Determining Groundwater Recharge to Quantify PFAS Mass Discharge from Unsaturated Source Zones

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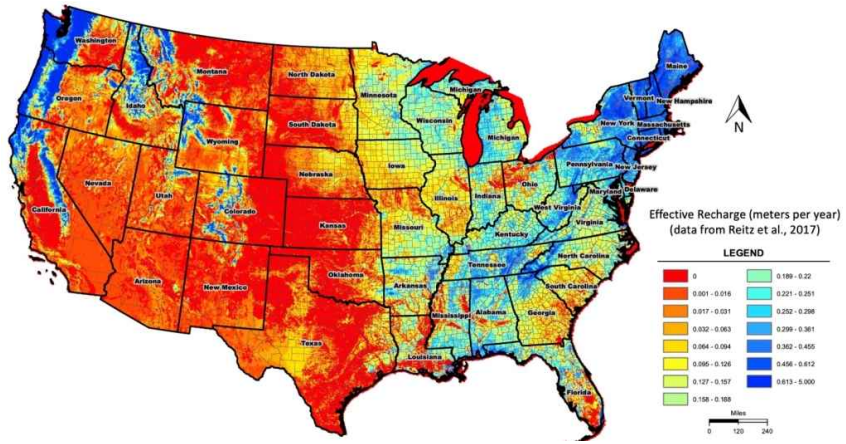
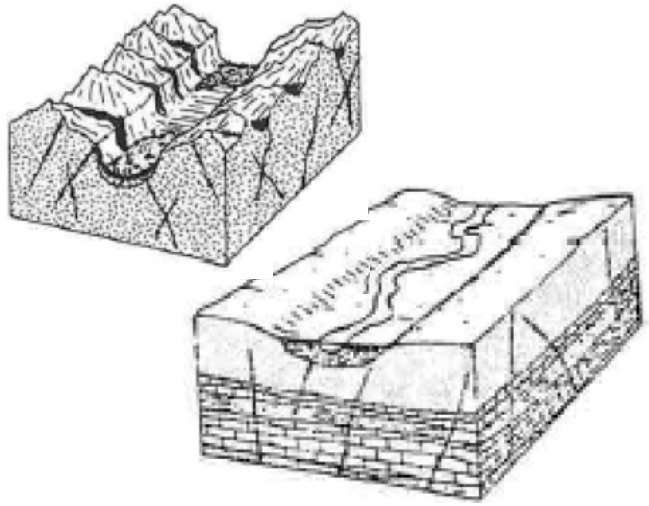
Battelle Bioremediation Symposium





May 2023

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GSI Environmental

R. Hunter Anderson

Air Force Civil Engineering Center

AGENDA

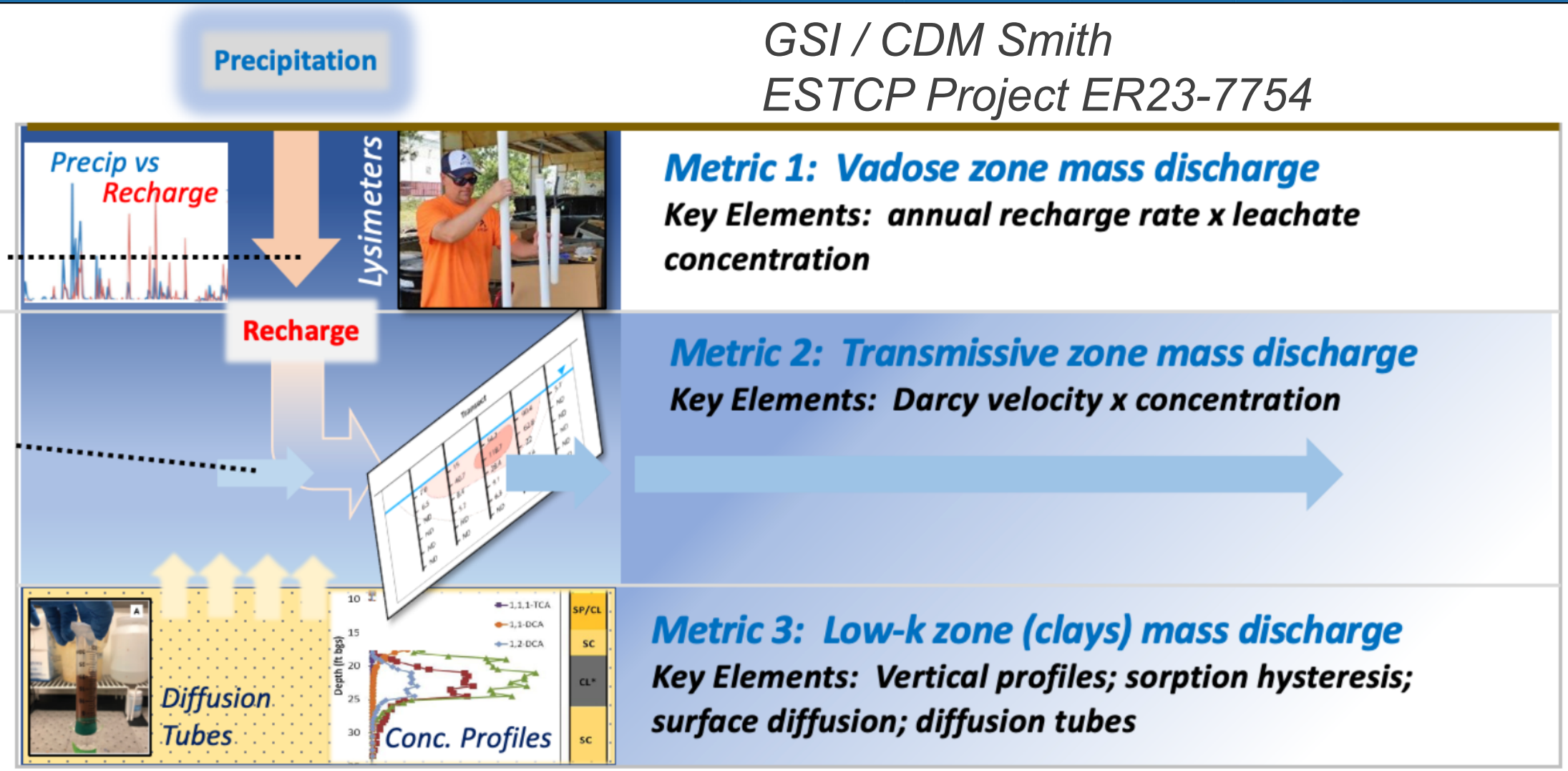
Vadose Zone Journal

Newell et al. (2023)

- The Problem and Two Roads
- Quantifying PFAS Mass Discharge from Unsaturated Source Zones
- Overview of Recharge Estimation Methods
- Tiered System to Estimate Recharge at PFAS Site

Mass Discharge (grams per year) is Key Metric for PFAS Sources

GSI / CDM Smith
ESTCP Project ER23-7754



Metric 1: Vadose zone mass discharge

Key Elements: annual recharge rate x leachate concentration

Metric 2: Transmissive zone mass discharge

Key Elements: Darcy velocity x concentration

Metric 3: Low-k zone (clays) mass discharge

Key Elements: Vertical profiles; sorption hysteresis; surface diffusion; diffusion tubes

Metric 4: Relative Contribution

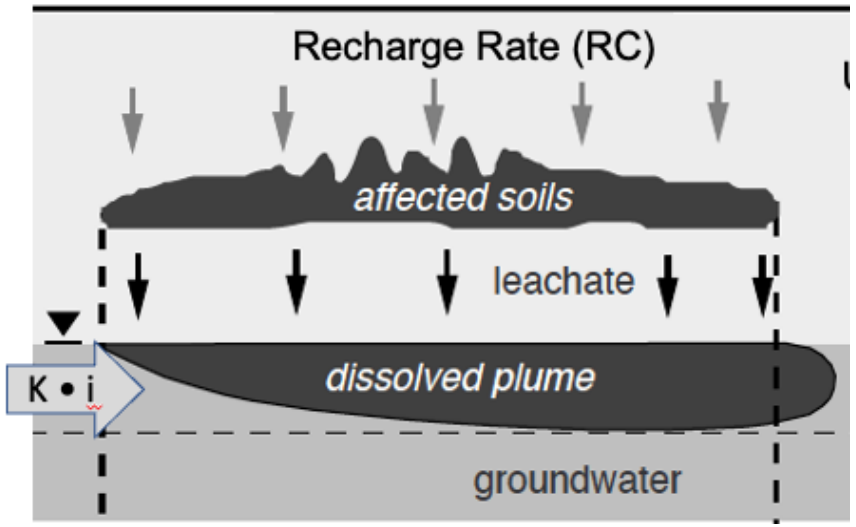
Key Elements: Subtract Metric 1 from Metric 2

