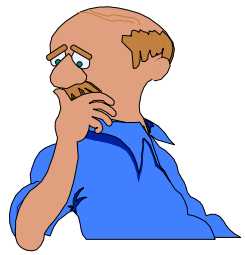
A simple mathematical model to predict Agri-chemical Losses in Agricultural Drainage Tiles

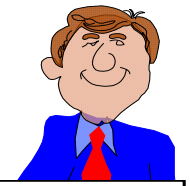


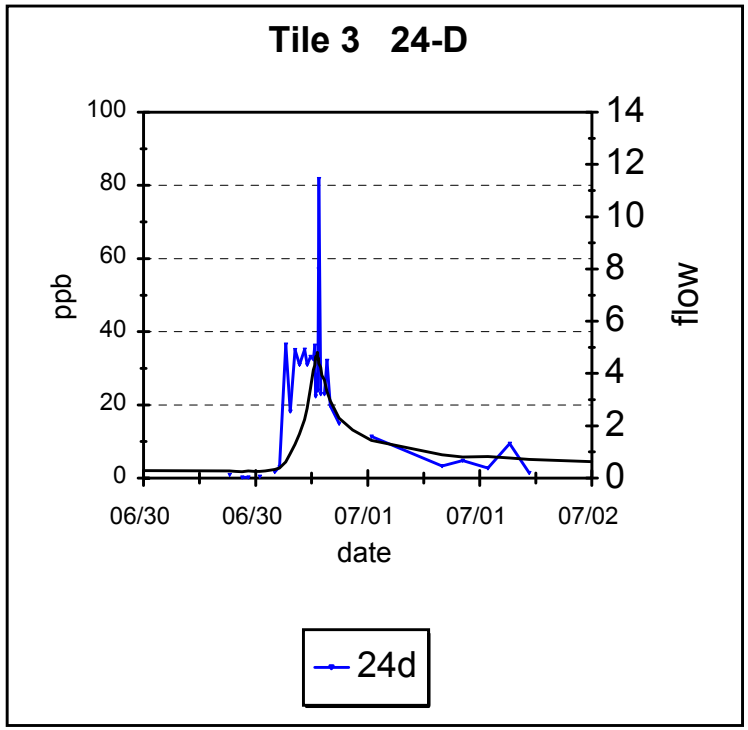
Robert Wells, Sunnie A. Aburime, Larry Geohring, Sam Kung, Rony Wallach and Tammo Steenhuis

