Rational Incorporation of Subsurface Drainage within an M-E Design Framework

January 2003

TRB COMMITTEE A2K06

SUBSURFACE DRAINAGE

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Mn/ROAD

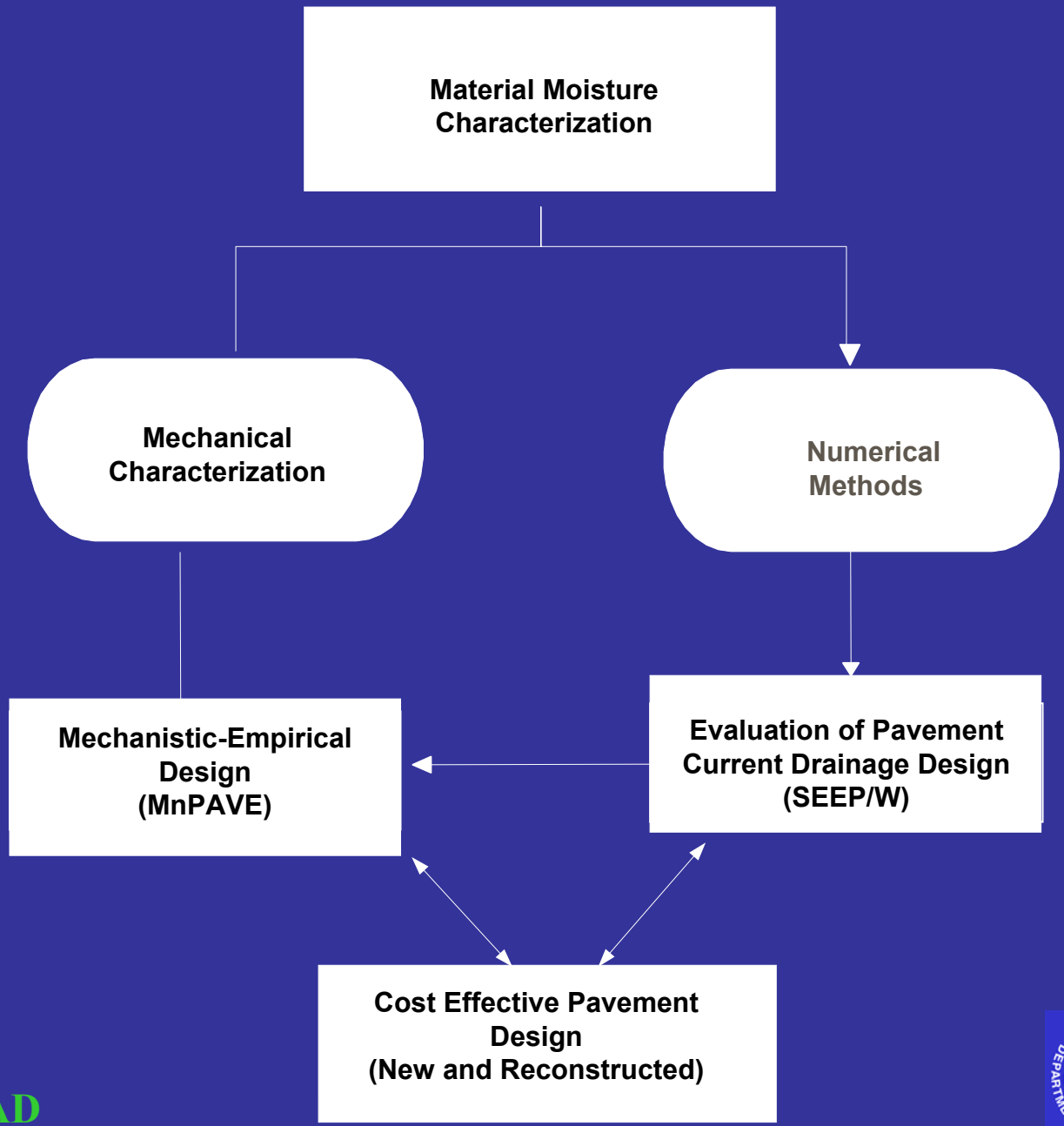
Office of Materials and Road Research

Acknowledgments

- Local Road Research Board (LRRB)

Special Thanks

- Dr. Bjorn Birgisson (U of Florida, Gainsville)
- Defne Apul (UNH, RMRC)
- Bruce Tanquist (Mn/DOT)



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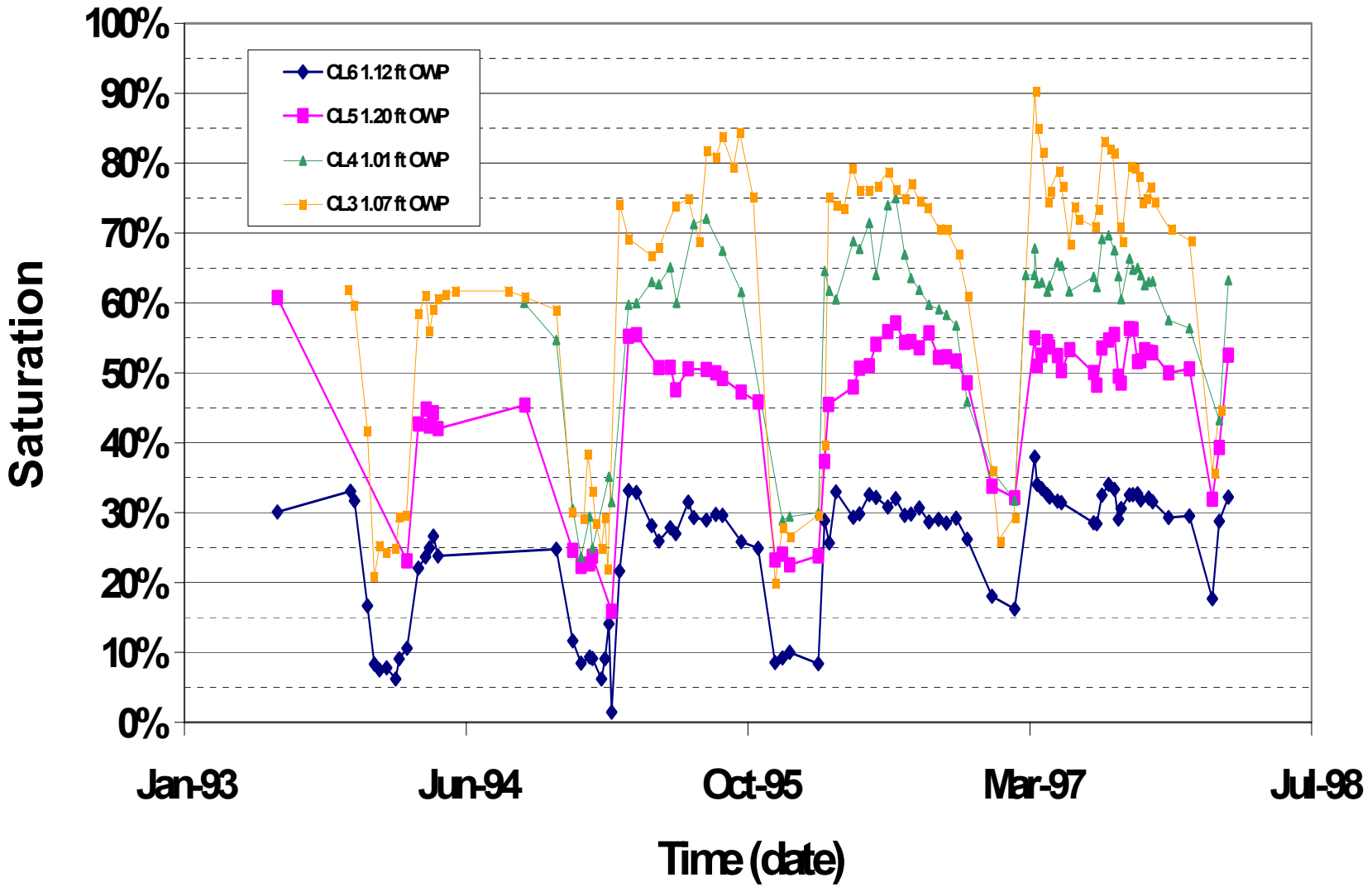
Objective

