Designing Soils for Infiltration, Drainage, and Stormwater Treatment

Designing Landscape Soils for Longwood Gardens

Reference Book

- Kays, Barrett L. 2013. Planting Soils for Landscape Architectural Projects, LATIS Series Publication, American Society of Landscape Architects

  - www.asla.org menu: learn tab: LATIS

Sand-Based Soil Design Projects

- **Great Lawn in Central Park, NY, NY**
  - Central Park Conservancy, Inc., NY, NY
- **Nelson Rockefeller Hudson River Park, NY, NY**
  - Battery Park City Authority, Inc., NY, NY
- **Dwight D. Eisenhower Memorial, Washington, DC**
  - Gehry Associates + AECOM JV, Los Angeles, CA & Arlington, VA
- **NC Museum of Art Garden Expansion, Raleigh, NC**
  - Civitas, Inc., Denver, CO & Stewart, Inc., Raleigh, NC
- **Moore Square Design, City of Raleigh, NC**
  - Sasaki Associates, Cambridge, MA
- **Main Fountain Garden, Longwood Gardens, PA**
  - West 8, New York, NY
- **National Air & Space Museum, Washington, DC**
  - AECOM, Arlington, VA

Attributes of Planting Soil for Longwood Gardens

- Aeration & Infiltration > 5-inches/hour
- Zero runoff for 100-year frequency
- Soil that remains porous after compaction
- Plant Available Water 20 to 35%
- Soil Depth 3-feet or deeper if needed
- Soil pH 6.5 to 7.5
- Soil Fertility, CEC, BS, & nutrients
- Organic humus > 3%
- Rich microbe flora and population
- Easy to install and cannot be overly compacted

