

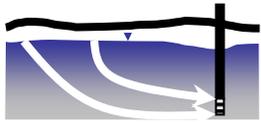
APPLICATION OF GROUND-WATER DATING TECHNIQUES FOR EVALUATING THE SUSCEPTIBILITY OF AQUIFERS AND PUBLIC-SUPPLY WELLS TO CONTAMINATION

National Water Quality
Monitoring Council Meeting
May 9, 2006

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John Karl Böhlke
Leon Kauffman

USGS National Water
Quality Assessment Program
(NAWQA)





TALK OUTLINE

- USGS NAWQA Transport of Anthropogenic & Natural Contaminants (TANC) to Supply Wells Study
- Considerations For Interpretation Of Environmental-Age Tracers In Public-Supply Wells
- Tracer Concentrations & Age Distributions In Selected Aquifers And Public-Supply Wells



APPARENT AGES MAY NOT BE SUFFICIENT TO FORECAST SUPPLY WELL SUSCEPTIBILITY

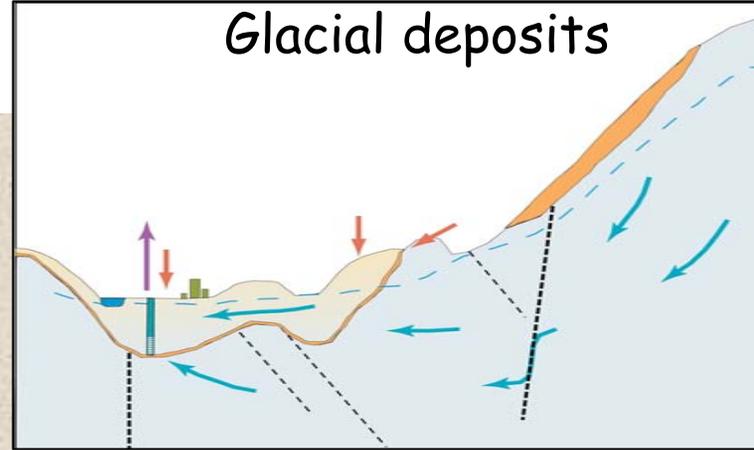
25 yrs

- bromoform
- chloroform
- tetrachloroethene
- nitrate
- atrazine
- DEA
- diuron
- arsenic
- uranium

7 yrs

- 1,1,1 trichloroethane
- cis-1,2 dichloroethene
- trichloroethene
- tetrachloroethene
- MTBE
- freon-11
- arsenic
- uranium

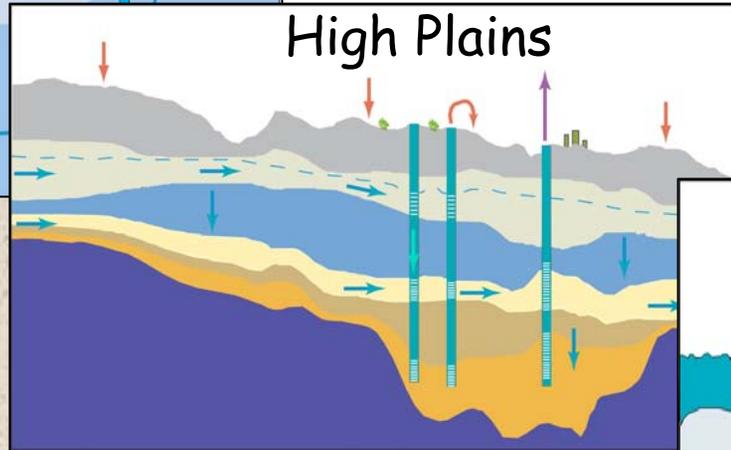
Glacial deposits



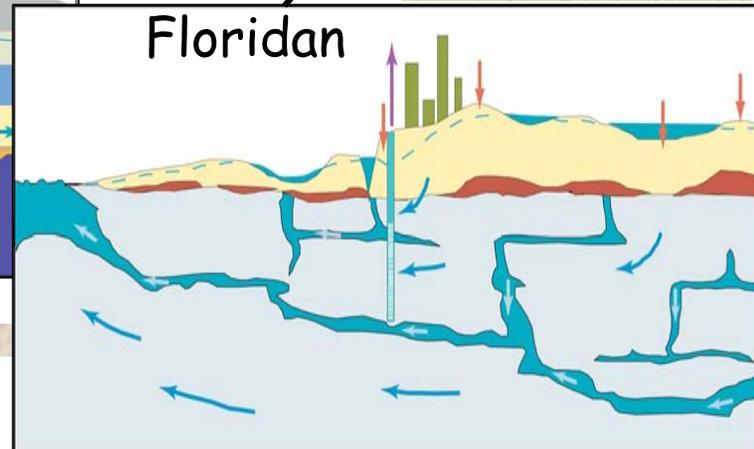
5 yrs

- chloroform
- trichloroethene
- arsenic
- uranium

High Plains



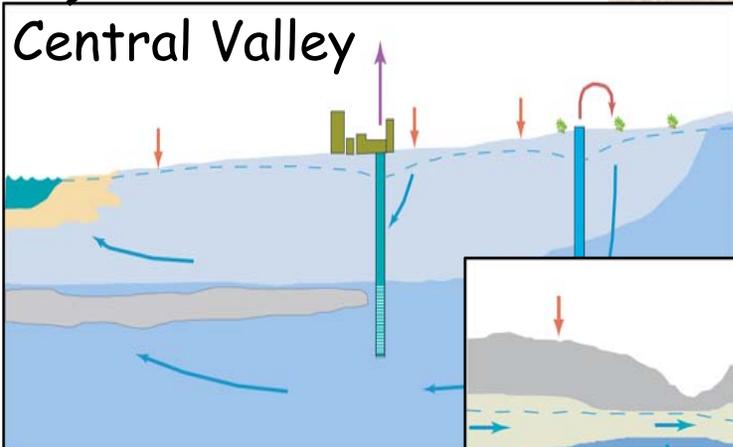
Floridan

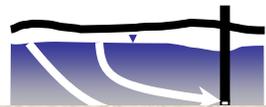


20 yrs

- cis-1,2 dichloroethene
- trichloroethene
- tetrachloroethene
- nitrate
- arsenic
- uranium

