Application of Expansive Soil Geotechnical Procedures

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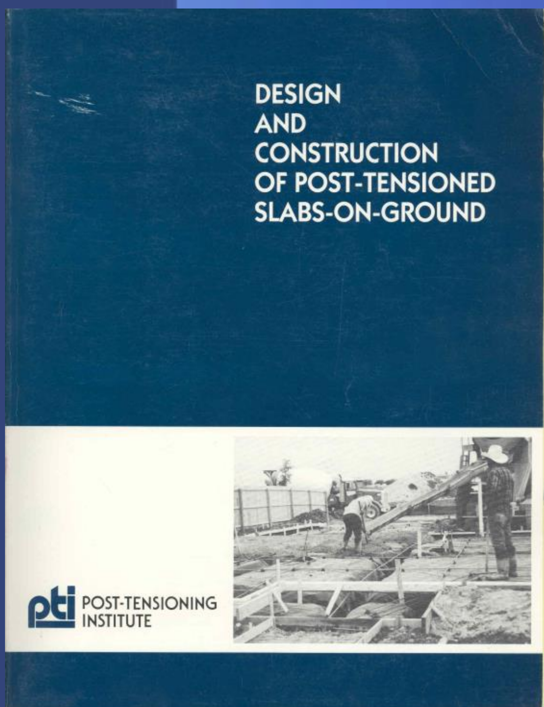
2015 PTI CONVENTION COMMITTEE MEETING

ROYAL SONESTA HOUSTON GALLERIA
HOUSTON, TEXAS

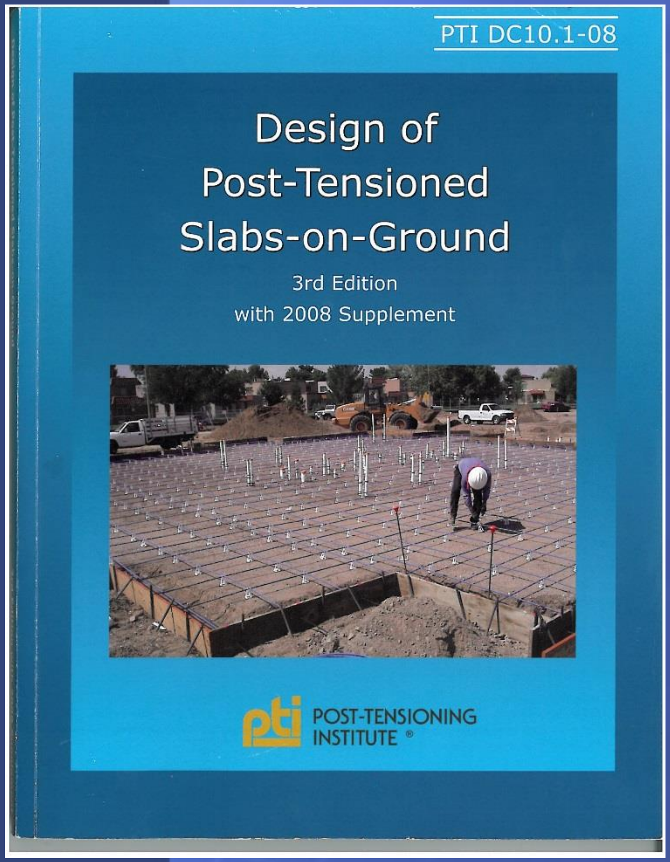
- PTI design is a CLIMATIC based model that has to be corrected for various non-climatic factors:
  - Deeper moisture equilibration is chief
    - Perched groundwater
    - Deeper tree/veg desiccation
    - Trails, roads and fence lines
    - Man-induced fill plecement

PTI 2nd Edition Manual



The "Design and Construction of Post-Tensioned Slabs-On-Ground", 2nd Edition manual was published by the Post-Tensioning Institute in October 1996.

PTI 3rd Edition Manual



The "Design of Post-Tensioned Slabs-On-Ground, 3rd Edition manual with 2008 Supplement".

Contains Addendum 1 and 2 with the two Standards as shown in the 2006 IRC.

Issued in May 2008

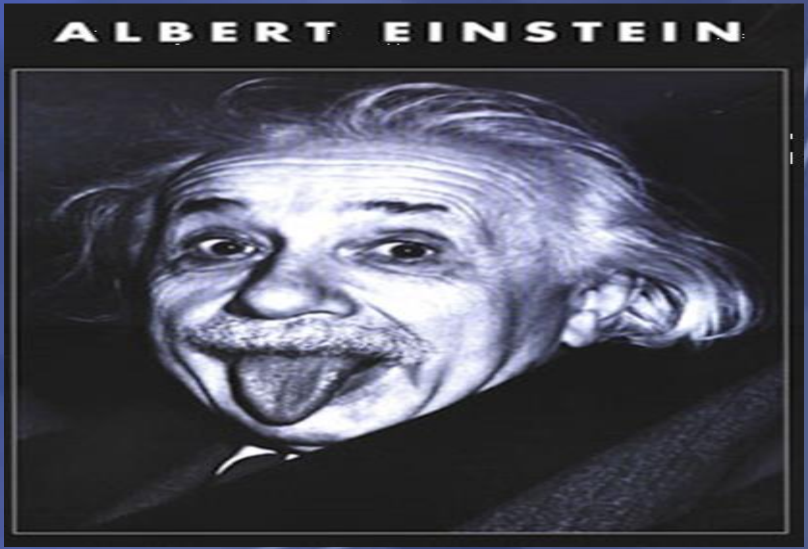
Issue: Complexity of the Procedure

URBAN MYTH 1: To use and understand the PTIGDPE you must either:

a. Be Albert Einstein?

b. Be a Protégé of Albert Einstein?

c. Know who Albert Einstein



d. None of the above?

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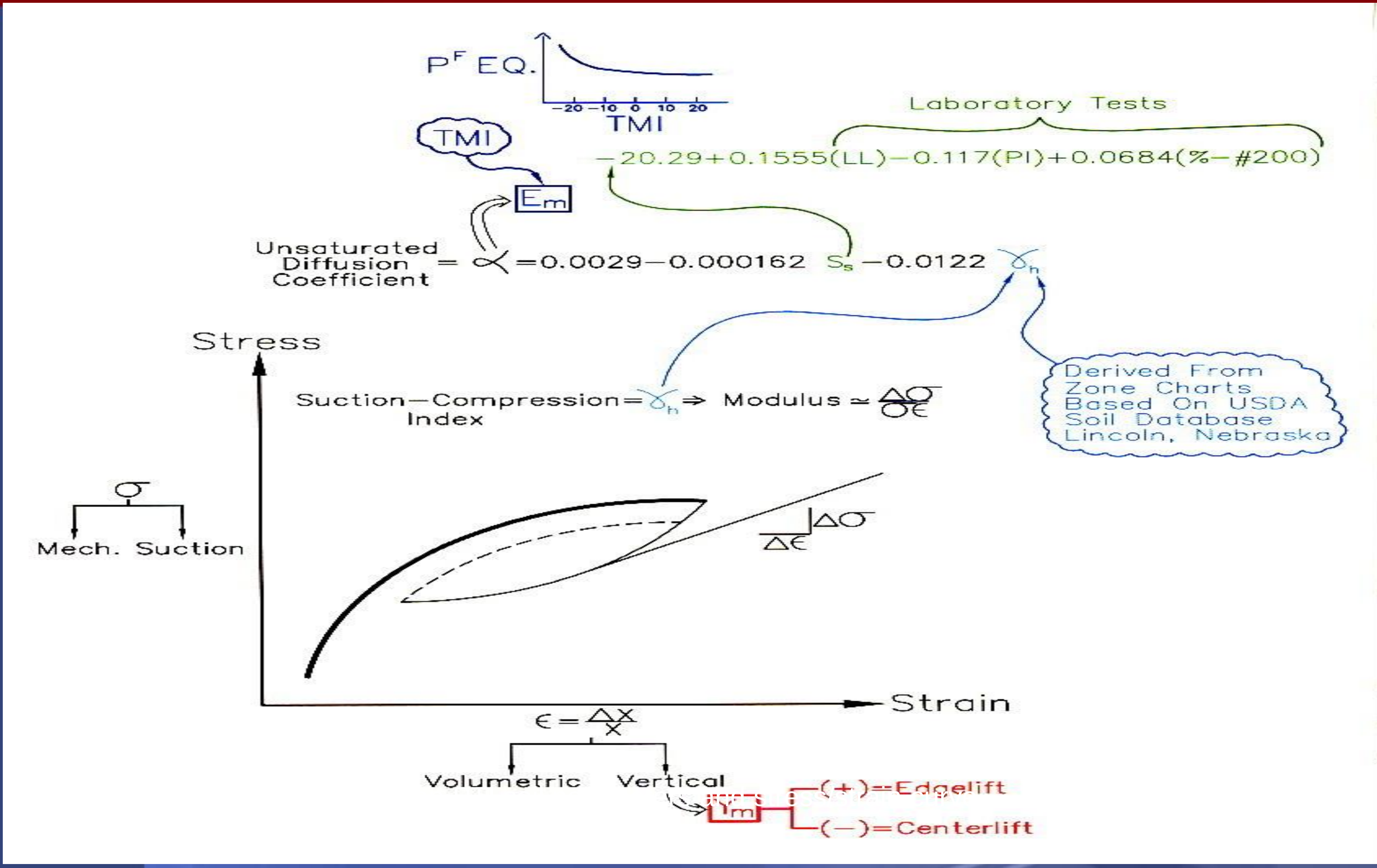
Fact: Answer is d, none of the above!

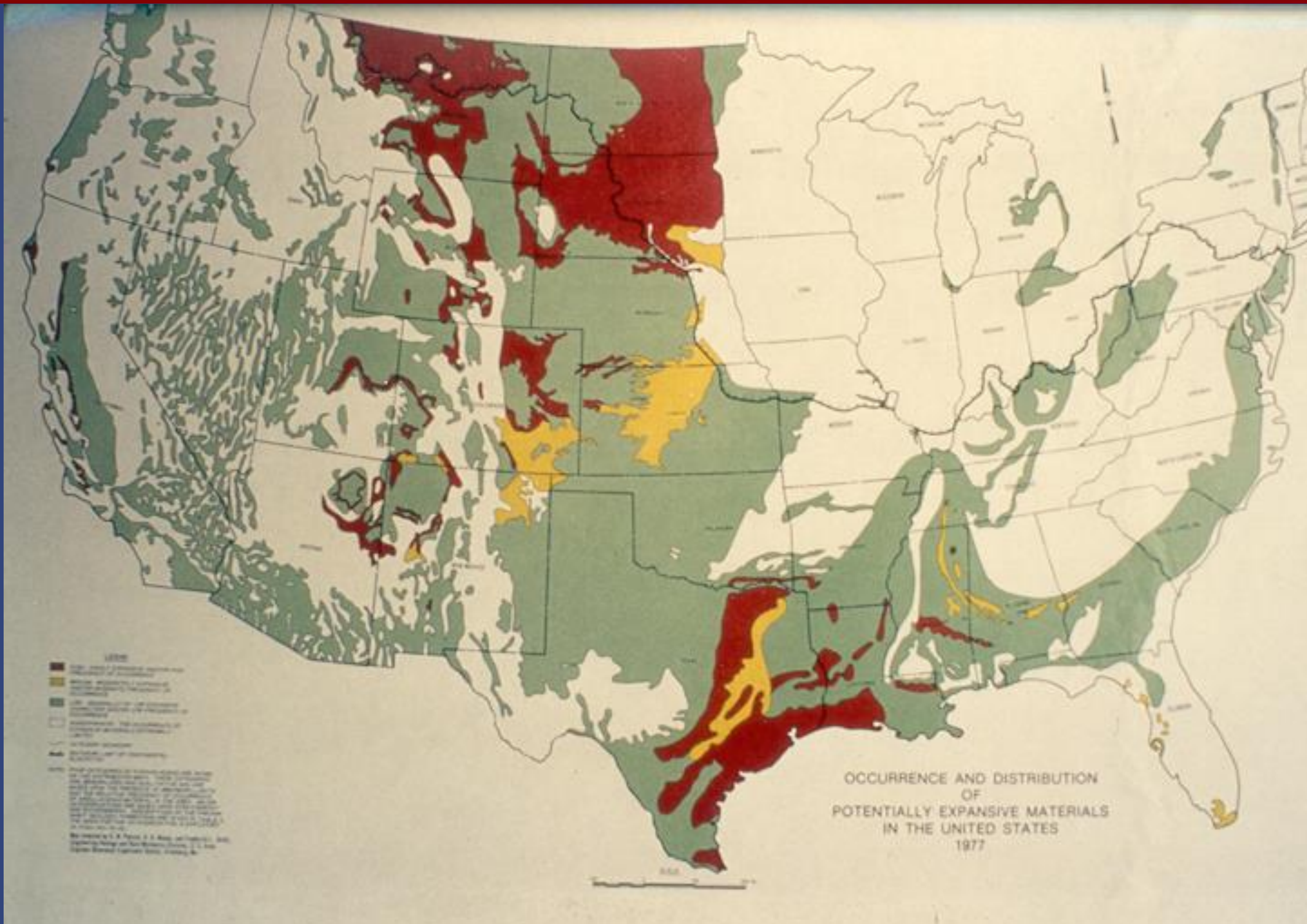
- The procedure is not difficult and is based simply on the relationship between stress and strain in material, which in this case is soil.
- Chart 1 helps to explain the relationships between the various known and unknown variables in the procedure.

- PTI design is a CLIMATIC based model that has to be corrected for various non-climatic factors:
  - Deeper moisture equilibration is chief
    - Perched groundwater
    - Deeper tree/veg desiccation
    - Trails, roads and fence lines
    - Man-induced fill plecement



P^F EQ.
-20 -10 0 10 20
TMI
Laboratory Tests
TMI
−20.29+0.1555(LL)−0.117(PI)+0.0684(%−#200)
Em
Unsaturated Diffusion Coefficient = α = 0.0029 − 0.000162 Ss − 0.0122 γh
Stress
Suction−Compression Index = γh ⇒ Modulus ≃ Δσ/Δε
Derived From Zone Charts Based On USDA Soil Database Lincoln, Nebraska
σ
Mech. Suction
Δσ
Δε
Strain
ε = ΔX/X
Volumetric
Vertical
ym
(+)=Edgelift
(−)=Centerlift

Distribution of Expansive Soils



Expansive Soil?