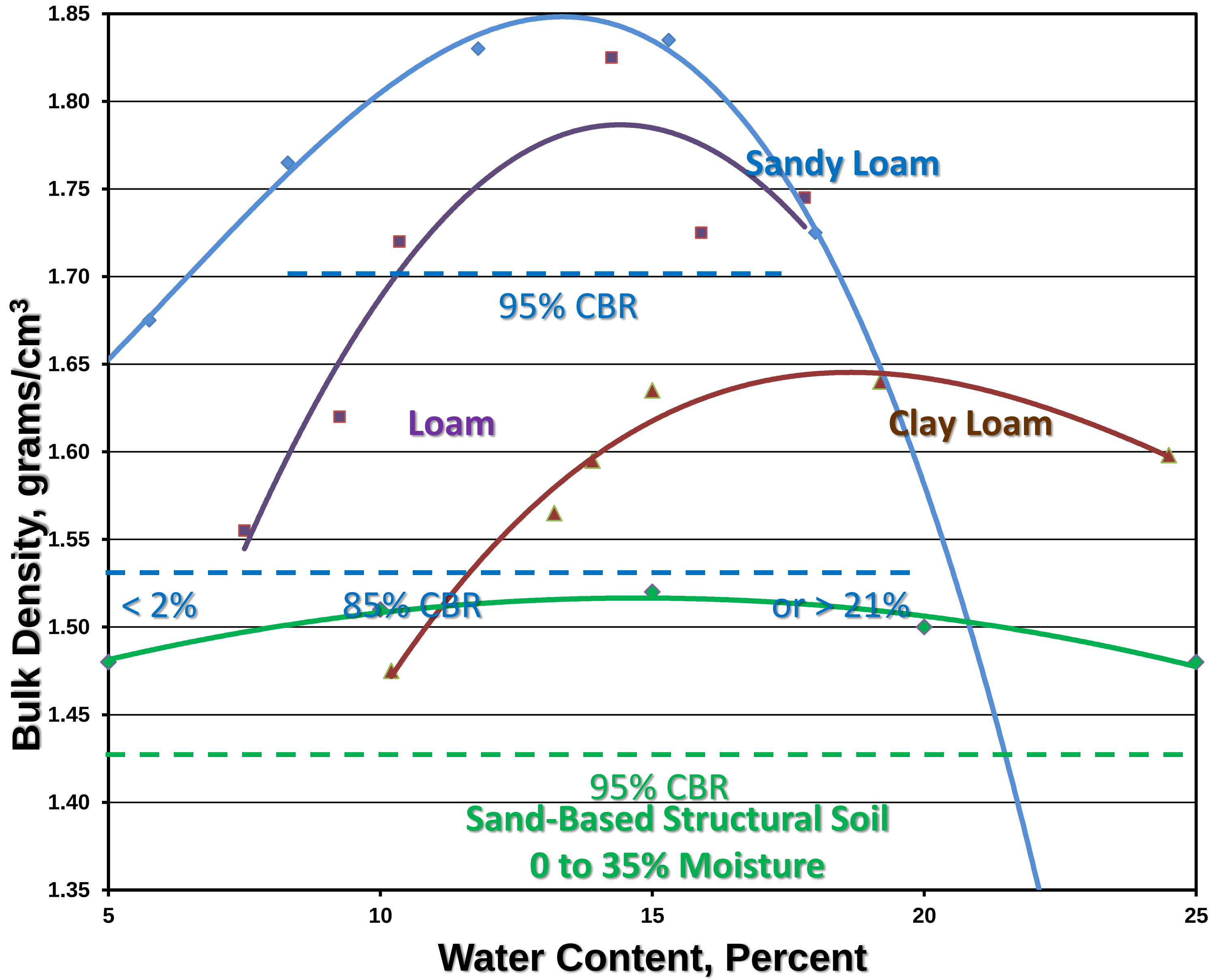
Designing Soils

- Create a design soil that's contains all of the above attributes

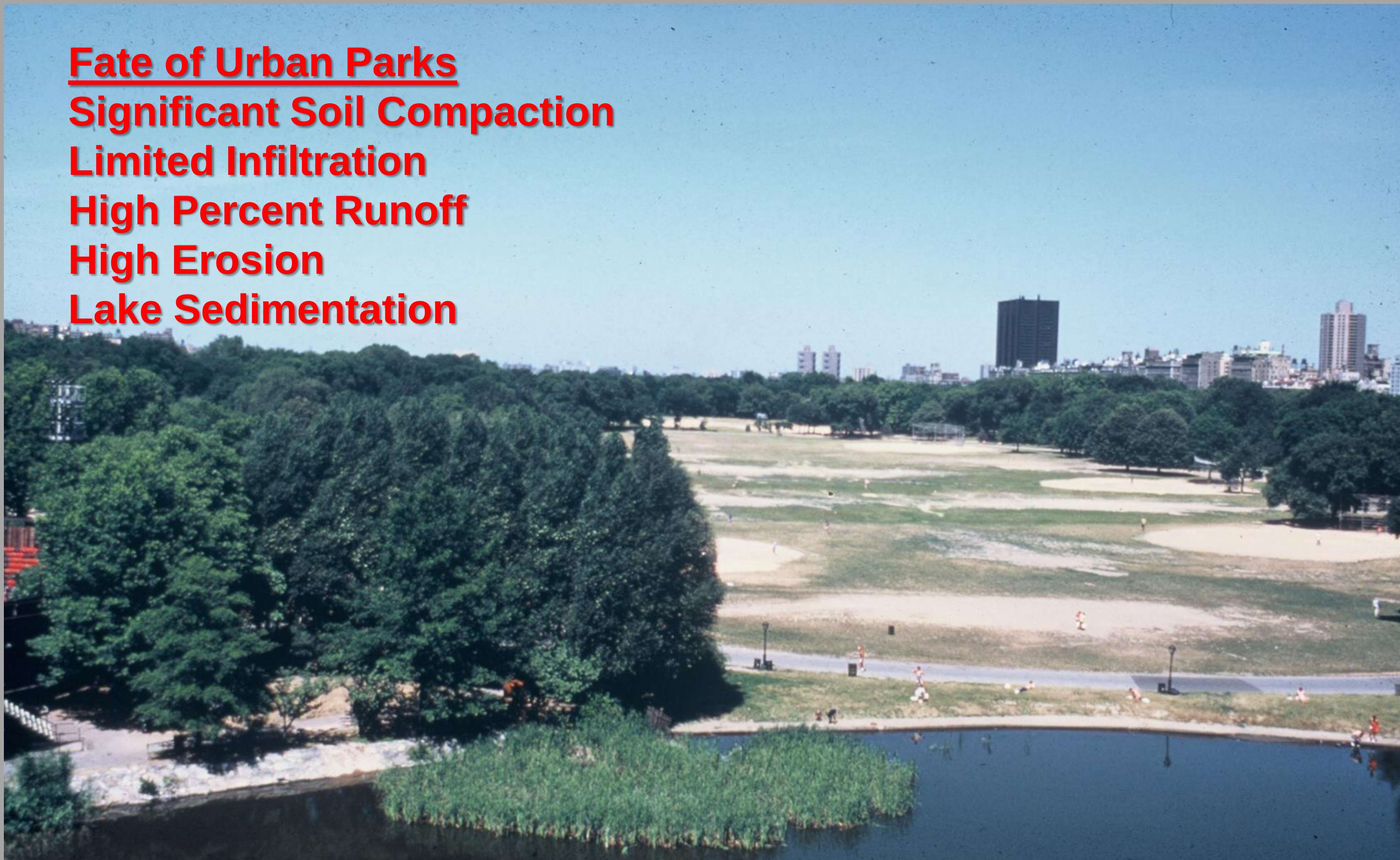
- Create a soil that drains well when saturated and stops draining to storage as much water as a silt loam textured soil