Linking Material Moisture Characteristics to Design Parameters

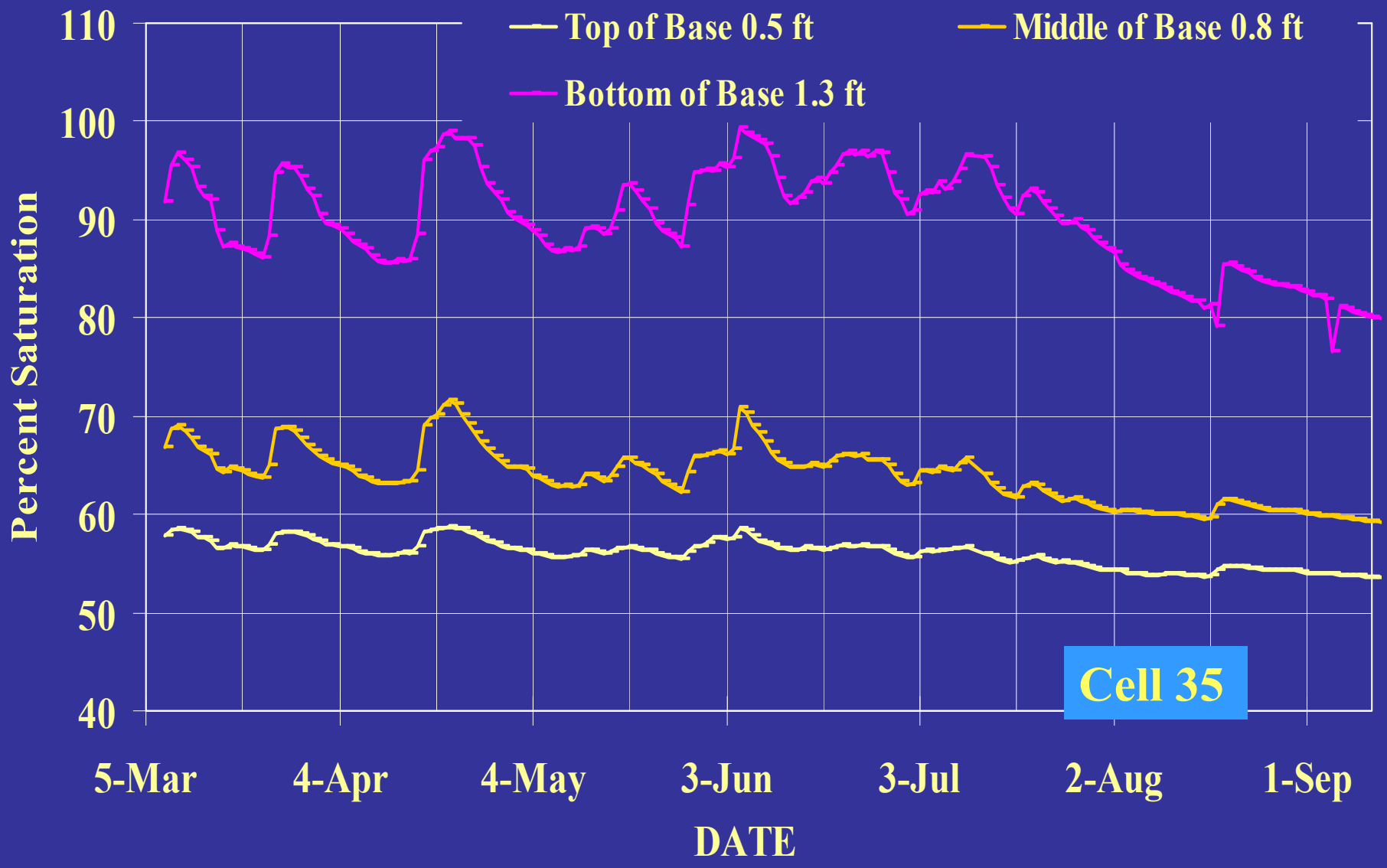
Material Characterization for M-E and Drainage Design

- Develop Framework for Incorporation Into Design
  - Measurements and Instrumentation (MnROAD)
  - Moisture Conditions
    - Determine moisture regime
    - Develop soil property functions
    - Determine relationship to design variables
- Implementation
  - Design
    - M-E design (Material Properties)
    - Evaluating Current Drainage Designs