PTI 3.2.1 - Expansive Soil Design is applicable if:

- All three of the following are true
  - Weighted PI of soil profile >= 15
  - Weighted Passing #200 Sieve > 10%
  - Weighted Finer than 5 micron > 10%
- Or EI > 20

Modified definition of an expansive site included in Addendum #1

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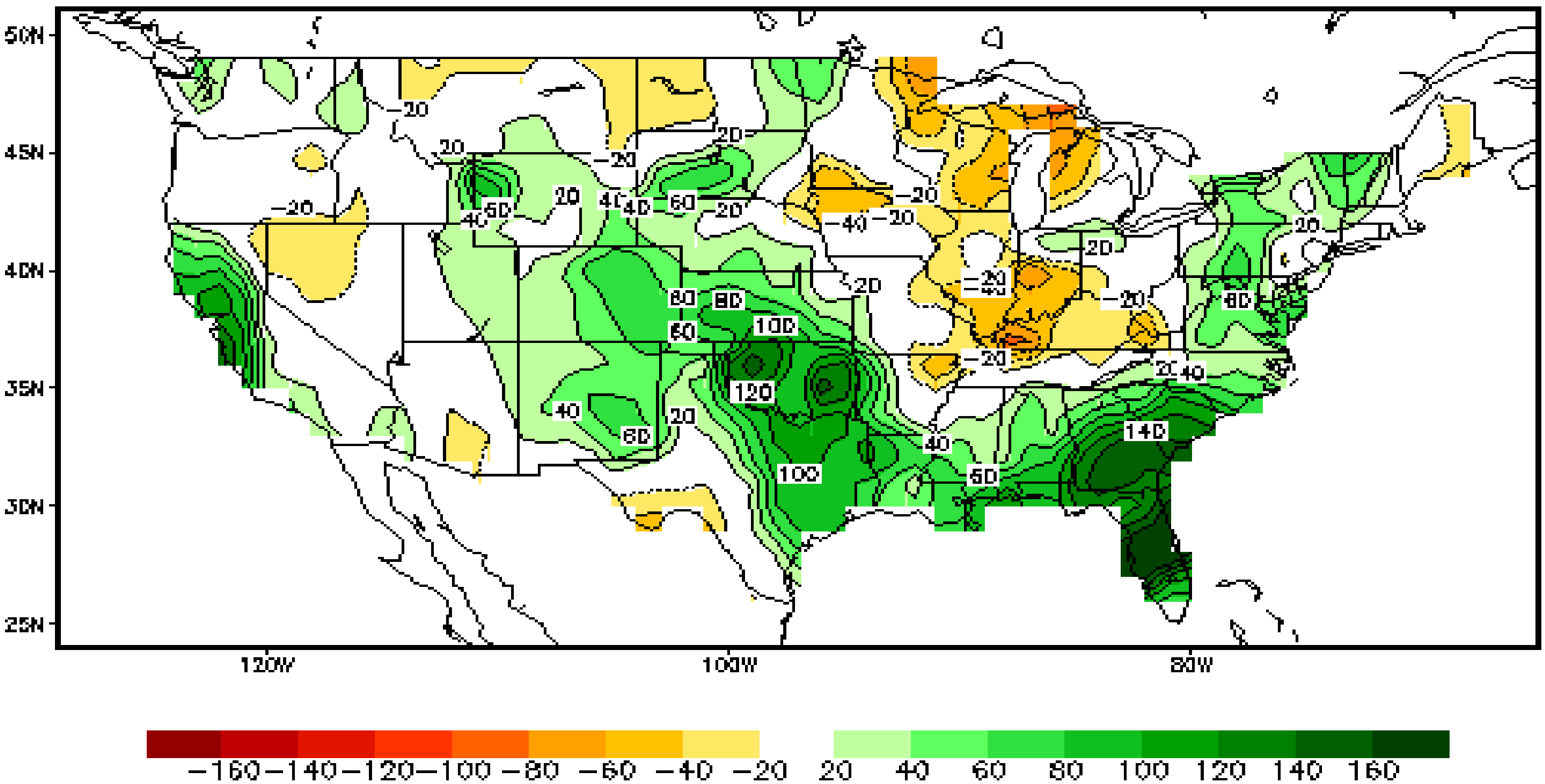
Calculated Soil Moisture Anomaly (mm)
JAN, 1998



Soil Structure Interaction – Center Lift

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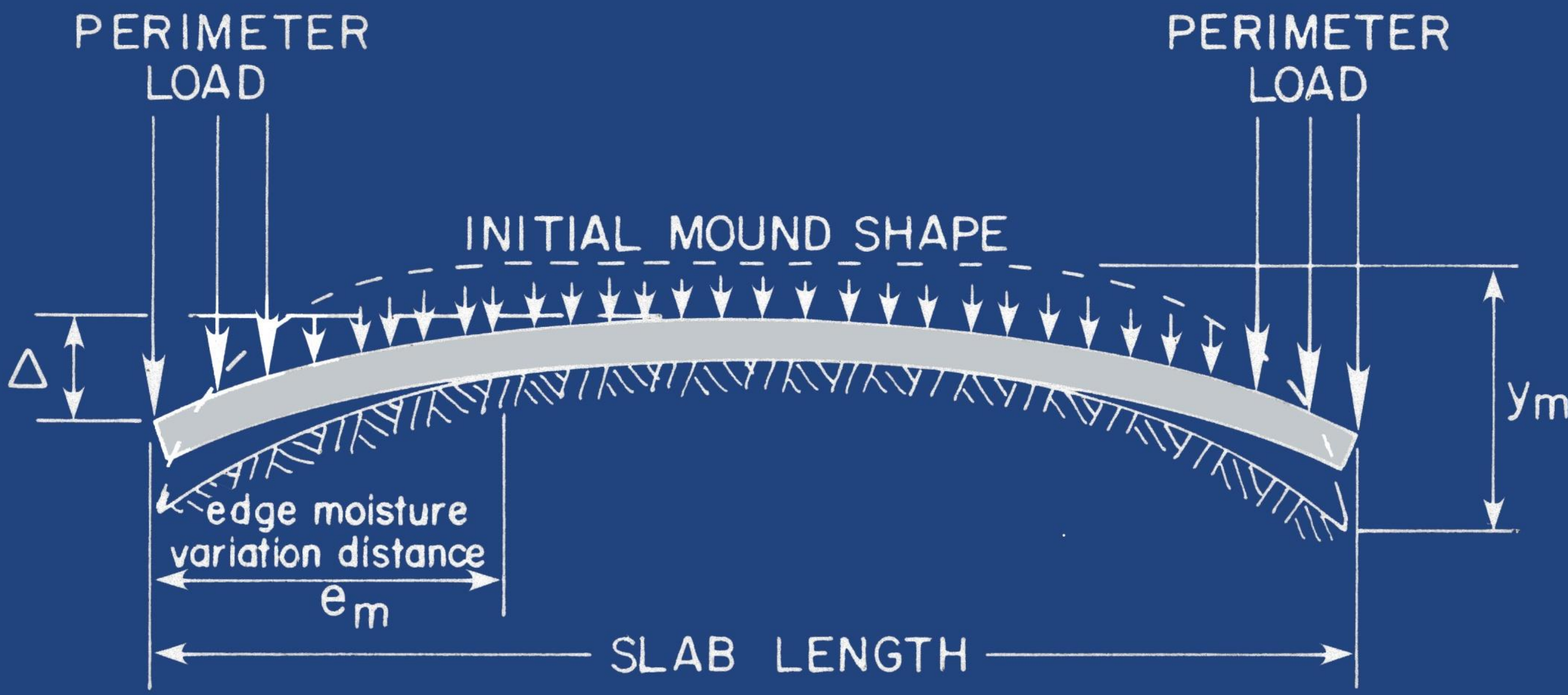
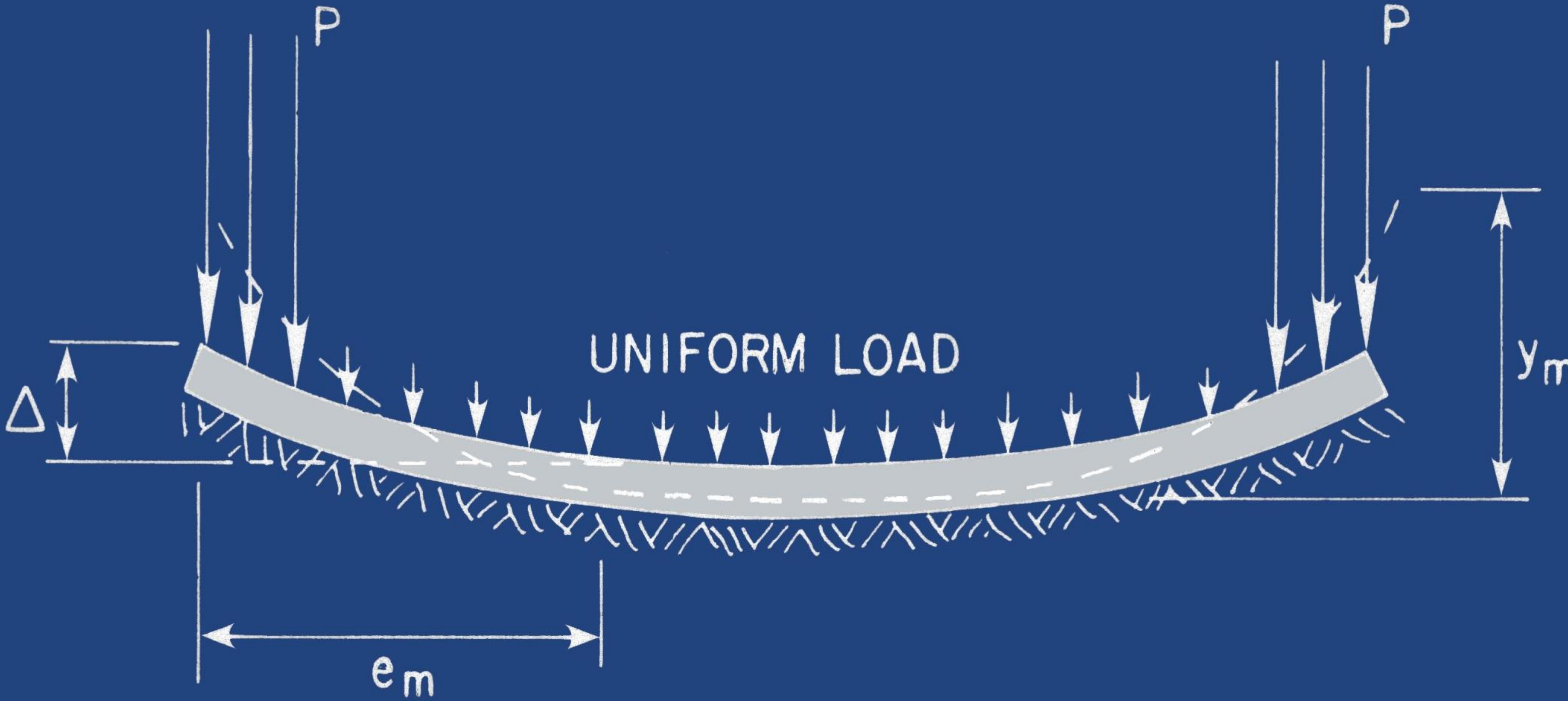


CENTER LIFT (Also commonly referred to as Edge Drop)

Soil Structure Interaction – Edge Lift



EDGE LIFT

Differential Soil Movement, y_m

- Differential Soil Movement - y_m represents the change in soil surface elevation at two locations separated by a distance e_m.
- y_m can be determined using the Stress Change Factor (SCF) method or computer methods.

Differential Soil Movement, y_m

- y_m is NOT the expected differential deflection of the foundation. y_m should always be greater than the actual differential deflection of the foundation due to foundation stiffness.
- y_m would only equal the differential deflection for a "perfectly flexible" foundation with no externally applied loads.
- y_m is NOT the same as Potential Vertical Rise (PVR). PVR is a commonly used swell predictor used in Texas.

Edge Moisture Variation Distance, e_m

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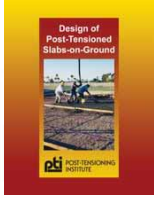
- Edge Moisture Variation Distance
  - **e_m** represents the distance measured inwards from the edge of a shallow foundation within which moisture will change due to wetting or drying influences around the perimeter of the foundation.
- **e_m** is a function of both climatic and soil properties.
  (2nd Edition only included the effect of climate on e_m)



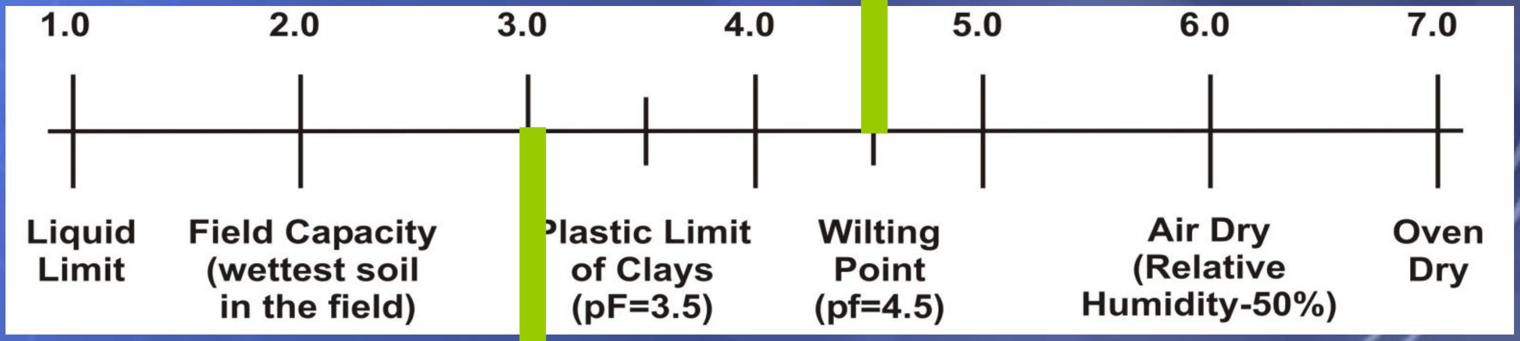
Depth to Constant Suction

- The Depth to Constant Suction can be estimated by several different methods:
  - Published analytical procedures
  - The depth at which the suction changes less than 0.027 pF (difficult to measure to this accuracy)
  - 2 feet deeper than the deepest root
  - Depth of "moisture active zone" (difficult to determine, can vary on different sites)
- While the Depth to Constant Suction is commonly assumed to be 9 feet it can be significantly deeper.

y_m Step 8 – Develop Suction Envelopes

What values of the surface suction should be used for "typical" design?