Metric 5: Change in Mass Discharge Over Time

Key Elements: Equilibrium and Diffusion Models

The Problem and Two Roads to Get Mass Discharge (grams per year) To Groundwater

1. Soil Samples + Partitioning + Recharge



1. Analyze soil samples for **mg/kg**
2. Convert to mg/L via partitioning
3. Multiply by recharge rate and area

2. Suction Lysimeters + Recharge

1. Analyze porewater for **ng/L**
2. Multiply by recharge rate and area

Figure: CDM Smith ER20-5088

The Problem and Two Roads to Get Mass Discharge (grams per year) To Groundwater

	1. Soil Samples + Partitioning + Recharge	*2. Suction Lysimeters + Recharge*
PROS	• Used for most other organic COCs • Collect soil sample any time • Can be incorporated in models	• No need for partitioning calcs • Direct measurement of porewater
CONS	• PFAS Air/water partitioning increases complexity, variability	• Unfamiliar to many practitioners • Some questions about temporal change on concentration

Key Point: Guidance on Estimating Recharge at PFAS Sites Would be Beneficial

Three Key Recharge References

American Petroleum Institute

STEP

Estimation of Infiltration and Recharge for Environmental Site Assessment

API PUBLICATION NUMBER 4643

PREPARED UNDER CONTRACT BY:

DANIEL B. STEPHENS & ASSOCIATES, INC.
ALBUQUERQUE, NEW MEXICO

Stephens Associates, 1996

Home > Hydrogeology Journal > Article

Paper | Published: 17 January 2002

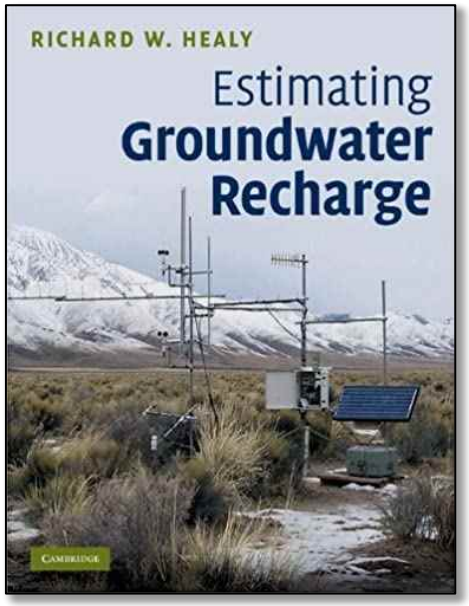
Choosing appropriate techniques for quantifying groundwater recharge

Bridget R. Scanlon, Richard W. Healy & Peter G. Cook

Hydrogeology Journal **10**, 18–39 (2002) | Cite this article

8106 Accesses | **1092** Citations | **22** Altmetric | Metrics

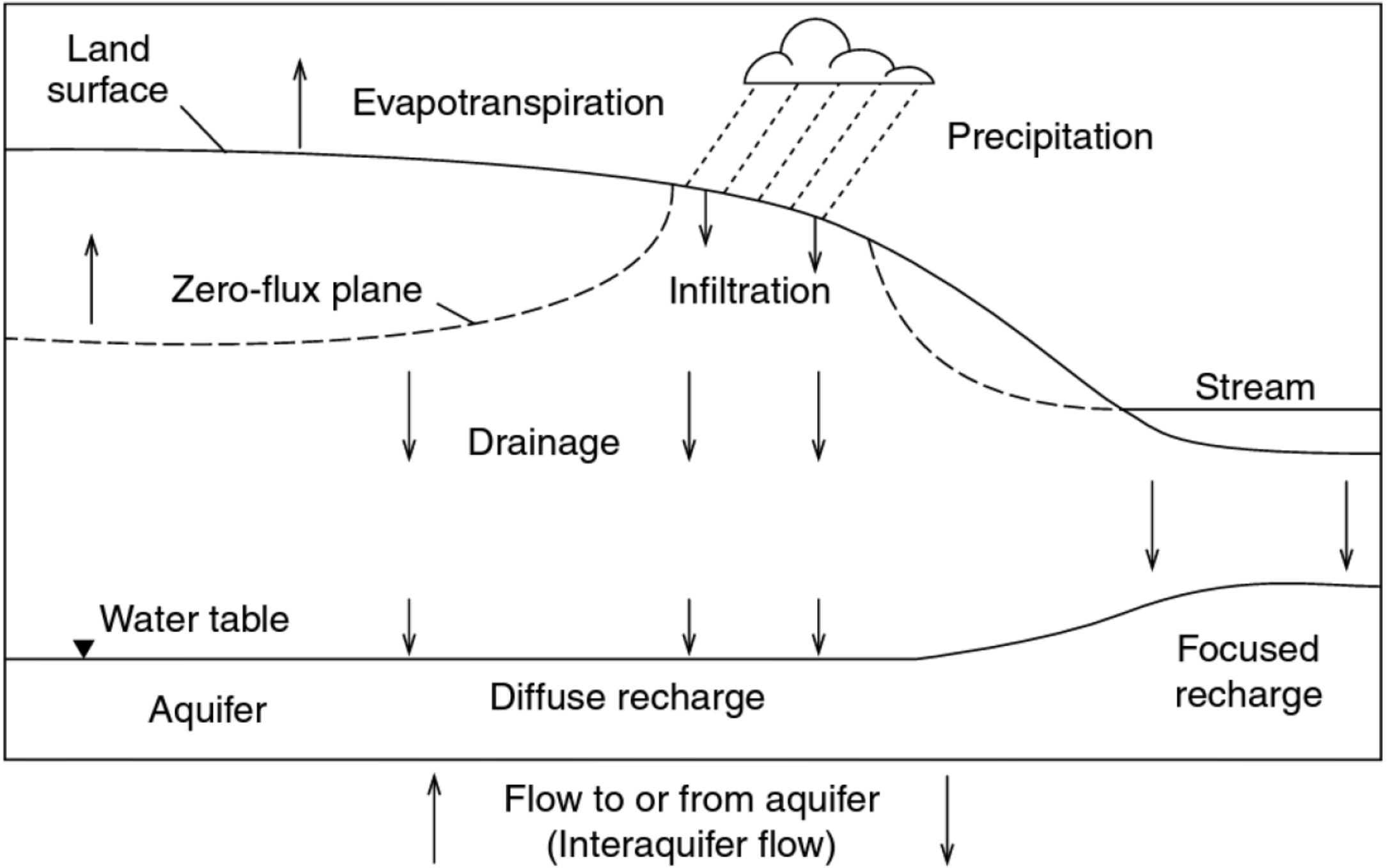
Scanlon et al., 2002



Healy, 2010

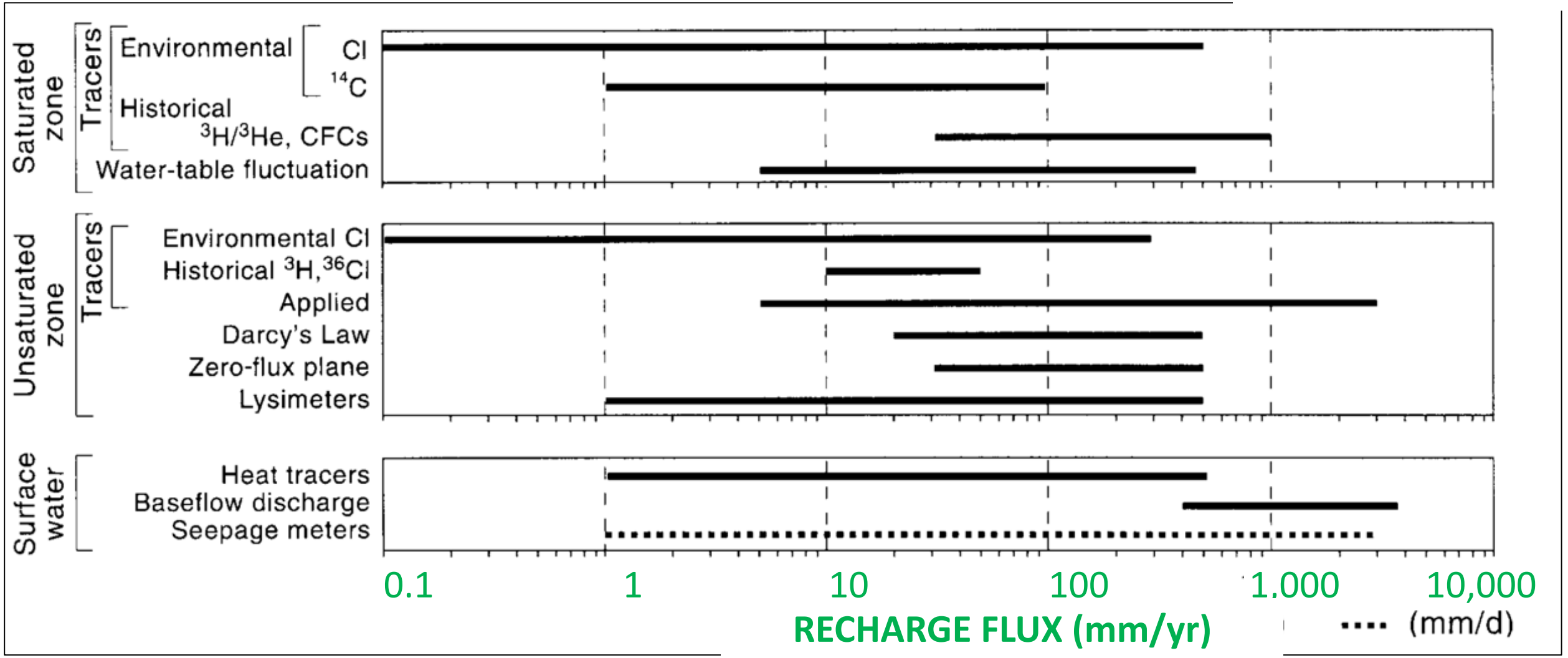
Conceptual vertical cross section of key recharge processes *(Healy, 2010).*