Central Valley

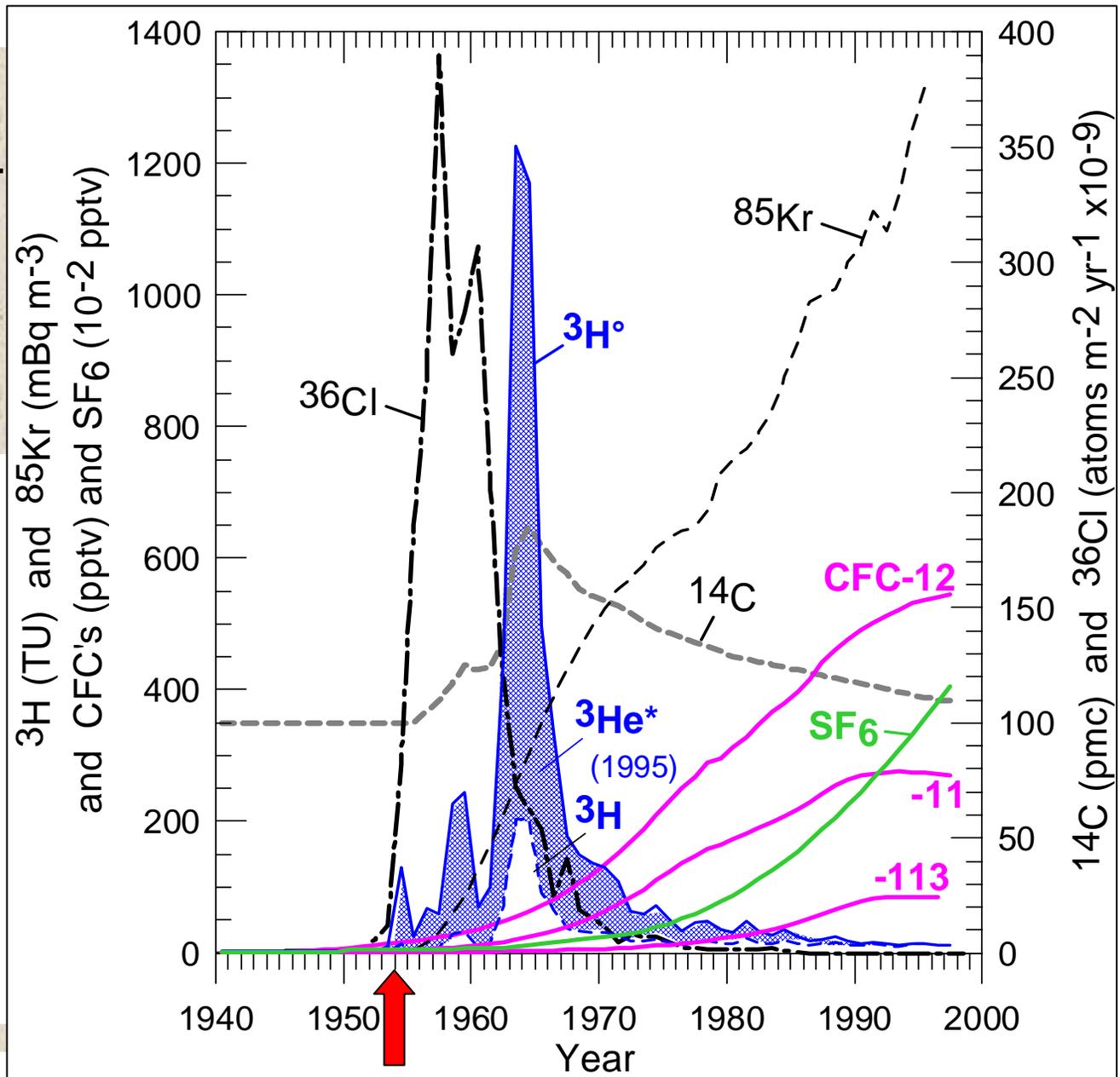




SELECTED ENVIRONMENTAL TRACERS USED TO INFER GROUND-WATER AGE

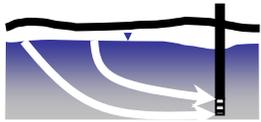
Age: Time Elapsed Since Recharge To The Water Table

- Tracer-Based Ages Are Apparent Ages
- Tracer-Based Ages Are Model Dependent



Cook and Böhlke, 2000

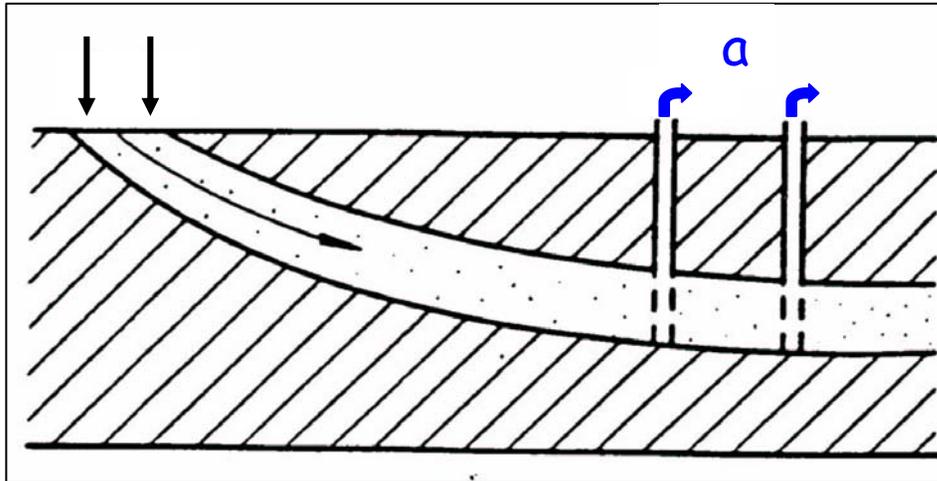




AGE INTERPRETATION

-- Piston Flow Model Assumption --

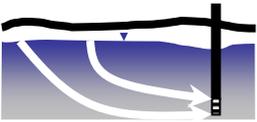
a PFM = piston-flow model



A water sample is a mixture of waters from all flow lines that reach the sampling point.

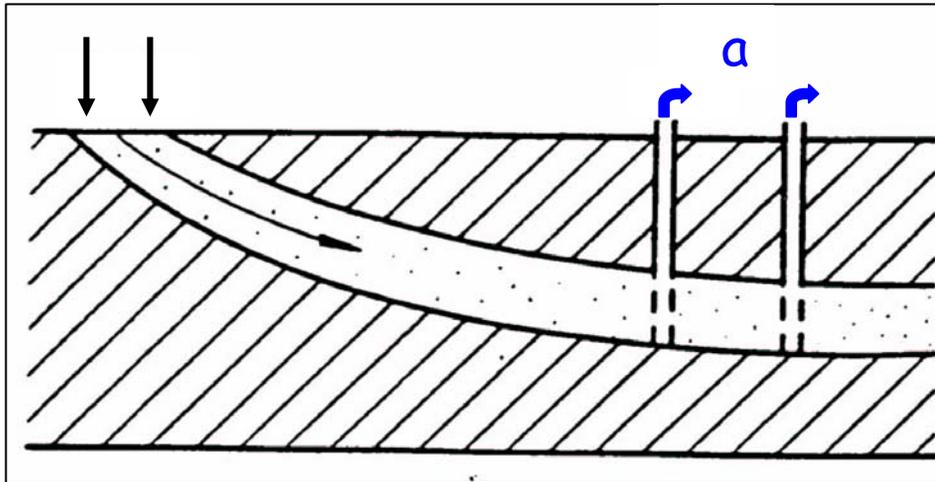
If the flow lines are associated with a narrow range of ages, the apparent age of the sample may reasonably represent the travel time from the point of recharge.

Zuber, 1986



AGE INTERPRETATION

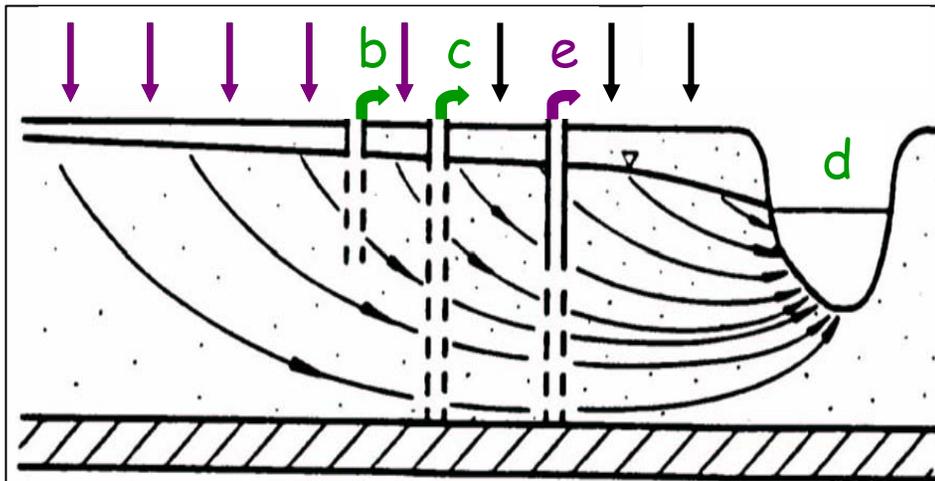
-- Lumped Parameter Models for Ground-Water Mixtures --



a PFM = piston-flow model

b, c, d EM = exponential model

e EPM = exponential piston-flow model



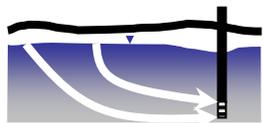
Additional models

LM = linear

LPM = linear-piston

DM = dispersion

Lumped-parameter models ...
simple mathematical functions
that describe age distributions
for various combinations of
recharge area, aquifer geometry,
and sample type (Zuber, 1986)



