Aquifer nitrate:
perspectives from streambed sampling

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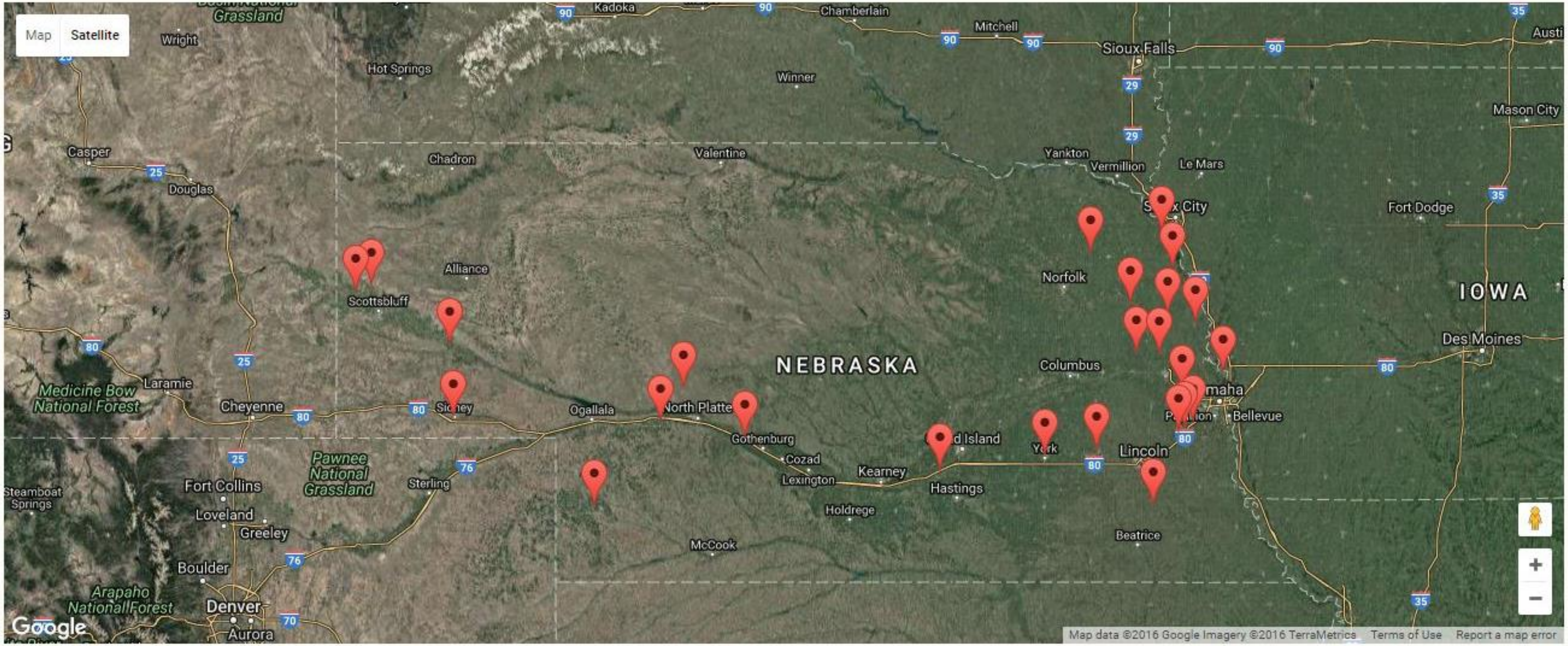
Groundwater Age and Transit Times in Nebraska

Authors: Troy Gilmore (Conservation and Survey Division, School of Natural Resources) and Mason Johnson

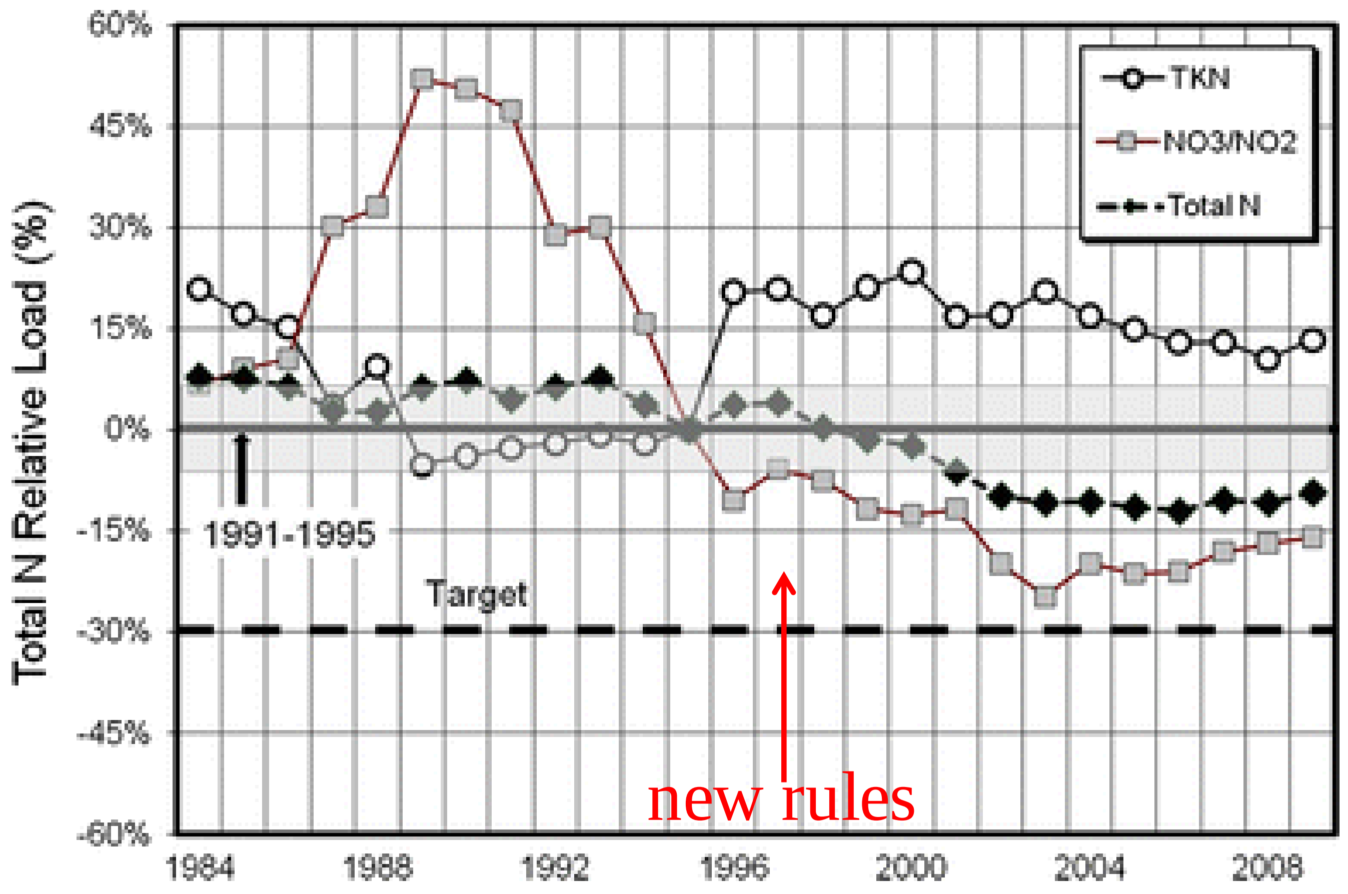


https://go.unl.edu/gwage

Nitrogen

- most widespread contaminant in groundwater
- excess N linked to negative environmental impacts <u>globally</u> (“in the news”: hypoxia, algal blooms, fish kills)

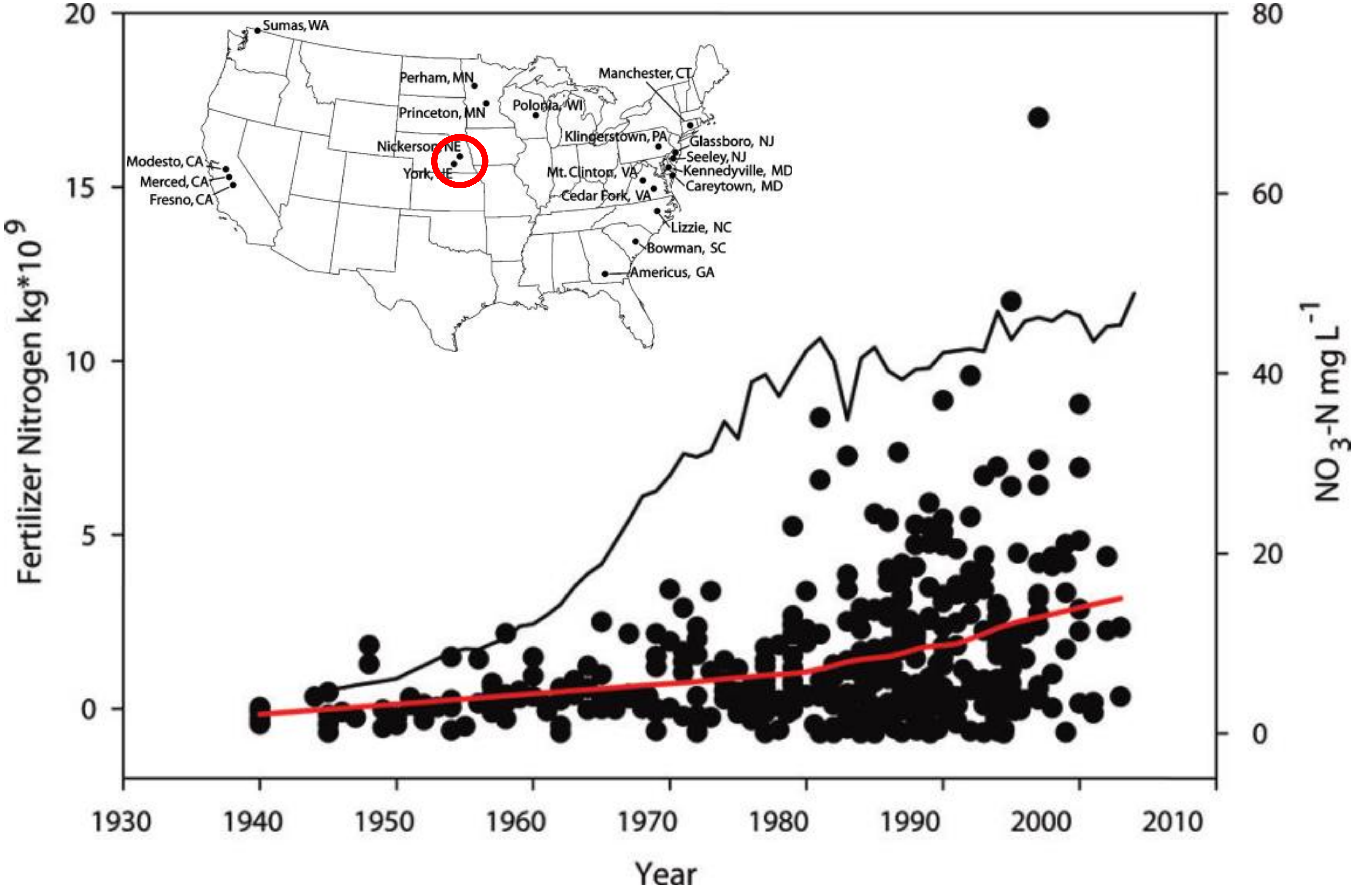
- Important topic in NC: Neuse River "Nutrient Sensitive Waters" rules in 1997
  - 30% reduction target not met
  - discharge from GW systems could contribute to “stubborn persistence”



