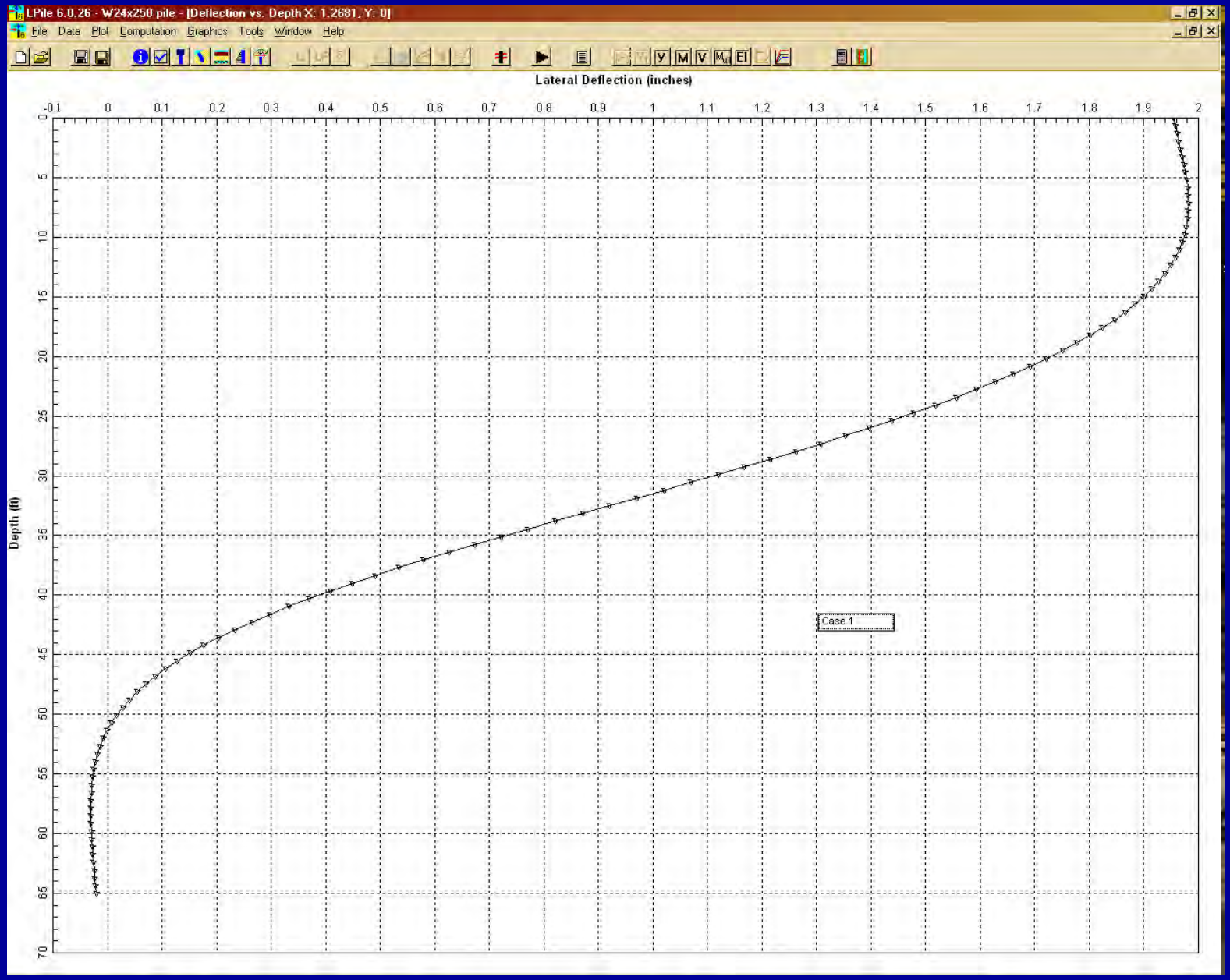
Distributed lateral load is input in units of force per unit length of pile.


LPile 6.0.26 - W24x250 pile - [Deflection vs. Depth X: 2.5762, Y: 0]
File Data Plot Computation Graphics Tools Window Help
Lateral Deflection (inches)
-0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4 4.2 4.4 4.6 4.8 5
Depth (ft)
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
Case 1