- Such a soil does <u>not</u> occur in nature, so typically we have it manufactured from locally available components

Maximum Density Curves



Central Park Great Lawn in 1984



Restoration of Great Lawn in Central Park, NY, NY for Central Park Conservancy, Inc.

Nelson Rockefeller Hudson River Park for Battery Park City Authority, NY, NY

Dwight D. Eisenhower Memorial for Gehry Associates + AECOM, Washington, DC

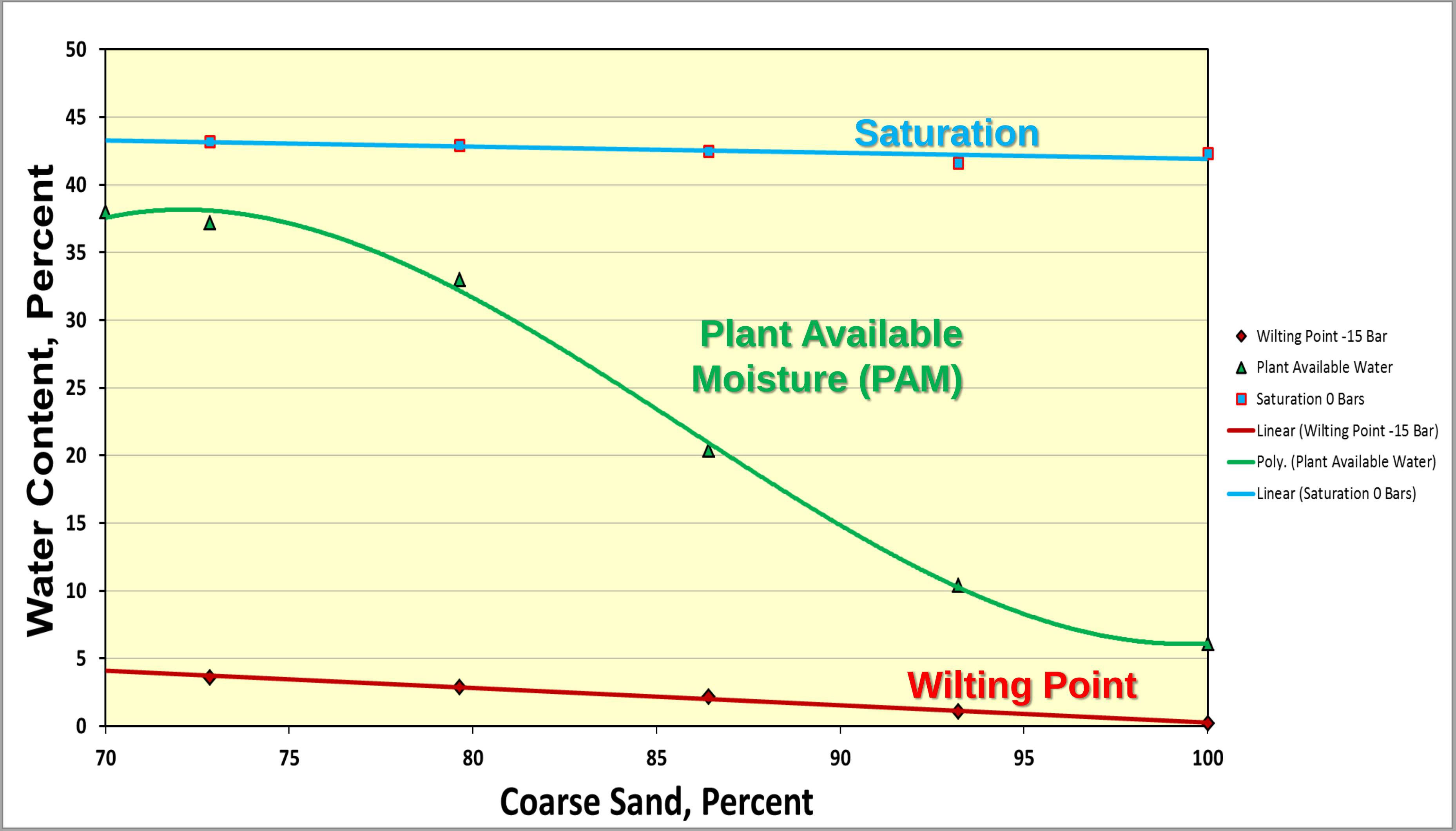
Soil Particle Sizes

- **Particle size diameters**
  - Very coarse sand – 1.00 to 2.00 mm
  - Coarse sand – 0.50 to 1.00 mm
  - Medium sand – 0.25 to 0.50 mm
  - Fine sand – 0.125 to 0.25 mm