4.5 Typical dry limit suction value



3.0 Typical wet limit suction value

Changed to 3.0 from 2.5 in Addendum #1.

y_m Step 8 – Develop Suction Envelopes

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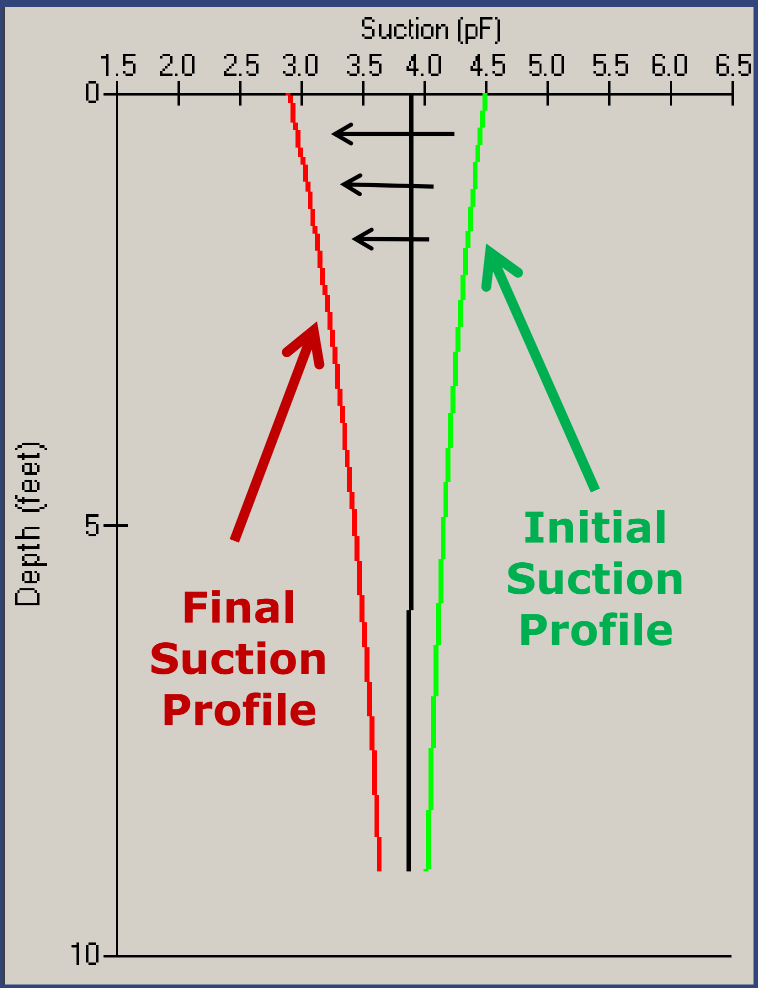
WET DRY



- A Suction Envelope consists of an Initial Suction Profile and a Final Suction Profile between which the actual field suction is expected to change.
- The suction profiles do not represent the actual field suction but the boundary condition which the suction is not expected to go beyond.
- A suction change from dry (higher suction) to wet (lower suction) results in swell ($y_{m\ edge}$).
- A suction change from wet (lower suction) to dry (higher suction) results in shrink ($y_{m\ center}$).

y_m Step 8 – Develop Suction Envelopes

The Suction Profiles (initial or final) can model:

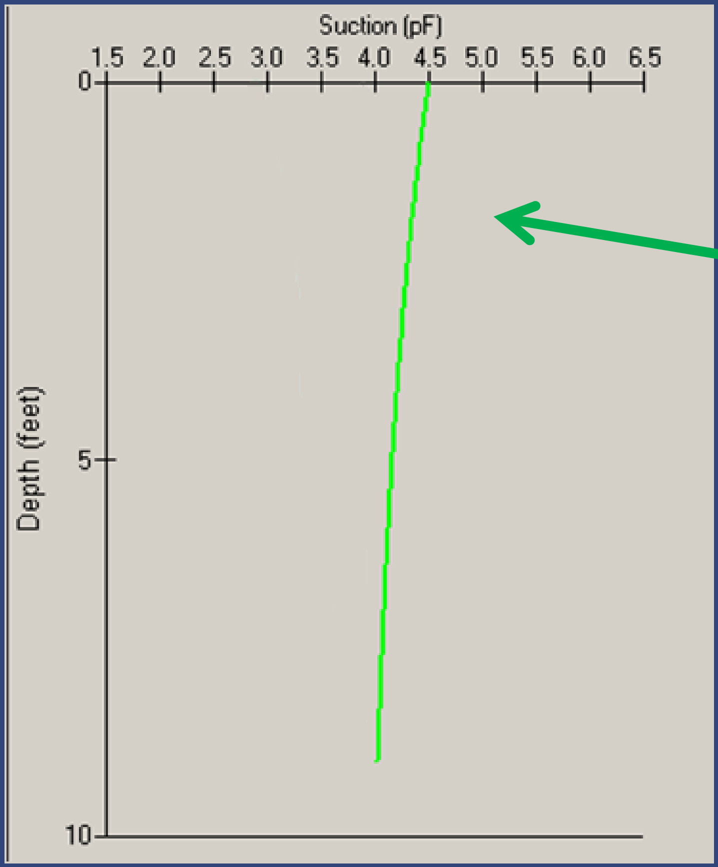
- Sites controlled by climate (precipitation, evaporation, etc.) – (typical profiles for design)
- Equilibrium condition (typical profile for design)
- Site modifications such as:
  - Moisture controlled fill pads
  - Moisture injection
- Vertical moisture barriers
- Vegetation
  - Trees
  - Flower Beds
- Poor Drainage

A Suction Envelope can consist of a combination of profiles (one for the initial profile and one for the final profile).

y_m Step 8 - Develop Suction Envelopes

The suction profile for a site controlled by climate takes the form of a "trumpet" shape based on Mitchell's suction distribution.

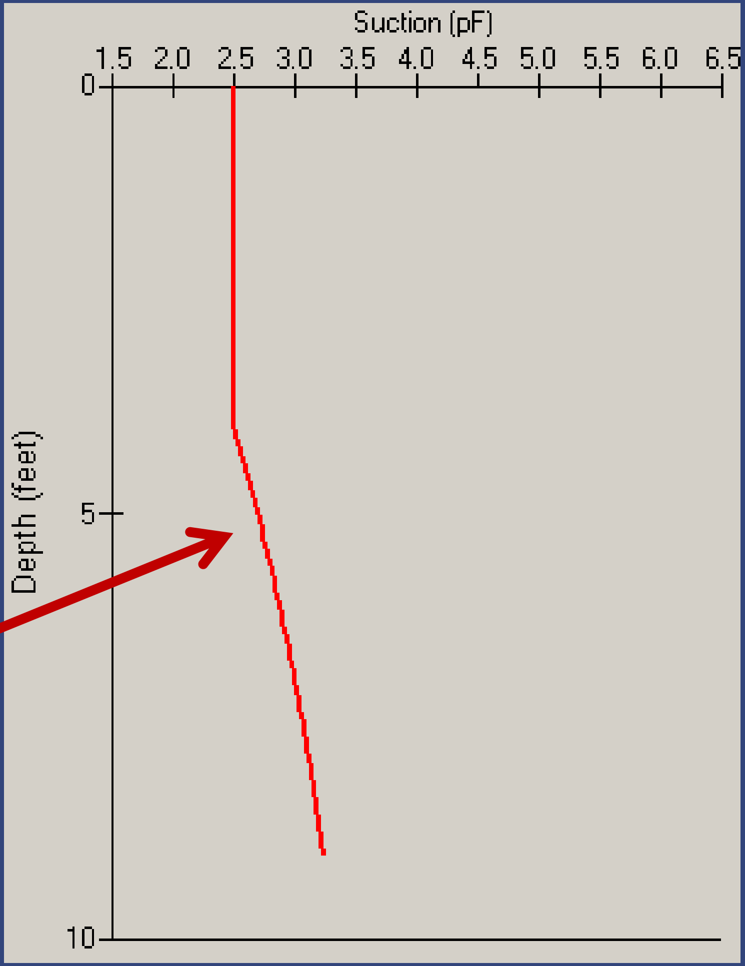
Typically used for design cases.



Initial Suction Profile for a site controlled by climate only

Suction profile for "Bad Drainage".

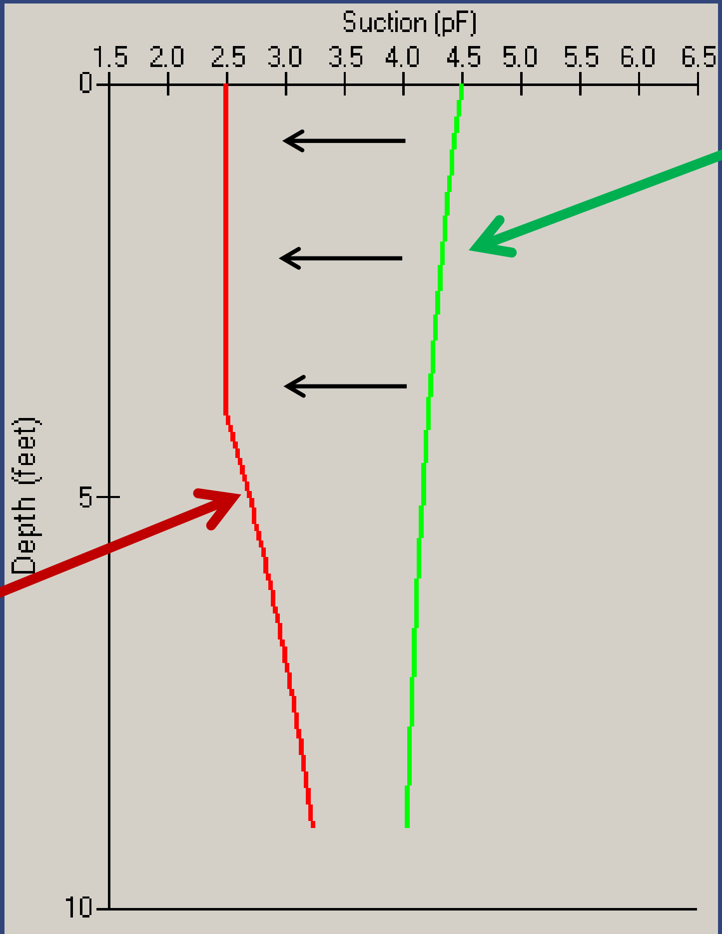
Final Suction Profile for a site controlled by "Bad Drainage"



Not typically used for design cases. Used more for analysis cases.

y_m Step 8 - Develop Suction Envelopes

Combining the Initial Suction Profile and the Final Suction Profile results in the Suction Envelope.



Initial Suction Profile for a site controlled by climate

Final Suction Profile for a site controlled by "Bad Drainage"

Not a typical Suction Envelope used for design cases.

y_m Step 8 - Develop Suction Envelopes

Typical Suctions Envelopes used for design

Post-Equilibrium Suction Envelopes start with an equilibrium initial suction profile and changes to either a wet or dry climate controlled final suction profile.

Post-Construction Suction Envelopes start with either a wet or dry climate controlled initial suction profile and changes to the opposite climate controlled suction profile.

y_m Step 8 – Develop Suction Envelopes

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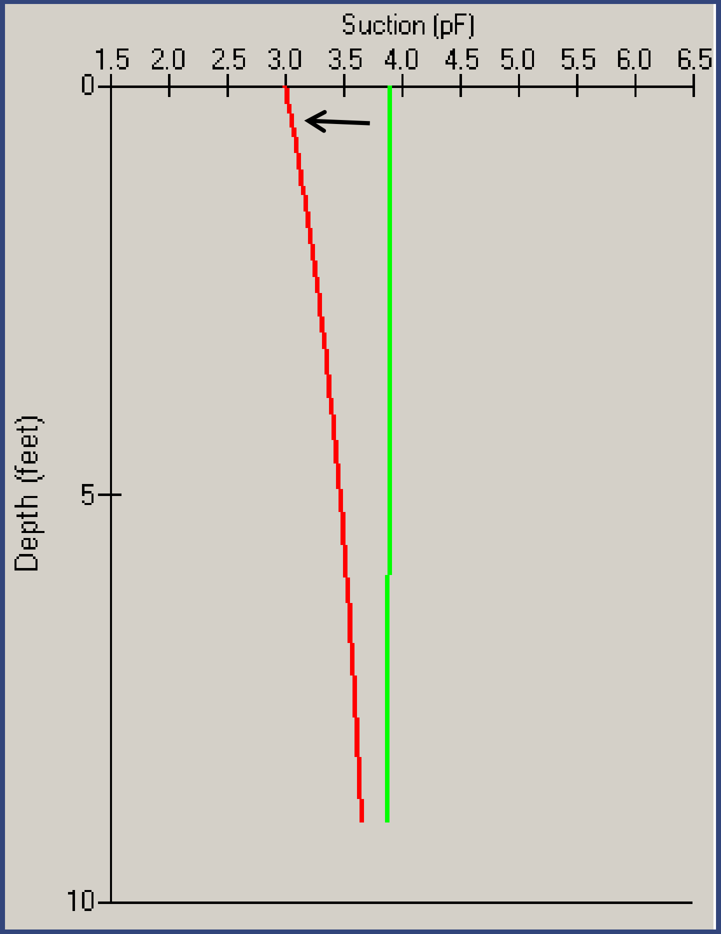
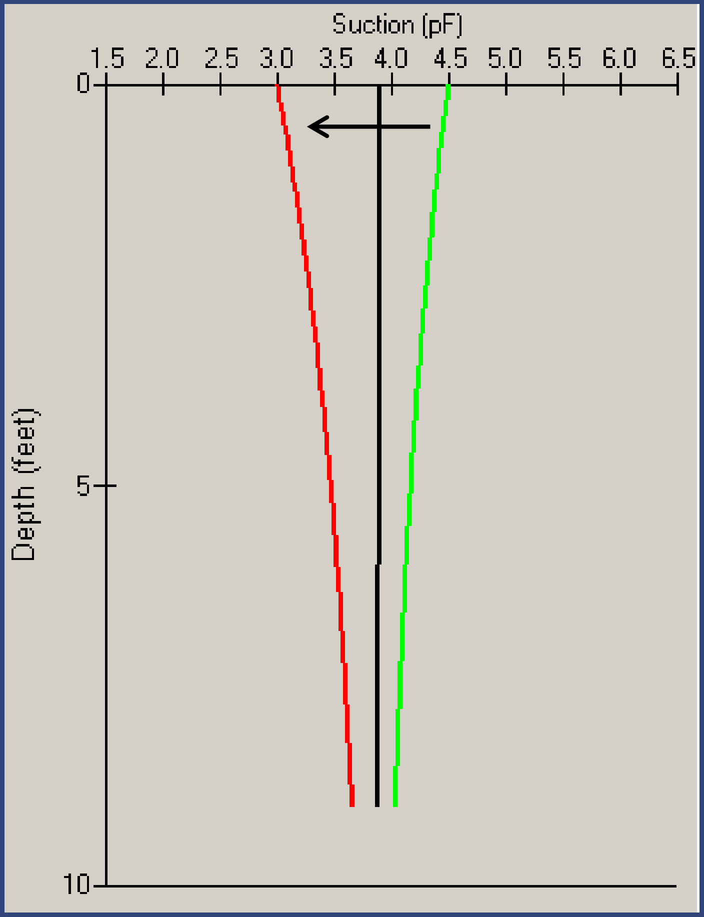
Swell Case – Both envelopes start dry and end wet.



