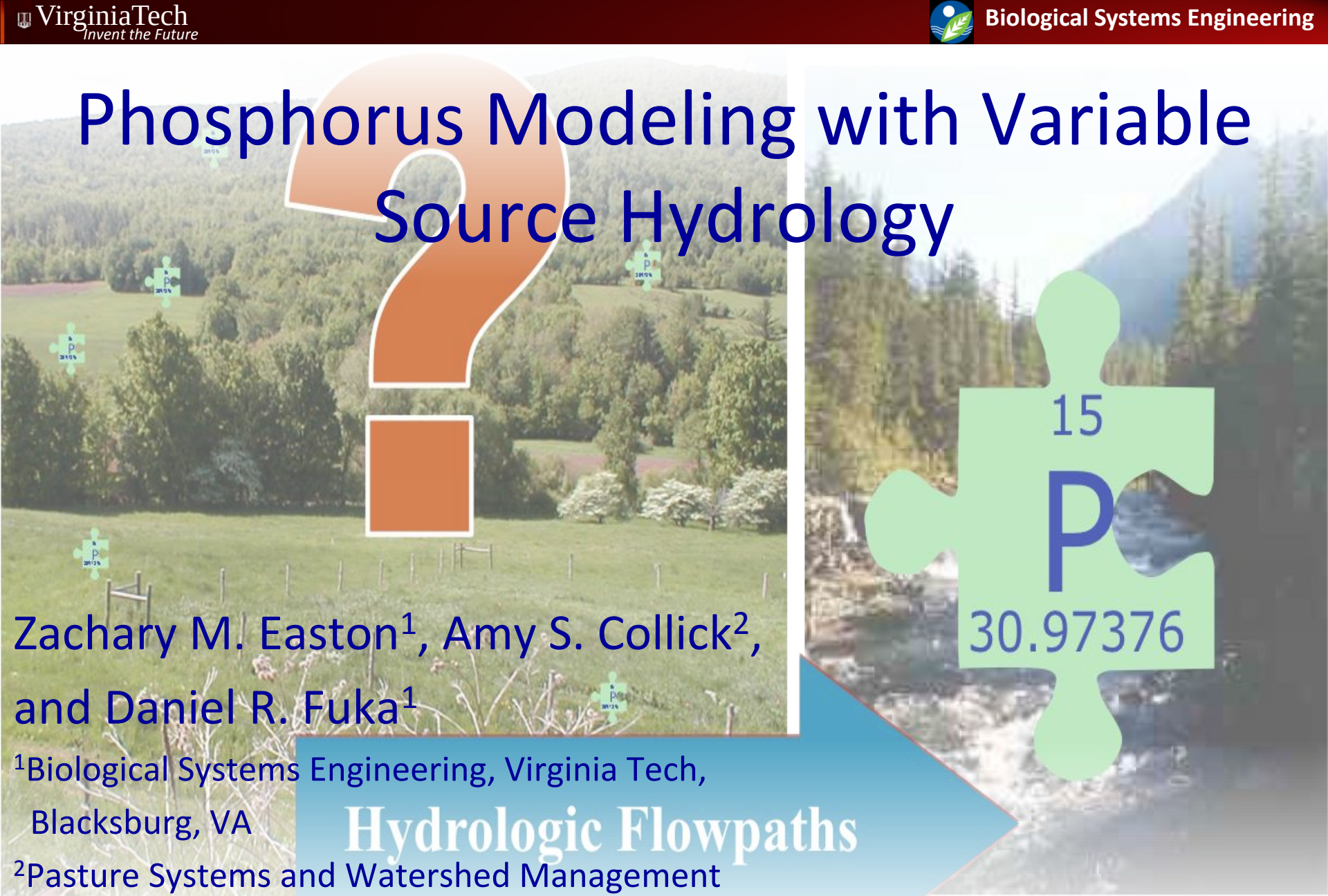
Phosphorus Modeling with Variable Source Hydrology



Zachary M. Easton[1], Amy S. Collick[2], and Daniel R. Fuka[1]

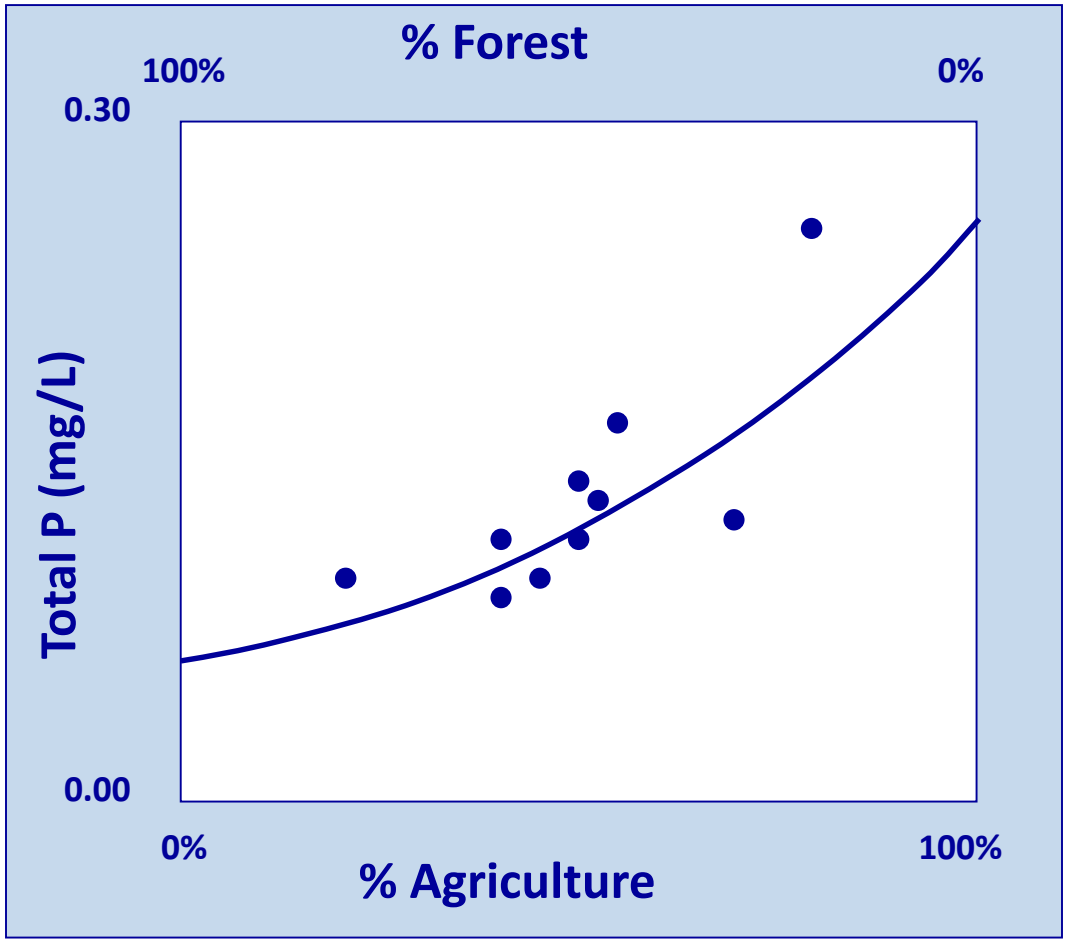
[1]Biological Systems Engineering, Virginia Tech, Blacksburg, VA

[2]Pasture Systems and Watershed Management Research Unit, USDA-ARS, University Park, PA

zeaston@vt.edu

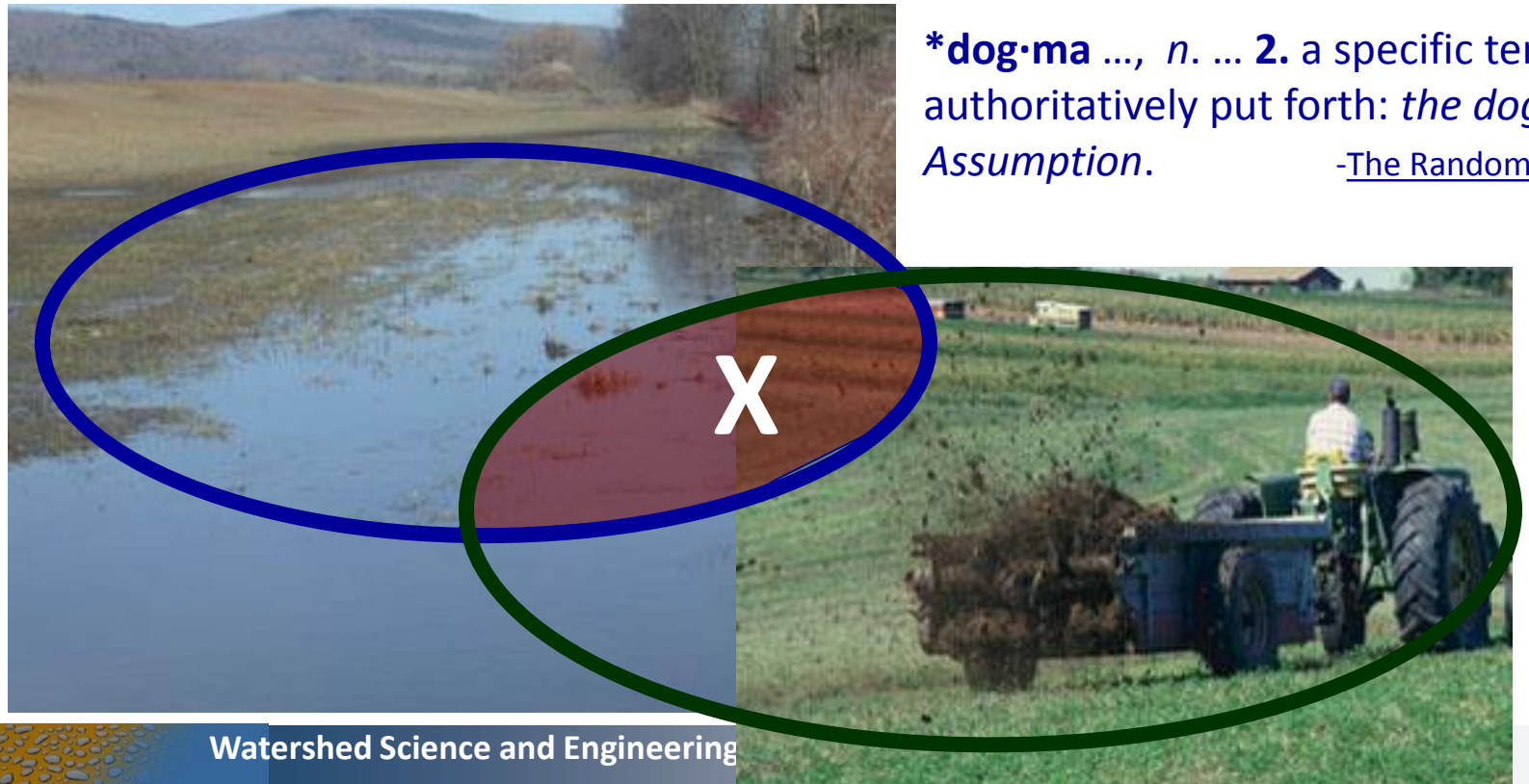
How is P management evaluated?