  - Very fine sand – 0.050 to 0.125 mm
  - Silt – 0.002 to 0.50 mm
  - Clay - < 0.002 mm
- **Well graded sands** – good in concrete; very bad in soils
  - 0.05 to 1.00 mm – very fine sand to coarse sand
  - Particles pack together and create less porosity and smaller effective pore diameters
- **Uniformly graded sands** – good for infiltration
  - 0.25 to 1.00 mm – medium and coarse sand; remove particles < 0.25 mm and particles > 1.00 mm
  - Particles do not tightly pack and create more porosity and larger effective pore diameters

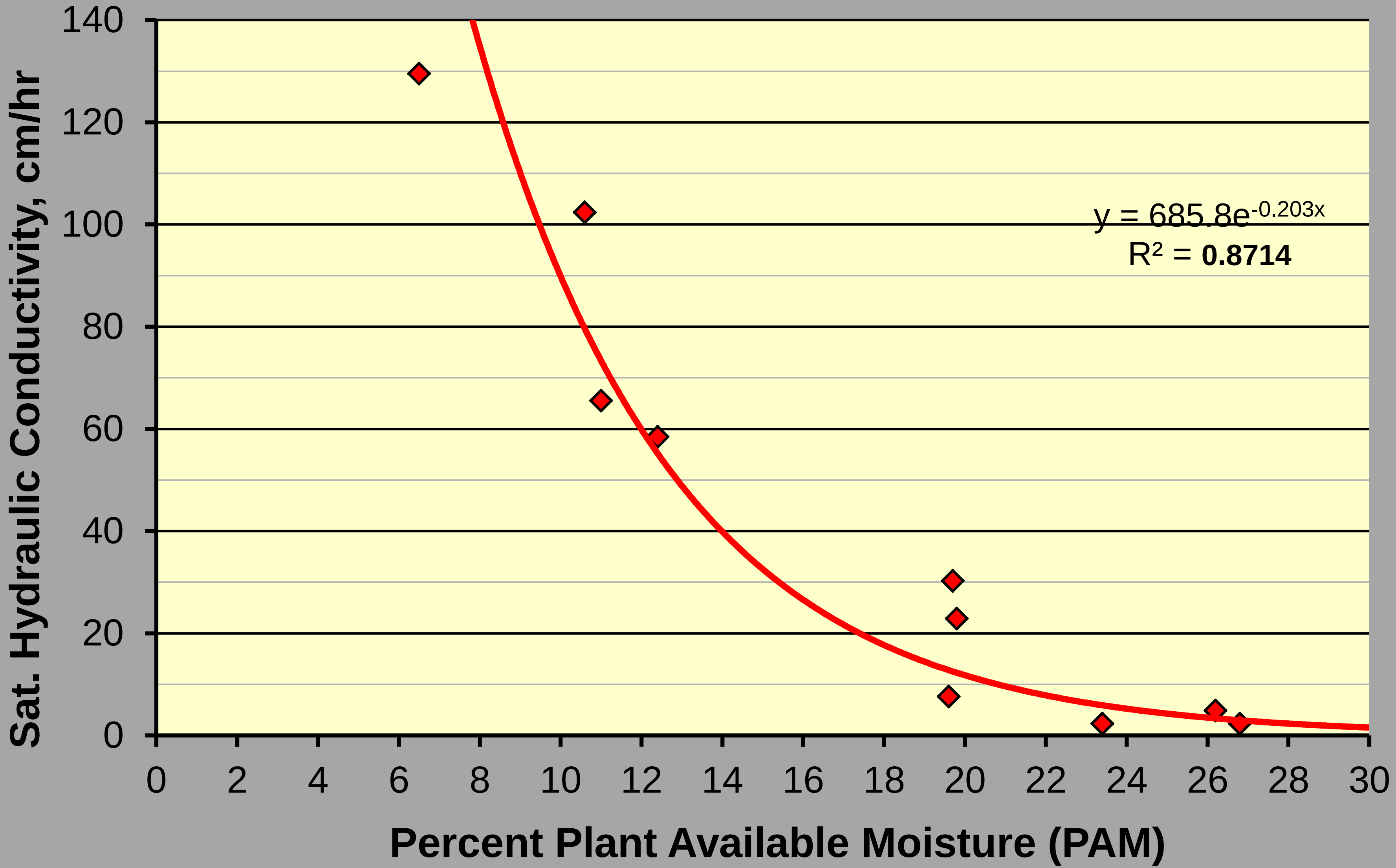
Ideal Design Soil:
A Marriage of Conflicting Goals

