A Method to Evaluate the Hydraulic Loading Rate of a Marginal Soil

John R. Buchanan, Ph.D., P. E.

Associate Professor

Department of Biosystems Engineering & Soil Science

University of Tennessee

THE UNIVERSITY of TENNESSEE

Agricultural Experiment Station

Sponsored in Part by:

- Curt Silverstone Foundation
- Tennessee Water Resources Research Center
- Tennessee AgResearch
- TDEC-DWR
- Water & Wastewater Authority of Wilson County
- Don Chambers – Property Owner
- Lonnie Norrod – Soil Scientists

A Method to Evaluate the Hydraulic Loading Rate of a Marginal Soil

- Issue
  - We have outstanding soils professionals
    - that can determine the texture, structure and depth to a restrictive layer at potential land application sites

Soil Morphology

All that can be seen and felt about a soil

- Thankfully
  - the perc test is mostly relegated to history
  - we evaluate the soil morphology
    - with respect to hydraulic functionality
  - ensures that there is sufficient pore connectivity to convey water

For Sites with Suitable Soils

- The actual hydraulic conductivity is likely 10 times greater than our design value
  - tremendous safety factor

For Sites with Unsuitable Soils

- Water or Rock layer too close to surface
  – no opportunity for soil-based treatment
- Expansive soils
  – water cannot move through
- Thick clay layer
- Structure
  – platy
  – weak

What about Marginal Soils

- The soils that have limited ability to move water
  - the actual hydraulic conductivity may only be twice the design rate
    - much less safety factor
  - thinner clay layer
  - soil pores line up, some pore connectivity
- not much history to base the loading rate
  - when in doubt, just say no

- For basal applications at Decentralized Sites
  - we don't have as much history as compared to trench systems
    - we use the table values
    - and if it works, we really did not learn anything
  - not willing to push the loading rate to failure
    - when 150 homes are attached to the system

Table VII.
Hydraulic Loading Rates (gpd/ft^2) - For Subsurface Drip Disposal (SDD) Systems

TEXTURE	STRUCTURE: SHAPE	STRUCTURE: GRADE	HYDRAULIC LOADING RATE (gpd / ft^2) BOD ≤ 30 mg/L
Coarse Sand, Loamy Coarse Sand	NA	NA	NA*
Sand	NA	NA	NA*
Loamy Sand, Fine Sand, Loamy Fine Sand, Very Fine Sand, Loamy Very Fine Sand	Single Grain	Moderate, Strong	0.50
		Massive, Weak	0.40
Coarse Sandy Loam, Sandy Loam	Massive	Structureless	0.30
	Platy	Weak	0.20
		Moderate, Strong	Not Used
	Blocky, Granular	Weak	0.40
		Moderate, Strong	0.50
Loam	Massive	Structureless	0.20
	Platy	Weak, Moderate, Strong	Not Used
	Blocky, Granular	Weak	0.30
		Moderate, Strong	0.40
Silt Loam	Massive	Structureless	0.20
	Platy	Weak, Moderate, Strong	Not Used
	Blocky, Granular	Weak	0.20
		Moderate, Strong	0.30
Sandy Clay Loam, Clay Loam, Silty Clay Loam	Massive	Structureless	NA*
	Platy	Weak, Moderate, Strong	Not Used
	Blocky, Granular	Weak	0.20
		Moderate, Strong	0.20
Sandy Clay, Clay, Silty Clay	Massive	Structureless	Not Used
	Platy	Weak, Moderate, Strong	Not Used
	Blocky, Granular	Weak	0.075
		Moderate, Strong	0.10

An Added Complication

- We assume that the actual loading rate will be less than the design loading rate
  - so, again, we really don’t learn what the soil can actually handle
    - the long-term acceptance rate (LTAR)
  - we must have safety factors when we don’t have a full understanding of processes
    - are we comfortable loading the soil at the full loading rate everyday?