Lebo et al. (2012), *Env. Management*

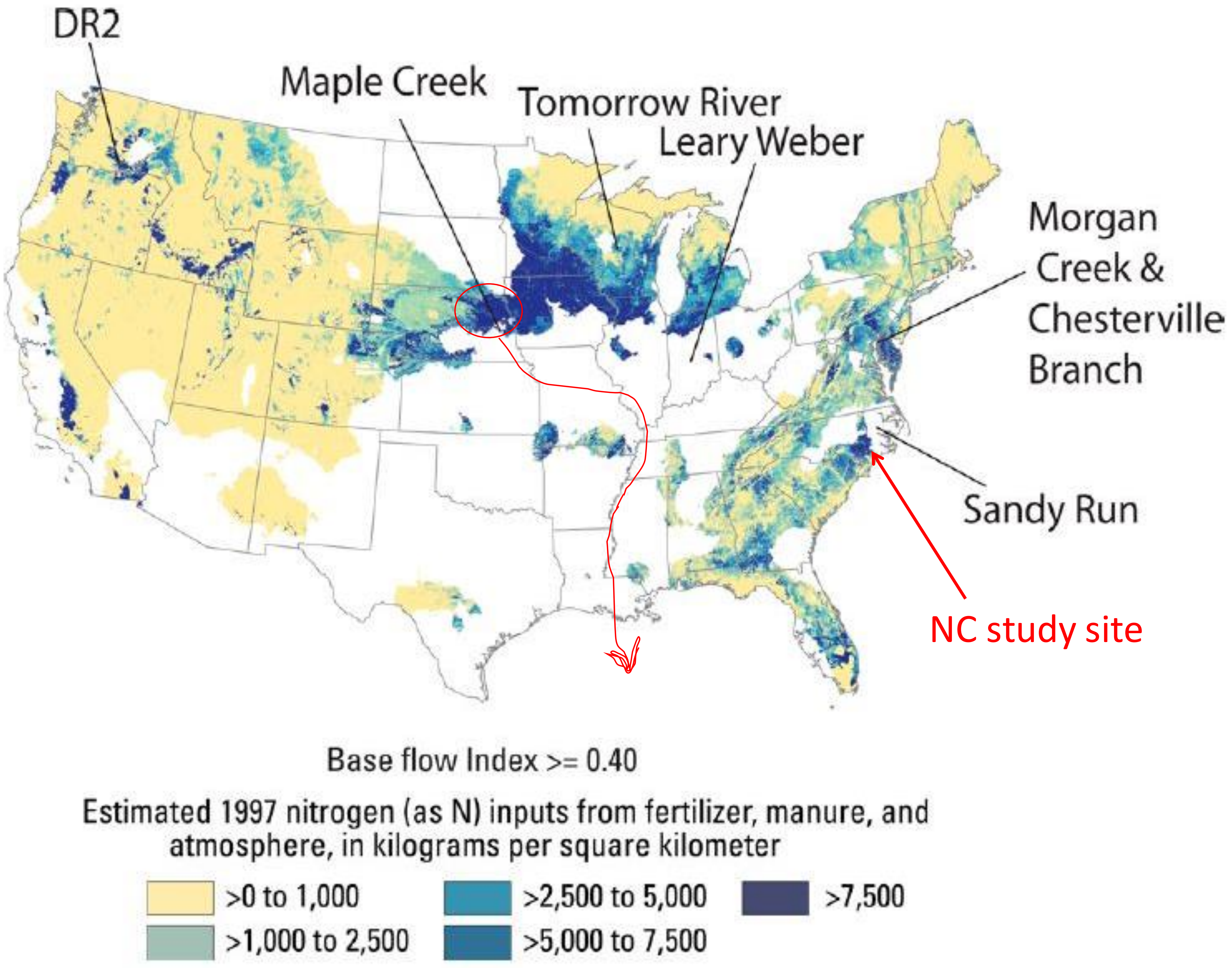
Age-dating to assess "recharge" nitrate concentrations

20 Watersheds Across the US



Puckett et al. (2011) *Environmental Science & Technology* 45: 839-844

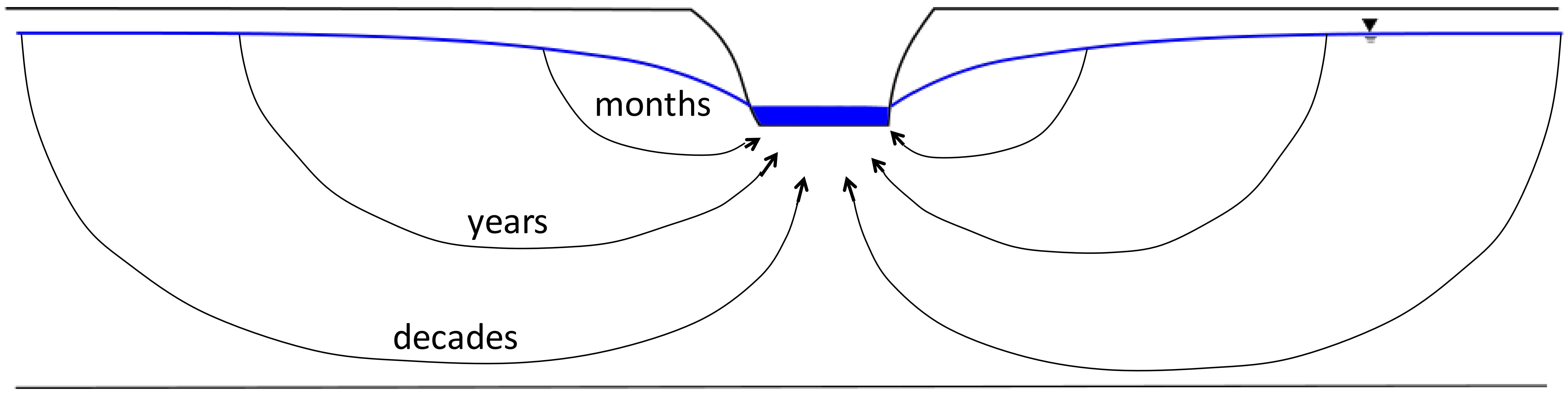
Stream vulnerability to GW contamination



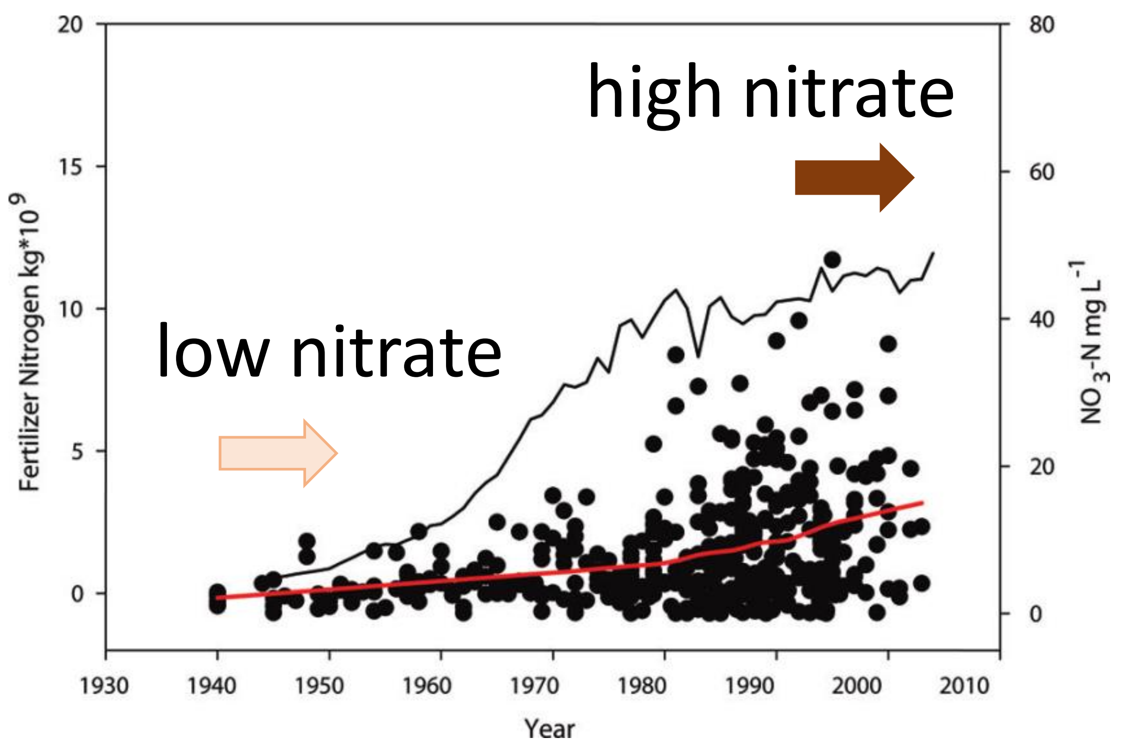
Tesoriero et al. (2013)

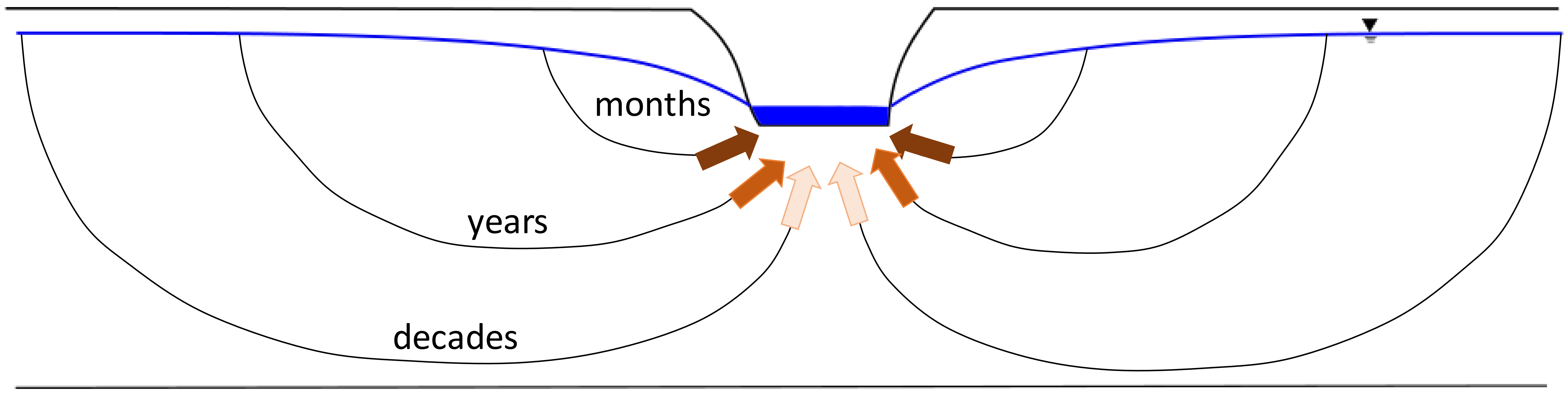
Groundwater and nitrate discharge to streams

- transit times (GW age)
- denitrification
- groundwater discharge rates



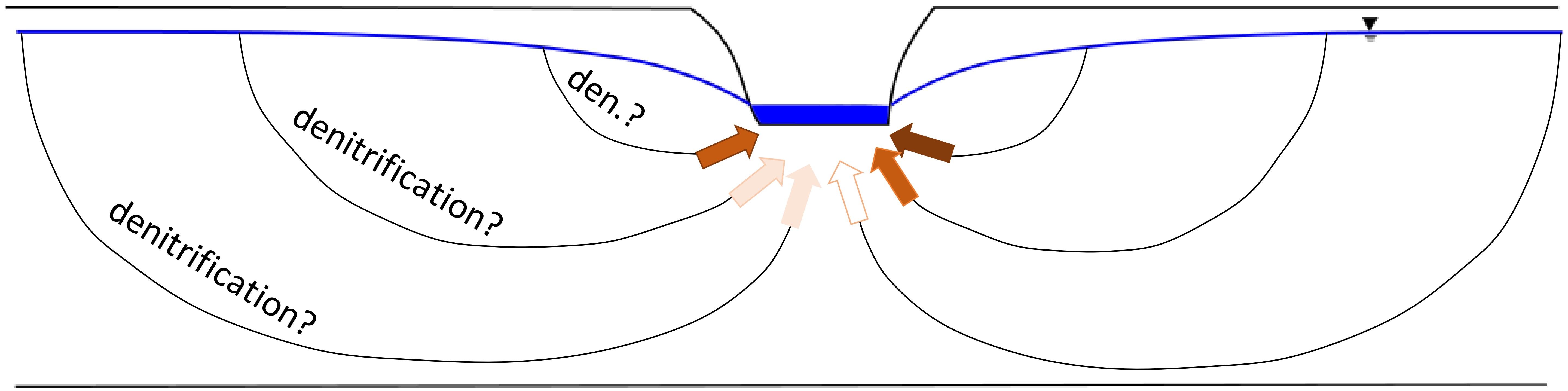
GW Transit Times … influence on NO_3^- conc.