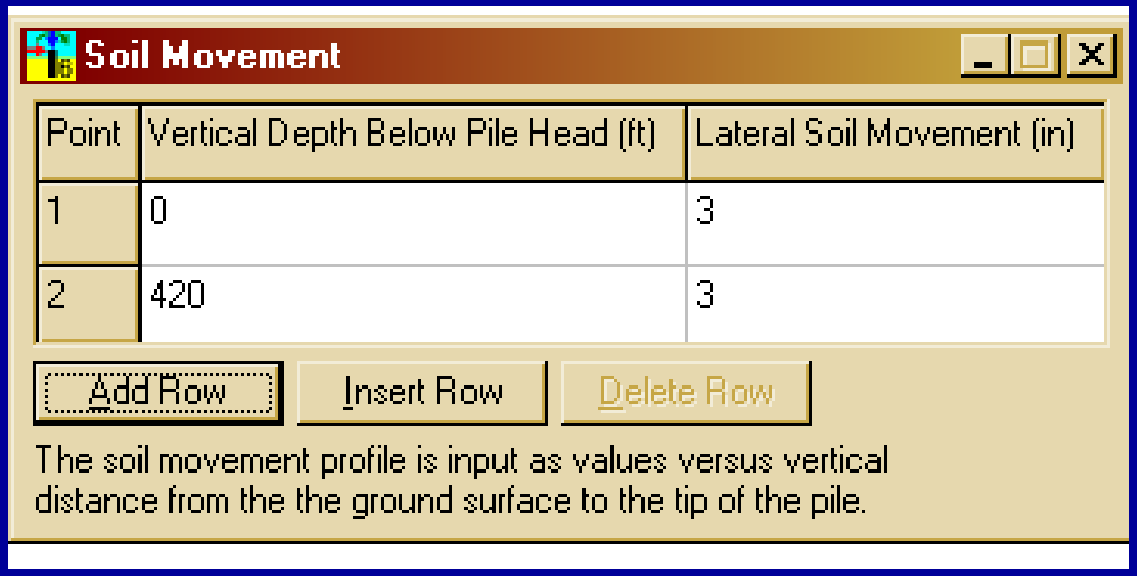
Design

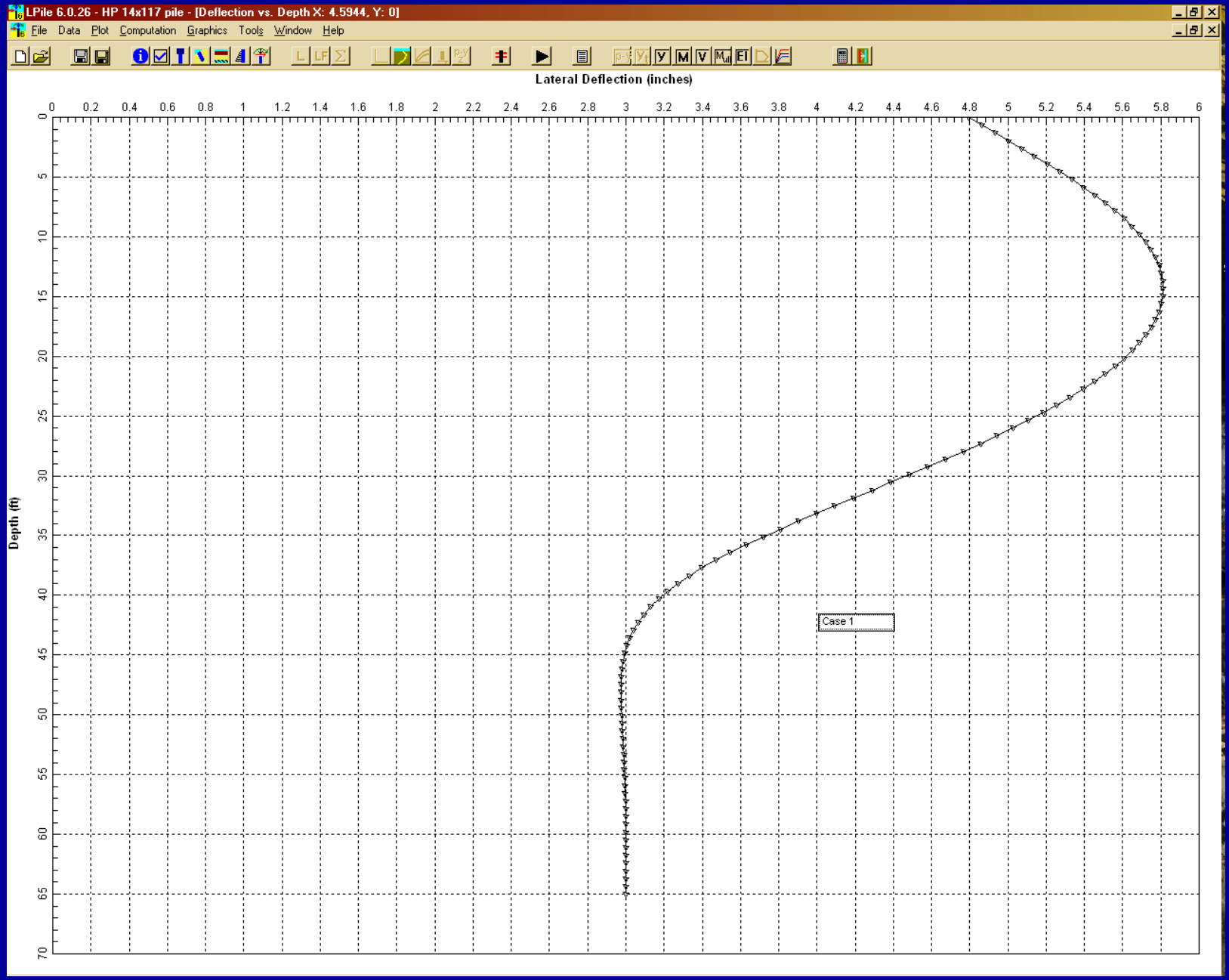


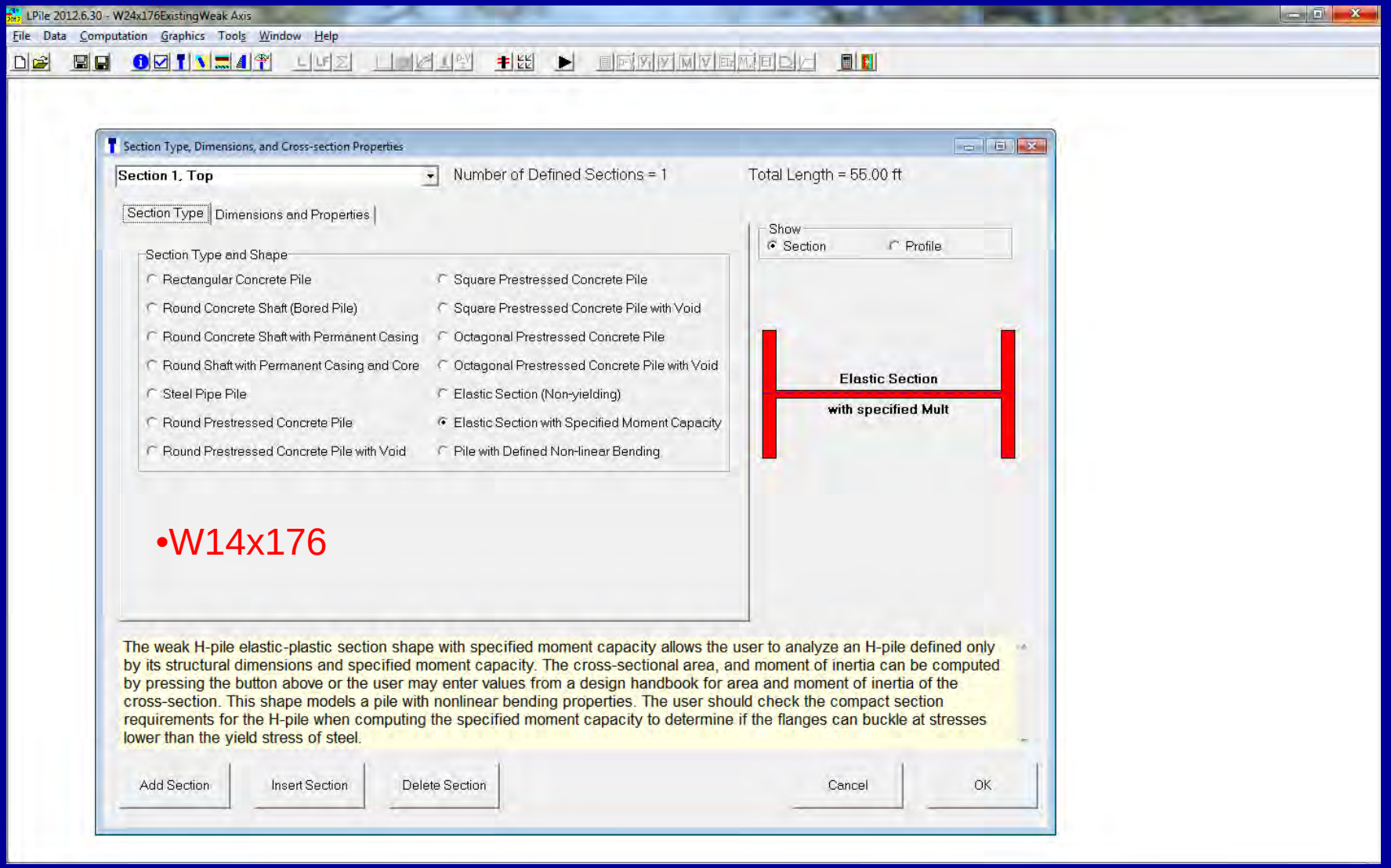
- Maximum batter of 4” on 12”

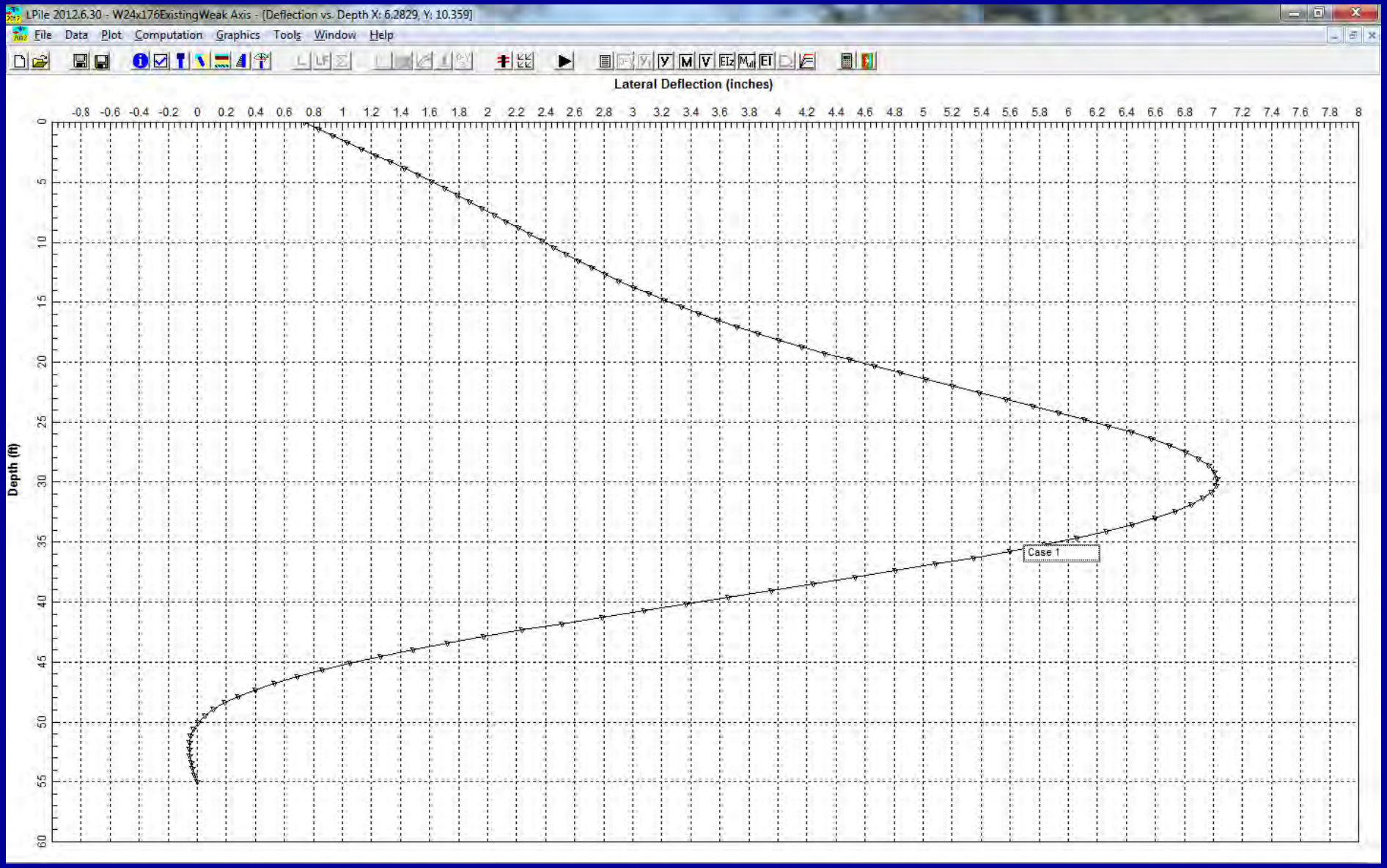

LPile 6.0.26 - W24x250 pile - [Deflection vs. Depth X: 1.2681, Y: 0]
File Data Plot Computation Graphics Tools Window Help
Lateral Deflection (inches)
-0.1 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2
Depth (ft)
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
Case 1

