

# Material Moisture Characterization



*Unsaturated Soil Engineering:  
Applications in Pavements*

*August 5, 2002*

*Ruth Roberson*



**Material Moisture  
Characterization**  
**Dr. Gupta CTS PS026**

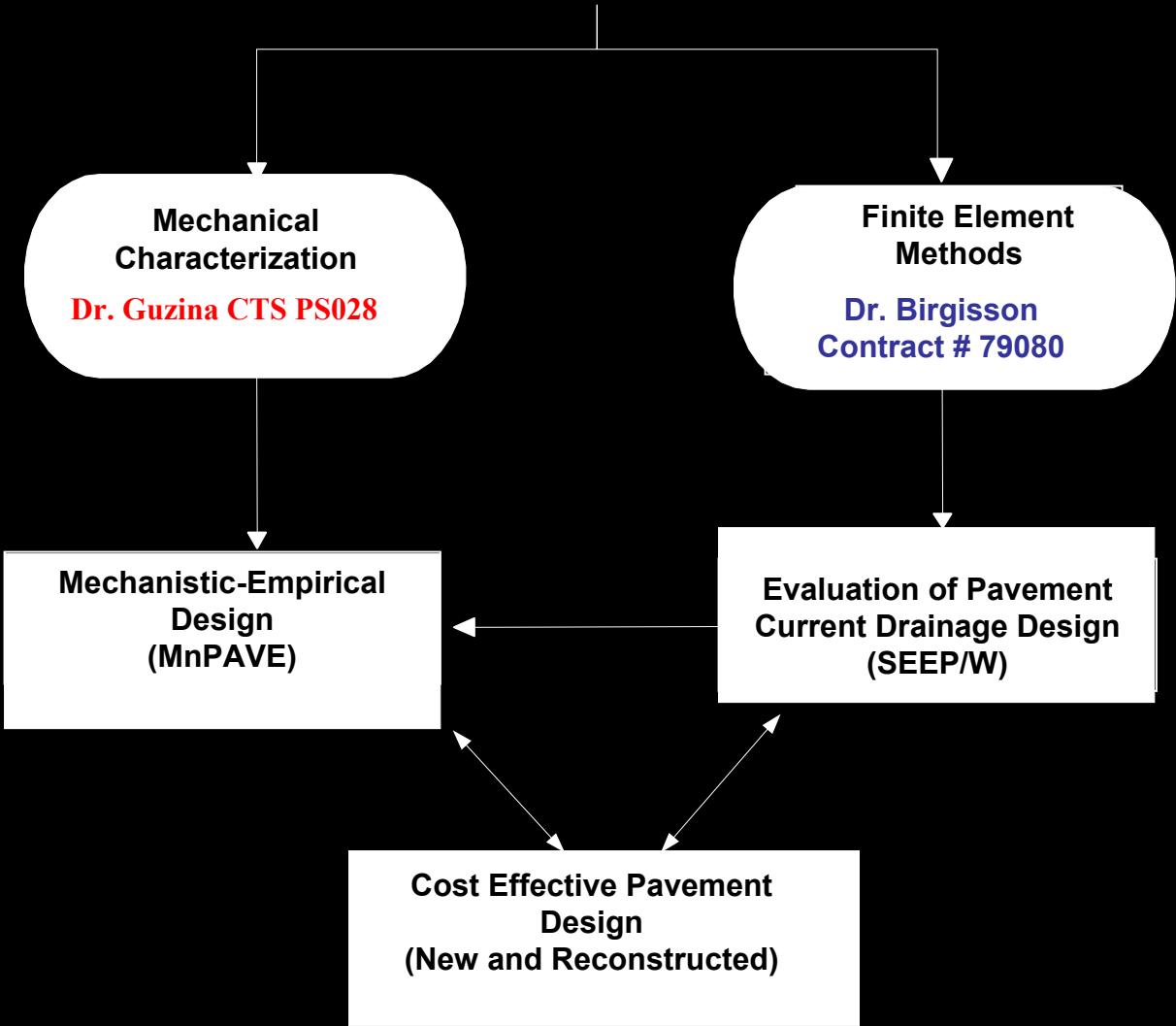
**Mechanical  
Characterization**  
**Dr. Guzina CTS PS028**

**Finite Element  
Methods**  
**Dr. Birgisson  
Contract # 79080**

**Mechanistic-Empirical  
Design  
(MnPAVE)**

**Evaluation of Pavement  
Current Drainage Design  
(SEEP/W)**

**Cost Effective Pavement  
Design  
(New and Reconstructed)**



# Material Characterization for M-E and Drainage Design

## ■ Objective

- Linking Material Moisture Characteristics to Design Parameters

## ■ Process

- Determine moisture regime
- Develop soil property functions
- Determine relationship to design variables

# Material Moisture Characterization

- Measurements and Instrumentation (MnROAD)
- Moisture Conditions
- Application of Information
  - Design
    - M-E design (Material Properties)
    - Evaluating Current Drainage Designs
  - Preventive Maintenance
    - Edge drain maintenance
    - Edge-joint Sealing
  - New Instrumentation Technologies

# Environmental Measurements

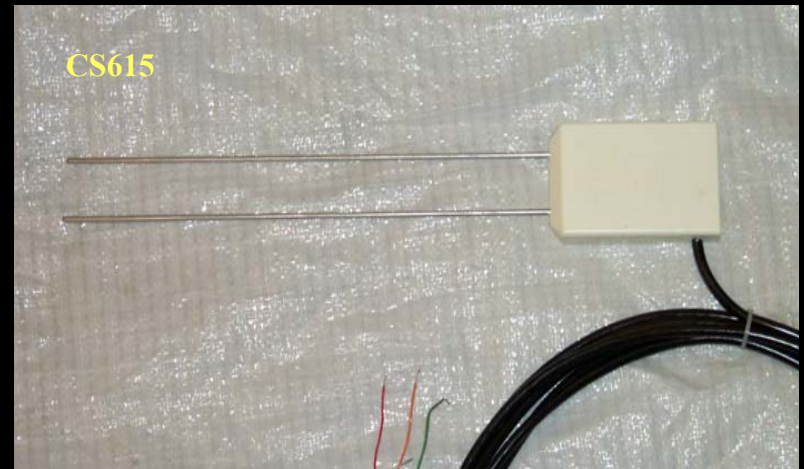
- Instrumentation (manual and automated)
  - Precipitation
    - Weather Station
  - Moisture Content
    - TDR waveguides
  - Ground Water Table
    - Slope Indicator
    - Pressure Transducers
    - Air Dielectric Coaxial Cable
  - Drainage
    - Tipping Buckets

# Moisture Measurements and Instrumentation





**Time Domain Reflectometry Probe:** Installed in all 40 test cells during construction. Manual measurement 1993-1998.



**Water Content Reflectometer (uses tdr methods):** Installed in reconstructed cells 27,28,33-35 (1999). Automated measurements 1999-present.