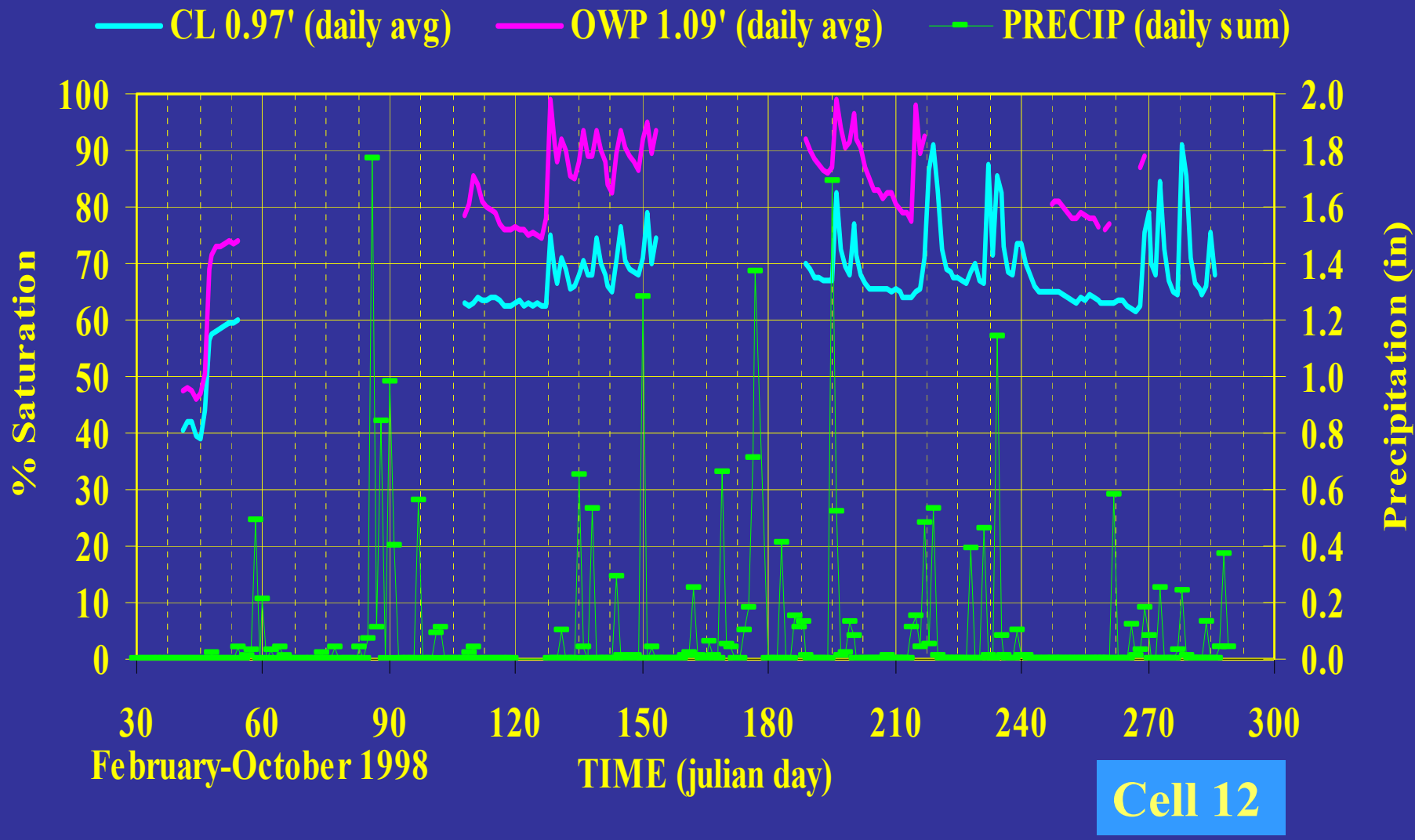
Mn/ROAD Seasonal Moisture Content



Base Water Contents



Base Water Contents



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.

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
  - Resilient Modulus
  - Pore suction resistance factors
    - $\tau = c' + (\sigma_n - u_a) \tan \phi' + (u_a - u_w) [(\Theta^k) \tan \phi']$ (Vanapalli 1996)

Applications

- Design
  - Evaluating Current Drainage Designs
  - ME-design

Soil Water Movement

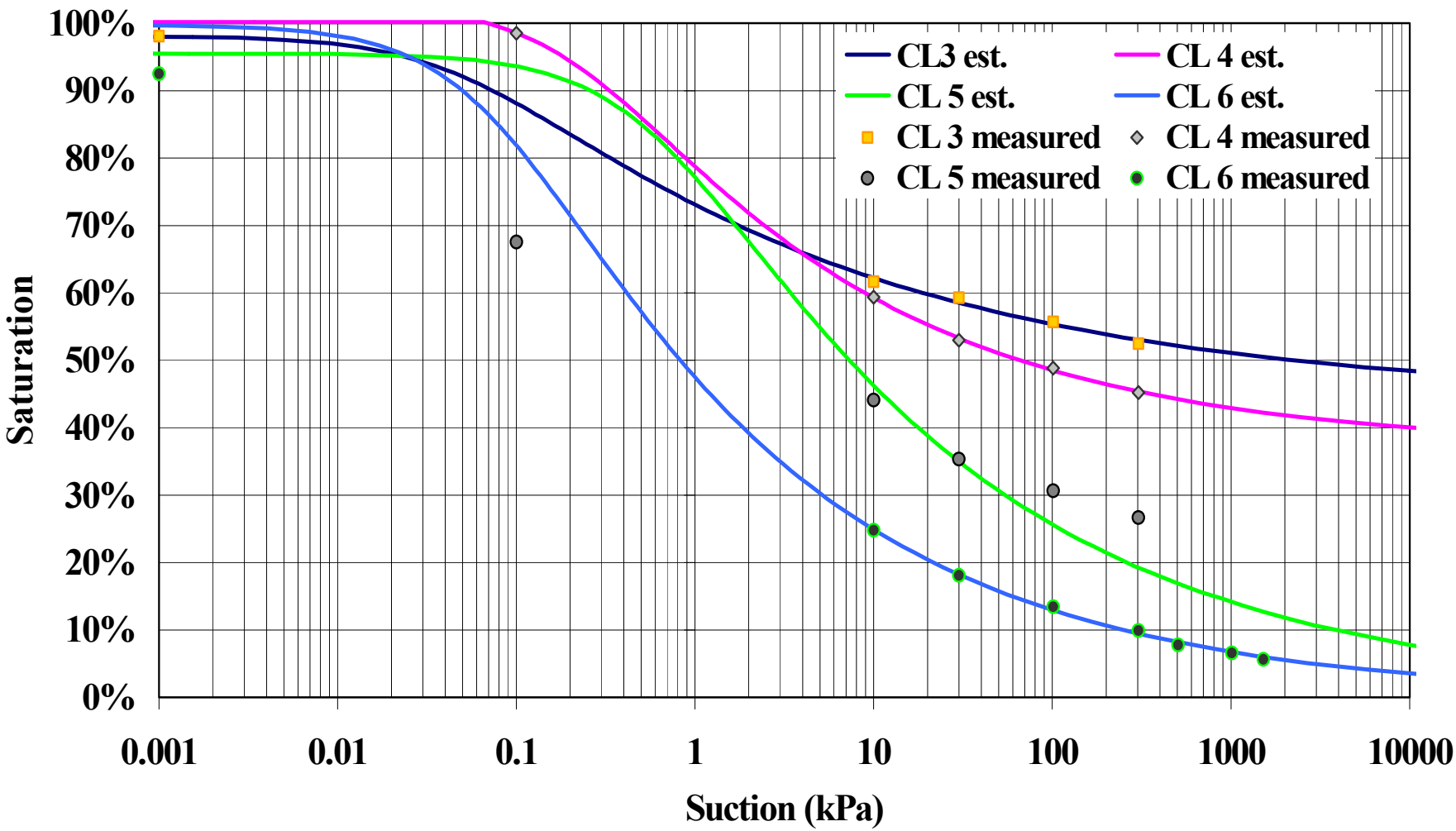
- **Flux is the volume flow rate per unit area ($cm^3/sec/cm^2$).**
- **Saturated conditions: flux is proportional to the gradient and the hydraulic potential is independent of the conductivity.**
- **Unsaturated conditions: flux remains proportional to the hydraulic gradient but conductivity depends on hydraulic potential.**

$$q = -K\nabla H \text{ (Darcy's law)}$$

$$q = -K(\Psi)\nabla H \text{ (Richards 1931)}$$

$$\partial\theta/\partial t = \nabla\cdot[K(\Psi)\nabla H] \text{ (Richards equation)}$$