Lack of Confidence in Loading Rate Tables

- These numbers are BPGs
  - Best Professional Guesses
    - from really good practitioners
    - but not from measurements
- Is the difference between 0.10 and 0.075 gpd/ft^2 real?
  - it's only 0.025 gpd/ft^2
    - 3.2 fluid oz. per day per square foot
      - difference of 20 homes with 5 acres of drip

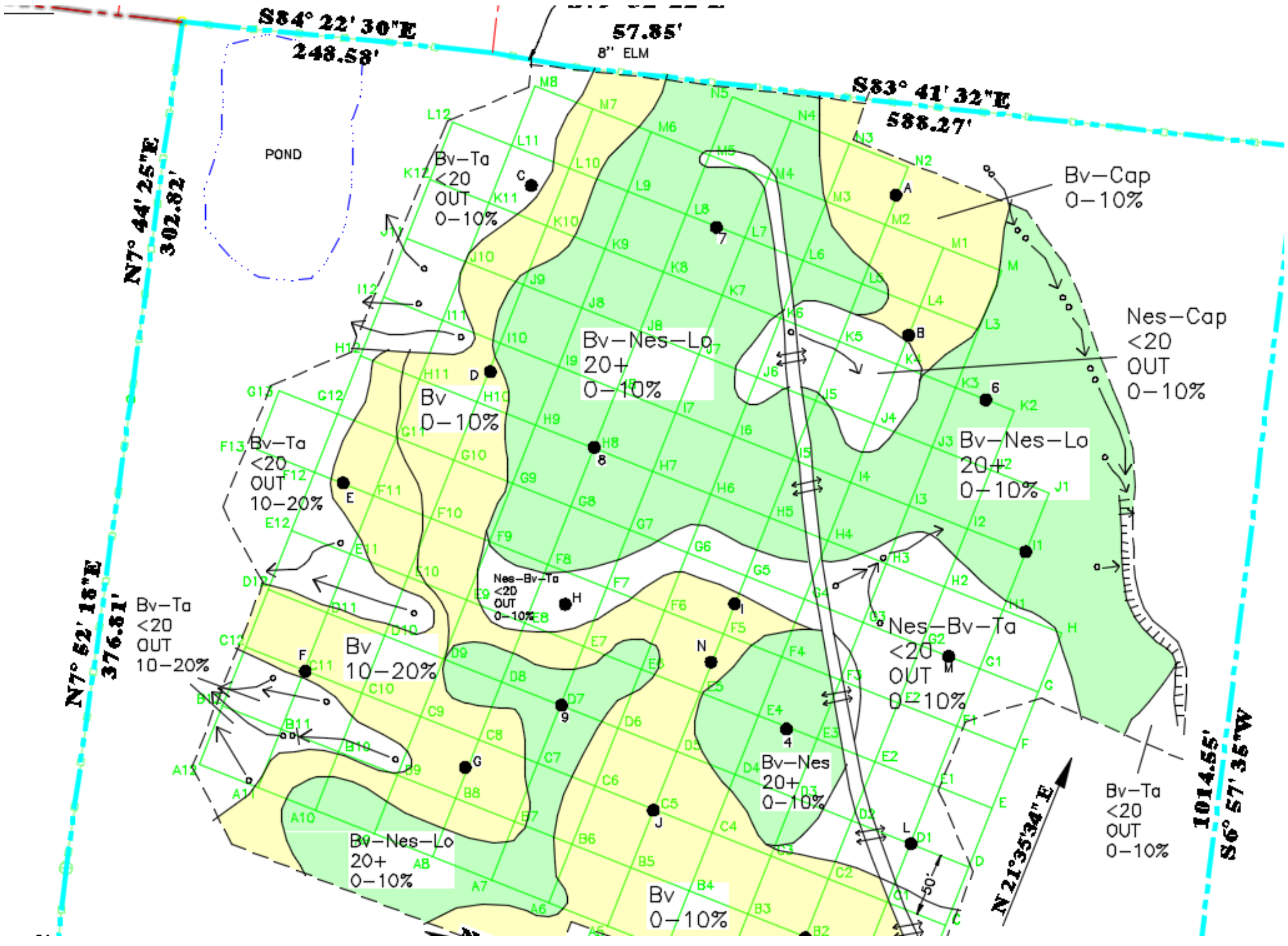
Question

- Why not use a small-scale water application system to simulate large-scale water application
  - monitor soil moisture with sensors
  - measure weather parameters to account for rainfall and evapotranspiration
- Use clean water
  - we can push the boundaries of the hydraulic loading rate with no public health risk

Site

- Gladeville, Wilson County
  - in the shadow of the Amazon warehouse
- Unsuitable
  - clayey soil with weak blocky structure
- Guidelines changed?
  - 0.075 gpd/ft^2

Nesbitt, Bradyville, Capshaw & Lomond



Suitable Soil?