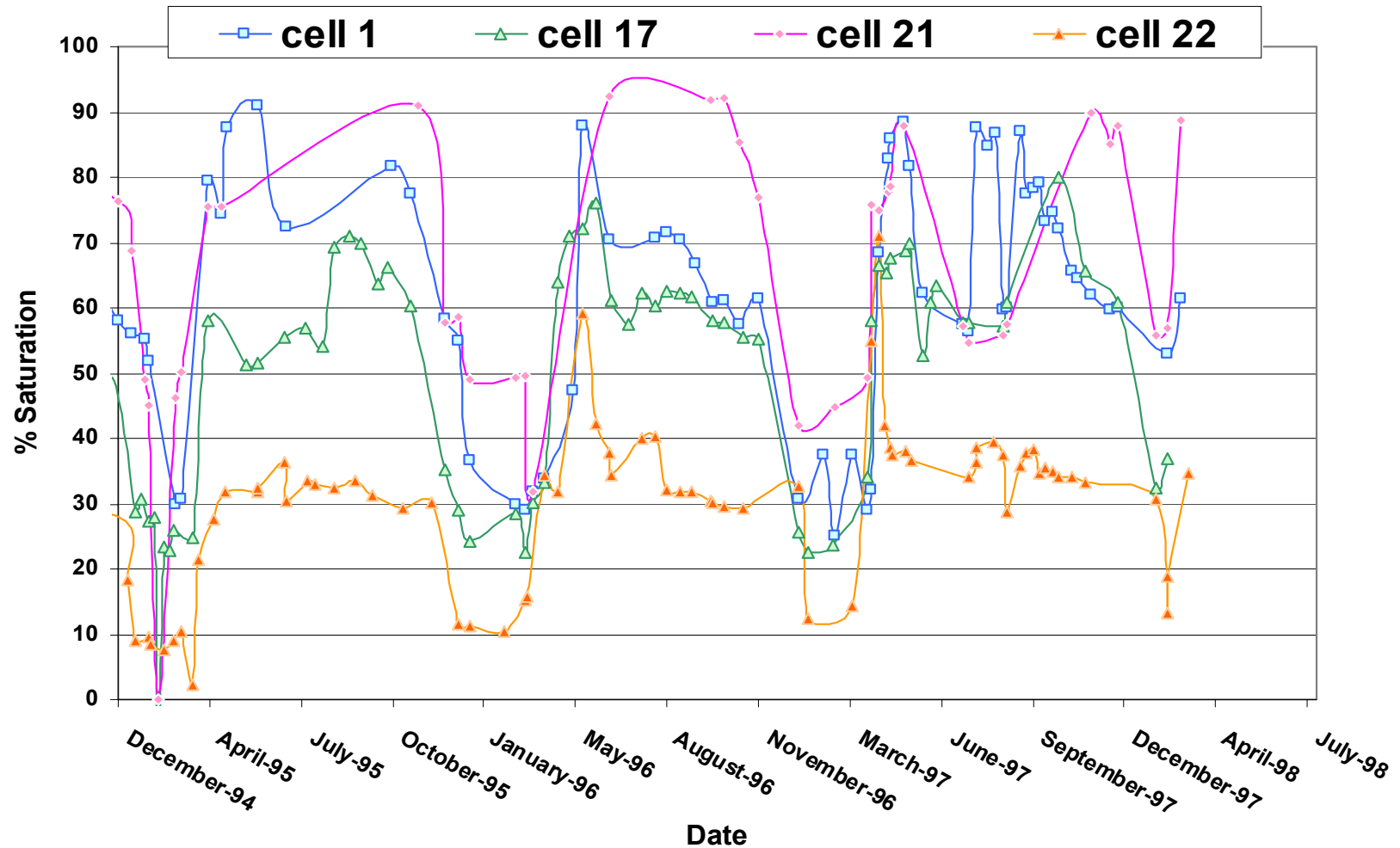
**Time Domain Reflectometry Probe:** Installed in reconstructed cells 27,28,33-35 (1999). Automated measurements 1999-present.