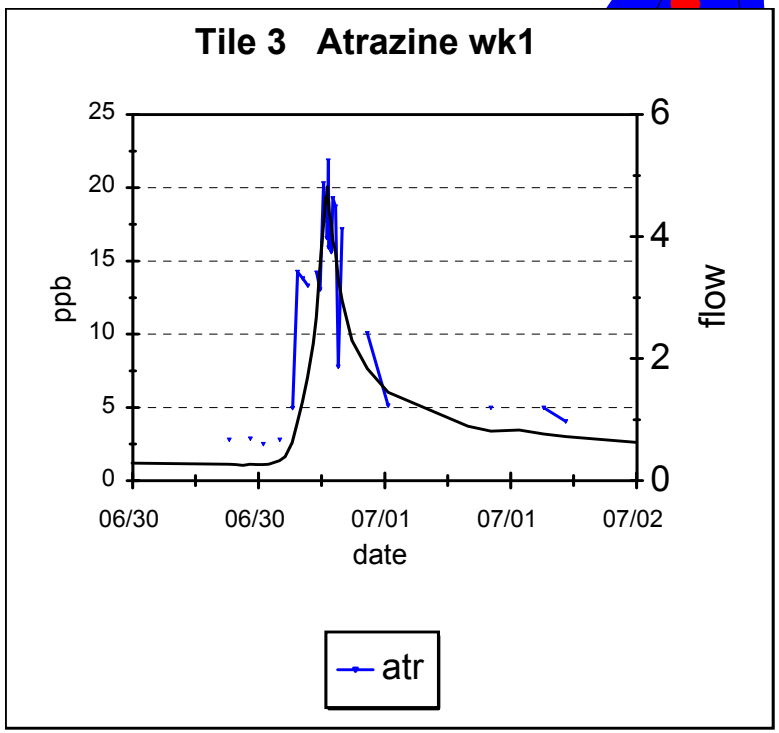
CHEMICAL MOVEMENT

- knowledge limiting
- much faster than can be predicted with standard models

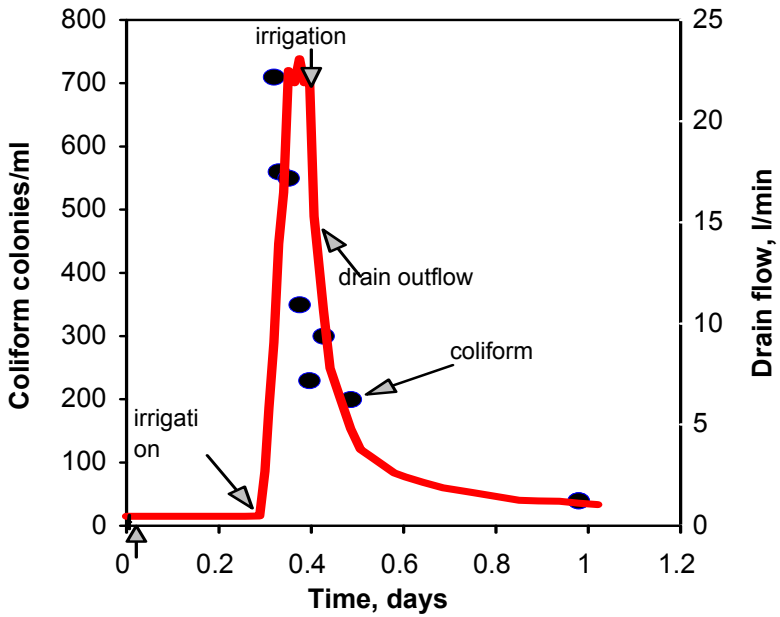
PESTICIDE LOSS IN TILE LINES

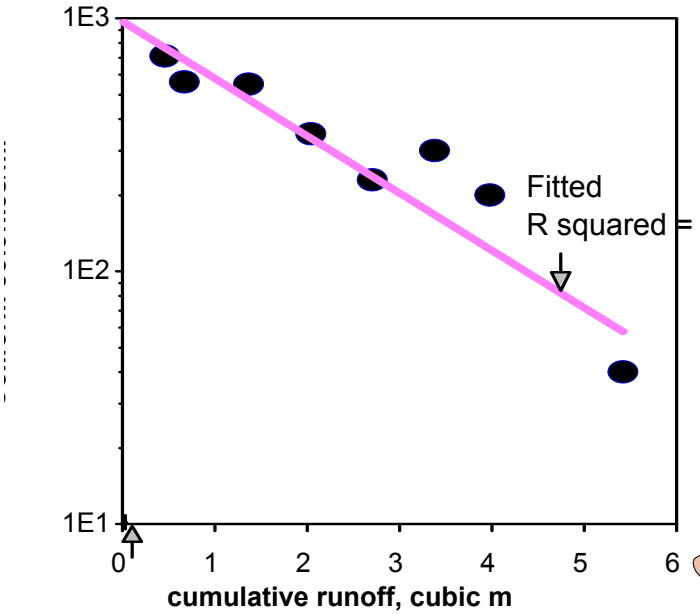


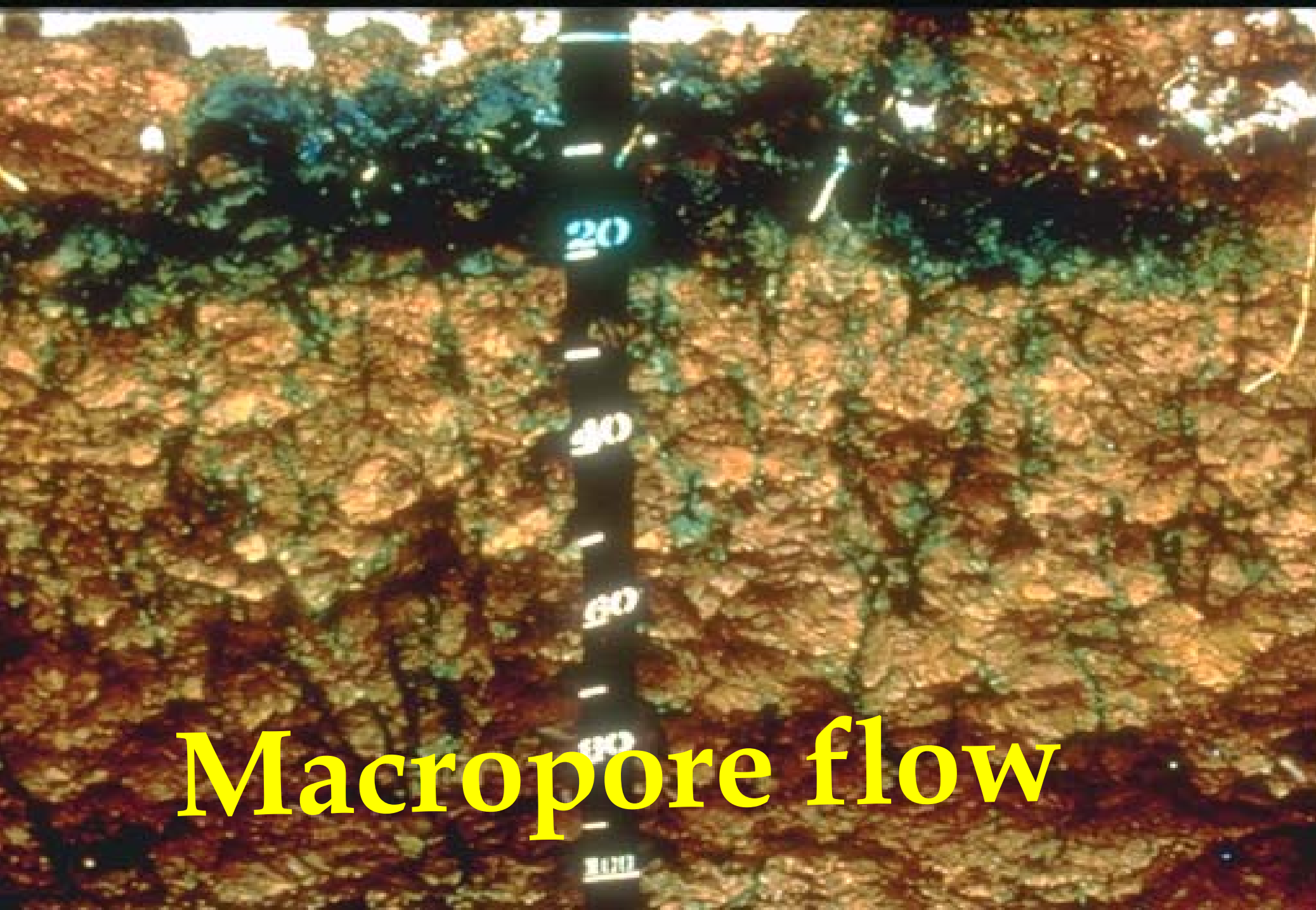




COLIFORM IN TILE WATER






Macropore flow

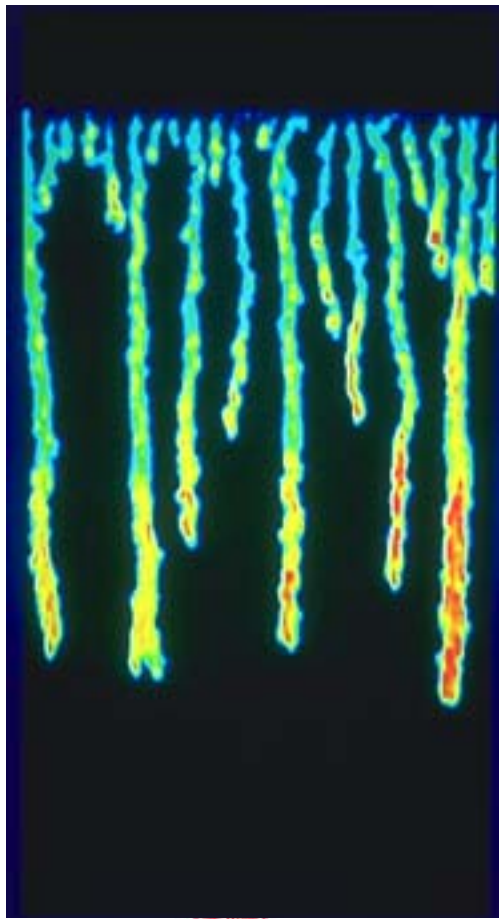

Funnel Flow

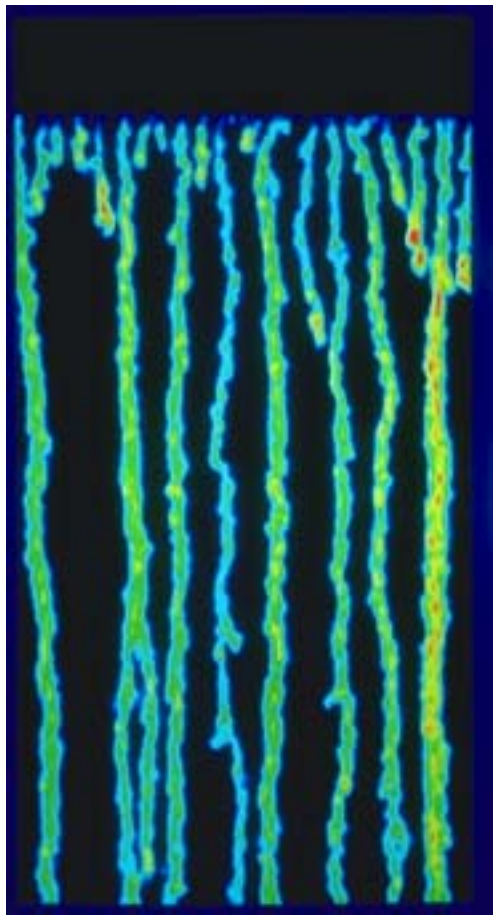
Funneled Finger Flow


Layered soil
Coarse layer