Date: 14 AUG 2018 Described By: Lonnie Norod QA/QC By: Terry Henry & Allen Rather

Site Name & Location: Beaty Farm County: WILSON

Stop or Pit #: E 12 SOP # (office use only):

Soil Series: Bradyville Drainage Class: well

Soil Control Section: fine Ground Water or Water Table: None

Parent Material: residuum Erosion: moderate

Climate: thermic Land Cover: mixed grasses

Slope of Map Unit: 10-20% Slope of Pit: 10%

Geomorphic Description: upland Latitude/Longitude (Center of soil area):

Physiographic Location: NB

Additional Notes:

Soil Pedon Description

Horizon	Depths (Inches)	Matrix Color	Redox Depletions/Concentrations	Depth to Low Chroma Mottles (inches)	Soil Texture	Soil Structure Grade	Soil Structure Size	Soil Structure Type	Soil Horizon Notes
Ap	0-5				SiL	1/2	F/M	GR/SBK	
BA	5-8				SiCL	2	M	SBK	
Bt1	8-18				SiCL	2	M	SBK	
Bt2	18-24				C	1	M	SBK	
Bt3	24-28				C	1	M	SBK	
C	28-44				C	0		M	

Bradyville Series

- TYPE LOCATION:
  - Rutherford County, Tennessee; 0.2 mile east of Windrow; 100 feet north of private drive to Windrow homestead.
- DRAINAGE AND PERMEABILITY:
  - Well drained; medium to rapid runoff; moderately slow permeability.
- Well drained

Well Drained

- NRCS Definition
  - Water is removed from the soil readily but not rapidly. Internal free water occurrence commonly is deep or very deep; annual duration is not specified. Water is available to plants throughout most of the growing season in humid regions. Wetness does not inhibit growth of roots for significant periods during most growing seasons. The soils are mainly free of the deep to redoximorphic features that are related to wetness.

Bradyville Series

- The Bradyville series consists of
  - deep, well drained soils on uplands.
  - These soils formed in residuum of limestone or in a thin silty mantle and the underlying clayey residuum of limestone.
  - Slopes range from 0 to 30 percent.
- Taxonomic Class
  - Fine, mixed, semiactive, thermic Typic Hapludalfs
    - fine texture
    - mixed clay mineralogy
    - semi-active cation exchange
    - Southeaster U.S. climate
    - minimal horizonation, humid conditions

TYPICAL PEDON: Bradyville silt loam - cultivated. (Colors are for moist soil unless otherwise stated.)
Ap--0 to 6 inches, dark reddish brown (5YR 3/4) silt loam; moderate medium granular structure; friable; many fine roots; medium acid; abrupt smooth boundary. (4 to 8 inches thick)
Bt1--6 to 12 inches, red (2.5YR 4/6) silty clay loam; moderate medium subangular blocky structure; friable; few faint clay films; common fine roots
Bt2--12 to 20 inches, red (2.5YR 4/6) silty clay loam; moderate medium subangular blocky structure; firm; common fine root; common faint clay film
Bt3--20 to 27 inches, red (2.5YR 4/6) clay; few medium distinct yellowish brown (10YR 5/6) and strong brown (7.5YR 5/6) mottle; strong medium subangular blocky structure; firm; plastic; few fine roots; common distinct clay films
Bt4--27 to 36 inches, yellowish red (5YR 4/6) clay; common fine to coarse yellowish brown (10YR 5/6) and strong brown (7.5YR 5/6) mottles; moderate medium subangular blocky structure; very firm; plastic (Combined thickness of the Bt horizon range from 25 to 48 inches)
BC--36 to 48 inches, yellowish red (5YR 4/6) clay; many medium and coarse prominent light yellowish brown (10YR 6/4) and few fine prominent light brownish gray (10YR 6/2) mottles; weak coarse and medium angular blocky structure; very firm and very plastic; few thin slabs of hard limestone;
R--48 inches; limestone rock.

