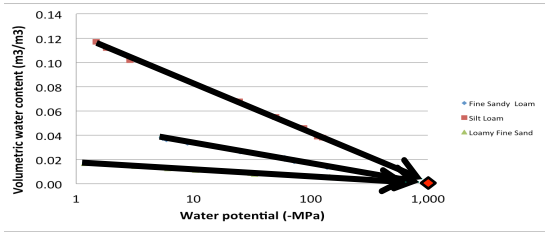


Washington State University

Generating Dry End Soil Water Characteristic Curves with a Single Point

Doug Cobos, Leo Rivera, Gaylon Campbell

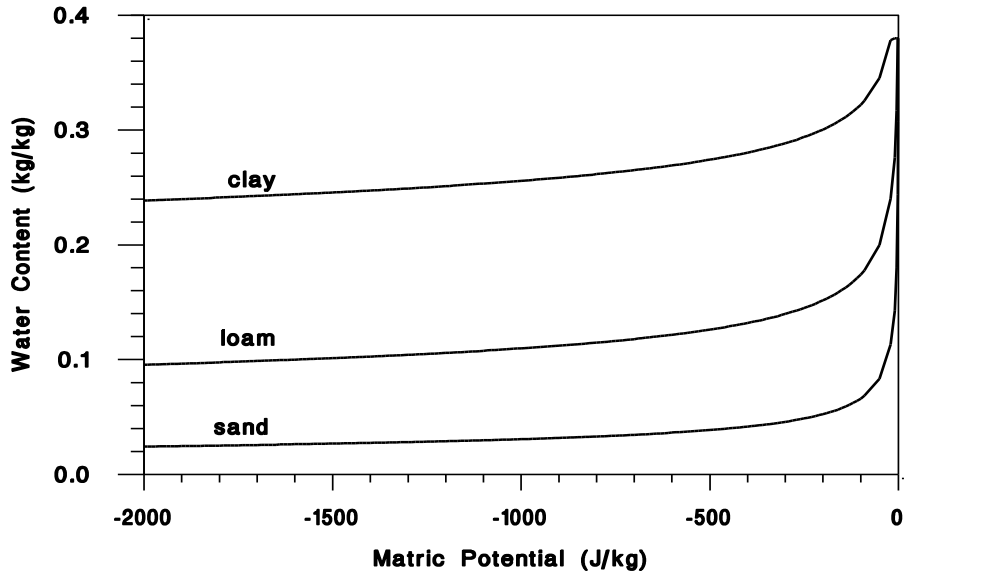
Decagon Devices and Washington State University

Outline

- SWCC basics
- Dry end SWCC
- Dry end SWCC applications
- Single point SWCC
- Single point SWCC study
- Conclusion

Soil Water Characteristic Curve (SWCC)

- Moisture release curve, water retention function, pF curve, moisture sorption isotherm
- Relationship between water content and water potential (water activity, suction, pF, chi)



Generating SWCC

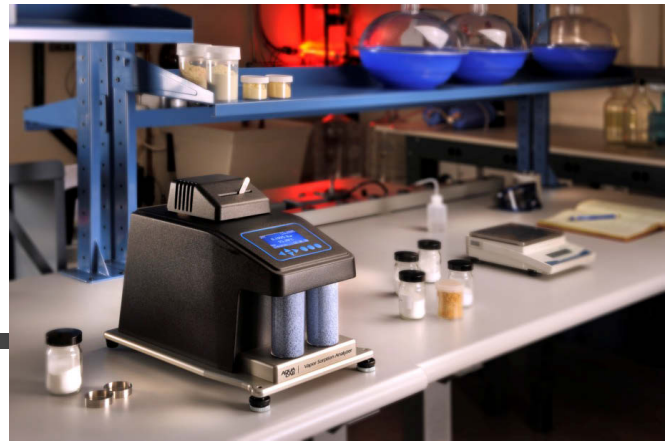
- Measuring water *content* is easy
  - Gravimetric analysis (oven drying)
- Measuring water *potential* is difficult
  - No single instrument can make accurate measurements from wet to dry

Dry end SWCC

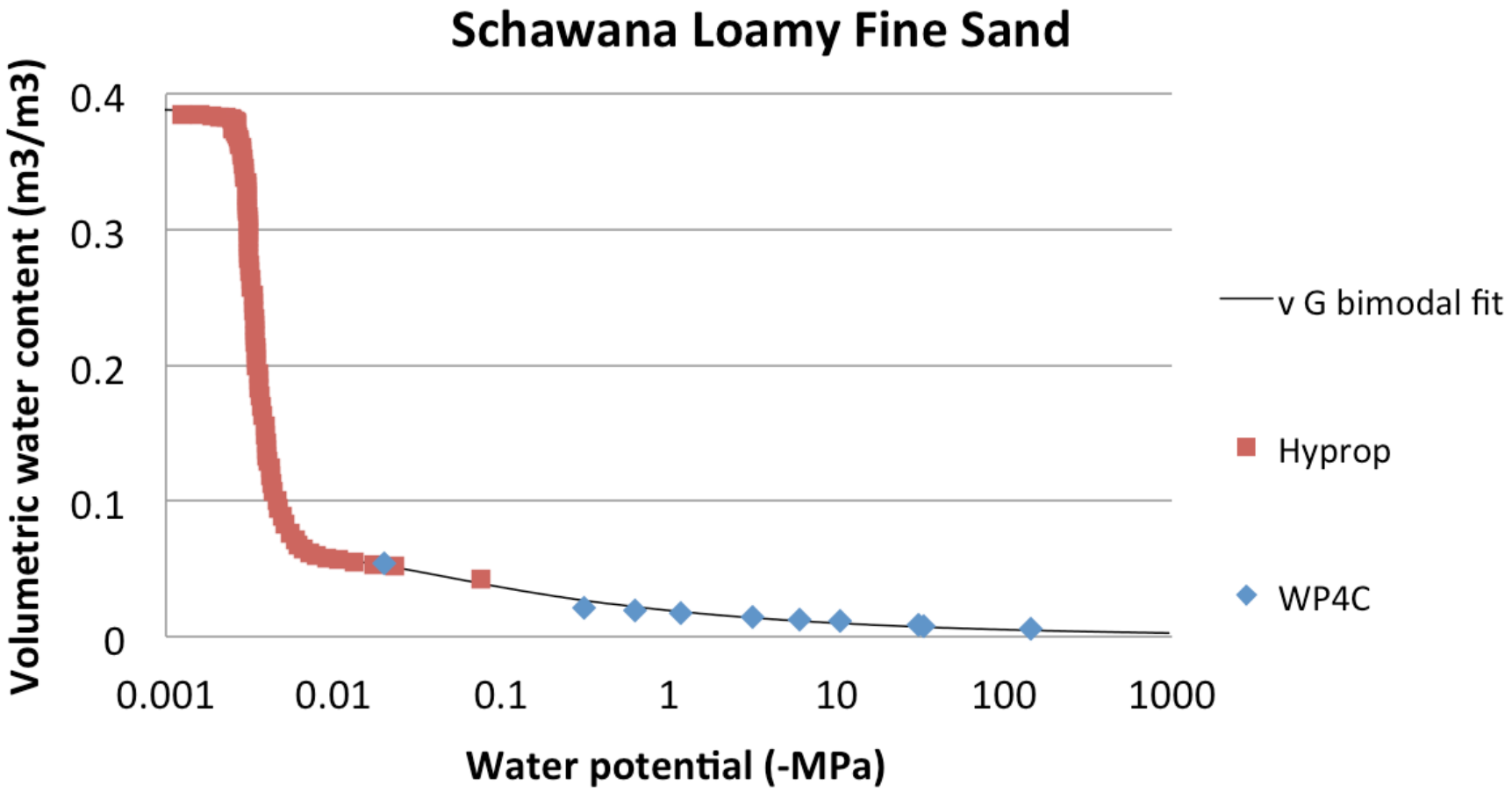
- Historically very difficult to obtain
  - Campbell and Shiozawa (1992) cited over 70 times and data used many by many authors
  - Introduction of WP4, WP4T, WP4C made dry end SWCC more accessible