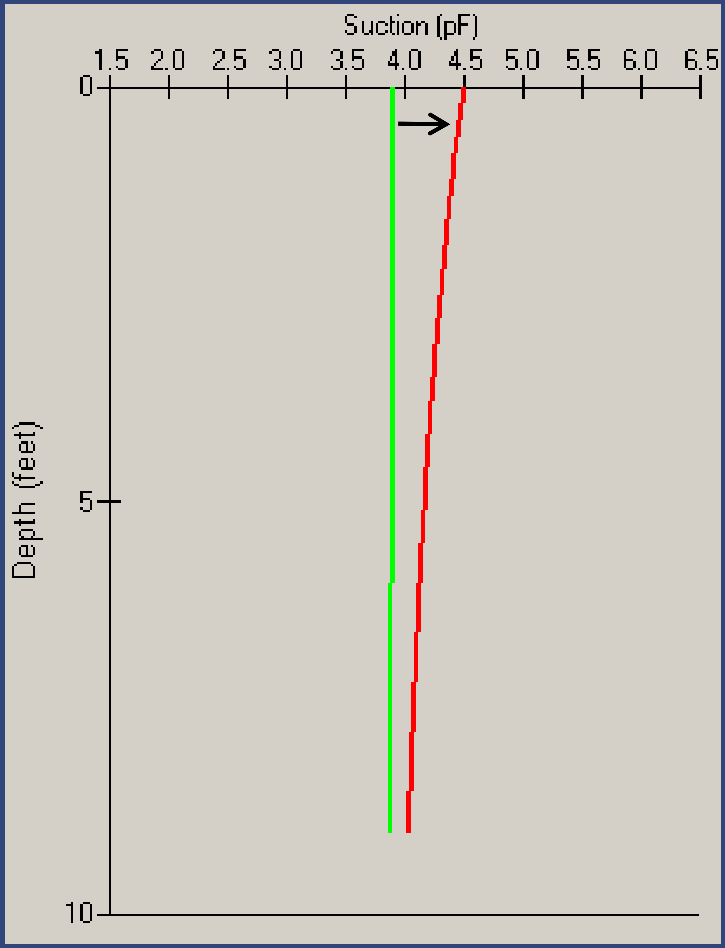


Post–Equilibrium

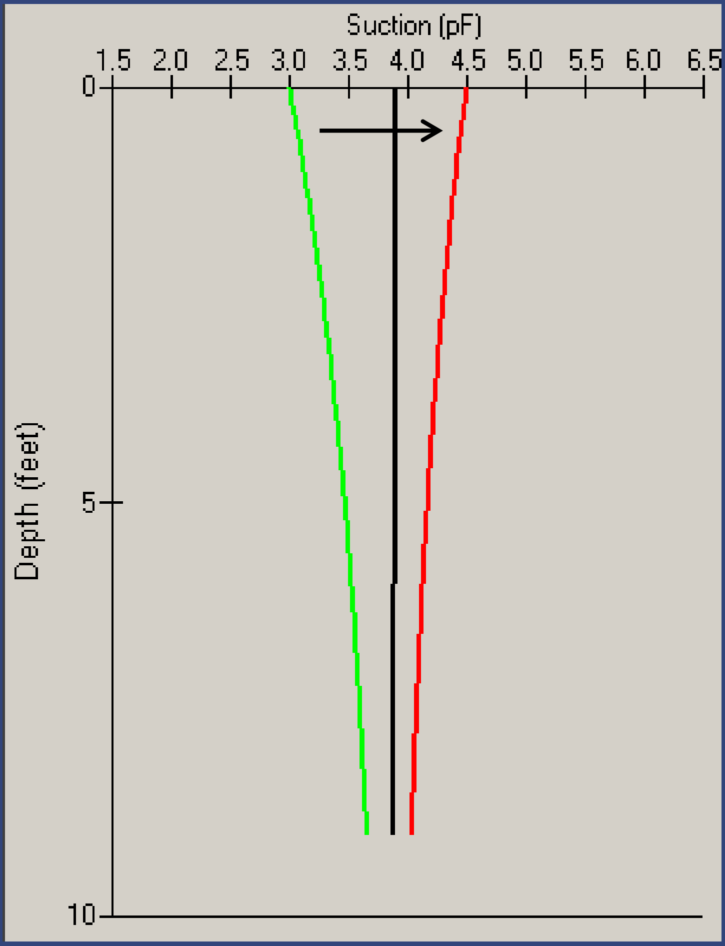
Post–Construction

y_m Step 8 - Develop Suction Envelopes

Shrink Case – Both envelopes start wet and end dry.



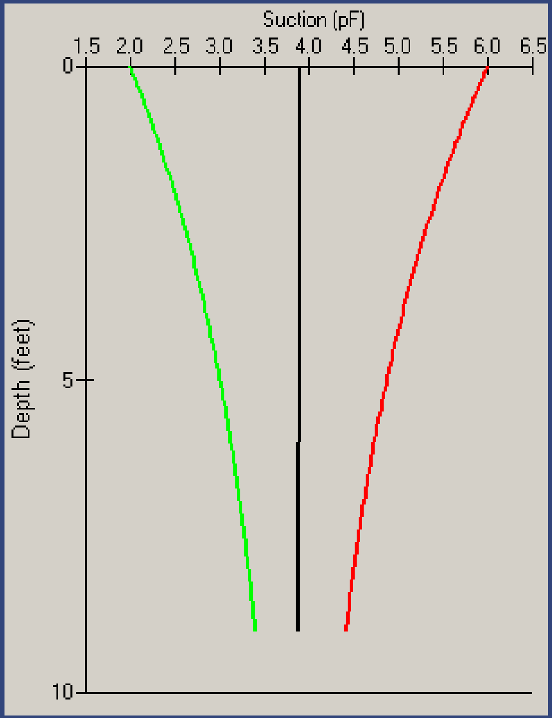
Post–Equilibrium



Post–Construction

y_m Step 8 - Develop Suction Envelopes

The magnitude of shrink and swell is a function of the area between the two profiles.

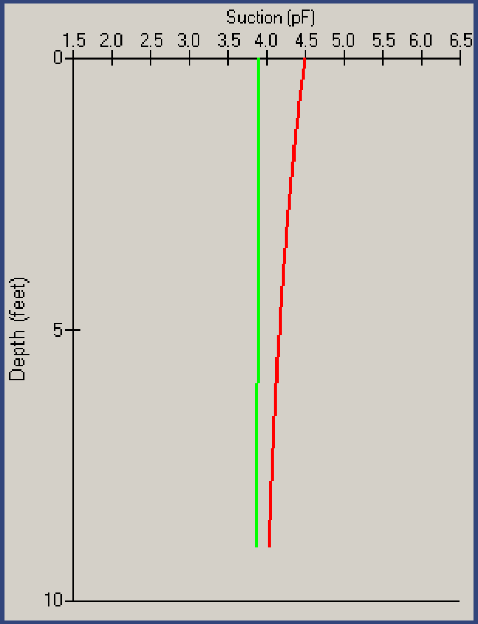


For the same soil the envelope on the right will produce significantly more shrink.

Note the right envelope is for illustration purposes only and is NOT representative of an envelope that should be used for design purposes.

y_m Step 8 - Develop Suction Envelopes

The magnitude of shrink and swell is a function of the area between the two profiles.

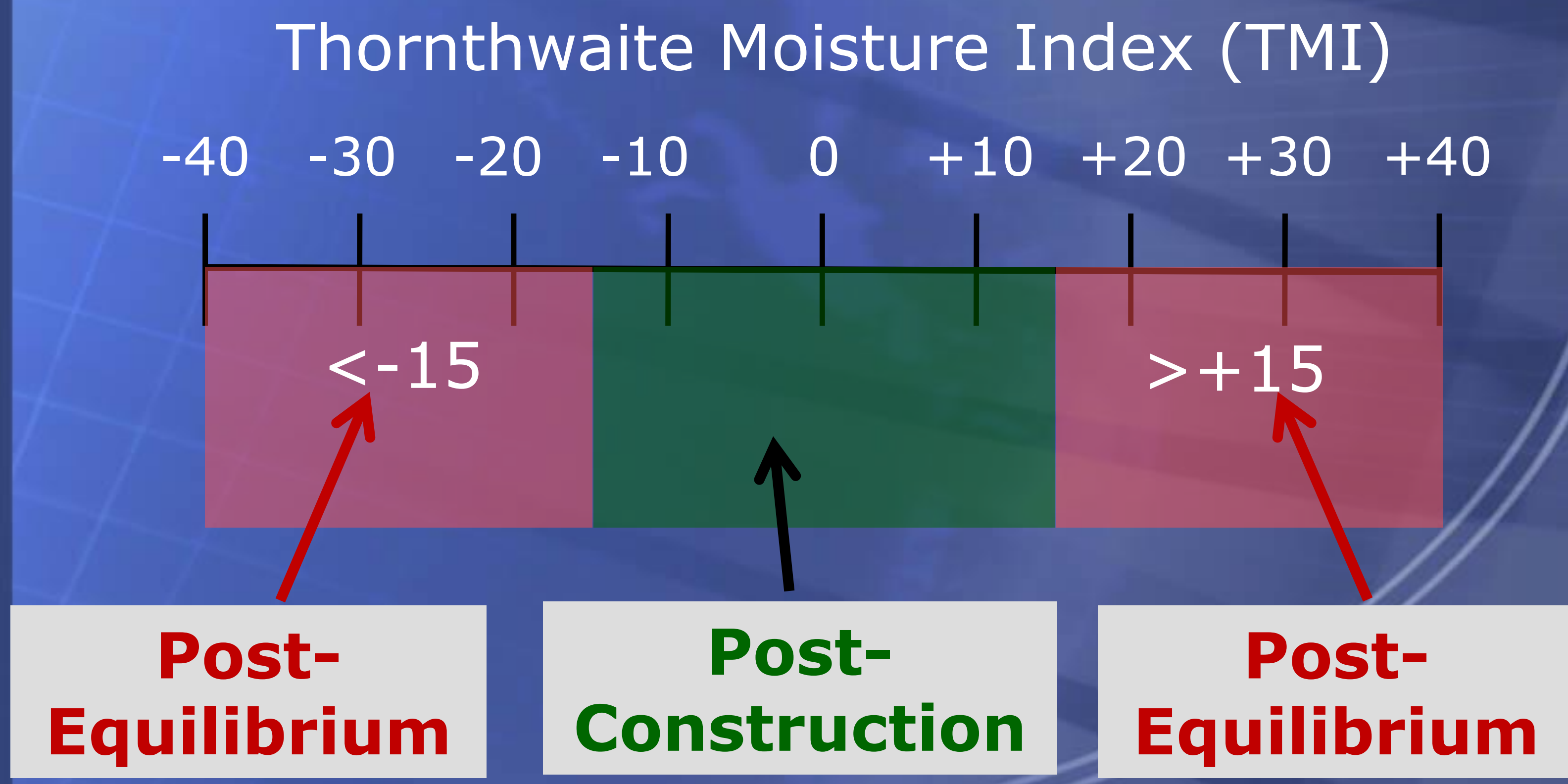


Post-Equilibrium

Post-Construction

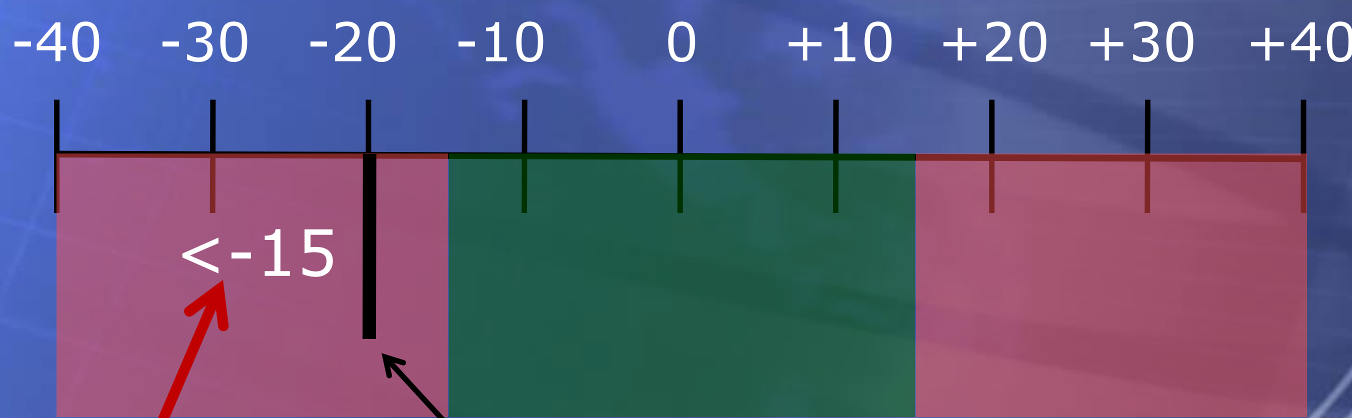
For the same soil, the Post-Construction Envelope (on the right) will produce significantly more shrink than the Post-Equilibrium Envelope on the left.