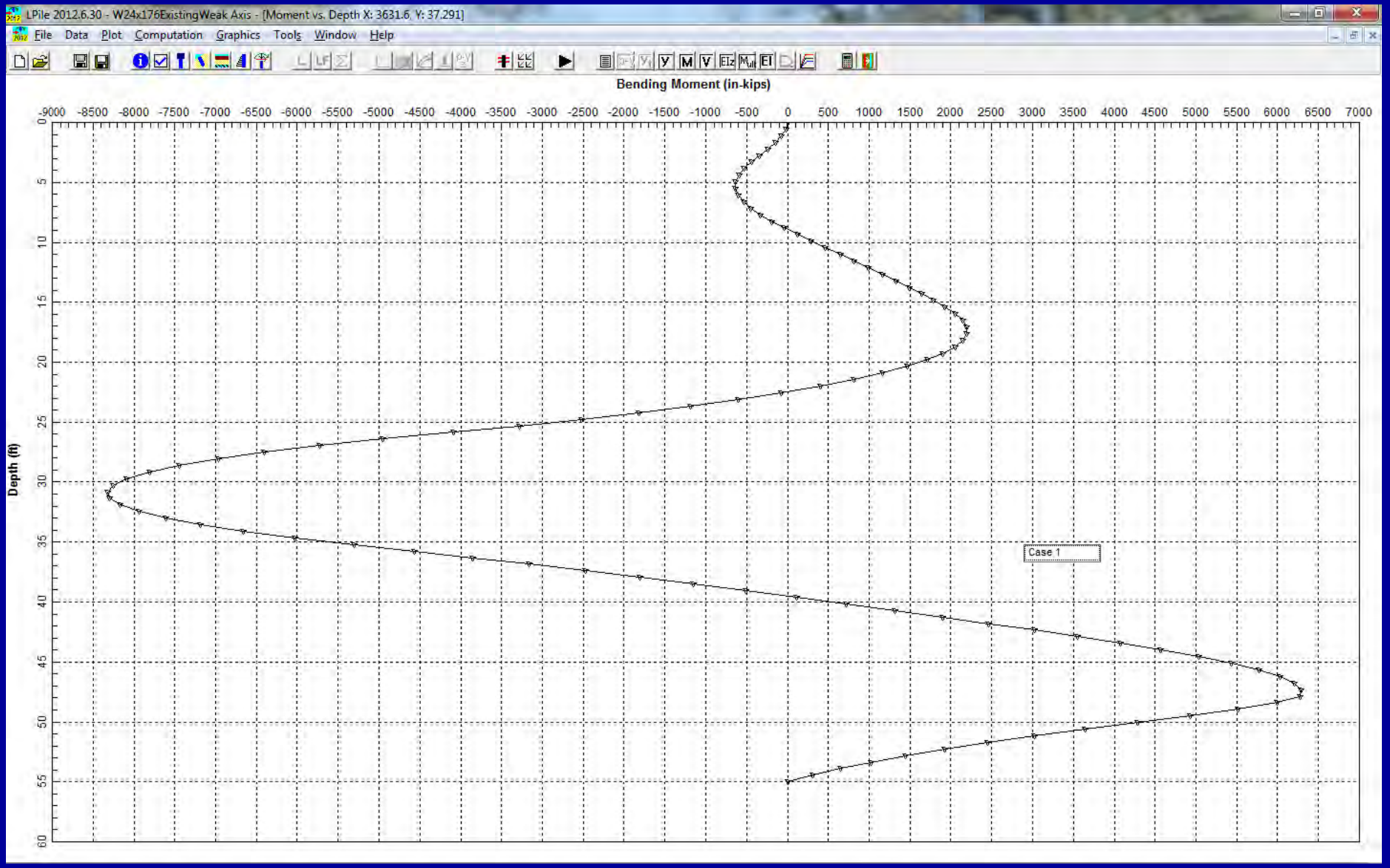
Design


Soil Movement
Point
Vertical Depth Below Pile Head (ft)
Lateral Soil Movement (in)
1
0
3
2
420
3
Add Row
Insert Row
Delete Row
The soil movement profile is input as values versus vertical distance from the the ground surface to the tip of the pile.