- Aquasorp/VSA instruments are the next step

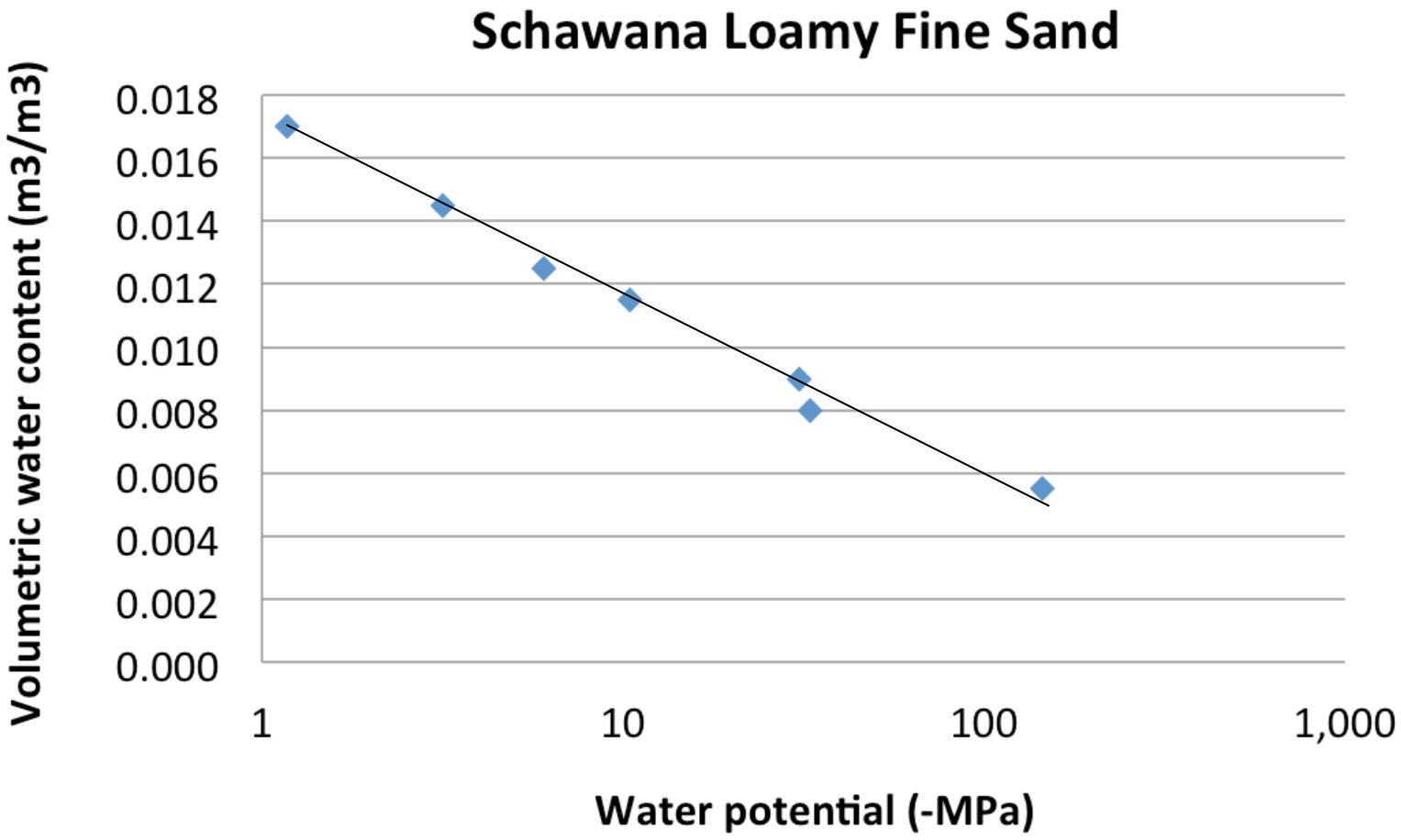




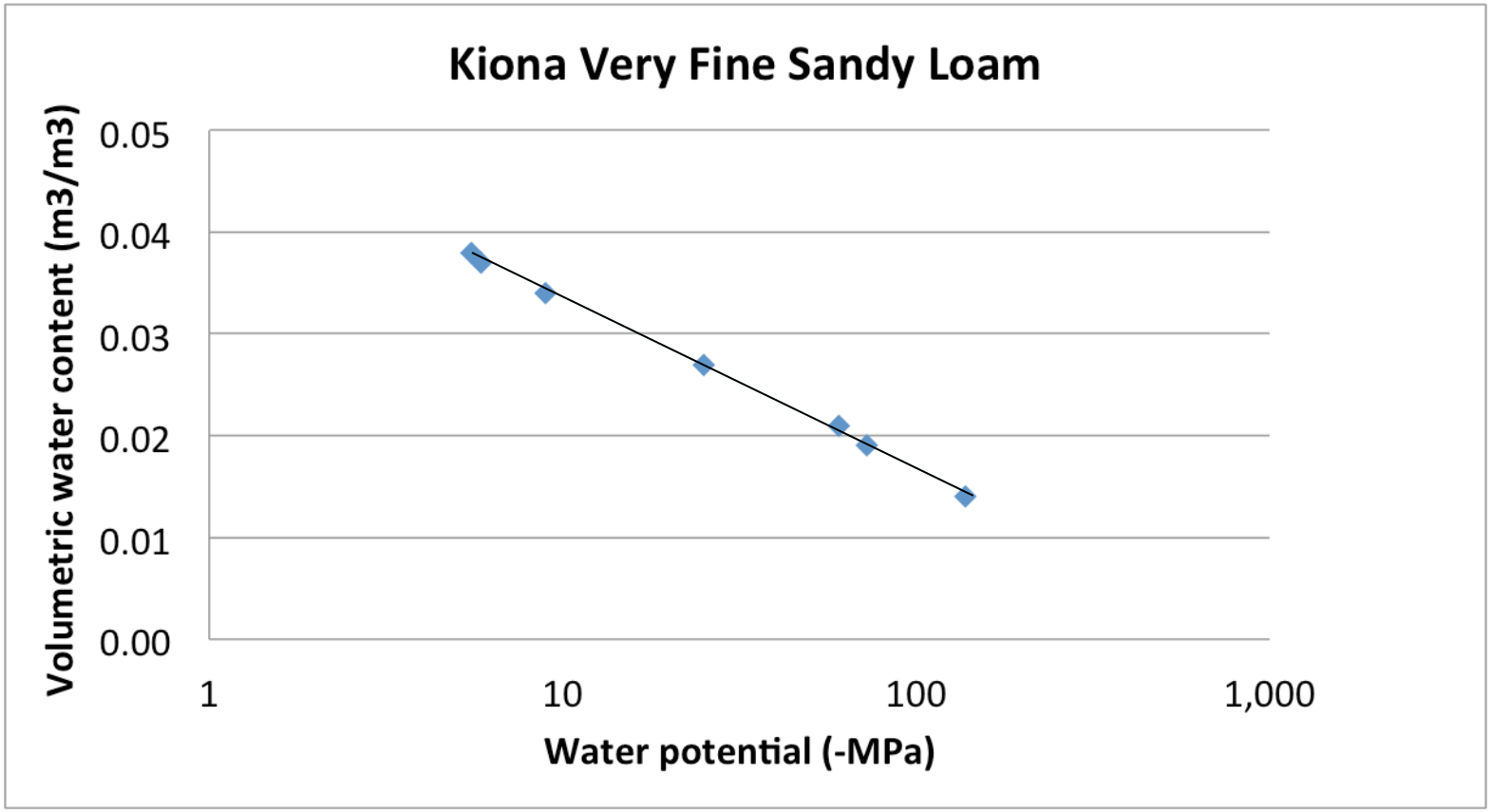
SWCC semi-log plot



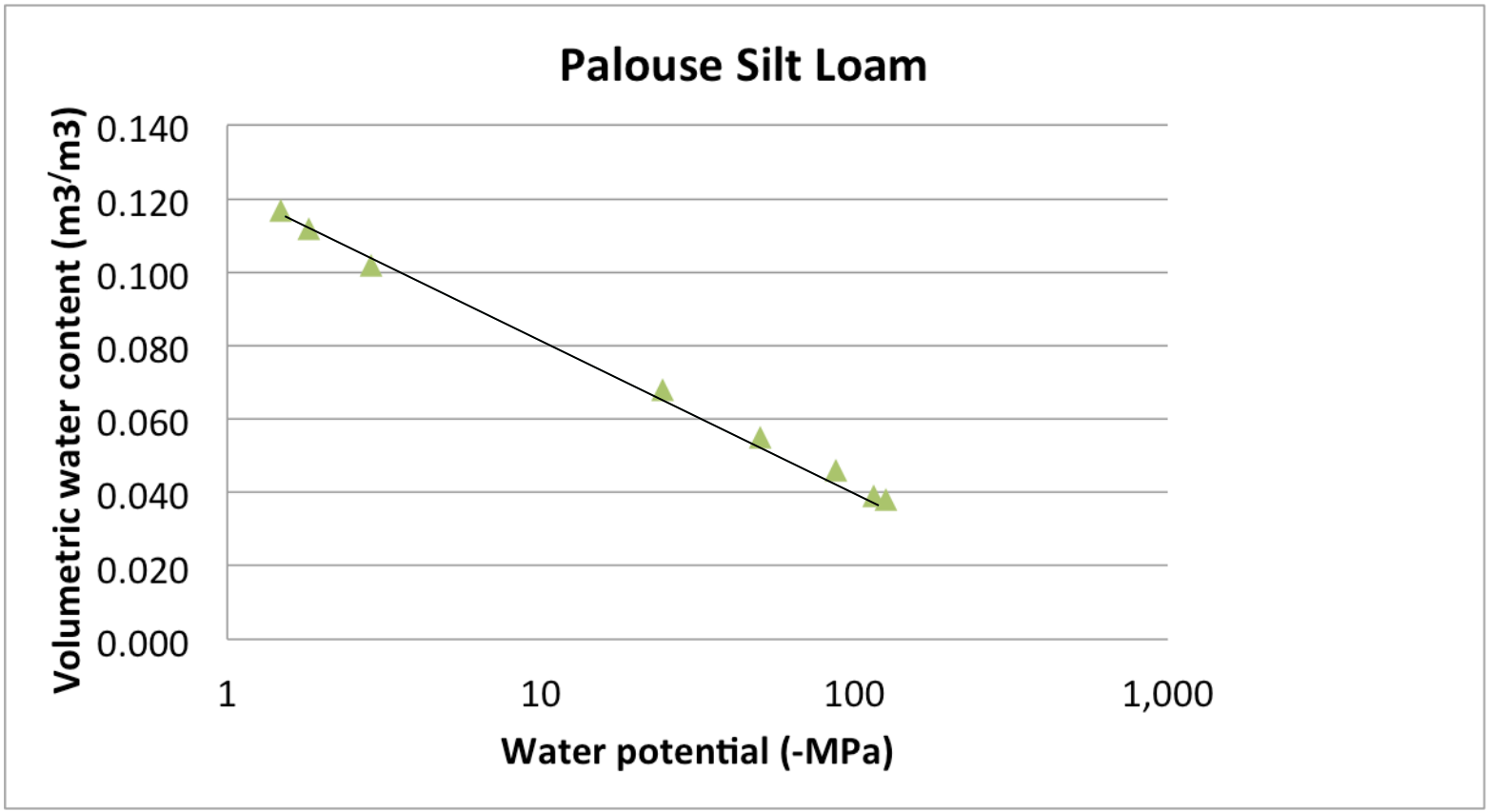
Semi-log SWCC, dry end



Semi-log SWCC, dry end



Semi-log SWCC, dry end



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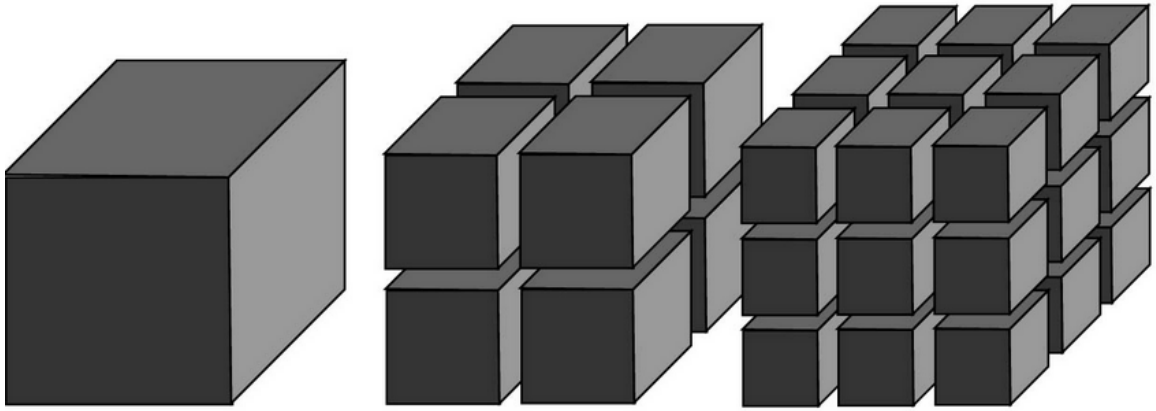
Soil specific surface area (SSA)



- SSA highly correlated to slope of semi-log SWCC

Slope of semi-log SWCC

Specific Surface Area (SSA)

Condon (2006) predicted SSA from slope of semi-log SWCC

$SSA = f*S*a$

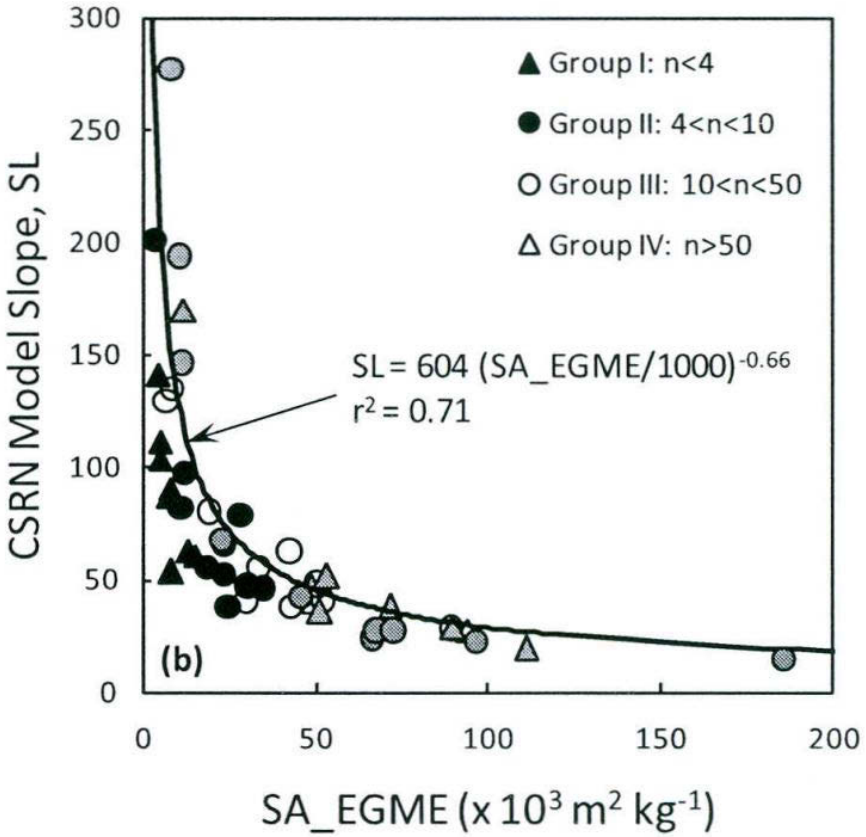
S is slope of semi-log plot (g/g)