When to use Post-Equilibrium Envelopes versus Post-Construction Envelopes? (Addendum #1)



When to use Post-Equilibrium Model versus Post-Construction Model? (Addendum #1)

Thornthwaite Moisture Index (TMI)



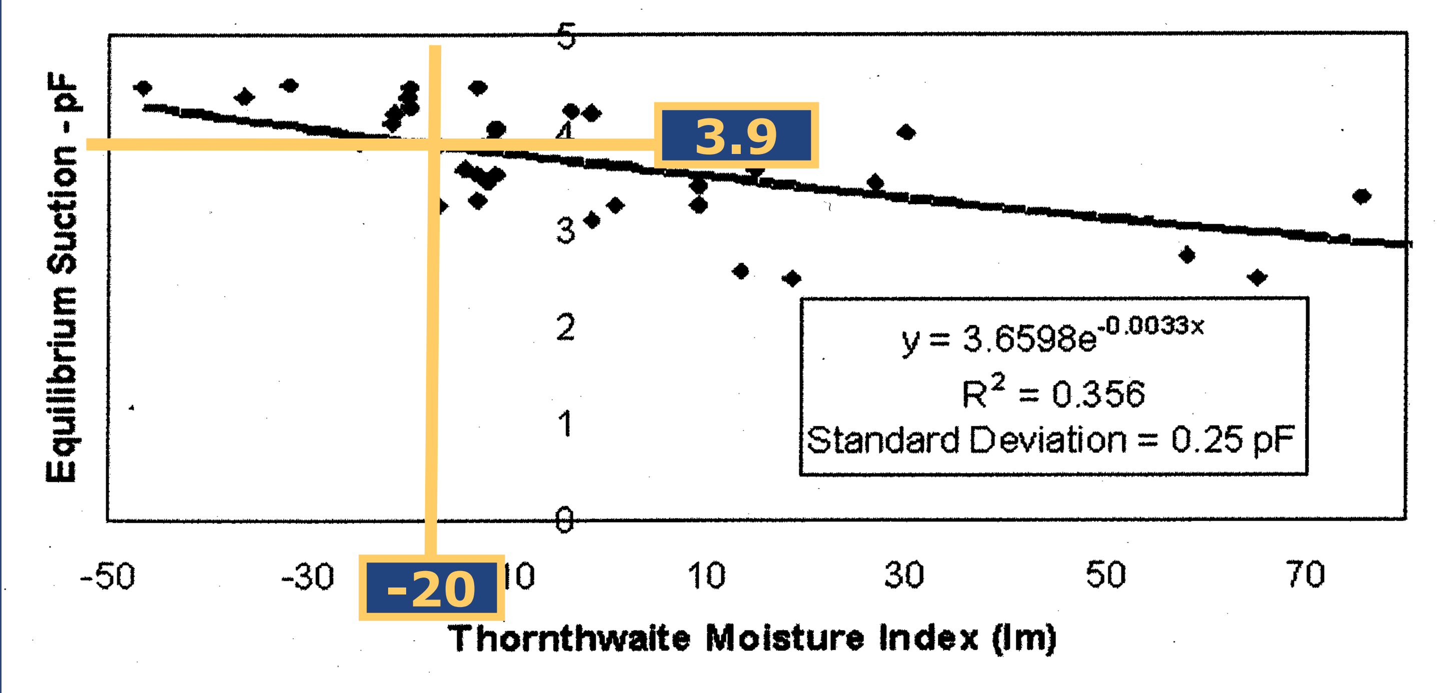
Post-Equilibrium

Sacramento, California (I_m = -20)

USE POST-EQUILIBRIUM MODEL

What value do I use for the Equilibrium Suction?

Equilibrium Suction may be estimated from the correlation below in the absence of local observations:



Note: Also referred to as constant suction or measured suction at depth. This figure has changed from 2nd Edition.

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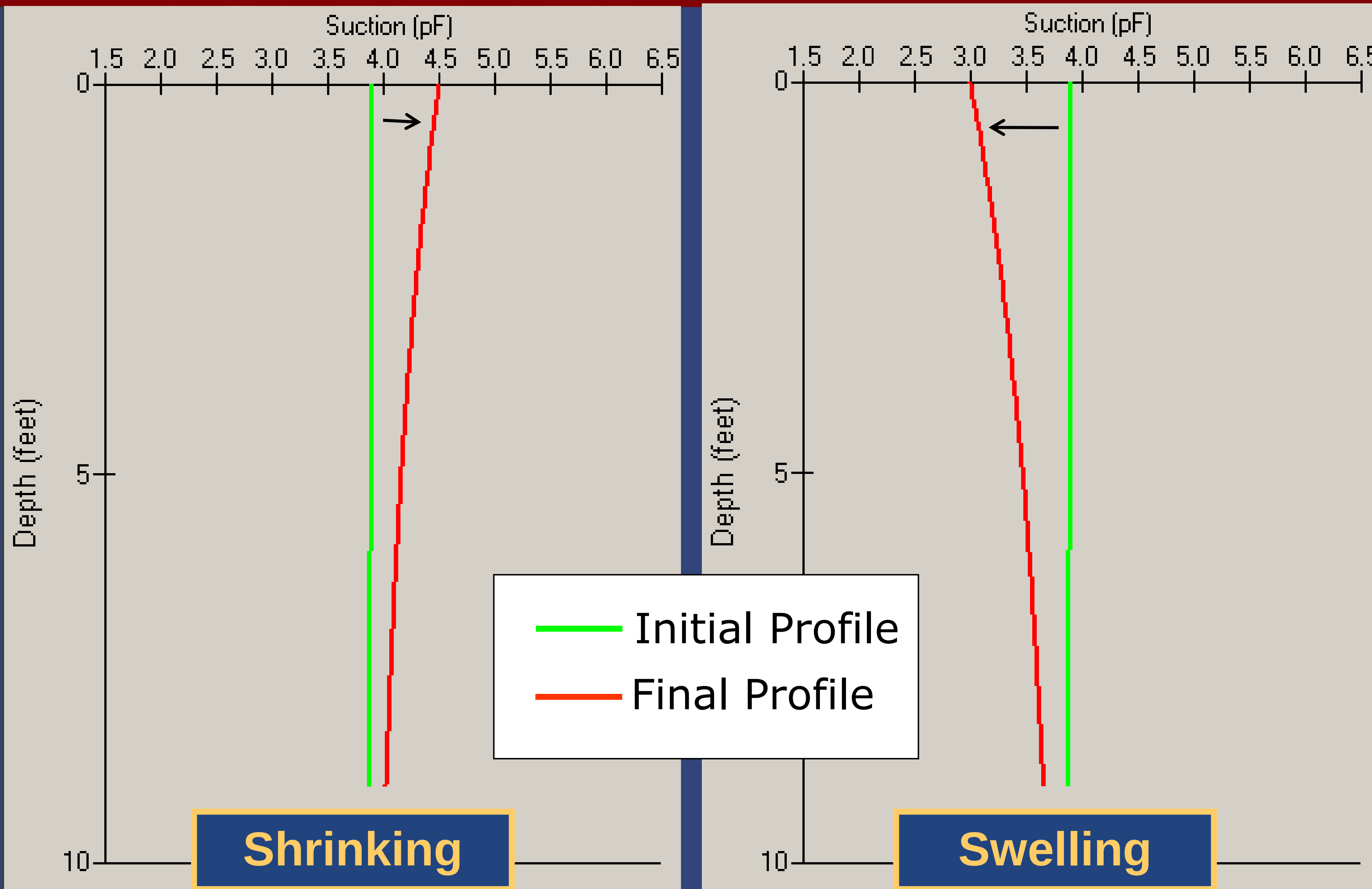
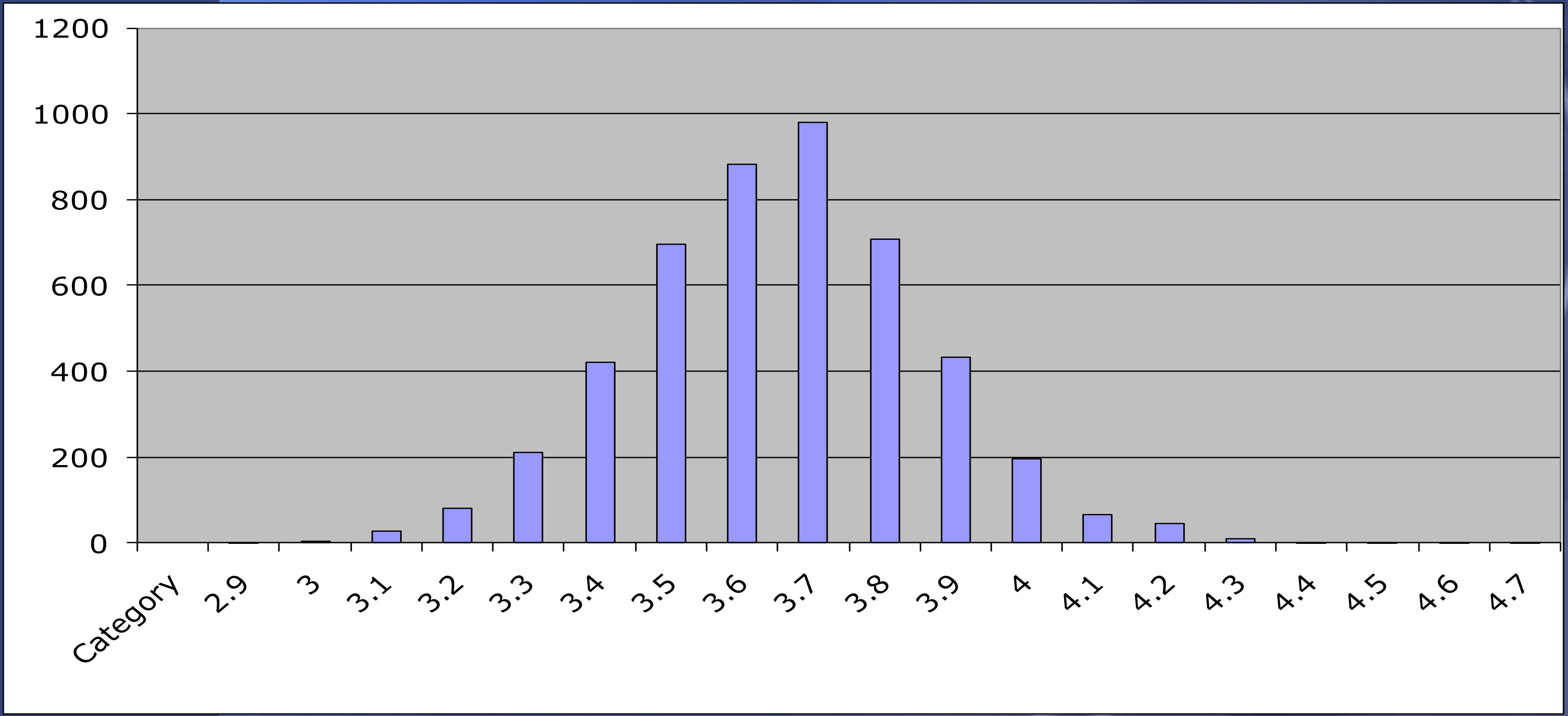
y_m Step 8 – Develop Suction Envelopes



Reasonable Suction Change Range

- 2003 TOTAL SOIL SUCTION DATA (4776 OBSERVATIONS)