There are roughly ***40 different methods*** *to estimate recharge*



Methods by Amount of Recharge Flux

Scanlon et al., 2002



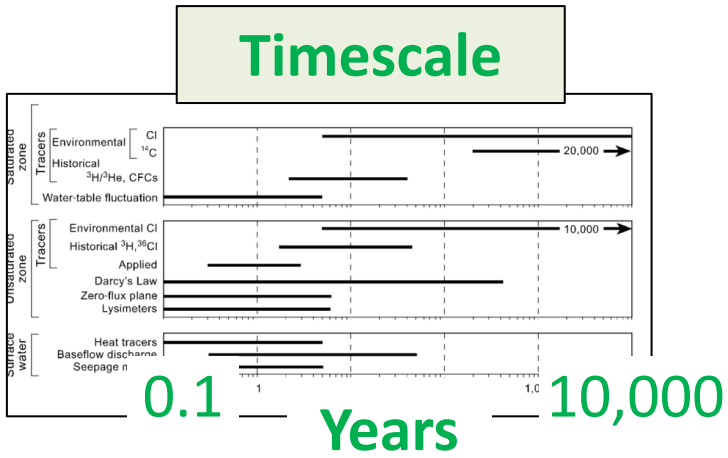
Recharge Methods
Scanlon et al., 2002

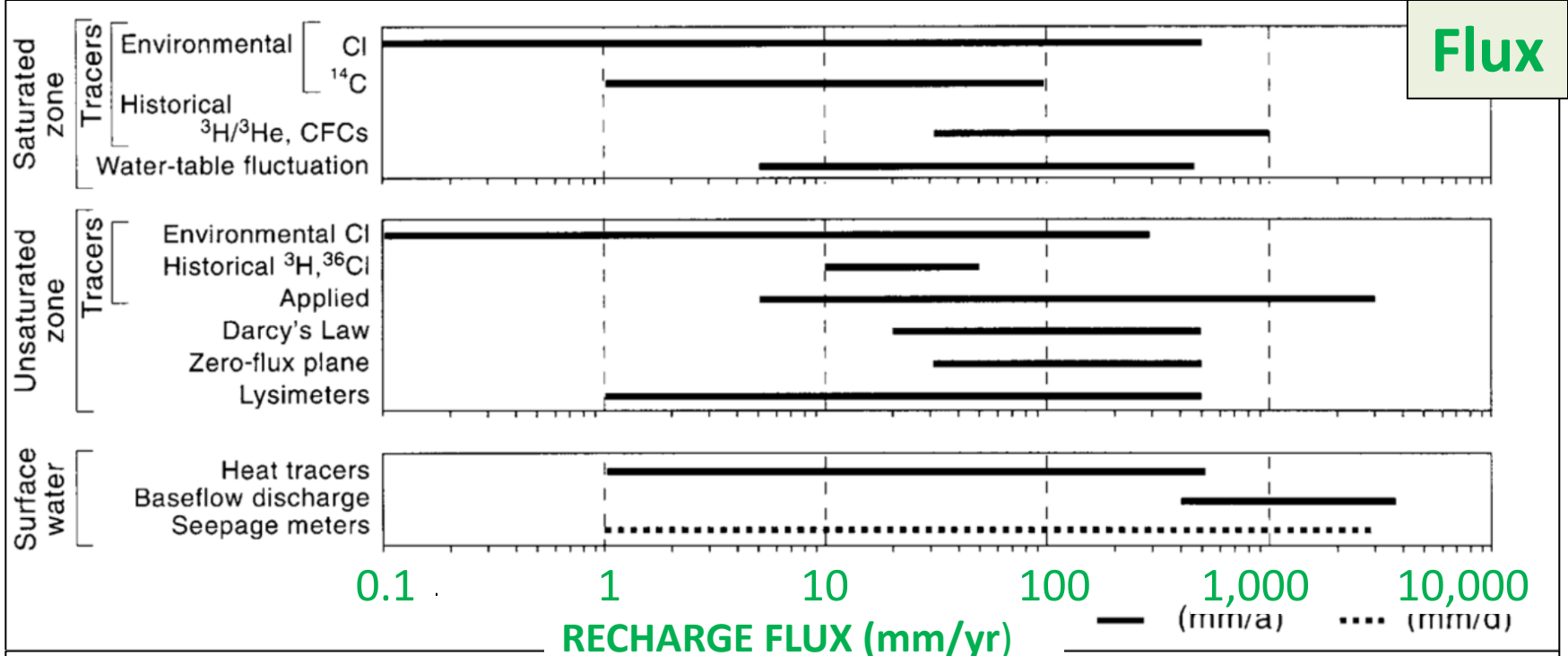
THREE METRICS, THREE GRAPHS

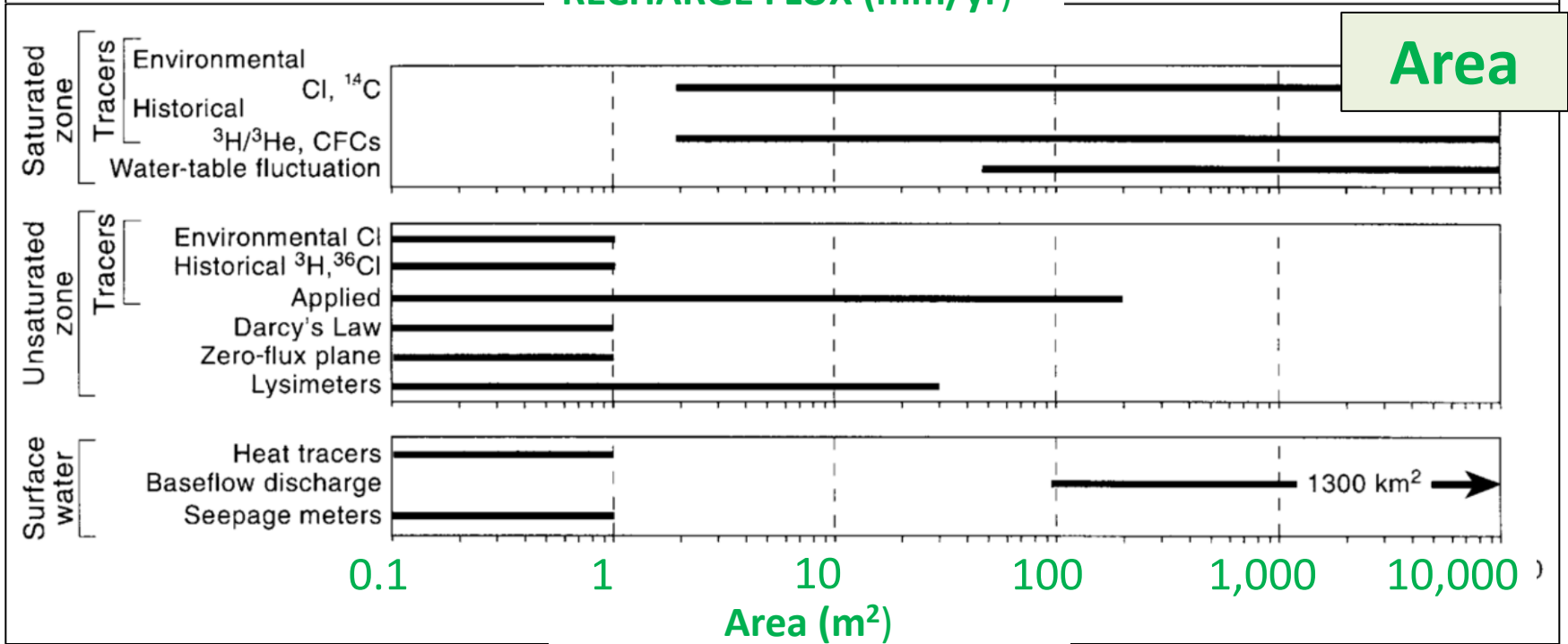
S-1: Recharge Flux Range

S-2: Measurement Area Range

S-3: Time Range (years)