a is monolayer coverage (3500 $m^2\ g^{-1}$)
f is factor of 1.84

❖Condon, J. B. 2006. Surface Area and Porosity Determination by Physisorption: Measurements and Theory. Elsevier, Amsterdam.

Slope of semi-log SWCC

Specific Surface Area (SSA)

- Resurreccion et al., (2011)
- Used semi-log SWCC to predict SSA



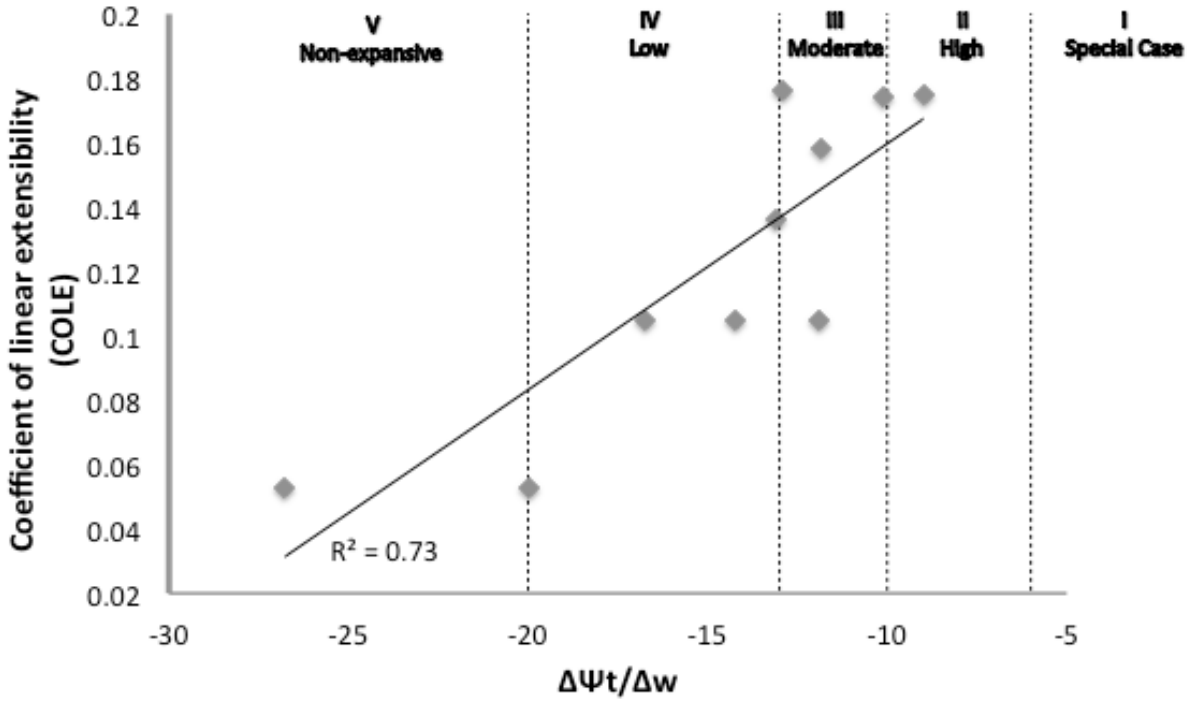
❖Resurreccion, A. C., P. Moldrup, M. Tuller, T.P.A. Ferre, K. Kawamoto, T. Komatsu, L. W. de Jonge. Relationship between specific surface area and the dry end of the water retention curve for soils with varying clay and organic carbon contents. Water Resources Research 47, W06522