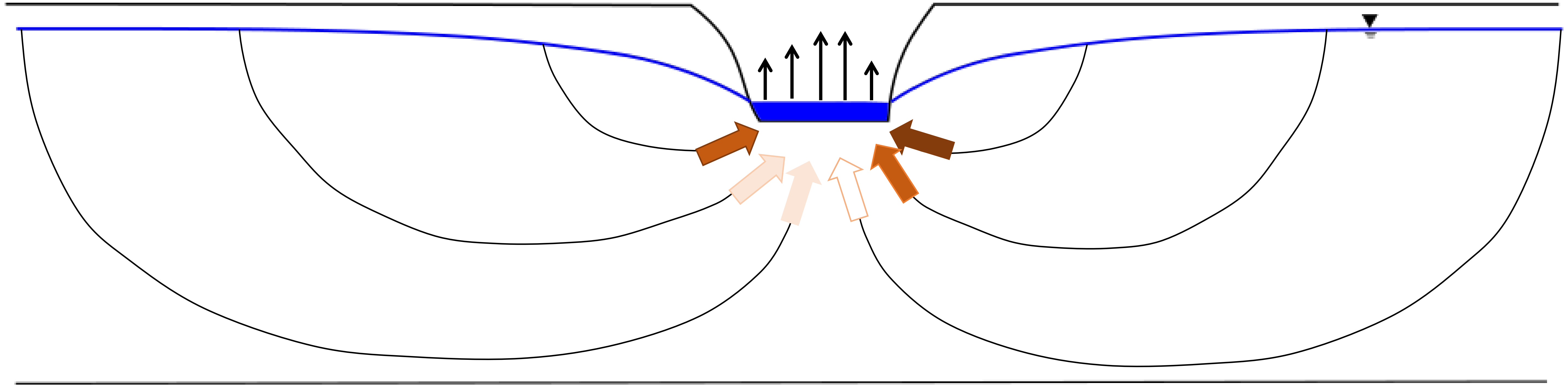


The Fate of Aquifer Nitrate: denitrification

$$5\text{“}CH_2O\text{”} + 4NO_3^- + 4H^+ \rightarrow 7H_2O + 2N_2 + 5CO_2$$

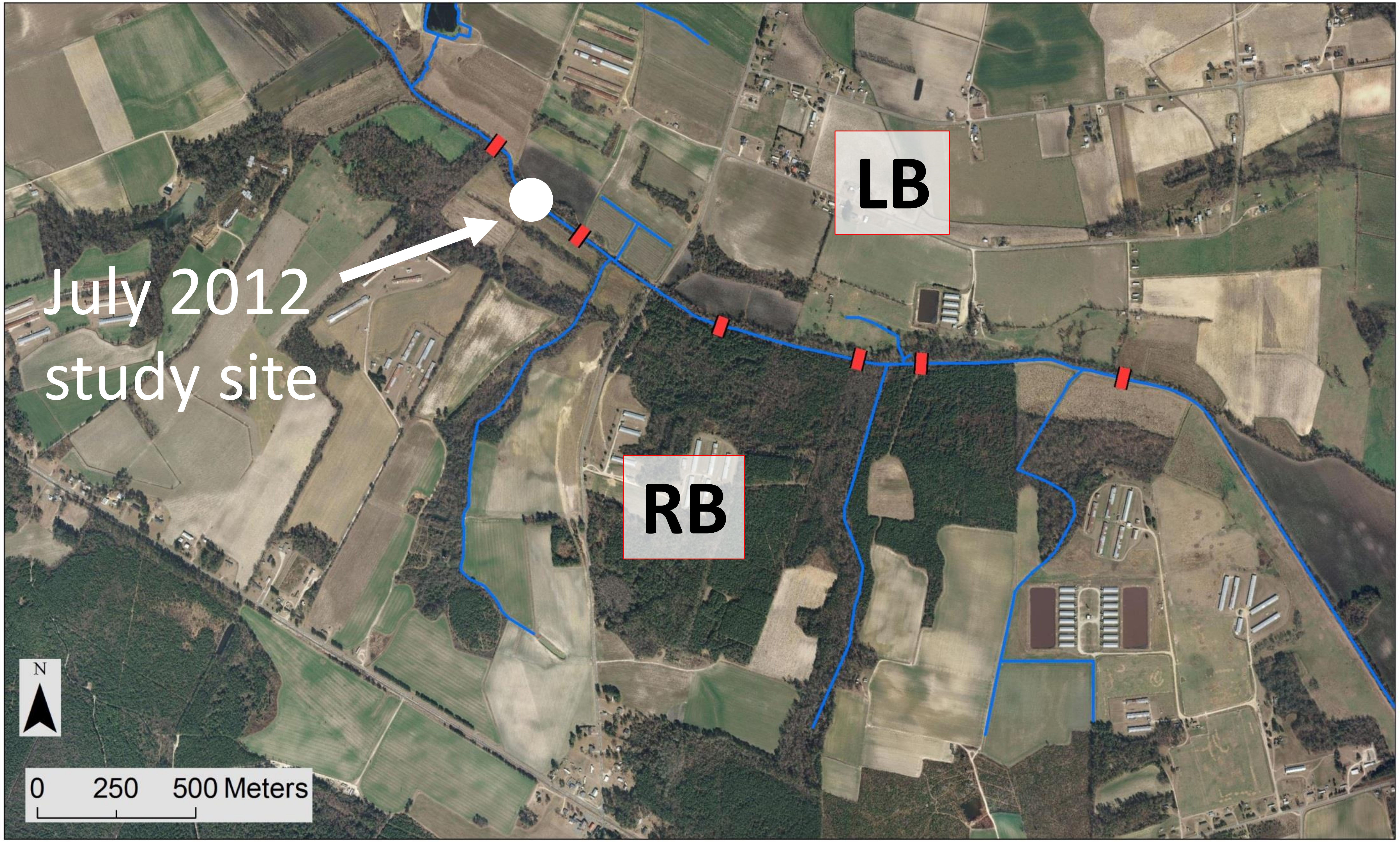


The other fate: GW discharge to streams



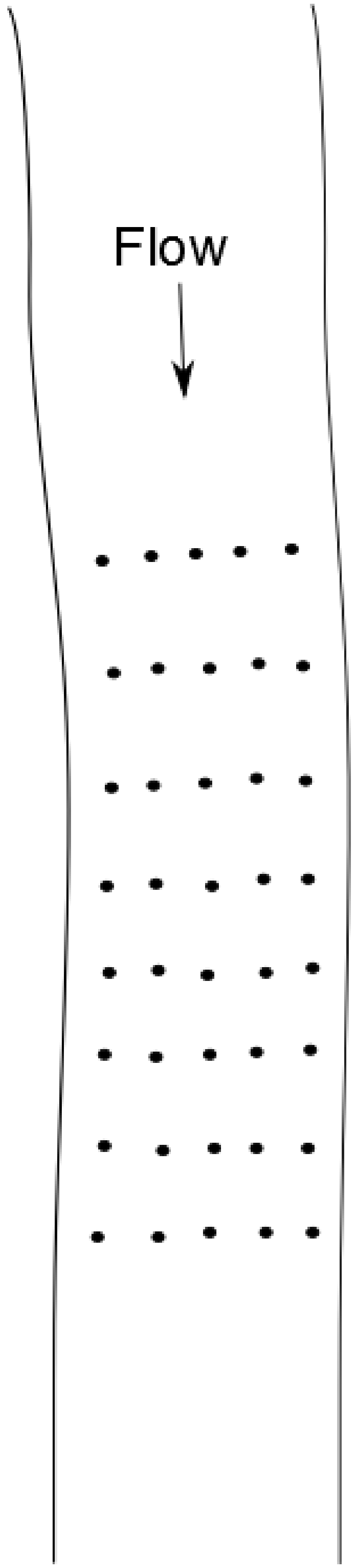
West Bear Creek Watershed, North Carolina, USA

West Bear Creek, near Goldsboro, North Carolina, USA

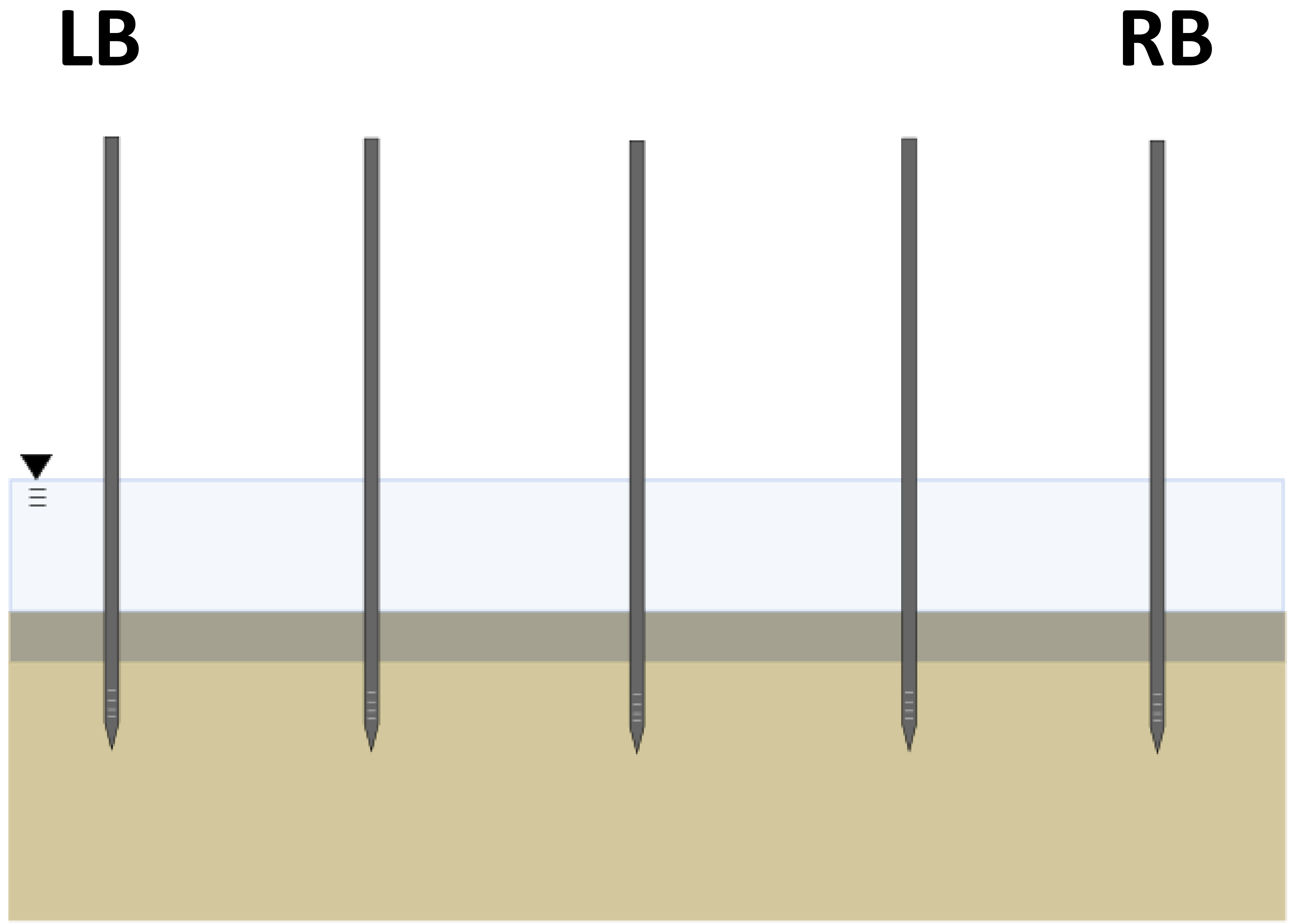


West Bear Creek watershed,
March 2013

Data collection:

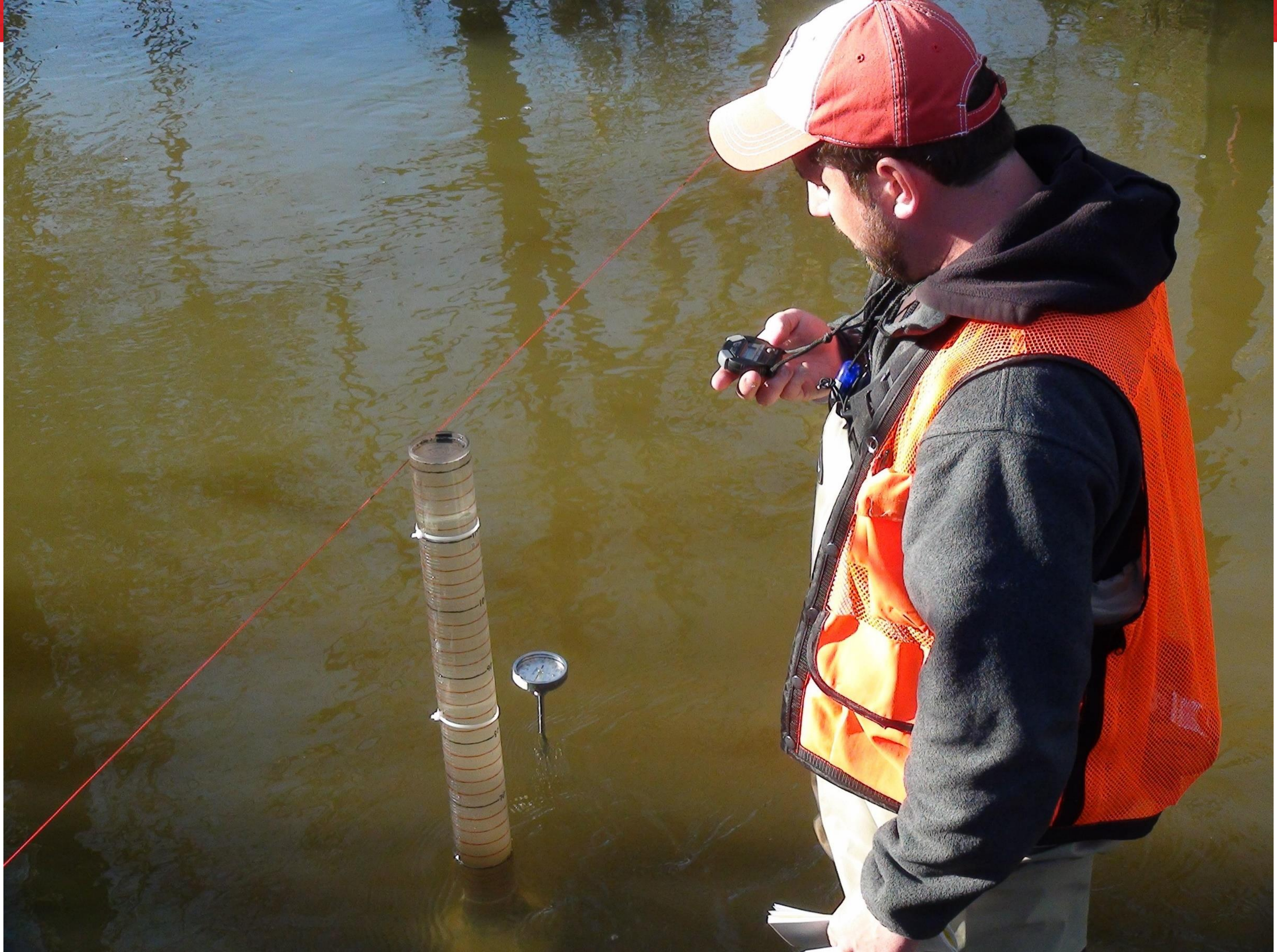


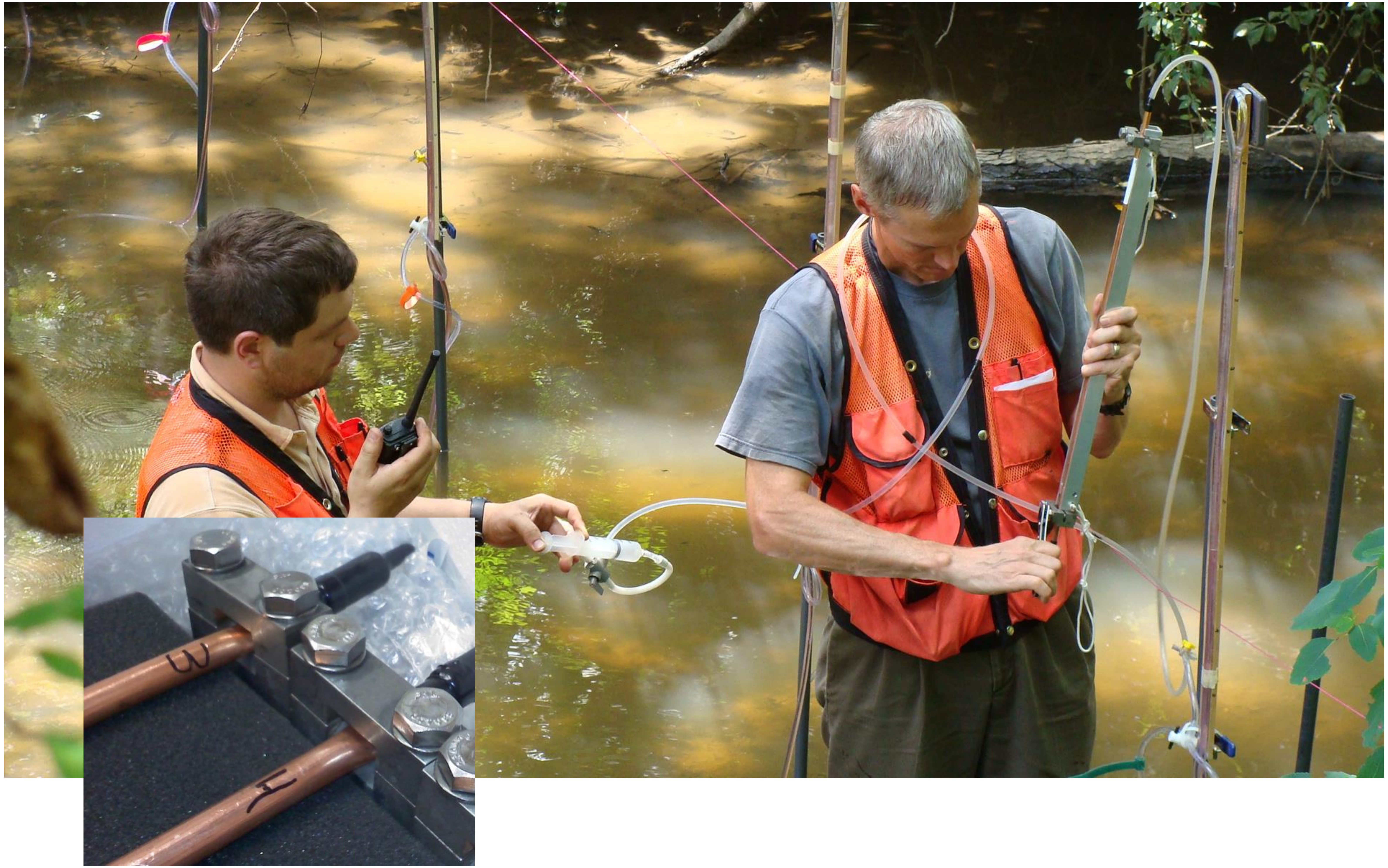
Kennedy et al. 2007, 2009;
Genereux et al. 2008



Data Collection

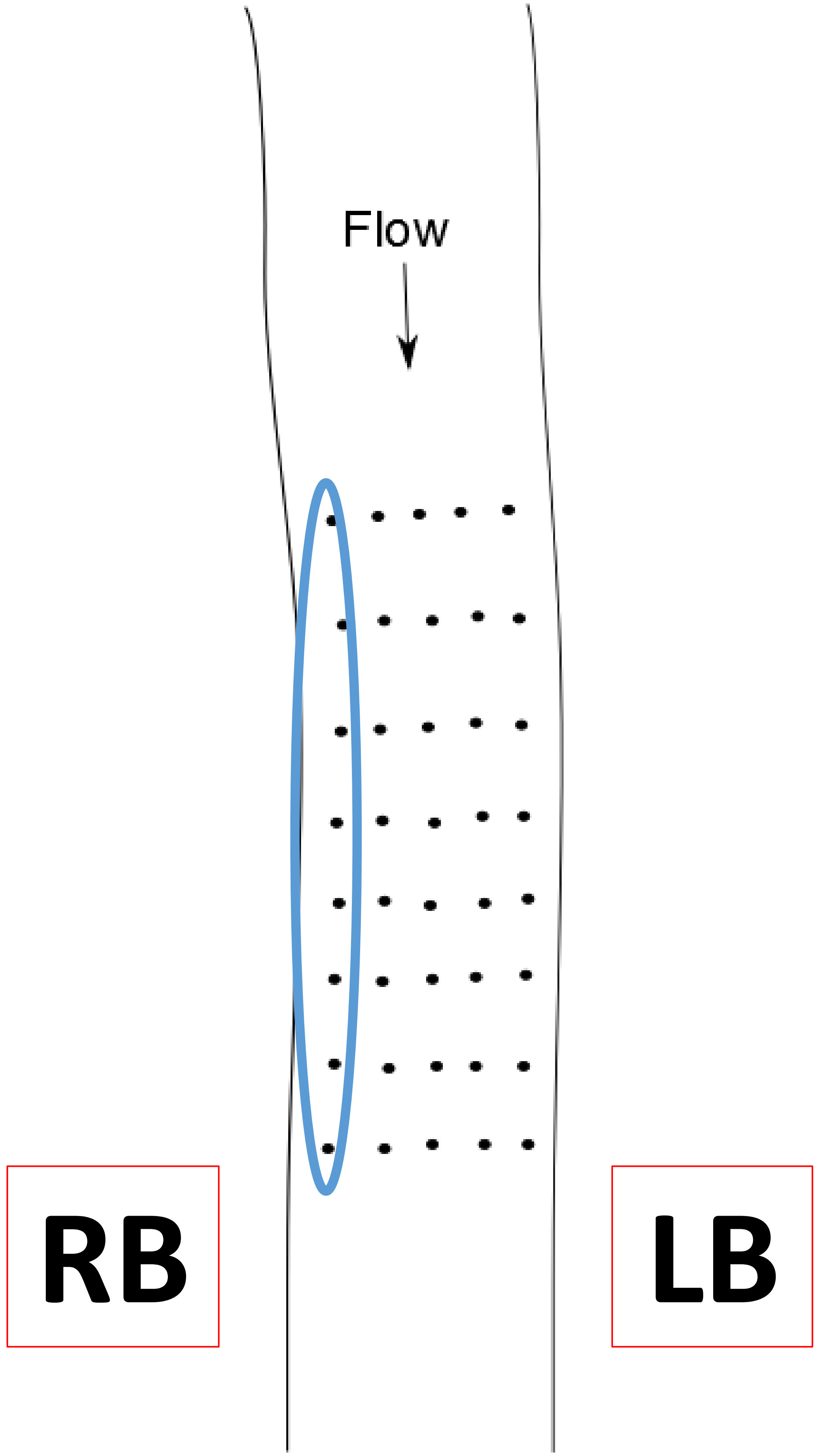
1. Groundwater discharge
2. Groundwater nitrate concentration
3. GW dissolved gases (incl. age-dating tracers)

