THE UNIVERSITY OF TEXAS AT AUSTIN
CENTER FOR TRANSPORTATION RESEARCH

5-6048-01-P1

SPREADSHEET WITH SWELLING CURVES FOR CLAYS IN TEXAS (WITH SUPPLEMENTARY MATERIALS)

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TxDOT Project 5-6048-01: Pilot Implementation to Benefit from Centrifuge Technology for Characterization of Expansive Clays in the Austin District

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Center for Transportation Research

Transmittal

To:	Mike Arellano, German Claros
From:	Jorge G. Zornberg
Subject:	TxDOT Project 5-6048-01 – Product P1
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Please refer to attached Excel spreadsheet, PowerPoint presentation, and the key to Excel spreadsheet.

TxDOT Project 5-6048-01

Pilot Implementation to Benefit from Centrifuge Technology for Characterization of Expansive Clays in the Austin District

Product P1: **Spreadsheet with swelling curves for clays in Texas.**

Comments: Spreadsheet to be delivered in Excel format; Task 3 training material to be included also (provided as PowerPoint file).

Note: Key to Excel spreadsheet is included as a companion to the spreadsheet delivered in Excel format. Relevant properties of the tested soils are also included. Discussion of the centrifuge results, their use in PVR prediction, and characterization of tested soils will be included in the Technical Report (5-6048-01-1).

Table 1: Key for P1 Summary Sheet of Centrifuge Test Results

	Label in Spreadsheet	Key
Column A	Sample Number	The number of the compacted sample.
Column B	Test Date	The date of testing
Column C	Test ID Number	The ID Number consists of the following: Type of Clay – Target G-Level – Target Moisture Content – Target Relative Compaction – Cup Number
Column D	Cup Number	The number of the cup used for the specific soil sample
Column E	Test Operator	The person who ran the test
Column F	Soil Type	This soil used in the test. EF is Eagle Ford, BT is Black Taylor, HB is Houston Black, TT is Tan Taylor, S5 is Soil no. 5. Refer to Table 2 for Geotechnical Properties
Column G	Target G-Level	The G-Level of the centrifuge test (target value)
Column H	Actual G-Level	The average G-Level during the test. Note: Does not include the compression and decompression cycle
Column I	Water Content	The target water content condition. OPT is Optimum, WOPT is Wet of Optimum (+3% of optimum), and DOPT is Dry of Optimum (-3% of optimum).
Column J	Target Water Content (%)	The target water content of the soil sample at which the sample was prepared
Column K	Actual Water Content (%)	The actual water content of the soil during compaction (measured after centrifuge testing)
Column L	Relative Compaction (%)	The target relative compaction for the test. $RC = \gamma_{d,actual}/\gamma_{d,max}$
Column M	Target Dry Unit Weight (kN/m^3)	The target dry unit weight following compaction at which the sample was prepared (for the target RC)
Column N	Actual Dry Unit Weight (kN/m^3)	The actual dry unit weight of soil following compaction (measured after centrifuge testing)
Column O	Sample Height (cm)	The height of the soil sample after compaction
Column P	Overburden Mass (g)	The mass of overburden on the soil during testing. This value includes the weight of the washers and LPS. It does not include the weight of the water layer.
Column Q	Height of water (cm)	The height of the water added to the soil before placement in the centrifuge.
Column R	End of Swell Water Content (%)	The water content of the soil after test completion.
Column S	Change in Water Content (%)	The difference in the water content between the soil at compaction and soil after test completion.
Column T	Swell (%)	The vertical strain of the soil sample.

Table 2: Descriptive Geotechnical Properties of Soils in Database

	Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)	Soil Classification (USCS)	Clay Content (%)	Organic Content (%)	Specific Gravity (Gs)	OMC (Std. Proctor) (%)	Max. Yd (Std. Proctor) (kN/m³)
Eagle Ford	88	39	49	CH	64	0.07632	2.74	24.3	15.25
Houston Black	62	27	35	CH	58	3.6741	2.701	25.5	14.72
Black Taylor	55	28	27	CH	52	3.6747	2.712	23.3	15.34
Tan Taylor	82	35	47	CH	50	-	2.76	25	13.56
Soil 5	25	14	11	CL	49	-	2.71	12.6	18.92