**Percometer:** Provides measurements of dielectric value, electrical conductivity and temperature.

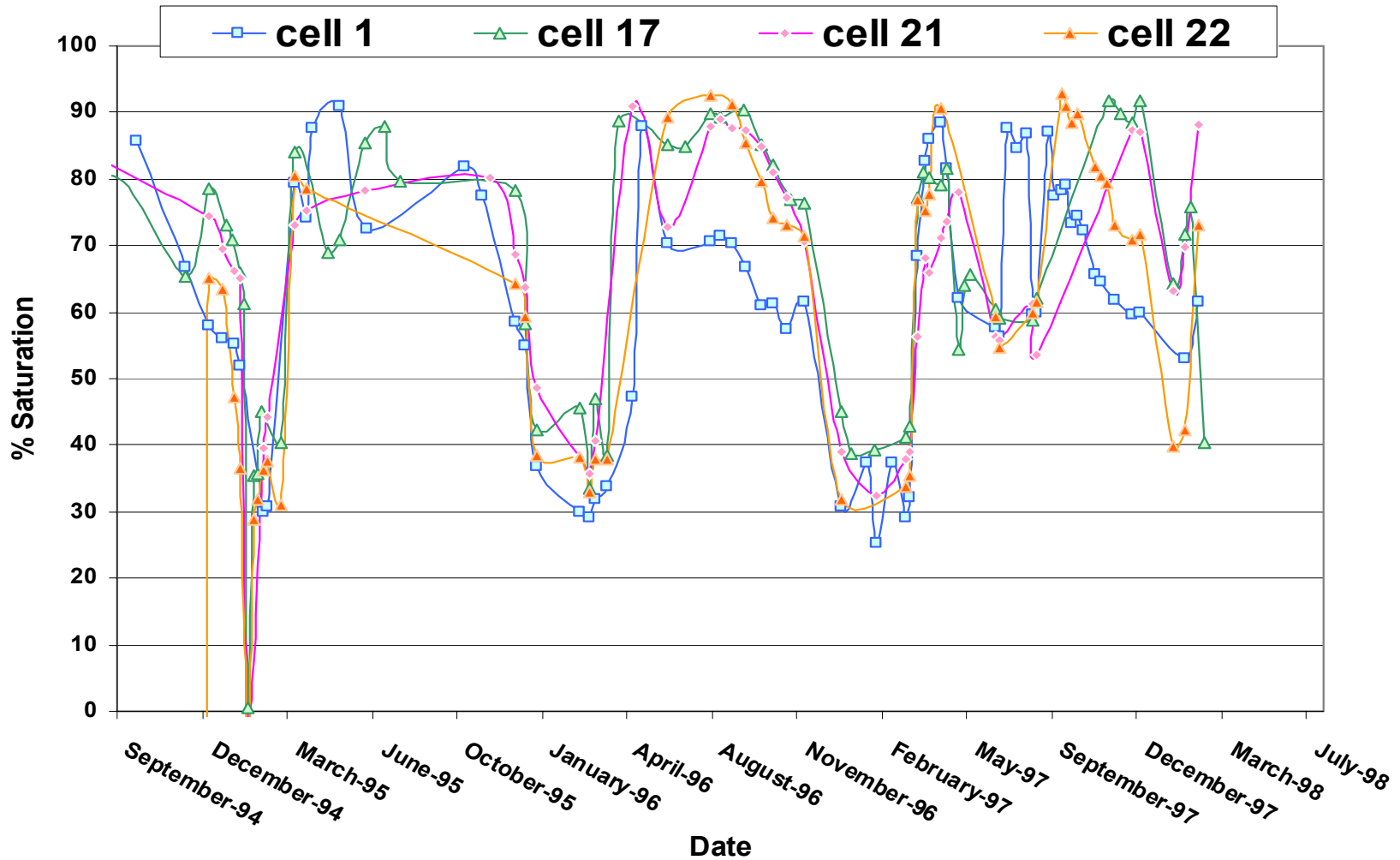
# Subgrade Moisture Content

## Mainline HMA



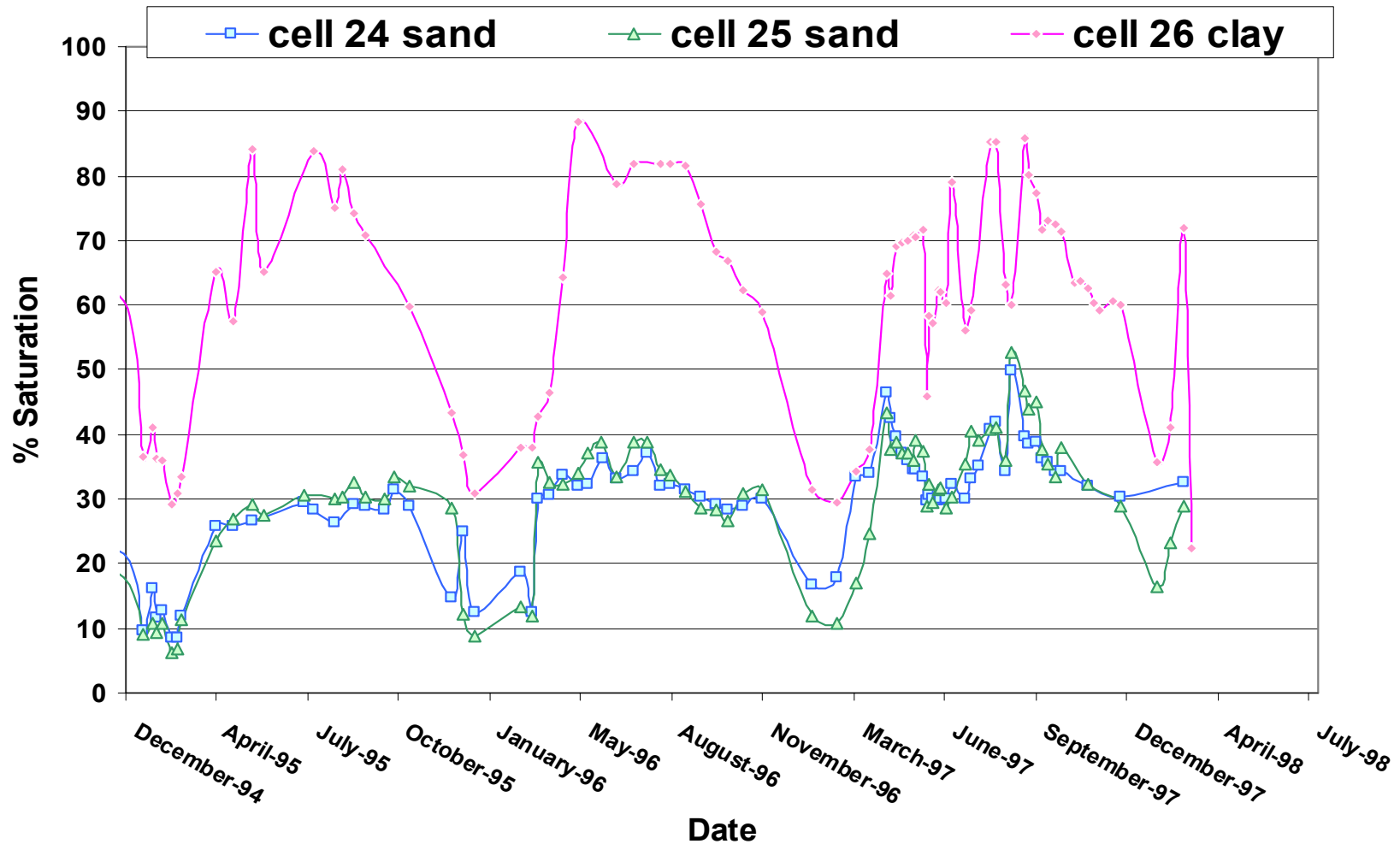
# Subgrade Moisture Content

## Mainline HMA

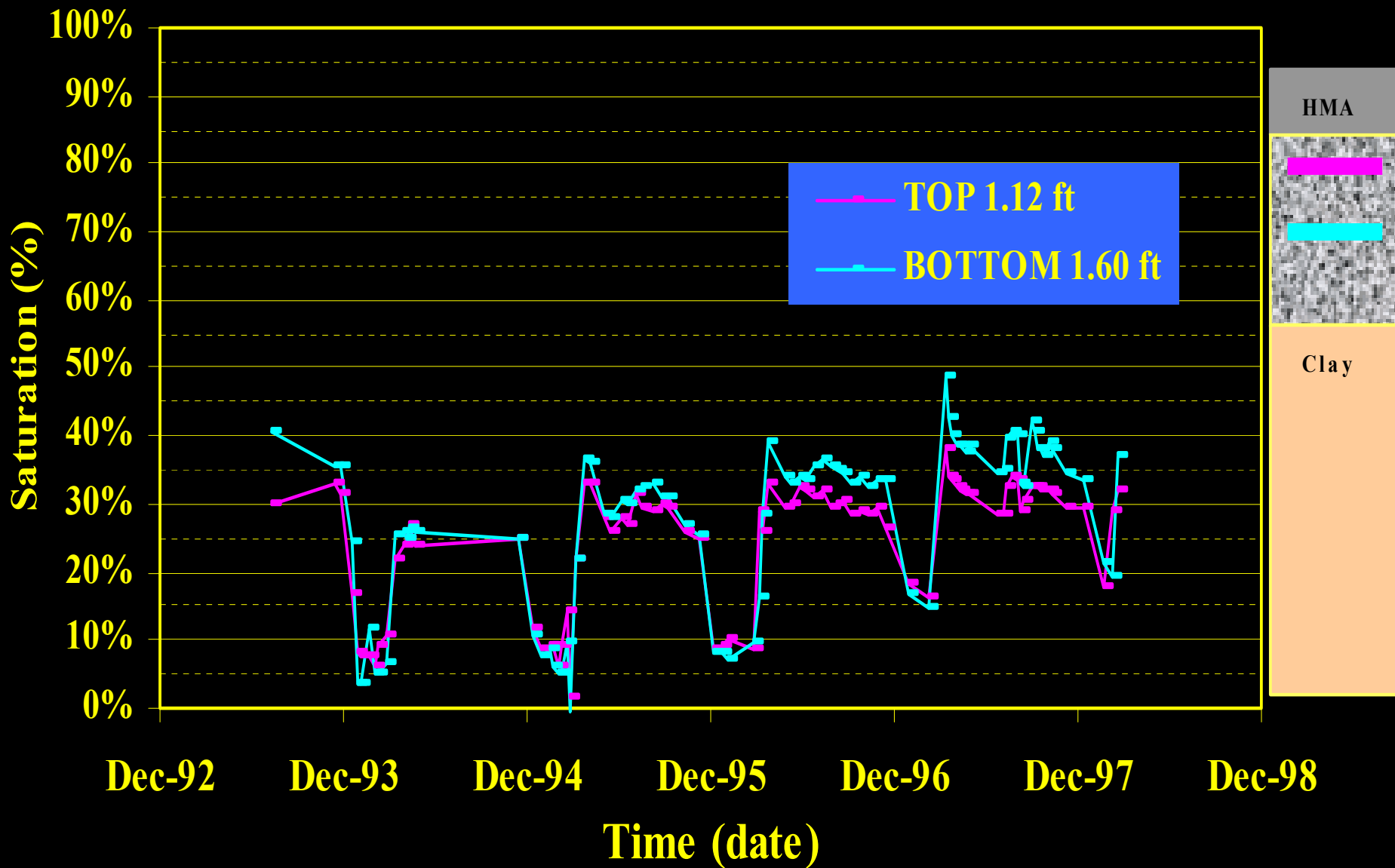


# Subgrade Moisture Content

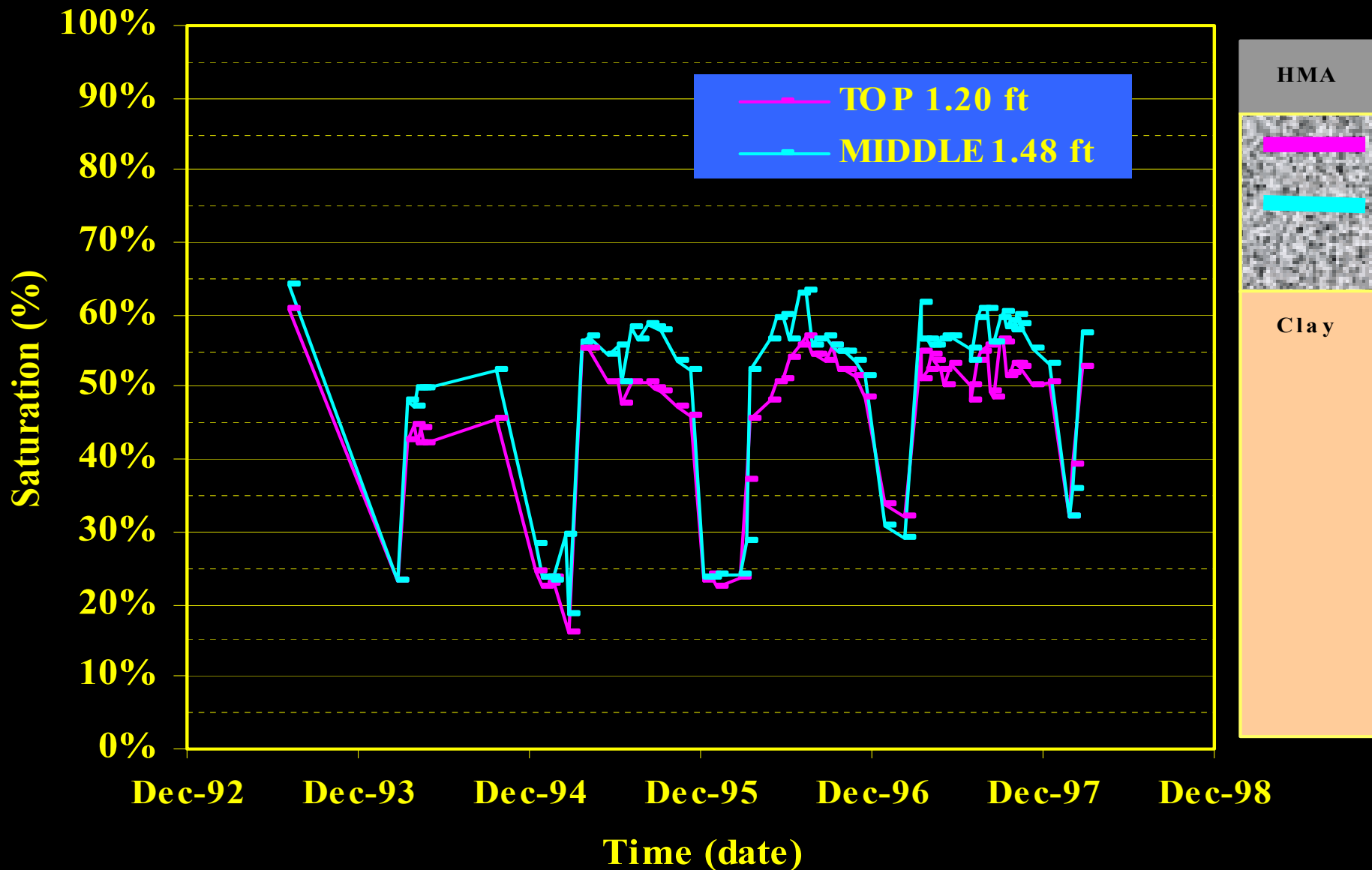