COMPETING SERIES

- These are the Archer, Conasauga, Mimosa, Talbott and Winnsboro series in the same family and the closely related Collegedale, Dewey and Fullerton series. Archer soils have a sandy loam to sand surface layer and significantly more sand in the upper part of the B horizon. Conasauga and Mimosa soils have hues of 7.5YR to 2.5Y. In addition Conasauga has a paralithic contact within 40 inches. Talbott soils have hard bedrock within 40 inches and typically have a higher clay content in the upper part of the B horizon. Waynesboro soils have hue of 7.5YR to 2.5Y and have a paralithic contact at a depth of 40 to 70 inches. Collegedale, Dewey and Fullerton soils have base saturation of less than 35 percent and have sola greater than 60 inches thick.

Water Application Layout

- Grid of emitters
  - six emitters per lateral
  - six laterals
  - 36 emitters
  - 1’ by 1’ spacing
  - 0.55 gph flow rate
- Placed on soil surface on contour

Dose Control System

- Battery operated
  - diaphragm pump
  - bladder tank
  - water meter
  - solenoid valve
  - inline pressure regulator
  - filter
  - solar panel/battery
- Not winter proof
- Not on telemetry

Water Supply

- 330 gallon tote
  - refilled as needed by John Smith
    - Senior Engineer
    - WWAWC

Weather Station

- Measures
  - wind speed
  - wind direction
  - solar radiation
  - air temperature
  - relative humidity
  - rain depth
- Allows computation of Potential ET using a short grass reference

Soil Moisture Sensors

- WaterScout
  - capacitance based
  - provides voltage response to volumetric water content
  - $120 each
  - easy to install with soil probe

Use Soil Probe to Open Hole

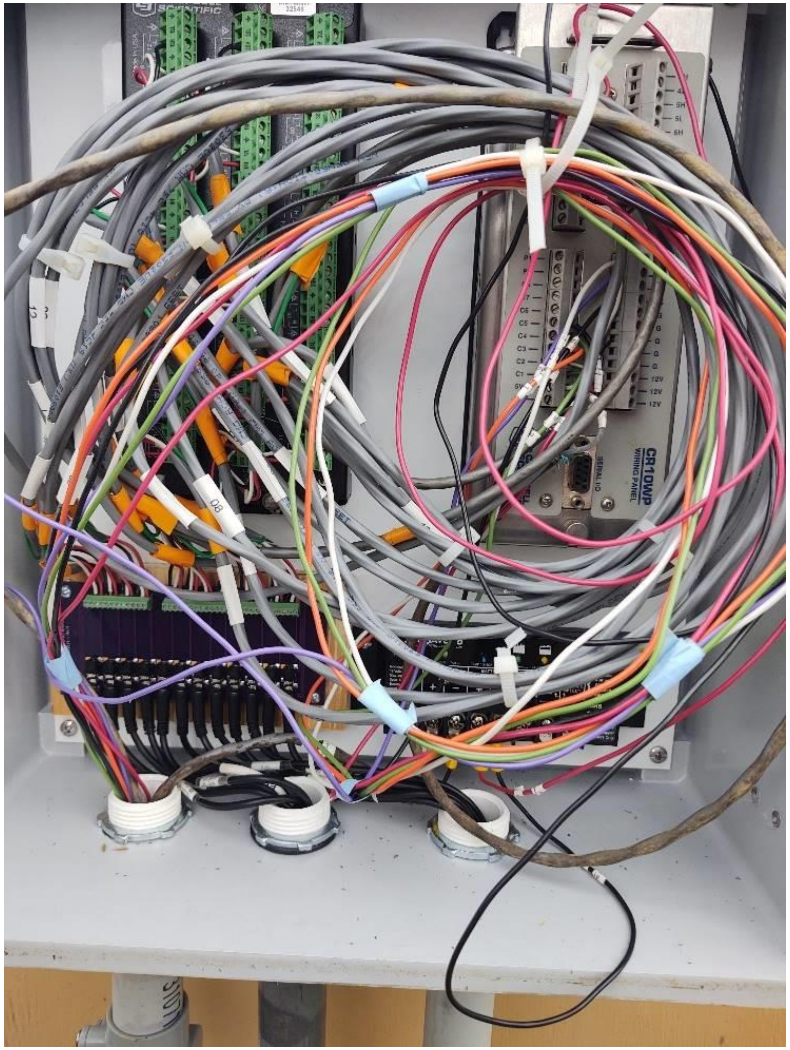
- Add water to soften soil at bottom of hole
- Push sensor into undisturbed soil at bottom
- Backfill