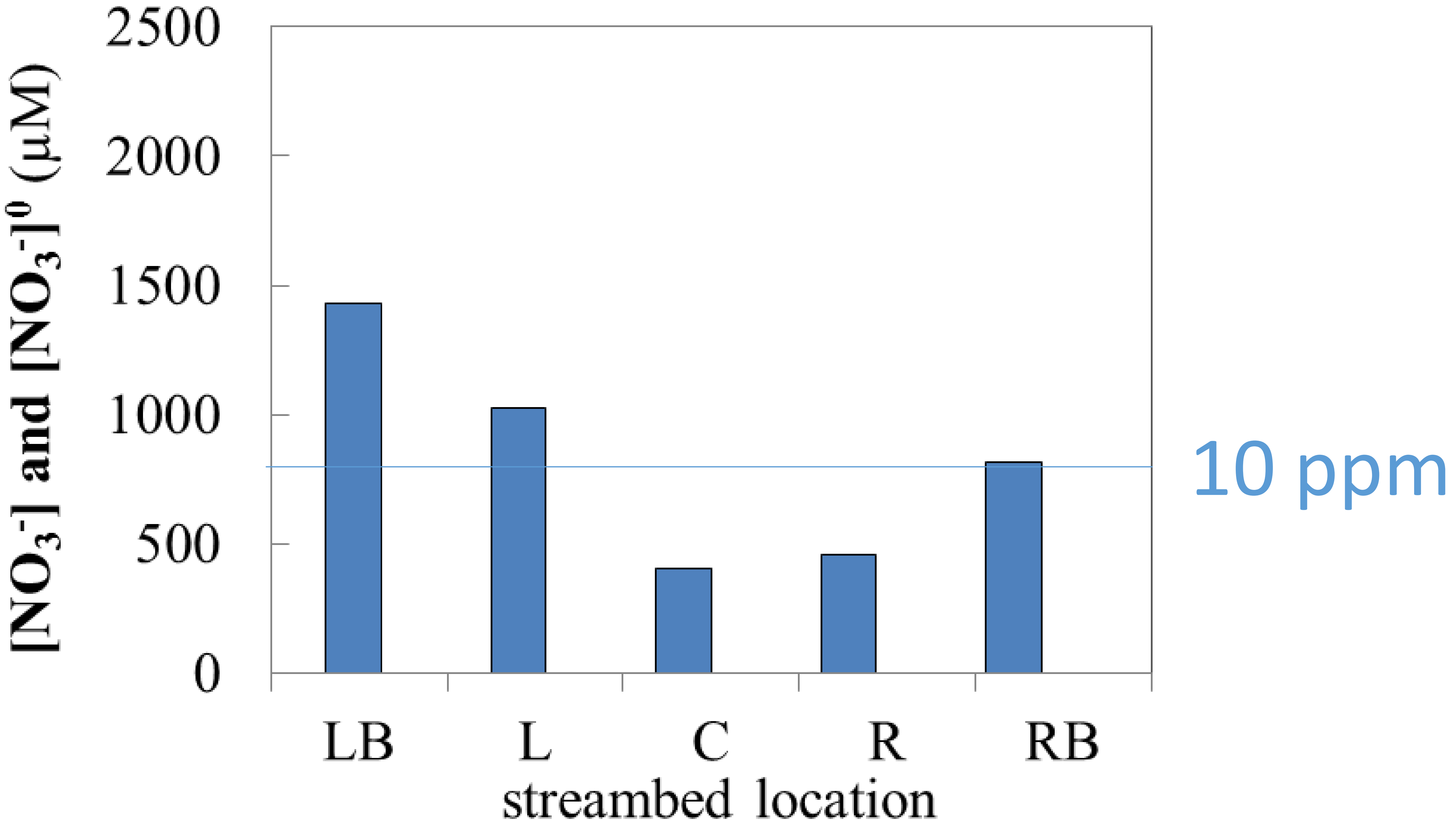


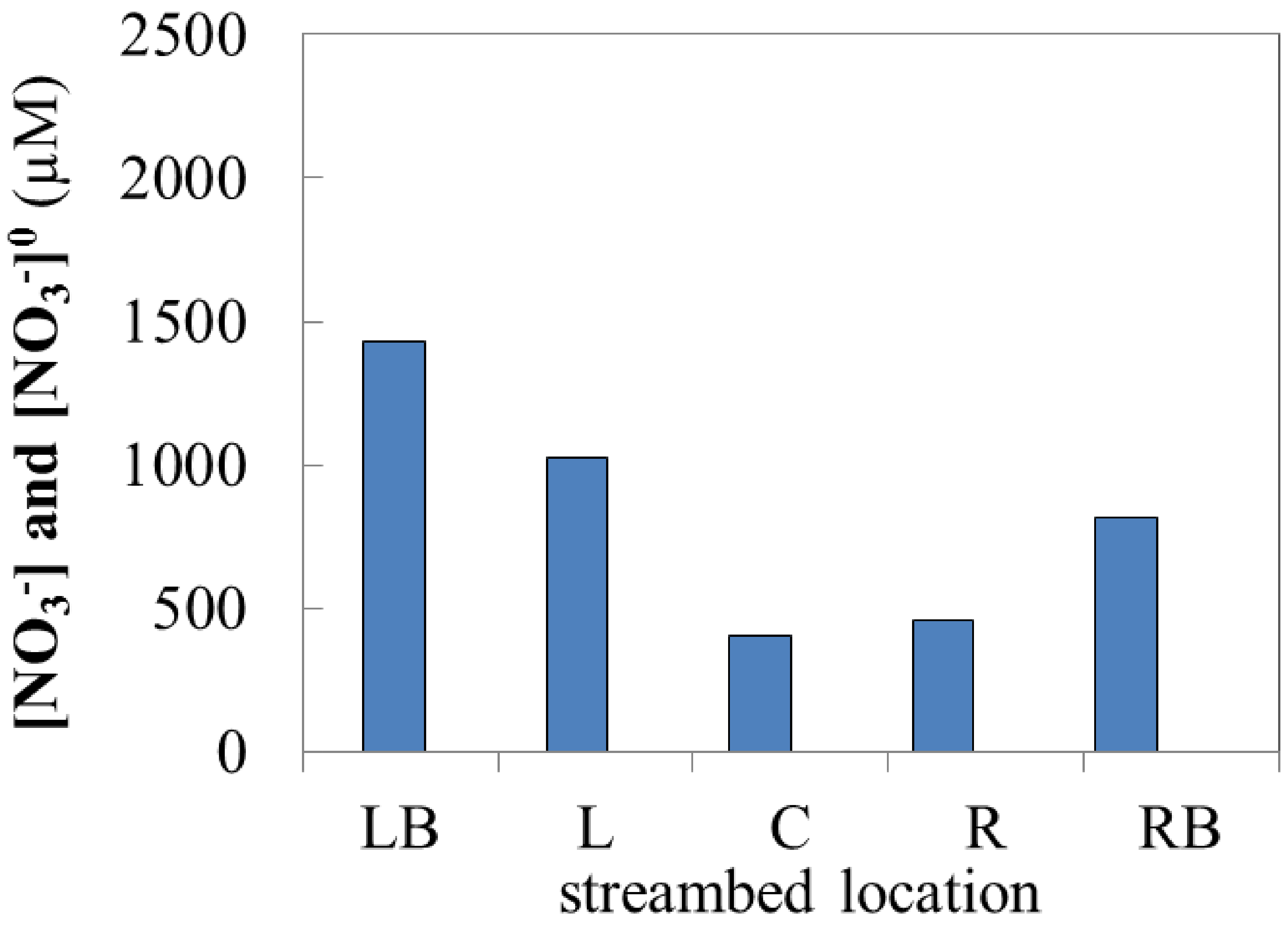

3
4

Results

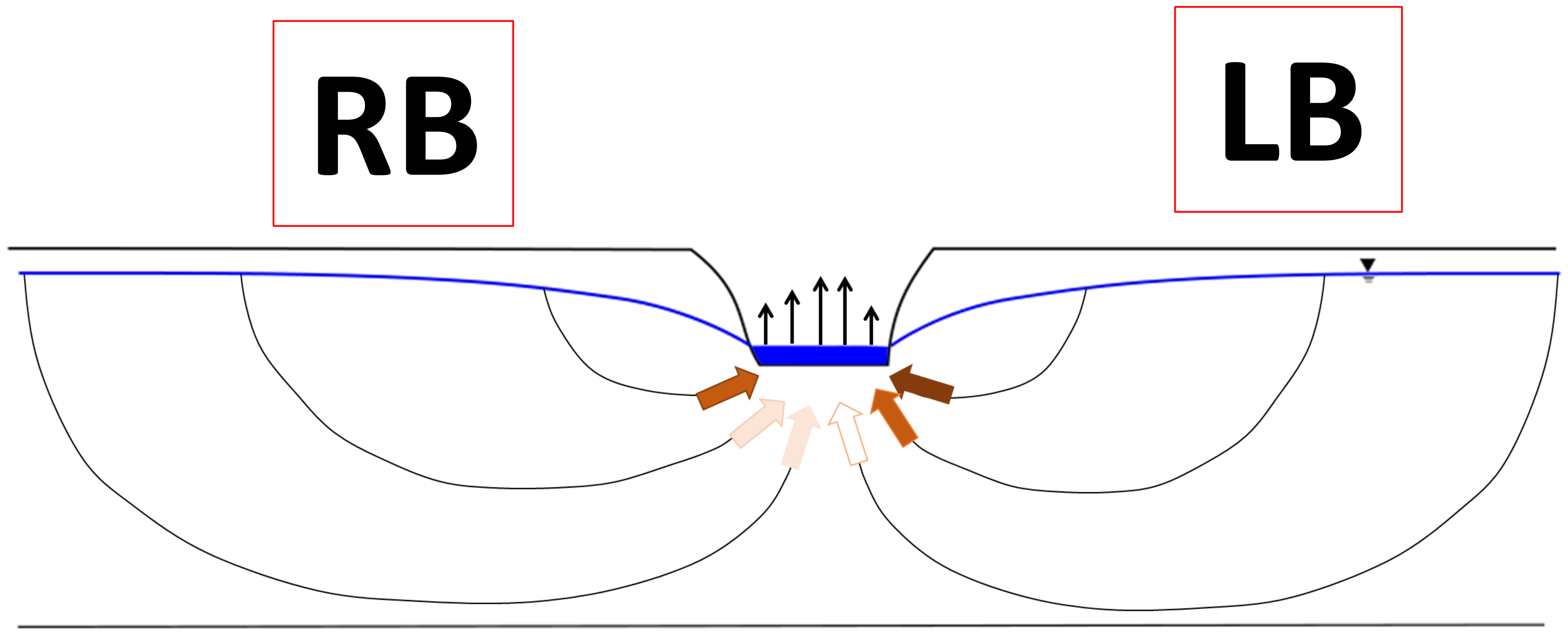
1. Link GW age and nitrate
2. Gauge future discharge of aquifer nitrate


Flow
RB
LB


$[NO_3^-]$ and $[NO_3^-]^0$ (μM)
2500
2000
1500
1000
500
0
LB
L
C
R
RB
streambed location
10 ppm



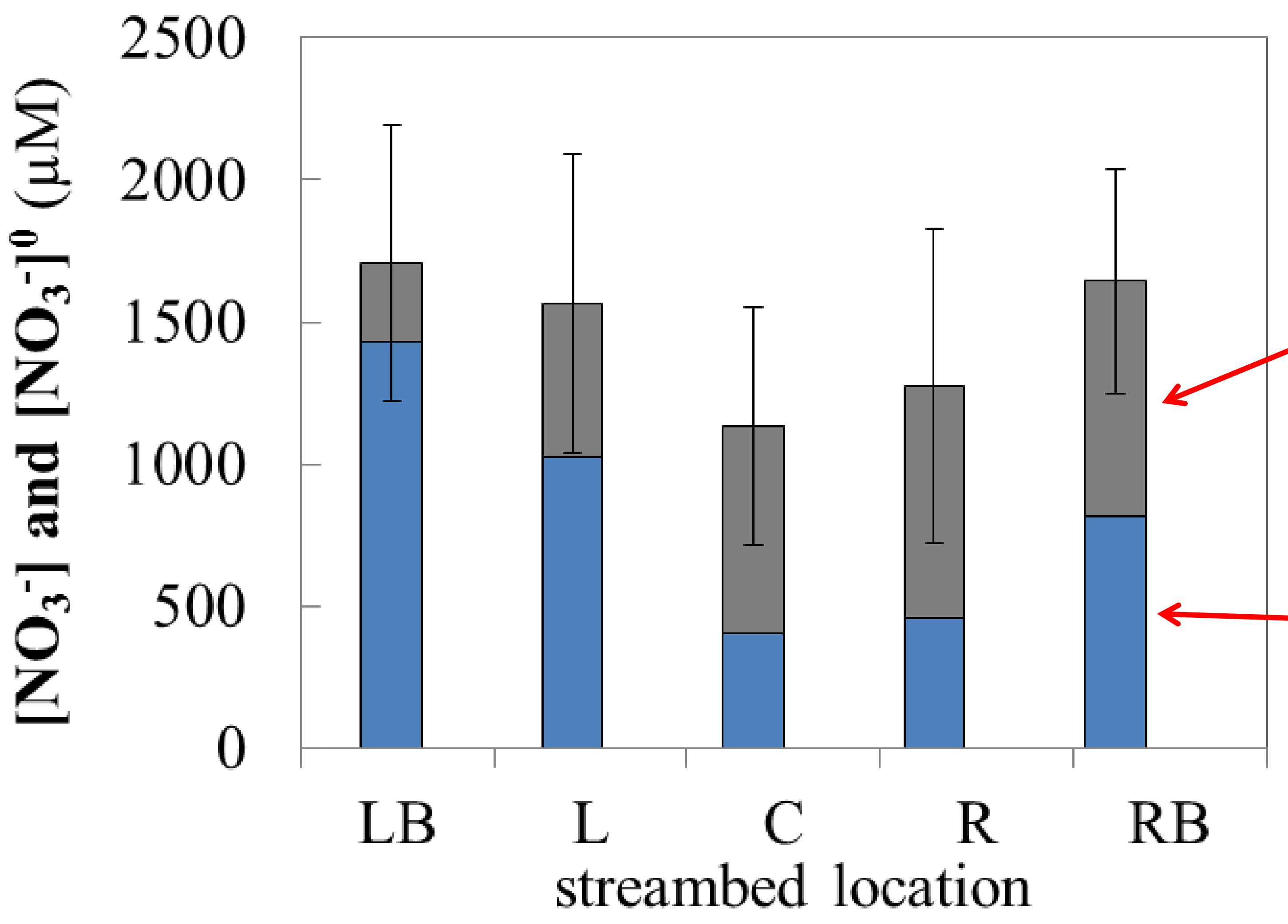
2500
2000
1500
1000
500
0
$[NO_3^-]$ and $[NO_3^-]^0$ (μM)
LB
L
C
R
RB
streambed location