Typical Suction Envelope

Unsaturated Soil Mechanics

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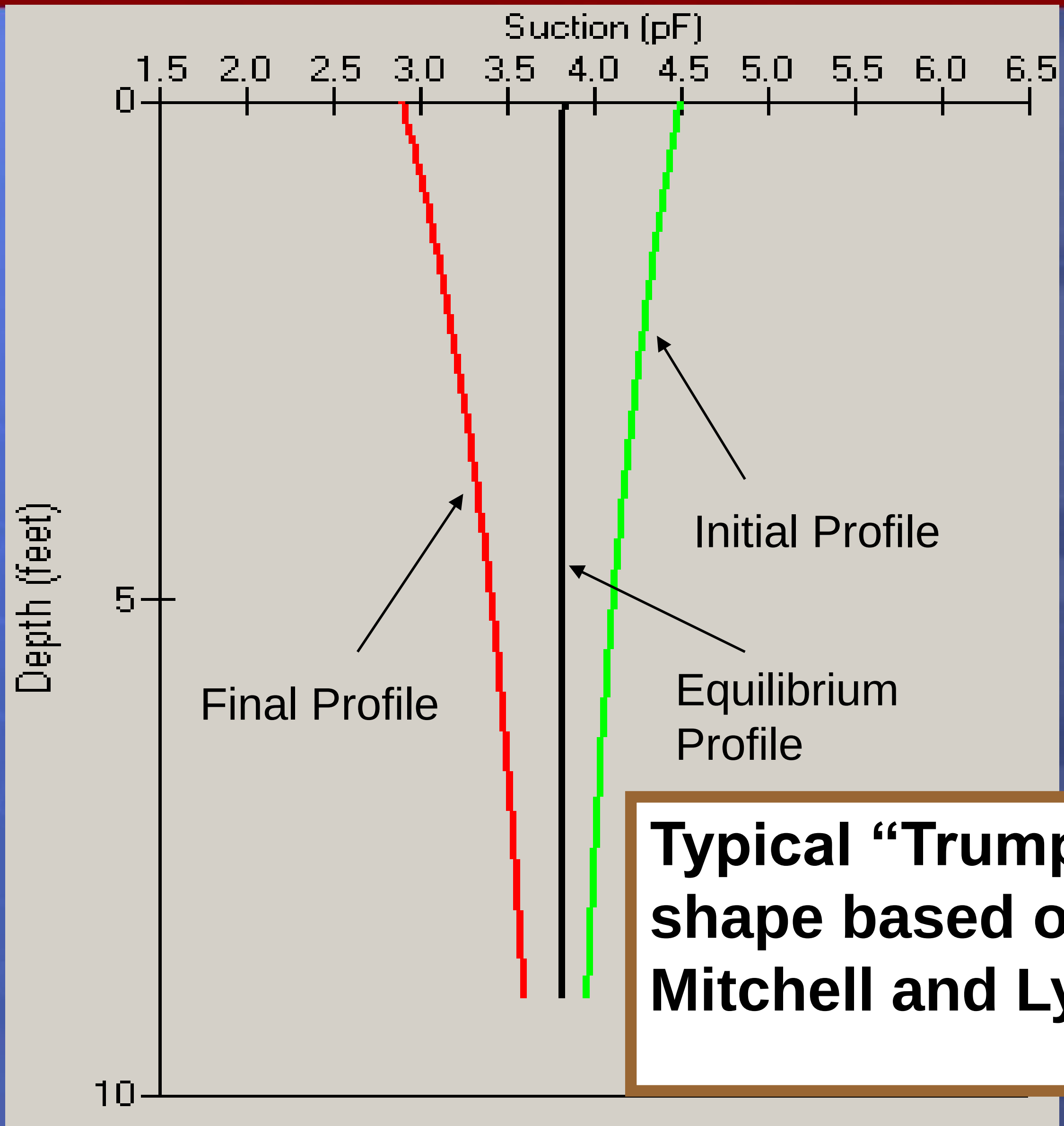
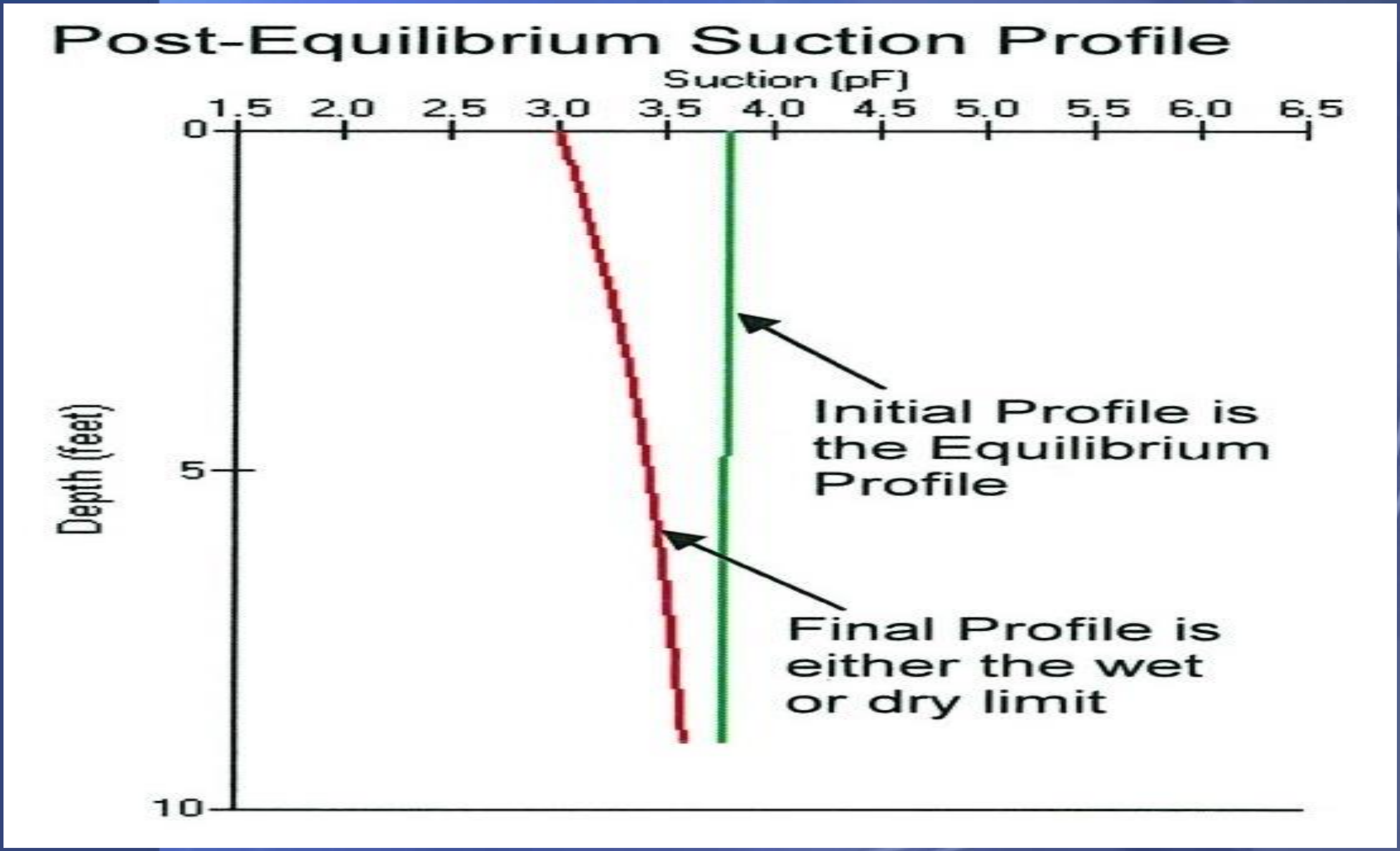
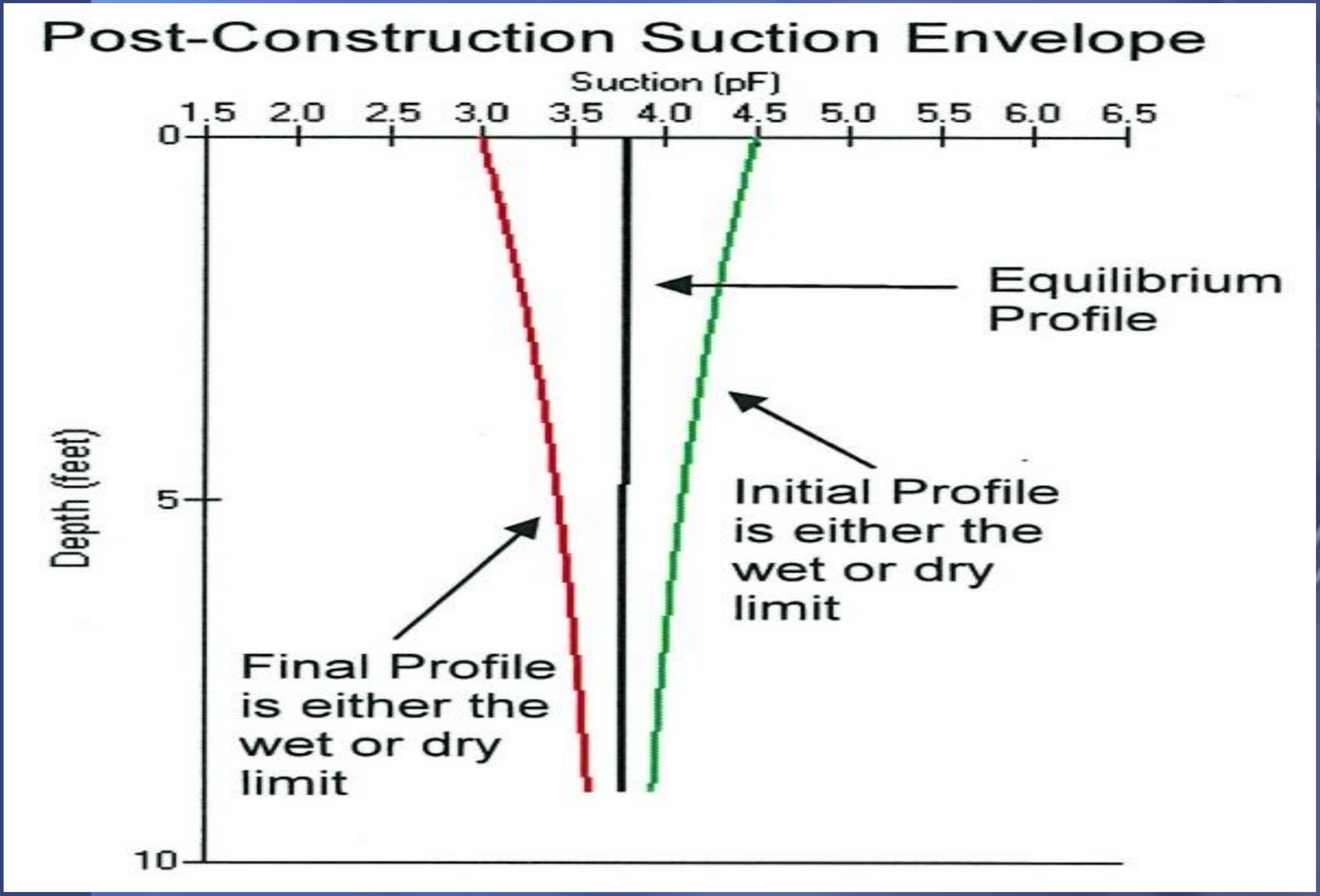


Typical "Trumpet" shape based on Mitchell and Lytton.

Post Equilibrium



Post Construction



Unsaturated Soil Mechanics

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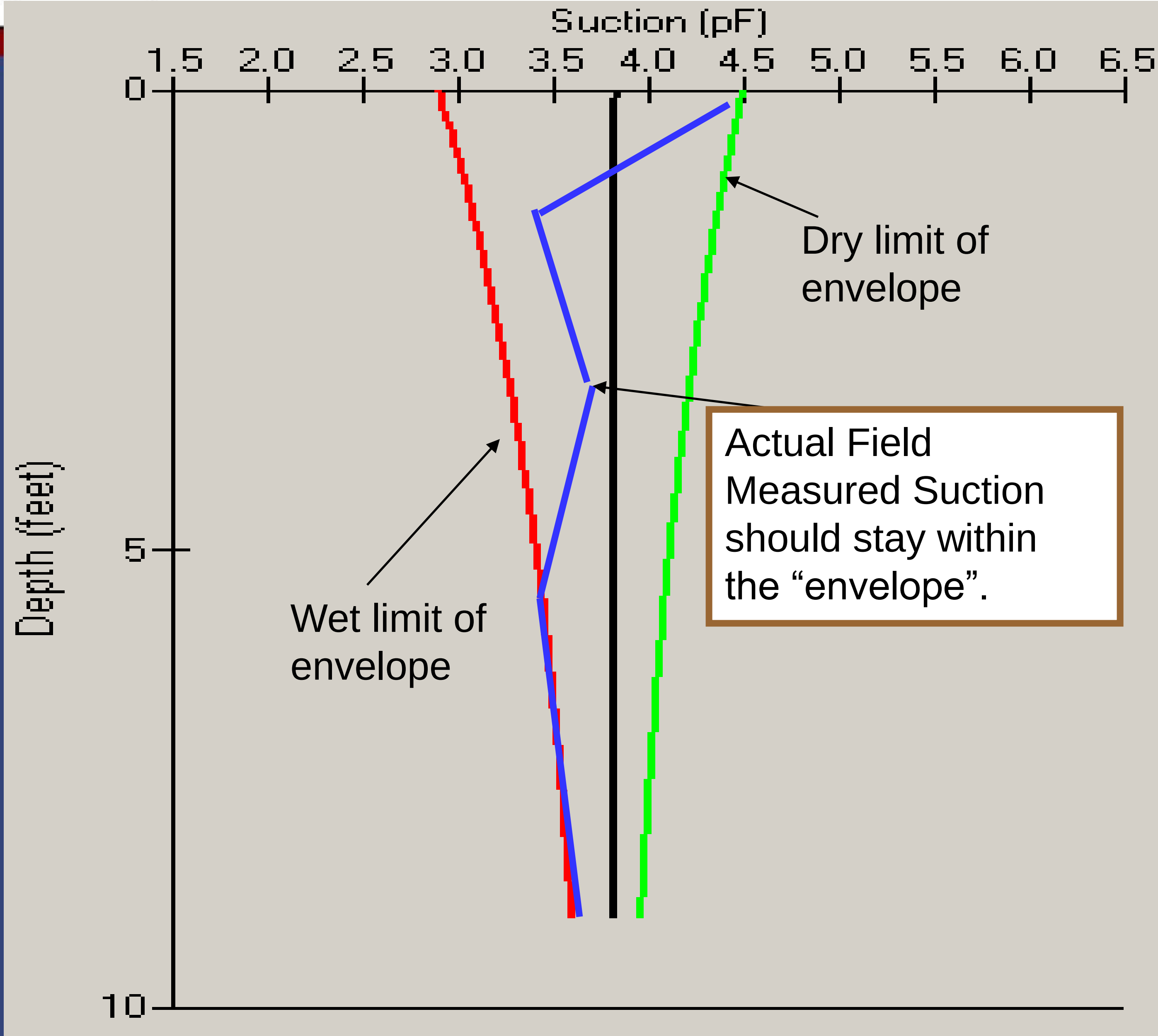
Suction Envelope



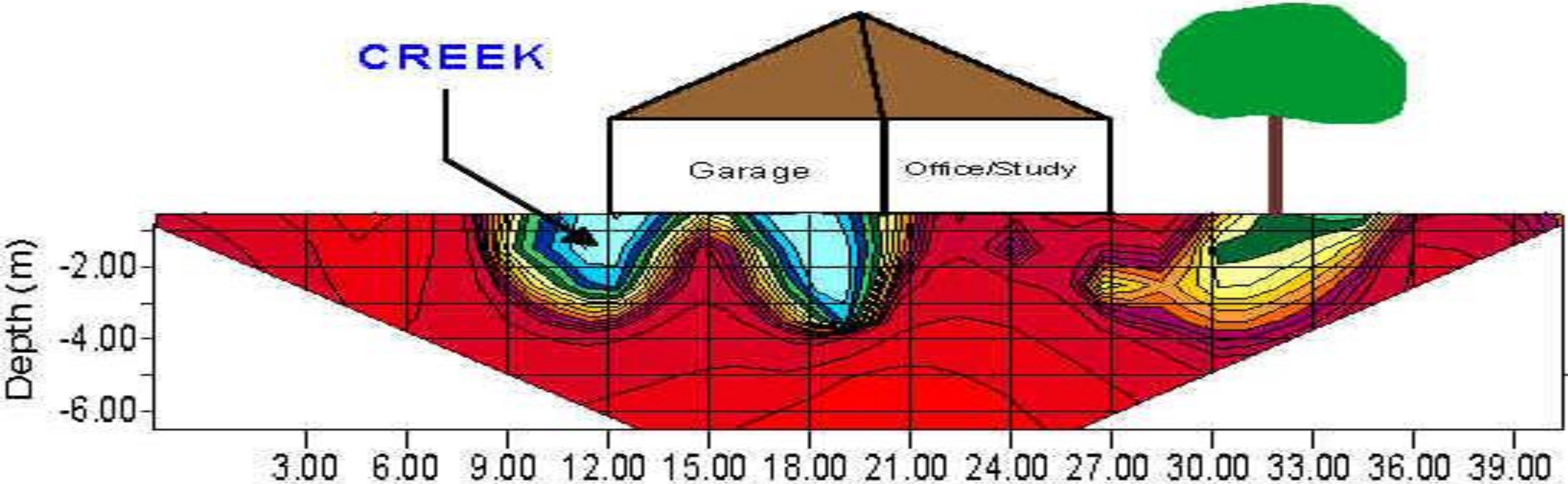
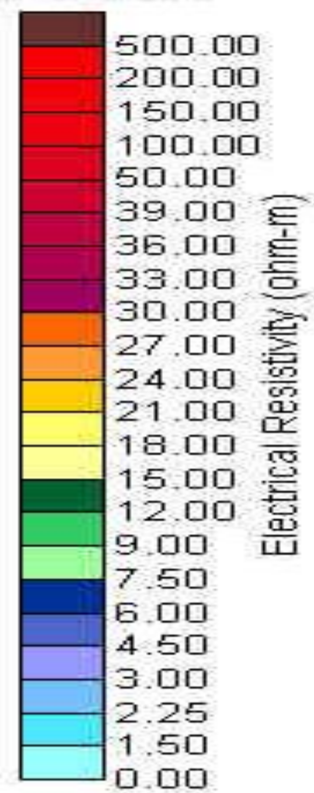


Figure 9. GMMIR Profile - Horizontal Distance (m) at the Woodbine site.