## Low Volume HMA



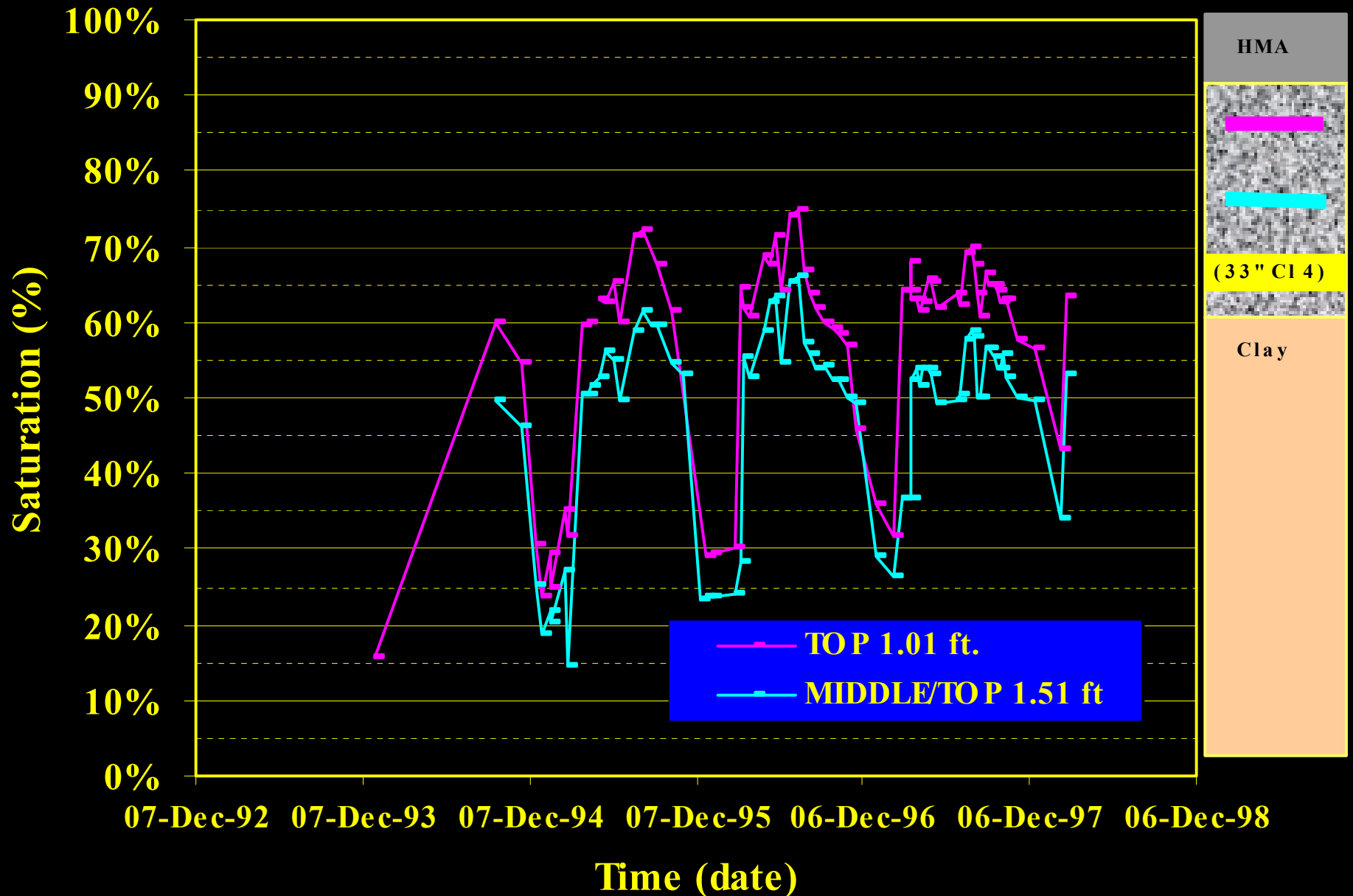
# Mn/ROAD Class 6 Base Cell 22



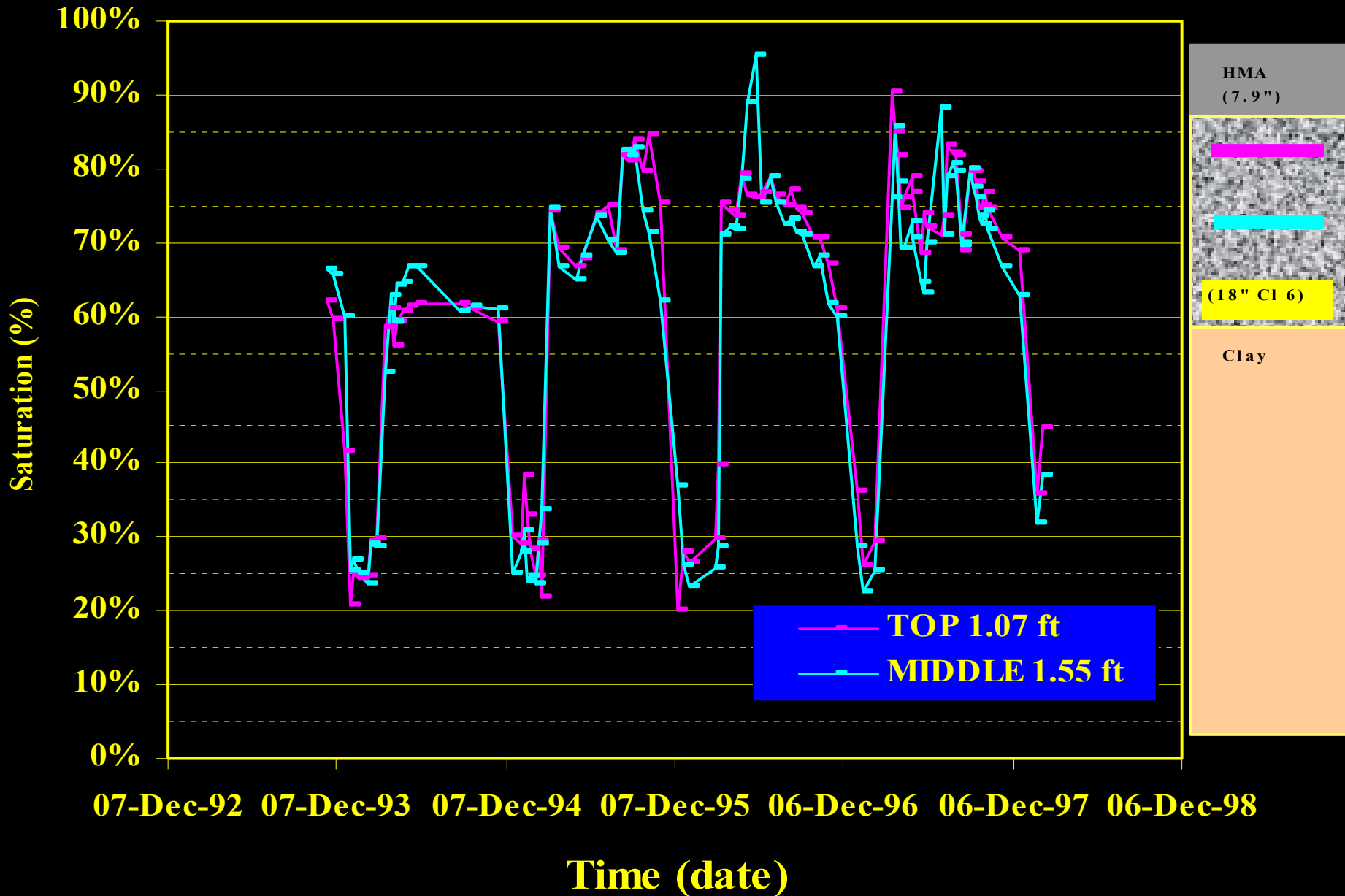
# Mn/ROAD Class 5 Base Cell 21



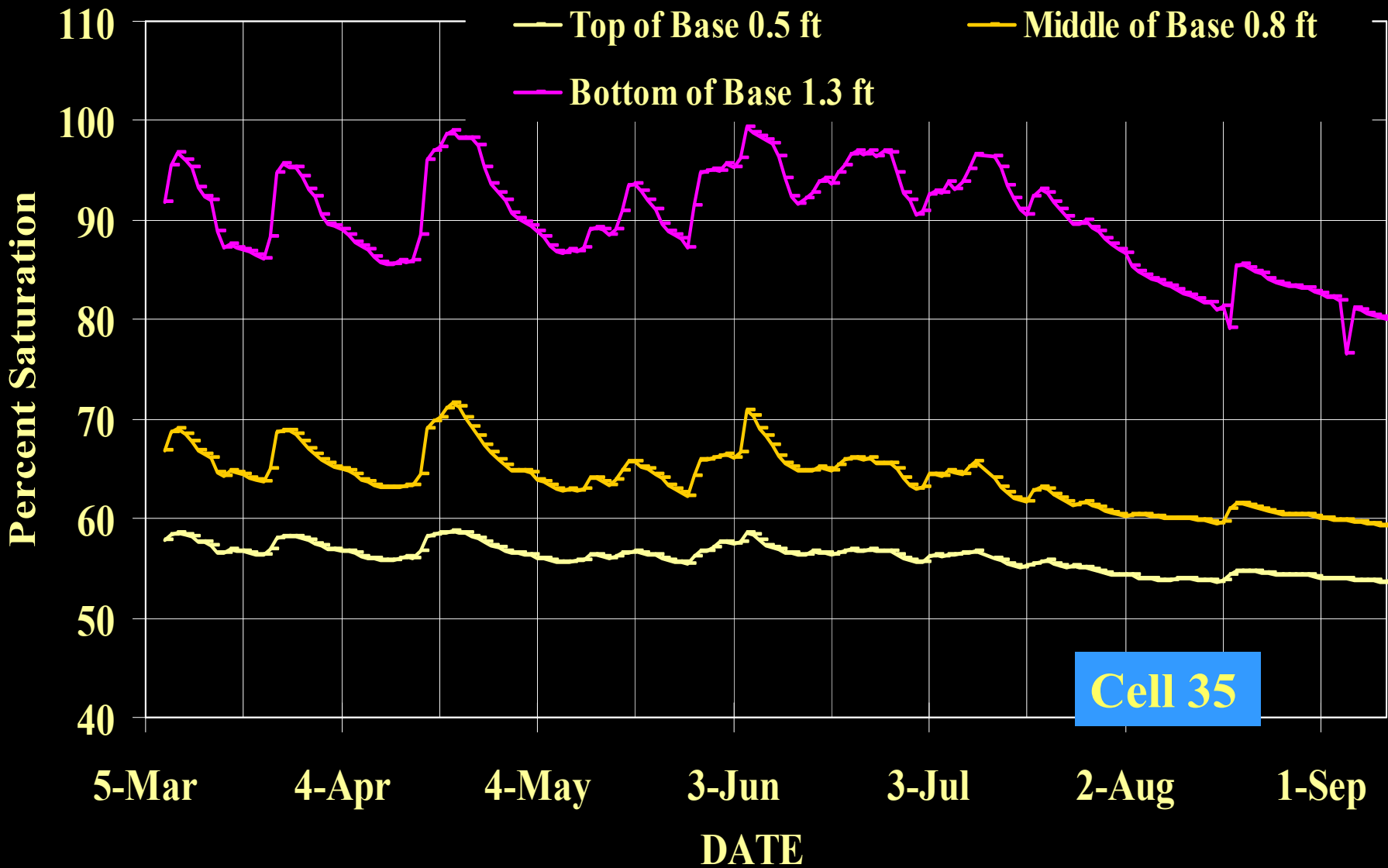
# Mn/ROAD Class 4 Base Cell 1



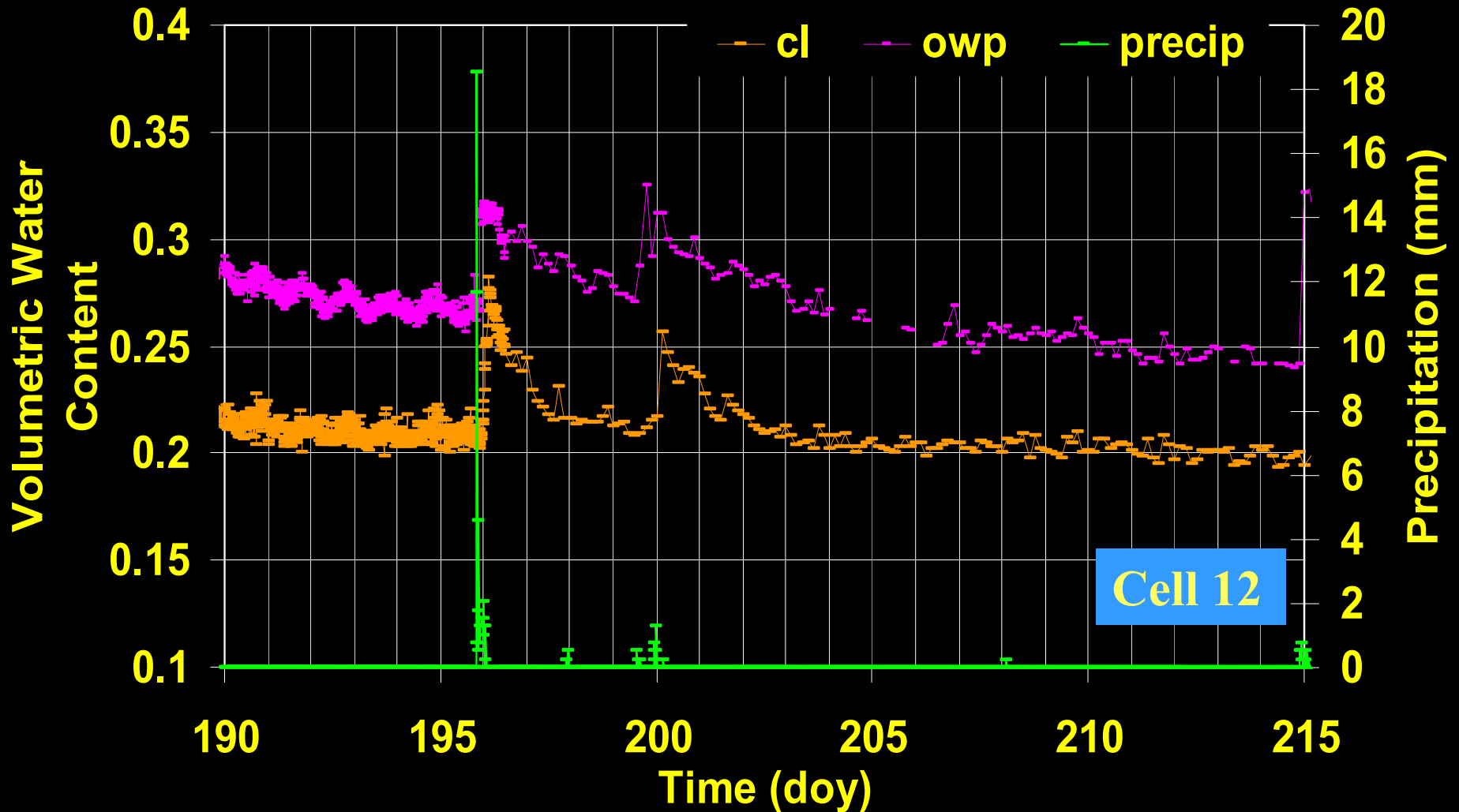
# Mn/ROAD Class 3 Base Cell 17



# Base Water Contents



# Base Moisture Conditions in Drained Concrete Section



# Moisture Conditions

- Moisture conditions within the pavement system vary over time and space.
- Material characterization must take into account both saturated and unsaturated properties.
- Saturated and unsaturated properties must be considered in M-E and pavement drainage design.