- Rapidly drainage:
  - Saturated infiltration rate of 5-inches per hour
  - Zero runoff for 10-inch rainfall or 100-year event
- Excellent moisture retention:
  - Plant available water of 20 to 35%
  - PAW equivalent to silt loam soil
- Soil remains porous at 95% compaction

Plant Available Moisture (PAM)



Sat. Hydraulic Conductivity v. PAM



Six Principles of Water Movement in Soils

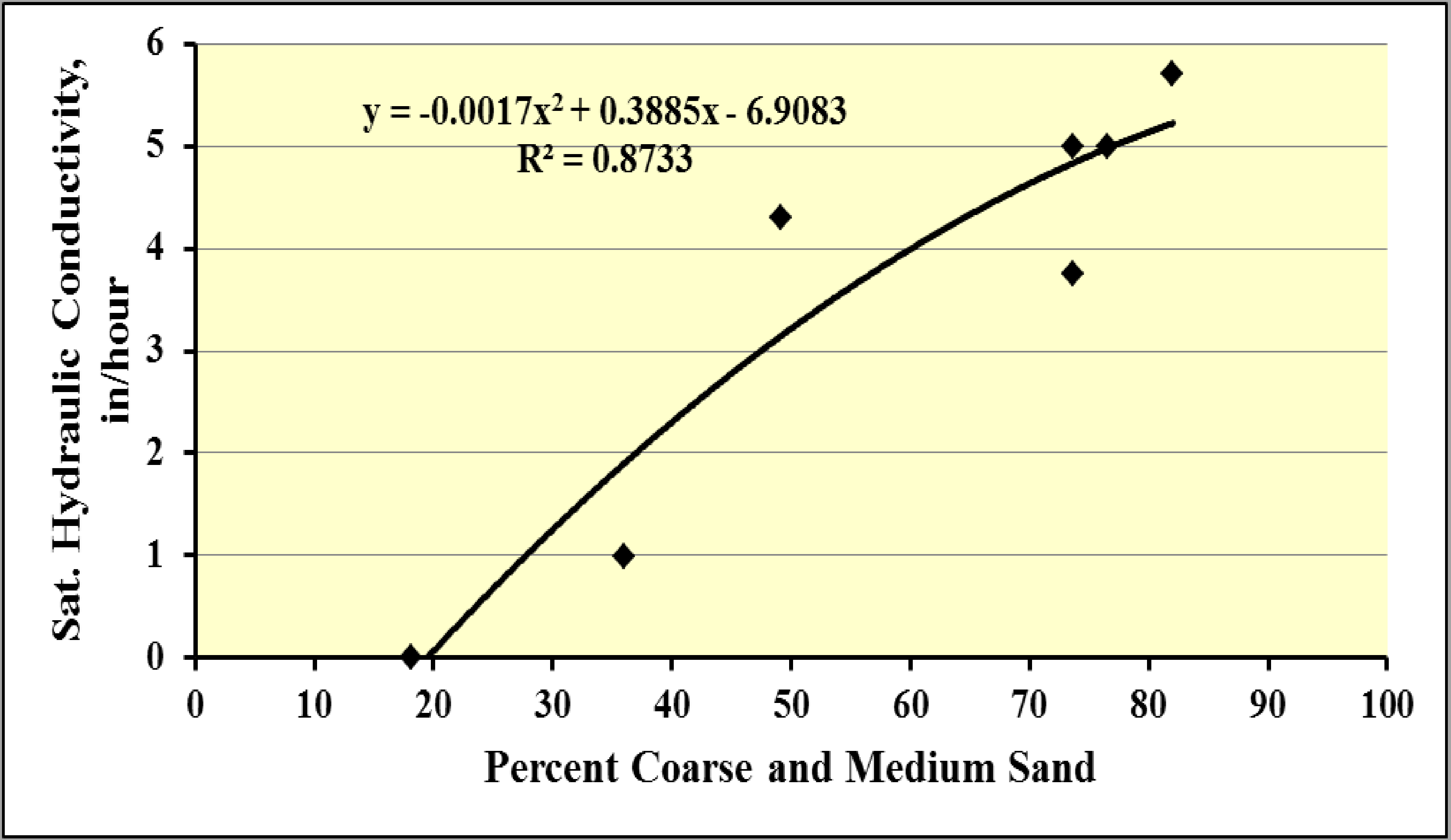
Principles of Water Movement: Sandy Soil over Gravel Layer