Expansive (shrink-swell) soils

Slope of semi-log SWCC

Expansive soil characterization

- McKeen (1992)
- COLE and semi-log SWCC slope highly correlated

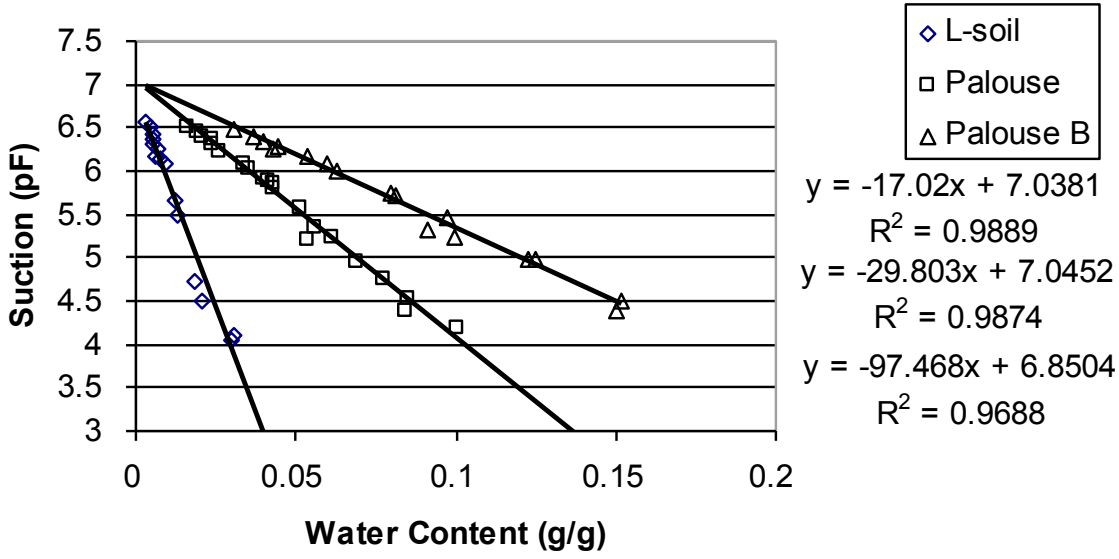


R.G. McKeen. 1992. A Model for Predicting Expansive Soil Behavior. *7th International Conference on Expansive Soils* 1:1-6. Dallas, TX

Slope of semi-log SWCC

Expansive soil characterization

- McKeen expansive soil framework
  - Often utilized by Geotechnical Engineers



Class	Slope	Expansion
I	> -6	special case
II	-6 to -10	high
III	-10 to -13	medium
IV	-13 to -20	low
V	< -20	non-expansive

Dry end SWCC
Other possible uses

- Gas movement in soil
  - Simulations of water vapor transport for pesticide volatilization (Chen et al., 2000)
  - Remediation of Volatile Organic Carbon compounds (Batterman et al., 1995)
- Cation exchange capacity (CEC)

Batterman, S.A., A. Kulshrethsa, and H.Y. Chang. 1995. Hydrocarbon vapour transport in low moisture soils . Environmental Science and Technology 29: 171-180

Chen, D., D.E. Rolston, and P. Moldrup. 2000. Coupling diazinon volatilization and water evaporation in unsaturated soils: I. Water transport, Soil Science 165: 681-689

Outline

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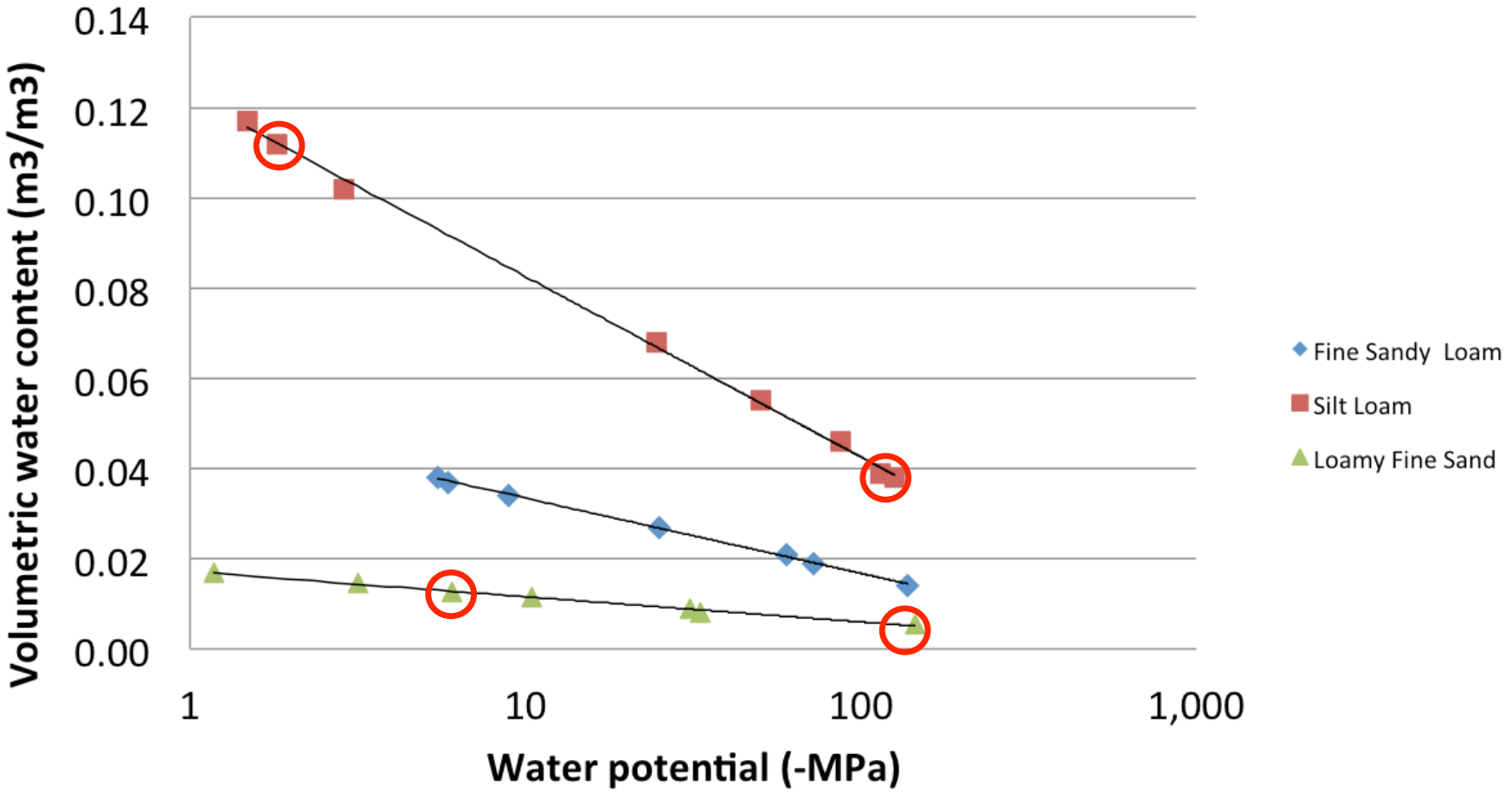
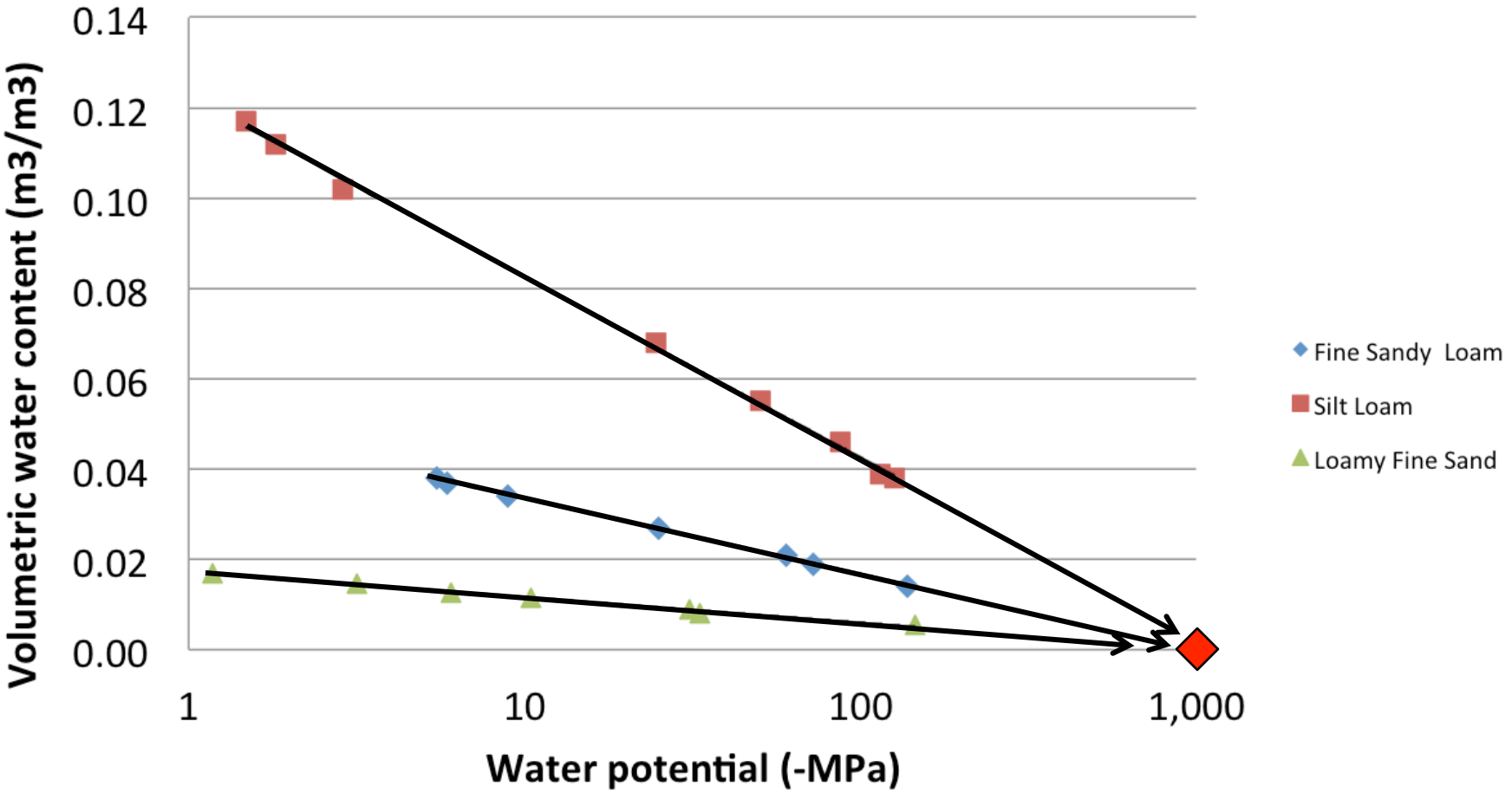
Two points define a line