# Applications

## ■ Design

- ME-design
- Evaluating Current Drainage Designs

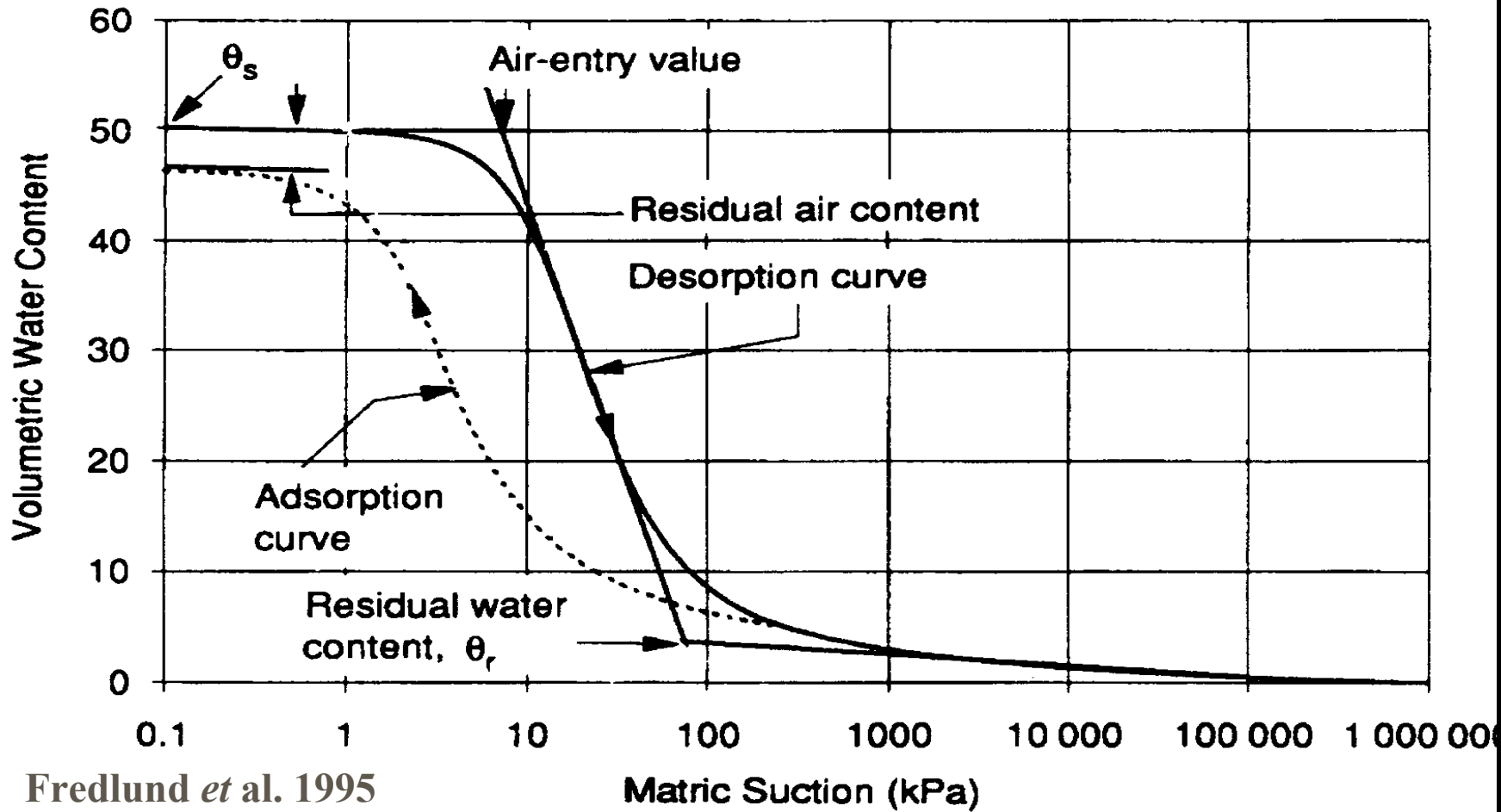
## ■ Preventive Maintenance

- Edge-joint Sealing

## ■ Research

- Instrumentation Technologies

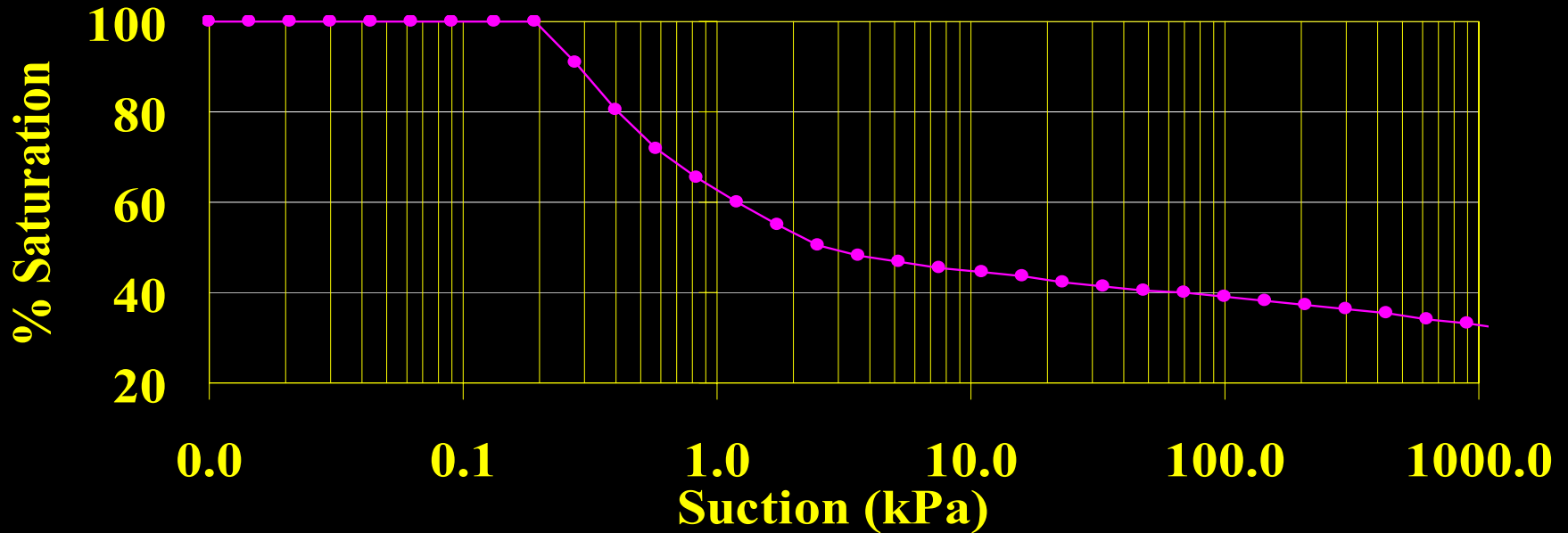
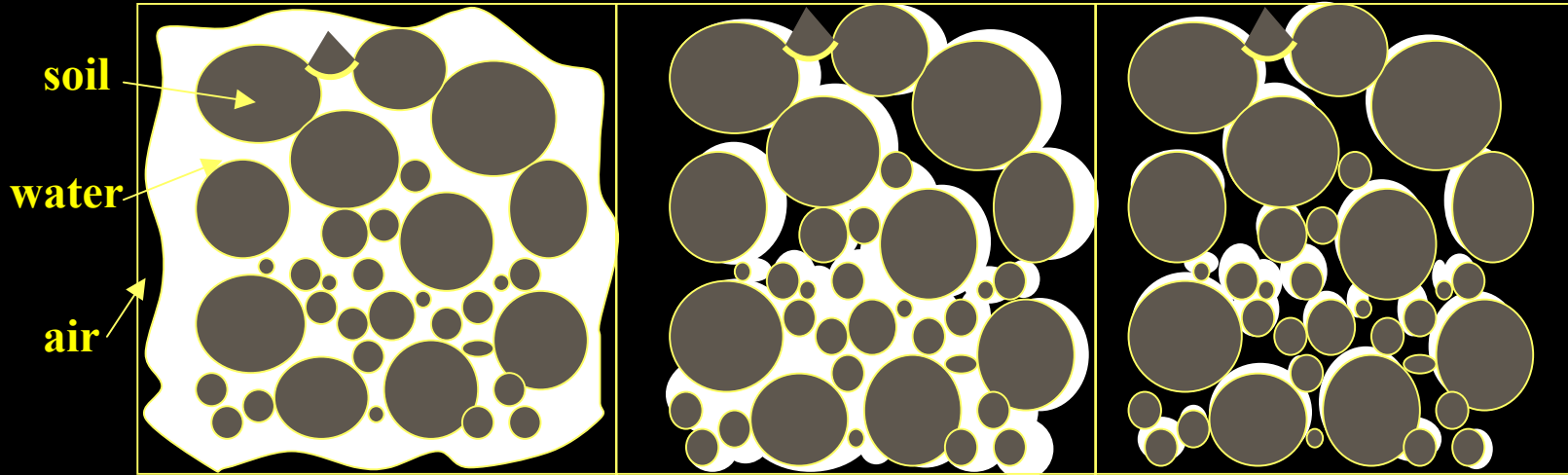
# Soil Water Characteristic Curve (SWCC)