RB
LB

from N_2 and other noble gas data

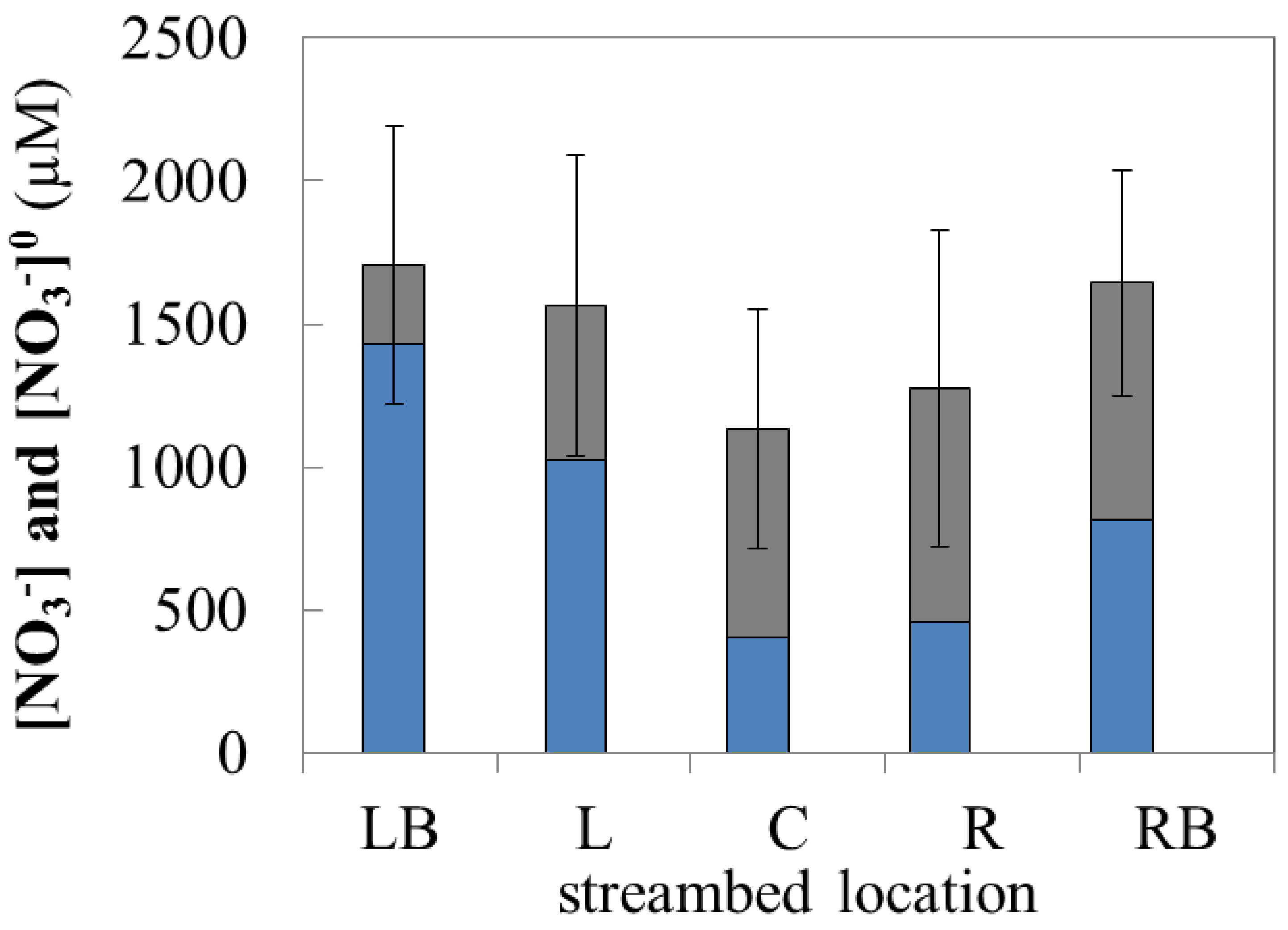
$$[NO_3]^0 = [NO_3] + 2[N_2\text{-den}] \quad (\mu M)$$