AGE

INTERPRETATION

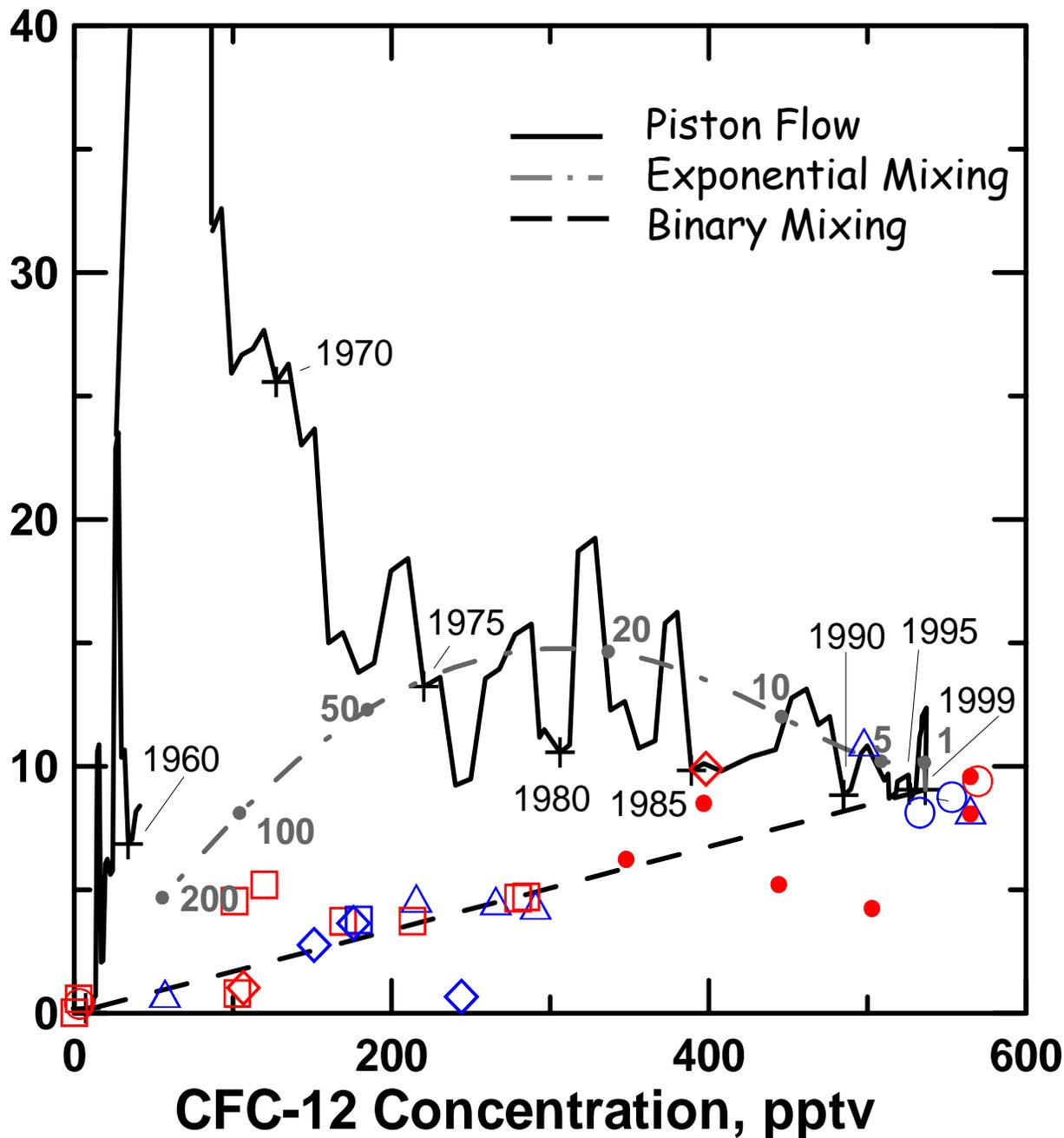
-- Tracer Plots --



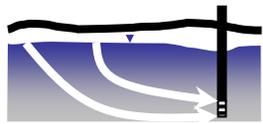
➤ Can Be Used To Recognize Cases Of Piston Flow And Binary Mixing With Tracer Free Fraction (Dilution)

➤ Elimination Of Some Mixing Models

^3H Decayed to Year 1999, TU



Modified from Plummer, written commun., 2006



AGE INTERPRETATION

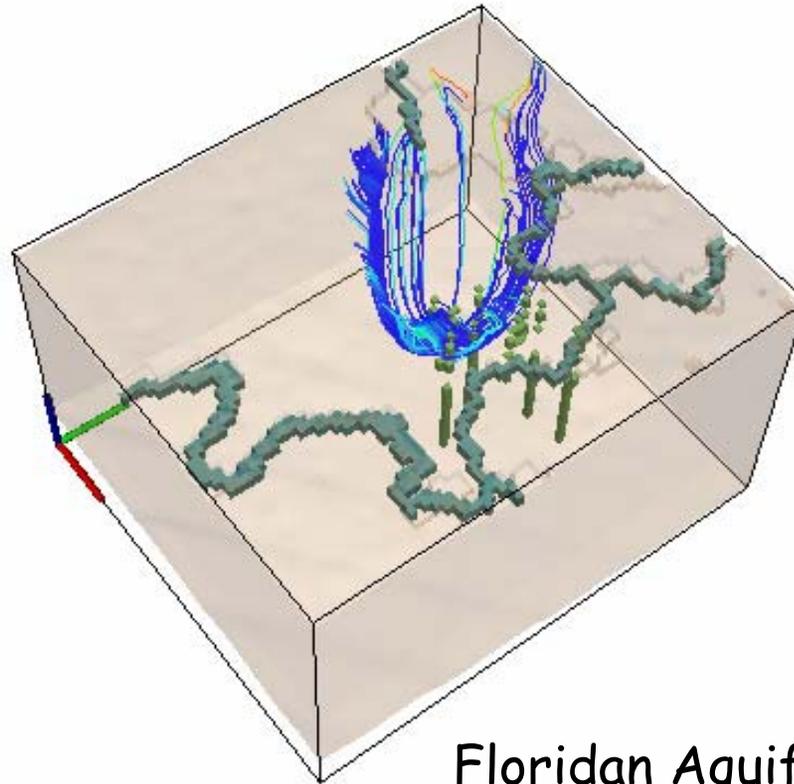
-- Flow Model Calibration and Simulation of Age Distributions --