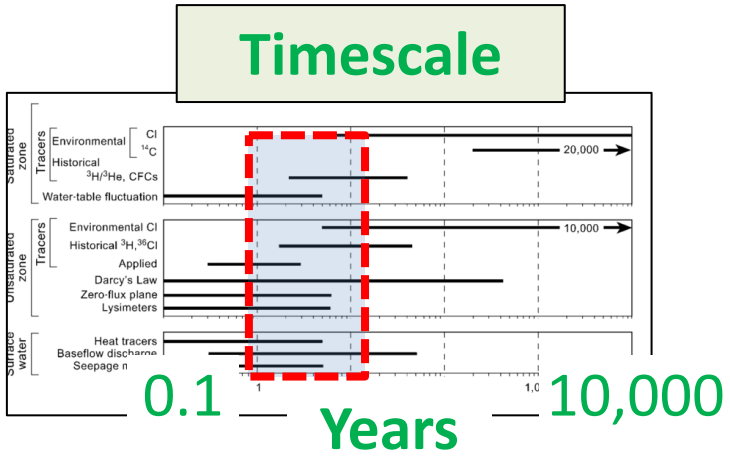


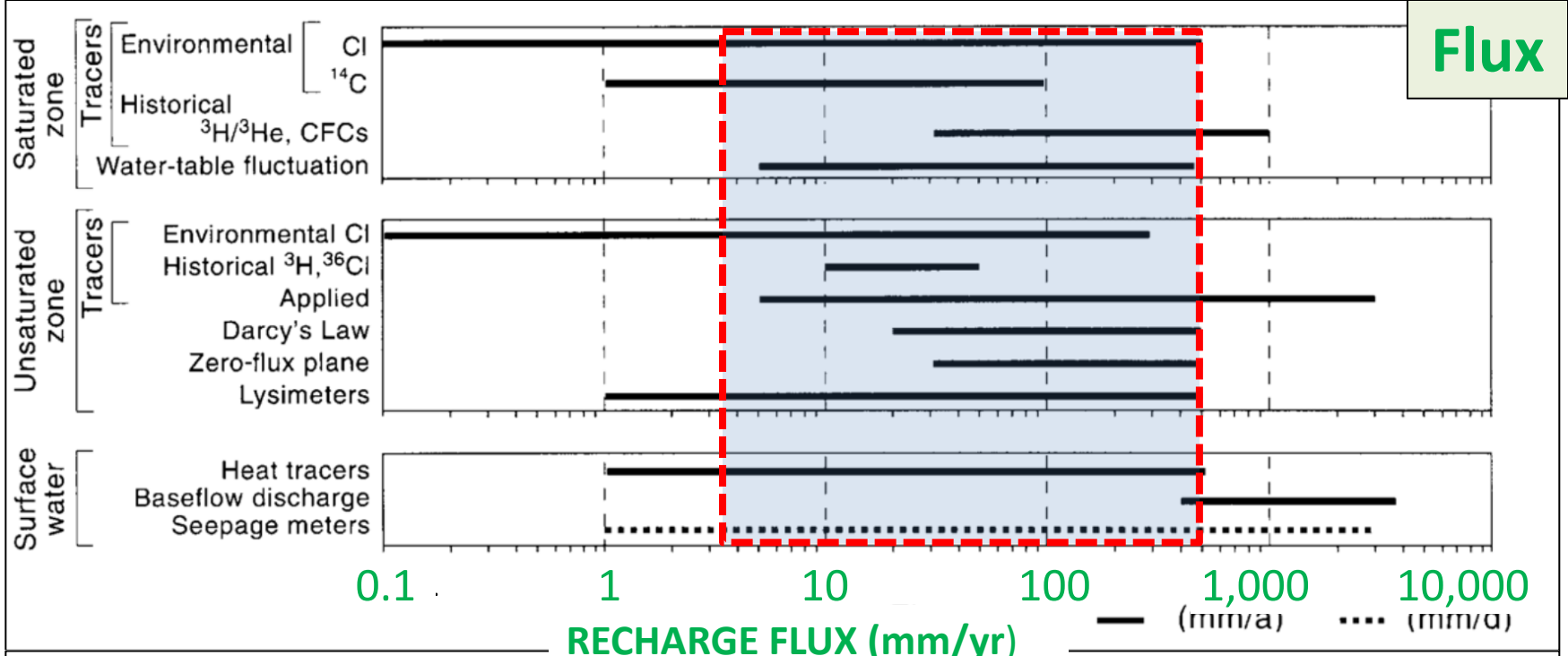
Recharge Methods For PFAS Sites

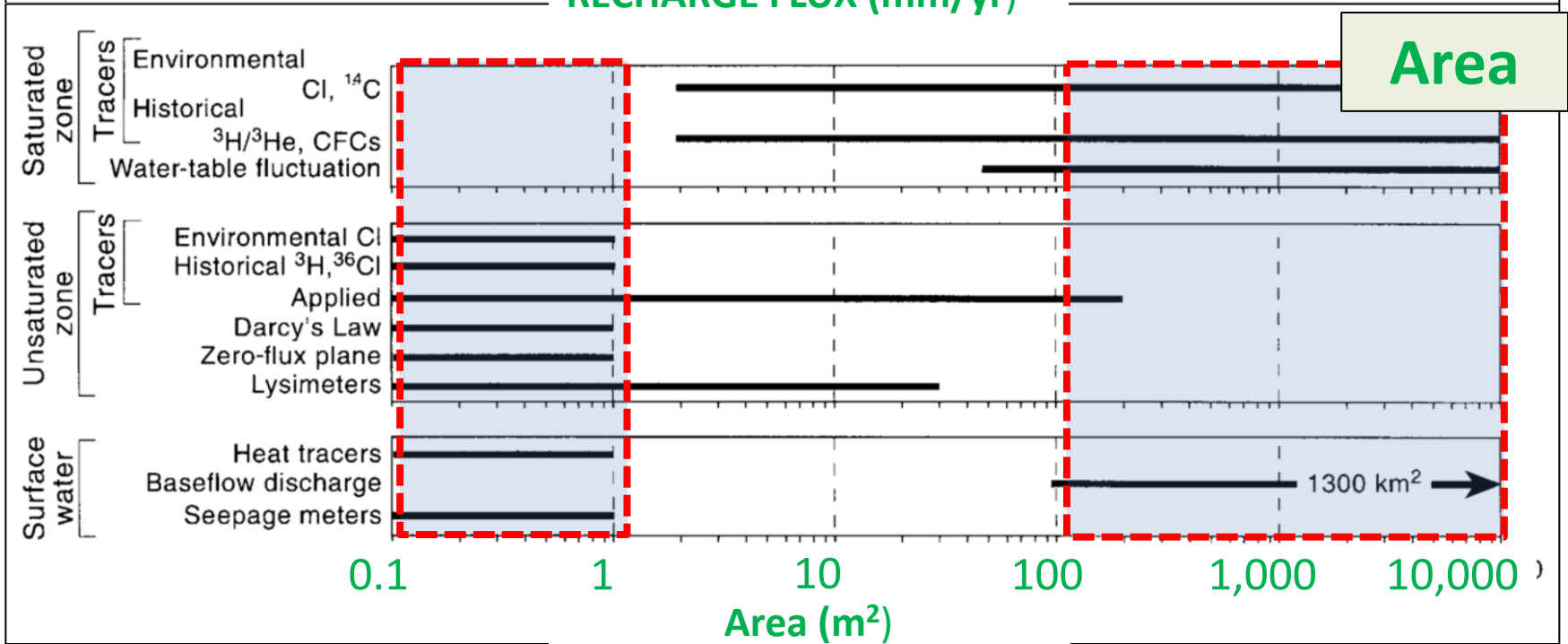
(Newell et al., 2023)

Key Point:

*We narrowed down list of methods to ones **most applicable for PFAS sites***







Tiered Approach To PFAS Recharge

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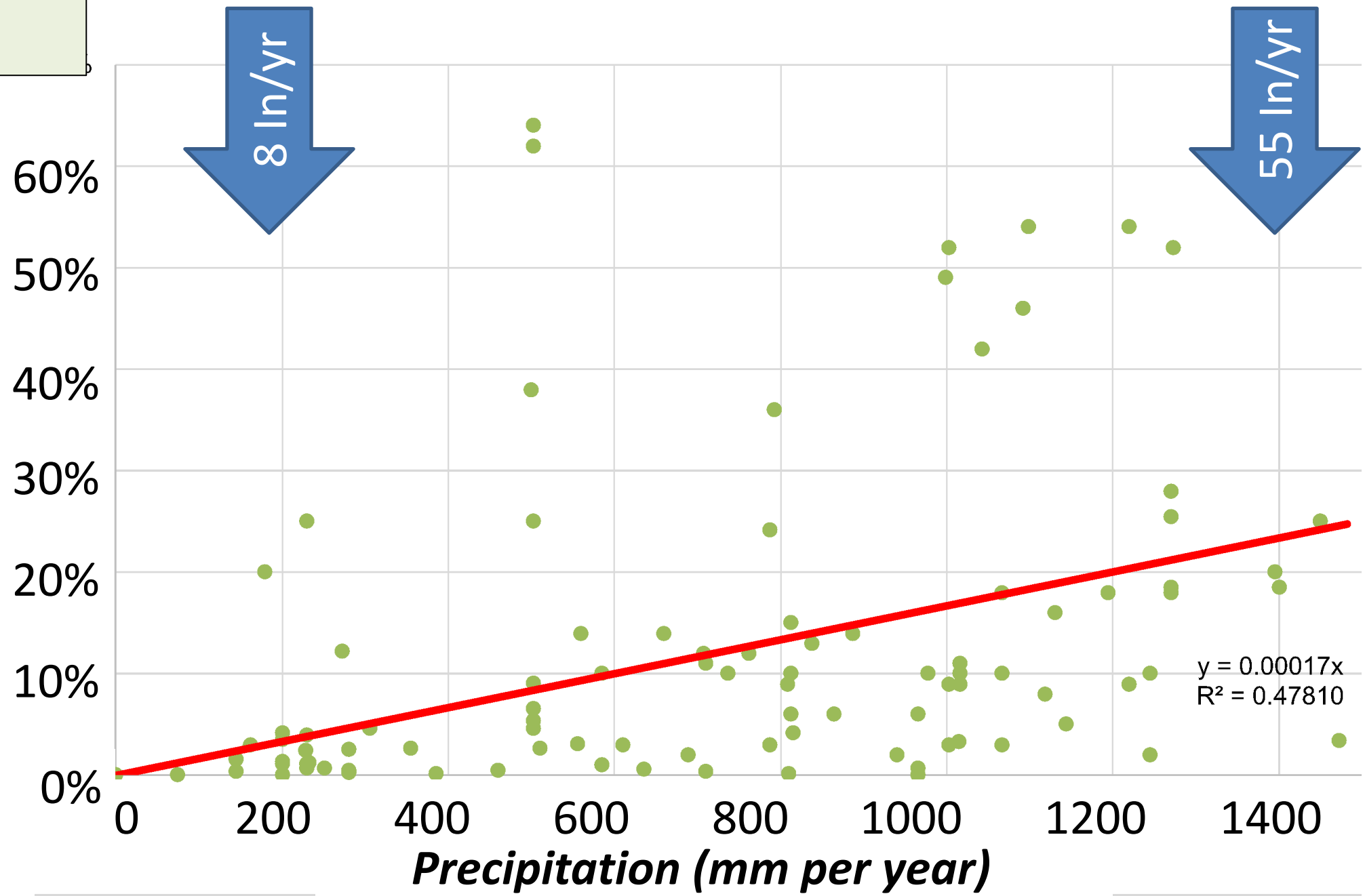
Tier (# of Methods)	Objective	Target PFAS Sites	Need Field Data?	Level of Effort
Tier 1 (4)	Simple source zone recharge estimate	Smaller, low risk	No	Little or no field time. A few hours for analysis.
Tier 2 (6)	Moderate level of effort	Moderate risk	Limited	A few days in the field and a few days for analysis.
Tier 3 (5)	Detailed recharge estimates	Most complex, important sites	Extensive	More extensive field and analysis time than Tier 2 methods.

Method T1-A
Tier 1 Method

Groundwater Recharge as % of Precipitation



Data from Stephens et al., 1996

Method T1-A
Tier 1 Method

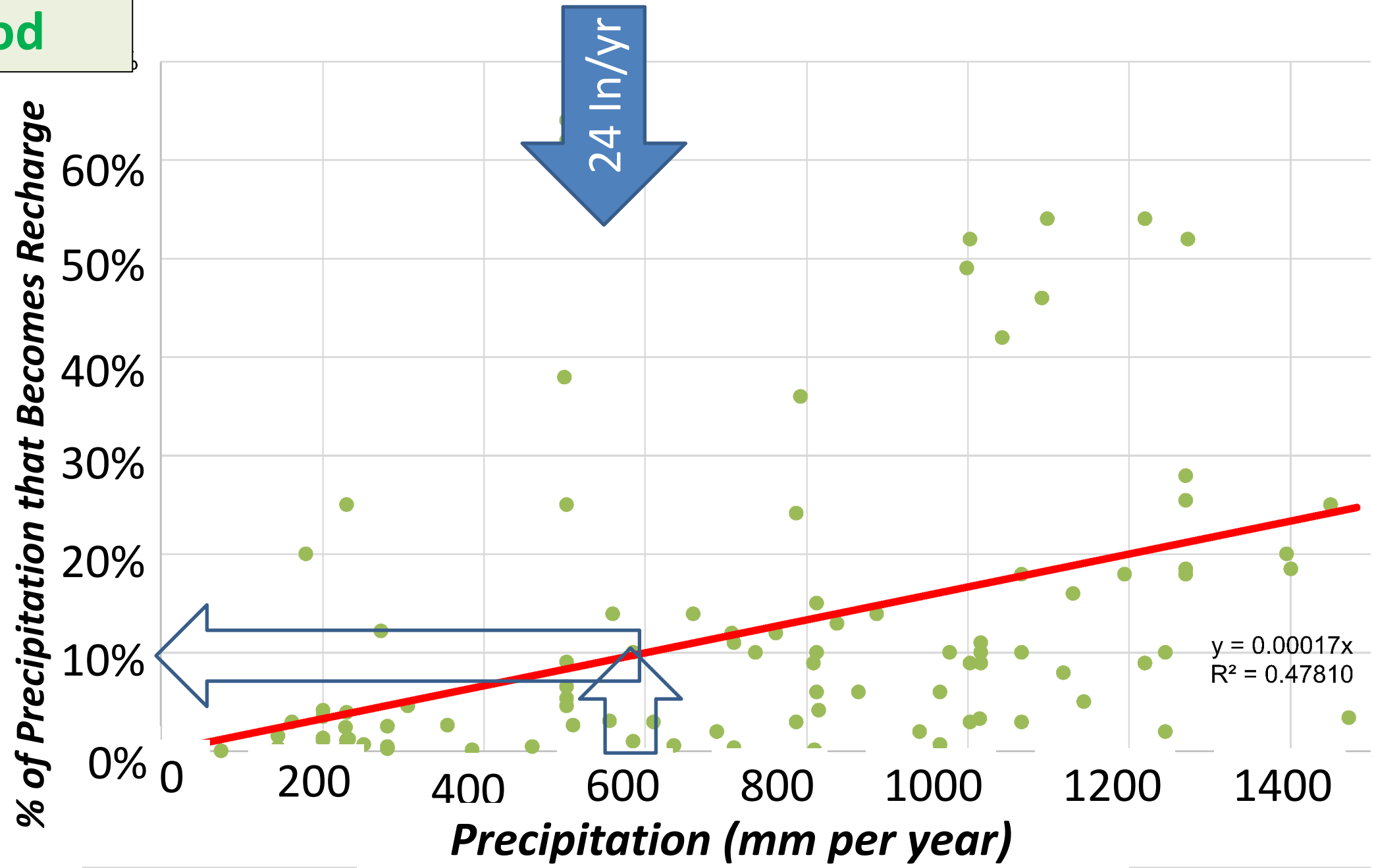
Groundwater Recharge as % of Precipitation