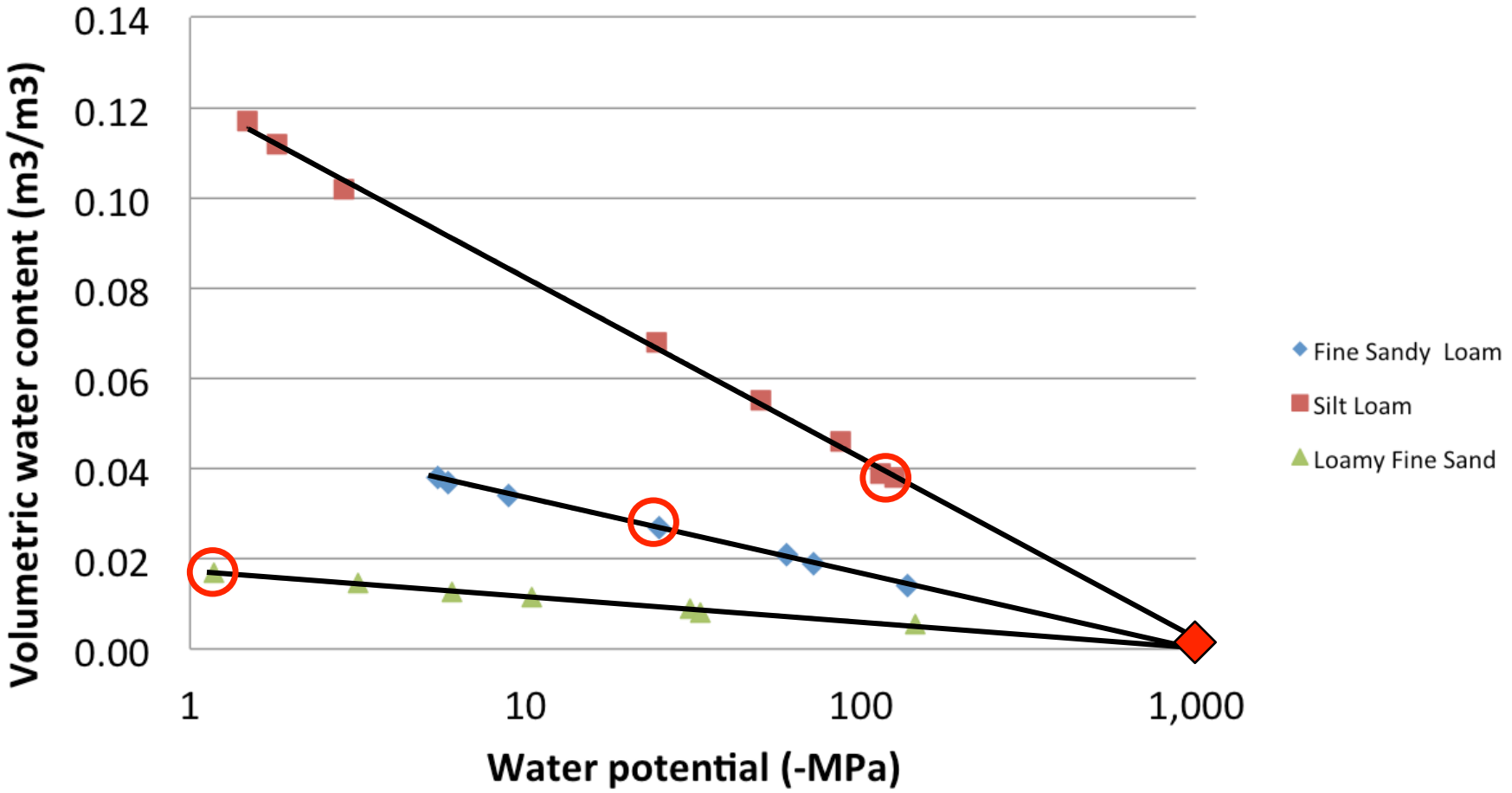
Zero water content intercept



Zero water content intercept

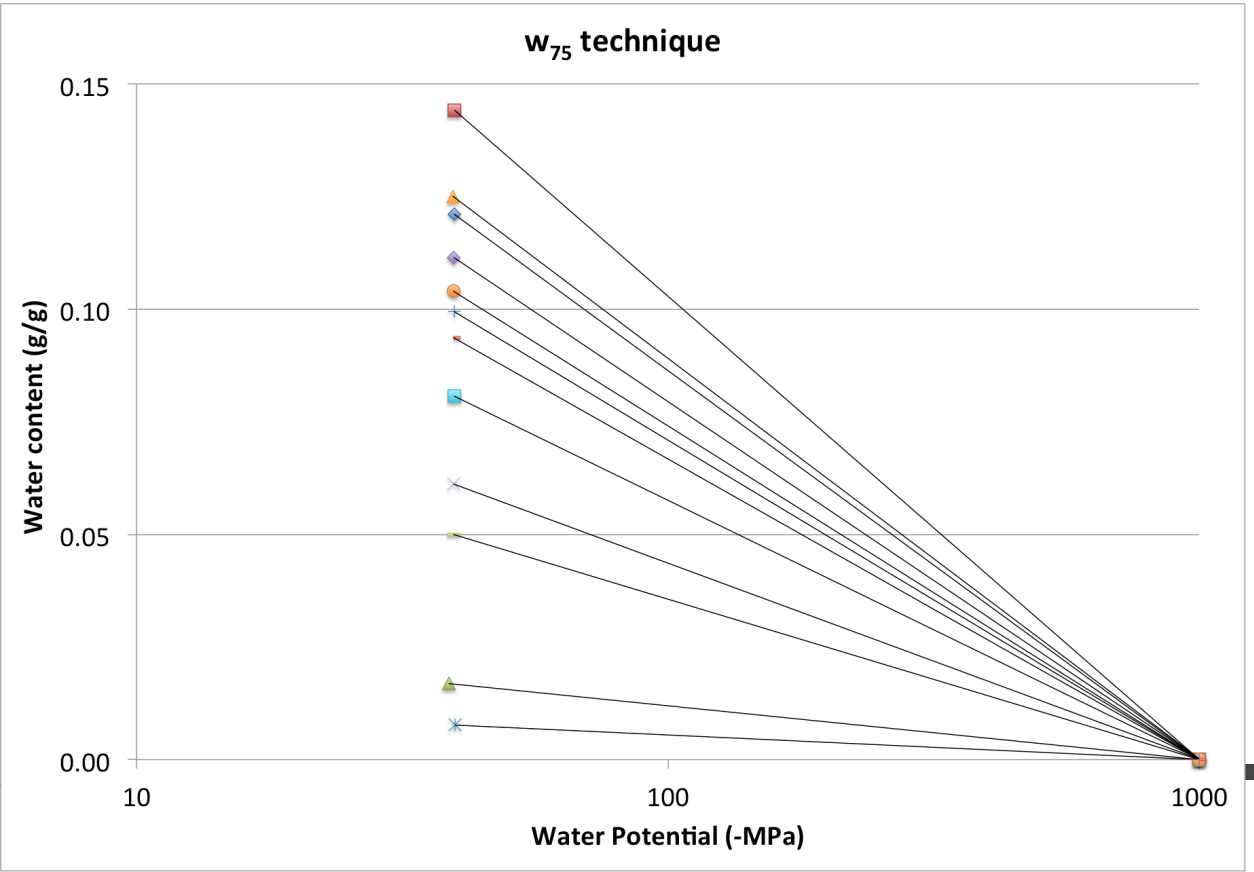
- -1000 MPa
- -1 X 10^6 kPa
- 6.0 log kPa
- 7.0 pF
- Chi -2.0
- 0.06% relative humidity

Single point dry end SWCC



w_{75} technique

- Water content at 75% rh (-40 MPa) used to classify expansive soil
- Essentially a 1-point SWCC



Likos, W.J. 2008. Vapor Adsorption Index for Expansive Soil Classification.J. Geotechnical and Geoenvironmental Engineering. 134: 1005-1009

Outline

- SWCC basics
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Single point SWCC study

- Soils
  - Four soils from the well-known Campbell and Shiozawa (1992) paper
  - 13 well-characterized soils from Texas A&M University soil library
  - Bentonite

- Objectives
  - Take a closer look at zero water content intercept concept
  - Revisit McKeen expansive soil characterization framework

Campbell, G.S. and Shiozawa. "Prediction of hydraulic properties of soils using particle-size distribution and bulk density data." *Proc. Int. Workshop on Indirect Methods for Estimating the Hydraulic Properties of Unsaturated Soils.* UC Riverside. 1992.