Sample #	Test Date	Test ID Number	Cup #	Test Operator	Soil Type	Target G-Level	Actual G-Level	Water Content	Target Water Content (%)	Actual Water Content (%)	Relative Compaction (%)	Target Dry Unit Weight (kN/m3)	Actual Dry Unit Weight (kN/m3)	Sample Height (cm)	*Overburden Mass (g)	Height of Water (cm)	End of Swell Water Content (%)	Change in Water Content (%)	Swell (%)
1	10-14-11	EF-25-OPT-100-1	1	Trevor	EF	25	23.9	OPT	24	24.43	100	15.25	15.22	1.000	21.09	2	40.87	16.44	18.87
2	10-14-11	EF-25-OPT-100-2	2	Trevor	EF	25	23.9	OPT	24	24.43	100	15.25	15.17	1.003	21.14	2	40.60	16.17	18.42
3	10-18-11	EF-200-OPT-100-1	1	Trevor	EF	200	195.7	OPT	24	24.40	100	15.25	15.25	1.000	21.08	2	34.67	10.27	8.99
4	10-18-11	EF-200-OPT-100-2	2	Trevor	EF	200	195.7	OPT	24	24.40	100	15.25	15.22	1.000	21.21	2	34.77	10.37	8.58
5	10-22-11	BT-25-OPT-100-1	1	Trevor	BT	25	28.9	OPT	23.3	23.67	100	15.34	15.33	0.997	21.08	2	27.59	3.92	2.63
6	10-22-11	BT-25-OPT-100-2	2	Trevor	BT	25	28.9	OPT	23.3	23.67	100	15.34	15.35	0.997	21.21	2	27.35	3.68	2.03
7	10-25-11	BT-200-OPT-100-1	1	Trevor	BT	200	203.1	OPT	23.3	23.57	100	15.34	15.34	1.000	21.08	2	26.12	2.55	1.55
8	10-25-11	BT-200-OPT-100-2	2	Trevor	BT	200	203.1	OPT	23.3	23.57	100	15.34	15.31	1.000	21.22	2	26.12	2.55	1.67
9	11-4-11	HB-25-OPT-100-1	1	Trevor	HB	25	30.2	OPT	25.5	25.47	100	14.72	14.74	1.000	21.09	2	29.70	4.23	2.28
10	11-4-11	HB-25-OPT-100-2	2	Trevor	HB	25	30.2	OPT	25.5	25.47	100	14.72	14.69	1.000	21.21	2	30.27	4.80	3.18
11	12-20-11	EF-25-OPT-97-1	1	Trevor	EF	25	27.4	OPT	24	23.86	97	14.79	14.96	0.992	21.22	2	42.12	18.26	17.76
12	12-20-11	EF-25-OPT-97-4	4	Trevor	EF	25	27.4	OPT	24	23.86	97	14.79	14.85	0.997	21.21	2	44.32	20.46	17.51
13	12-20-11	EF-25-WOPT-97-2	2	Trevor	EF	25	27.4	WOPT	27	27.36	97	14.79	14.77	1.000	21.08	2	43.58	16.22	13.99
14	12-20-11	EF-25-WOPT-97-3	3	Trevor	EF	25	27.4	WOPT	27	27.36	97	14.79	14.76	0.997	21.07	2	42.96	15.60	12.99
15	1-11-12	EF-25-OPT-94-1	1	Trevor	EF	25	25.2	OPT	24	23.57	94	14.34	14.50	0.992	21.21	2	42.94	19.37	17.57
16	1-11-12	EF-25-OPT-94-4	4	Trevor	EF	25	25.2	OPT	24	23.57	94	14.34	14.39	1.000	21.21	2	43.10	19.53	18.07
17	1-11-12	HB-25-OPT-97-2	2	Trevor	HB	25	25.2	OPT	25.5	25.34	97	14.28	14.34	1.000	21.08	2	32.12	6.78	4.75
18	1-11-12	HB-25-OPT-97-3	3	Trevor	HB	25	25.2	OPT	25.5	25.34	97	14.28	14.33	1.000	21.07	2	32.02	6.68	5.93
19	1-13-12	EF-200-OPT-94-1	1	Trevor	EF	200	200.2	OPT	24	24.04	94	14.34	14.36	0.997	21.06	2	37.60	13.56	7.57
20	1-13-12	EF-200-OPT-94-4	4	Trevor	EF	200	200.2	OPT	24	24.04	94	14.34	14.33	1.000	21.07	2	37.56	13.52	7.08
21	1-20-12	HB-25-OPT-100-1	1	Trevor	HB	25	26.6	OPT	25.5	25.13	100	14.72	14.72	1.000	21.07	2	30.31	5.18	3.15
22	1-20-12	HB-25-OPT-100-4	4	Trevor	HB	25	26.6	OPT	25.5	25.13	100	14.72	14.77	0.995	21.07	2	31.33	6.20	4.65
23	1-20-12	HB-25-OPT-94-2	2	Trevor	HB	25	26.6	OPT	25.5	25.13	94	13.84	13.89	1.000	21.24	2	35.16	10.03	4.91
24	1-20-12	HB-25-OPT-94-3	3	Trevor	HB	25	26.6	OPT	25.5	25.13	94	13.84	13.96	1.003	21.2	2	34.32	9.19	4.55
25	1-24-12	HB-200-OPT-100-1	1	Trevor	HB	200	203.1	OPT	25.5	25.07	100	14.72	14.81	1.000	21.07	2	29.58	4.51	2.65
26	1-24-12	HB-200-OPT-100-4	4	Trevor	HB	200	203.1	OPT	25.5	25.07	100	14.72	14.79	1.000	21.07	2	30.02	4.95	2.84
27	1-24-12	HB-200-OPT-94-2	2	Trevor	HB	200	203.1	OPT	25.5	25.07	94	13.84	13.89	1.000	21.24	2	32.08	7.01	2.85
28	1-24-12	HB-200-OPT-94-3	3	Trevor	HB	200	203.1	OPT	25.5	25.07	94	13.84	13.90	1.000	21.21	2	32.15	7.08	3.11
29	1-26-12	BT-25-OPT-97-1	1	Trevor	BT	25	26.2	OPT	23.3	23.63	97	14.88	14.86	1.000	21.24	2	29.66	6.03	3.34
30	1-26-12	BT-25-OPT-97-4	4	Trevor	BT	25	26.2	OPT	23.3	23.63	97	14.88	14.85	1.000	21.21	2	29.83	6.20	3.30
31	1-26-12	BT-25-WOPT-97-2	2	Trevor	BT	25	26.2	WOPT	26.3	26.65	97	14.88	14.85	1.000	21.07	2	29.71	3.06	2.42
32	1-26-12	BT-25-WOPT-97-3	3	Trevor	BT	25	26.2	WOPT	26.3	26.65	97	14.88	14.85	1.003	21.08	2	29.21	2.56	1.66
33	1-28-12	BT-200-OPT-97-1	1	Trevor	BT	200	202.6	OPT	23.3	23.10	97	14.88	14.91	1.000	21.24	2	30.07	6.97	2.64
34	1-28-12	BT-200-OPT-97-4	4	Trevor	BT	200	202.6	OPT	23.3	23.10	97	14.88	14.95	0.997	21.2	2	26.95	3.85	1.88
35	1-28-12	BT-200-WOPT-97-2	2	Trevor	BT	200	202.6	WOPT	26.3	26.19	97	14.88	14.92	1.000	21.07	2	27.59	1.40	1.28
36	1-28-12	BT-200-WOPT-97-3	3	Trevor	BT	200	202.6	WOPT	26.3	26.19	97	14.88	14.93	1.000	21.07	2	24.46	-1.73	0.93
37	1-31-12	BT-25-OPT-100-1	1	Trevor	BT	25	27.1	OPT	23.3	23.52	100	15.34	15.37	0.997	21.24	2	28.22	4.70	3.90
38	1-31-12	BT-25-OPT-100-4	4	Trevor	BT	25	27.1	OPT	23.3	23.52	100	15.34	15.34	1.000	21.2	2	27.77	4.25	3.64
39	1-31-12	BT-25-OPT-94-2	2	Trevor	BT	25	27.1	OPT	23.3	23.52	94	14.42	14.50	0.992	21.07	2	30.60	7.08	3.25
40	1-31-12	BT-25-OPT-94-3	3	Trevor	BT	25	27.1	OPT	23.3	23.52	94	14.42	14.44	0.997	21.07	2	29.92	6.40	2.21
41	2-2-12	BT-200-OPT-100-1	1	Trevor	BT	200	201.8	OPT	23.3	23.82	100	15.34	15.32	0.997	21.24	2	27.17	3.35	1.98
42	2-2-12	BT-200-OPT-100-4	4	Trevor	BT	200	201.8	OPT	23.3	23.82	100	15.34	15.27	1.000	21.2	2	26.90	3.08	1.84
43	2-4-12	EF-25-OPT-97-2	2	Trevor	EF	25	25.7	OPT	24	24.37	97	14.79	14.77	1.000	21.07	2	41.52	17.15	17.14
44	2-4-12	EF-25-OPT-97-3	3	Trevor	EF	25	25.7	OPT	24	24.37	97	14.79	14.74	1.000	21.07	2	41.11	16.74	16.04
45	2-6-12	BT-200-DOPT-97-1	1	Trevor	BT	200	201.9	DOPT	20.3	20.35	97	14.88	14.91	0.997	21.24	2	29.44	9.09	4.96
46	2-6-12	BT-200-DOPT-97-4	4	Trevor	BT	200	201.9	DOPT	20.3	20.35	97	14.88	14.91	1.000	21.2	2	29.76	9.41	5.25
47	2-6-12	EF-200-OPT-97-2	2	Trevor	EF	200	201.9	OPT	24	23.61	97	14.79	14.92	0.995	21.07	2	35.75	12.14	8.52
48	2-6-12	EF-200-OPT-97-3	3	Trevor	EF	200	201.9	OPT	24	23.61	97	14.79	14.82	1.000	21.07	2	35.97	12.36	8.14
49	2-8-12	EF-200-WOPT-97-1	1	Trevor	EF	200	199.4	WOPT	27	27.30	97	14.79	14.77	0.997	21.23	2	35.93	8.63	5.61
50	2-8-12	EF-200-WOPT-97-4	4	Trevor	EF	200	199.4	WOPT	27	27.30	97	14.79	14.80	0.995	21.2	2	35.68	8.38	5.95
51	2-8-12	EF-200-DOPT-97-2	2	Trevor	EF	200	199.4	DOPT	21	21.28	97	14.79	14.74	1.000	21.05	2	37.17	15.89	7.77
52	2-8-12	EF-200-DOPT-97-3	3	Trevor	EF	200	199.4	DOPT	21	21.28	97	14.79	14.78	1.000	21.07	2	37.82	16.54	7.90
53	2-10-12	BT-25-DOPT-97-1	1	Trevor	BT	25	25.4	DOPT	20.3	20.79	97	14.88	14.87	0.997	21.23	2	30.93	10.14	5.87
54	2-10-12	BT-25-DOPT-97-4	4	Trevor	BT	25	25.4	DOPT	20.3	20.79	97	14.88	14.90	0.995	21.2	2	31.30	10.51	7.13
55	2-10-12	EF-25-DOPT-97-2	2	Trevor	EF	25	25.4	DOPT	21	21.45	97	14.79	14.82	0.995	21.07	2	42.56	21.11	18.71
56	2-10-12	EF-25-DOPT-97-3	3	Trevor	EF	25	25.4	DOPT	21	21.45	97	14.79	14.77	0.997	21.07	2	42.97	21.52	18.35
57	2-13-12	HB-5-OPT-97-2	2	Trevor	HB	5	7.1	OPT	25.5	25.11	97	14.28	14.33	1.000	21.07	2	33.45	8.34	5.76
58	2-13-12	HB-5-OPT-97-3	3	Trevor	HB	5	7.1	OPT	25.5	25.11	97	14.28	14.29	1.003	21.07	2	31.44	6.33	6.50