- **P-1: When saturated to the surface water flows in proportion to size of pores, head, and drains readily into the gravel layer**
  - When the soil is completely saturated it is at zero negative pressure,
  - The gravel layer has large pores which are also at zero negative pressure, so
  - Water can flow from the soil layer into the gravel layer.

Principles of Water Movement – Sandy Soil over Gravel Layer

- **P-2: Uniformly graded coarse and medium sand conducts water faster when saturated than well graded sands**
  - Uniformly graded sands have had all of the finer sand particles removed, so all of pores are large and about the same size
  - Well graded sands a variety of sizes of sand particles. The finer sands will pack into the voids around the larger sand particles and restrict the flow.

Analysis of Large Stormwater Systems



Principles of Water Movement: Sandy Soil over Gravel Layer

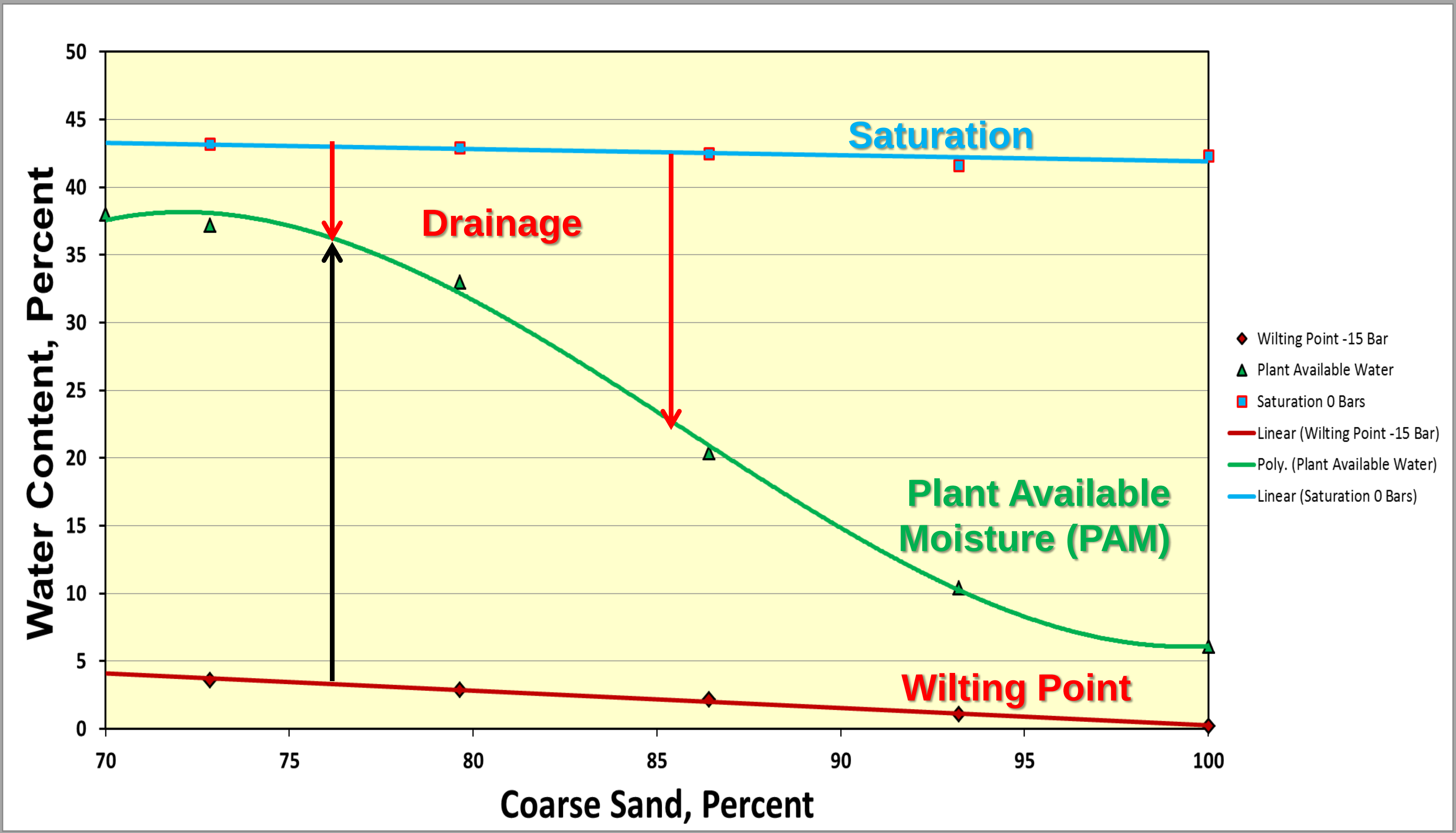
- **P-3: When unsaturated, water stops flowing into gravel layer, due to the greater negative pressures in the sandy soil**