Fredlund *et al.* 1995

**Permeability Decreases  
Continuous Water Films Decrease**

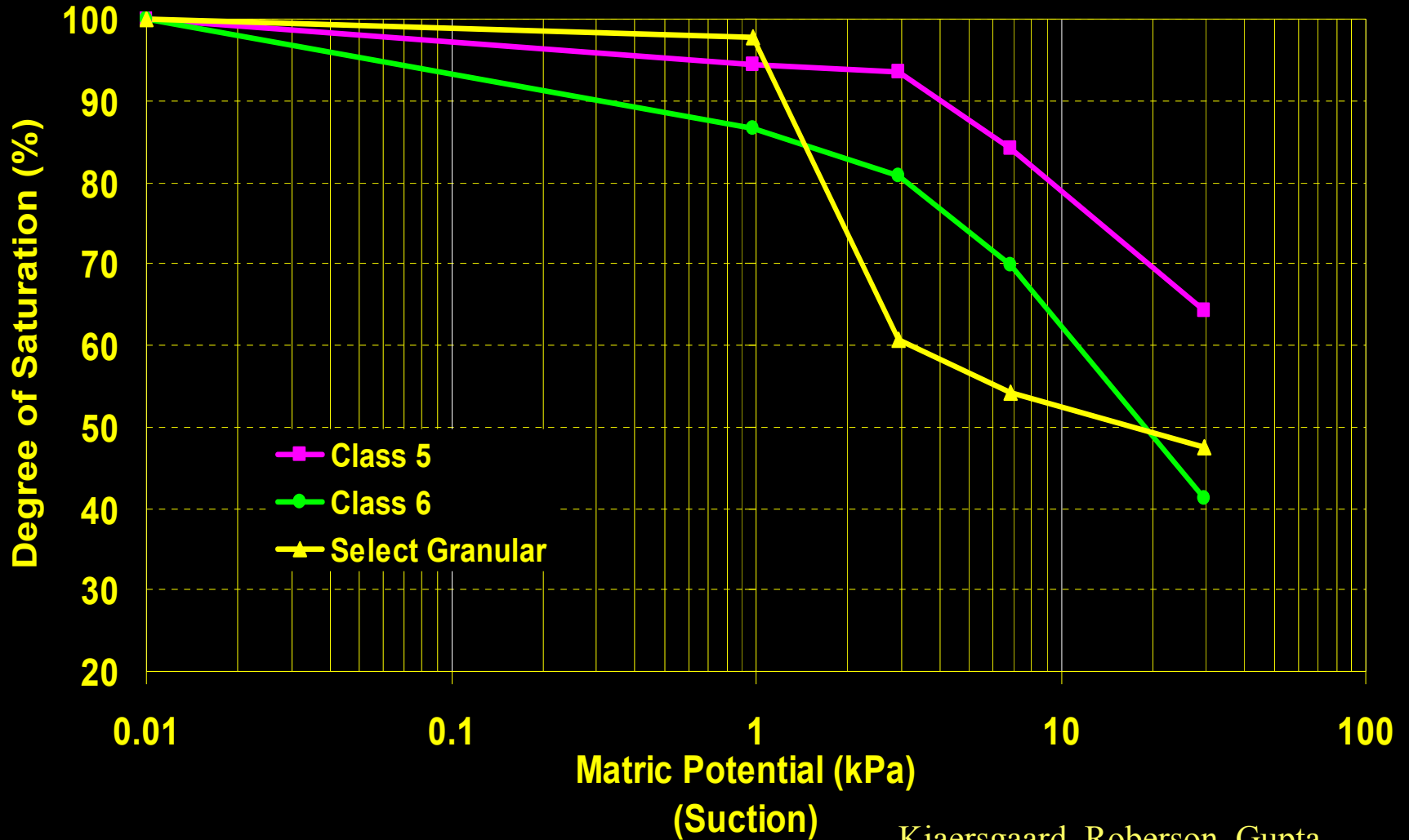
**Suction Increases →  
Unsaturated Modulus and Shear Strength Increases**