Models



If land use is your only variable, management options are extremely limited

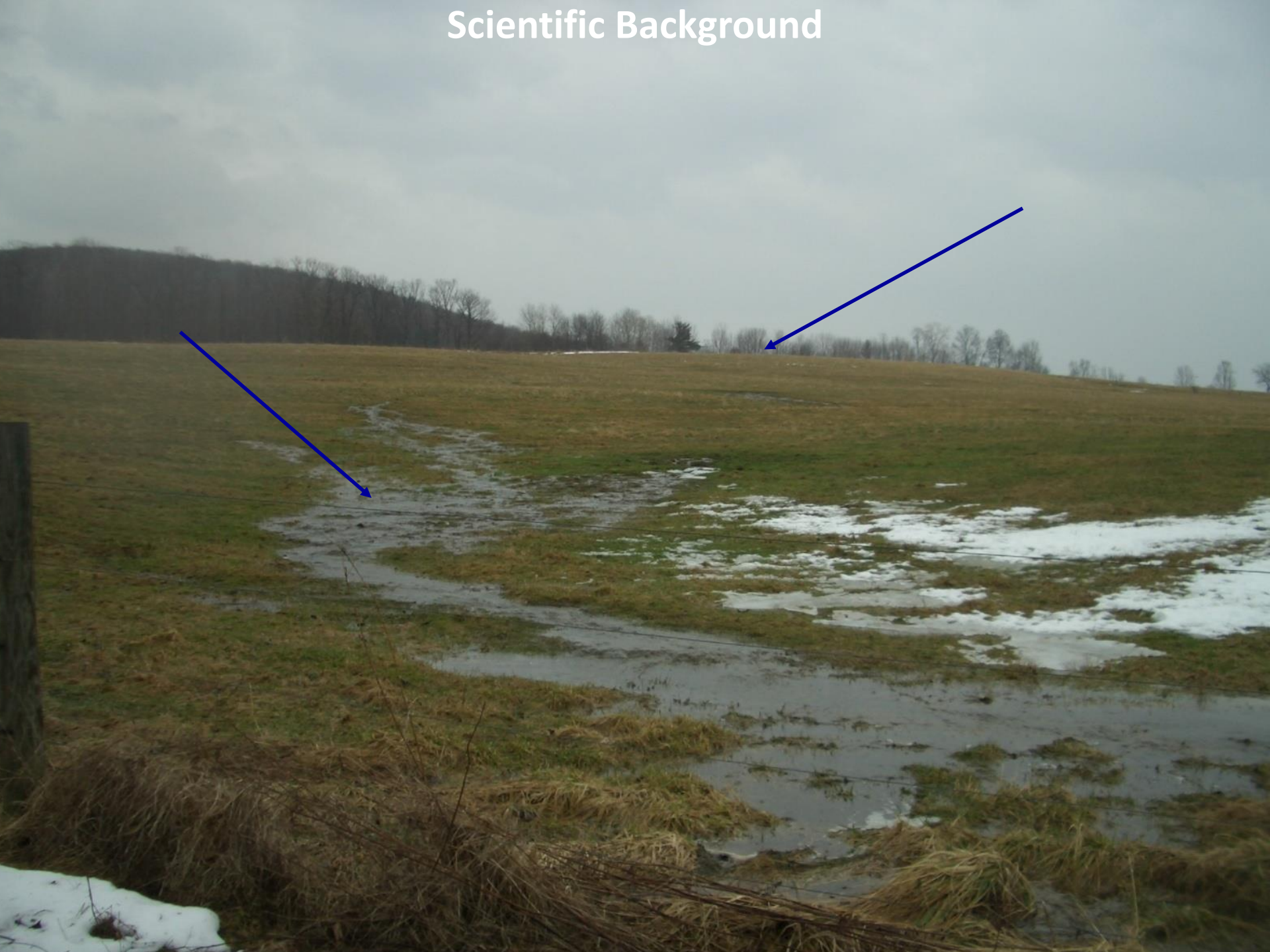
- As a result, we have sometimes dogmatically* developed nonpoint source pollution control practices based on specific land uses and ignored the interaction between land management and physical, landscape scale processes.



***dog·ma** …, *n*. … **2.** a specific tenet of doctrine authoritatively put forth: *the dogma of the Assumption*.

-The Random House Dictionary

Scientific Background



Models Need to:

- **Consider spatially distributed properties other than land use and soils**

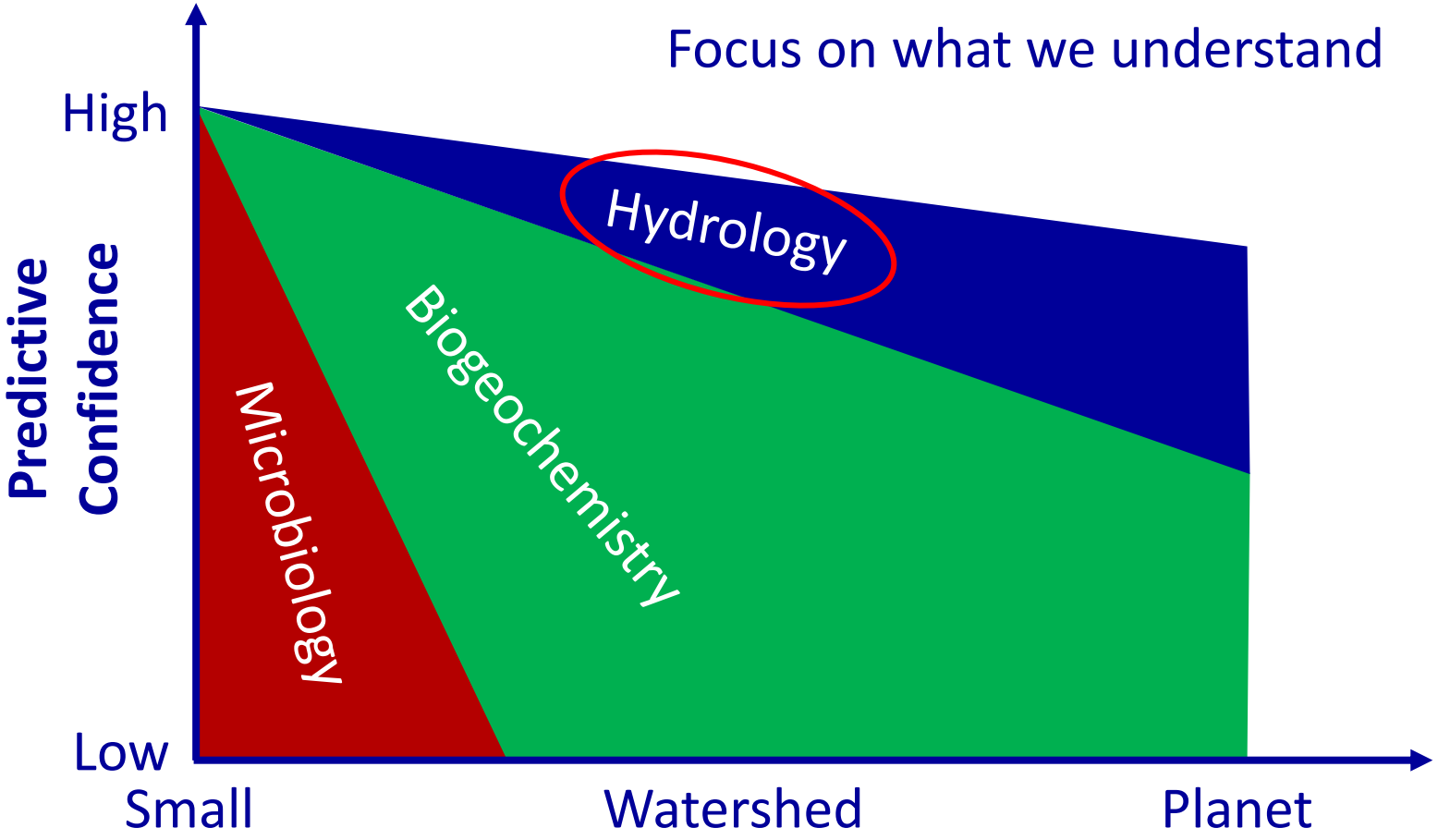
Models Need to:

- Consider the spatial distribution of hydrological patterns
- Account for locations of features (e.g., potential pollutant sources) relative to streams

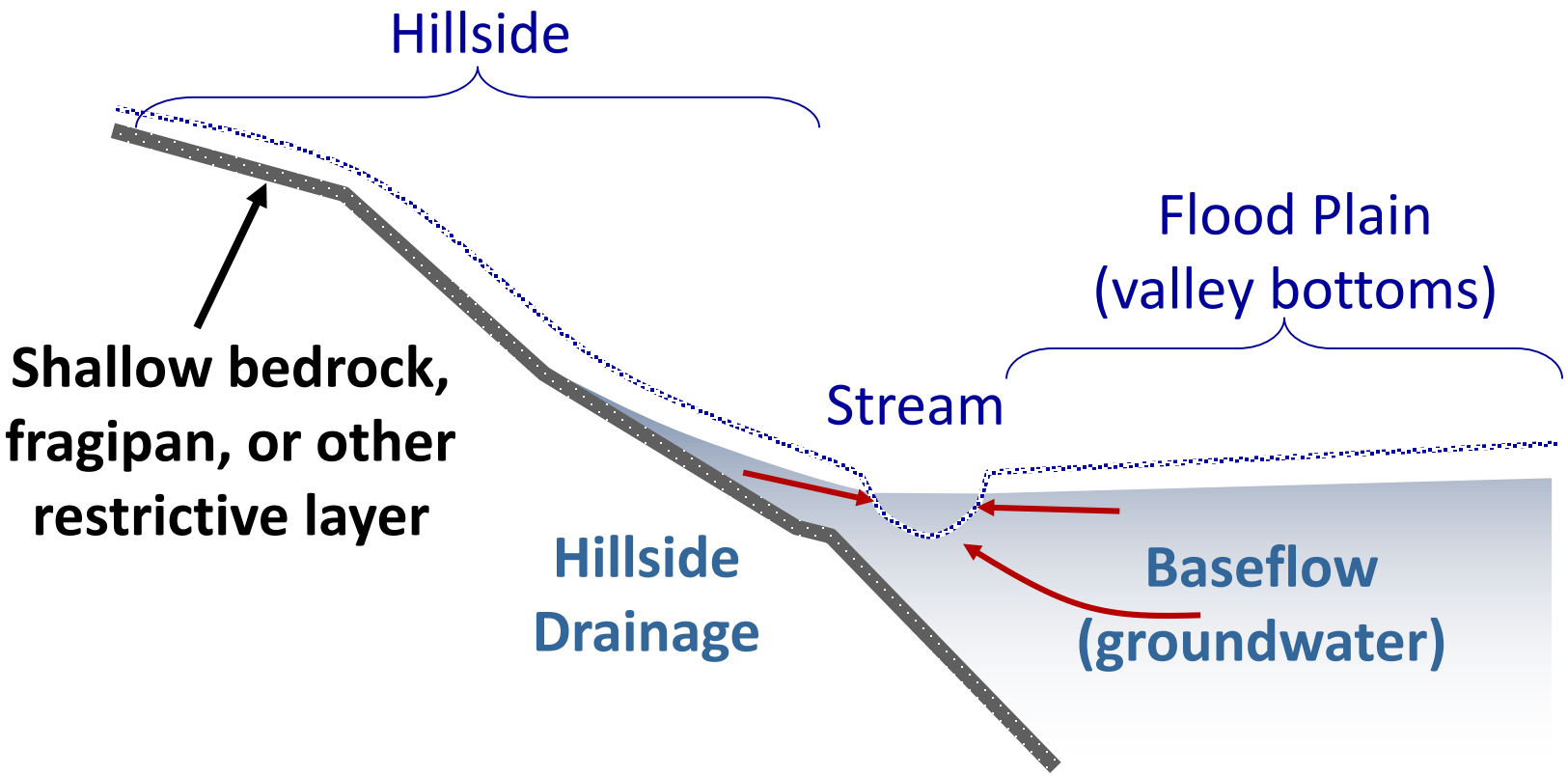
Models Need to:

- Consider the spatial distribution of hydrological and chemical patterns
- Account for locations of features (e.g., potential pollutant sources) relative to streams
- Minimize (or eliminate) model calibration

Modeling Strategy

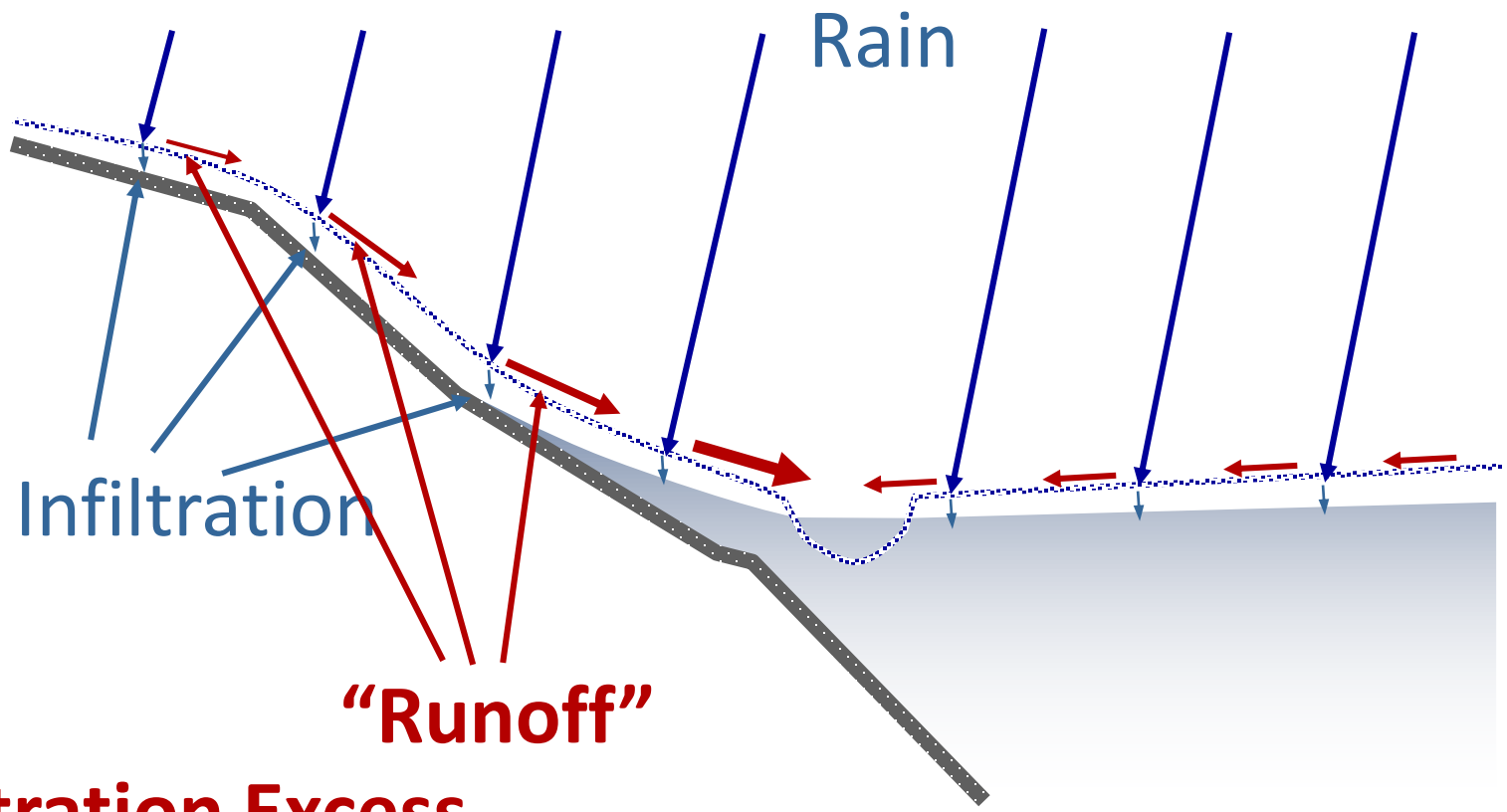


Hydrology


Hillside
Flood Plain
(valley bottoms)
Shallow bedrock,
fragipan, or other
restrictive layer
Stream
Hillside
Drainage
Baseflow
(groundwater)

Common Perception of Runoff

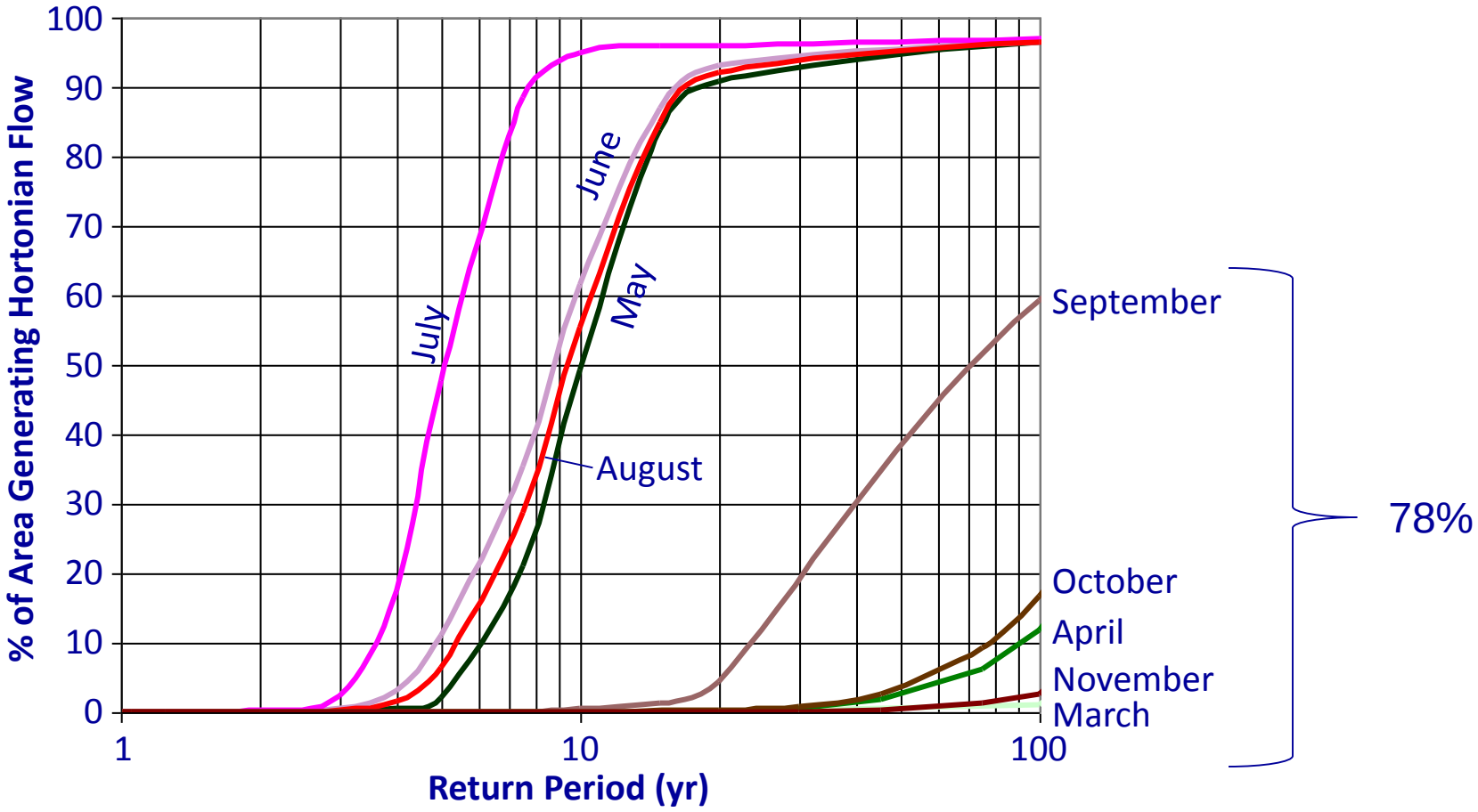
CN-method based on this theory (Horton 1933, 1940)