SF₆
Flow-Weighted
Particle Tracking:
4.14 pptv

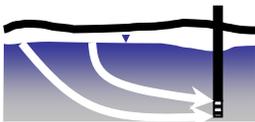
Supply-Well
Sample:
4.53 pptv

³H
Flow-Weighted
Particle Tracking:
1.98 TU

Supply-Well
Sample:
2.1 TU

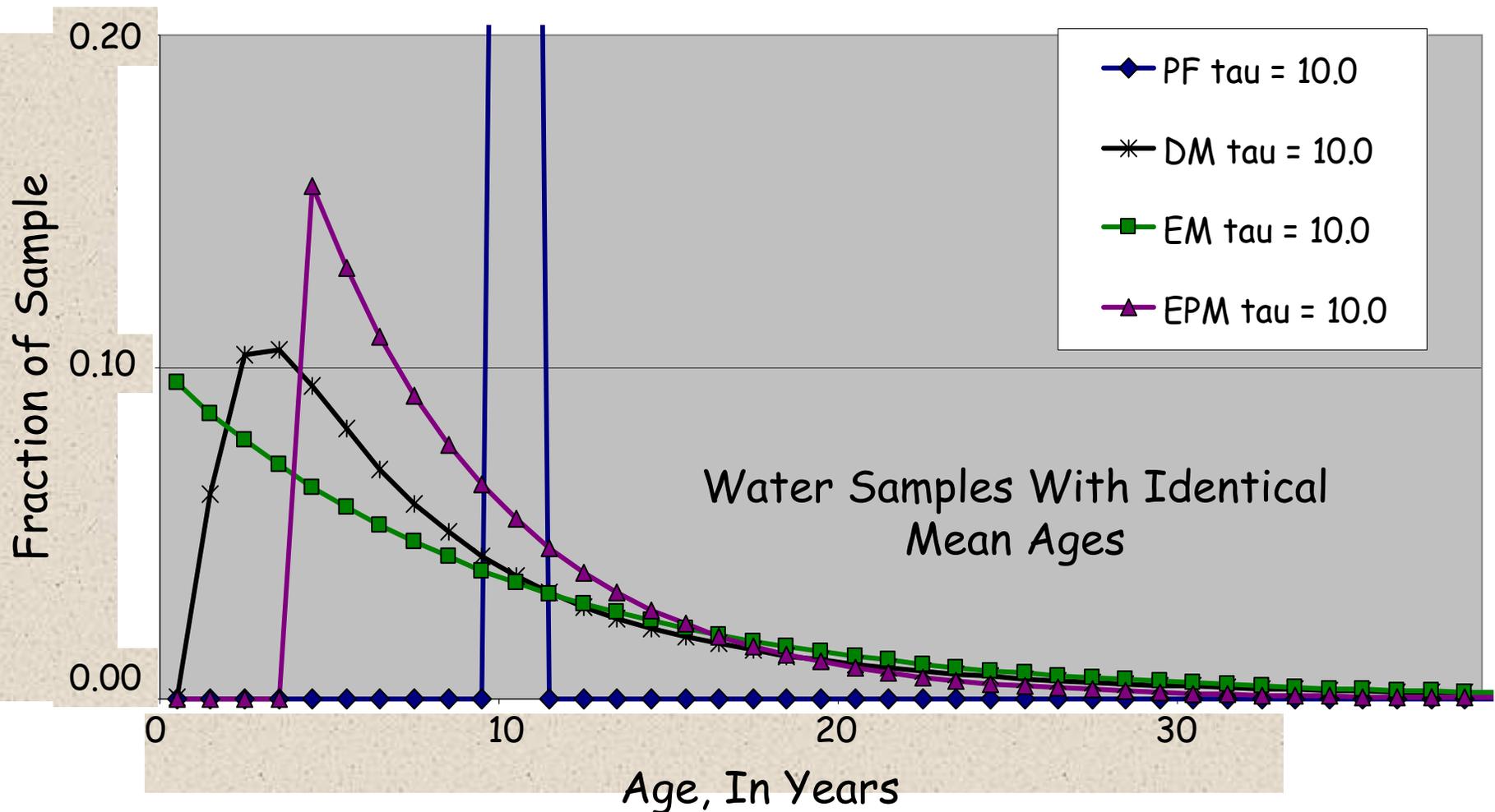


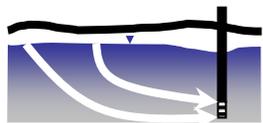
Floridan Aquifer System
Public-Supply Well



AGE DISTRIBUTIONS IN GROUND WATER MIXTURES

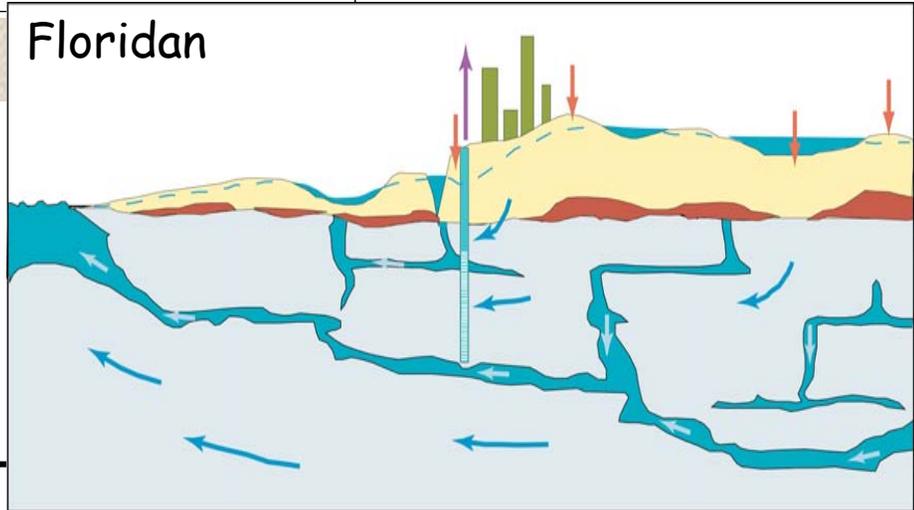
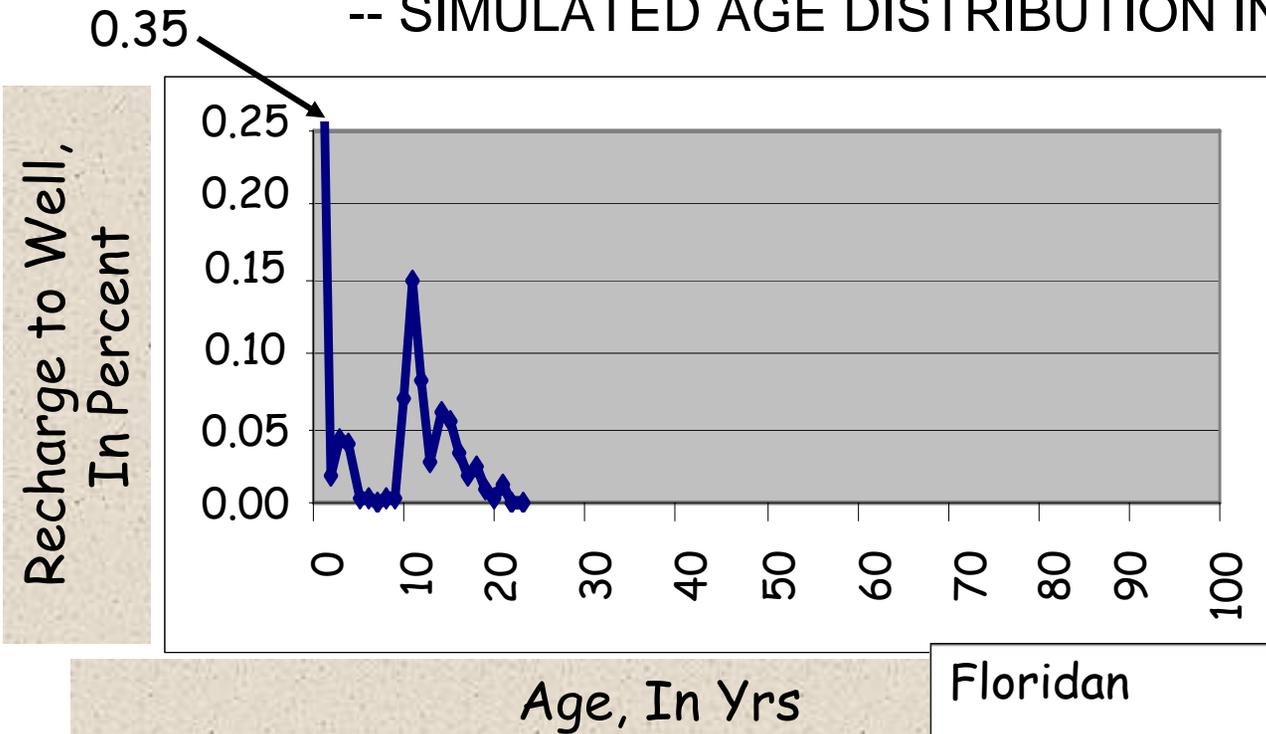
-- Implications for Susceptibility --