# Tempe Cell and Pressure Plate Extraction



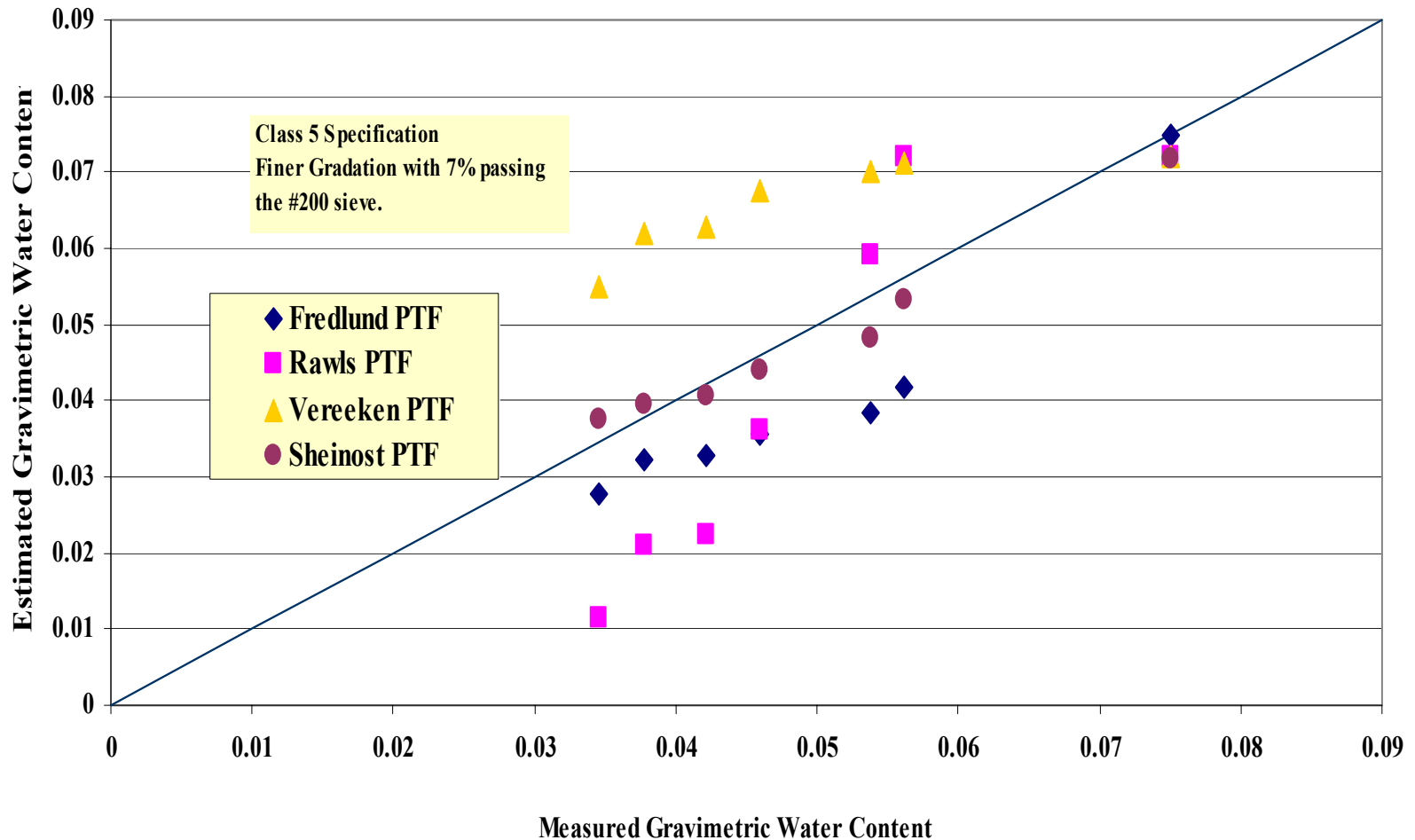
# Soil Water Characteristic Curve



Kjaersgaard, Roberson, Gupta

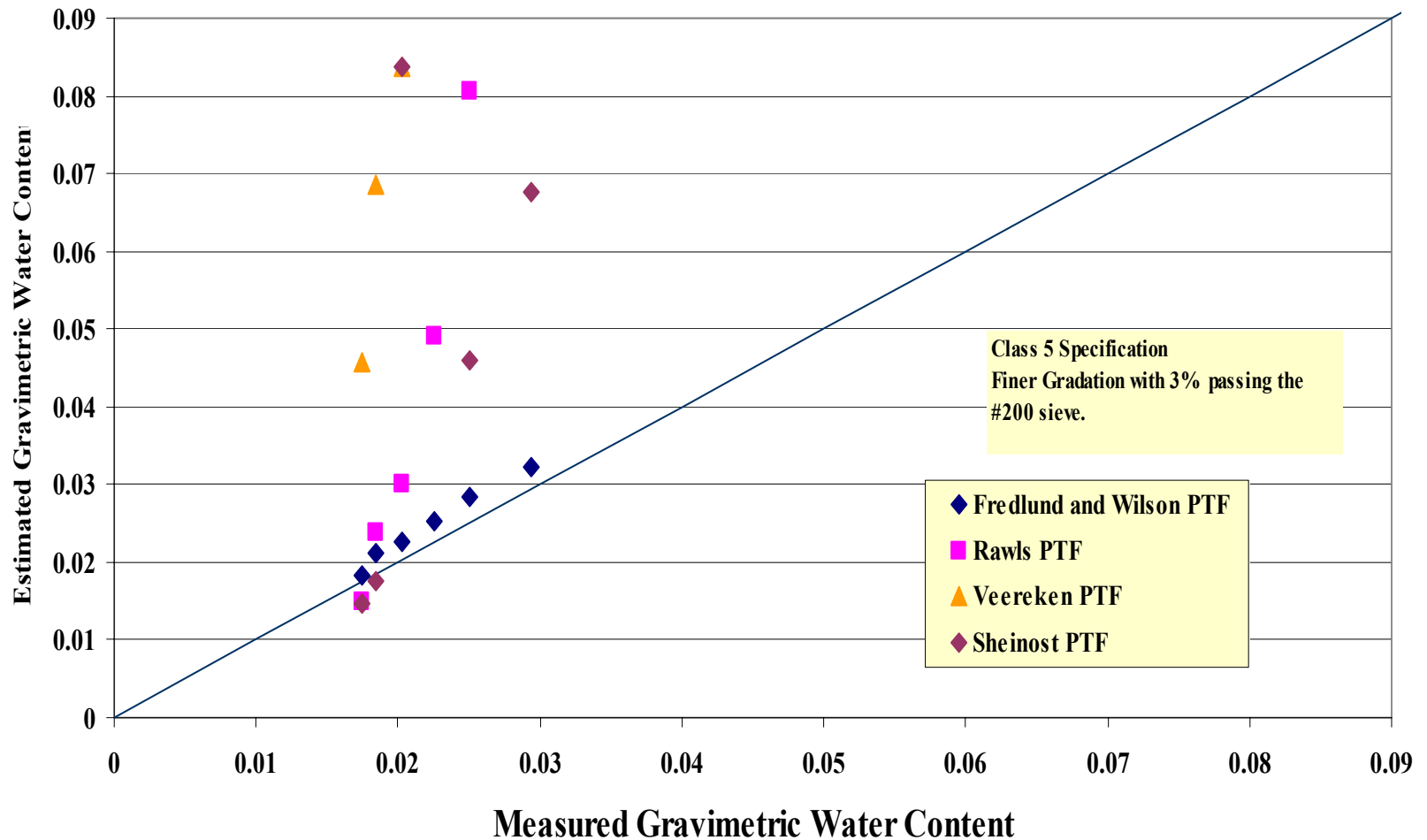
# Soil Water Characteristic Curve

## SWCC Estimated From Pedo-Transfer Functions



# Soil Water Characteristic Curve

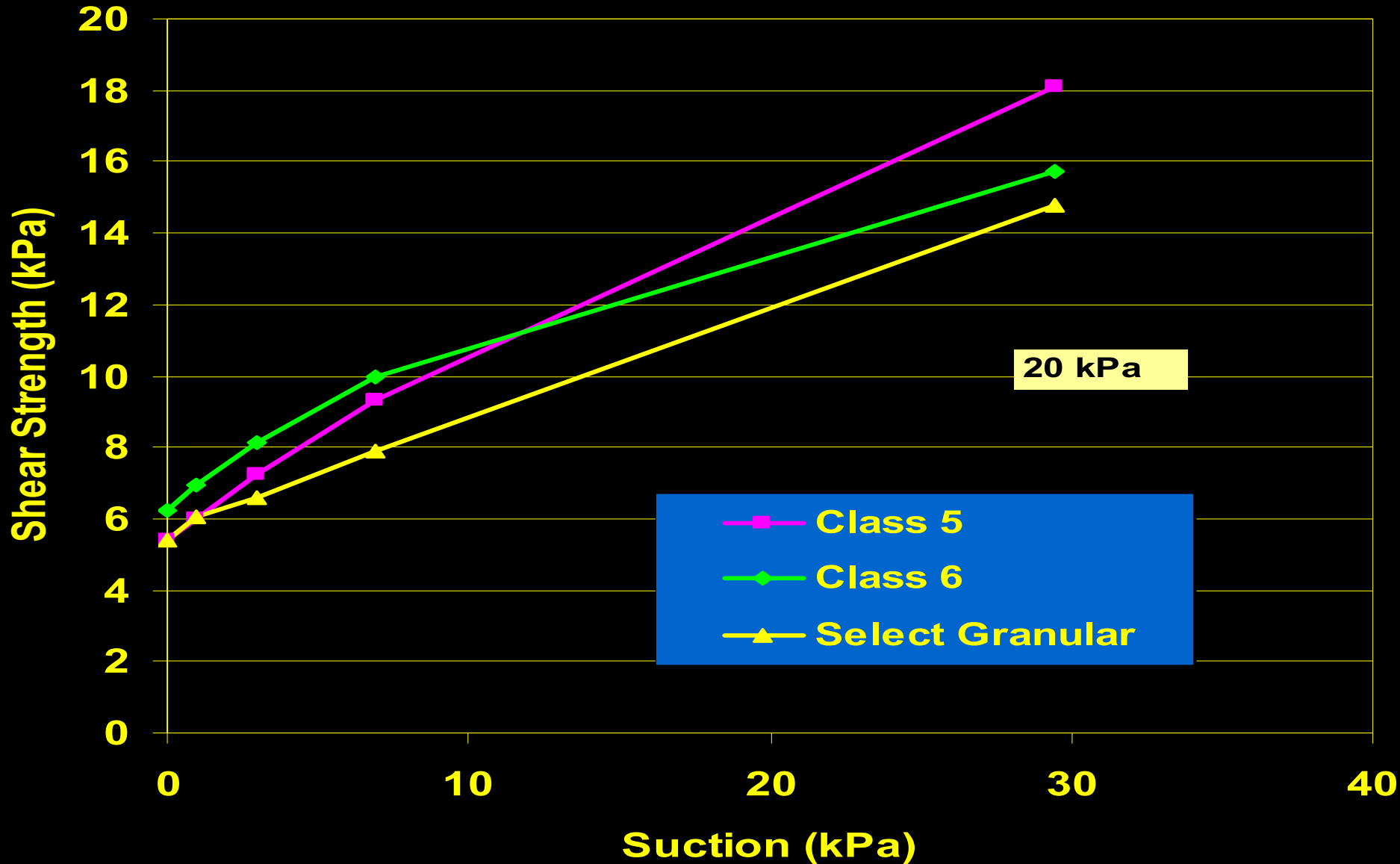
SWCC Estimated From Pedo-Transfer Functions



# Material Characterization for M-E and Drainage Design

- Estimating SWCC (SV Database)
  - Pedo-transfer function
  - Van Genuchten, Fredlund and Xing, Brooks and Corey, etc.. (Cu, PI, D10, D60, density)
- Evaluate Drainage Designs (SEEP/W)
- M-E Design
  - Pore suction resistance factors
    - $\tau = c' + (\sigma_n - u_a) \tan \phi' + (u_a - u_w) [(\Theta^k) \tan \phi']$   
(Vanapalli 1996)

# Estimating Shear Strength



# Current and Future Research

- Current analysis methods are based on numerous assumptions and design criteria which over simplify in situ conditions.
- Continue to develop an extensive and comprehensive database of unsaturated material properties
- Incorporate unsaturated properties into M-E pavement design process

# Cooperating Universities and Researchers

- University of Minnesota, Department of Soil, Water, and Climate (Dr. Gupta and Dr. Wang)
- University of New Mexico, Albuquerque (Dr. John Stormont)
- University of Florida, Gainesville (Dr. Bjorn Birgisson)
- Recycled Materials Resource Center (RMRC), University of New Hampshire (Defne Apul Ph. D candidate, Drs. Eighmy and Gardner)
- Lakehead University, Thunder Bay (Dr. Vanapalli)