$2[N_2\text{-den}]$ = nitrate removed in the aquifer

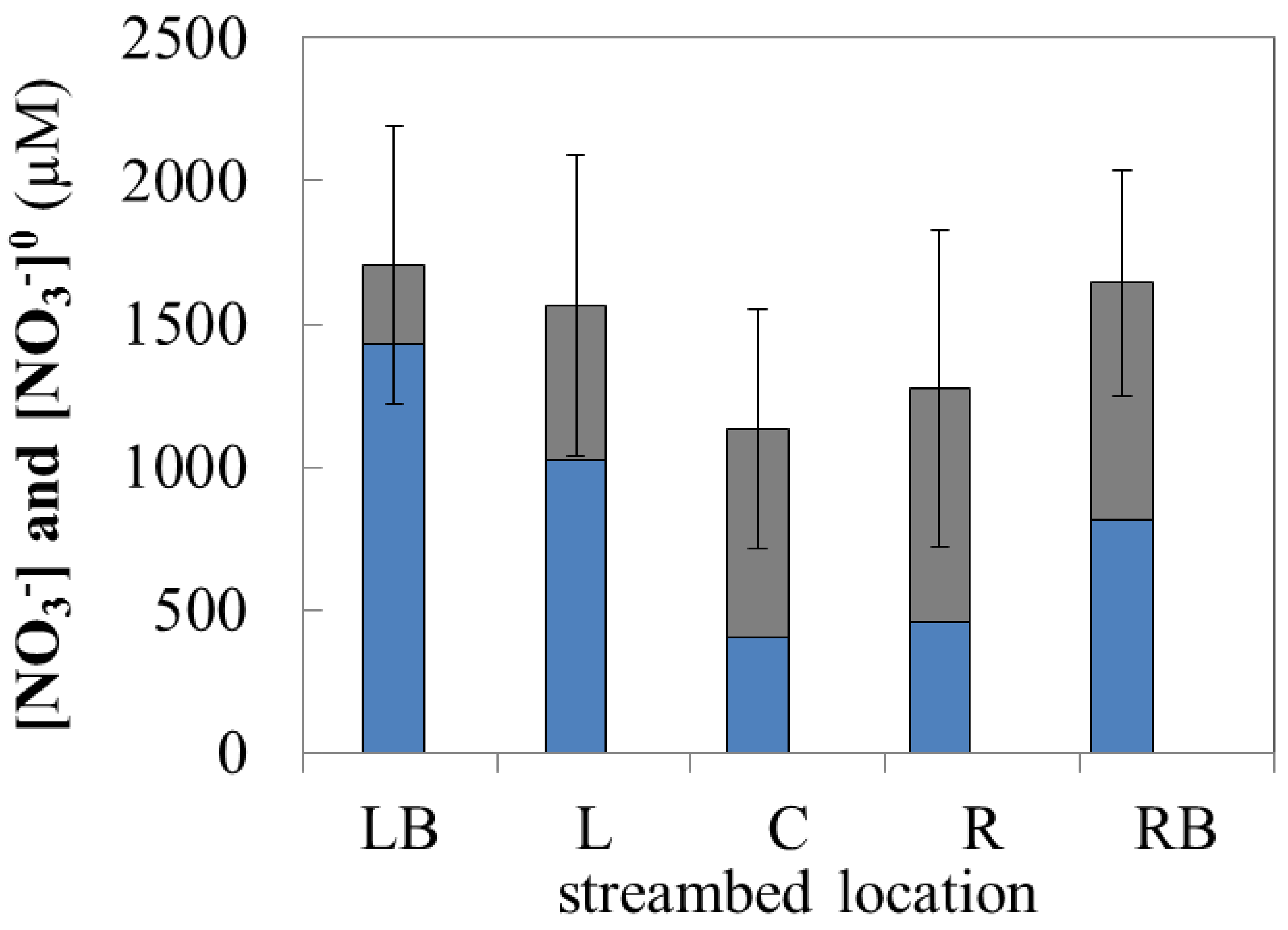
observed $[NO_3^-]$

July 2012
58 m reach



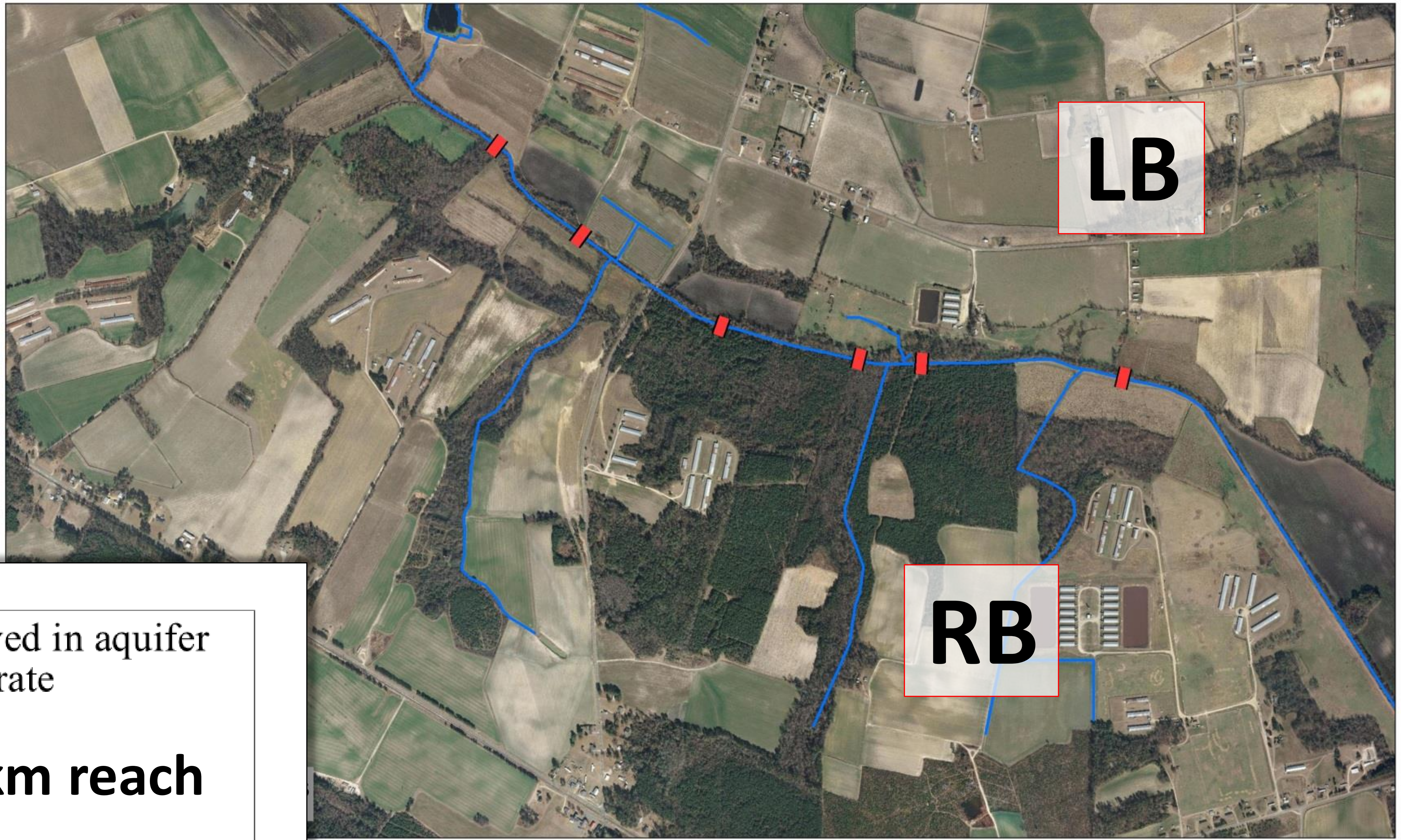
$[NO_3]^0_{FWM} = 18$ mg N/L

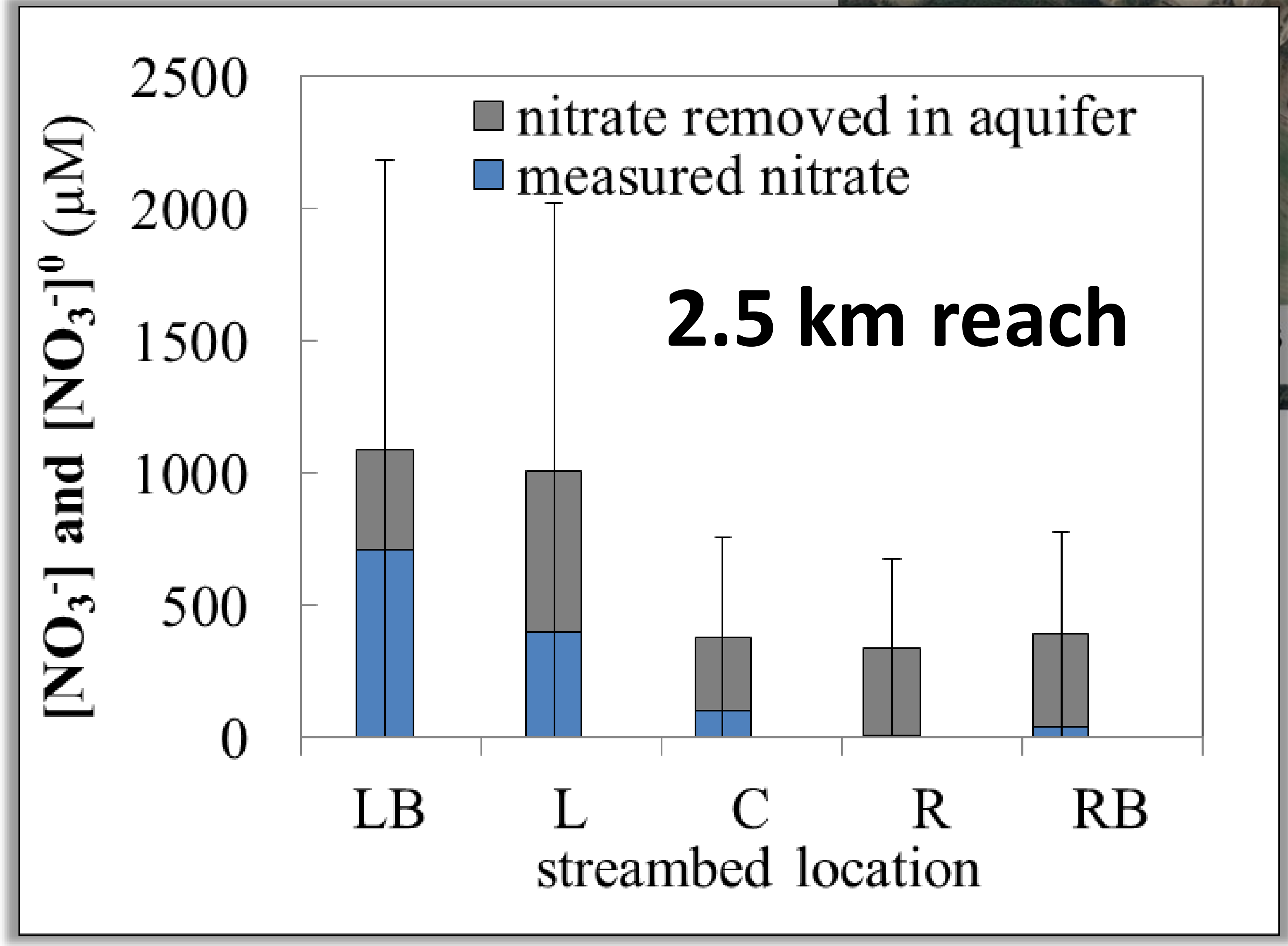
July 2012
58 m reach



$[NO_3]^0_{FWM}$ = 18 mg N/L

Mean denitrification = 50%

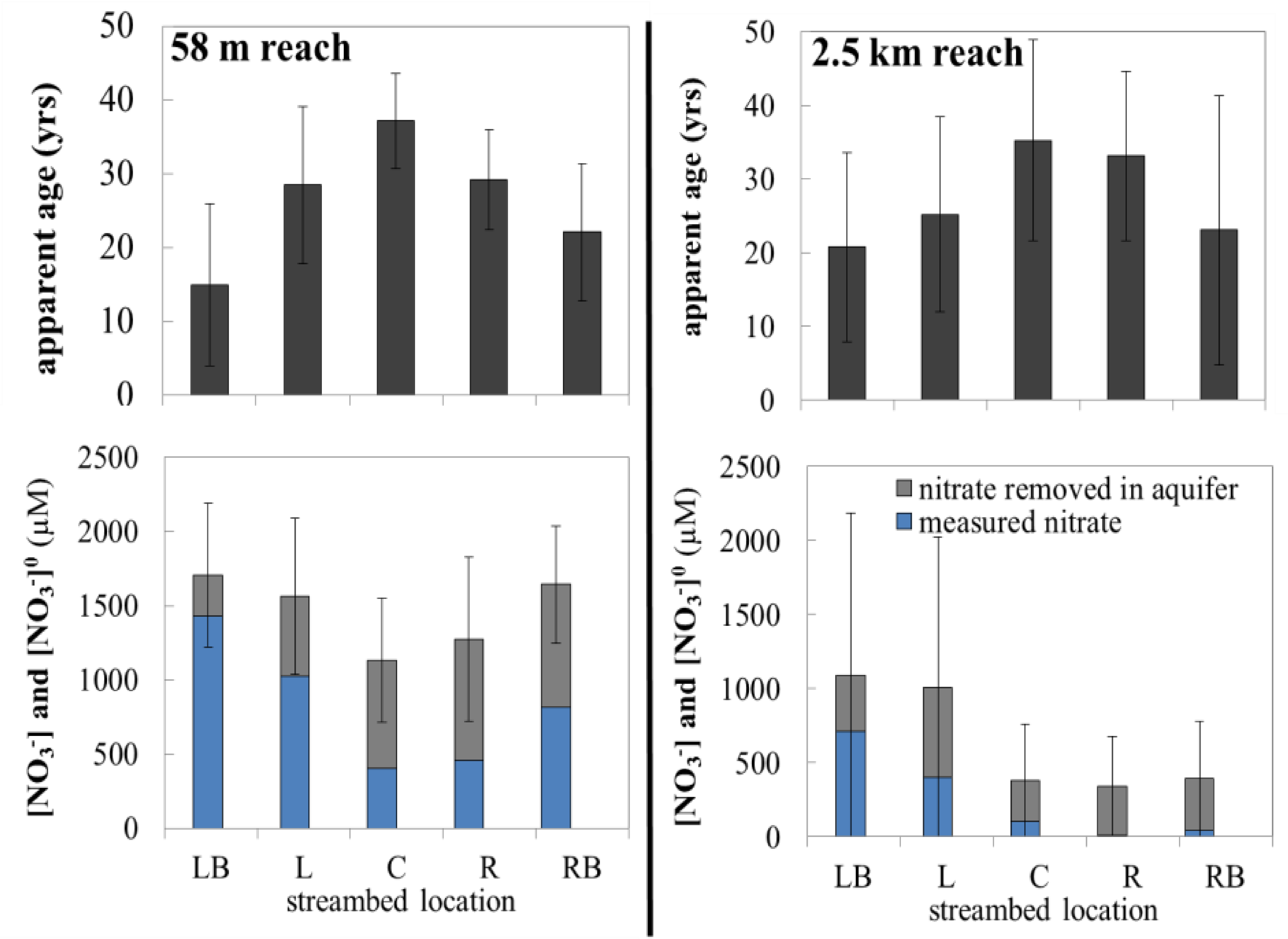




$[NO_3]^0_{FWM}$ = 7 mg N/L

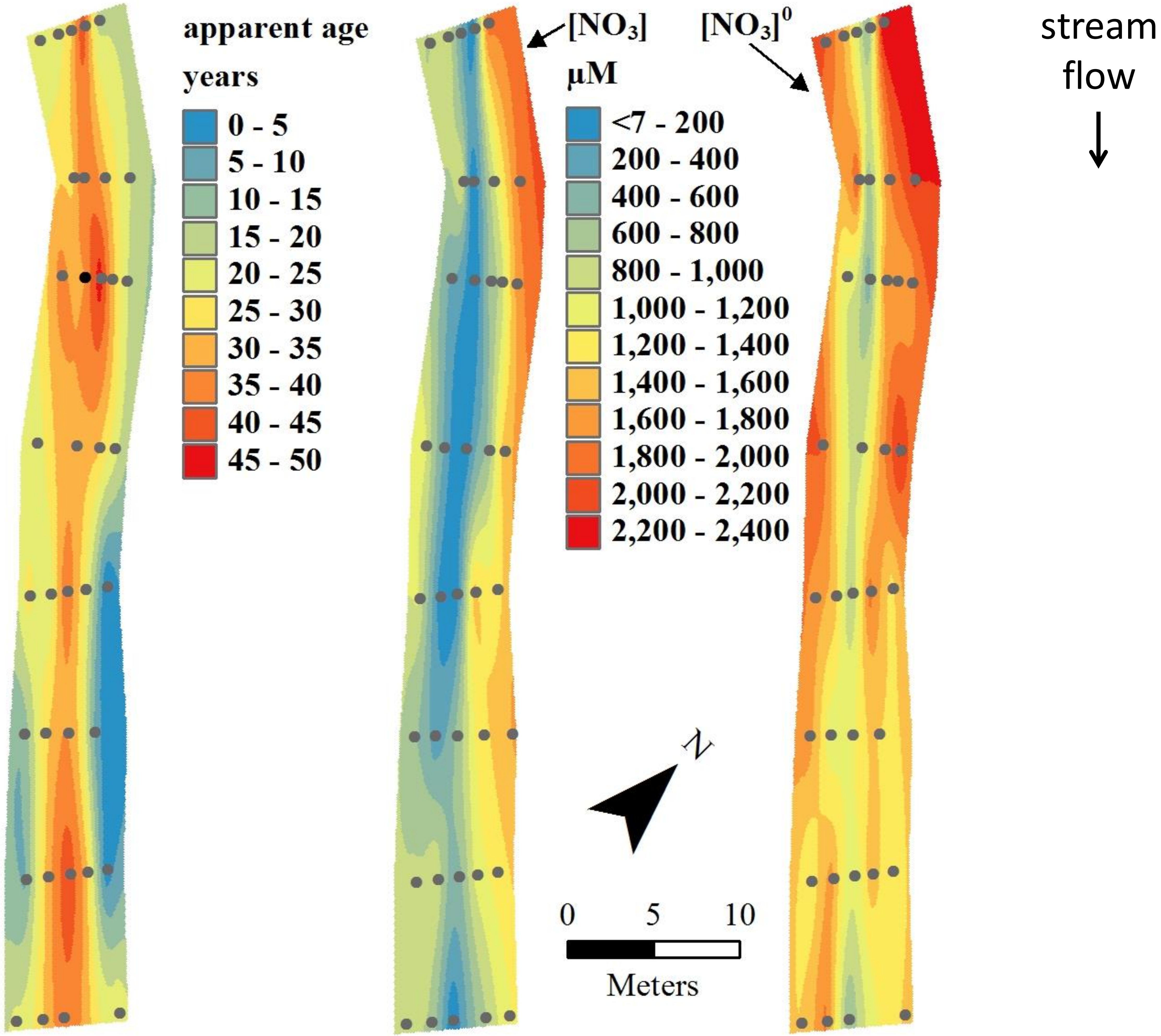
Mean denitrification = 78%

Linking GW apparent age and NO_3^-

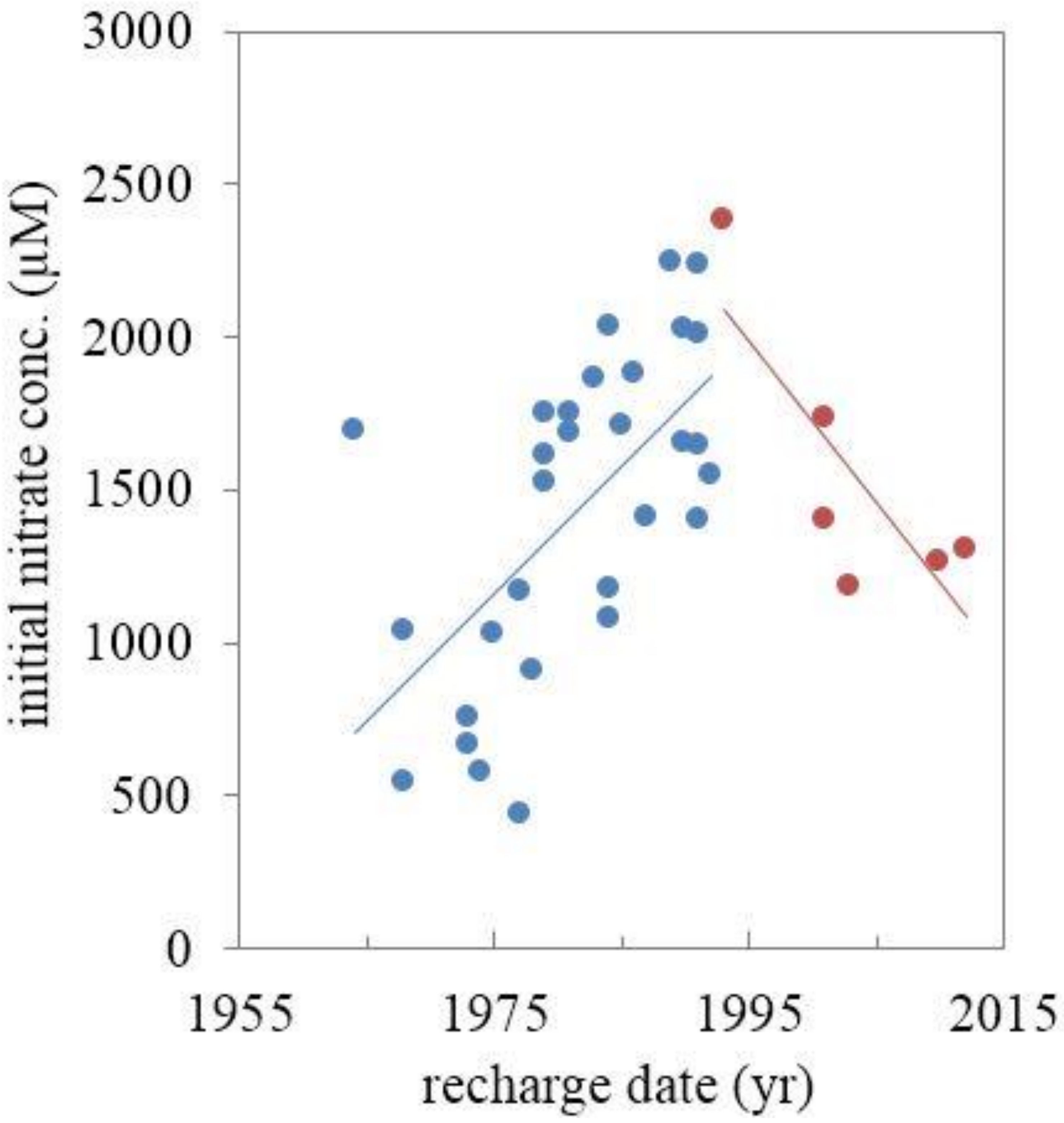


Another visual of NO_3 and age linkage

July
2012



Nitrate concentration in youngest GW suggests recent improvements



Nitrate conc. dropping by about 0.7 ppm per year

Results

1. Link GW age and nitrate