59	2-15-12	HB-25-OPT-100-1	1	Trevor	HB	25	27.0	OPT	25.5	25.83	100	14.72	14.73	0.997	21.23	2	30.91	5.08	4.63
60	2-15-12	HB-25-OPT-100-2	2	Trevor	HB	25	27.0	OPT	25.5	25.83	100	14.72	14.63	1.003	21.2	2	29.54	3.71	3.17
61	2-17-12	BT-5-OPT-97-1	1	Trevor	BT	5	6.7	OPT	23.3	23.27	97	14.88	14.87	1.000	21.17	2	30.81	7.54	4.66
62	2-17-12	BT-5-OPT-97-4	4	Trevor	BT	5	6.7	OPT	23.3	23.27	97	14.88	14.88	1.000	21.21	2	29.87	6.60	7.11
63	2-17-12	EF-5-OPT-100-2	2	Trevor	EF	5	6.7	OPT	24	23.91	100	15.25	15.29	0.997	21.06	2	47.25	23.34	29.81
64	2-17-12	EF-5-OPT-100-3	3	Trevor	EF	5	6.7	OPT	24	23.91	100	15.25	15.25	1.003	21.07	2	48.31	24.40	31.12
65	2-21-12	HB-200-WOPT-97-1	1	Trevor	HB	200	202.2	WOPT	28.5	28.41	97	14.28	14.24	1.000	21.06	2	30.47	2.06	1.37
66	2-21-12	HB-200-WOPT-97-4	4	Trevor	HB	200	202.2	WOPT	28.5	28.41	97	14.28	14.33	1.000	21.07	2	30.70	2.29	1.48
67	2-21-12	HB-200-DOPT-97-2	2	Trevor	HB	200	202.2	DOPT	22.5	22.61	97	14.28	14.30	1.003	21.17	2	30.04	7.43	2.21
68	2-21-12	HB-200-DOPT-97-3	3	Trevor	HB	200	202.2	DOPT	22.5	22.61	97	14.28	14.26	1.000	21.2	2	29.96	7.35	2.17
69	3-6-12	HB-25-WOPT-97-1	1	Trevor	HB	25	26.2	WOPT	28.5	28.00	97	14.28	14.35	1.000	21.17	2	30.90	2.90	2.01
70	3-6-12	HB-25-WOPT-97-4	4	Trevor	HB	25	26.2	WOPT	28.5	28.00	97	14.28	14.39	0.995	21.21	2	30.85	2.85	1.59
71	3-6-12	HB-25-DOPT-97-2	2	Trevor	HB	25	26.2	DOPT	22.5	22.15	97	14.28	14.49	0.990	21.05	2	33.34	11.19	6.57
72	3-6-12	HB-25-DOPT-97-3	3	Trevor	HB	25	26.2	DOPT	22.5	22.15	97	14.28	14.32	1.000	21.06	2	33.34	11.19	6.07
73	3-8-12	HB-200-OPT-97-2	2	Trevor	HB	200	199.5	OPT	25.5	25.97	97	14.28	14.28	0.997	21.05	2	29.74	3.77	1.58
74	3-8-12	HB-200-OPT-97-3	3	Trevor	HB	200	199.5	OPT	25.5	25.97	97	14.28	14.23	1.000	21.05	2	29.18	3.21	1.34
75	3-12-12	EF-200-DOPT-97-1	1	Trevor	EF	200	200.8	DOPT	21	21.44	97	14.79	14.72	1.000	21.16	2	35.88	14.44	7.52
76	3-12-12	EF-200-DOPT-97-4	4	Trevor	EF	200	200.8	DOPT	21	21.44	97	14.79	14.81	0.995	21.2	2	35.78	14.34	7.82
77	3-17-12	EF-200-OPT-97-1	1	Trevor	EF	200	200.7	OPT	24	24.35	97	14.79	14.75	0.997	21.17	2	33.72	9.37	6.21
78	3-17-12	EF-200-OPT-97-4	4	Trevor	EF	200	200.7	OPT	24	24.35	97	14.79	14.79	0.995	21.2	2	33.99	9.64	6.17
79	3-19-12	EF-100-OPT-97-1	1	Trevor	EF	100	100.2	OPT	24	24.28	97	14.79	14.77	1.000	21.16	2	35.77	11.49	9.63
80	3-19-12	EF-100-OPT-97-4	4	Trevor	EF	100	100.2	OPT	24	24.28	97	14.79	14.76	0.997	21.2	2	35.50	11.22	8.98
81	3-23-12	EF-5-OPT-97-1	1	Trevor	EF	5	6.7	OPT	24	24.08	97	14.79	14.80	0.997	21.15	2	48.59	24.51	27.31
82	3-23-12	EF-5-OPT-97-4	4	Trevor	EF	5	6.7	OPT	24	24.08	97	14.79	14.76	1.000	21.21	2	47.30	20.08	26.68
83	3-28-12	BT-25-OPT-94-1	1	Trevor	BT	25	27.4	OPT	23.3	23.16	94	14.42	14.51	0.995	21.15	2	29.79	6.63	3.12
84	3-28-12	BT-25-OPT-94-4	4	Trevor	BT	25	27.4	OPT	23.3	23.16	94	14.42	14.42	1.000	21.21	2	29.44	6.28	3.18
85	4-5-12	BT-200-OPT-94-1	1	Trevor	BT	200	200.7	OPT	23.3	23.25	94	14.42	14.45	0.997	21.14	2	27.95	4.70	1.25
86	4-5-12	BT-200-OPT-94-4	4	Trevor	BT	200	200.7	OPT	23.3	23.25	94	14.42	14.47	0.997	21.2	2	29.54	6.29	2.98
87	4-12-12	EF-25-OPT-97-1	1	Trevor	EF	25	26.6	OPT	24	24.03	97	14.79	14.77	1.000	21.14	2	44.65	20.62	15.30
88	4-12-12	EF-25-OPT-97-4	4	Trevor	EF	25	26.6	OPT	24	24.03	97	14.79	14.81	1.000	21.2	2	44.37	20.34	15.33
89	7-9-12	EF-5-OPT-97-2	2	Das	EF	5.00	4.8	OPT	24	24.20	97	14.79	14.86	0.998	22.26	2.00	47.06	22.86	19.41
90	7-14-12	EF-5-OPT-97-1	1	Das	EF	5.00	5.7	OPT	24	24.40	97	14.79	14.84	0.998	22.26	2.00	48.24	23.84	20.39
91	7-14-12	EF-5-OPT-97-2	2	Das	EF	5.00	5.7	OPT	24	24.40	97	14.79	14.84	0.998	22.27	2.00	48.61	24.21	20.94
92	7-14-12	EF-5-OPT-100-3	3	Das	EF	5.00	5.7	OPT	24	24.40	100	15.25	15.13	0.999	21.62	2.00	48.05	23.65	21.35
93	7-14-12	EF-5-OPT-100-4	4	Das	EF	5.00	5.7	OPT	24	24.40	100	15.25	15.13	0.999	21.72	2.00	48.34	23.94	22.59
94	7-19-12	BT-5-OPT-97-1	1	Das	BT	5.00	6.0	OPT	23.3	23.70	97	14.88	14.95	1.000	22.26	2.00	26.95	3.25	1.52
95	7-19-12	BT-5-OPT-97-2	2	Das	BT	5.00	6.0	OPT	23.3	23.70	97	14.88	14.79	1.000	22.26	2.00	5.73	4.09	1.64
96	8-5-12	BT-5-OPT-94-2	2	Das	BT	5.00	7.3	OPT	23.3	23.70	94	14.42	14.36	1.000	22.27	2.00	29.08	5.38	2.37
97	8-5-12	EF-5-OPT-94-1	1	Das	EF	5.00	7.3	OPT	24	23.80	94	14.34	14.31	1.000	22.26	2.00	44.46	20.66	19.00
98	8-11-12	BT-25-OPT-97-3	3	Das	BT	25.00	26.6	OPT	23.3	23.80	97	14.88	14.81	1.000	21.62	2.00	28.04	4.24	1.32
99	8-11-12	EF-25-OPT-97-1	1	Das	EF	25.00	26.6	OPT	24	24.30	97	14.79	14.64	1.000	22.26	2.00	36.76	12.46	10.37
100	8-11-12	EF-25-OPT-97-2	2	Das	EF	25.00	26.6	OPT	24	24.30	97	14.79	14.69	1.000	22.27	2.00	38.52	14.22	11.21
101	9-19-12	BT-5-OPT-94-1	1	Das	BT	5.00	7.3	OPT	23.3	23.80	94	14.42	14.35	1.000	22.26	2.00	29.88	6.08	1.72
102	9-19-12	BT-5-OPT-94-2	2	Das	BT	5.00	7.3	OPT	23.3	23.80	94	14.42	14.34	0.998	22.27	2.00	30.09	6.29	1.81
103	9-19-12	BT-5-OPT-100-4	4	Das	BT	5.00	7.3	OPT	23.3	23.80	100	15.34	15.26	1.000	21.72	2.00	31.96	8.16	2.04
104	9-26-12	BT-5-DOPT-97-1	1	Das	BT	5.00	7.6	DOPT	20.3	20.60	97	14.88	14.92	1.000	22.26	2.00	29.56	8.96	4.47
105	9-26-12	BT-5-DOPT-97-2	2	Das	BT	5.00	7.6	DOPT	20.3	20.60	97	14.88	14.94	1.000	22.26	2.00	29.62	9.02	4.76
106	9-26-12	BT-5-WOPT-97-4	4	Das	BT	5.00	7.6	WOPT	26.3	25.90	97	14.89	14.97	0.997	21.72	2.00	28.21	2.31	1.49
107	10-1-12	HB-5-DOPT-97-1	1	Das	HB	5.00	7.8	DOPT	22.5	22.10	97	14.28	14.37	1.000	22.26	2.00	31.31	9.21	2.74
108	10-1-12	HB-5-DOPT-97-2	2	Das	HB	5.00	7.8	DOPT	22.5	22.10	97	14.28	14.42	1.000	22.26	2.00	34.42	12.32	3.43
109	10-1-12	HB-5-WOPT-97-3	3	Das	HB	5.00	7.8	WOPT	28.5	28.10	97	14.28	14.21	1.000	21.62	2.00	29.14	1.04	0.71
110	10-4-12	HB-5-OPT-94-1	1	Das	HB	5.00	6.9	OPT	25.5	25.10	94	13.84	13.91	1.000	22.26	2.00	29.36	4.26	1.37
111	10-4-12	HB-5-OPT-97-2	2	Das	HB	5.00	6.9	OPT	25.5	25.10	97	14.28	14.39	1.000	22.26	2.00	29.21	4.11	1.18
112	10-4-12	HB-5-OPT-100-3	3	Das	HB	5.00	6.9	OPT	25.5	25.10	100	14.72	14.66	1.002	21.62	2.00	27.95	2.85	0.58
113	10-10-12	HB-5-OPT-97-1	1	Chris	HB	5	7.5	OPT	25.5	33.09	97	14.29	13.54	0.997	22.31	2	38.21	5.11	1.20
114	10-10-12	HB-5-OPT-94-2	2	Chris	HB	5	7.5	OPT	25.5	33.09	94	13.85	13.12	0.997	22.25	2	36.43	3.34	1.20
115	10-17-12	EF-5-DOPT-97-4	4	Chris	EF	5.00	7.27	DOPT	21	24.03	97	14.80	11.93	1.003	21.71	2.00	54.54	30.51	27
116	10-17-12	HB-5-OPT-94-1	1	Chris	HB	5.00	7.27	OPT	25.5	24.73	94	13.84	13.96	1.000	22.32	2.00	33.88	9.15	3.5
117	10-17-12	HB-5-OPT-97-2	2	Chris	HB	5	7.3	OPT	25.5	25.62	97	14.29	14.24	1.002	22.26	2	32.49	6.87	5.00
118	10-17-12	HB-5-OPT-97-3	3	Chris	HB	5.00	7.27	OPT	25.5	24.73	97	14.29	14.46	0.995	21.60	2.00	33.78	9.05	4
119	10-21-12	EF-5-OPT-97-2	2	Chris	EF	5.00	7.48	OPT	24	25.58	97	14.80	14.56	1.003	22.25	2.00	50.01	24.43	24
120	10-21-12	HB-5-OPT-97-1	1	Chris	HB	5.00	7.48	OPT	25.5	25.58	97	14.29	14.36	0.997	22.31	2.00	32.81	7.23	5.4
121	10-23-12	BT-5-OPT-94-4	4	Chris	BT	5.00	7.7	OPT	23.3	24.09	94	14.42	14.42	1.000	21.71	2.00	30.31	6.22	3.10