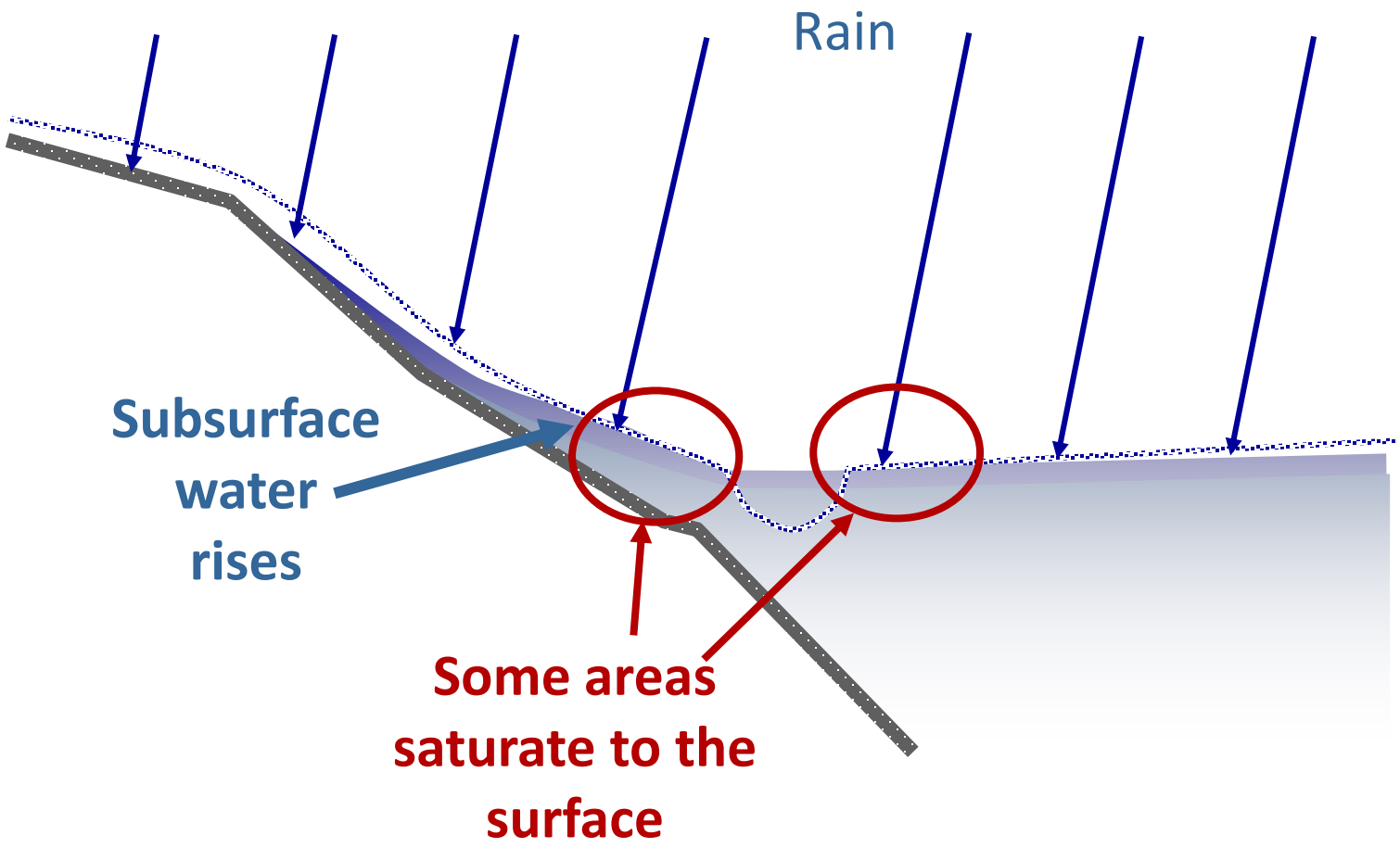
Infiltration Excess

a.k.a. Hortonian Flow

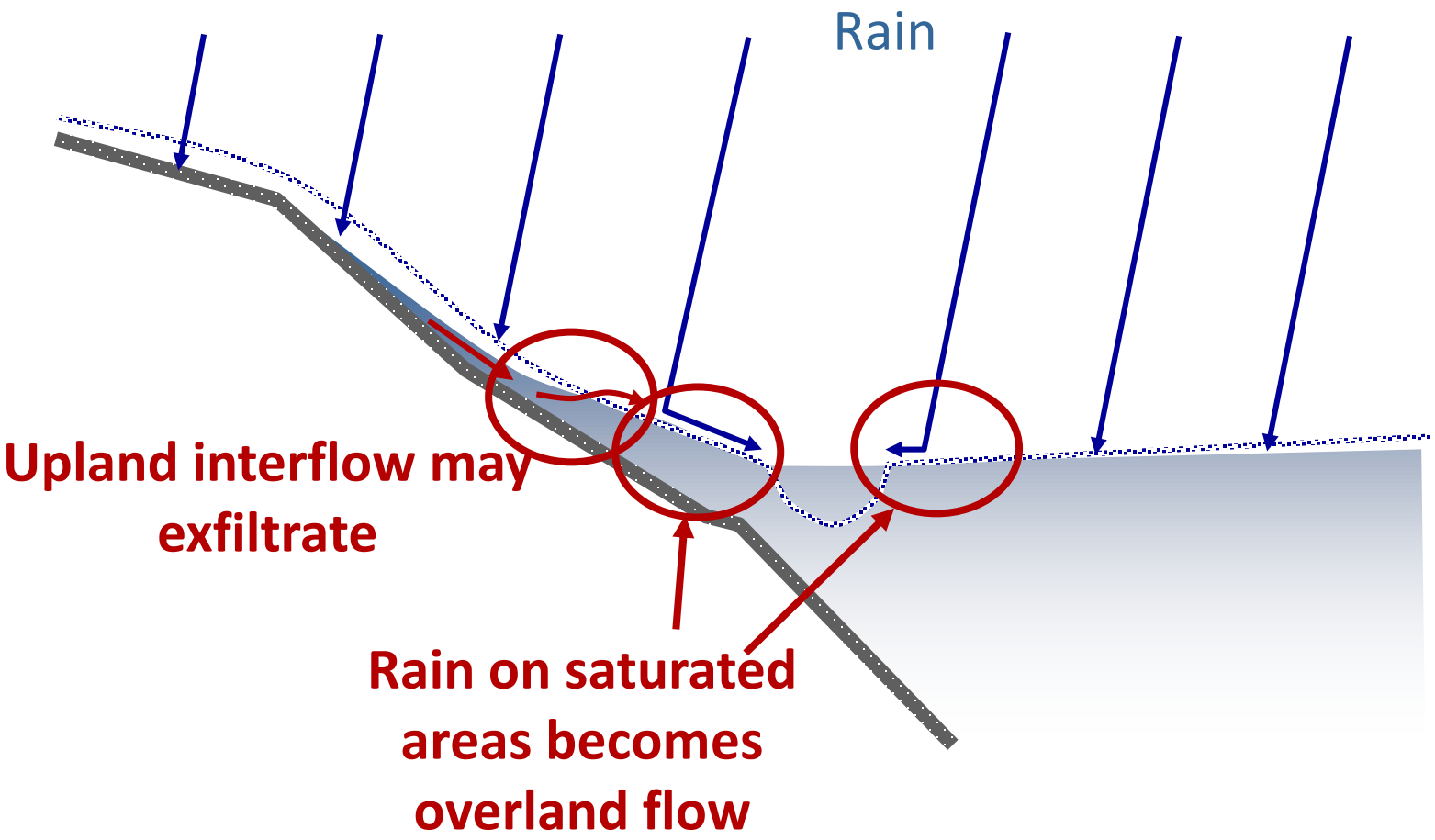
Is Hortonian Flow Common?



Saturation Excess Runoff

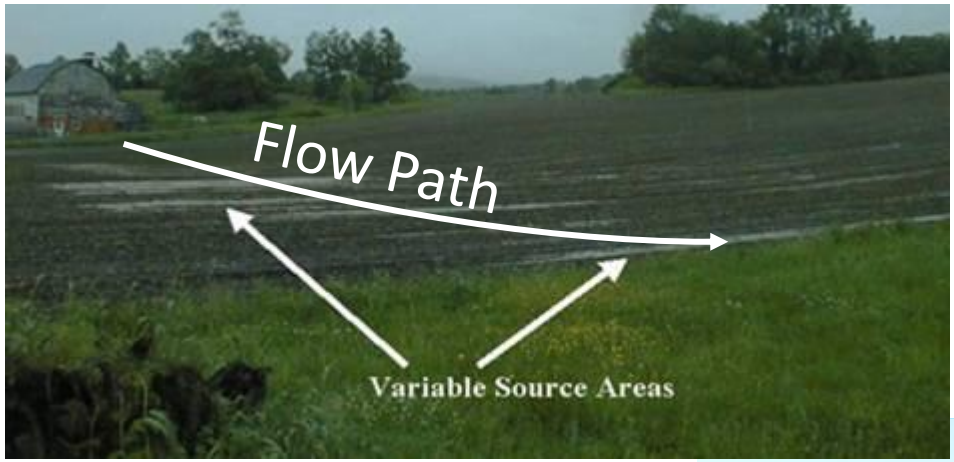


Saturation Excess Runoff



Dunne and Black. 1970. *Water Resour. Res.*

Variable Source Areas



Most Watershed Models were not intended to capture this complexity

- Soil and Water Assessment Tool (SWAT)
- General Watershed Loading Function (GWLF)
- Agricultural Nonpoint Source Pollution Model (AGNPS)
- Hydrologic Simulation Program Fortran (HSPF)

The Curve Number as an example

$$\text{“Runoff”} = P_e^2/(P_e+S)$$

$$S = 25400/CN - 254$$

Tables link CN to land use and soil drainage class

But maybe the tables are misleading

$$\text{“Runoff”} = P_e^2/(P_e+S)$$

Victor Mockus justified his model largely “on grounds that it produces rainfall–runoff curves of a type found on natural watersheds”

He later concluded that *saturation excess* was probably the “likely runoff mechanism to be simulated by the method…”

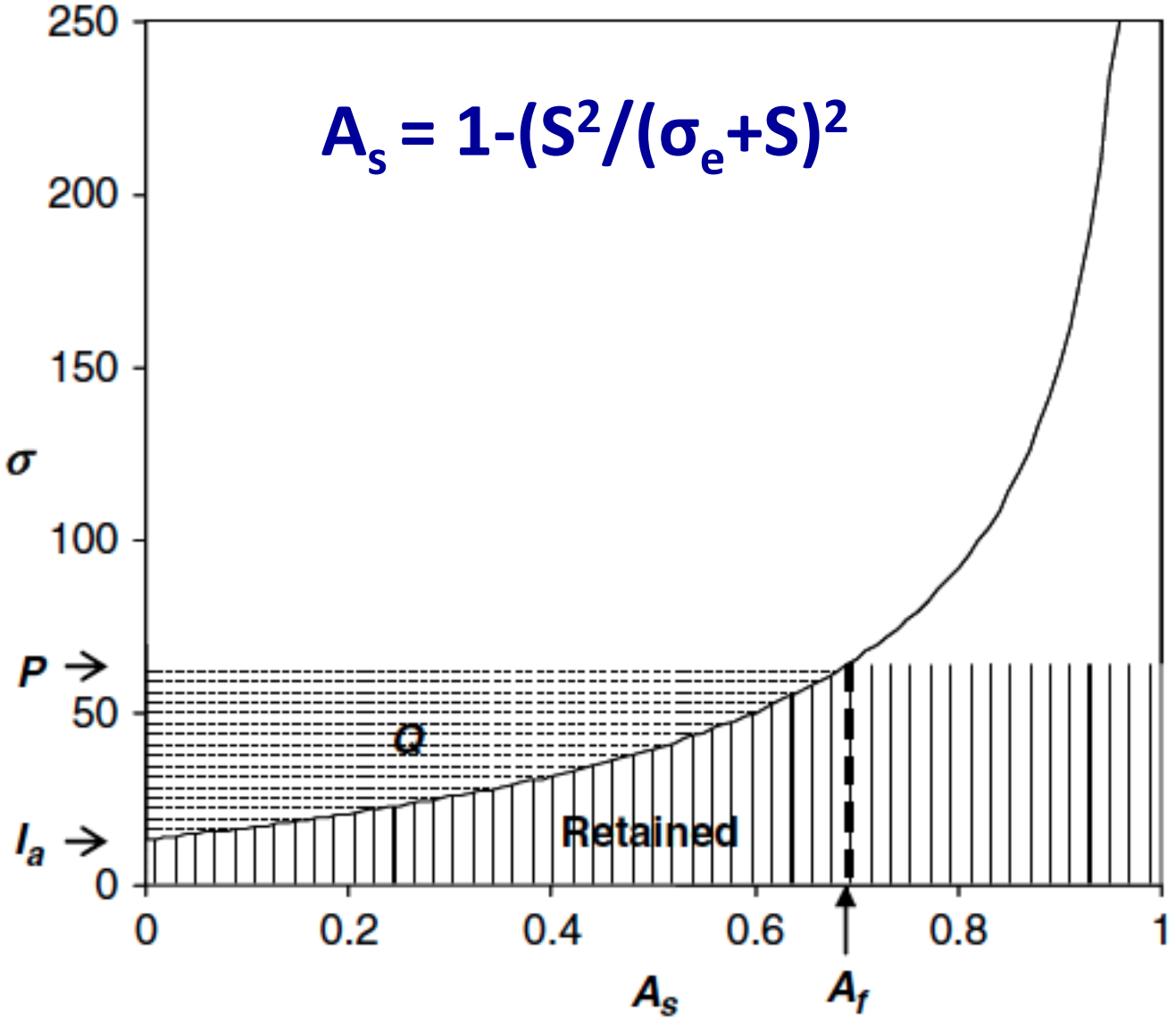
Cu gy

Wa

Unsa

Satu

$A_s = 1-(S^2/(\sigma_e+S)^2$



$/\partial P_e$

$_e+S)^2$

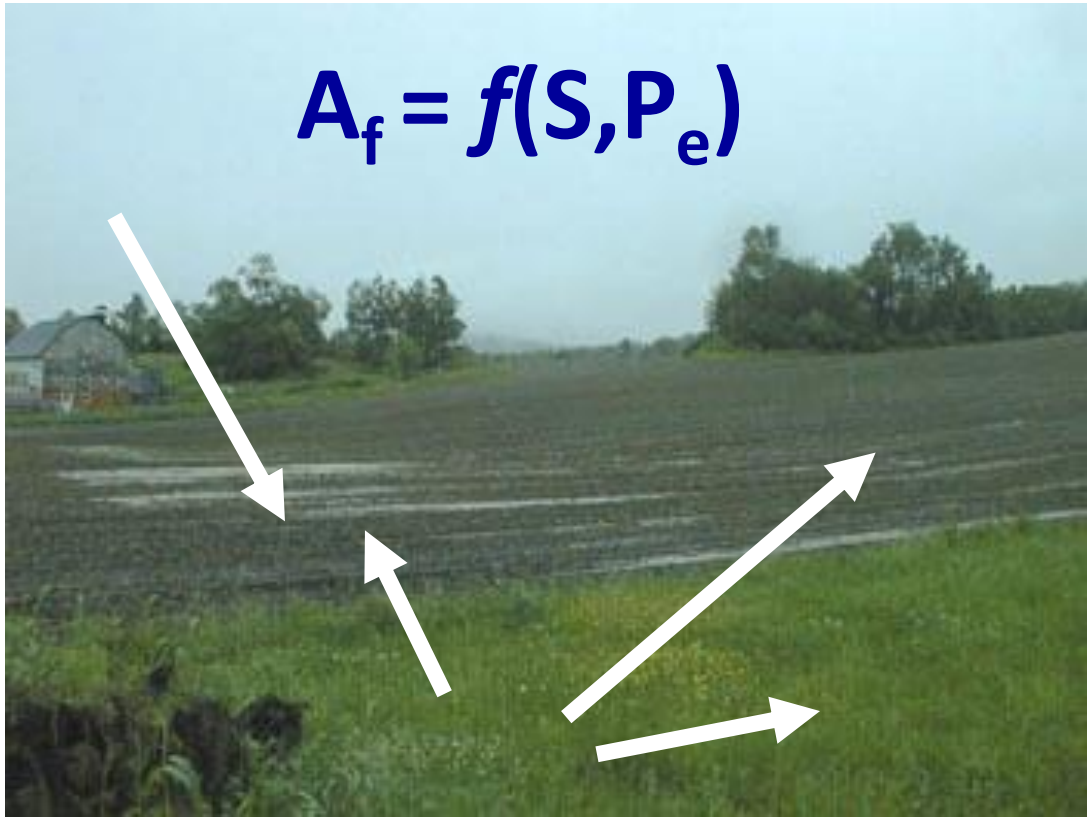
mflow or
cess" water)