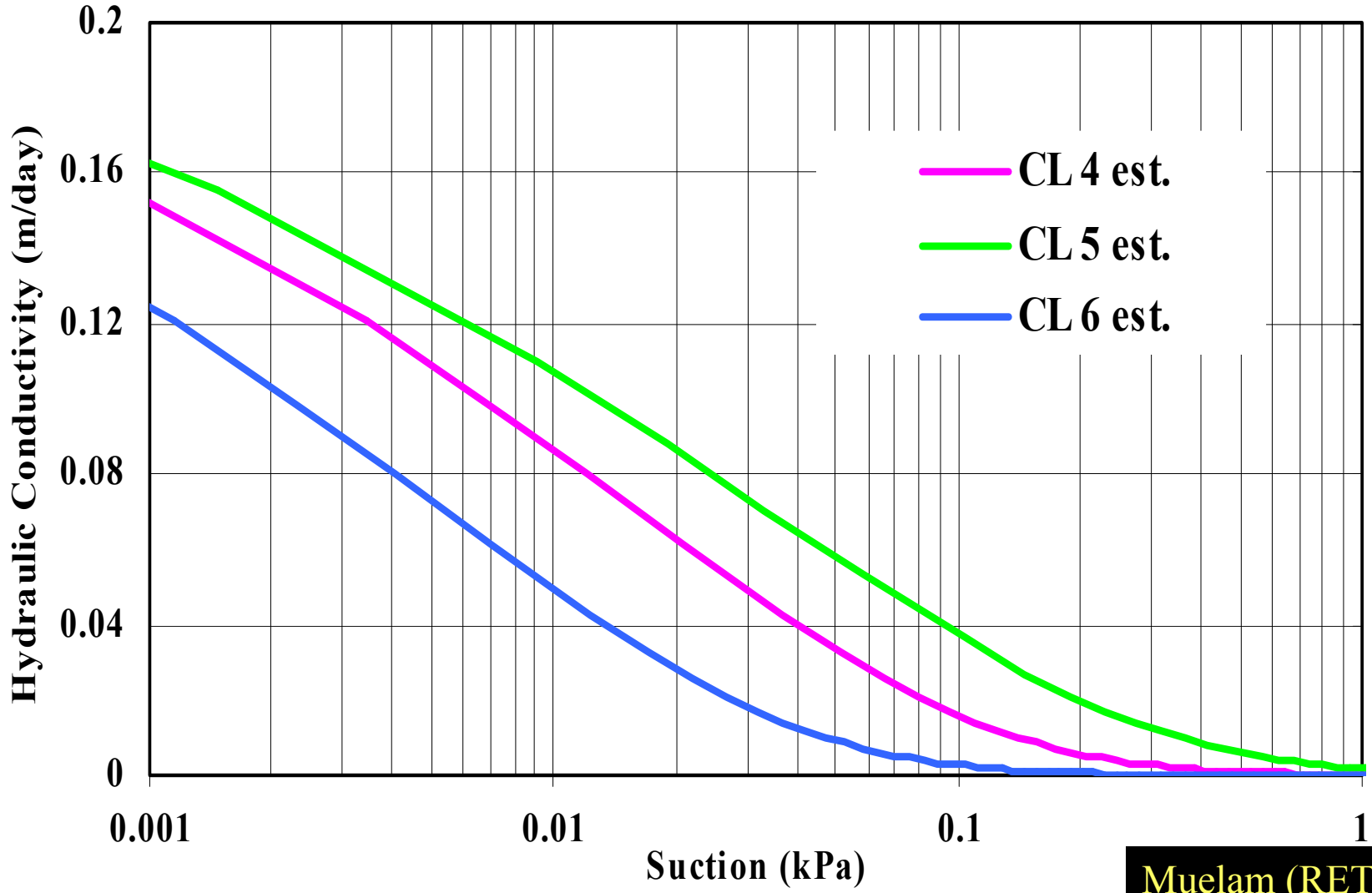
Soil Water Characteristic Curve



Van Genuchten fit (RETC)

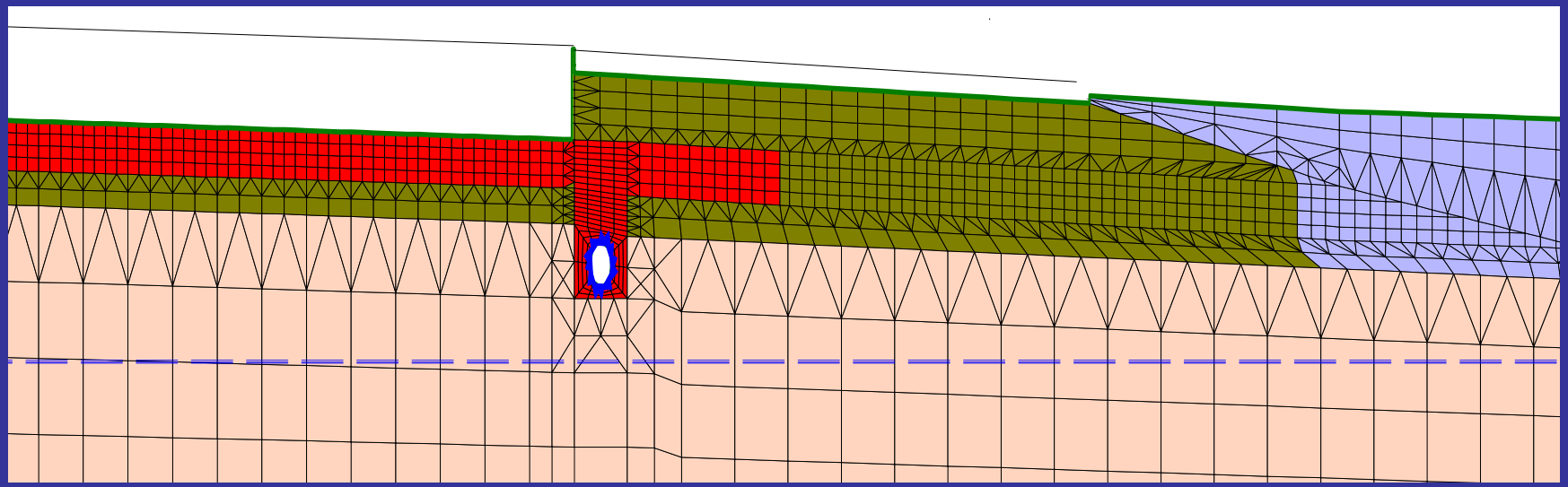
Tempe Cell and Pressure Plate Extraction