FLORIDAN AQUIFER SYSTEM

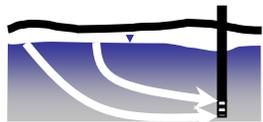
-- SIMULATED AGE DISTRIBUTION IN SUPPLY WELL --



BINARY MIXTURE:

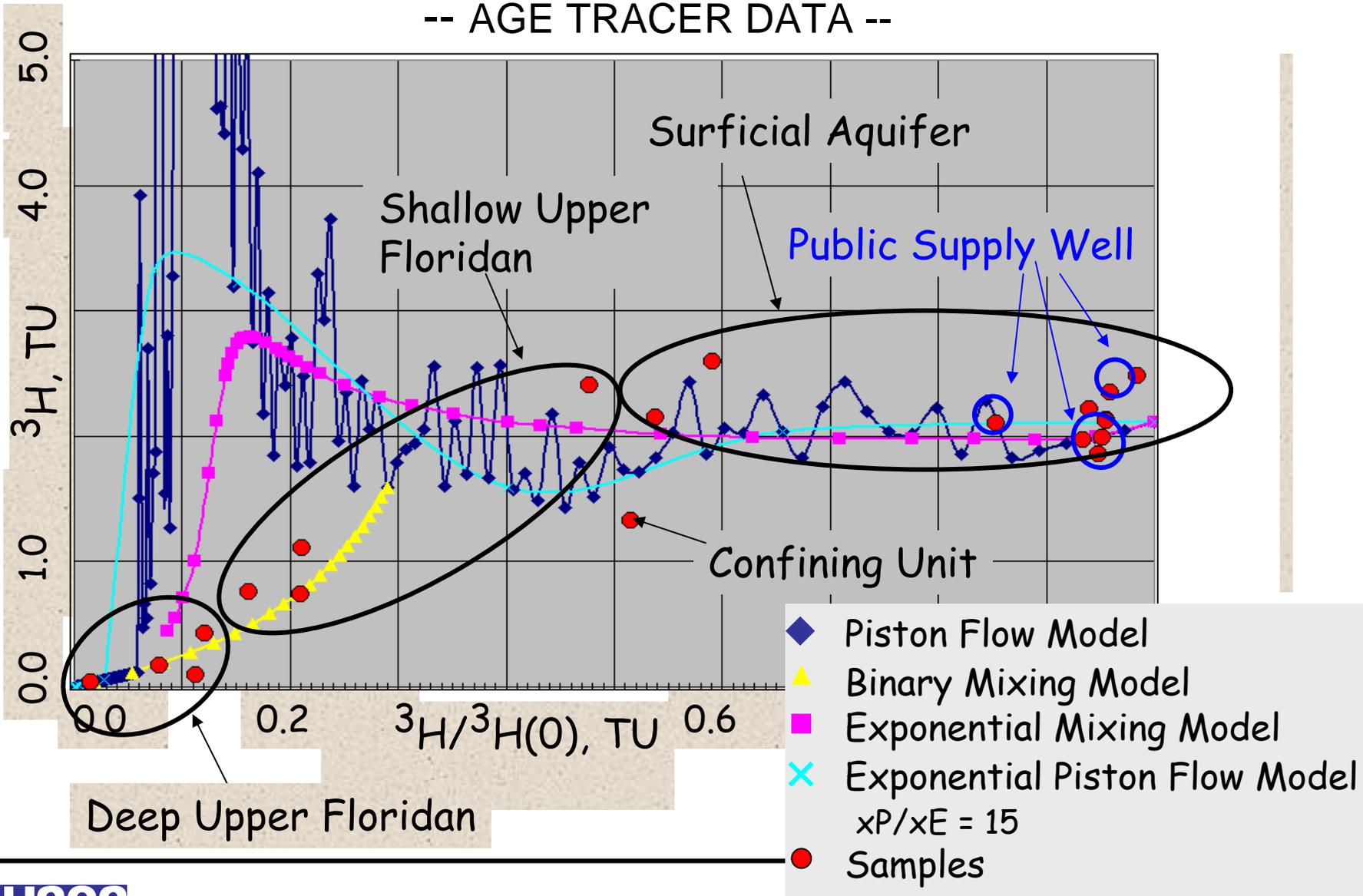
Piston Flow (v. young)
and Exponential Piston Flow (older)