Finished Installation

- Minimum soil disturbance during installation
  - easy to break sensor during installation
- However,
  - this is still a soil disturbance
  - this column of soil will behave differently than the adjacent soil

Placement

- Installed 12 sensors
  - two, 4” wet side
  - two, 4” dry side
  - two, 8” wet side
  - two, 8” dry side
  - two 12” wet side
  - two, 12” dry side



System Operation

- Instantaneous application
  - 0.55 gallon per hour per square foot
- System can
  - vary the dose frequency
  - vary the dose duration
- For example
  - 1-min dose every 30 minutes
  - 0.44 gpd/ft^2

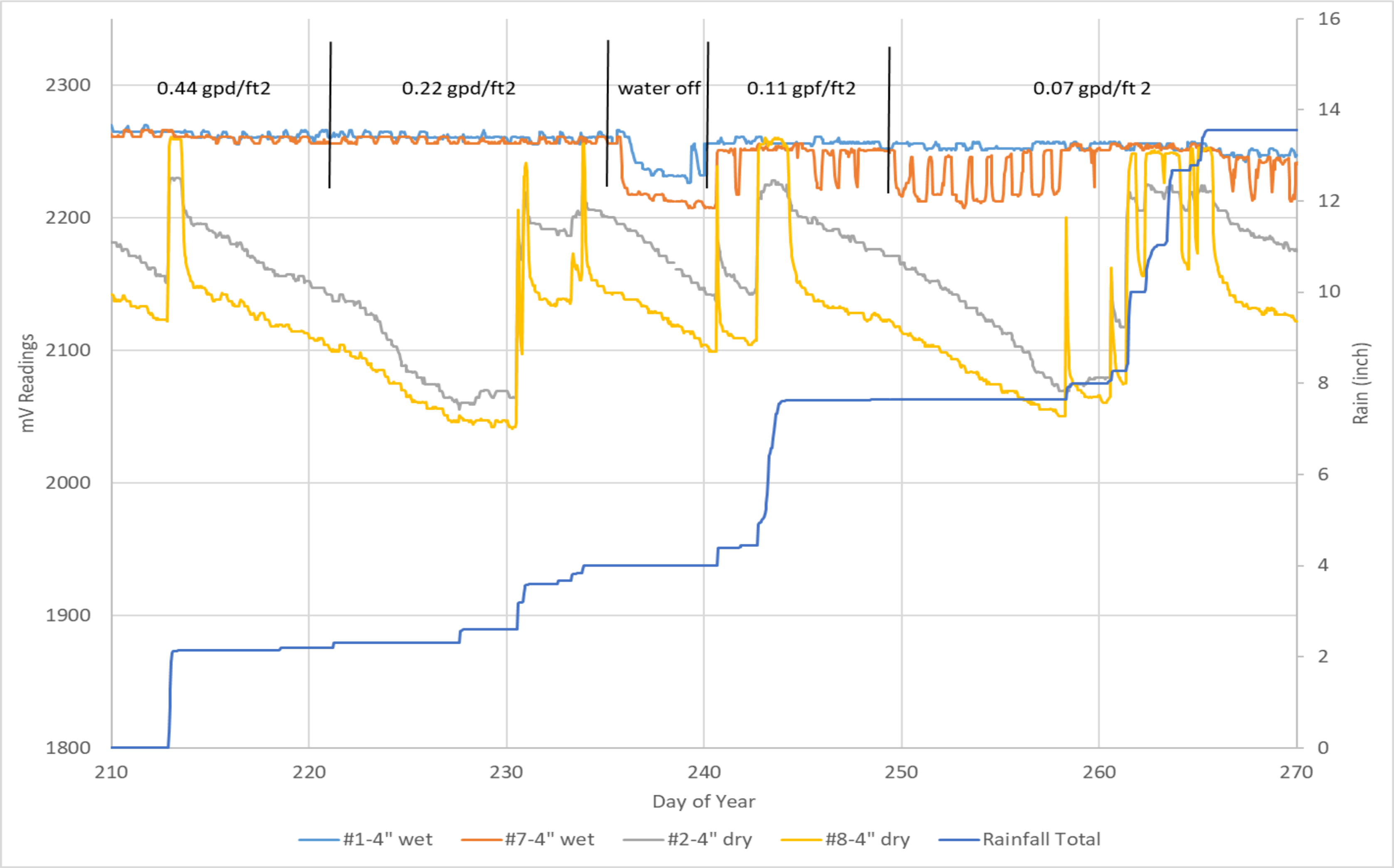
Loading Rates

- Decided to start at high-end of loading rate
  - to get water moving through profile
  - to see if we would have surface ponding
  - to see how the soil moisture sensors would respond
- 2.2 gpd/ft^2
  - 10 times greater that allowed in Tennessee
    - purposefully flooded the soil over 2 weeks