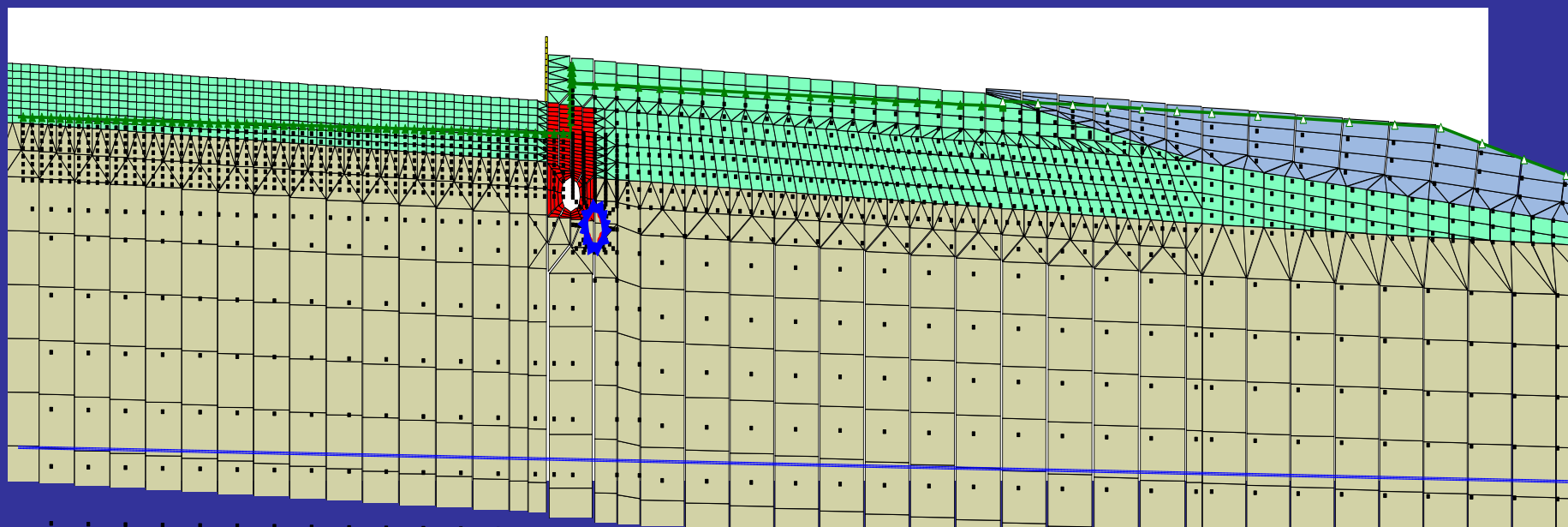
Estimate Hydraulic Conductivity Function



Muelam (RETC)

Evaluating Current Drainage Designs





Applications

- Design
  - Evaluating Current Drainage Designs
  - M-E Design

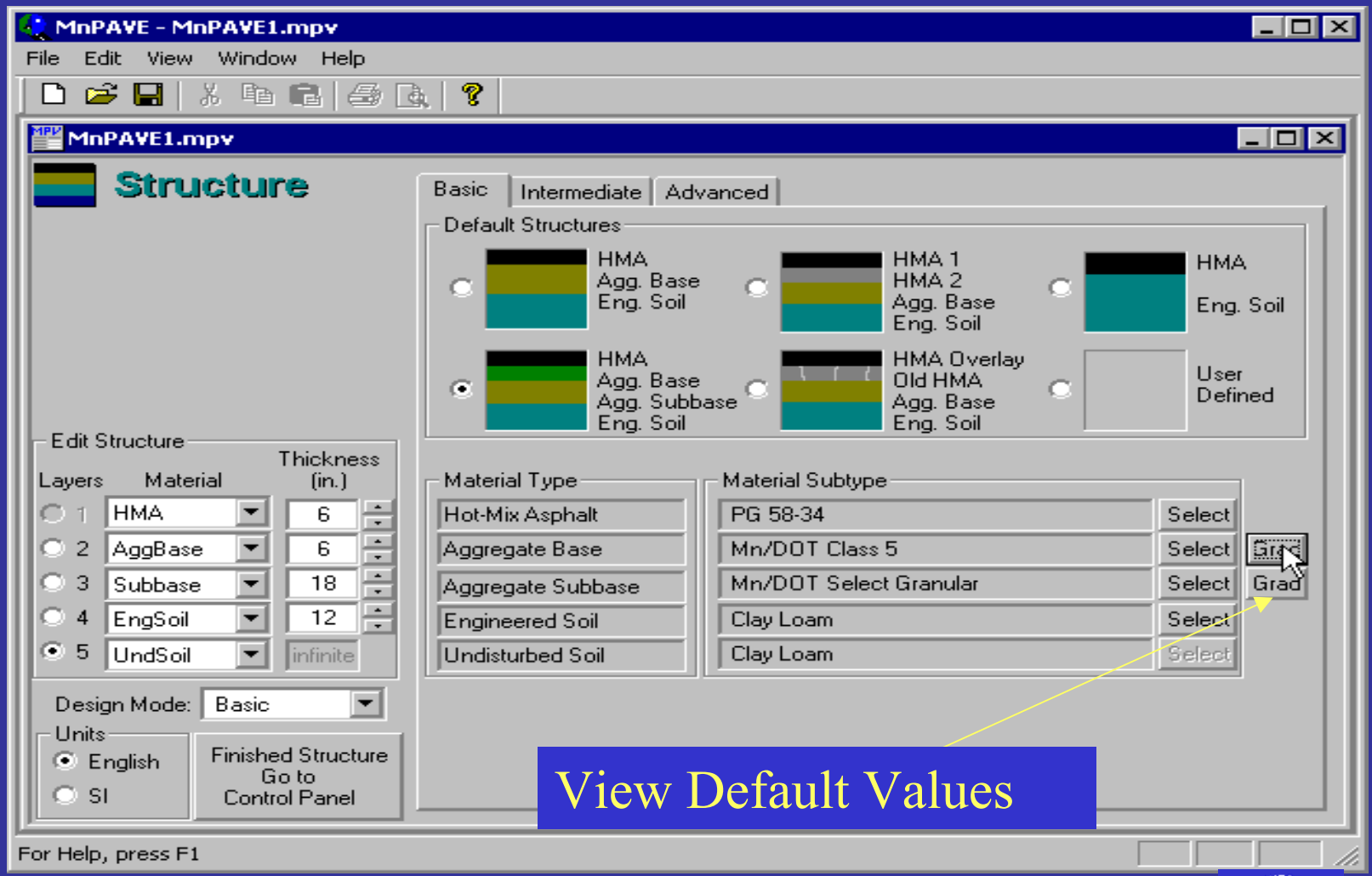
Seasonal Pore Suction Resistance Factors

Material	% Saturation		
	*Mean (summer)	SD	Suction (kPa)
Mn/ROAD Class 3	74	6.0	0.81
Mn/ROAD Class 4	60	6.0	8.36
Mn/ROAD Class 5	54	4.0	5.11
Mn/ROAD Class 6	33	4.0	3.46

*difference is significant, n=418

- Generated From Mn/ROAD Test Sections
- Used as MnPAVE default values (Basic Level)