Example:
Precip = 600 mm/yr (24 in/yr

10% becomes recharge

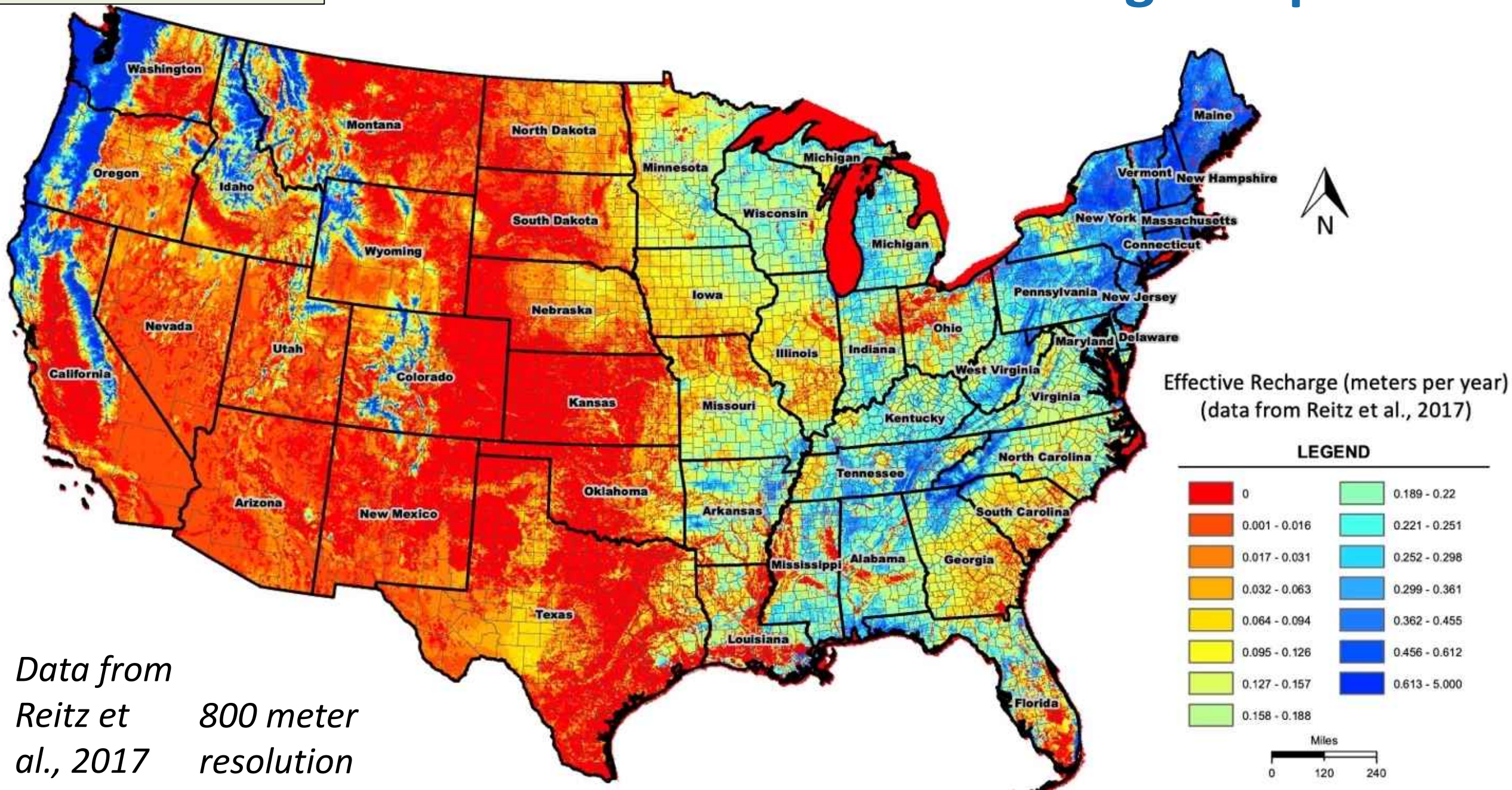
Recharge = 2.4 in/yr

Data from Stephens et al., 1996



Method T1-B

Groundwater Recharge Map

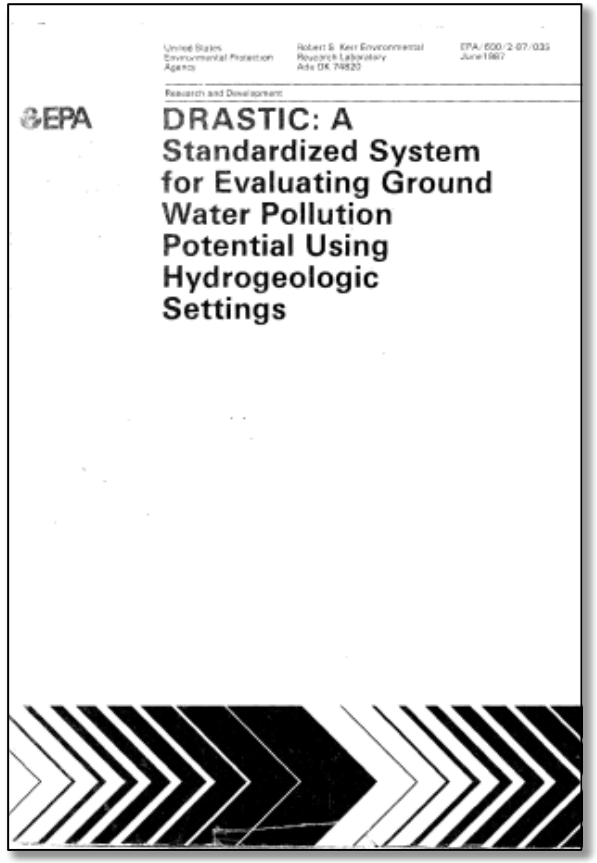


Data from Reitz et al., 2017

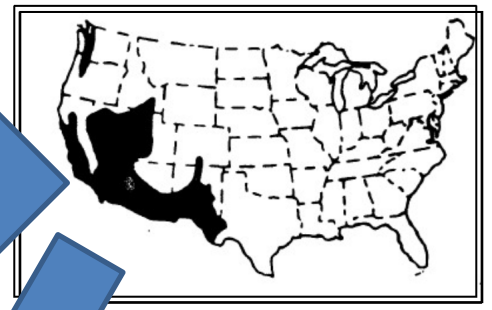
800 meter resolution

Method T1-C

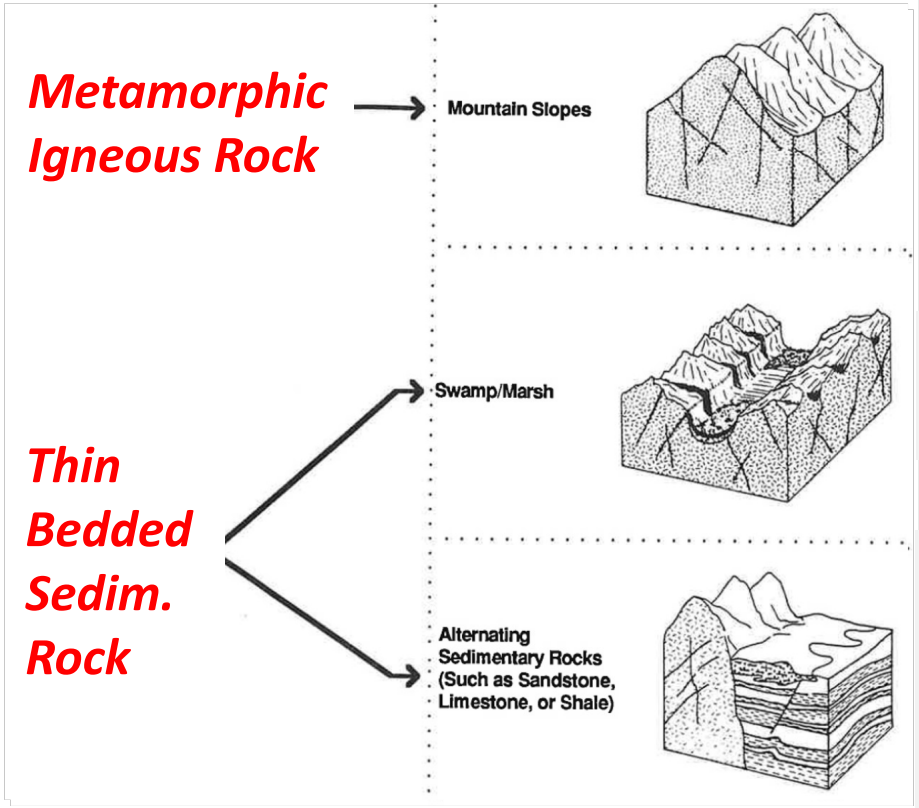
DRASTIC HEURISTIC METHOD



b)