122	10-23-12	EF-5-WOPT-97-3	3	Chris	EF	5.00	7.7	WOPT	27	27.81	97	14.80	14.76	0.993	21.60	2.00	48.80	20.99	20.90
123	10-23-12	HB-5-OPT-100-1	1	Chris	HB	5.00	7.7	OPT	25.5	21.98	100	14.72	15.08	1.005	22.32	2.00	32.30	10.33	6.14
124	10-23-12	HB-5-OPT-97-2	2	Chris	HB	5.00	7.7	OPT	25.5	21.98	97	14.29	14.71	1.001	22.26	2.00	32.72	10.74	4.70
125	10-25-12	EF-5-WOPT-97-1	1	Chris	EF	5.00	7.4	WOPT	27	23.48	97	14.80	15.24	0.998	22.30	2.00	51.89	28.41	24.70
126	10-25-12	HB-5-OPT-97-2	2	Chris	HB	5.00	7.4	OPT	25.5	24.12	97	14.29	14.14	1.023	22.27	2.00	31.19	7.07	2.60
127	10-25-12	HB-5-DOPT-97-3	3	Chris	HB	5.00	7.4	DOPT	22.5	24.12	97	14.28	14.18	0.994	21.60	2.00	34.23	10.11	2.91
128	10-25-12	HB-5-DOPT-97-4	4	Chris	HB	5.00	7.4	DOPT	22.5	24.12	97	14.28	14.13	0.996	21.71	2.00	33.12	9.00	3.00
129	10-30-12	EF-5-OPT-97-4	4	Chris	EF	5.00	7.2	OPT	24	24.62	97	14.80	14.67	1.005	21.70	2.00	52.53	27.91	27.75
130	10-30-12	HB-5-OPT-97-1	1	Chris	HB	5.00	7.2	OPT	25.5	26.77	97	14.29	14.08	1.004	22.32	2.00	29.29	2.52	2.35
131	10-30-12	HB-5-OPT-97-2	2	Chris	HB	5.00	7.2	OPT	25.5	26.77	97	14.29	14.12	1.001	22.25	2.00	48.42	21.65	1.81
132	10-30-12	HB-5-OPT-97-3	3	Chris	HB	5.00	7.2	OPT	25.5	26.77	97	14.29	14.16	0.998	21.58	2.00	44.41	17.64	4.40
133	11-2-12	HB-5-OPT-97-1	1	Chris	HB	5.00	7.2	OPT	25.5	27.41	97	14.29	14.04	1.004	22.32	2.00	35.83	8.42	2.78
134	11-2-12	HB-5-OPT-97-2	2	Chris	HB	5.00	7.2	OPT	25.5	27.41	97	14.29	13.95	1.009	22.26	2.00	34.65	7.24	2.49
135	11-1-11	S5-5-OPT-100-1	1	Trevor	S5	5	5.0	OPT	12.6	12.60	100	18.92	18.90	1.000	22.26	2	-	-	0.60
136	11-1-11	S5-20-OPT-100-1	1	Trevor	S5	20	20.0	OPT	12.6	12.60	100	18.92	18.90	1.000	22.26	2	-	-	0.60
137	11-1-11	S5-20-OPT-100-2	2	Trevor	S5	20	20.0	OPT	12.6	12.60	100	18.92	18.90	1.000	22.26	2	-	-	0.60
138	11-1-11	S5-200-OPT-100-1	1	Trevor	S5	200	200.0	OPT	12.6	12.60	100	18.92	18.90	1.000	22.26	2	-	-	0.60

TRAINING MATERIAL: PVR METHODOLOGY

The University of Texas at Austin

Available Methods

Three methods to calculate the Potential Vertical Rise (PVR) of an expansive soil are illustrated in this presentation:

1. Tex-124-E from TxDOT
   - Based on correlations of PI to swelling (traditional approach)
2. 6048 - Method A
   - Uses **a database** of swell test results for clays from the central Texas area, generated using centrifuge technology
3. 6048 - Method B
   - Uses **project-specific** swell test results on clays, generated using centrifuge technology

Example Problem

Problem Statement:

Consider a subgrade with a single stratum of Eagle Ford Clay:

- Layer thickness = 10 ft
- $\omega = 27\%$
- $\gamma = 121$ pcf
- LL = 88%
- PI = 49%
- %< No.40 Sieve = 93%

Objective:

Calculate PVR using the three proposed methods. For Method 6048(A) use the available database of swell test results on Eagle Ford Clay. For Method 6048(B) use project-specific data from three centrifuge tests conducted on site.

Tex-124-E Methodology

- Modified procedure from McDowell’s 1959 method
  - Includes “Free Swell” conversion ratio
- Based on the correlation of PI to swelling potential
- Subdivide soil in layers
  - Typically uses 0.6 m (2 ft) sub-layers for simplicity

Tex-124-E Methodology

- From collected samples, determine ω, γ, LL, PL, PI, % soil binder (< No. 40 Sieve)
- Consider the following for the calculations:
  - Determine load on top and bottom of each sub-layer.
  - Determine dry, wet, and average moisture content.
    - $\omega_d = .2 * LL + 9\%$
      - For EF, $\omega_d = 27\%$
    - $\omega_w = .47 * LL + 2\%$
      - For EF, $\omega_w = 43\%$
    - $\omega_a = 35\%$
  - Record moisture content, PI, and % soil binder for each sub-layer.

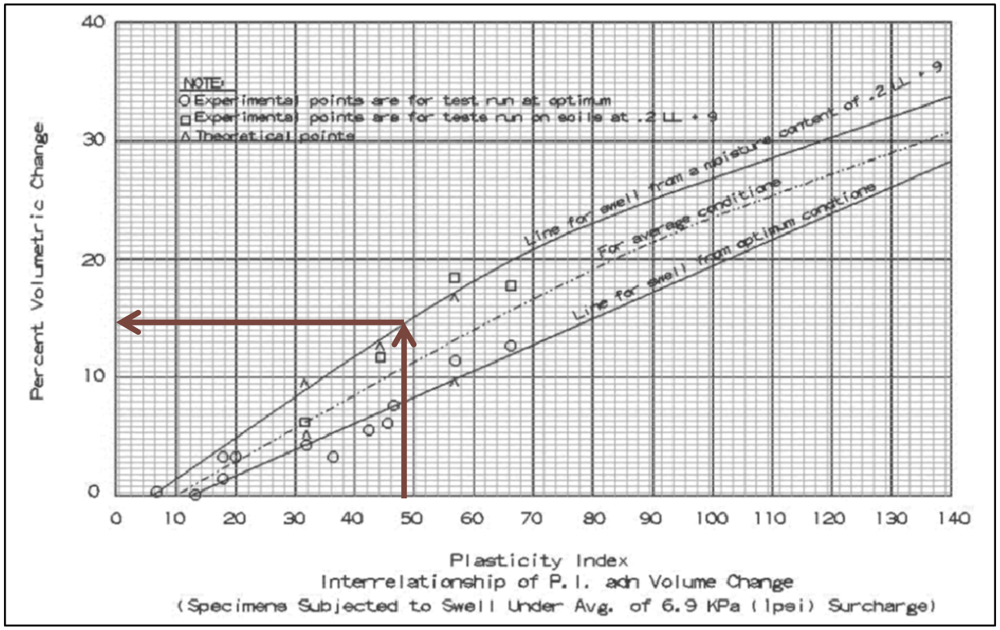
Tex-124-E Methodology

Information from the sub-layers considered in the calculation:

Depth (ft)	Thickness (ft)	Unit Weight (pcf)	Load at Top (psi)	Load at Bottom (psi)	Average Load (psi)	LL	Dry (%)	Wet (%)	w%	Dry/Avg /Wet	% Soil Binder	PI
0.0	2.0	121	0.0	1.7	0.8	88	27	43	27	Dry	93	49
2.0	2.0	121	1.7	3.4	2.5	88	27	43	27	Dry	93	49
4.0	2.0	121	3.4	5.0	4.2	88	27	43	27	Dry	93	49
6.0	2.0	121	5.0	6.7	5.9	88	27	43	27	Dry	93	49
8.0	2.0	121	6.7	8.4	7.6	88	27	43	27	Dry	93	49

Tex-124-E Methodology

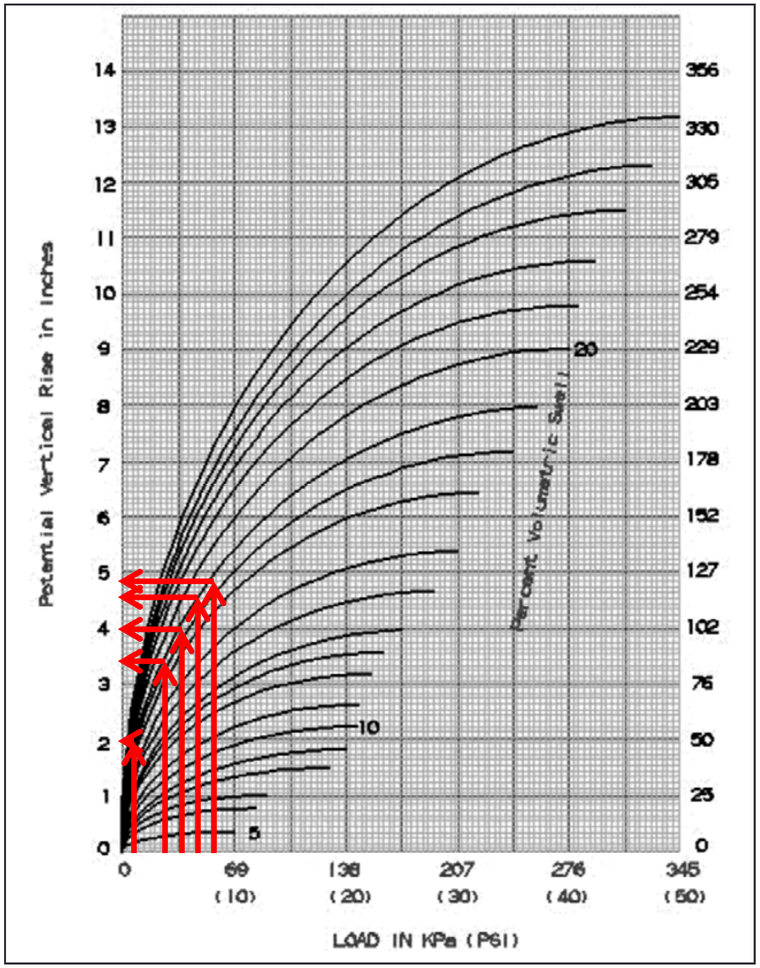
- Determine percent volumetric change (1 psi surcharge) using PI from graph.
  - % Vol Swell = 15%
- Determine swell under no loading.



$$\%Free\ Swell = (\%\,Vol\ Swell\ @\ 1psi) * 1.07 + 2.6\%$$
$$= 15\% * 1.07 + 2.6\% = 18.7\%$$

Tex-124-E Methodology

- Determine PVR at top and bottom of each sub-layer using figures.
  - Take load and go up to % free swell.
  - From there, determine PVR in inches.



Tex-124-E Methodology

- Correction for soil binder:
    - Assumes that it is all passing No. 40
    - $C_{SB} = \frac{\%\ less\ than\ 25\ \mu m}{100\%} = \frac{93\%}{100\%} = .93$
- Correction for wet density:
    - Assumes a density of 125 pcf
    - $C_{\gamma} = \frac{125\ pcf}{\gamma_a} = 1$
- The difference in PVR between top and bottom of sub-layer is the PVR of the sub-layer.
- Multiply this by correction factors to get corrected PVR.

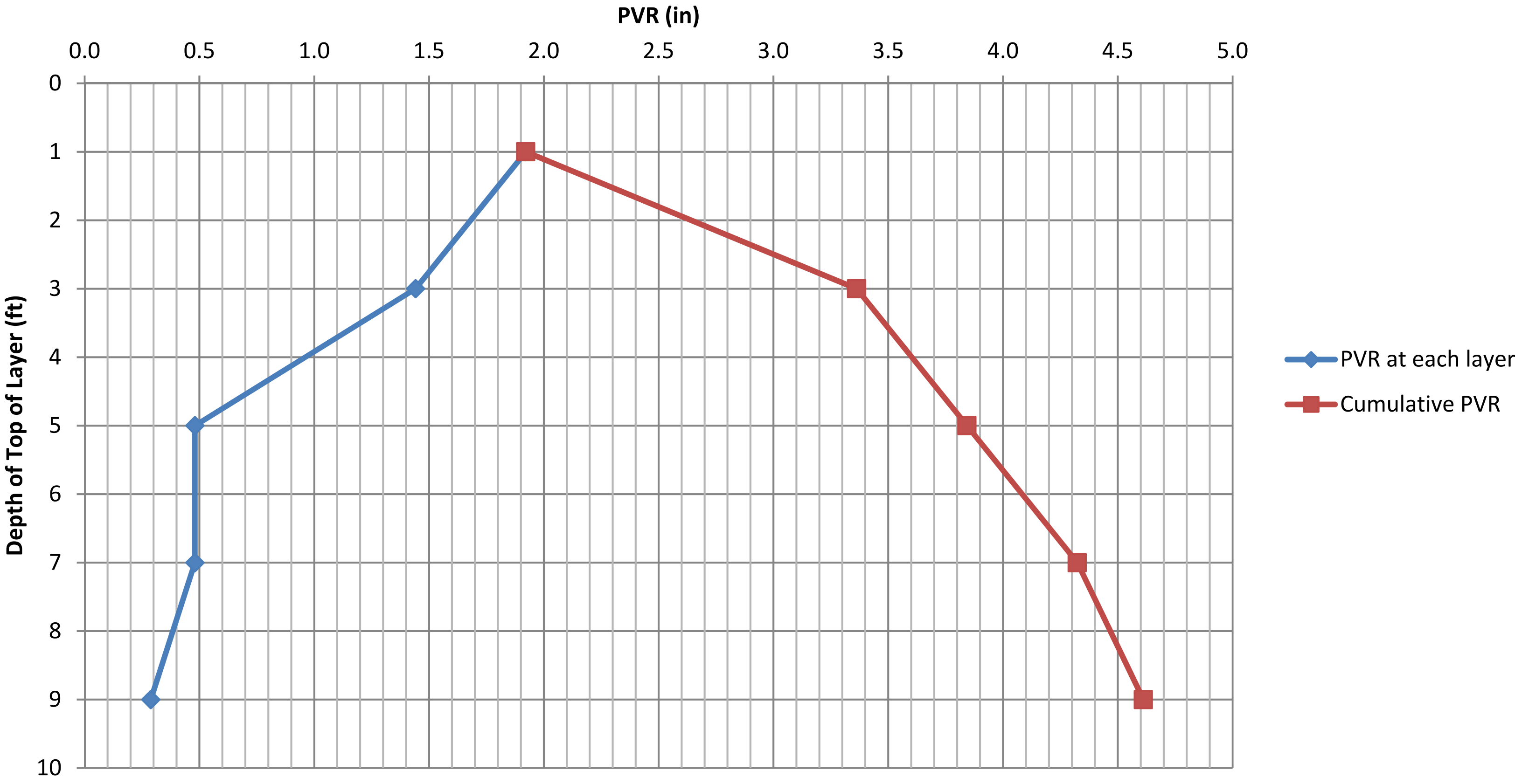
Tex-124-E Methodology

Tex-124-E calculations for each sub-layer:

Depth (ft)	Thickness (ft)	% Vol. Swell at 1psi	% Vol. Free Swell	PVR at Top (in)	PVR at Bottom (in)	Cor. Soil Binder	Cor. Density	PVR in Layer (in)	Cumulative PVR (in)
0.0	2.0	15	18.7	0	2	0.93	1.03	1.9	1.9
2.0	2.0	15	18.7	2	3.5	0.93	1.03	1.4	3.4
4.0	2.0	15	18.7	3.5	4	0.93	1.03	0.5	3.8
6.0	2.0	15	18.7	4	4.5	0.93	1.03	0.5	4.3
8.0	2.0	15	18.7	4.5	4.8	0.93	1.03	0.3	4.6