Issues with McKeen analysis

- Original data set used filter paper to generate SWCC
- Original paper points to 6.25 pF (-174 MPa) as a *benchmark zero water content intercept*

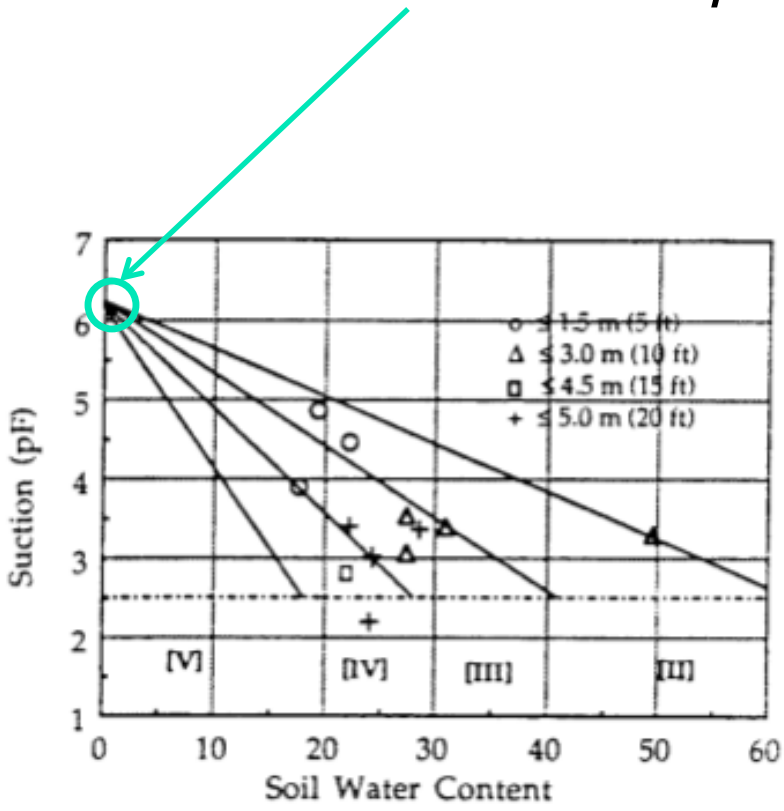


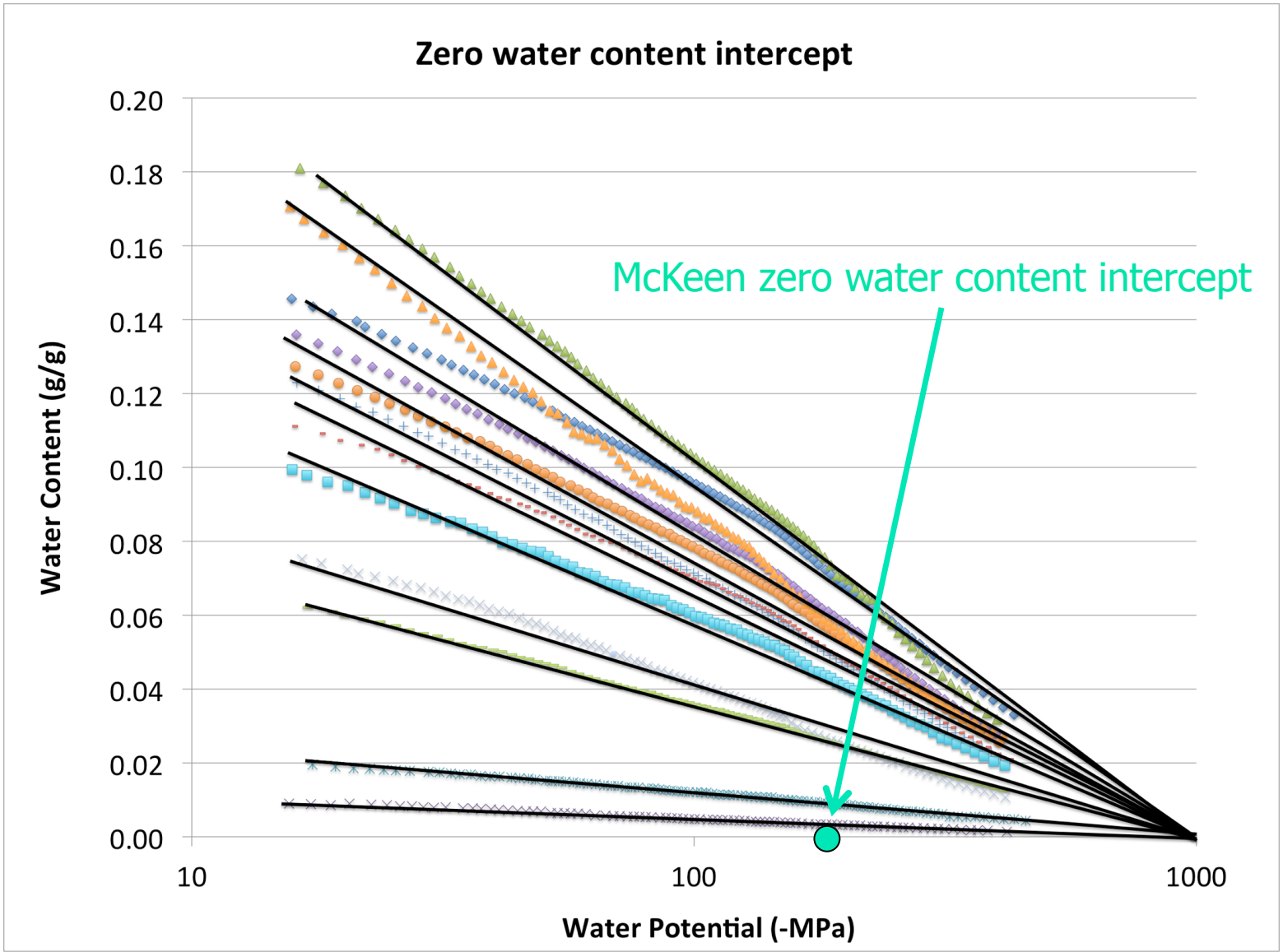
Fig. 6. Expansive Soil Classification System.

New(ish) method for SWCC

Vapor Sorption Analyzer (VSA)

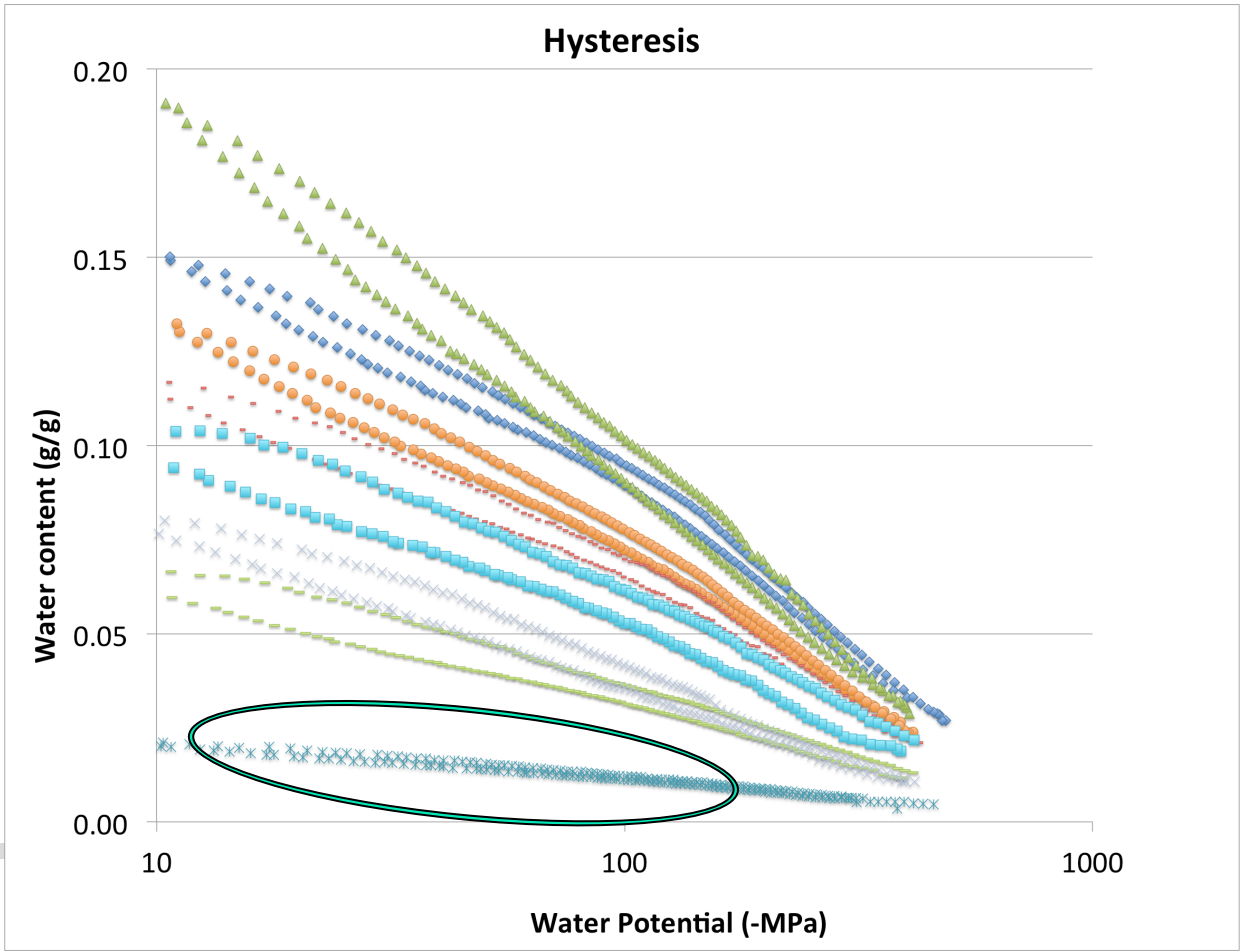
- Fully automated SWCC in dry water potential range
- Drying and wetting (hysteresis loop)
- Better data density than previously available