$\sigma_e+S)^2$

$_s))-1$

Easton et al., 2008. *J. Hydrol*
Schneiderman et al. 2007. *Hydrol. Proc.*

We know how much area is contributing…

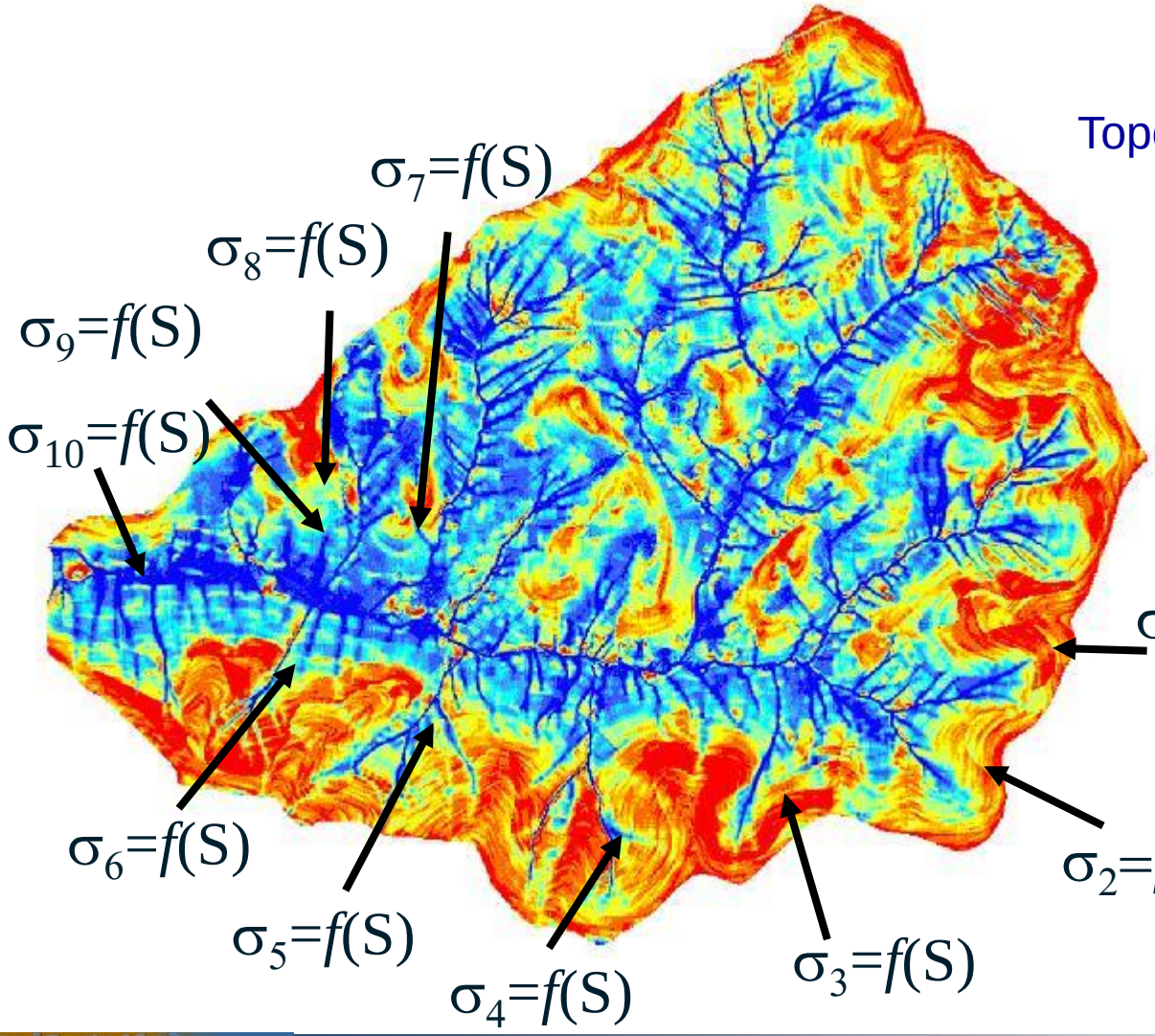


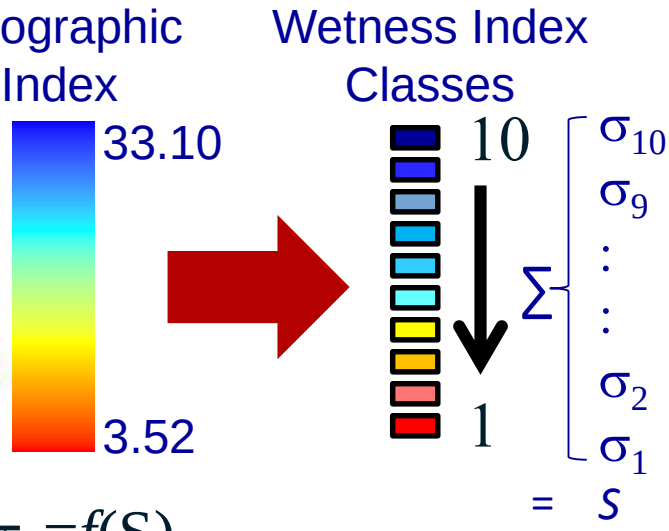
…but from where in the landscape?

Topographic Index

Wetness Index Classes

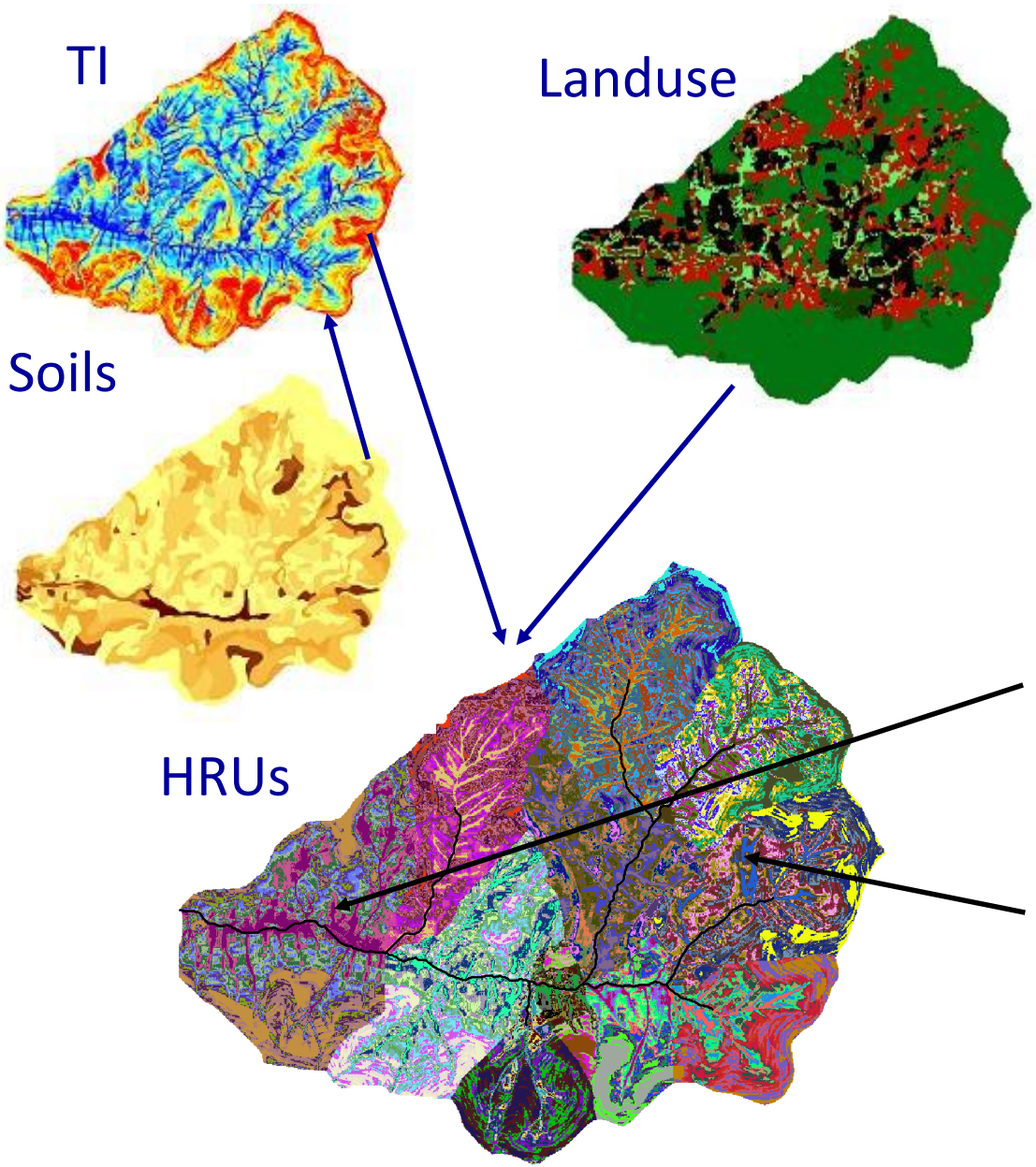
$$\lambda = \ln\left(\frac{a}{\tan\beta}\right)$$