  - After a small amount of water drain out of the sandy soil, it is no longer saturated and pore pressures in the soil become negative.

  - When unsaturated water always flows in the direction of the greatest negative pressures and since the pressure in the gravel is still zero, the water cannot move downward.

  - The gravel layer acts to impede unsaturated water movement from moving downward, thus leaves considerably more plant available water in the soil.

Change in Water Content After Initial Drainage



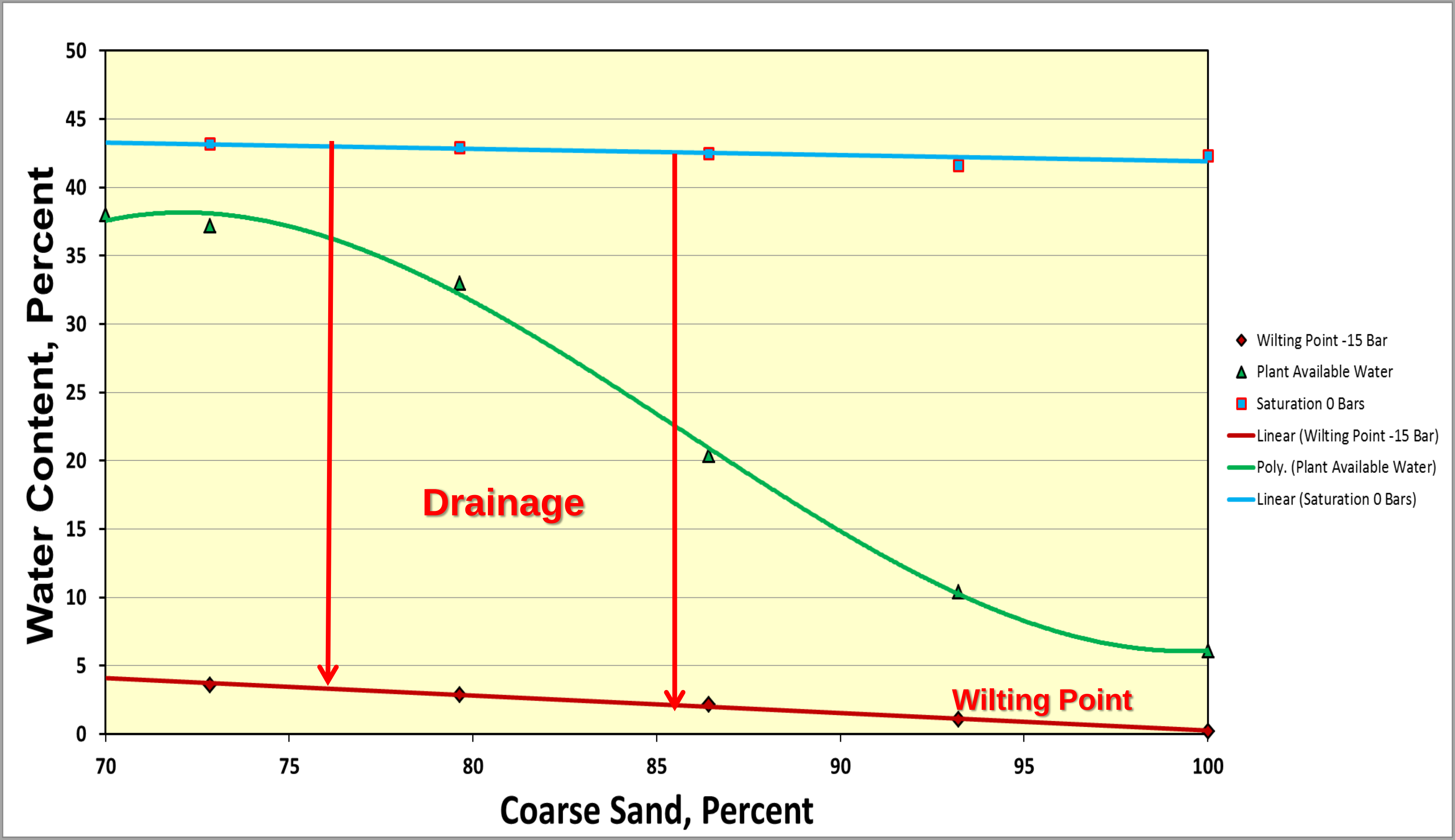
Principles of Water Movement: Sandy Soil over Gravel Layer