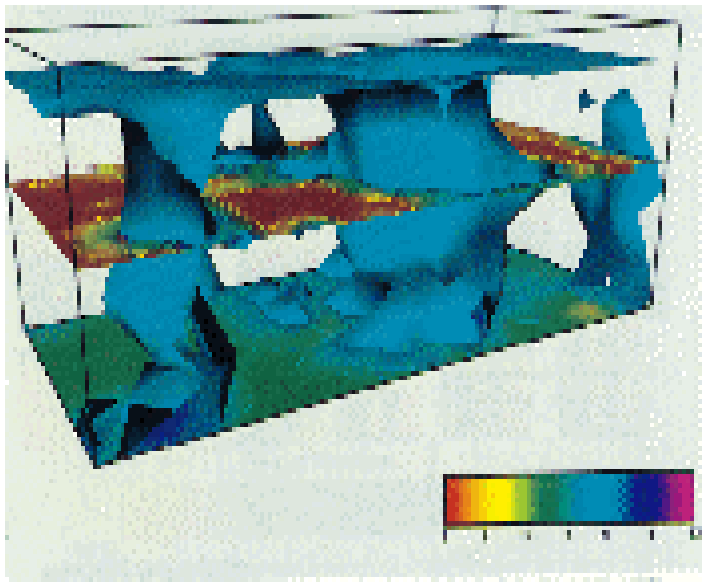
Fingered Flow in Homogeneous Sand

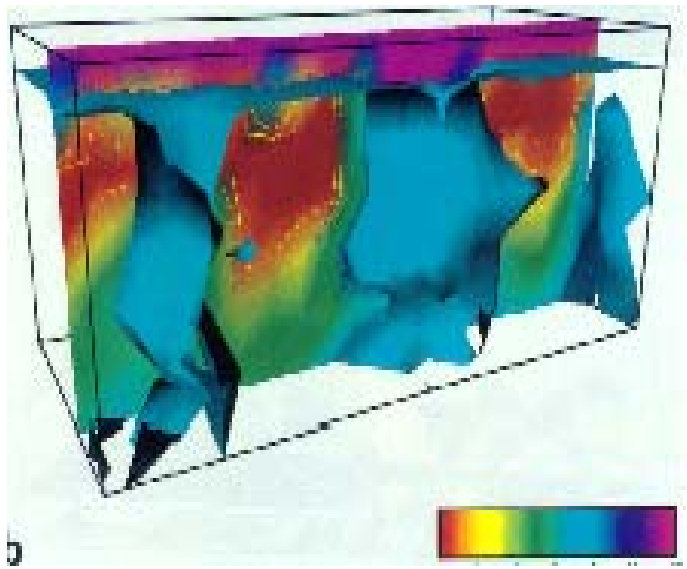
Finger Flow in Homegenous sand



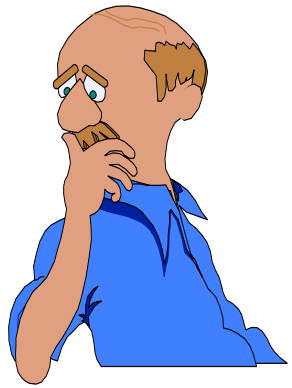


Finger Flow in Water Repellent Sand



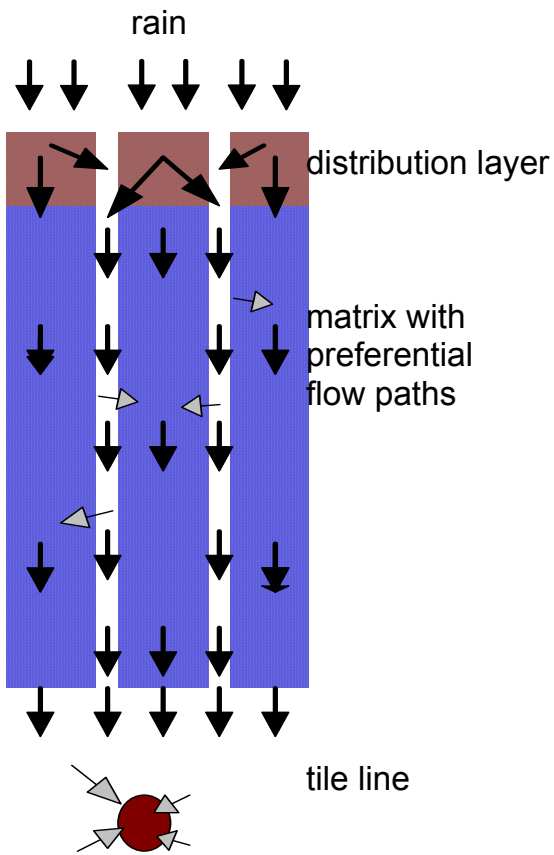


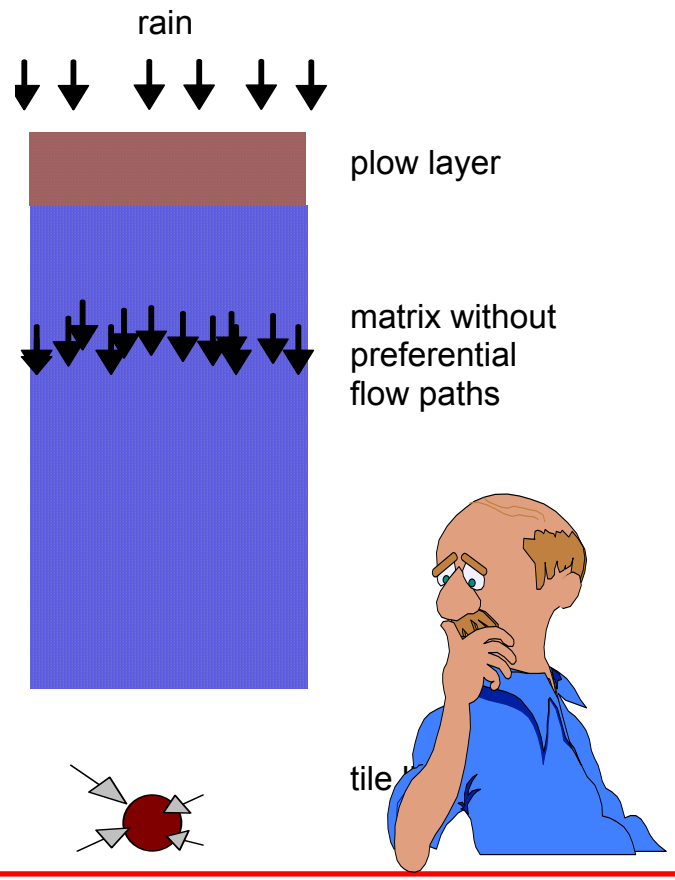
OBJECTIVE



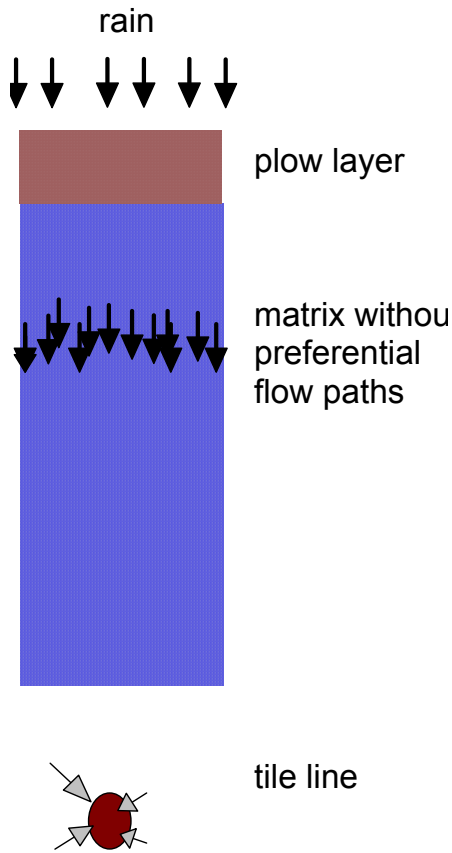
Use simple mathematical model to predict high concentrations in tile line water shortly after application