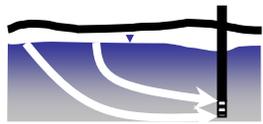




FLORIDAN AQUIFER SYSTEM

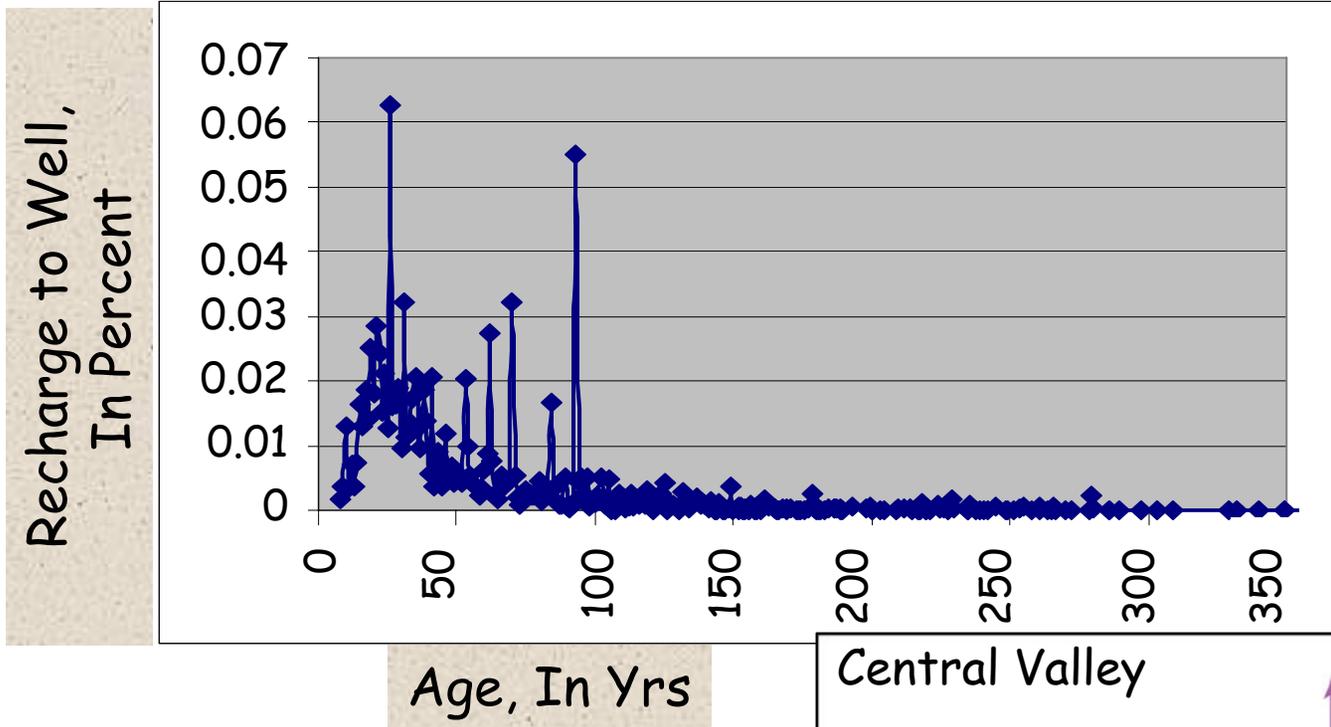
-- AGE TRACER DATA --



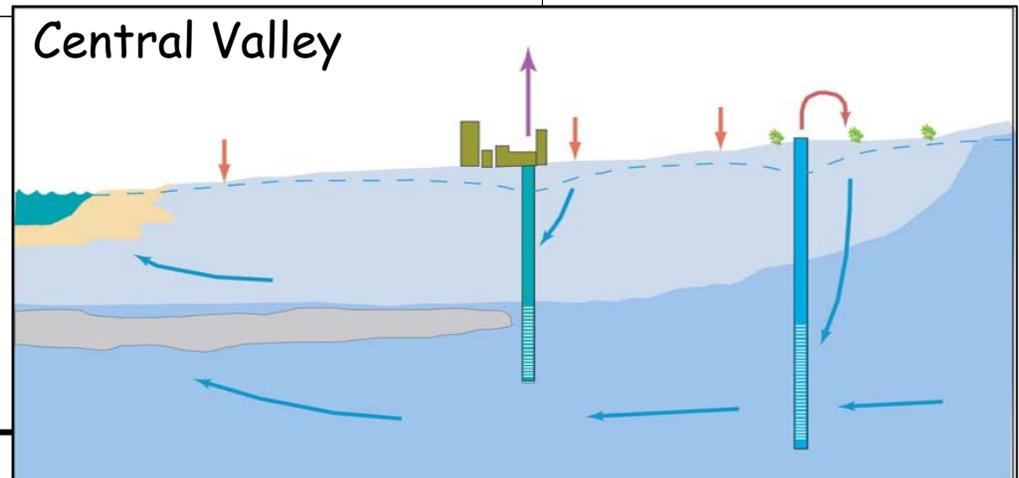


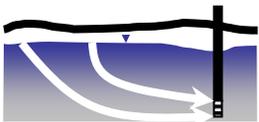
CENTRAL VALLEY AQUIFER SYSTEM

-- SIMULATED AGE DISTRIBUTION IN SUPPLY WELL --



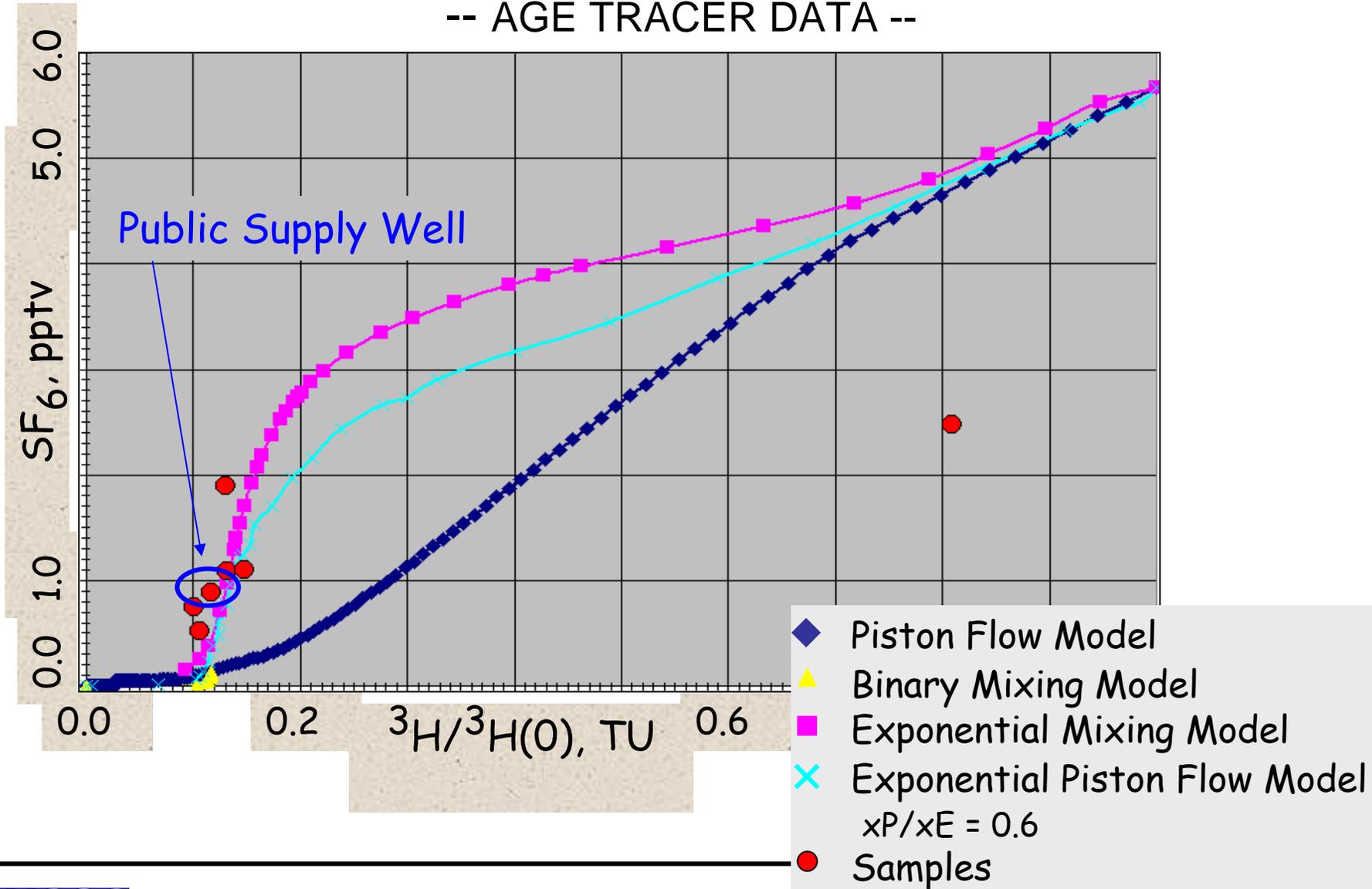
Exponential Piston Flow