Alluvial Basins Region
(2 Total Hydrogeologic Settings, 3 Shown below)



Mountain Slopes
Recharge:
0-2 Inches Per Year

Swamp/Marshes Recharge:
2-4 Inches Per Year

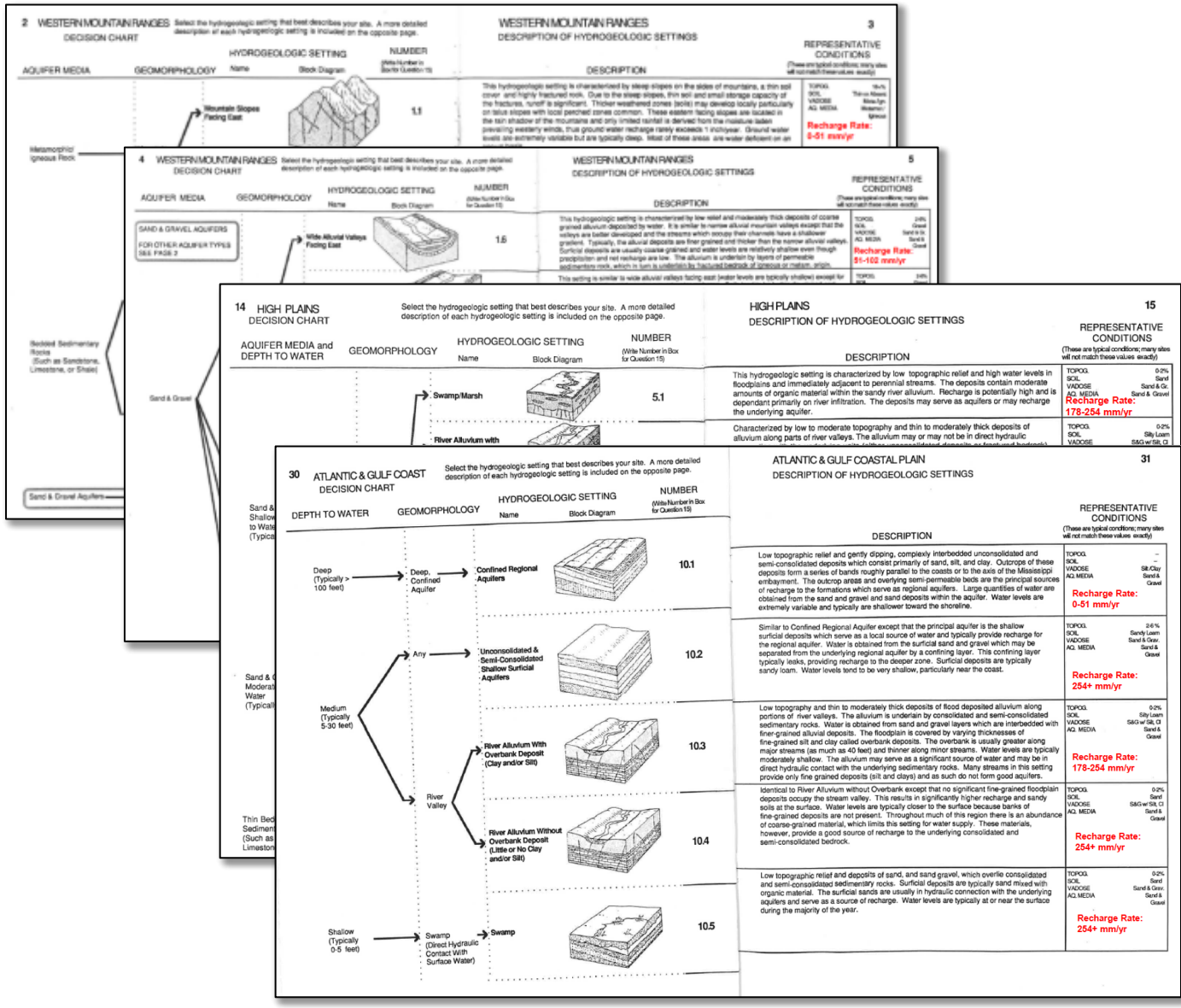
Alternating Sandstone – Shale Sequences
Recharge:
7-10 Inches Per Year

Method T1-C

DRASTIC HEURISTIC METHOD

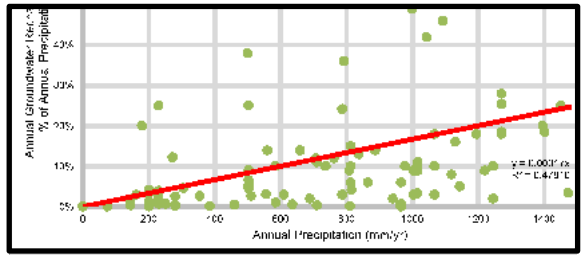
111 Different Hydrogeologic Recharge Estimates

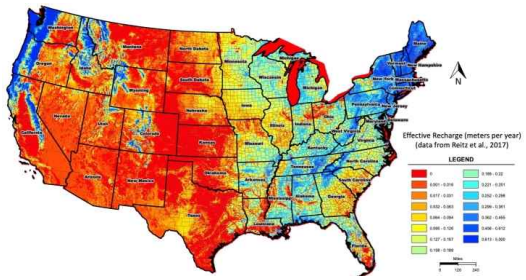
(30 Pages)

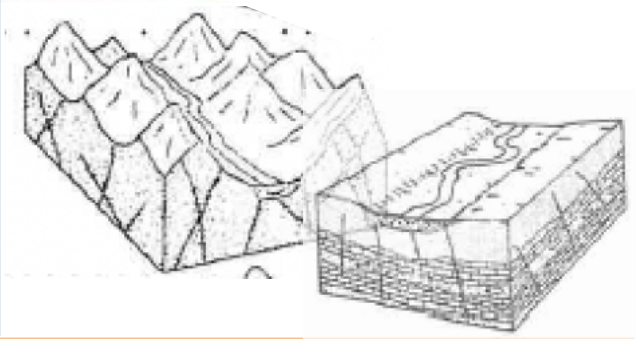


Comparison of Three Tier 1 Recharge Estimation Methods

K. Askarani

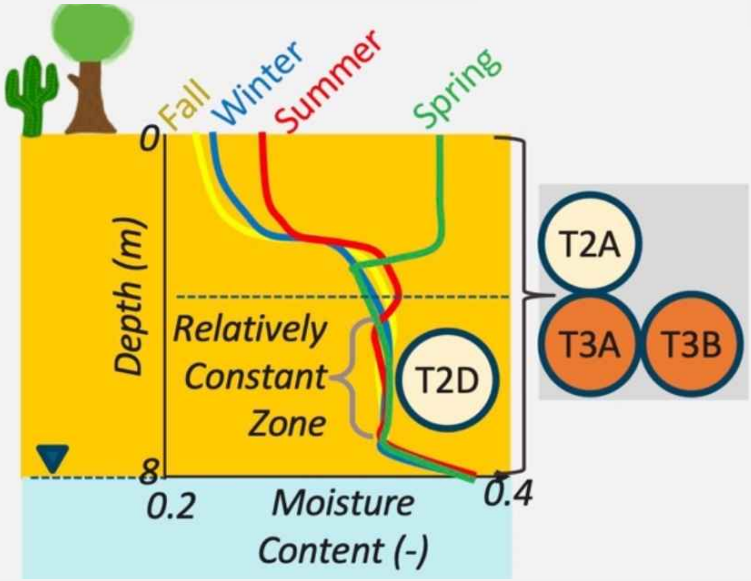




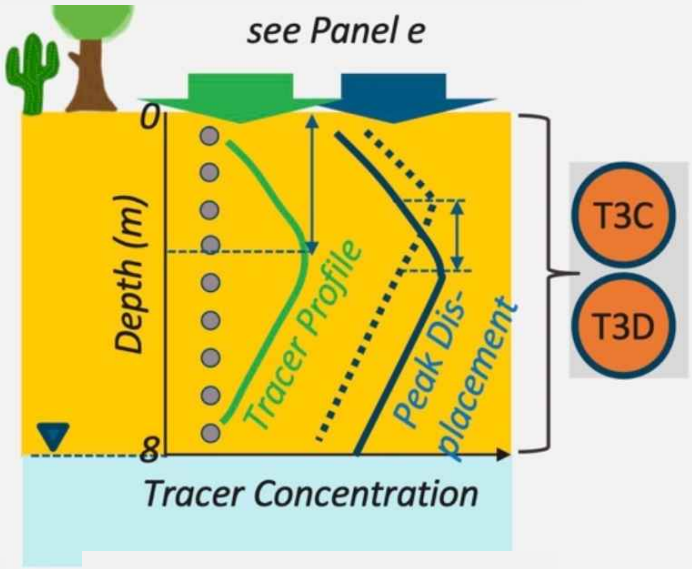


Site	Regression Method T1-A (inches per year)	Reitz Baseflow Method T1-B (inches per year)	DRASTIC Heuristic Method T1-C (inches per year)
Site 1 Wyoming, US	1.0	0.7	0-2
Site 2 Tennessee, US	15	9.3	7-10