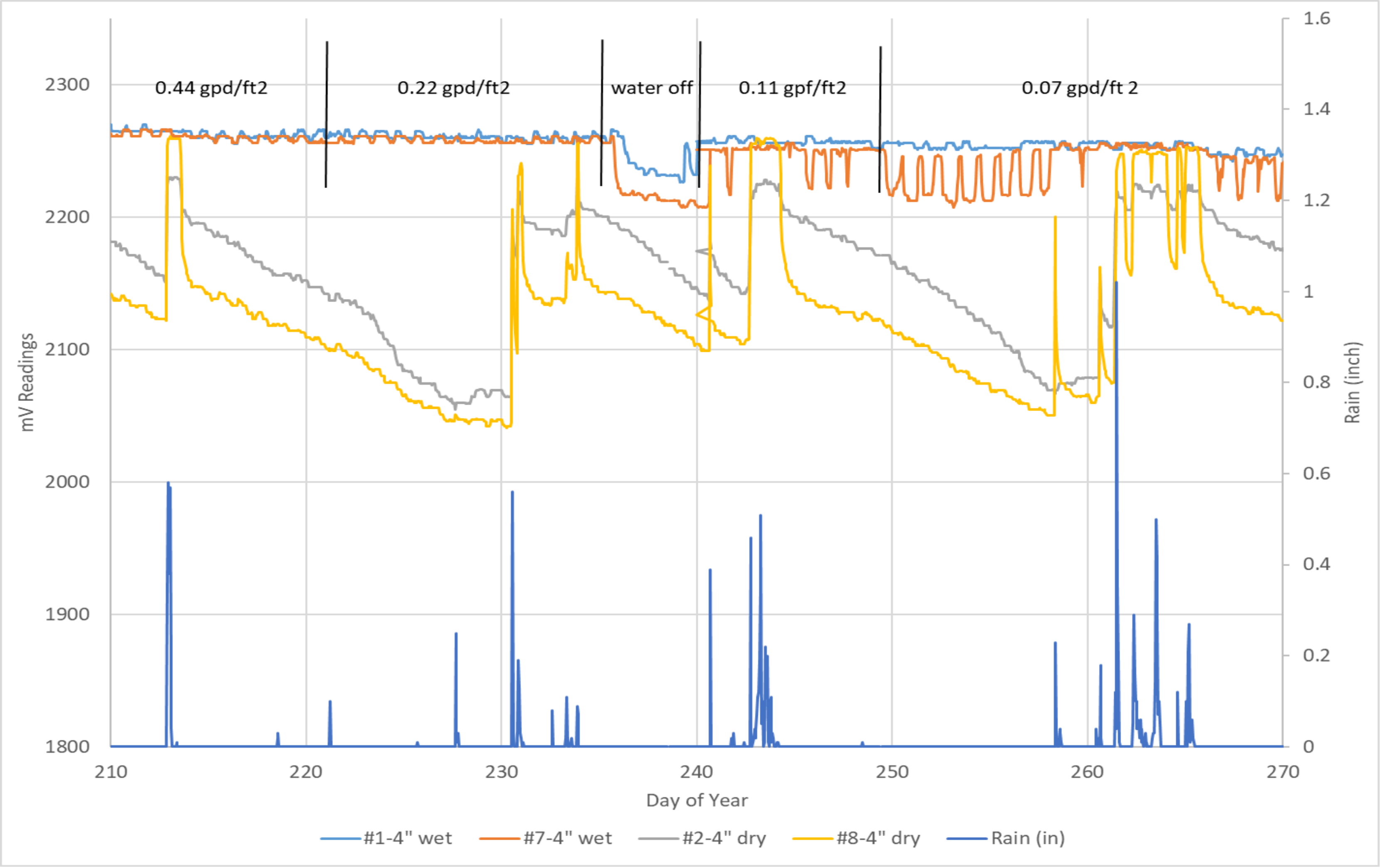
Reducing the Loading Rates

- 0.44 gpd/ft^2
  - still had ponding and runoff
  - still 6 times greater than design
- Operating at 0.22 gpd/ft^2
  - 1-min dose every two hours
  - three times greater than design