- **P-4: When unsaturated more water is held in the sandy soil with uniformly graded medium and coarse sand, than in well graded sands**
  - More water is held in the uniformly graded sands because it has a higher porosity due to same size of pores
  - Well graded sands have a variety of sand sizes that pack together, have a lower porosity, and water moves more slowly

Principles of Water Movement: Sandy Soil over Loamy Layer

- **P-5: When unsaturated water continues to drain from the sandy soil because the underlying loamy soil has a greater soil moisture tension**
  - When unsaturated water flows in the direction of the greatest negative pressures (greatest soil moisture tension) and since the tension in the loamy soil is greater, the water continues to move downward until the sandy soil is dry

Change in Water Content After Drainage



1. Which profile will drain the fastest when fully saturated?

2. Which profile will hold the most moisture after draining?

Layered Soil Systems

- **Layered systems are used to hold moisture in the rooting zone and prevent downward water movement; the gravel layer impedes drainage unless the soil is completely saturated**

- Used for structural soils, high infiltration rates, high quality lawn systems, high traffic areas, golf greens

- Standards for layer soil systems
  - Bridging Factor – allows bridging of a layer of finer particles over a layer of coarser particles; comparison of two layers
  - Uniformity Factor – determines whether layer is narrowly enough graded
  - Permeability Factor – determines the saturated hydraulic rate of a layer

Constructing Layered Soil System

Longwood Gardens 2015

Longwood's Main Fountain Garden

Longwood Gardens 2016
Terrace Landscape Bed

Graved-Based Structural Soil Under Drive

Installation of Boxwood Hedge

Cost of Stormwater Strategies

	Construction Cost/Gallon	Construction Cost/Acre
Preserving natural areas	$0.03 to 0.05	
Enhanced infiltration	$0.05 to 0.10	$5K to $10K
Stormwater wetland ponds	$0.25 to 1.25	
Sand/peat infiltration swales	$0.50 to 0.75	
Sand based infiltration system	$0.25 to 2.75	$10K to $125K
Rainwater harvesting	$0.50 to 2.50	
Sand/peat filtration	$2.50 to 3.50	
Recirculating sand/peat filtration	$4.50 to 7.50	
Renovation of urban streets	$5.00 to $12.50	

Designing Landscape Soils for Longwood Gardens

2015 NC ASLA Meeting
Sunset Beach, NC

by

Barrett L. Kays, Ph.D., FASLA, CPSS
Landis, PLLC, Raleigh, NC