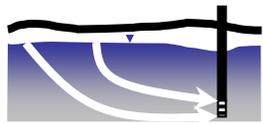




CENTRAL VALLEY AQUIFER SYSTEM

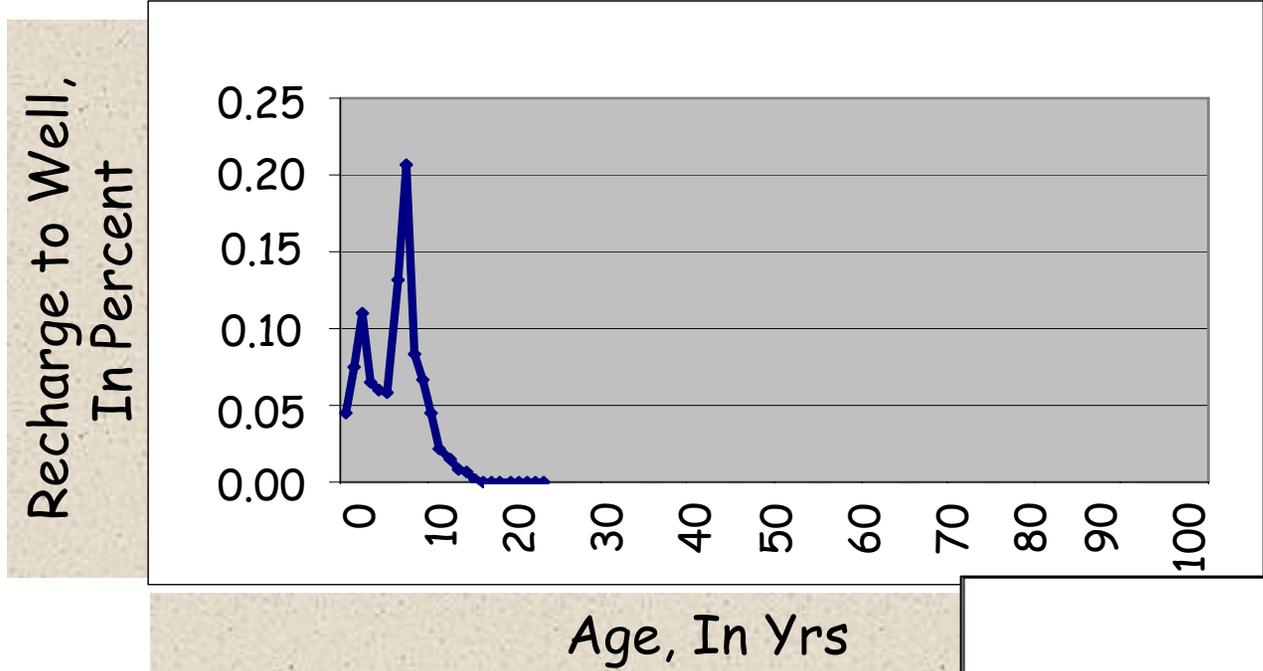
-- AGE TRACER DATA --



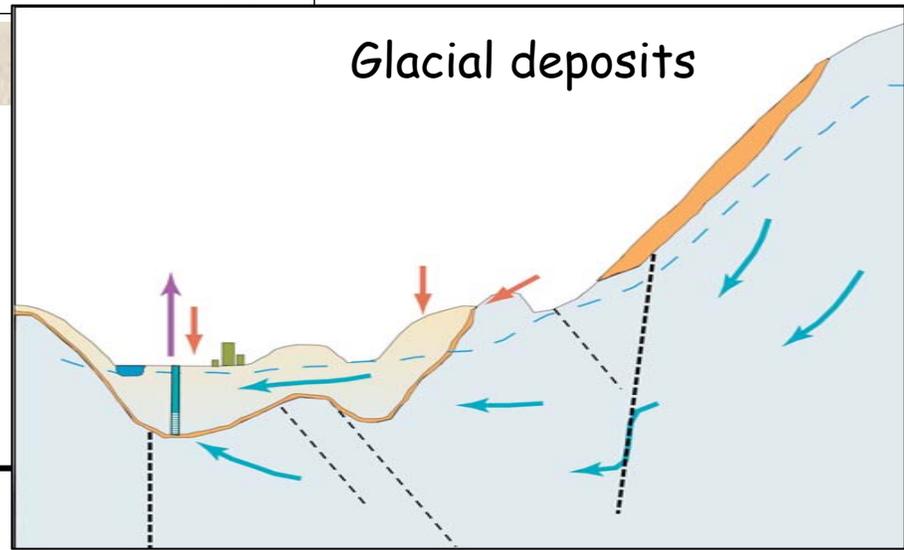


GLACIAL DEPOSITS

-- SIMULATED AGE DISTRIBUTION IN SUPPLY WELL --

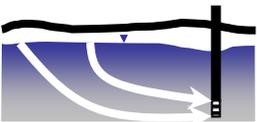


BINARY MIXTURE:
 Exponential (v. young)
 and Piston Flow (older)