Results – zero water content intercept



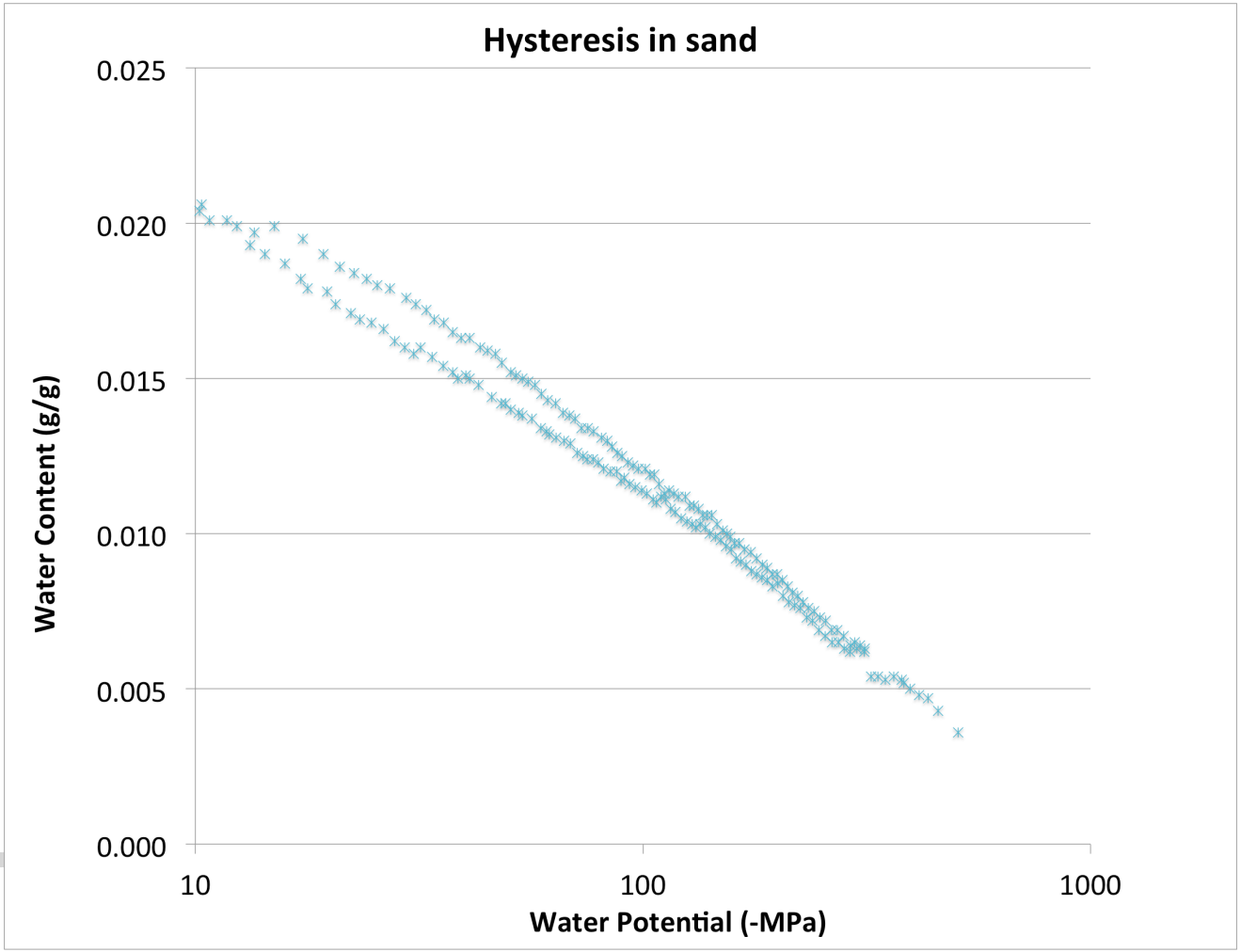
Results - Hysteresis

Hysteresis observed in all samples



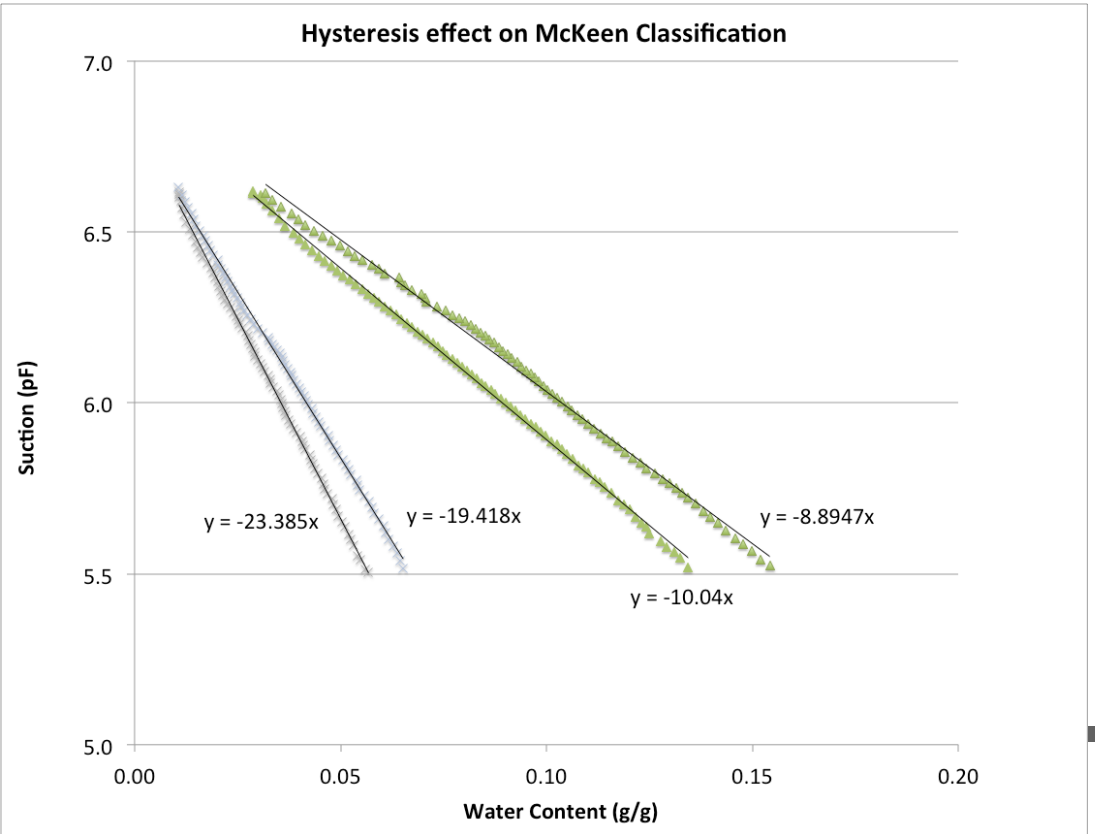
Hysteresis in sand

Hysteresis observed in all samples (even sand)



Hysteresis implications

- Slope of semi-log SWCC different if desorption leg used instead of adsorption
- Samples often jump to lower swelling classification in McKeen framework if wetting leg of hysteresis loop used