σ_i = local storage

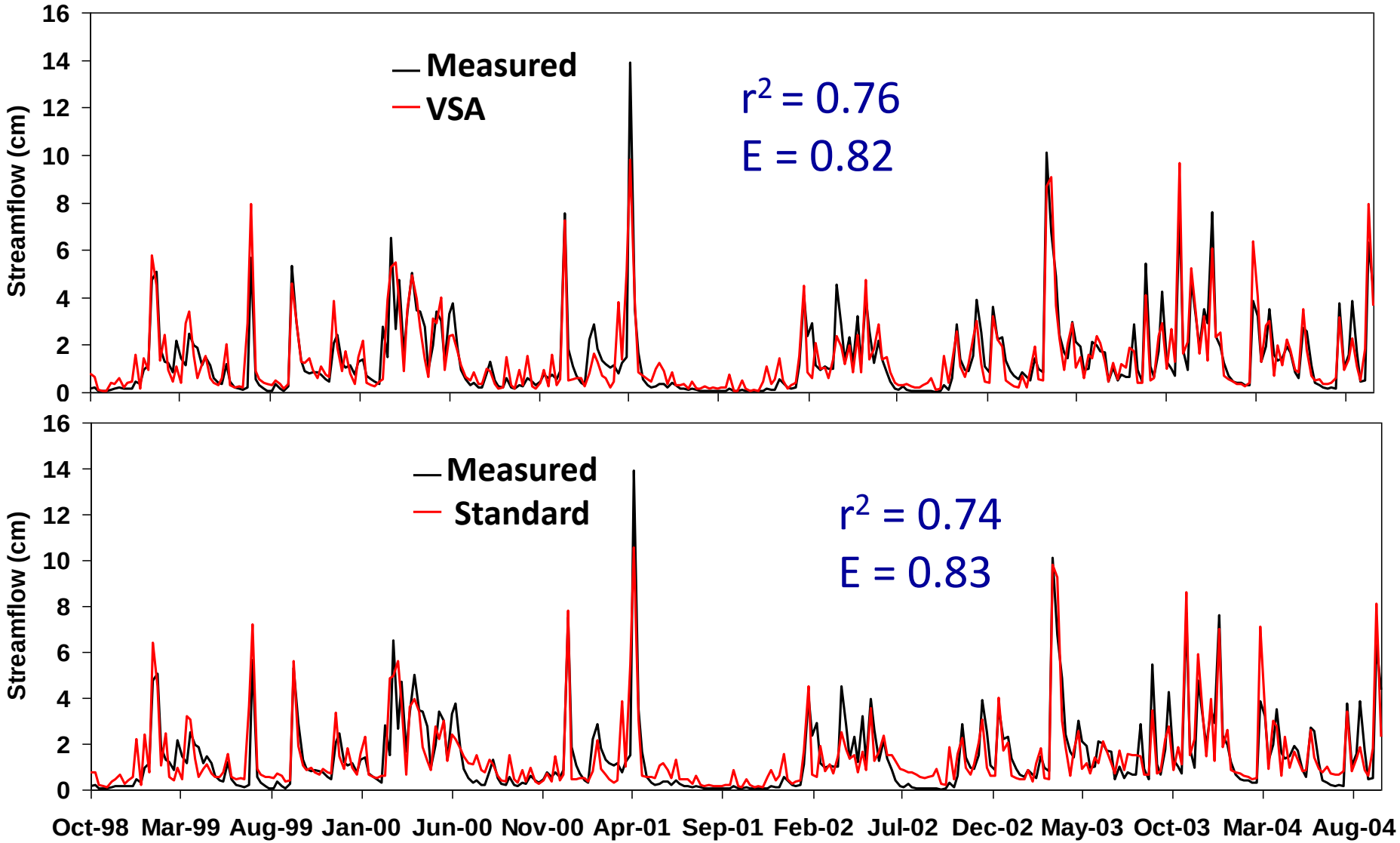
Easton et al., 2008. *J. Hydrol*
Easton et al., 2011. *Hydrol. Proc*
Schneiderman et al. 2007. *Hydrol. Proc.*



- VSA concept defines HRUs as the coincidence of topographic index and landuse

- So runoff/P loss is now not the same here (lowland pasture)
- As here (upland pasture)
- **Better Assumption?**