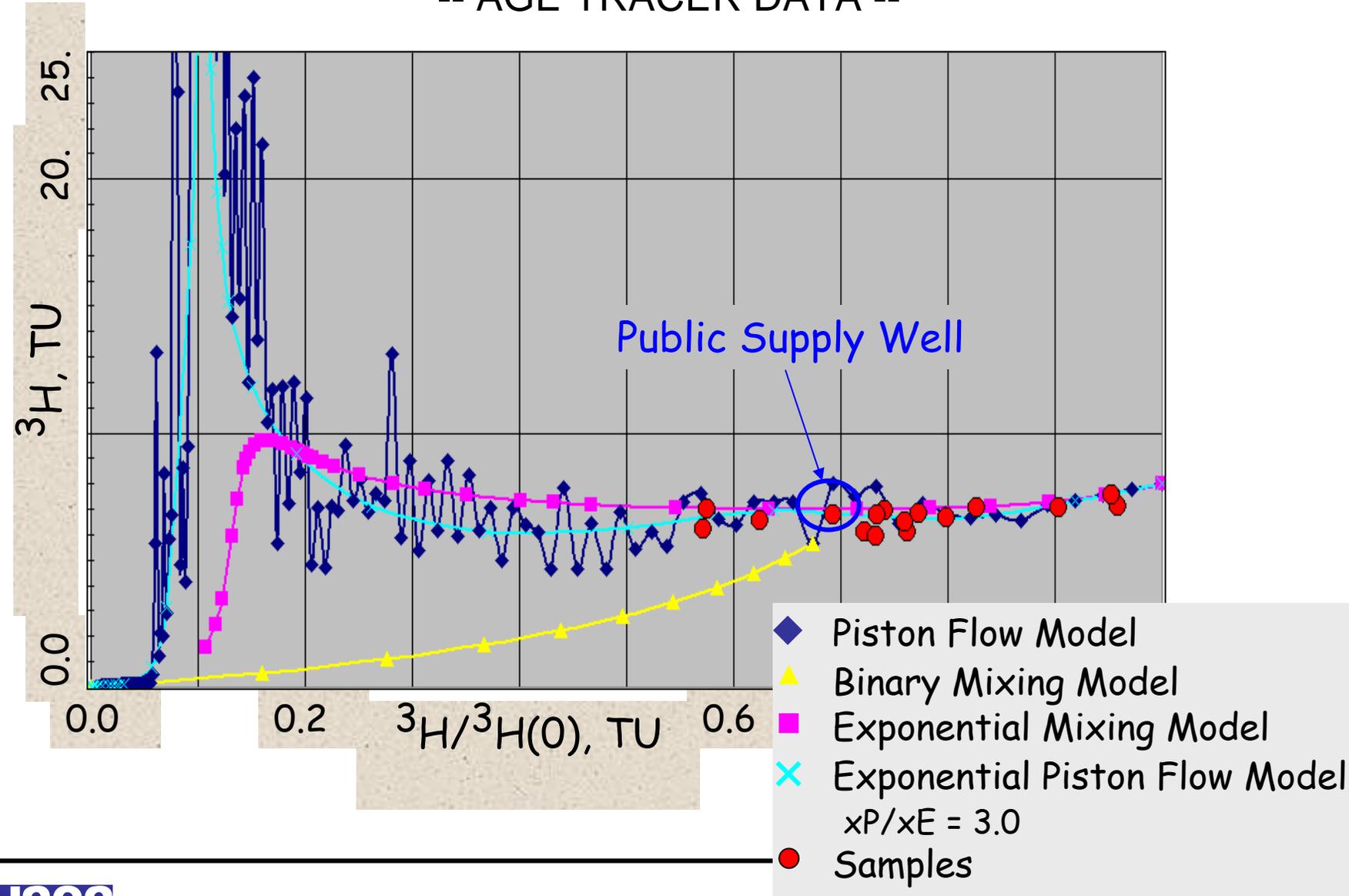
Not to Scale

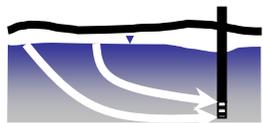




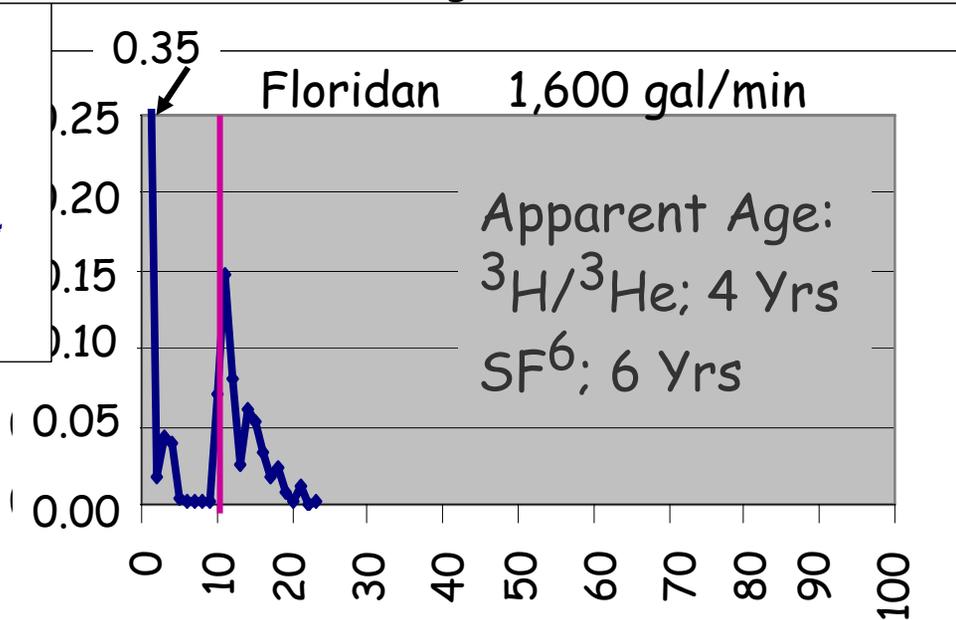
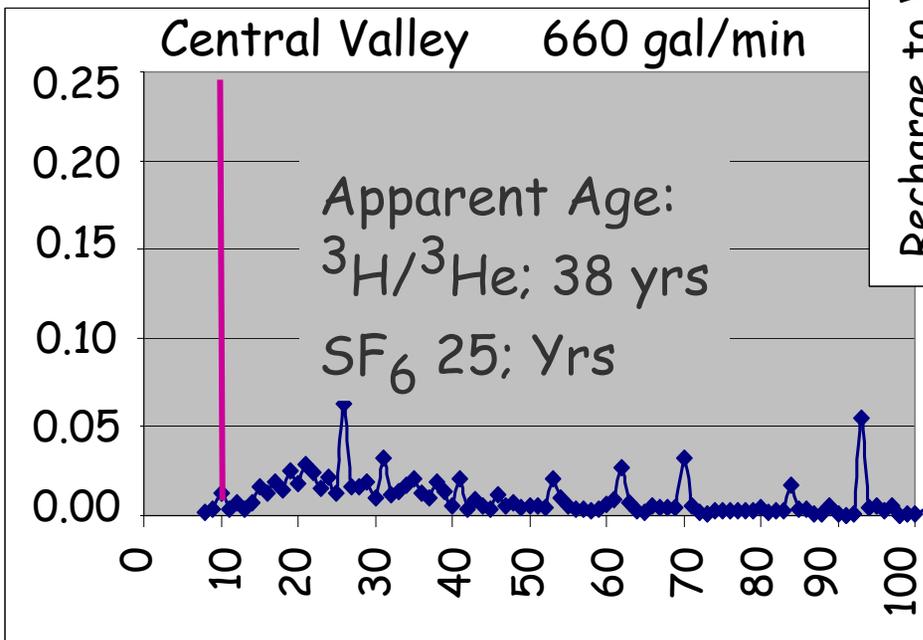
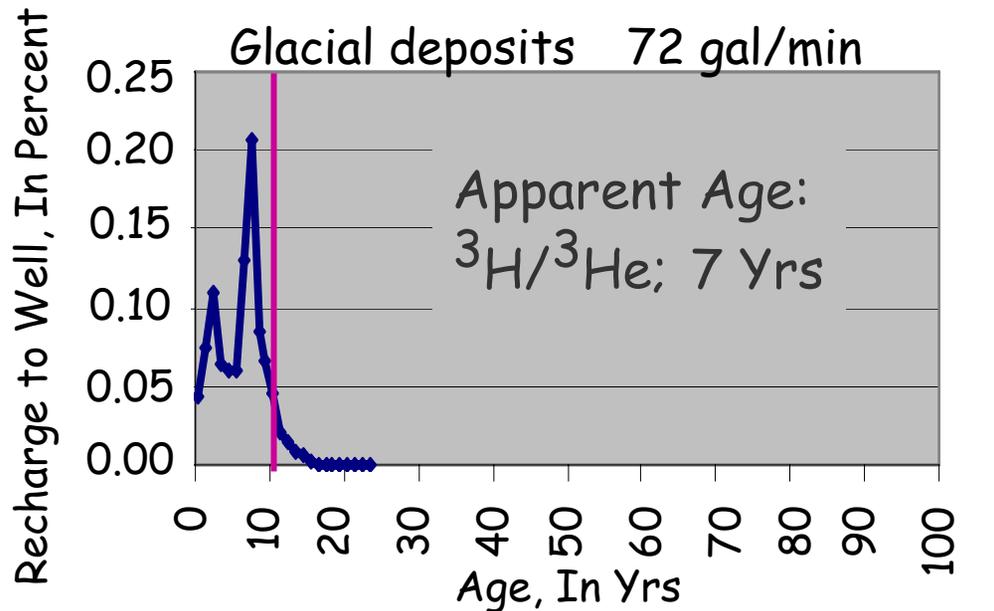
GLACIAL DEPOSITS

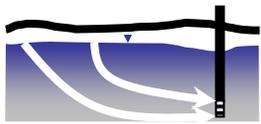
-- AGE TRACER DATA --





COMPARISON OF SIMULATED AGE DISTRIBUTIONS IN SUPPLY WELLS





CONCLUSIONS

- Age Distributions Are More Useful Than Apparent Mean Ages For Understanding Susceptibility
- Ground-Water Flow Models Calibrated To Age Tracer Concentrations Can Be Used To Simulate Age Distributions
- It May Be Possible To Describe Age Distributions In Public-Supply Wells Using Lumped-Parameter Models (Simple Mathematical Functions)
- Tracer-Tracer Plots Can Sometimes Provide Insight Into Age Distributions In Public-Supply Wells