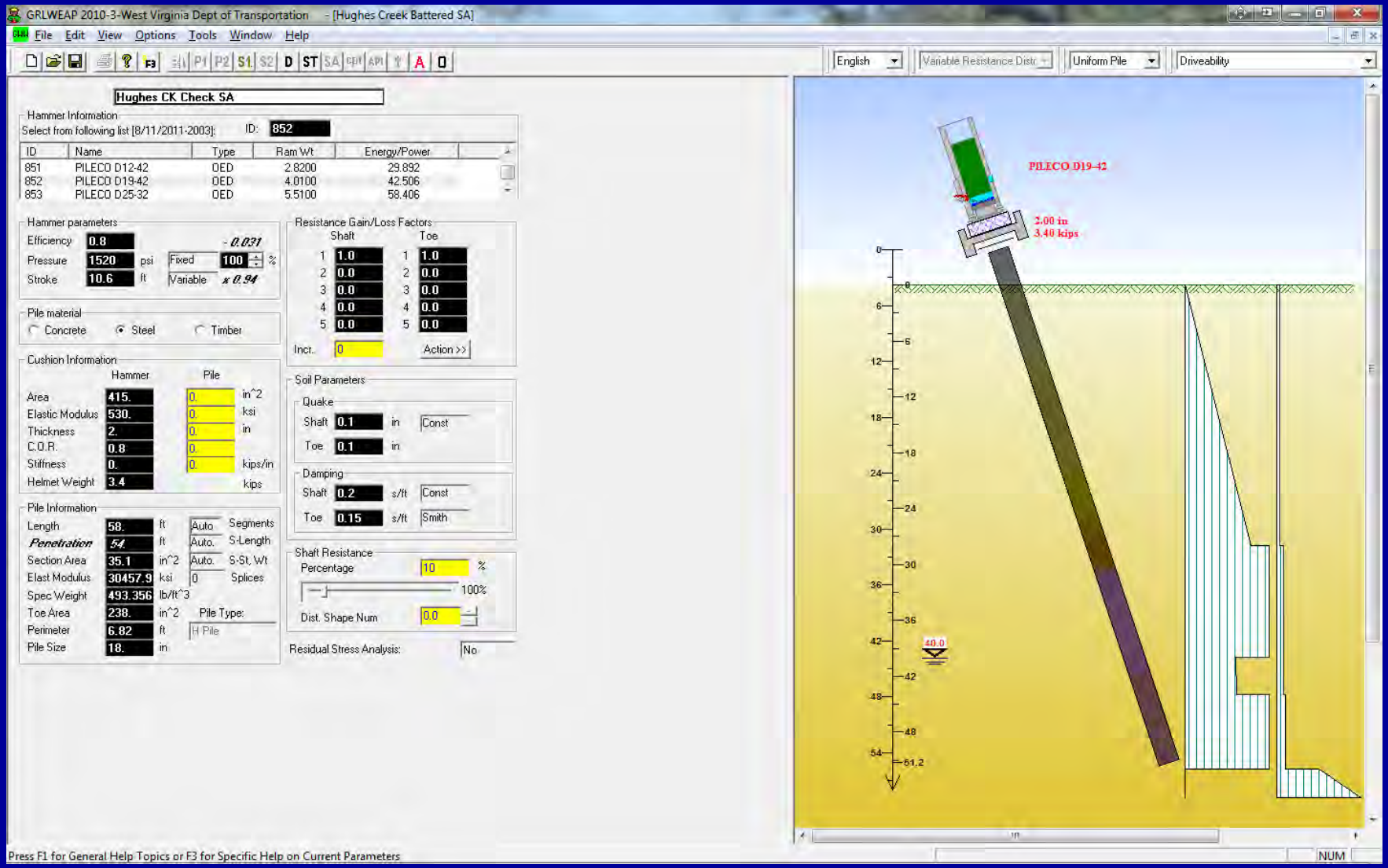

LPile 6.0.26 - HP 14x117 pile - [Deflection vs. Depth X: 4.5944, Y: 0]
File Data Plot Computation Graphics Tools Window Help
Lateral Deflection (inches)
Depth (ft)
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4 4.2 4.4 4.6 4.8 5 5.2 5.4 5.6 5.8 6
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
Case 1


LPile 2012.6.30 - W24x176ExistingWeak Axis
File Data Computation Graphics Tools Window Help
Section Type, Dimensions, and Cross-section Properties
Section 1, Top
Number of Defined Sections = 1
Total Length = 55.00 ft
Section Type
Dimensions and Properties
Section Type and Shape
Rectangular Concrete Pile
Round Concrete Shaft (Bored Pile)
Round Concrete Shaft with Permanent Casing
Round Shaft with Permanent Casing and Core
Steel Pipe Pile
Round Prestressed Concrete Pile
Round Prestressed Concrete Pile with Void
Square Prestressed Concrete Pile
Square Prestressed Concrete Pile with Void
Octagonal Prestressed Concrete Pile
Octagonal Prestressed Concrete Pile with Void
Elastic Section (Non-yielding)
Elastic Section with Specified Moment Capacity
Pile with Defined Non-linear Bending
Show
Section
Profile
Elastic Section
with specified Mult
•W14x176
The weak H-pile elastic-plastic section shape with specified moment capacity allows the user to analyze an H-pile defined only by its structural dimensions and specified moment capacity. The cross-sectional area, and moment of inertia can be computed by pressing the button above or the user may enter values from a design handbook for area and moment of inertia of the cross-section. This shape models a pile with nonlinear bending properties. The user should check the compact section requirements for the H-pile when computing the specified moment capacity to determine if the flanges can buckle at stresses lower than the yield stress of steel.
Add Section
Insert Section
Delete Section
Cancel
OK


LPile 2012.6.30 - W24x176ExistingWeak Axis - [Deflection vs. Depth X: 6.2829, Y: 10.359]
File Data Plot Computation Graphics Tools Window Help
Lateral Deflection (inches)
-0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4 4.2 4.4 4.6 4.8 5 5.2 5.4 5.6 5.8 6 6.2 6.4 6.6 6.8 7 7.2 7.4 7.6 7.8 8
Depth (ft)
0 5 10 15 20 25 30 35 40 45 50 55 60
Case 1


LPile 2012.6.30 - W24x176ExistingWeak Axis - [Moment vs. Depth X: 3631.6, Y: 37.291]
File Data Plot Computation Graphics Tools Window Help
Bending Moment (in-kips)
-9000 -8500 -8000 -7500 -7000 -6500 -6000 -5500 -5000 -4500 -4000 -3500 -3000 -2500 -2000 -1500 -1000 -500 0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000
Depth (ft)
0 5 10 15 20 25 30 35 40 45 50 55 60
Case 1

Design


GRLWEAP 2010-3-West Virginia Dept of Transportation - [Hughes Creek Battered SA]
File Edit View Options Tools Window Help
English
Variable Resistance Distr
Uniform Pile
Driveability
Hughes CK Check SA
Hammer Information
Select from following list [8/11/2011-2003]:
ID: 852
ID Name Type Ram Wt Energy/Power
851 PILECO D12-42 OED 2.8200 29.892
852 PILECO D19-42 OED 4.0100 42.506
853 PILECO D25-32 OED 5.5100 58.406
Hammer parameters
Efficiency 0.8
Pressure 1520 psi
Stroke 10.6 ft
Fixed 100 %
Variable
Pile material
Concrete Steel Timber
Cushion Information
Hammer Pile
Area 415. in^2
Elastic Modulus 530. ksi
Thickness 2. in
C.O.R. 0.8
Stiffness 0. kips/in
Helmet Weight 3.4 kips
Pile Information
Length 58. ft
Penetration 54. ft
Section Area 35.1 in^2
Elast Modulus 30457.9 ksi
Spec Weight 493.356 lb/ft^3
Toe Area 238. in^2
Perimeter 6.82 ft
Pile Size 18. in
Segments
S-Length
S-St, Wt
Splices
Pile Type:
H Pile
Resistance Gain/Loss Factors
Shaft Toe
1 1.0 1.0
2 0.0 0.0
3 0.0 0.0
4 0.0 0.0
5 0.0 0.0
Incr. 0
Action >>
Soil Parameters
Quake
Shaft 0.1 in Const
Toe 0.1 in
Damping
Shaft 0.2 s/ft Const
Toe 0.15 s/ft Smith
Shaft Resistance
Percentage 10 %
100%
Dist. Shape Num 0.0
Residual Stress Analysis: No
PILECO D19-42
2.00 in
3.40 kips
40.0
Press F1 for General Help Topics or F3 for Specific Help on Current Parameters
NUM