Test Results: Streamflow

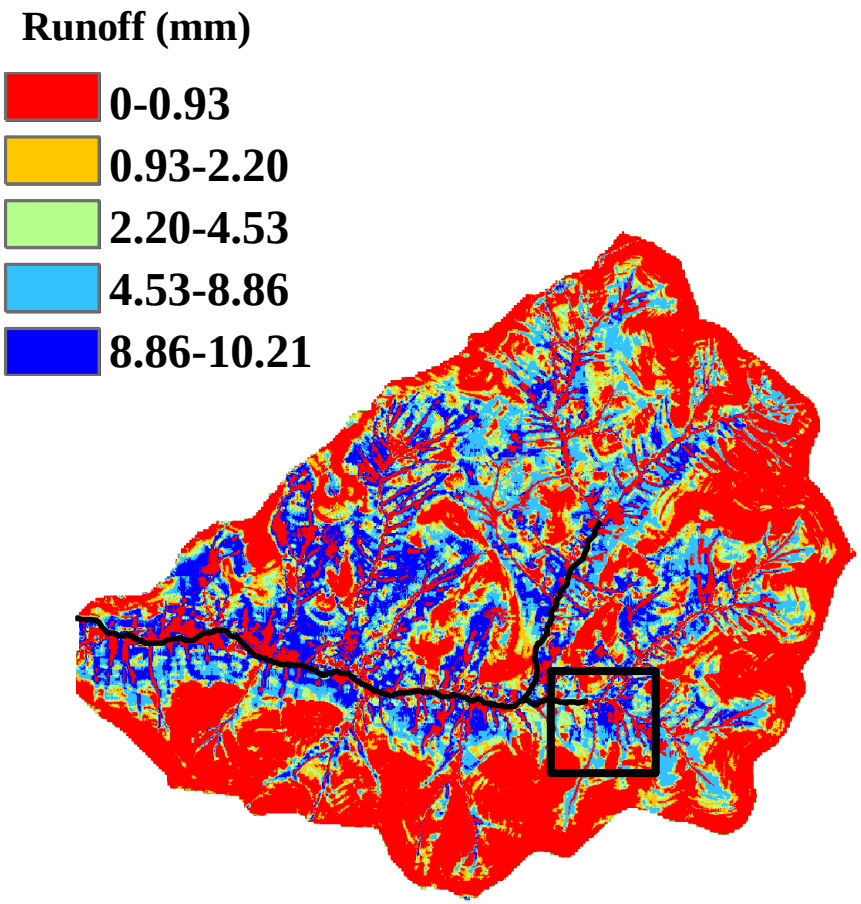


Fuka et al., 2014. *JAWRA*

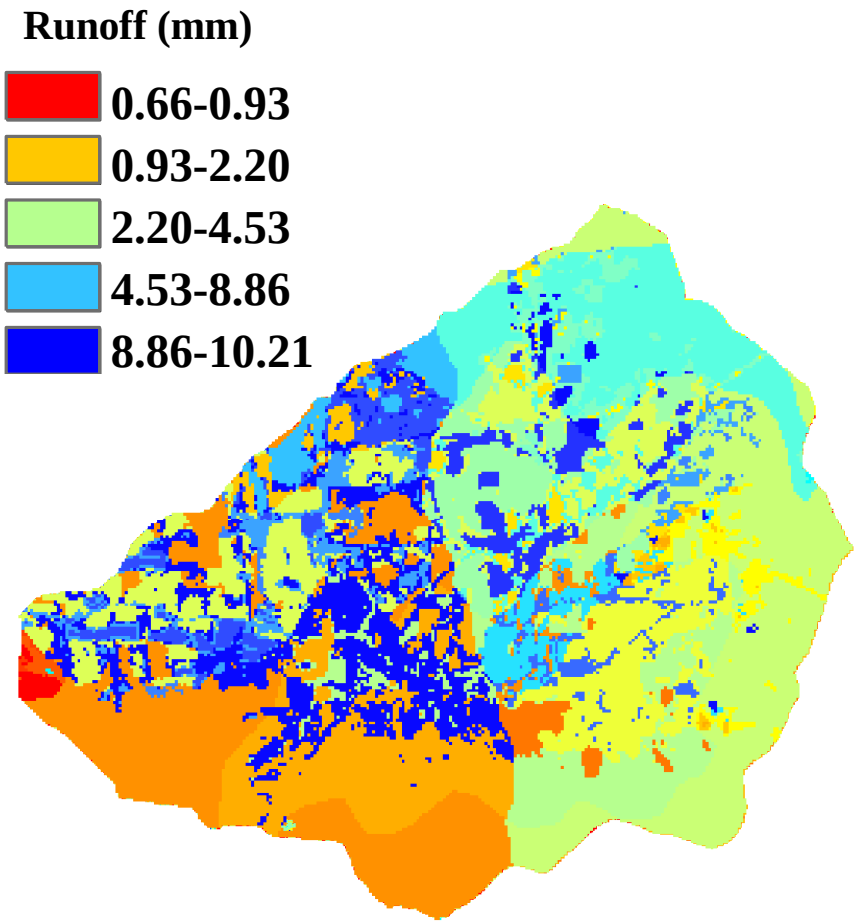
Easton et al., 2008. *J. Hydrol.*

Test Results: Runoff

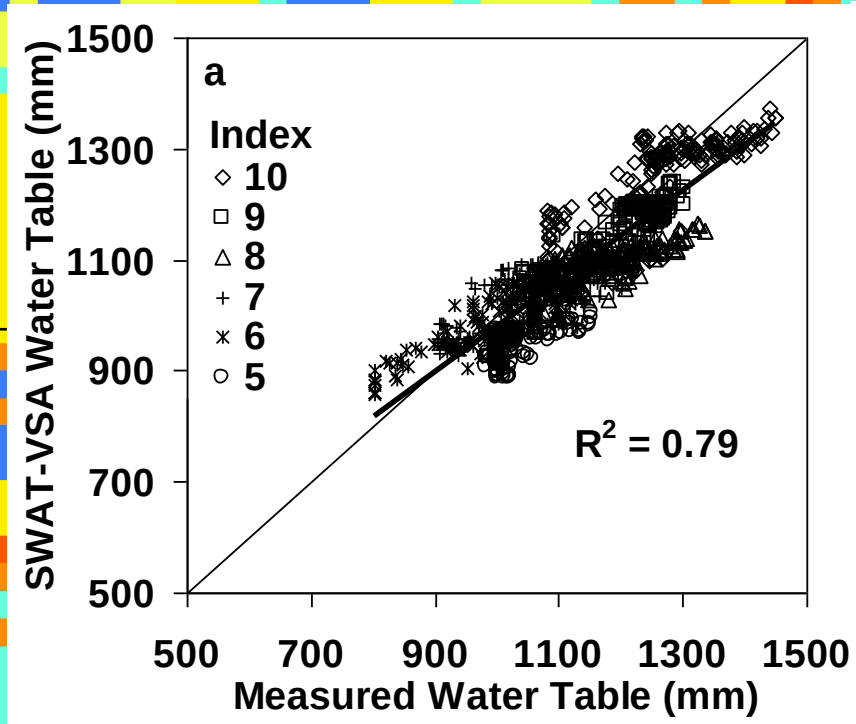
VSA

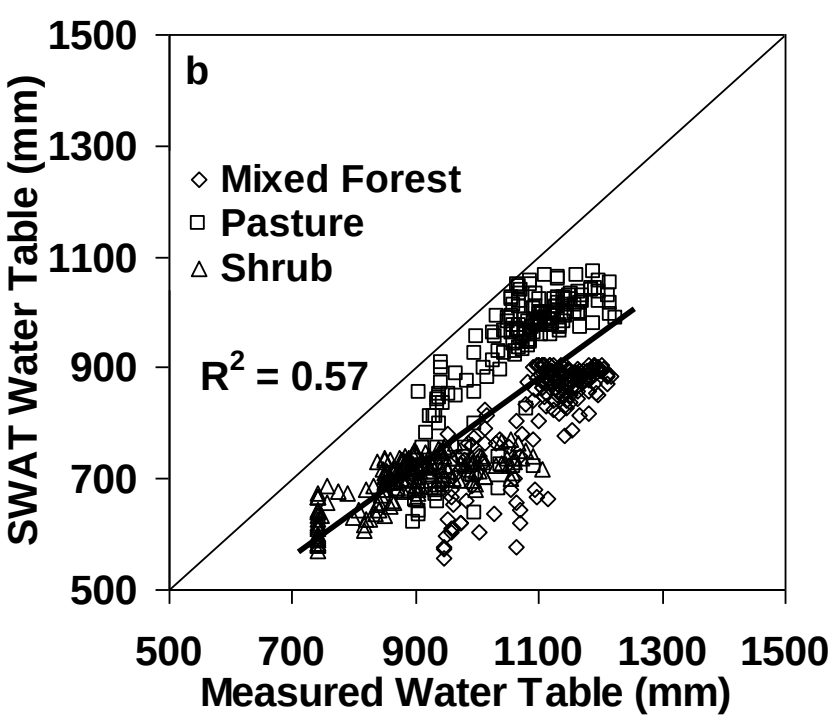


Standard

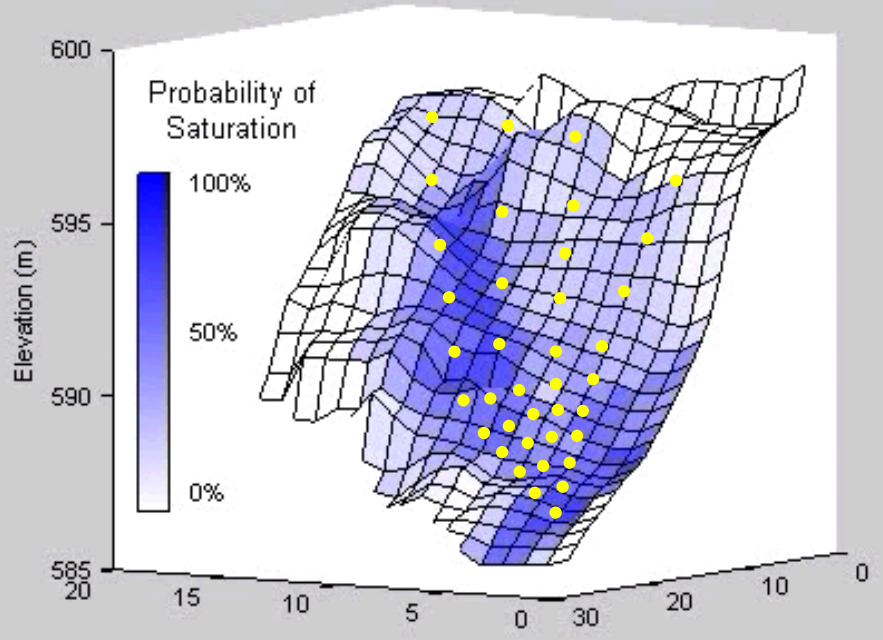


Easton et al., 2008. *J. Hydrol.*


a
Index
10
9
8
7
6
5
R^2 = 0.79
SWAT-VSA Water Table (mm)
Measured Water Table (mm)
500
700
900
1100
1300
1500

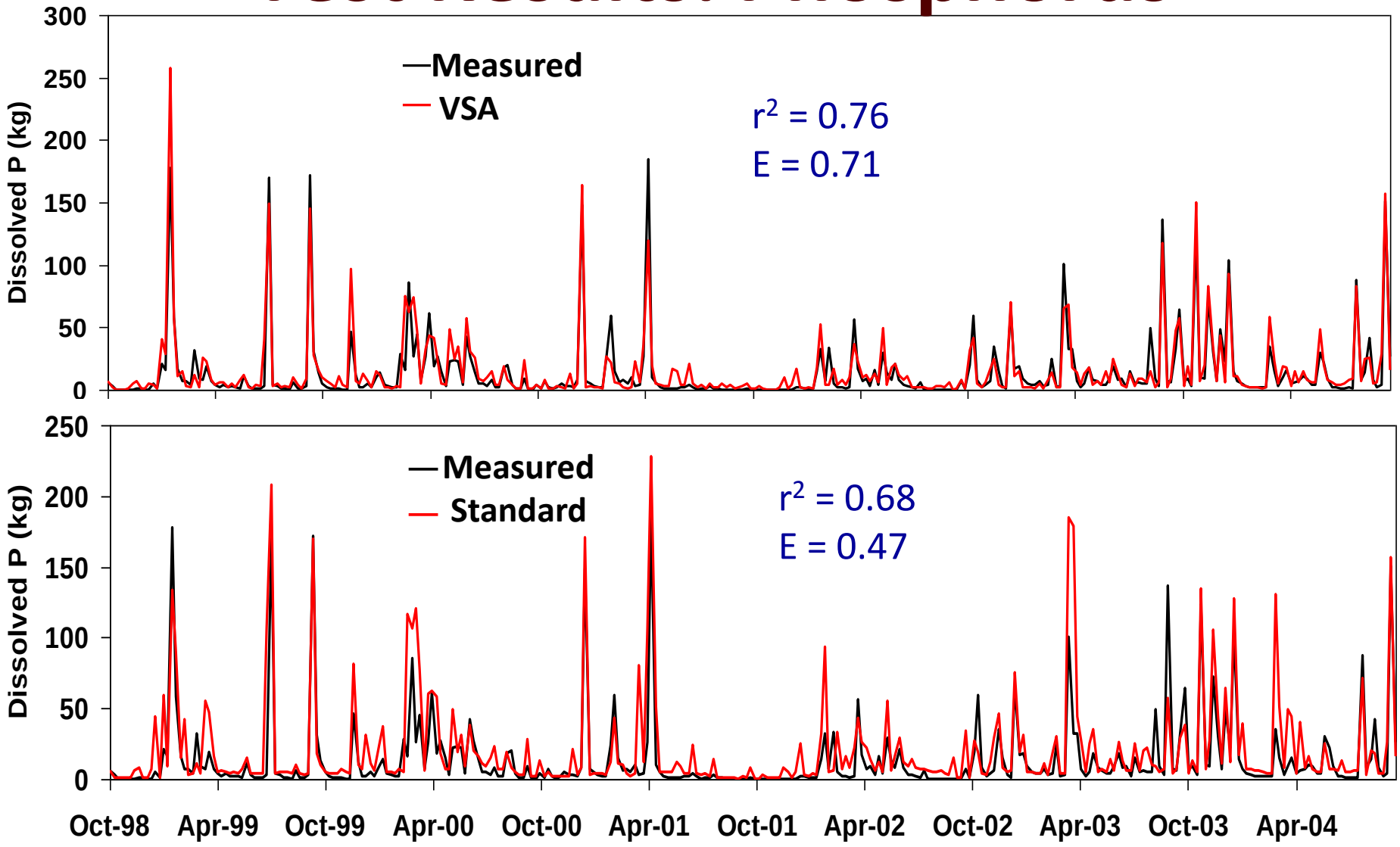

b
Mixed Forest
Pasture
Shrub
R^2 = 0.57
SWAT Water Table (mm)
Measured Water Table (mm)
500
700
900
1100
1300
1500

0
April
May
June
July

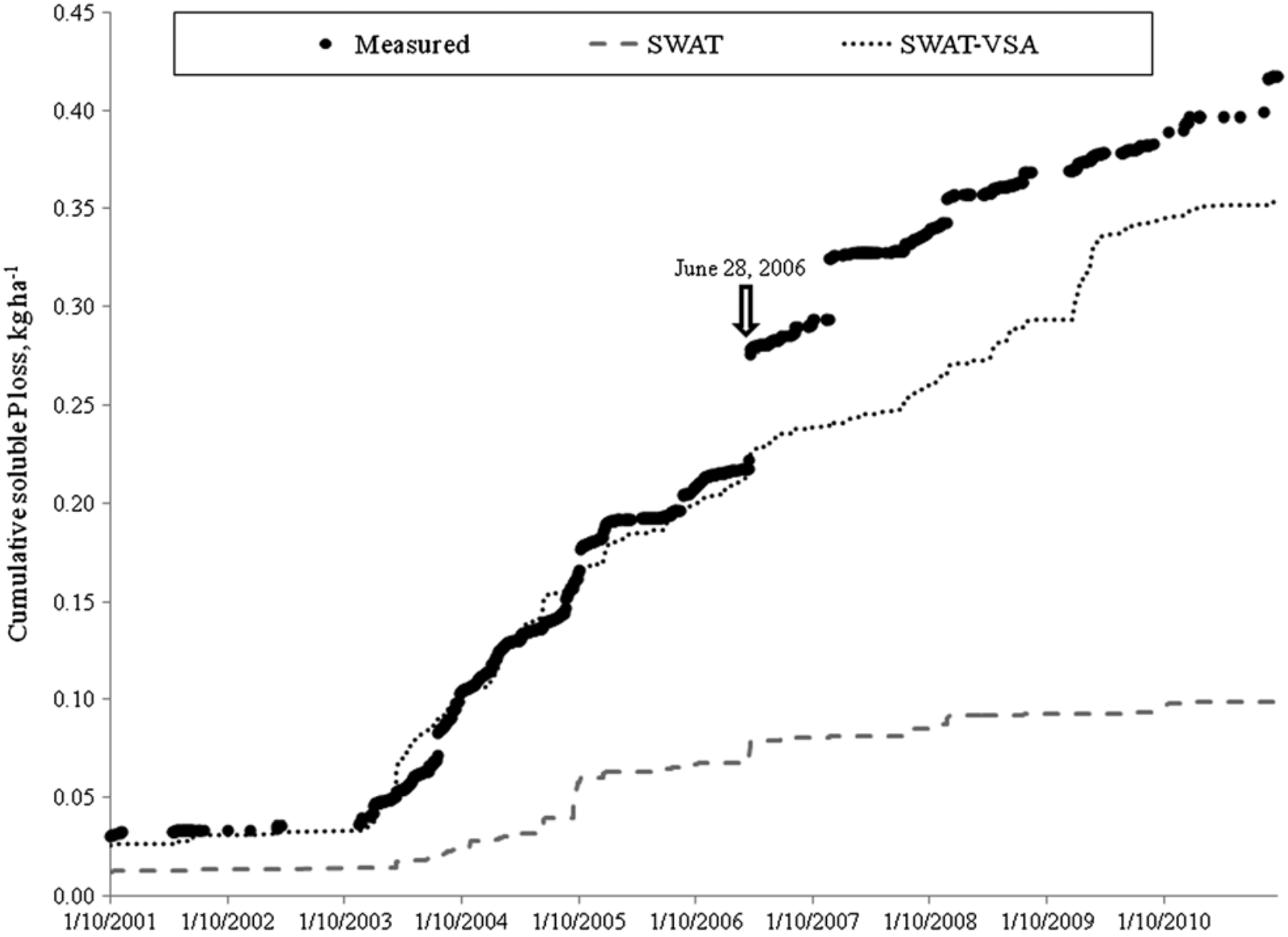

Probability of Saturation
100%
50%
0%
Elevation (m)
600
595
590
585
20
15
10
5
0
30
20
10
0