Notes: 1. Data at lower corners is interpolated.
2. Structure, Boring and Vegetation positions are approximate.
3. Patent Pending Process, All Rights Reserved.
US Patent Application S/N 09,071,577.

Unsaturated Soil Mechanics

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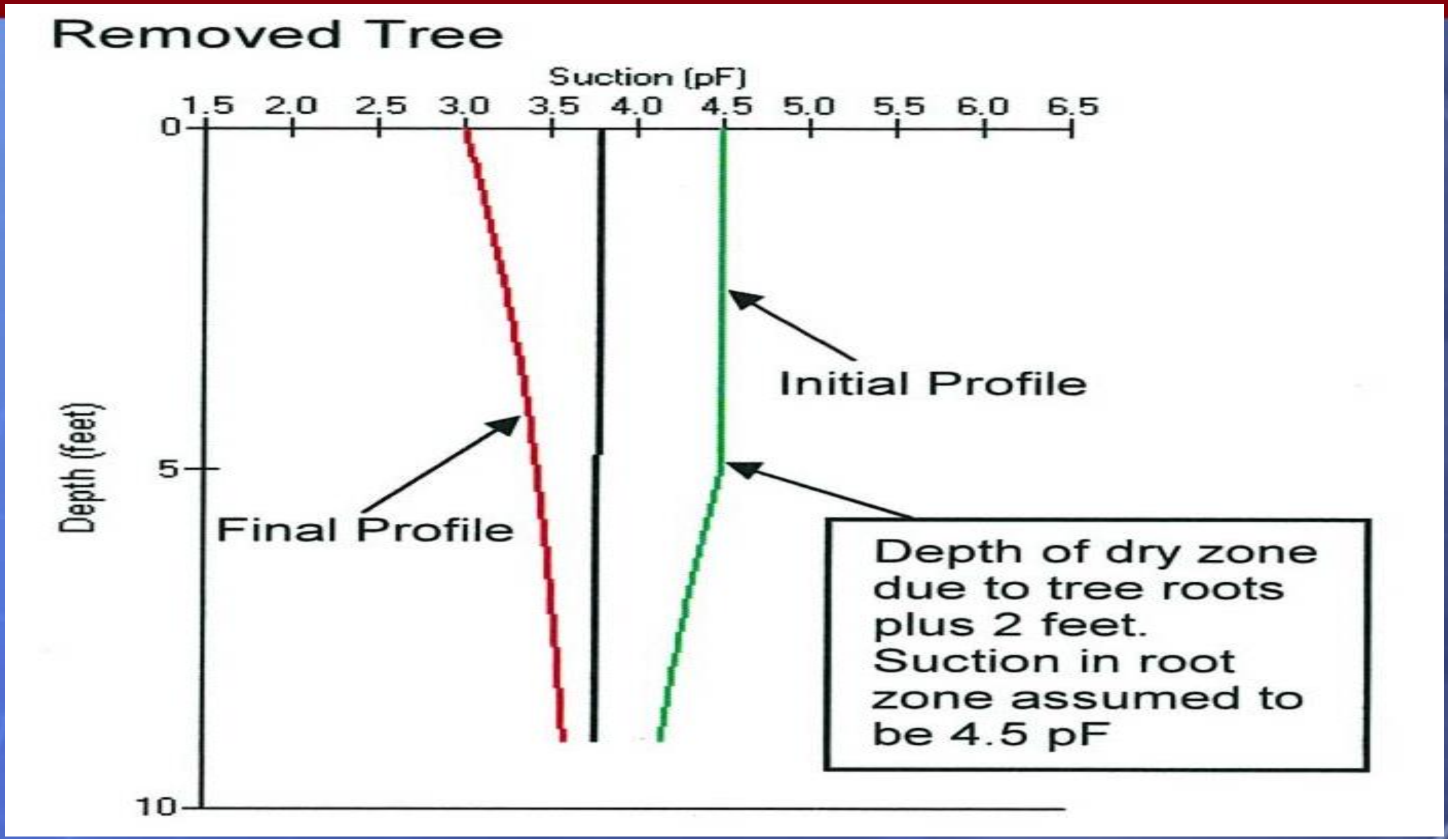
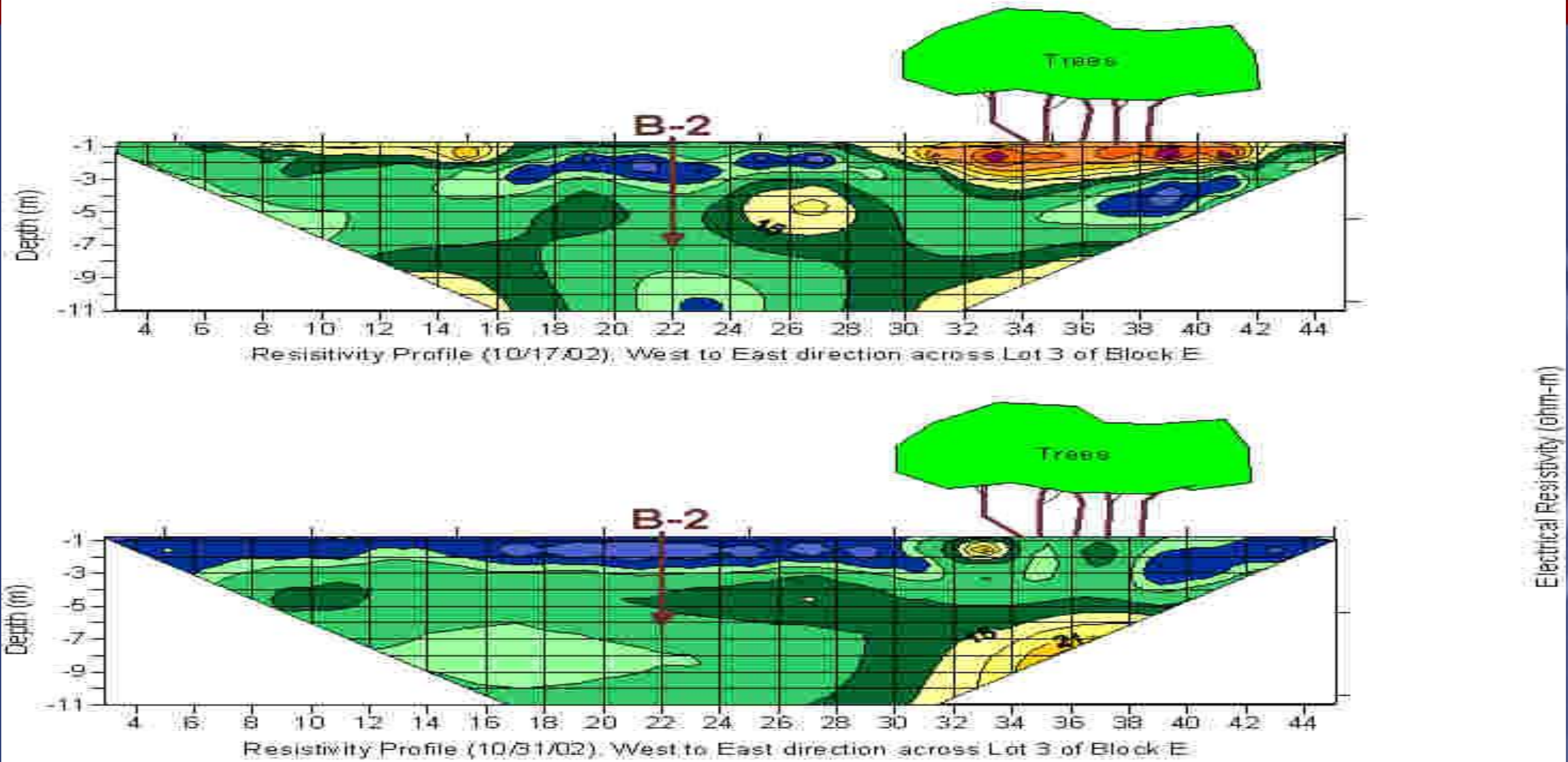
Removed Tree Envelope



The influence of Trees and effects of a significant rainfall event on a particular lot.



Notes: 1. Data at lower corners is interpolated.
2. Structure, Boring and Vegetation positions are approximate.
3. Patent Process, All Rights Reserved.
US Patent S/N 6,295,512

Unsaturated Soil Mechanics

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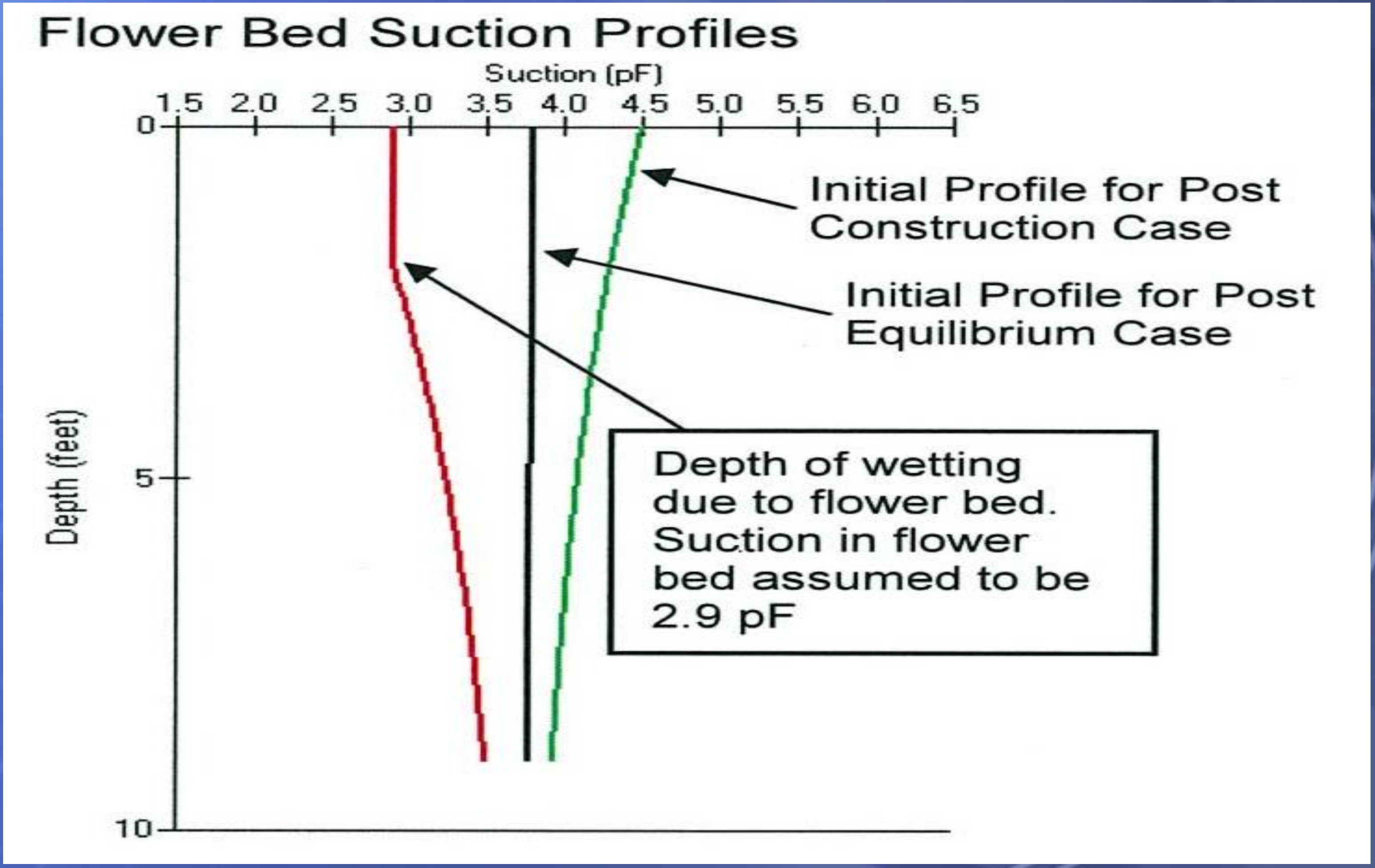
Flower Bed Envelope