Design

Driveability Graph - Hughes Creek Battered SA

File View Edit Window Help

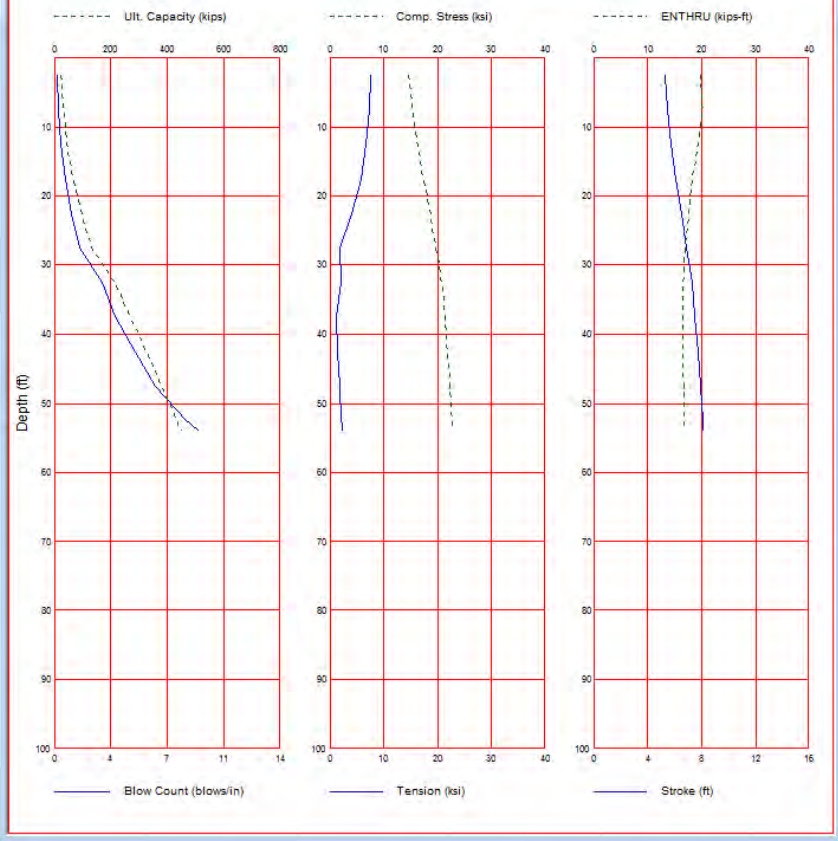
English | blows/in

Hughes Creek Battered SA

West Virginia Dept of Transportation
Hughes CK Check SA

Mar 19 2013
GRLWEAP Version 2010

Gain/Loss 1 at Shaft and Toe 1.000 / 1.000



Hughes Creek Battered SA

West Virginia Dept of Transportation
Hughes CK Check SA

Mar 19 2013
GRLWEAP Version 2010

Gain/Loss 1 at Shaft and Toe 1.000 / 1.000

Depth ft	Ultimate Capacity kips	Friction kips	End Bearing kips	Blow Count blows/in	Comp. Stress ksi	Tension Stress ksi	Stroke ft	ENTHRU kips-ft
2.5	24.2	0.9	23.3	0.2	14.669	-7.560	5.27	19.8
7.5	31.4	8.1	23.3	0.3	15.297	-7.385	5.44	20.1
12.5	45.7	22.4	23.3	0.4	16.259	-6.782	5.72	19.2
17.5	67.2	43.9	23.3	0.7	17.400	-5.730	6.07	18.2
22.5	95.9	72.6	23.3	1.0	18.759	-4.134	6.50	17.6
27.5	131.7	108.4	23.3	1.5	19.701	-1.912	6.83	17.0
32.5	214.0	156.8	57.2	2.9	20.851	-2.103	7.29	16.5
37.5	267.4	210.2	57.2	3.8	21.375	-1.074	7.49	16.4
42.5	326.4	262.2	64.2	5.0	21.846	-1.294	7.70	16.4
47.5	379.0	299.6	79.4	6.2	22.314	-1.736	7.89	16.6
52.5	432.4	353.0	79.4	8.2	22.677	-2.104	8.05	16.7
53.0	437.7	358.3	79.4	8.4	22.714	-2.140	8.06	16.7
54.0	448.4	369.0	79.4	8.9	22.800	-2.192	8.08	16.7

Total Continuous Driving Time 40.00 minutes; Total Number of Blows 1718

Design

Initial Design Recommendations:

- **Piling for this wall shall be W14x176 steel piles.**
- **Piles for this wall are to be driven to refusal defined as 20 blows per inch (BPI).**
- **We recommend a minimum nominal hammer size of 40,000 ft-lbs and a maximum nominal hammer size of 125,000 ft-lbs.**

Design

Pile Sizes That Are Rolled More Than Once A Year

- W6 X 9 – W6 X 25
- W8 X 10 – W8 X 67
- W10 X 22 – W10 X 112
- W12 X 16 – W12 X 210
- W14 X 22 – W 14 X 132
- W16 X 26 – W16 X 100
- W18 X 35 – W18 X 211
- W21 X 44 – W21 X 201
- W27 X 84 – W27 X 129
- W30 X 90 – W30 X 148
- W36 X 135 – W36 X 256 (12” FLANGE WIDTH ONLY) DO NOT USE W36 WITH A 16” FLANGE WIDTH)