VSA Demo

Test Results: Phosphorus



Easton et al., 2008. *J. Hydrol.*

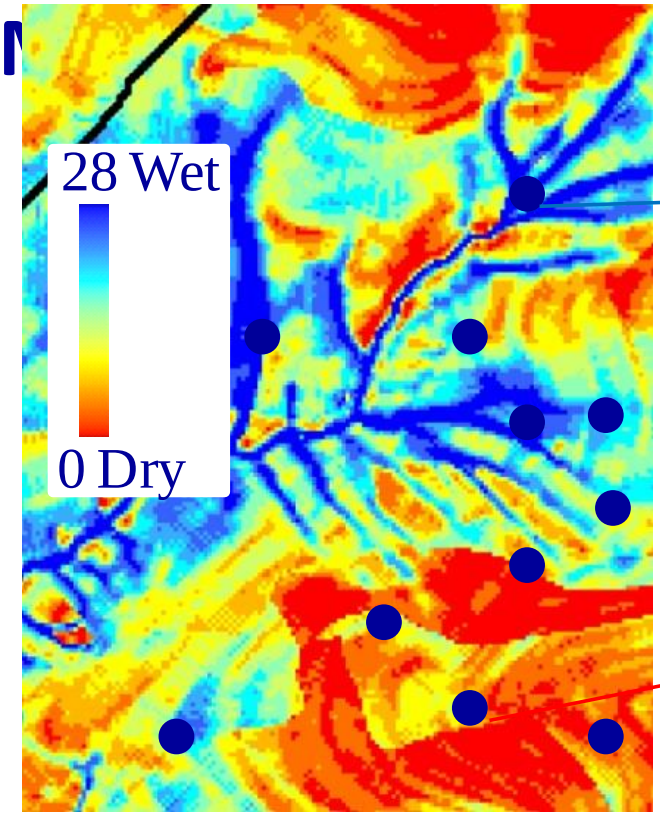


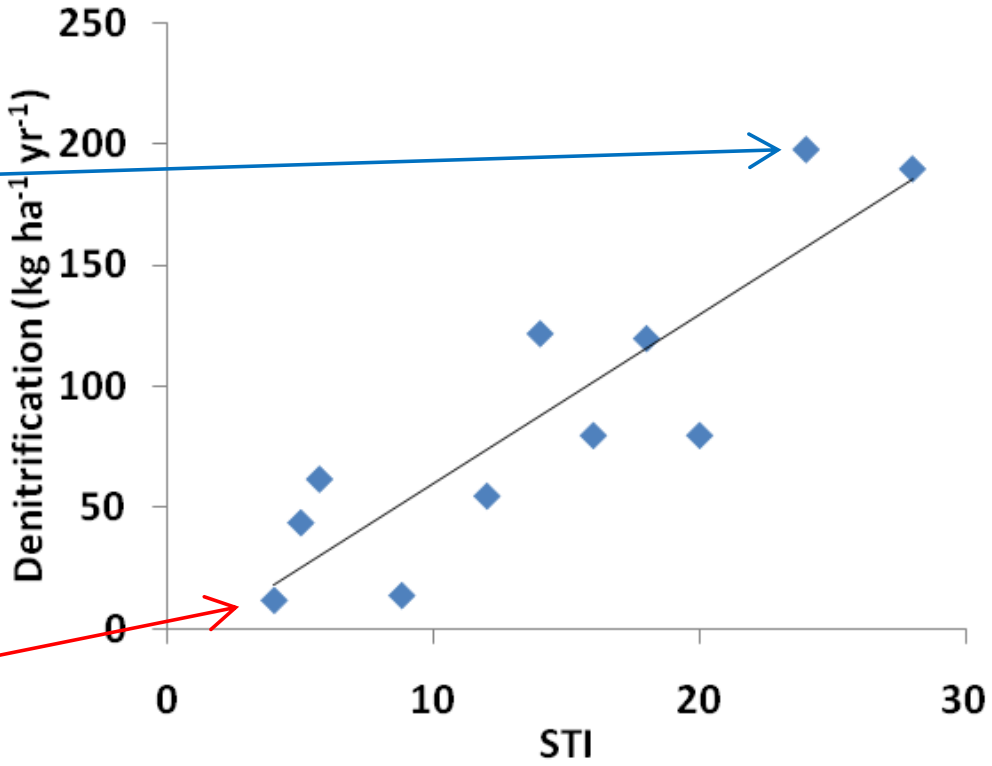
Collick et al., 2014. Hydrol Proc

Key Messages

- Identifying your dominant hydrology is a critical first step to correct characterization
- Do not be bound by what a model says it should be
  - Chose the right model for the right problem
- CAVEAT: as your DEM resolution converges with the depth of your hydrologically dynamic vadose zone you begin to violate the kinematic approximation that ties the topographic index to the theory of variable source hydrology, **Darcy's Law**

Strong correlation between *Terrain* and biochemical processes as well…**Denitrification,**





New NSF WSC–Cat 1 grant will be exploring how denitrification and biogeochemical cycling will change given the future climate, and how these landscape changes propagate to impact the estuary

Easton et al. 2014

Google Tile Server

Custom Tile Server

On Demand Tile Generator

3rd Party Java Script Libraries

Map Styling

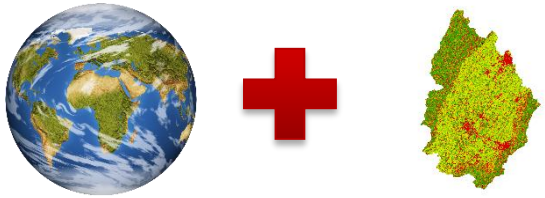
Geospatial Data

Client Side

Server Side

Model Side

Interactive HTML Web Map Displays Runoff, AWC, P Flux, and Erosion for 24, 48, 72 and 96 hr futurecasts



Tabular Data

Operational Script

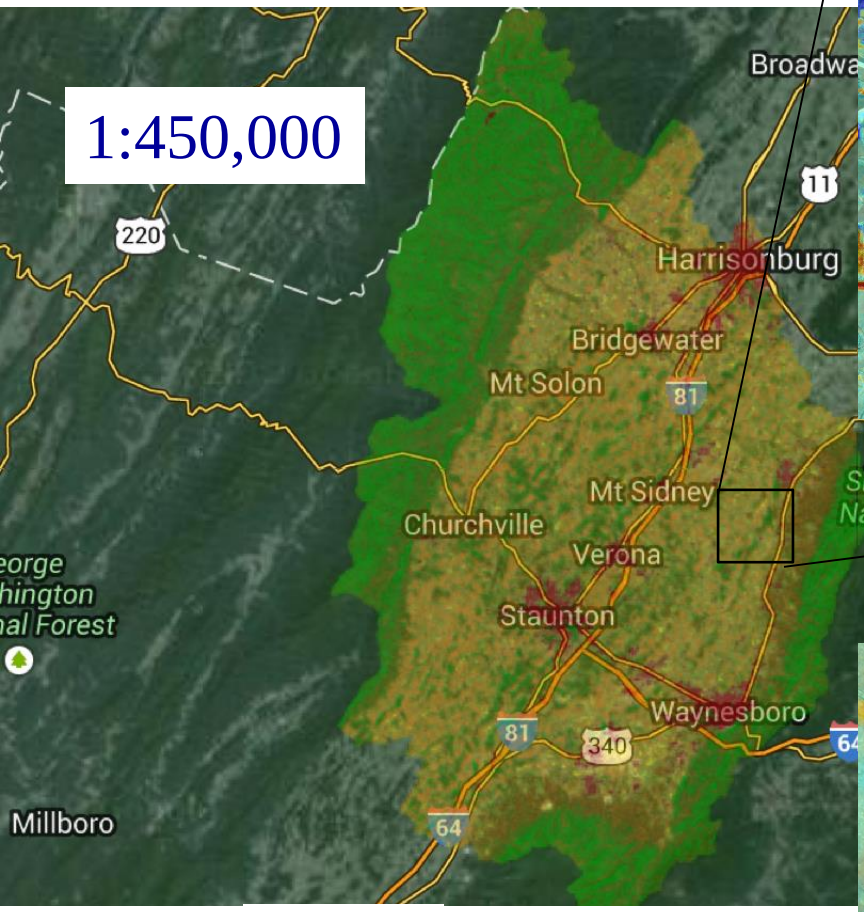
SWAT

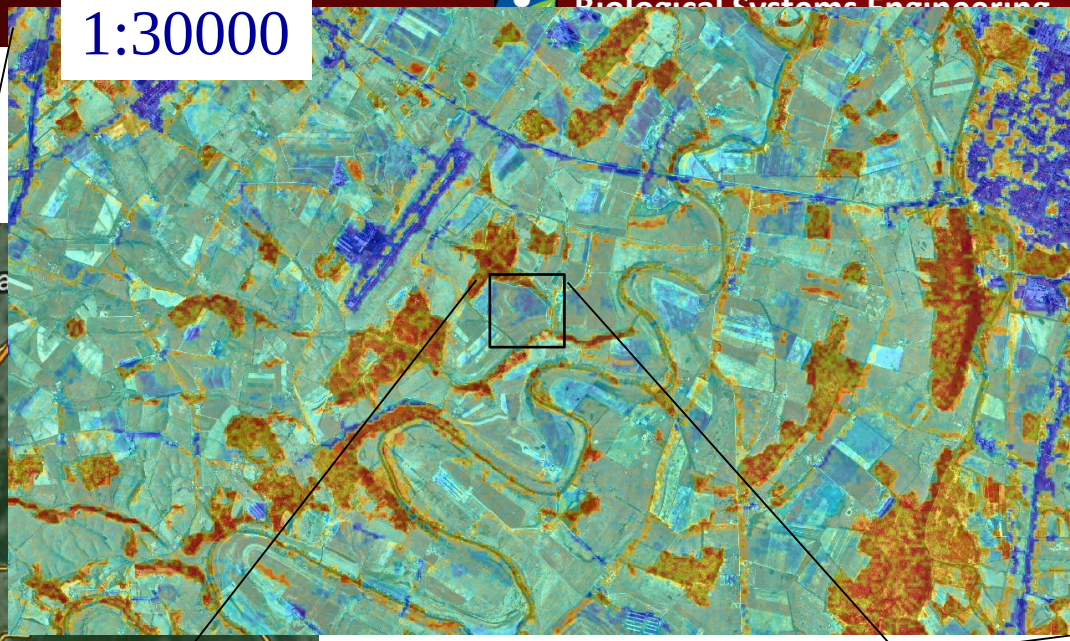
Forecast and Past Weather Data

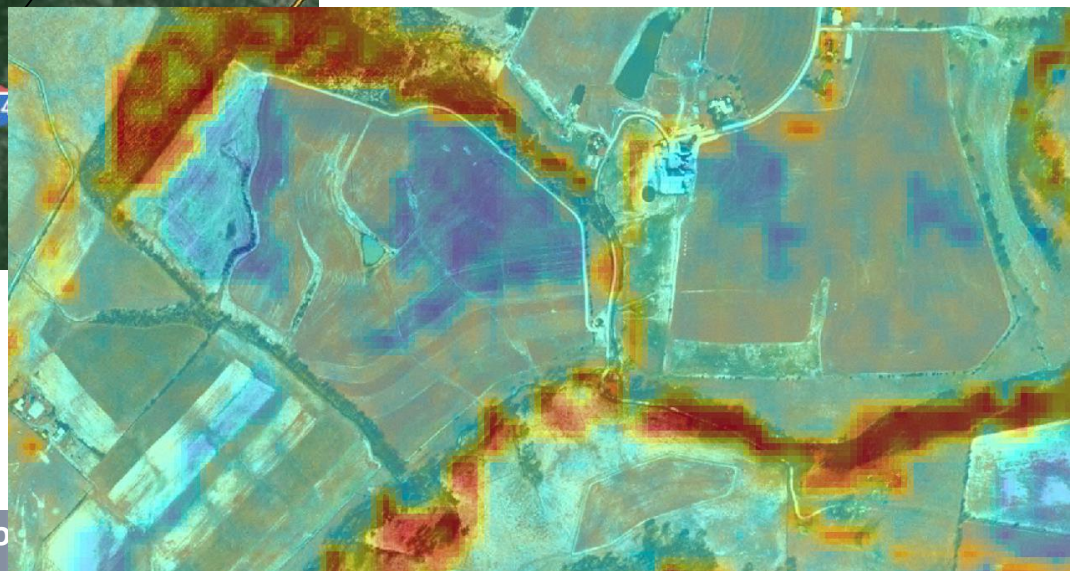
SWAT Inputs

Sommertlot and Easton 2014

Shenandoah







Runoff

28 mm
20
12
0 mm

1:5000

Hydrology Humor…Sorry