MnPAVE



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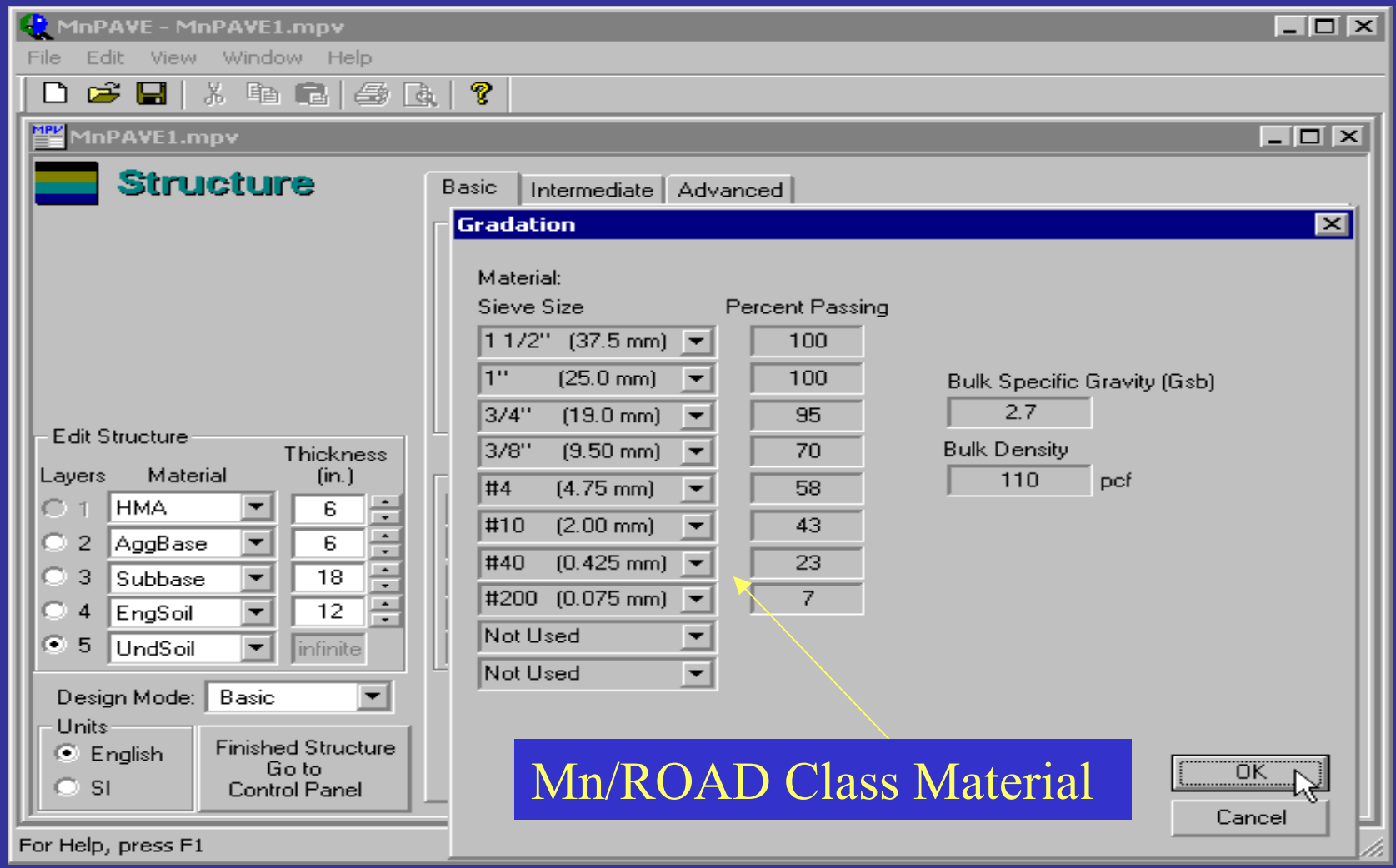

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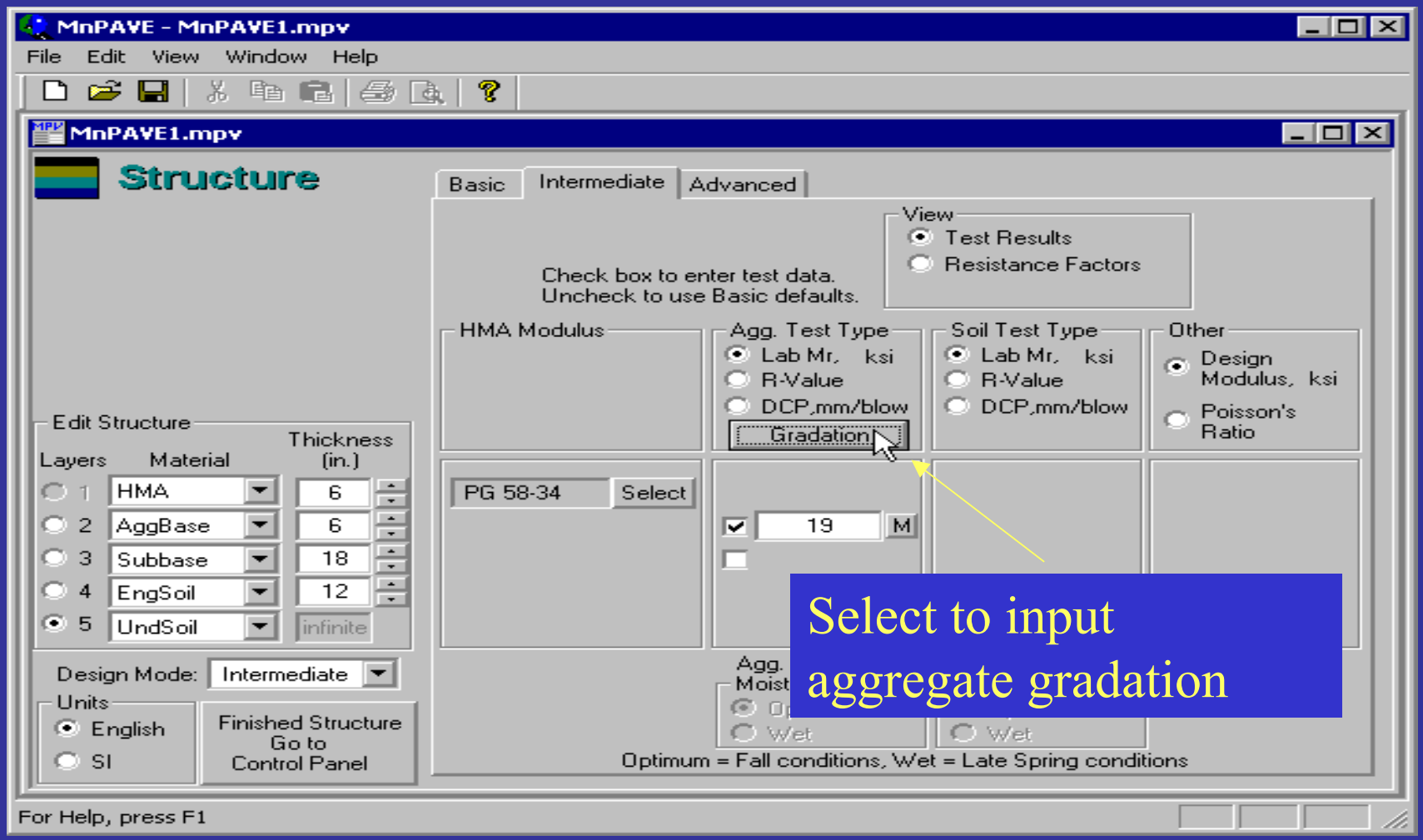