HP 8 X 36

- HP 10 X 42 – HP 10 X 57
- HP 12 X 53 – HP 12 X 84
- HP 14 X 73 – HP 14 X 117

Design

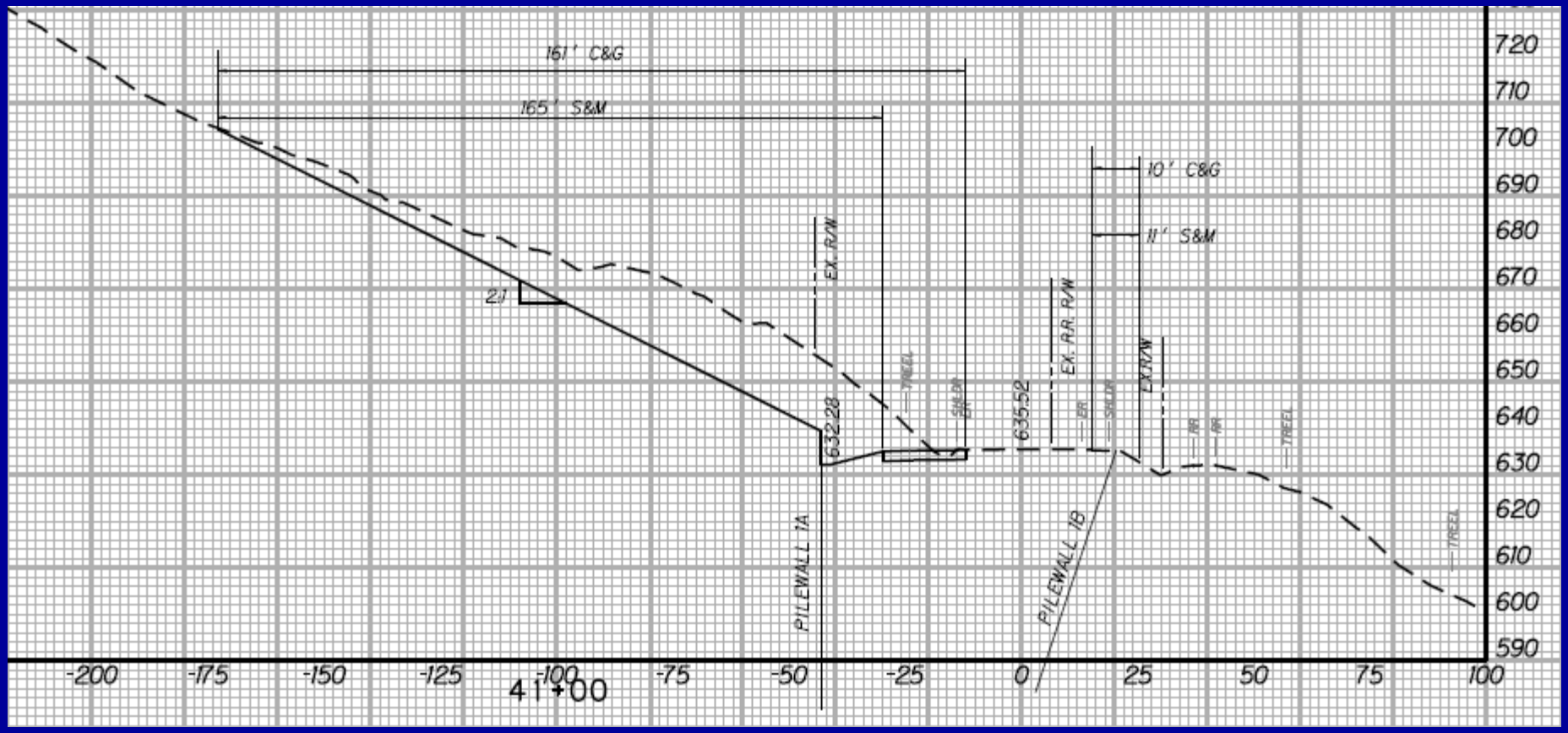
Piles Sizes Checked In Our Analysis

Pile Size	Plastic Mod	Facored Moment Capcity	I	bf	Pass/Fail		
W14x193	355	15975000	2400	15.7	P- 3.2 in Deflection		
W14x176	320	14400000	2140	15.7	P- 3.4 in Deflection		
W14x159	287	12915000	1900	15.6	P- 3.8 in Deflection		
W14x132	234	10530000	1530	14.7	F-Plastic Yielding		
W16x100	198	8910000	1490	10.4	F -Deflection		
W18x211	490	22050000	4330	11.6	F -Deflection		
W18X143	322	14490000	2750	11.2	F -Deflection		
W18X130	290	13050000	2460	11.2	F -Deflection		
W18X192	442	19890000	3870	11.5	F -Deflection		
W18X175	398	17910000	3450	11.4	F -Deflection		
W21X201	530	23850000	5310	12.6	F -Deflection		
W21X101	253	11385000	2420	12.3	F -Deflection		
W21X44	95.5	4297500	843	6.5	F -Deflection		
W27X129	395	17775000	4760	10	F -Deflection		
W27X84	106	4770000	2850	10	F -Deflection		
W30X148	500	22500000	6680	10.5	F -Deflection		
W30X90	283	12735000	3610	10.4	F -Deflection		
W36x256	1040	46800000	16800	12.2	F -Deflection		
W36x135	509	22905000	7800	12	F -Deflection		
HP14x117	172	7740000	1120	14.9	F-Plastic Yielding		
Weak Axis				Depth			
W36x256	137	6165000	528	37.4	P-0.32 in Deflection		
W36x135	59.7	2686500	225	35.6	P-0.31 in Deflection		
W30x148	68	3060000	227	30.7	P-0.52 in Deflection		
W30x90	34.7	1561500	115	29.5	P-0.47 in Deflection		
W27x84	33.2	1494000	106	26.7	P-0.77 in Deflection		
W21x201	133	5985000	542	23	P-0.83 in Deflection		
W21x101	61.7	2776500	248	21.4	P-1.05 in Deflection		
W21x93	34.7	1561500	92.9	21.6	P-1.17 in Deflection		
W21x73	26.6	1197000	70.6	21.2	P-1.26 in Deflection		
W21x68	24.4	1098000	64.7	21.1	F-Plastic Yielding		
W21x62	21.7	976500	57.5	21	F-Plastic Yielding		
W21x57	14.8	666000	30.6	21.1	F-Plastic Yielding		
W21x44	10.2	459000	20.7	20.7	F-Plastic Yielding		
W18x211	132	5940000	493	20.7	P-1.06 in Deflection		
W18x192	119	5355000	440	20.4	P-1.10 in Deflection		
W18x175	106	4770000	391	20	P-1.15 in Deflection		
W18x158	94.8	4266000	347	19.7	F-Plastic Yielding		
W18x143	85.4	3843000	311	19.5	F-Plastic Yielding		
W18x130	76.7	3451500	278	19.3	F-Plastic Yielding		
W18x119	69.1	3109500	253	19	F-Plastic Yielding	Passes with fs 1.2	