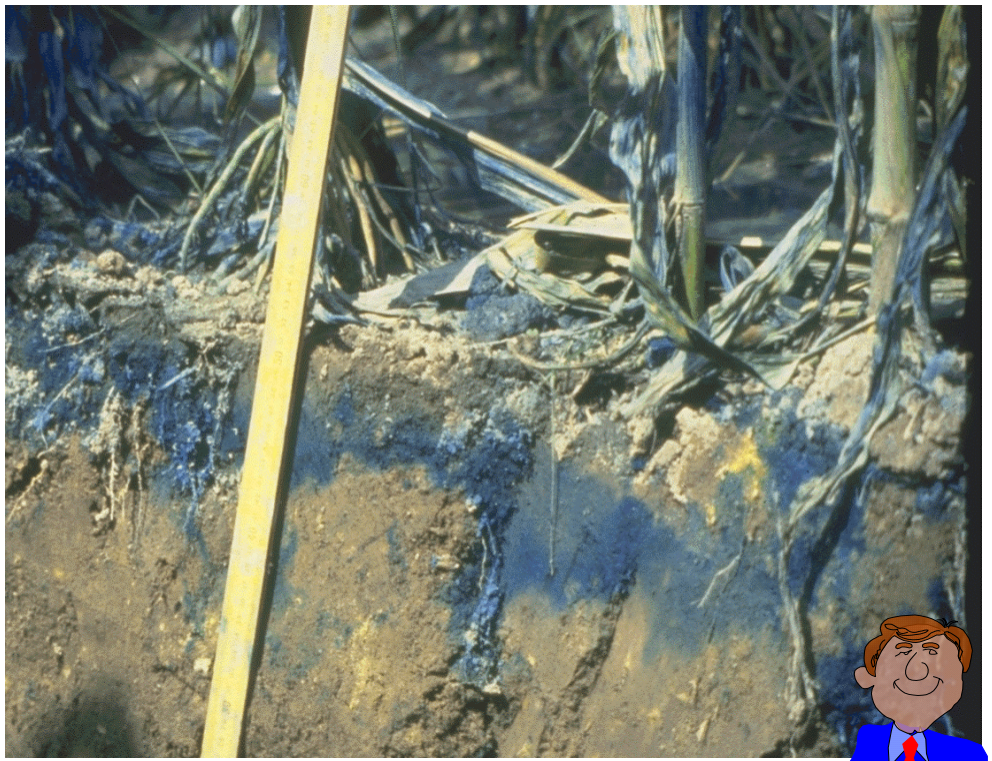
CONCEPTUAL MODEL



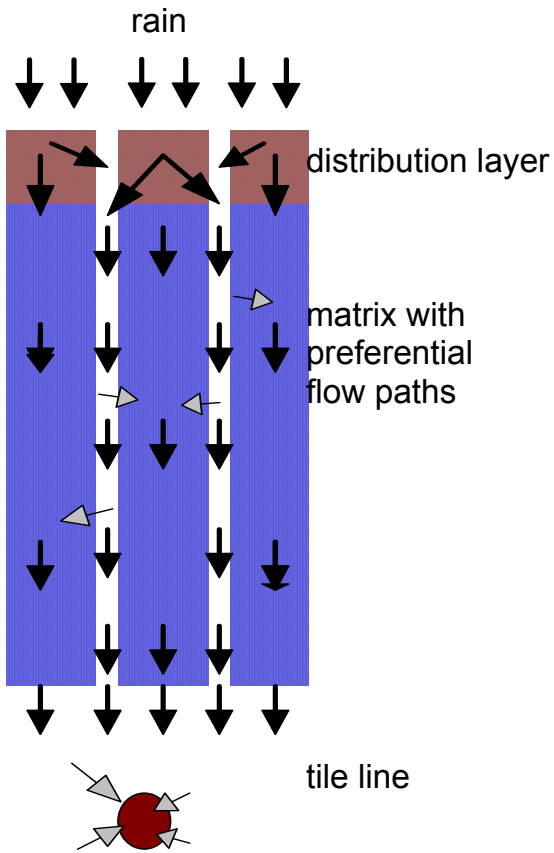


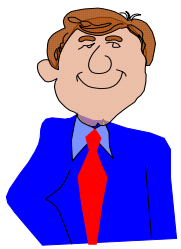
PLUG FLOW
CONVECTIVE DISPERSIVE



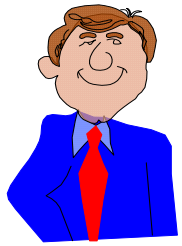


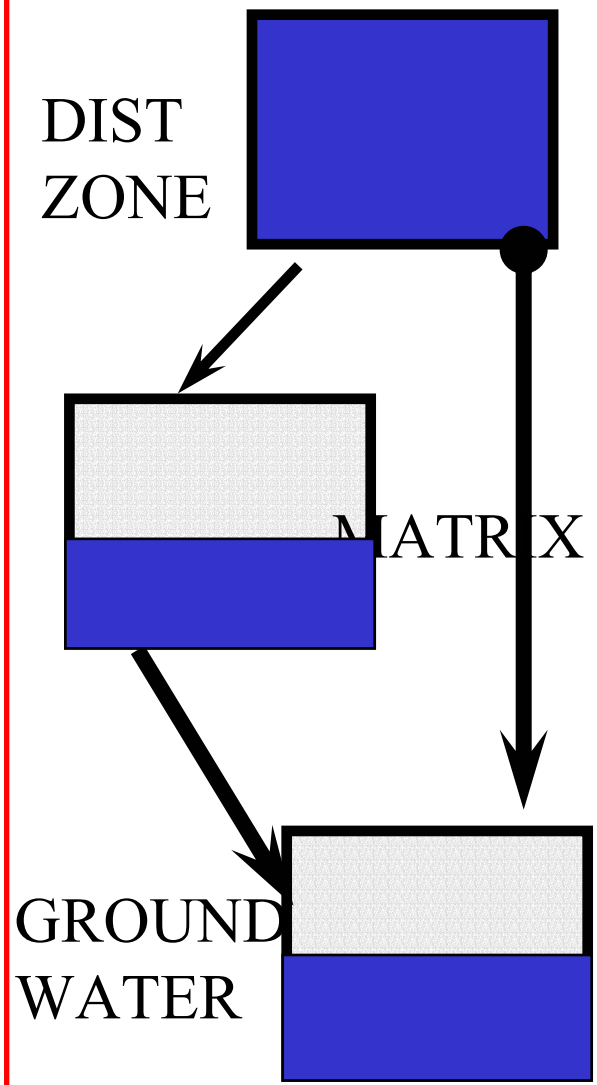
PREFERENTIAL FLOW

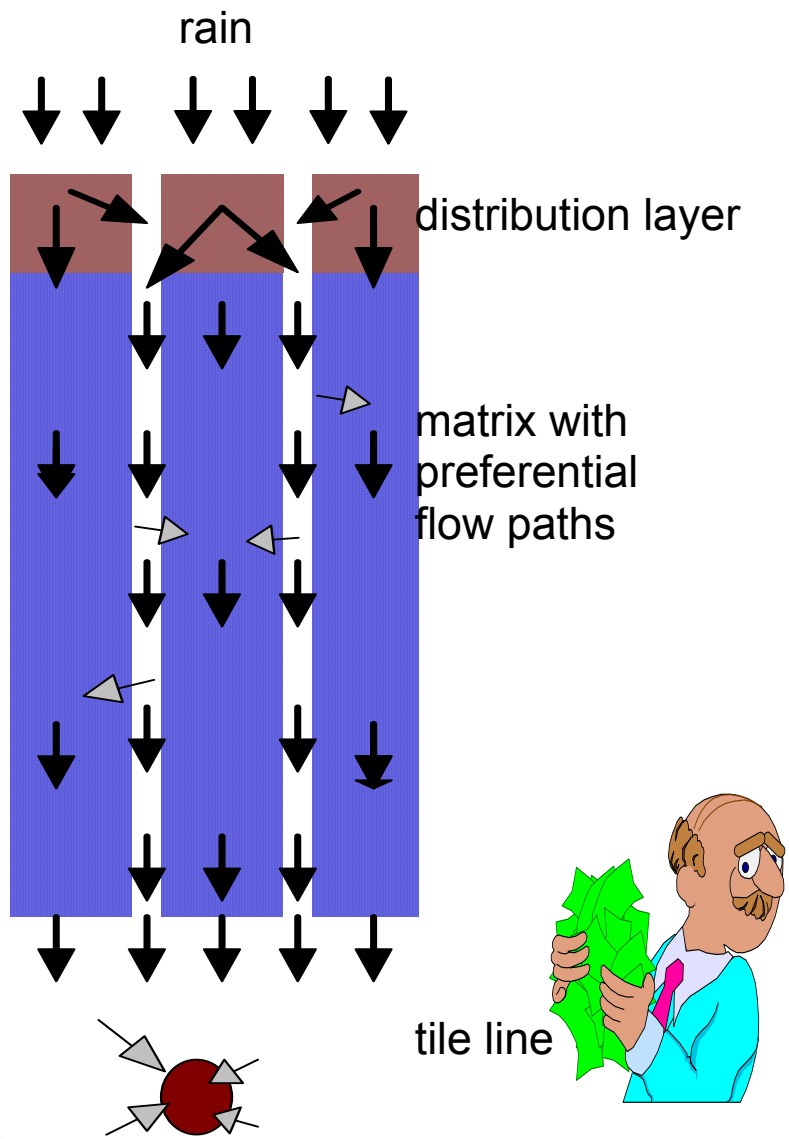




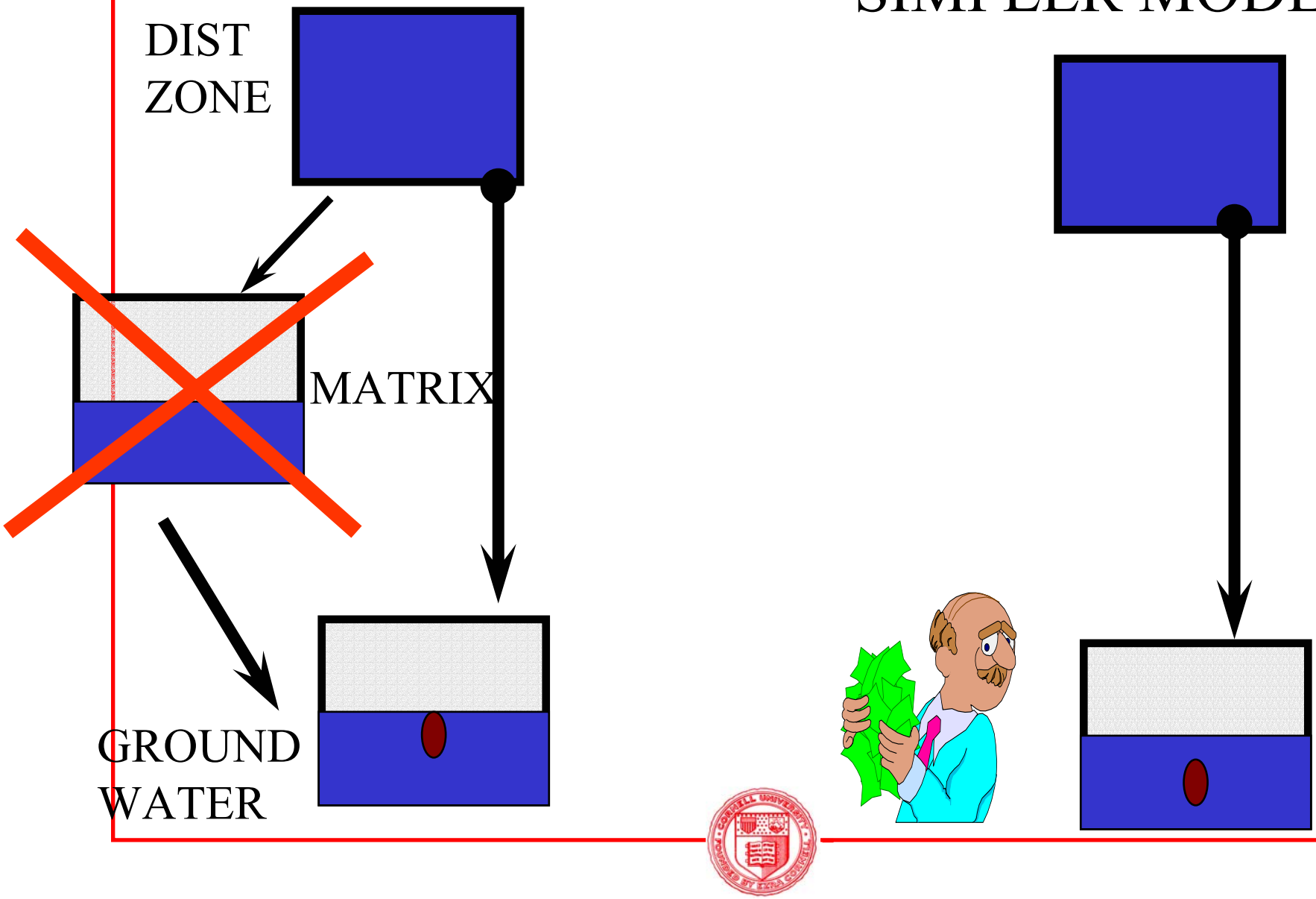
PREFERENTIAL FLOW



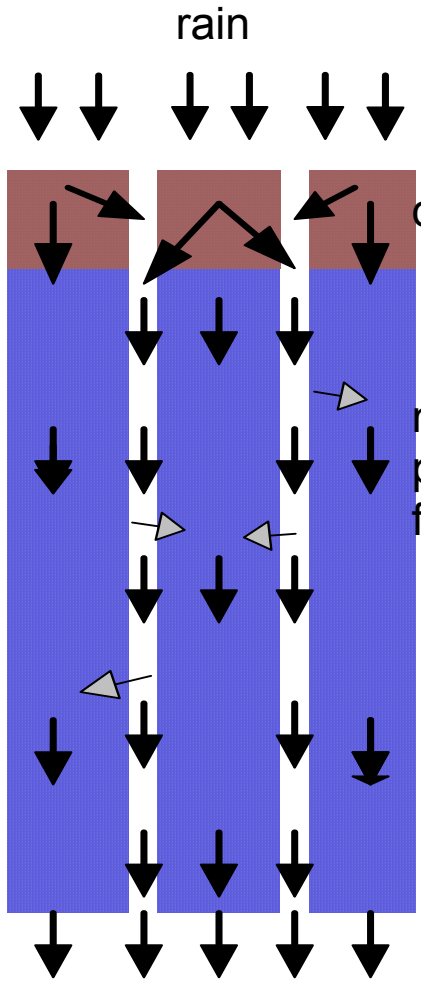

DIST
ZONE
MATRIX
GROUND
WATER

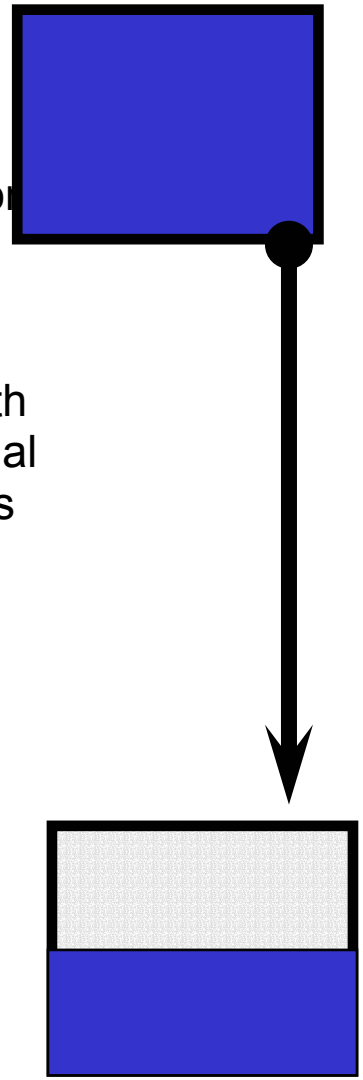

rain
distribution layer
matrix with
preferential
flow paths
tile line

SIMPLER MODEL

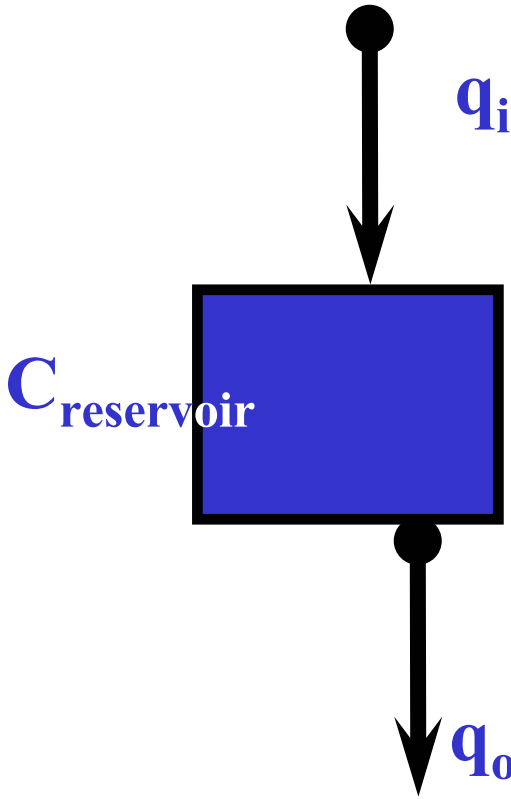


summary


rain
distribution