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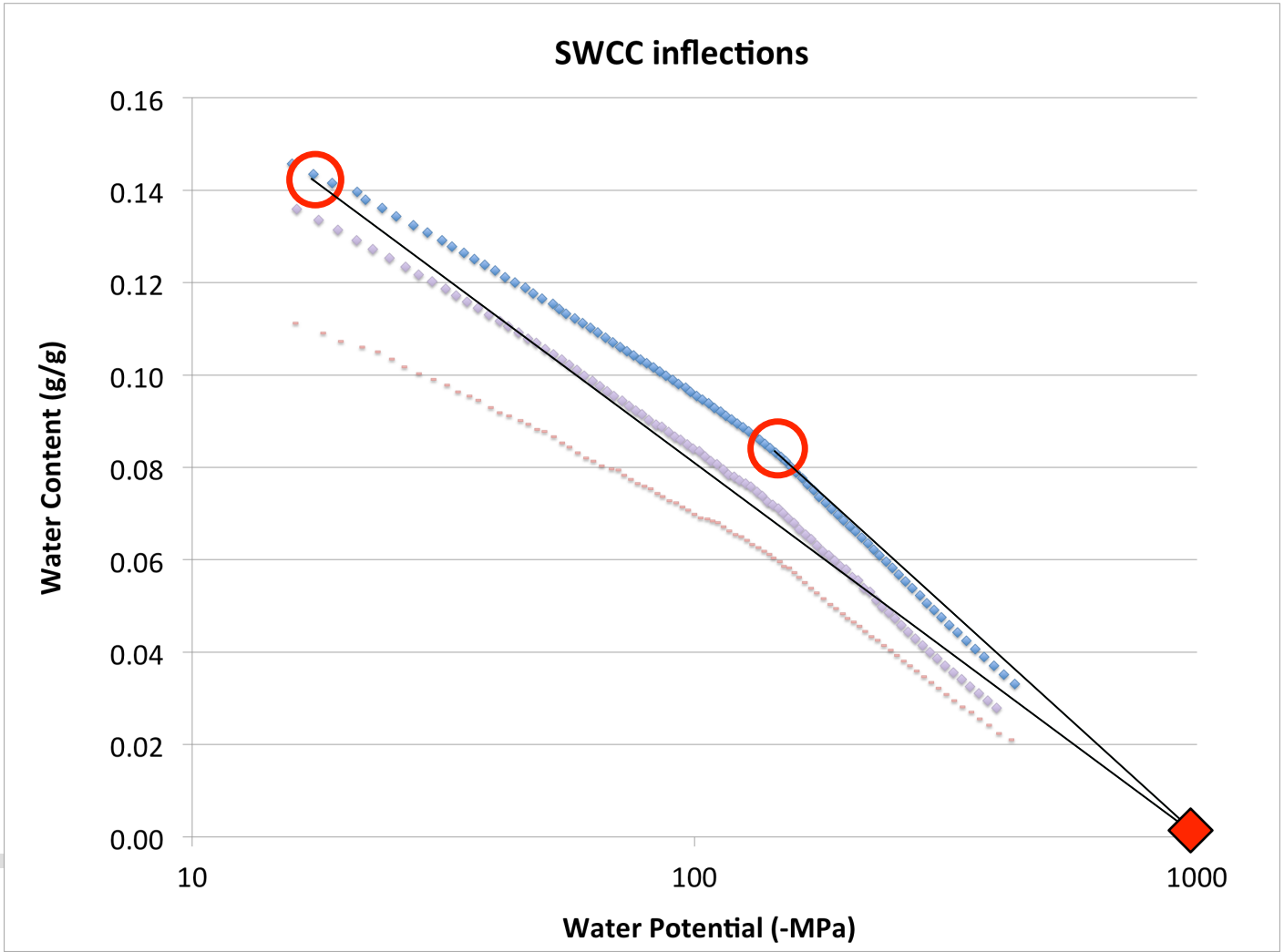
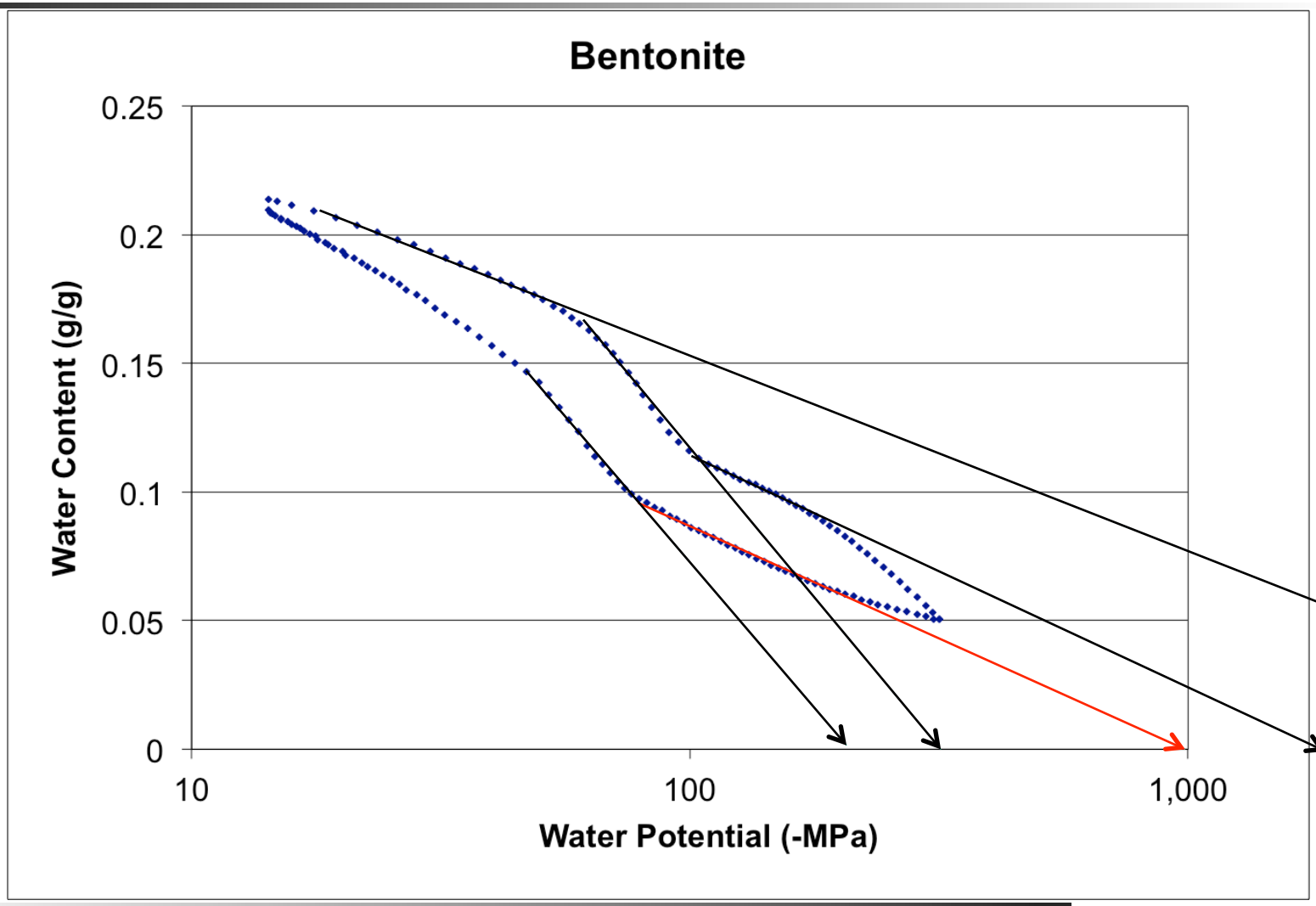
Non-linearity in high-clay samples



Extreme case - bentonite

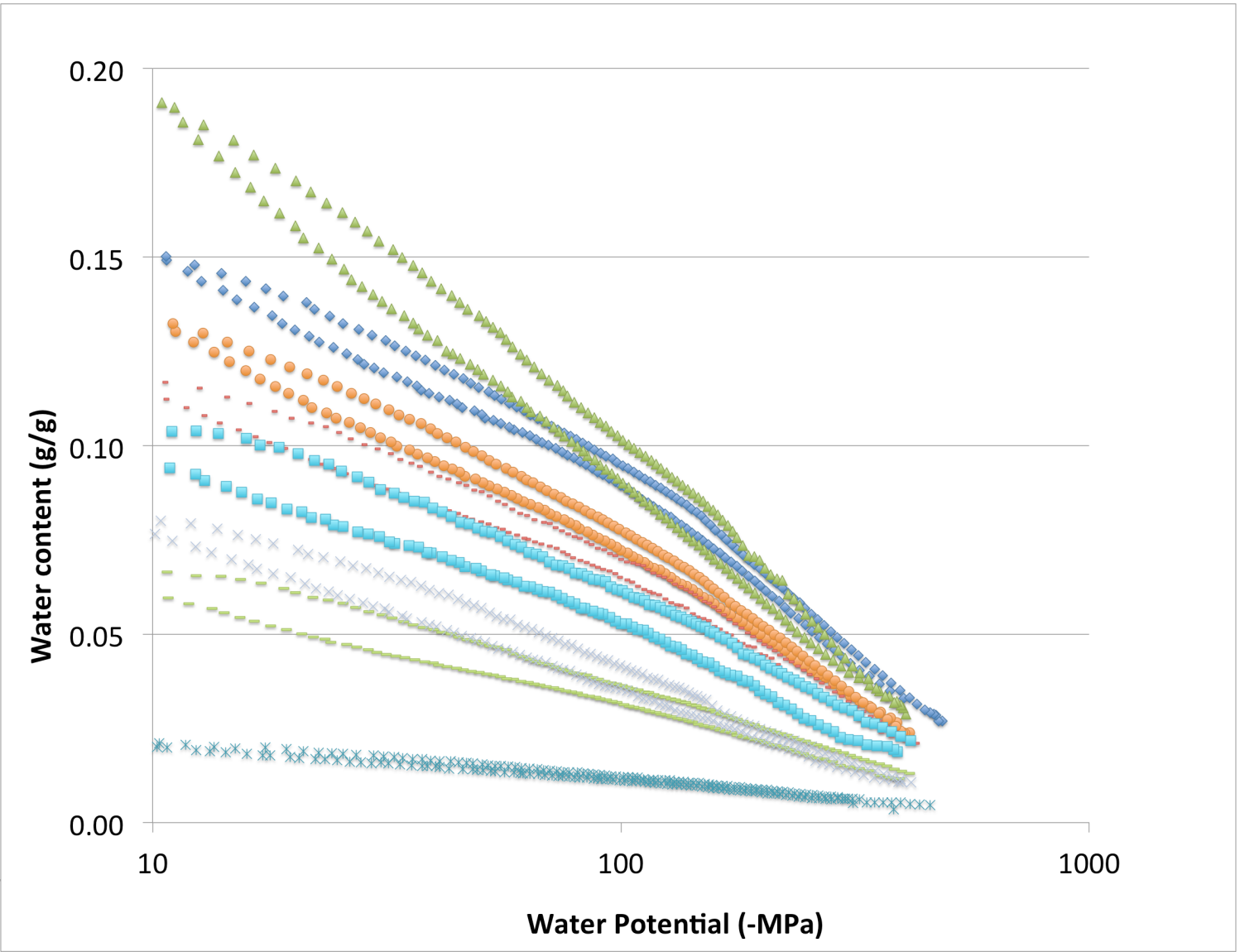


Take-home points

- Is single point SWCC valid? Sometimes…
  - Useful in low clay soils drier than -1 MPa
  - Zero water content intercept of -1000 MPa
    - McKeen's value of -174 MPa is wrong
- Hysteretic effects produce fundamentally different SWCCs in all soils
- Non-linearity in high clay soils (especially 2:1) confound single point SWCC method

Thank you!

doug@decagon.com



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