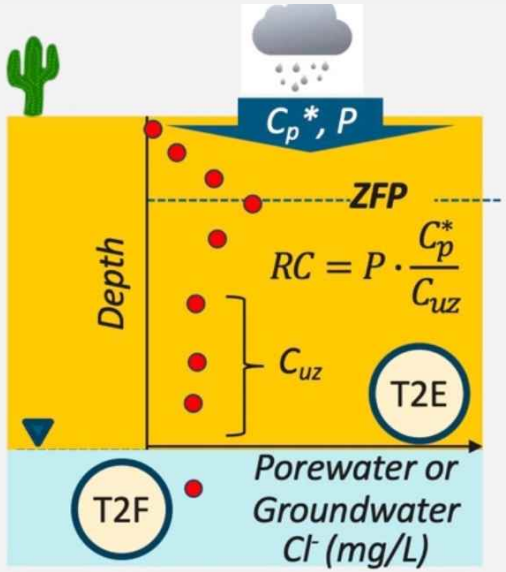
Soil Moisture



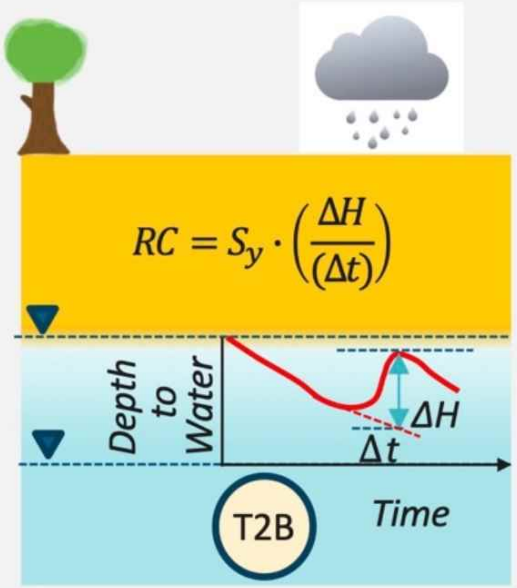
Unsat. Zone Tracers



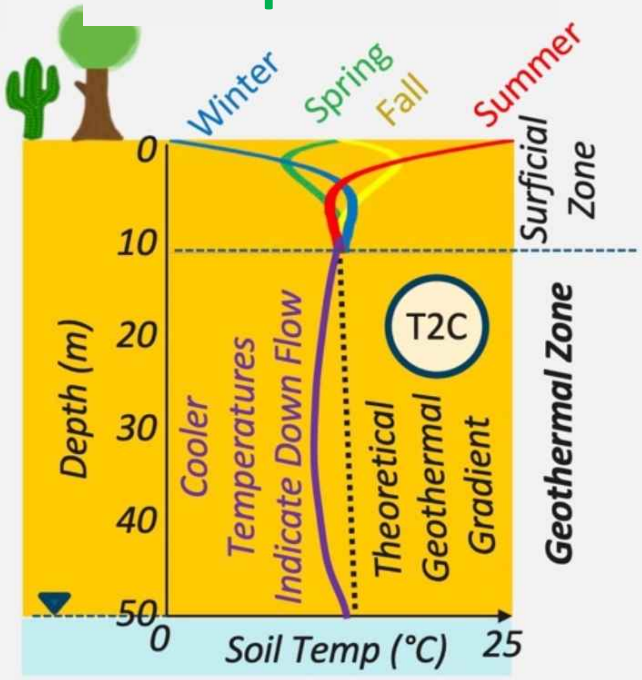
Meteoric Chloride



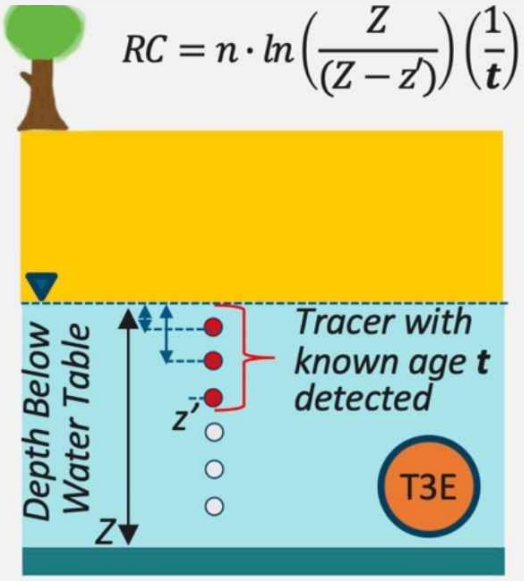
Water Table Fluctuation (WTF)



Temperature



Groundwater Tracers



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Legend

Generally better for:

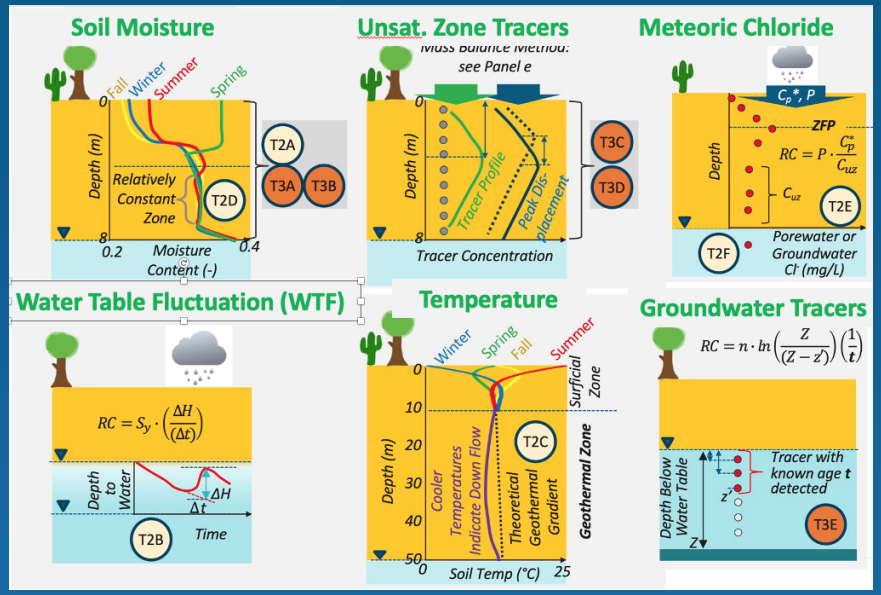
- *More Humid Climates*
- *More Arid Climates*

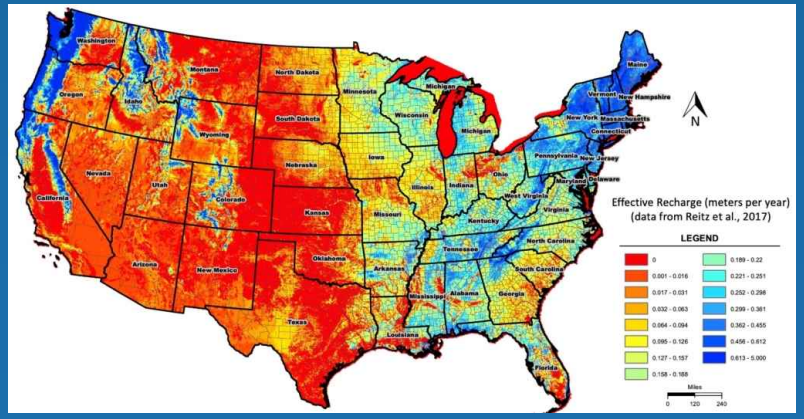
PFAS Recharge Methods:

- T1D *Tier 1*
- T2C *Tier 2*
- T3B *Tier 3*

WRAP UP

- PFAS Mass Discharge (Md) from the unsaturated zone is a key metric needed to manage PFAS sites
- Recharge needed to quantify Md
- *"Standing on the Shoulders of Giants"*
  - Vadose Zone Journal Article (Newell et al., 2023)
  - Reviewed 40 total methods based on Flux, Area, and Timescale
  - 15 potentially useful recharge estimation methods identified for PFAS sites
- A Tiered Approach was developed for PFAS sites, from simple to complex recharge methods





QUESTIONS

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