Simplified Approach Soil Design Parameters and Soil Data

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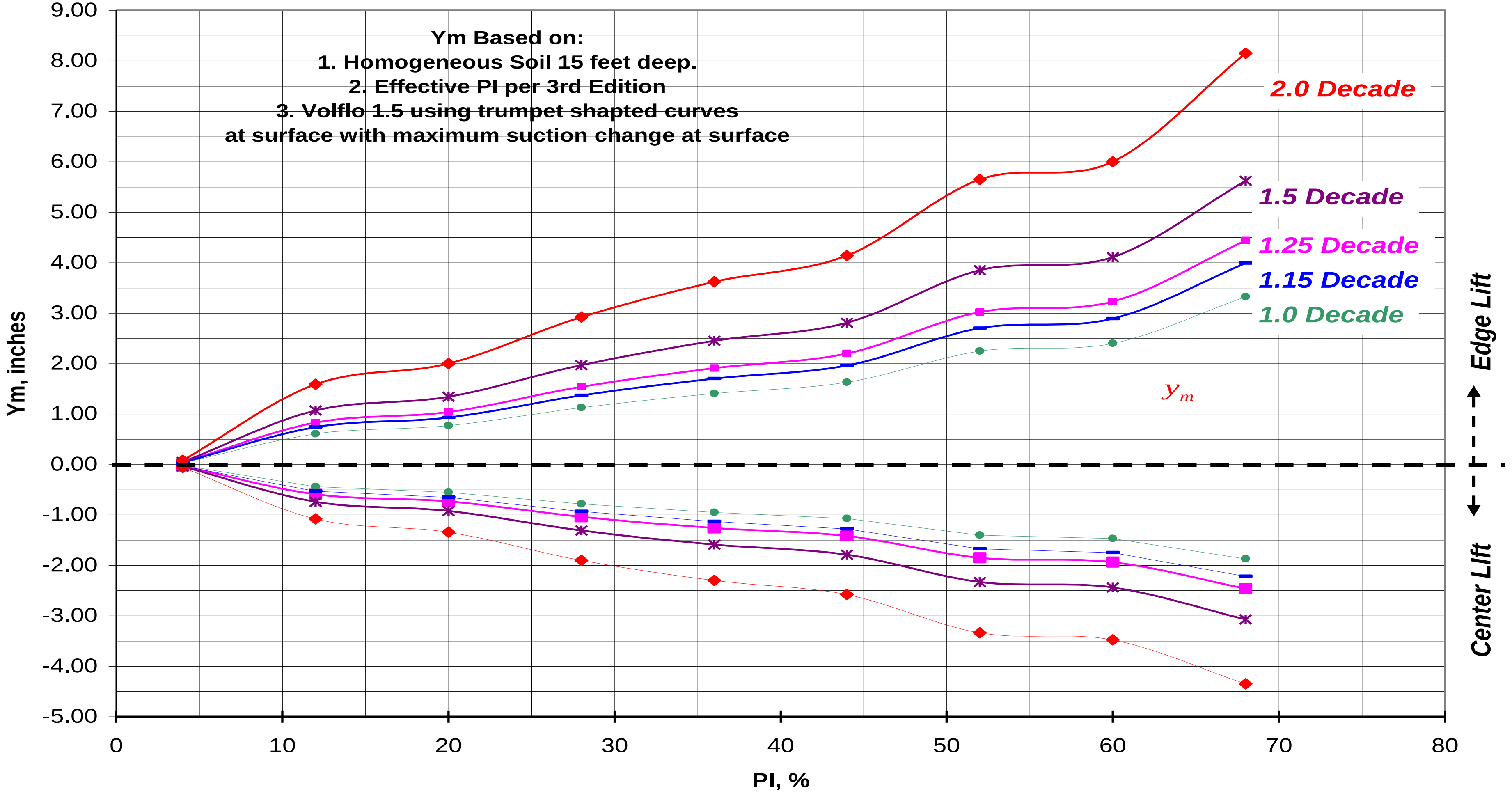
Table 1. Geotechnical Soil Parameters

Dry Density, pcf	Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	-200, %	2 micron, %	Fine Clay, %	e_m (FF=1) cl, ft	e_m (FF=1) el, ft	e_m (FF=1.2) cl, ft	e_m (FF=1.2) el, ft	y_m cl, in	y_m el, in
110	20	16	4	43.4	5	11.5	9	5.3	9	6.36	-0.04	0.05
110	30	18	12	51.4	10	19.5	9	4.9	9	5.88	-0.74	1.07
105	40	20	20	59.4	22	37.0	9	4.6	9	5.52	-0.92	1.34
105	50	22	28	67.4	37	54.9	8.3	4.2	9	5.04	-1.31	1.97
100	60	24	36	75.4	52	69.0	7.5	3.9	9	4.68	-1.59	2.45
100	70	26	44	83.4	67	80.3	6.7	3.6	8.04	4.32	-1.79	2.81
95	80	28	52	91.4	82	89.7	5.5	3.5	6.6	4.2	-2.33	3.85
95	90	30	60	99.4	97	97.6	4.2	3.5	5.04	4.2	-2.44	4.11
92	100	32	68	100	99	99.0	4.2	3.5	5.04	4.2	-3.07	5.62

Ym values as a function of PI



Simplified Approach PI = 40

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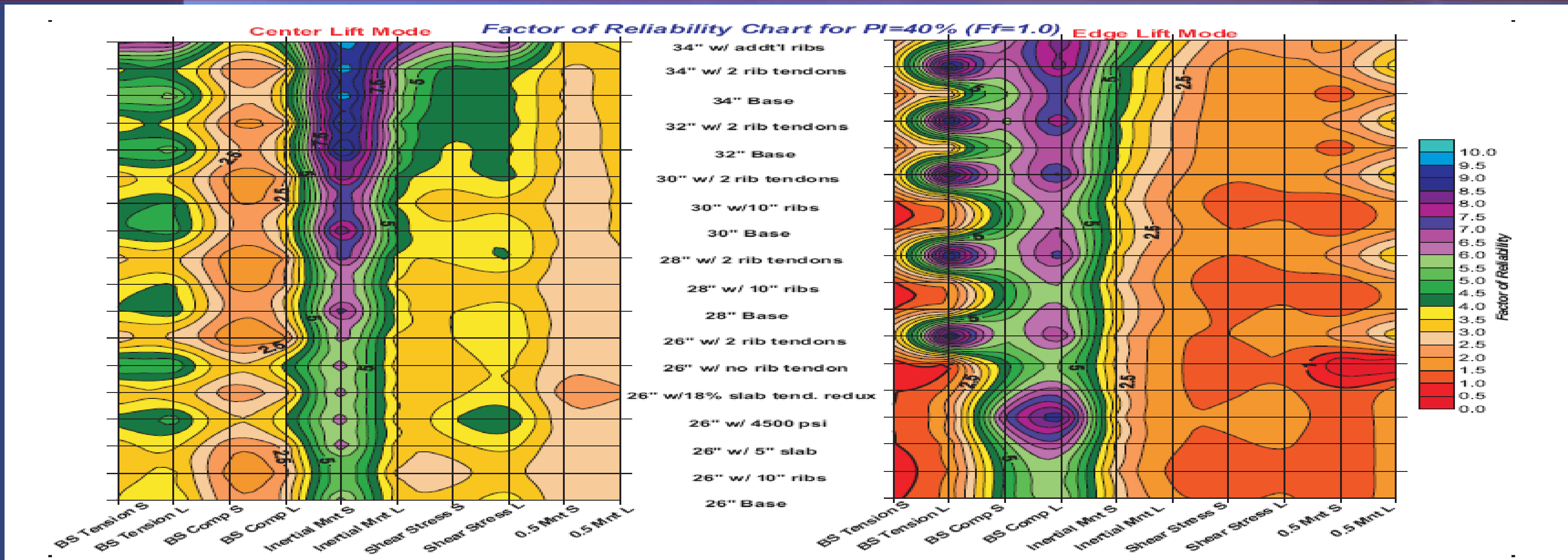
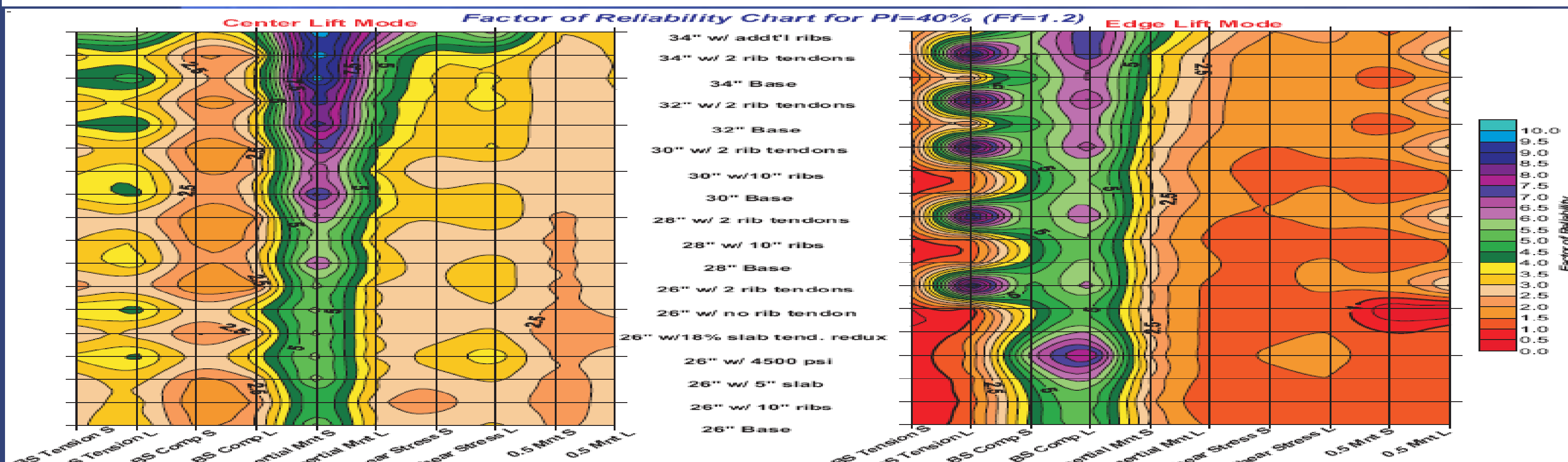
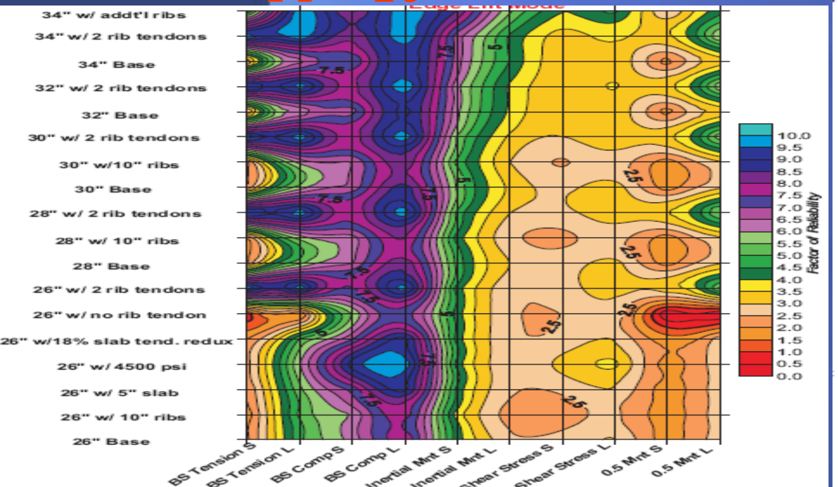




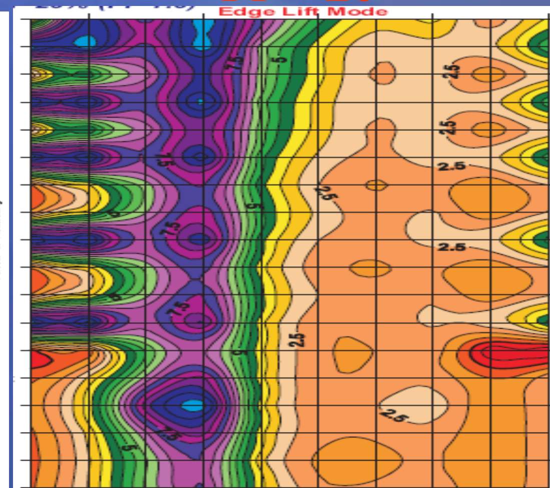
Legend:
PI – Plasticity index Ff – Fabric factor BS – Bending Stress Comp – Compression
S – Short side of slab L – Long side of slab Inertial Mnt – Stiffness criteria 0.5 Mnt – Crack moment capacity

Variation of PI on Reliability

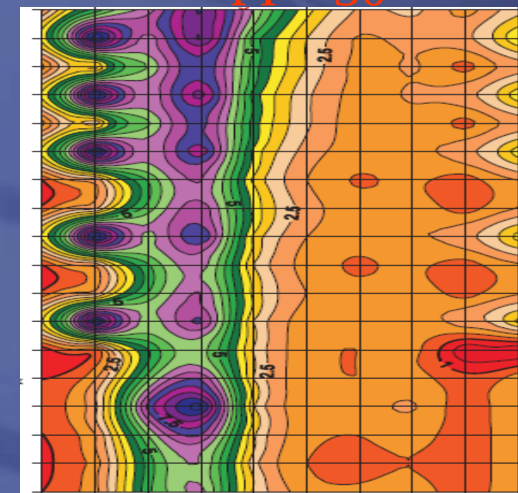
PI = 10



PI = 20



PI = 30



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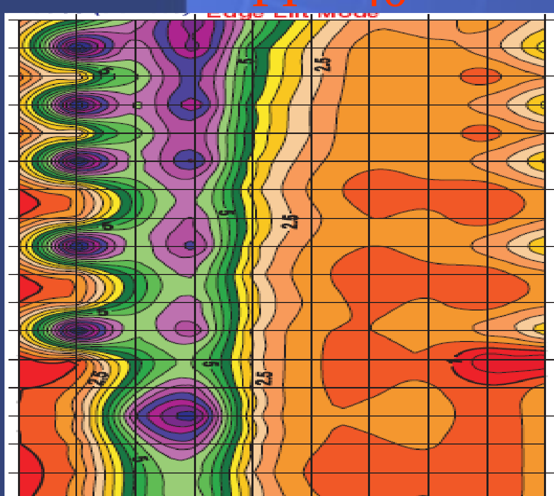
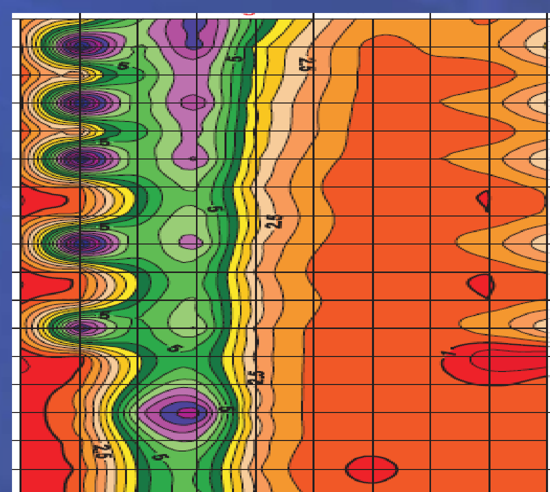


PI = 50



PI = 60