matrix with
preferential
flow paths
tile line



MODEL
general



$$\frac{\Delta M}{\Delta t} = q_{in}C_{in} - q_{out}C_{reservoir}$$

$$C_{reservoir} = \frac{M}{W}$$

SOLUTE FLOW MODEL assumptions

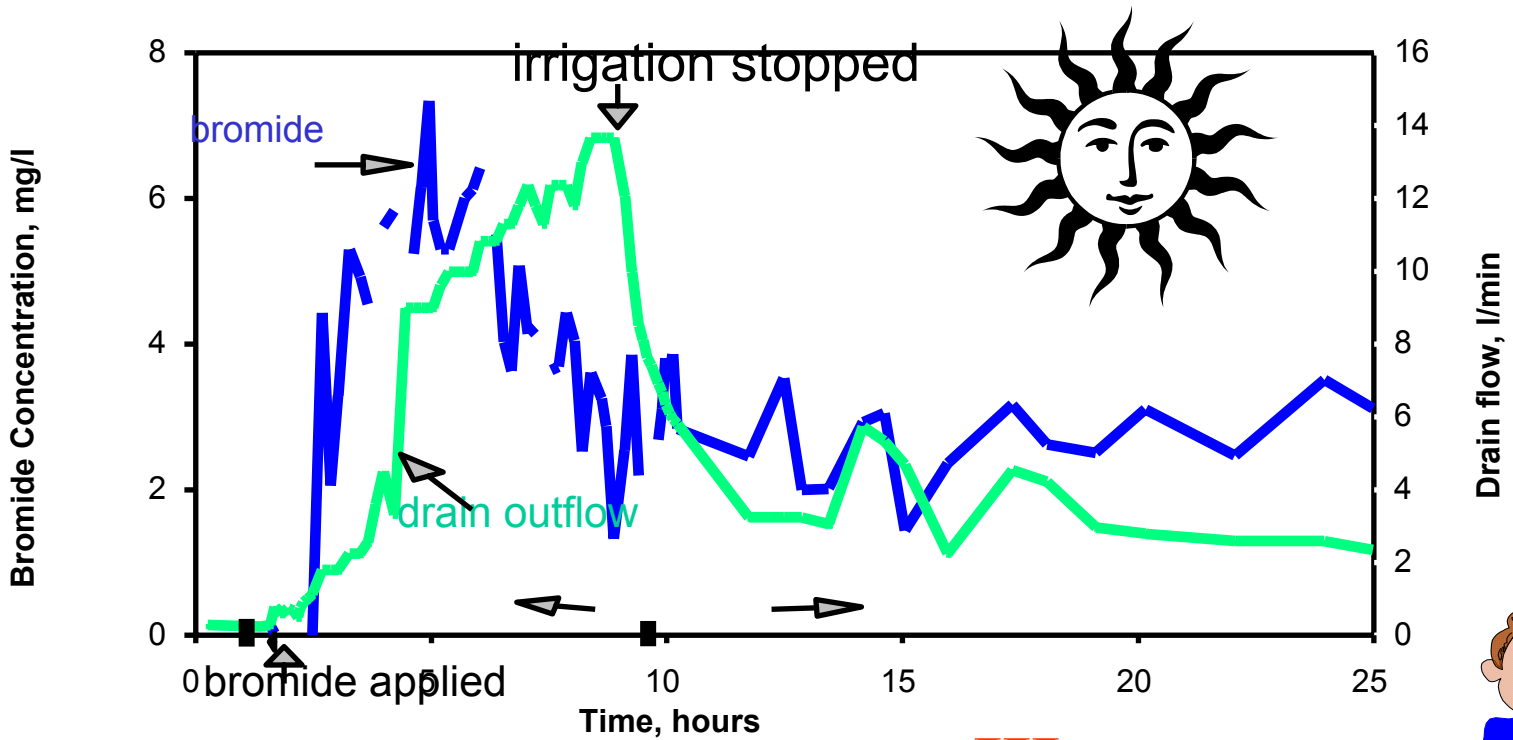
- travel time between reservoirs is short
- distribution zone and ground water are linear reservoirs
- not all land area between drains contributes water and solute to tile line

SOLUTE FLOW MODEL assumptions

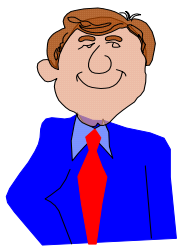
three distinct periods

- **period I: distribution layer fills up**
- **period II: water moves between reservoirs**
- **period III: rain has stopped and no recharge**