Case History

The Project Began in November 2012 and was Completed in about 1 year.

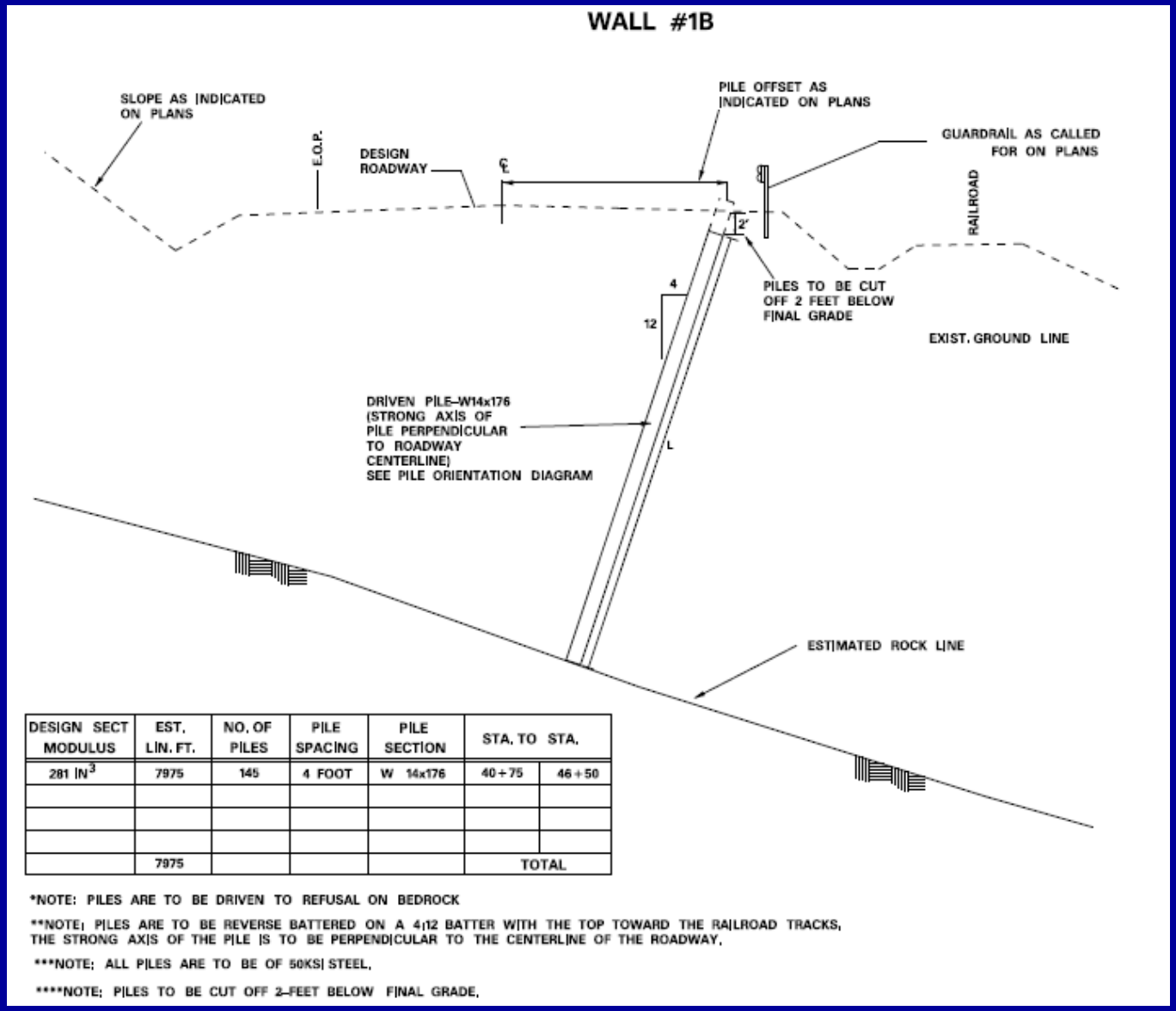
The Total Project Cost was $3,779,00 (Includes Excavation, Widening, and 4 Piling Walls).



Case History

The Cost of Battered Wall was $957,000 or $1,664/ Ft of Wall.

This Wall 575 Ft Long.



DESIGN SECT MODULUS	EST. LIN. FT.	NO. OF PILES	PILE SPACING	PILE SECTION	STA. TO STA.	
281 IN^3	7975	145	4 FOOT	W 14x176	40+75	46+50
	7975				TOTAL	

*NOTE: PILES ARE TO BE DRIVEN TO REFUSAL ON BEDROCK

**NOTE; PILES ARE TO BE REVERSE BATTERED ON A 4:12 BATTER WITH THE TOP TOWARD THE RAILROAD TRACKS, THE STRONG AXIS OF THE PILE IS TO BE PERPENDICULAR TO THE CENTERLINE OF THE ROADWAY.

***NOTE; ALL PILES ARE TO BE OF 50KSI STEEL.

****NOTE; PILES TO BE CUT OFF 2–FEET BELOW FINAL GRADE.

Case History

Case History

Case History

Time for Questions ?