Calculated PVR using Tex-124-E Methodology: **4.6 inches**

Tex-124-E Methodology



Proposed 6048(A) Methodology

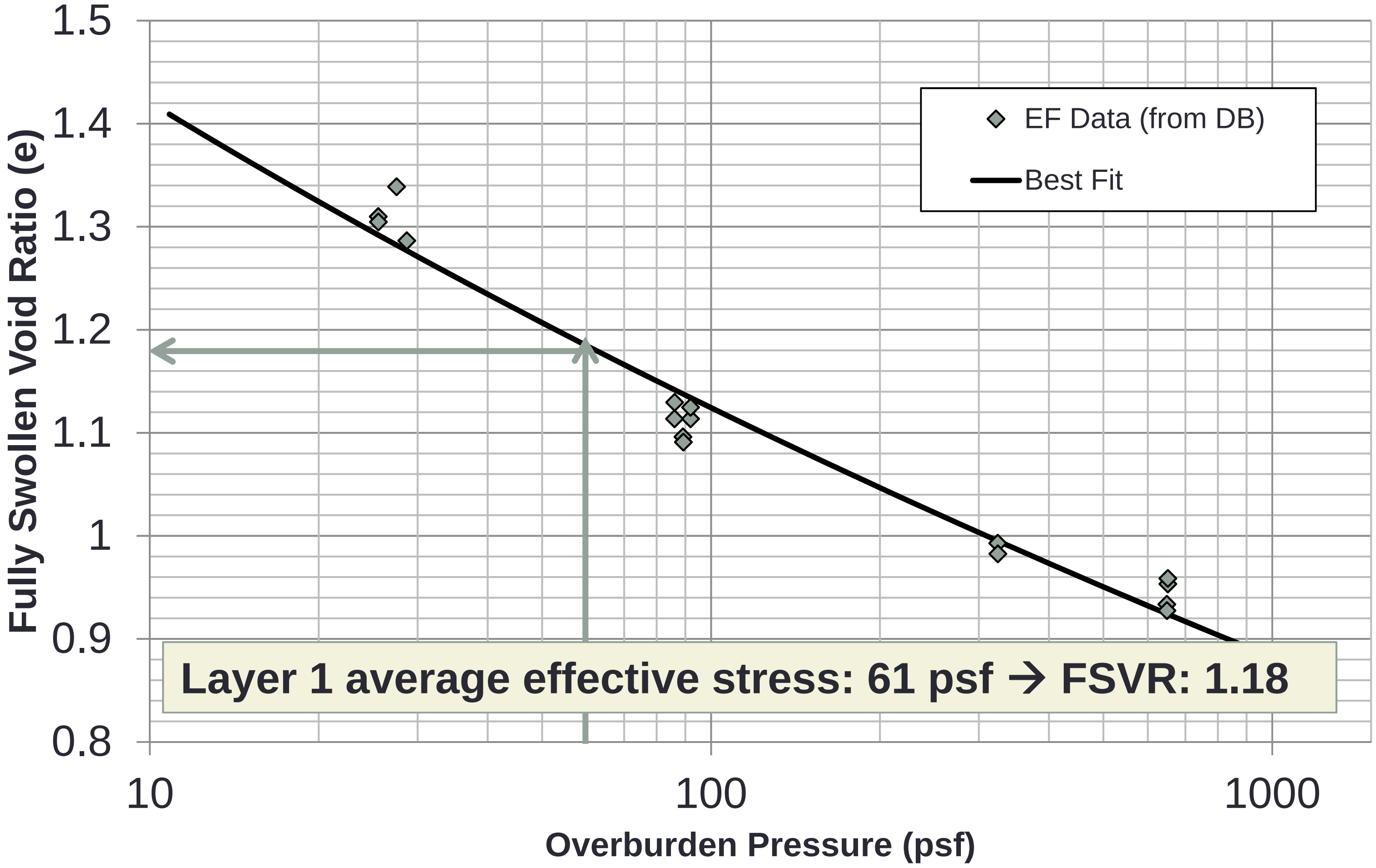
- Proposed Methodology 6048(A) uses results from a database of centrifuge swell tests to predict the vertical rise soil.
- This methodology is useful for preliminary evaluations for locations where no centrifuge tests have been conducted using project-specific clay samples.
  - Soil type of interest should be available in database.
  - Current database includes soils from five locations from select sites around Austin:
    - Eagle Ford Clay
    - Black Taylor Clay
    - Tan Taylor Clay
    - Houston Black Clay
    - Soil 5 (generic fill)

Proposed 6048(A) Methodology

<u>Procedure</u>:

1. Information should be obtained (e.g., available boring logs) or inferred on water content, void ratio, and soil type with depth.
    - Can also get index properties, grain size distributions, etc.
    - *For this example, Eagle Ford clay will be used with a void ratio of 0.82 and unit weight of 121 pcf.*
2. Divide soil profile into sub-layers; 2-ft layers are typical.
3. Determine the effective stress at the top and bottom of each layer.
4. From the matching curve in the database, obtain the average fully swollen void ratio (FSVR) for the range of stresses in each layer. The average FSVR may be taken:
    - as the FSVR corresponding to the effective stress at the center of the layer (less accurate).
    - as the FSVR corresponding to the log-average of the effective stress at the top and bottom of the layer.
    - by calculating the average of the FSVR curve across the range of stresses in the layer (most accurate, requires integration).

Fully Swollen Void Ratio (Eagle Ford)



Layer 1 average effective stress: 61 psf → FSVR: 1.18

Proposed 6048(A) Methodology

5. Calculate the difference between the current void ratio and the predicted FSVR for each sub-layer.
   - If the FSVR is less than the measured void ratio, the PVR of the layer is zero (this may occur for recently consolidated soils that were originally close to their FSVR; the stress history of soil will also affect results).
6. Calculate the swell of each layer as a percent:

$$swell(\%) = 100\frac{\Delta e}{1+e}$$

7. Multiply swell by layer thickness to determine the PVR of a layer.
8. Sum of PVR of each layer is the PVR of the soil.

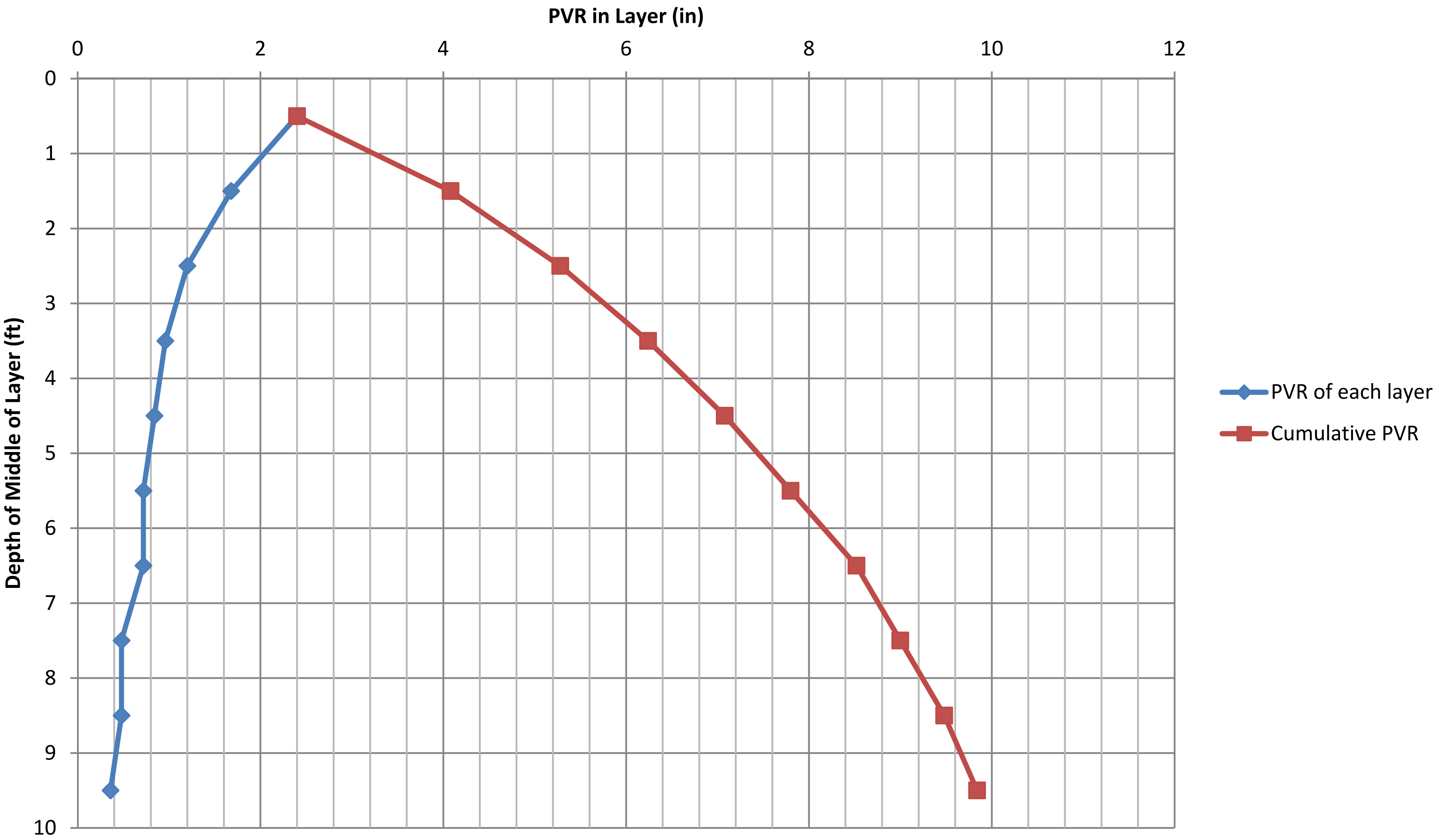
Proposed 6048(A) Methodology

6048(A) calculations for each sub-layer:

Depth (ft)	Thickness (ft)	w%	Unit Weight (pcf)	Void Ratio (e)	Average Effective Stress (psf)	Fully Swollen Void Ratio (e)	Strain (%)	Vertical Rise (in)	Cumulative PVR (in)
0.0	1.0	27	121	0.82	61	1.18	0.20	2.44	2.4
1.0	1.0	27	121	0.82	182	1.06	0.13	1.60	4.0
2.0	1.0	27	121	0.82	303	1.00	0.10	1.24	5.3
3.0	1.0	27	121	0.82	424	0.97	0.08	1.01	6.3
4.0	1.0	27	121	0.82	545	0.94	0.07	0.84	7.1
5.0	1.0	27	121	0.82	666	0.92	0.06	0.71	7.8
6.0	1.0	27	121	0.82	787	0.91	0.05	0.60	8.4
7.0	1.0	27	121	0.82	908	0.89	0.04	0.51	8.9
8.0	1.0	27	121	0.82	1029	0.88	0.04	0.43	9.4
9.0	1.0	27	121	0.82	1150	0.87	0.03	0.36	9.7

Calculated PVR using proposed 6048(A) Methodology: **9.7 inches**

Proposed 6048(A) Methodology



Proposed 6048(B) Methodology

- Method is based on directly testing in-situ samples in order to accurately predict the project-specific potential vertical rise.
  - Undisturbed clay samples collected using Shelby tubes should be tested using the centrifuge at a variety of stresses (three g-levels recommended) in order to create a project-specific swell-stress curve.
  - Determine the swell-stress curve to predict swell of clay layer.

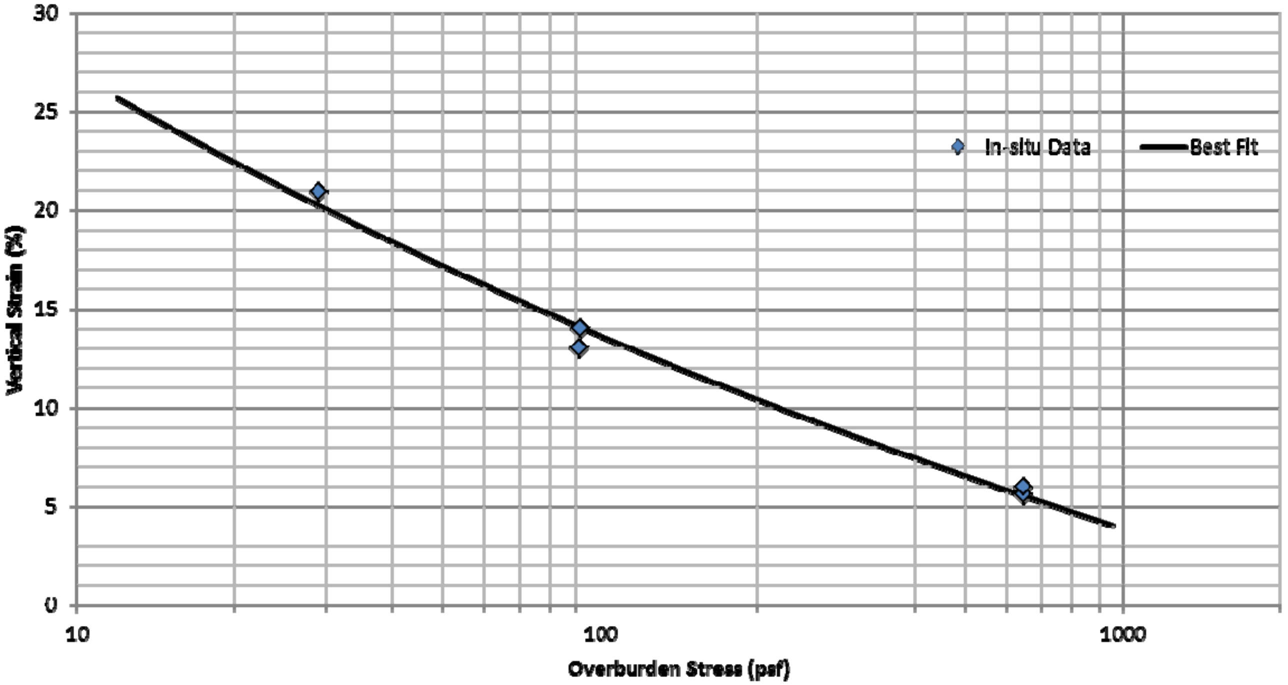
Proposed 6048(B) Methodology

- Run centrifuge test at three different effective stresses (5g, 25g, 200g).
  - Determine effective stresses at top and bottom of sample.
- Generate swell vs. effective stress from centrifuge test results in order to calculate swell for each layer.
- Multiply by height to determine PVR of each layer.
- Sum of PVR for each layer is total PVR.

Note on the example used in this presentation: Undisturbed in-situ Eagle Ford samples were not available at this stage in the implementation project. Instead, a set of results from remolded clay samples were used for illustration purposes.

Proposed 6048(B) Methodology

Determination of project-specific swell data using centrifuge samples tested at three g-levels:



Proposed 6048(B) Methodology

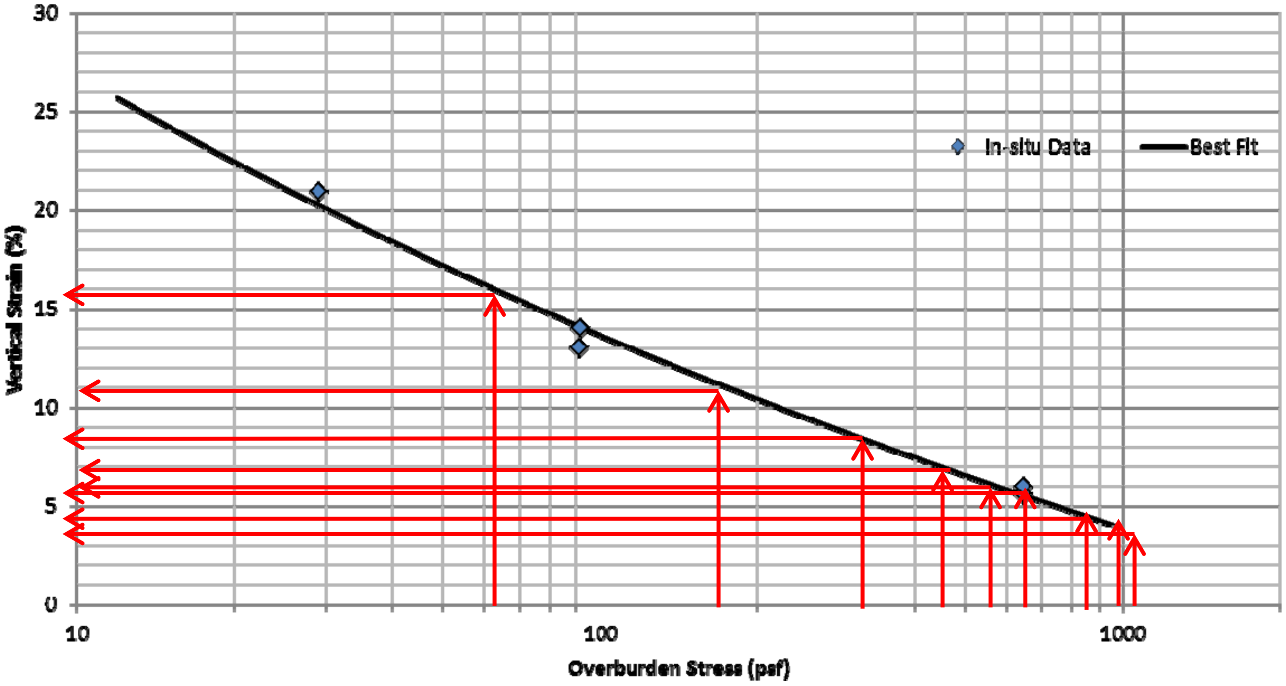
6048(B) calculations for each sub-layer:

Depth (ft)	Thickness (ft)	w%	Unit Weight (pcf)	Average Effective Stress (psf)	Swell (%)	PVR (in)	Cumulative PVR (in)
0.0	1.0	27	125	63	16	1.92	1.9
1.0	1.0	27	125	188	12	1.44	3.4
2.0	1.0	27	125	313	8.5	1.02	4.4
3.0	1.0	27	125	438	7.6	0.912	5.3
4.0	1.0	27	125	563	6	0.72	6.0
5.0	1.0	27	125	688	5.5	0.66	6.7
6.0	1.0	27	125	813	5	0.6	7.3
7.0	1.0	27	125	938	4	0.48	7.8
8.0	1.0	27	125	1063	4	0.48	8.2
9.0	1.0	27	125	1188	3.5	0.42	8.7