TIME PERIODS
solute flow model

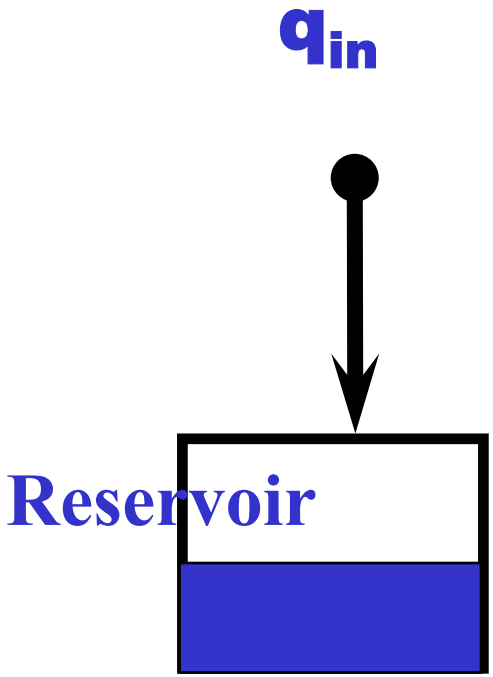


Periods I II III



DISTRIBUTION ZONE

period 1: raining



$$C_{reservoir} = \frac{M_0}{W}$$

DISTRIBUTION ZONE

period II
raining

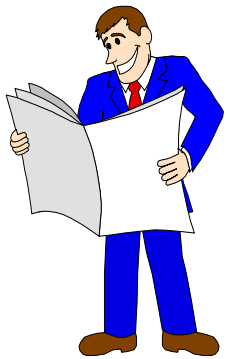
q_{in}

C_{reserv}

W

q_{out} with $C_{reservoir}$

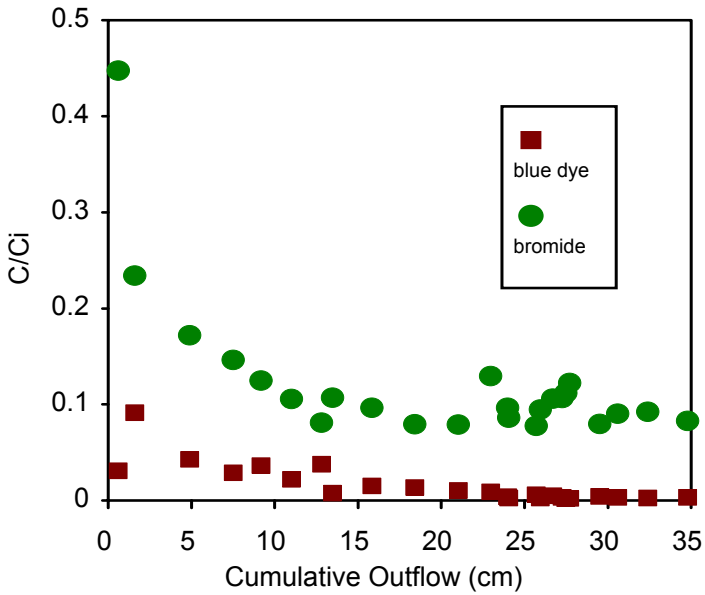
$$C = C_0 \exp - \frac{\sum q}{w}$$

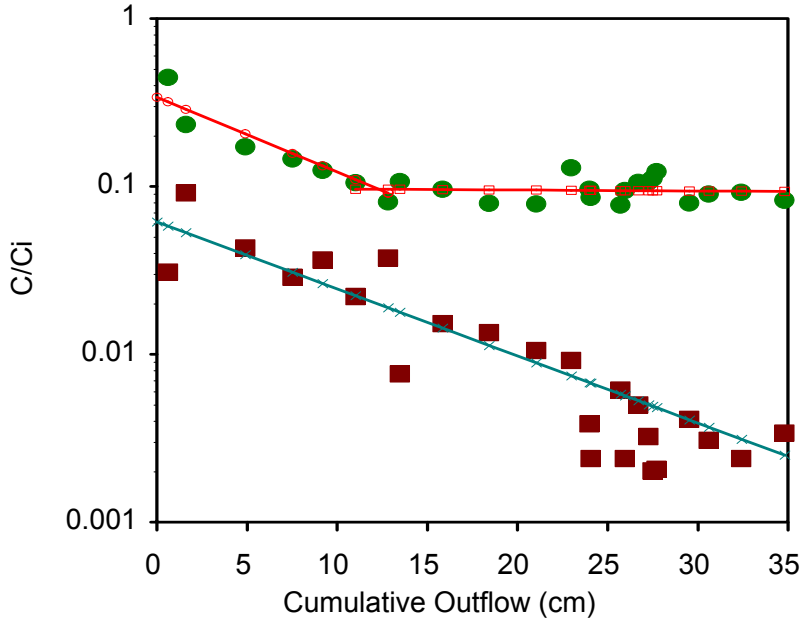


DISTRIBUTION ZONE BROMIDE + BLUE DYE PULSE

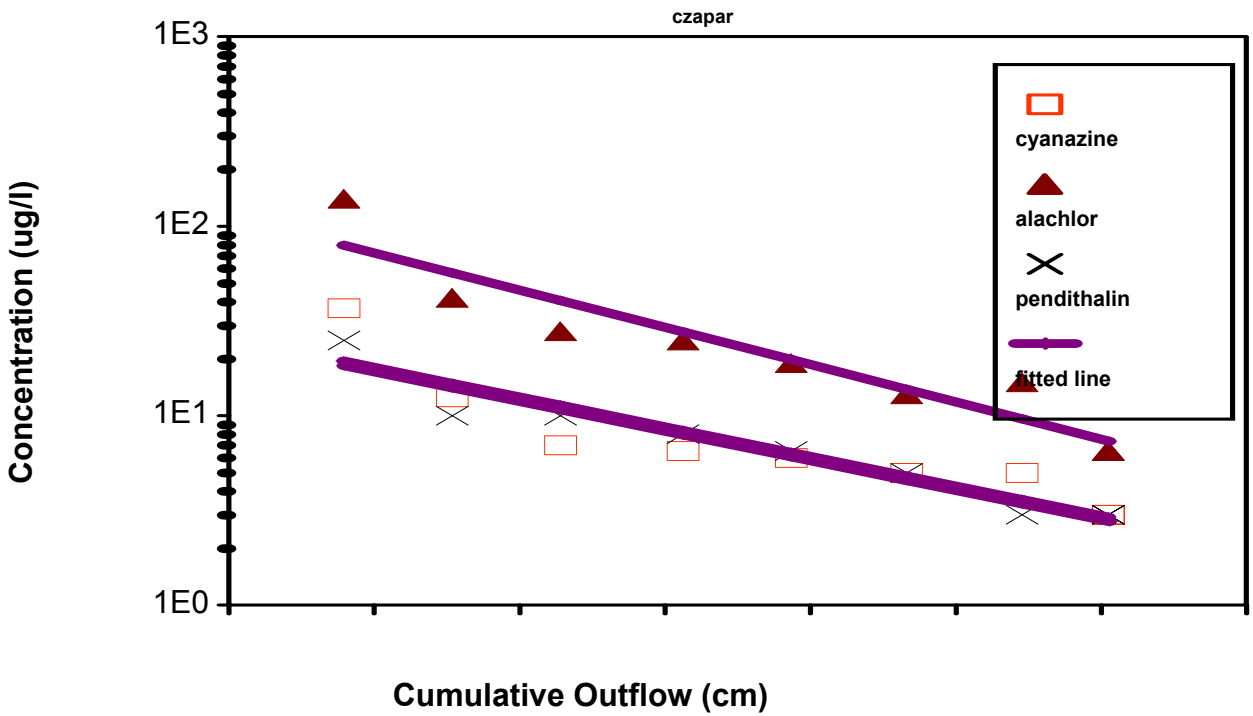
- bromide and blue dye added on day 1
- daily irrigation of 4 cm
- samples collected at 60 cm depth