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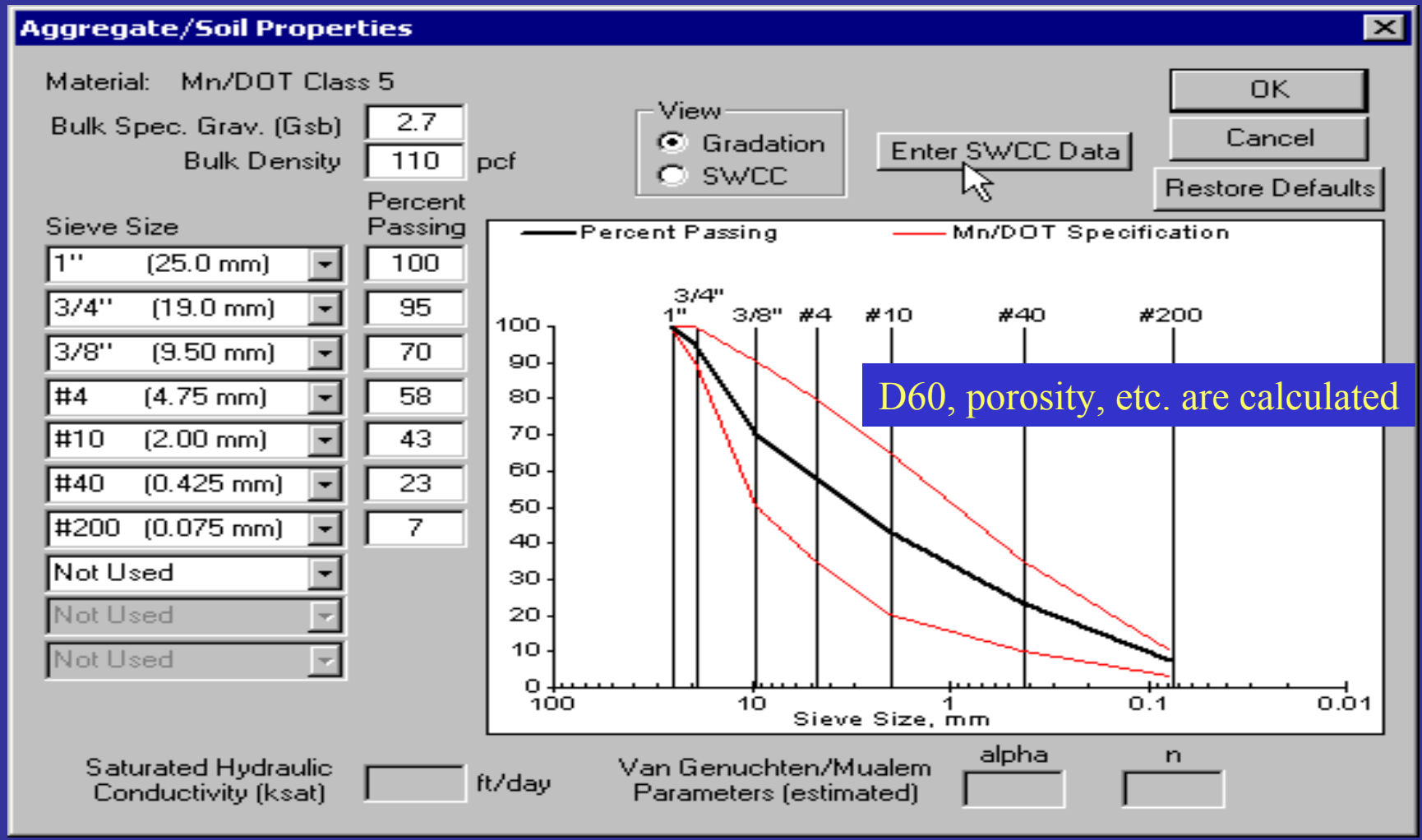
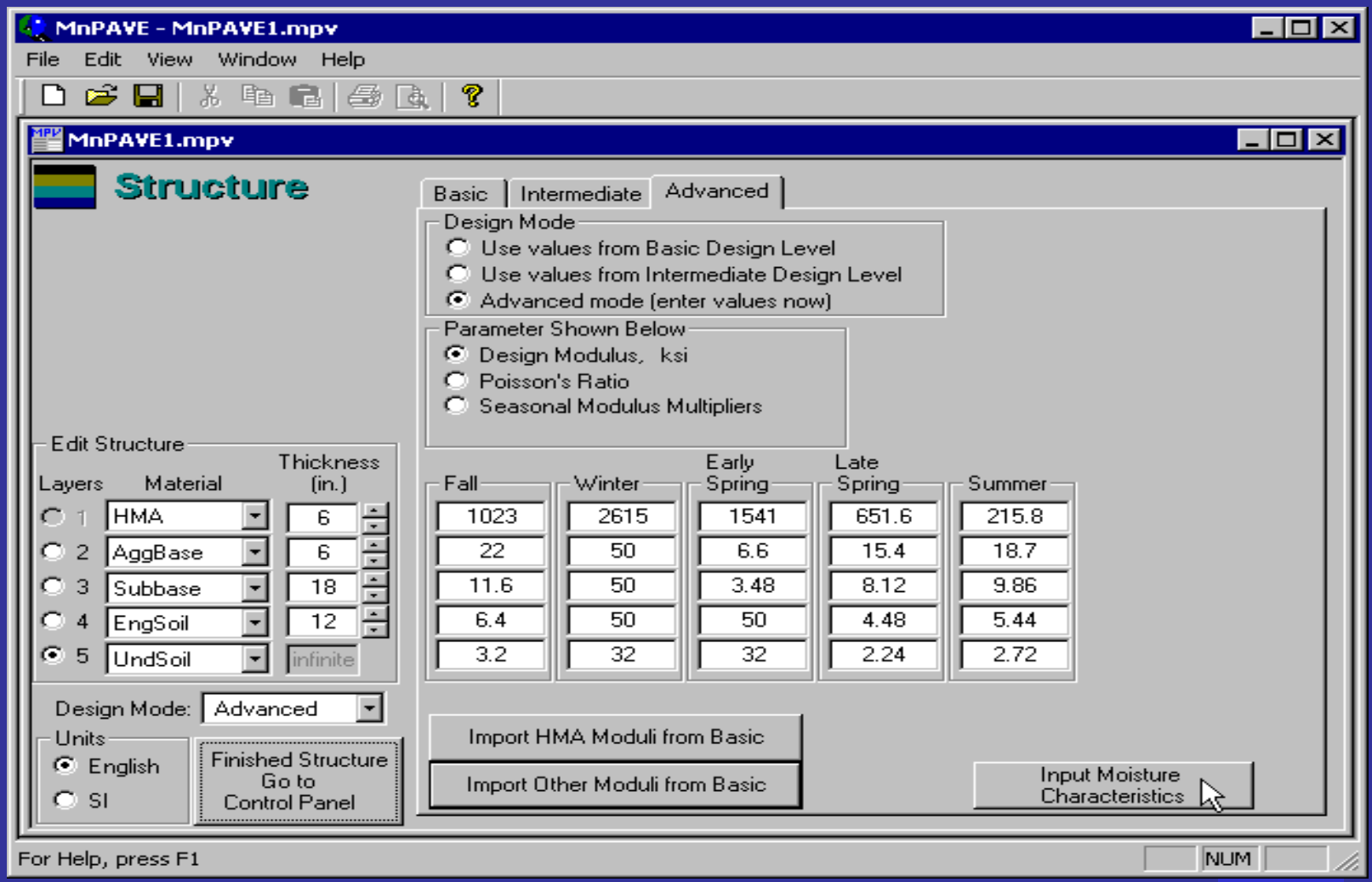