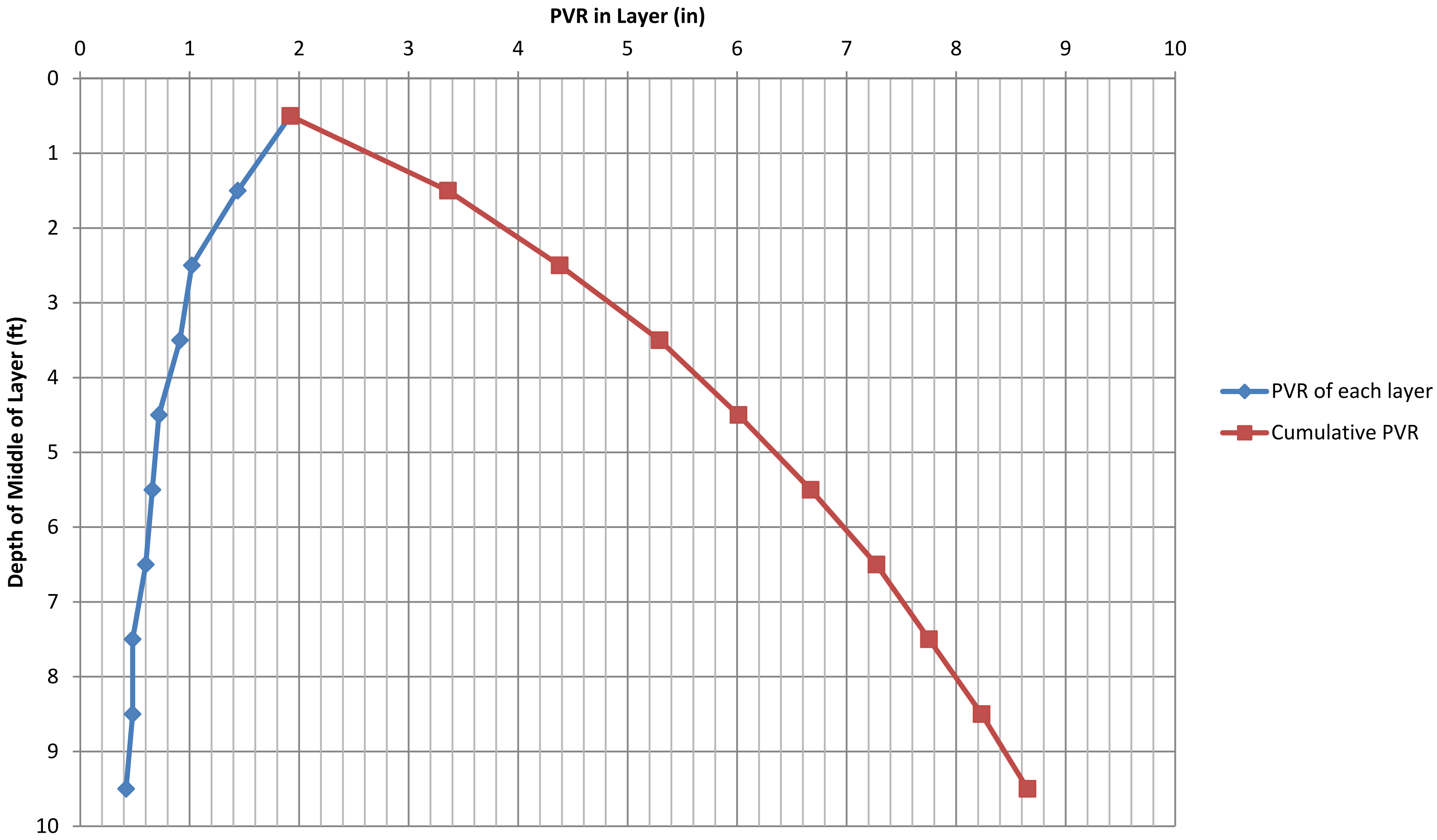
Calculated PVR using proposed 6048(A) Methodology: **8.7 inches**

Proposed 6048(B) Methodology

- Determination of swell for each sub-layer



Proposed 6048(B) Methodology

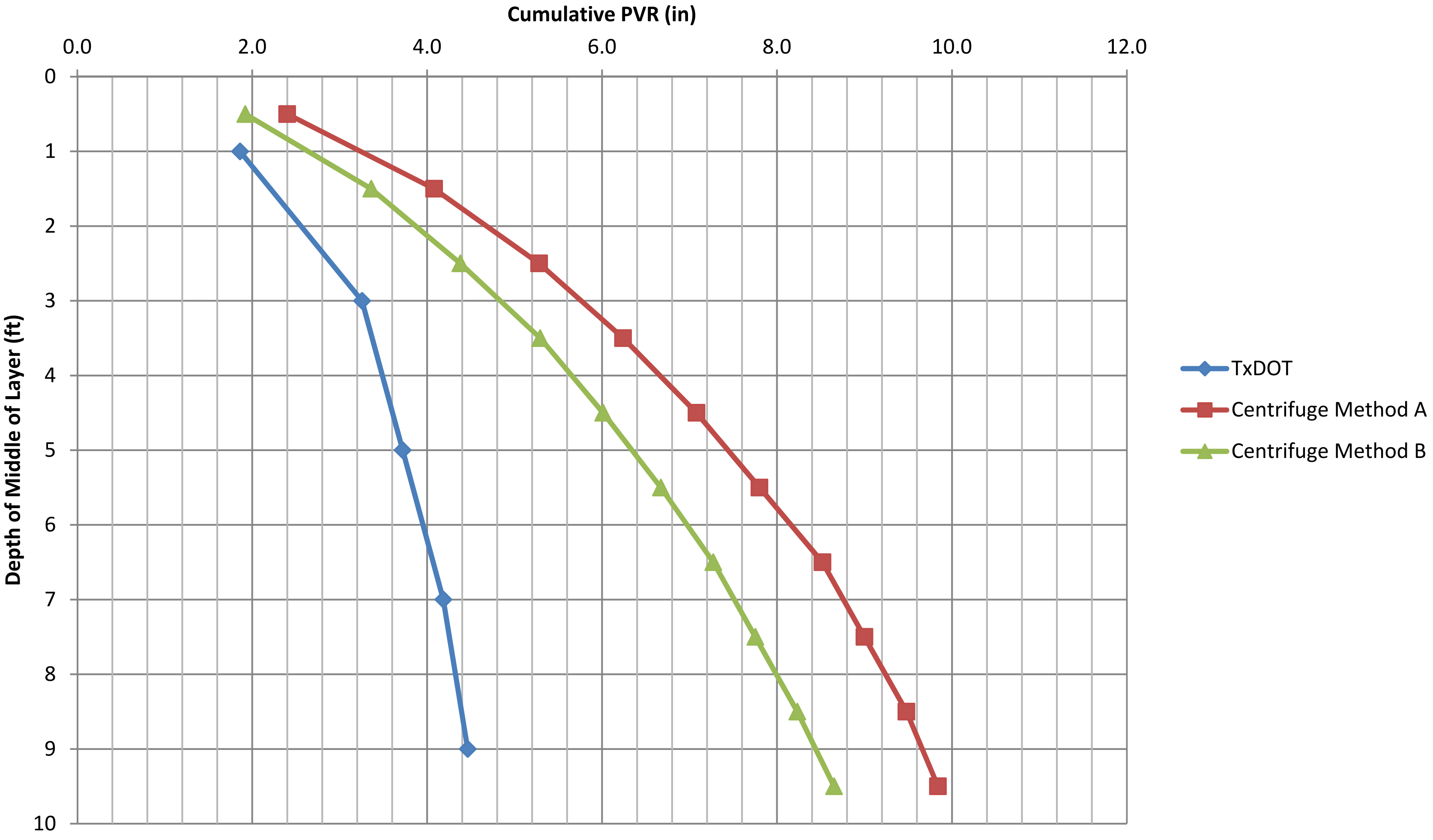


Comparison of Cumulative PVR

Summary of PVR predictions using the various methodologies:

- Tex-124-E Methodology:
  - 4.6 Inches
- Proposed 6048(A) Methodology:
  - 9.7 inches
- Proposed 6048(B) Methodology:
  - 8.7 Inches

Comparison of Cumulative PVR



Final Remarks

- At least for the case of Eagle Ford Clay, the PVR calculated using Tex-124-E Methodology significantly underpredicts the vertical rise (by approximately 50%), when compared with the vertical rise obtained using soil-specific data.
- The use of proposed Methodology 6048(A) is preferable to Tex-124-E as it leads to a soil-specific prediction of vertical rise.
- The use of proposed Methodology 6048(B) is recommended when project soil data is available. This approach leads to a project-specific prediction of vertical rise.
- At least for the example shown in this presentation, the PVR predicted using Methodologies 6048(A) and 6048(B) is similar (within approximately 10%). This is consistent with comparatively small variability in swell obtained in the database for results in the same clay but for different conditions/locations.
- The use of a database (Methodology 6048(A)) is suitable for preliminary predictions of PVR.
- Methodology 6048(B) is recommended for prediction of PVR for final design.
- Methodology 6048(B) cannot be implemented fully at this time, as the centrifuge equipment is not ready for testing undisturbed samples. Modification of the centrifuge cup sampler (to accommodate testing of undisturbed samples) is recommended.