DISTRIBUTION ZONE BROMIDE + BLUE DYE PULSE





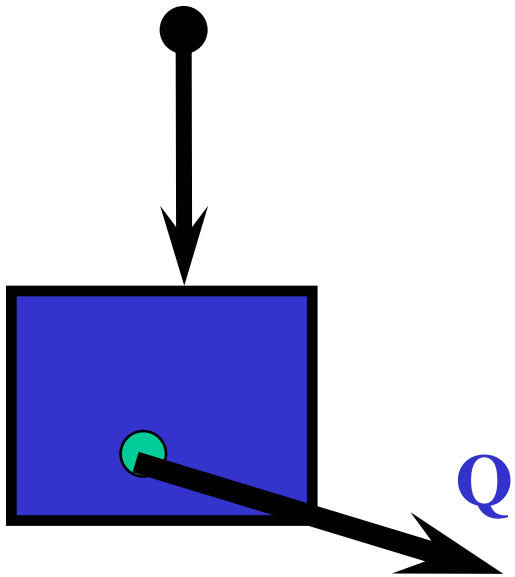
DISTRIBUTION ZONE
Pesticide pulse



GROUND WATER

period II, raining

q_{in} with $C_{distribution}$

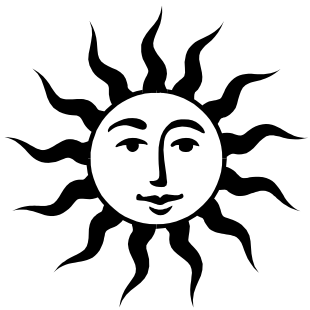


$$C_{distribution} = C_0 \exp - \frac{\sum q}{W}$$

Q_{out} with $C_{reservoir}$

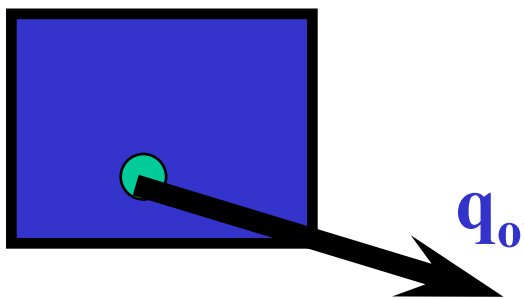
GROUND WATER

period III rain has stopped



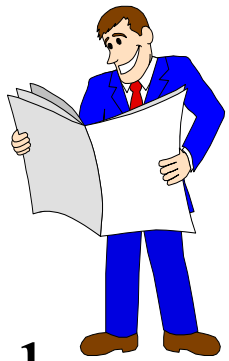
no inflow

$$C = C_{II} \exp - \frac{\sum q_{tile}}{w}$$



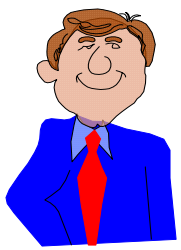
q_{out} with $C_{reservoir}$

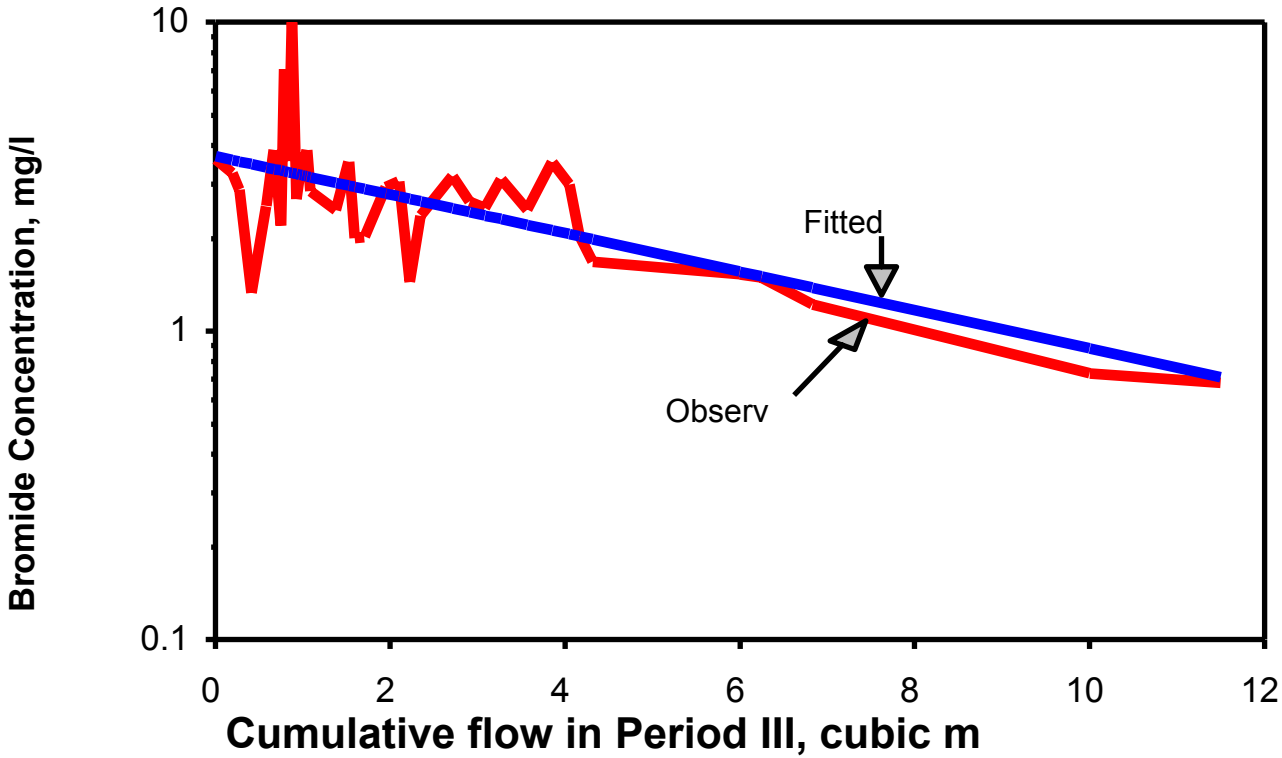
EXPERIMENTAL



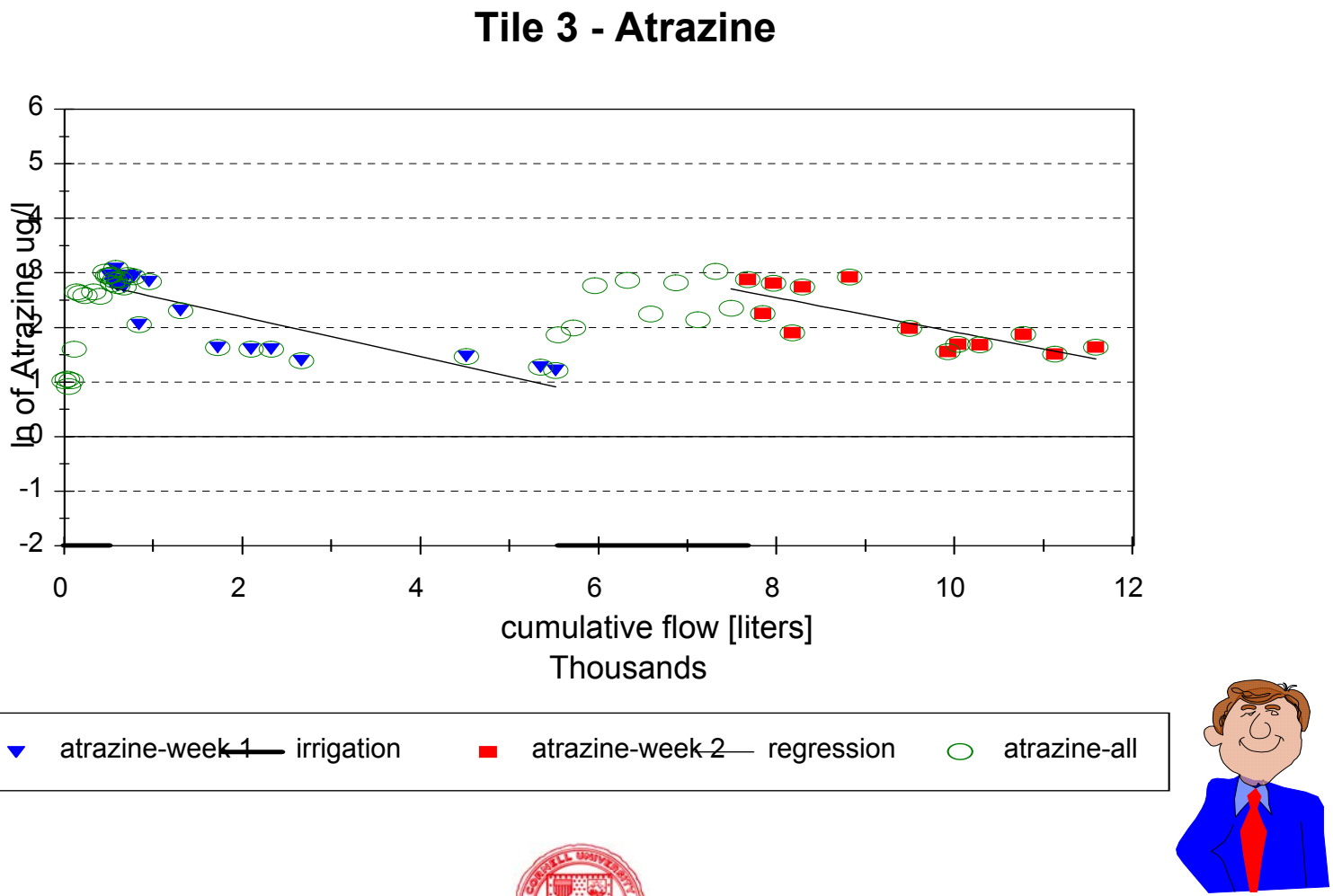
- solute applied before irrigation is started
- irrigation applied at rate of 1 cm/hr
- solute concentration and tile outflow rate observed
- plot size is 0.1 ha
- soil is sandy loam with tight layer from 30-60 cm.