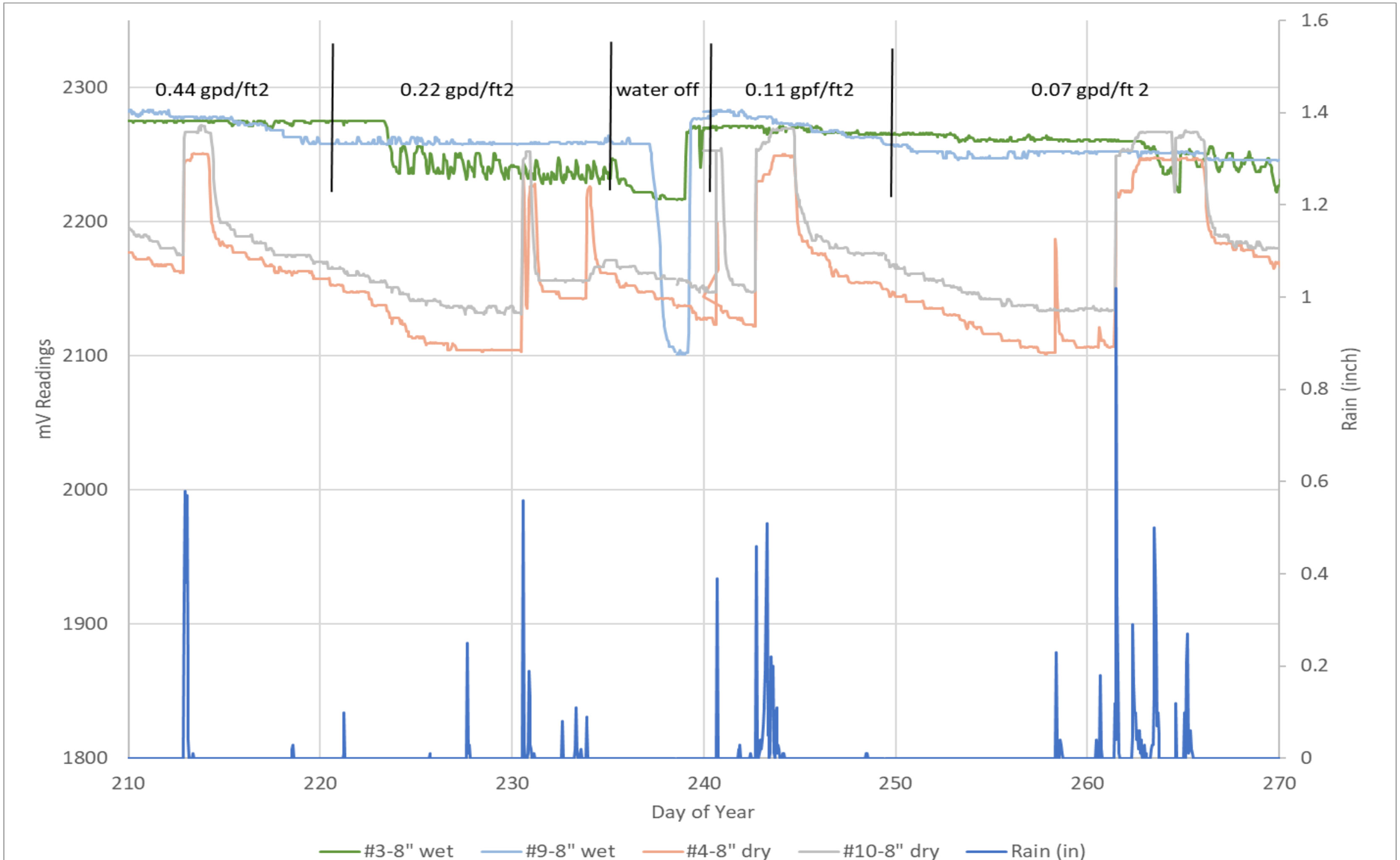
Confounding Factor - Rainfall



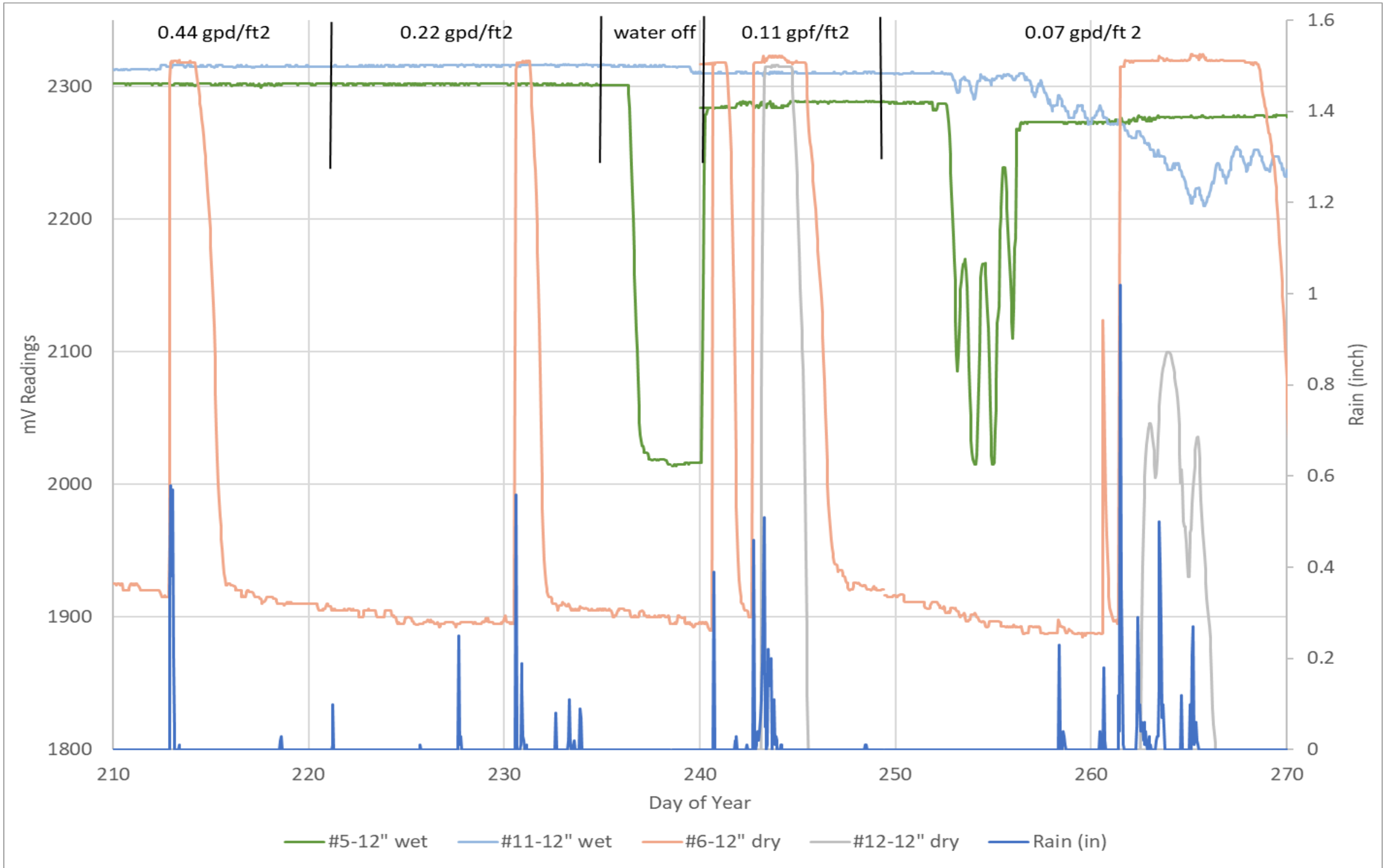
4-inch Sensor Data



8-inch Sensor Data



12-inch Sensor Data



Conclusions

- It is a marginal soil
  - there is risk and little margin for the over-application of effluent
  - system design will need to account for non-steady state flows
    - lowest laterals could receive twice the design load when water re-distributes within the tubing
  - set a design rate of 0.075 gpd/ft^2 and operate two zones at that rate to observe soil response

Discussion Time

John R. Buchanan
jbuchan7@utk.edu

THE UNIVERSITY of TENNESSEE
Agricultural Experiment Station