Aggregate/Soil Properties
Material: Mn/DOT Class 5
Bulk Spec. Grav. (Gsb) 2.7
Bulk Density 110 pcf
View
Gradation
SWCC
Enter SWCC Data
OK
Cancel
Restore Defaults
Sieve Size
Percent Passing
1" (25.0 mm) 100
3/4" (19.0 mm) 95
3/8" (9.50 mm) 70
#4 (4.75 mm) 58
#10 (2.00 mm) 43
#40 (0.425 mm) 23
#200 (0.075 mm) 7
Not Used
Not Used
Not Used
Percent Passing
Mn/DOT Specification
3/4"
1"
3/8"
#4
#10
#40
#200
100
90
80
70
60
50
40
30
20
10
0
100
10
1
0.1
0.01
Sieve Size, mm
D60, porosity, etc. are calculated
Saturated Hydraulic Conductivity (ksat)
ft/day
Van Genuchten/Mualem Parameters (estimated)
alpha
n

MnPAVE



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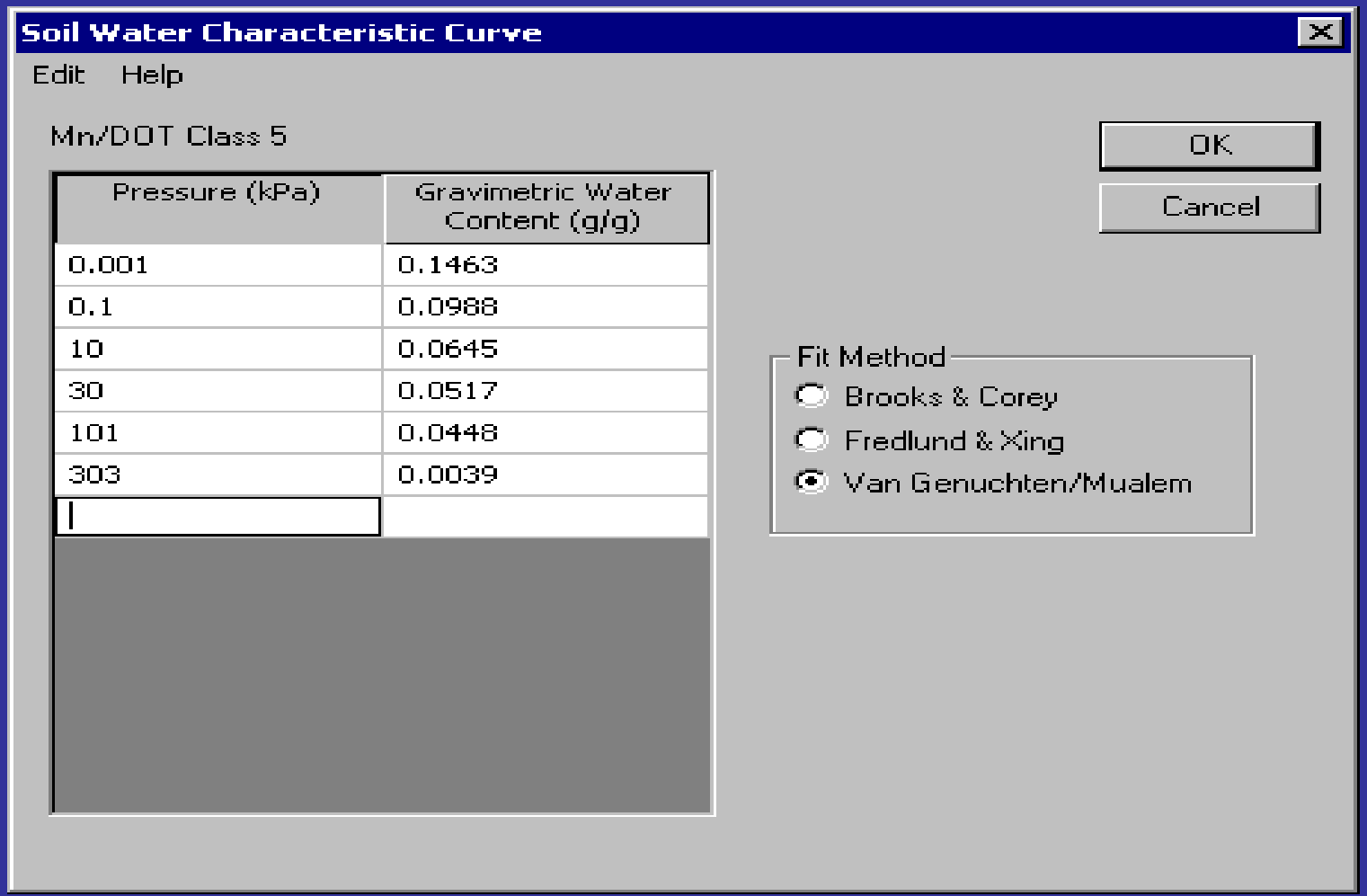

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Conclusion/ Current & Future Research

- Current drainage design and traditional soil mechanics methods are based on assumptions and design criteria which over simplify in situ conditions.
- Continue to develop and implement rational approach which incorporates unsaturated properties into the M-E and drainage design process.
- Continue to build extensive and comprehensive database of unsaturated material properties.
- Extend framework to recycled materials.

Cooperating Universities and Researchers

- University of Florida, Gainesville (Dr. Bjorn Birgisson)
- University of Minnesota, Department of Soil, Water, and Climate (Dr. Satish Gupta)
- Recycled Materials Resource Center (RMRC), University of New Hampshire (Defne Apul, Drs. Eighmy and Gardner)
- Lakehead University, Thunder Bay (Dr. Sai Vanapalli)

More Information

- **Unsaturated Properties of Engineered Materials Research**
  - http://mnroad.dot.state.mn.us/research/MnROAD_Project/me_group/UnsatProperties.asp
- **MnPAVE (Download M-E Design Software)**
  - http://mnroad.dot.state.mn.us/research/mnpave/mnpave.asp
- **M-E Design Implementation Resources**
  - http://mnroad.dot.state.mn.us/research/mnpave/meresource.asp
- **Recycled Materials in Pavements**
  - http://www.rmrc.unh.edu/
- Ruth Roberson (ruth.roberson@dot.state.mn.us) or (651) 779-5214