TILE OUTFLOW
period III

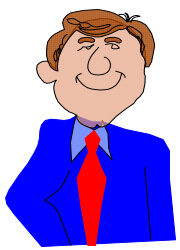


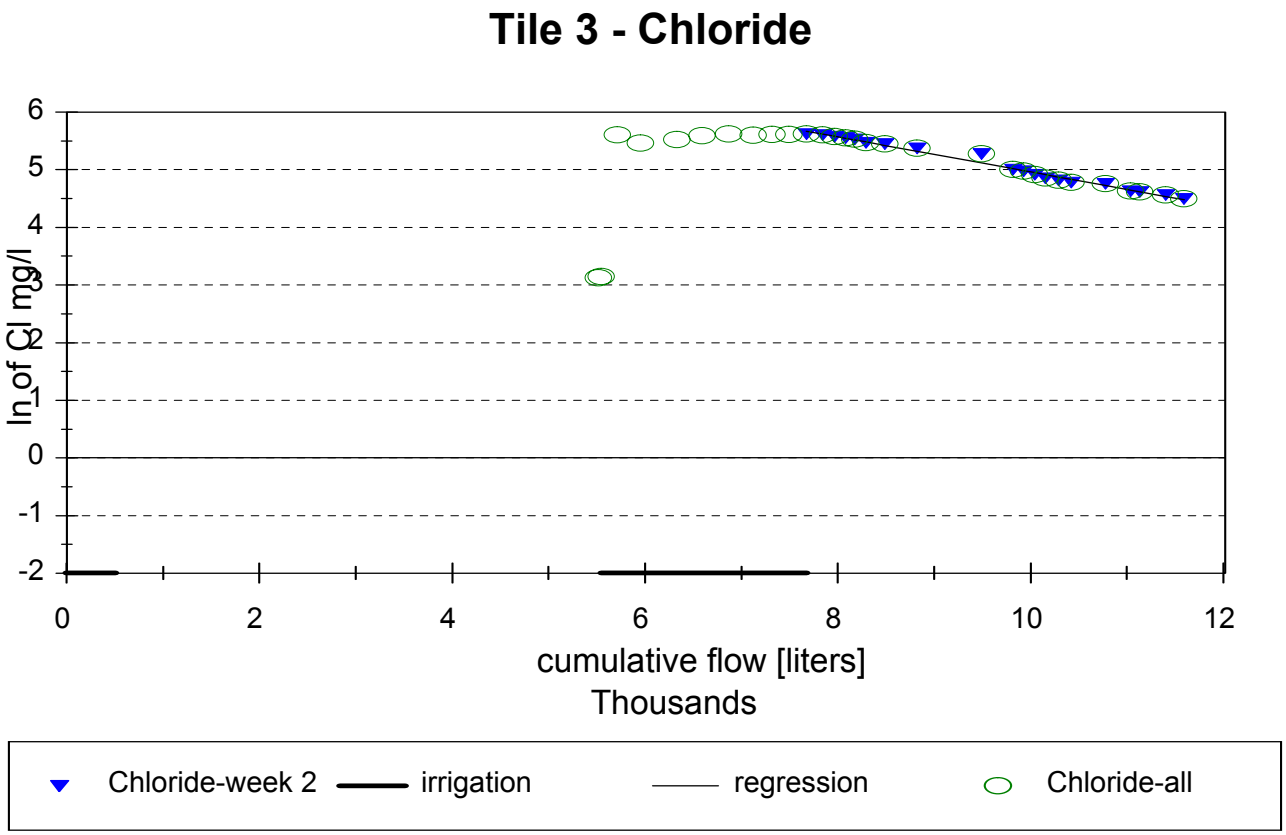


TILE OUTFLOW

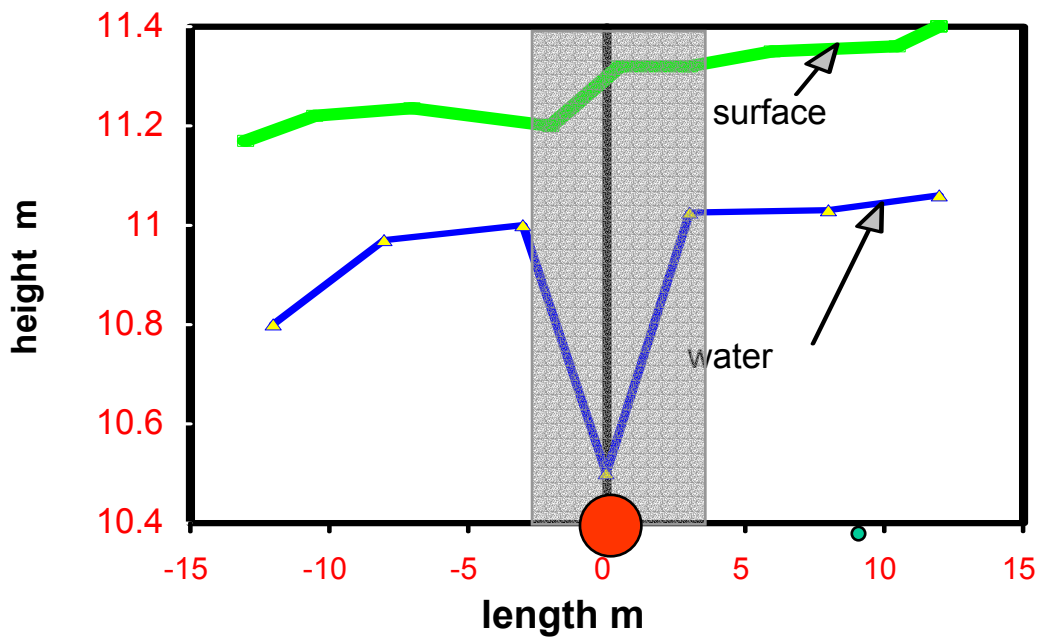


TILE OUTFLOW



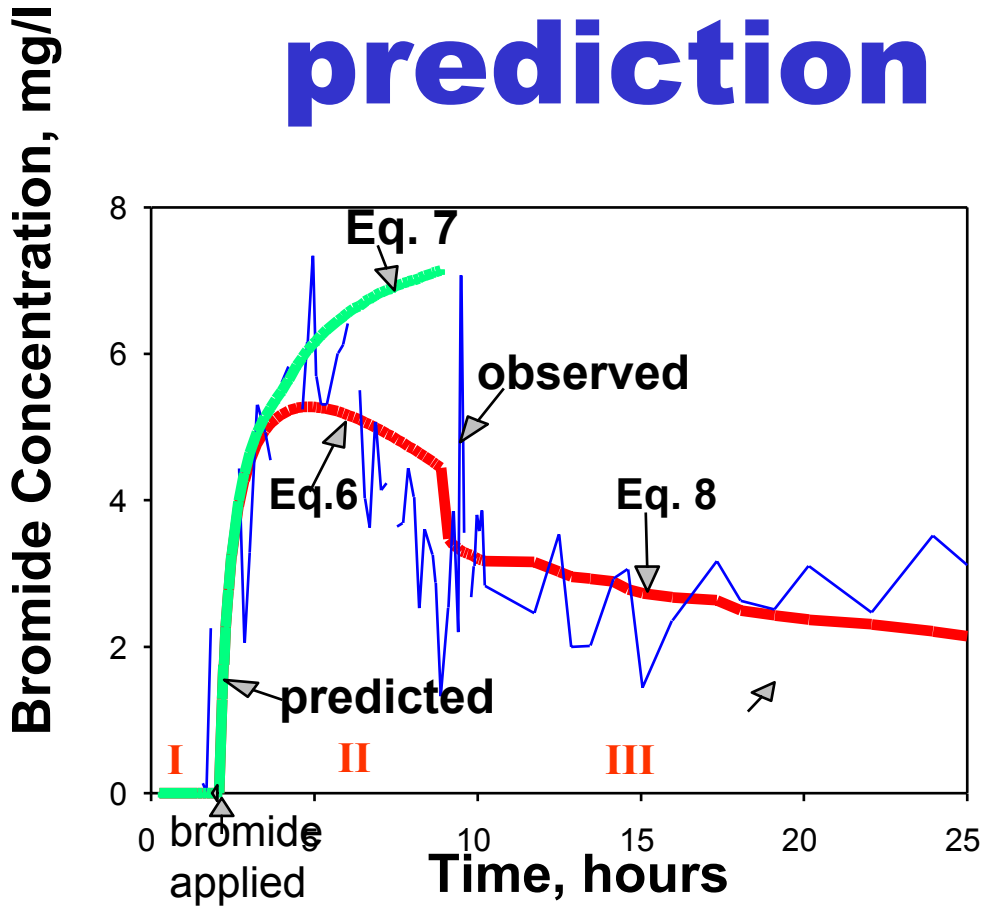


CONTRIBUTING AREA

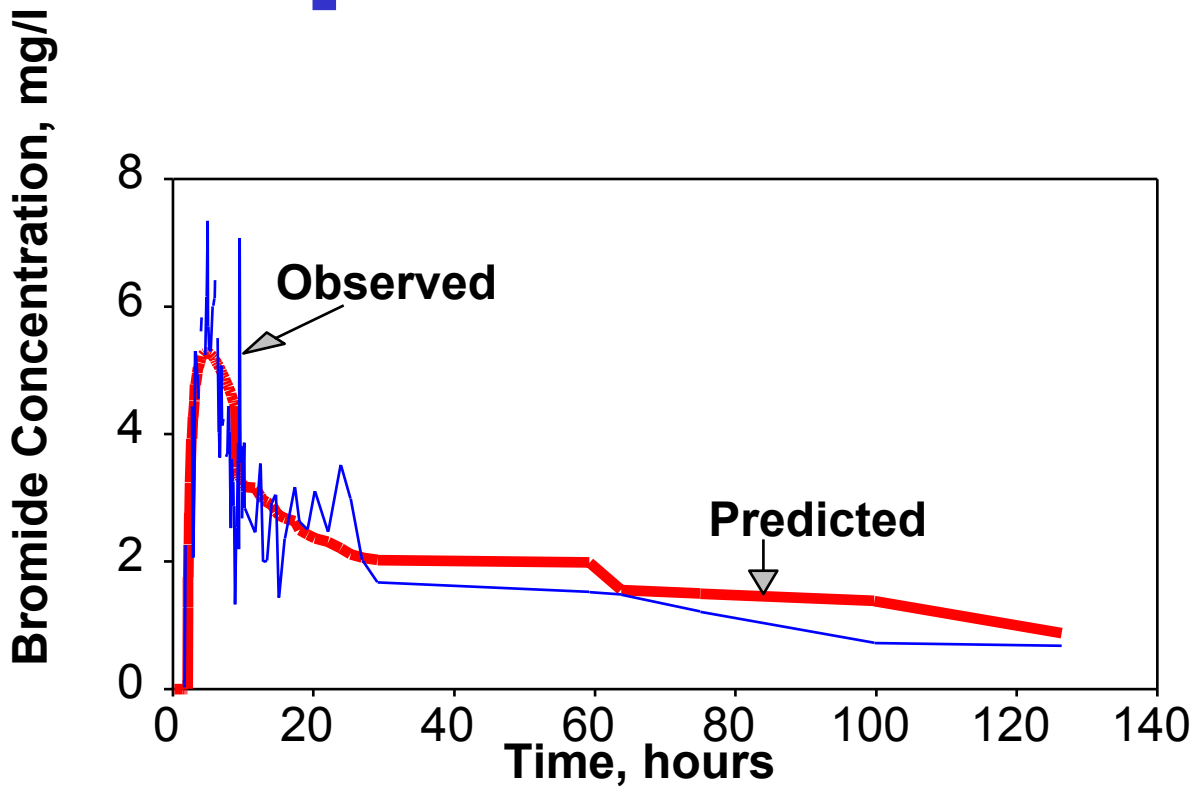


tile outflow during summer is approximately 20% of amount applied. This is consistent with water table observations

TILE OUTFLOW prediction



TILE OUTFLOW prediction



CONCLUSIONS

- simple two reservoir model can simulate the high concentrations in tile outflow shortly after application
- during summer less than 20% of the area contributes to tile outflow
- recent experiments of Kung indicates that observed phenomena are not limited to NY

Refer to the following paper for further details.:

Steenhuis, T.S., M. Bodnar, L.D. Geohring, S-A.E. Aburime, and R. Wallach. 1997. A Simple Model for Predicting Solute Concentration in Agricultural Tile Lines Shortly After Application. Hydrology and Earth System Sciences 4:823-833.