2. Gauge future discharge of aquifer nitrate

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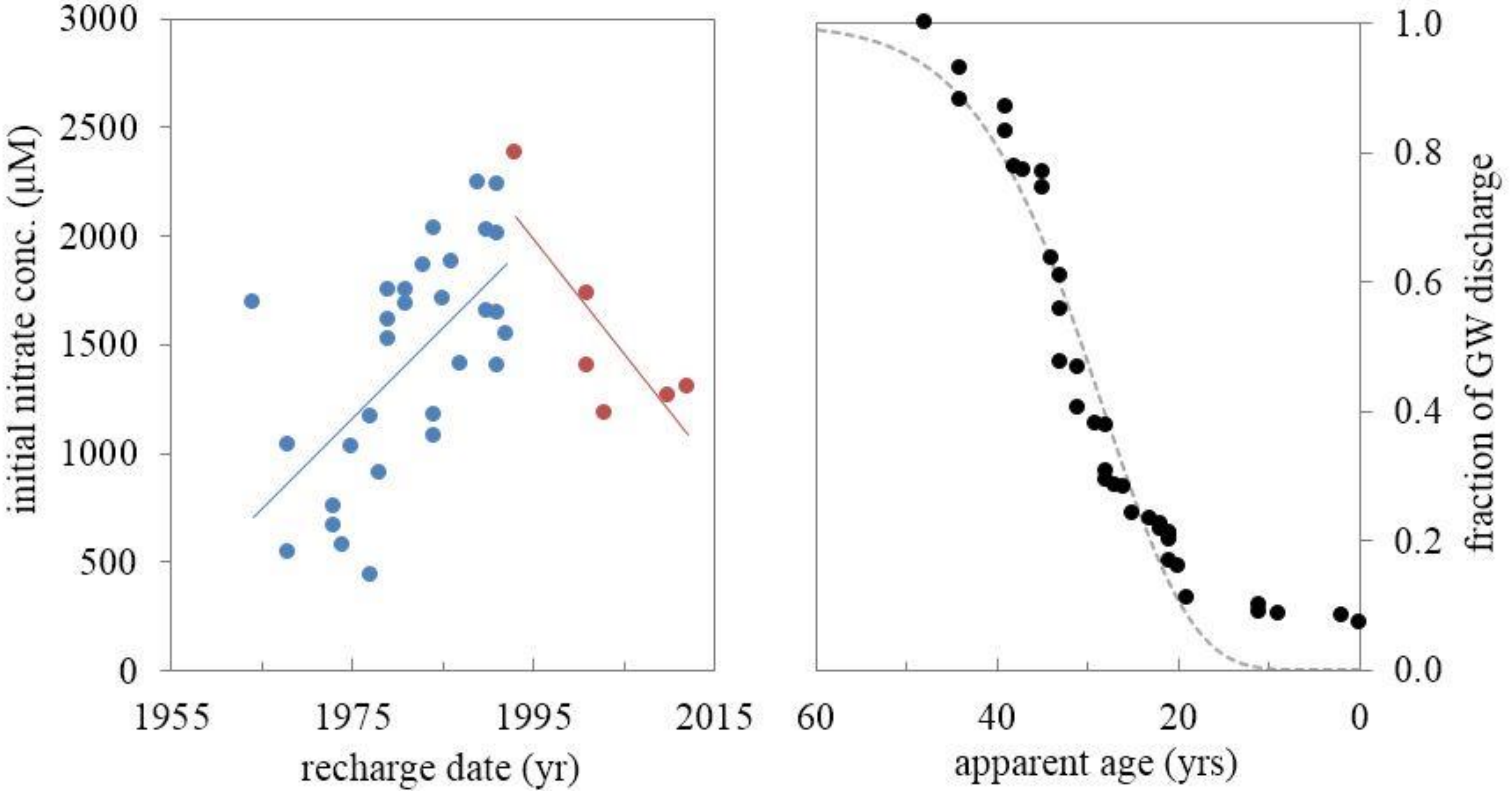
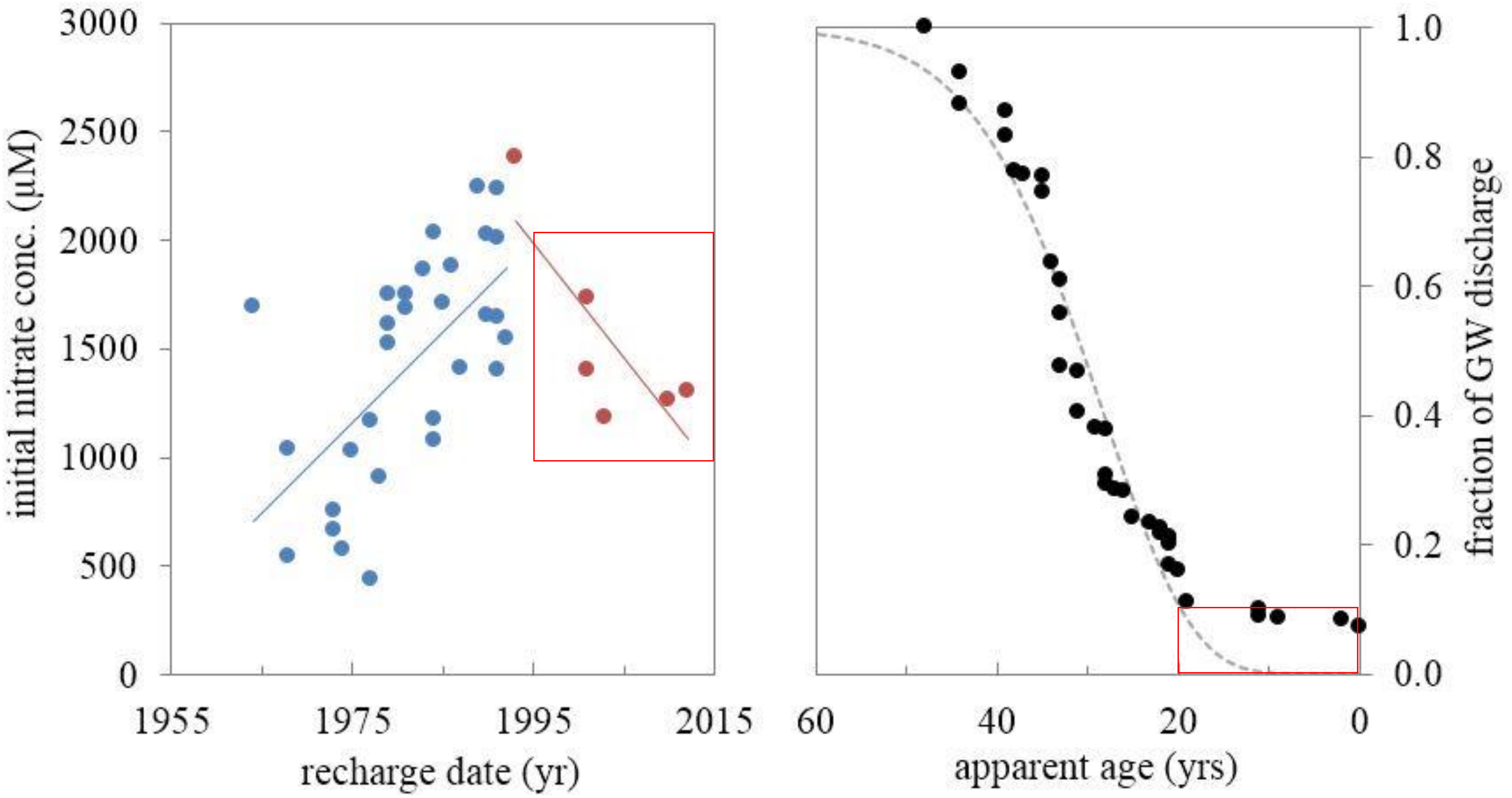
1. Link GW age and nitrate
2. Gauge future discharge of aquifer nitrate
   a. History of GW nitrate conc.
   b. GW discharge rates
   c. Denitrification rates
   d. Assumptions about future N inputs

(a) Nitrate history and (b) GW discharge rates



Why GW discharge data is important



(c) Denitrification rates

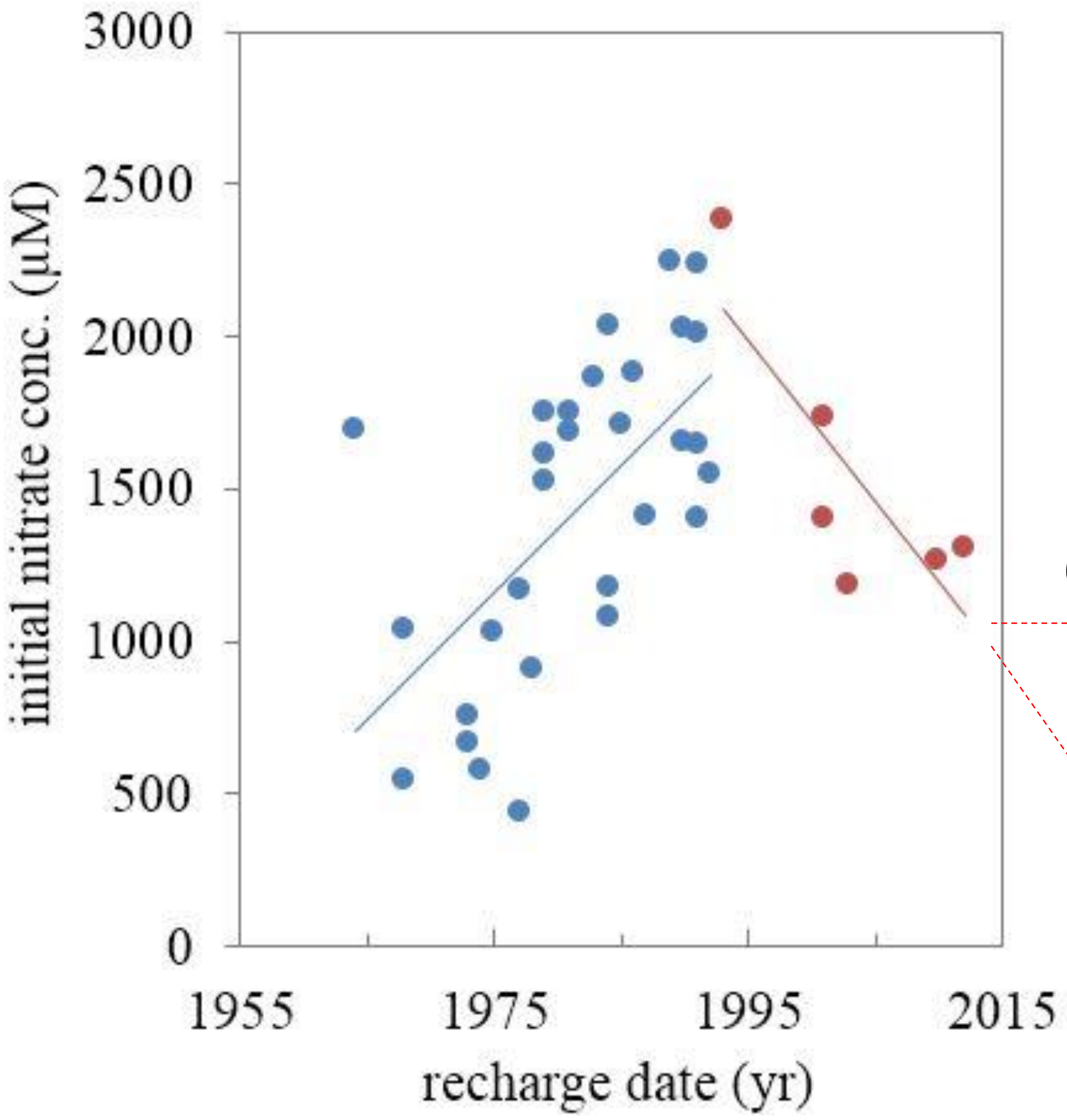
Example: zero-order kinetics assumption:

GW sample is 10 years old
10 ppm nitrate removed, based on N_2 data

→ average aquifer denitrification rate would be 1 ppm/year

In this study, average was about 0.4 ppm/year

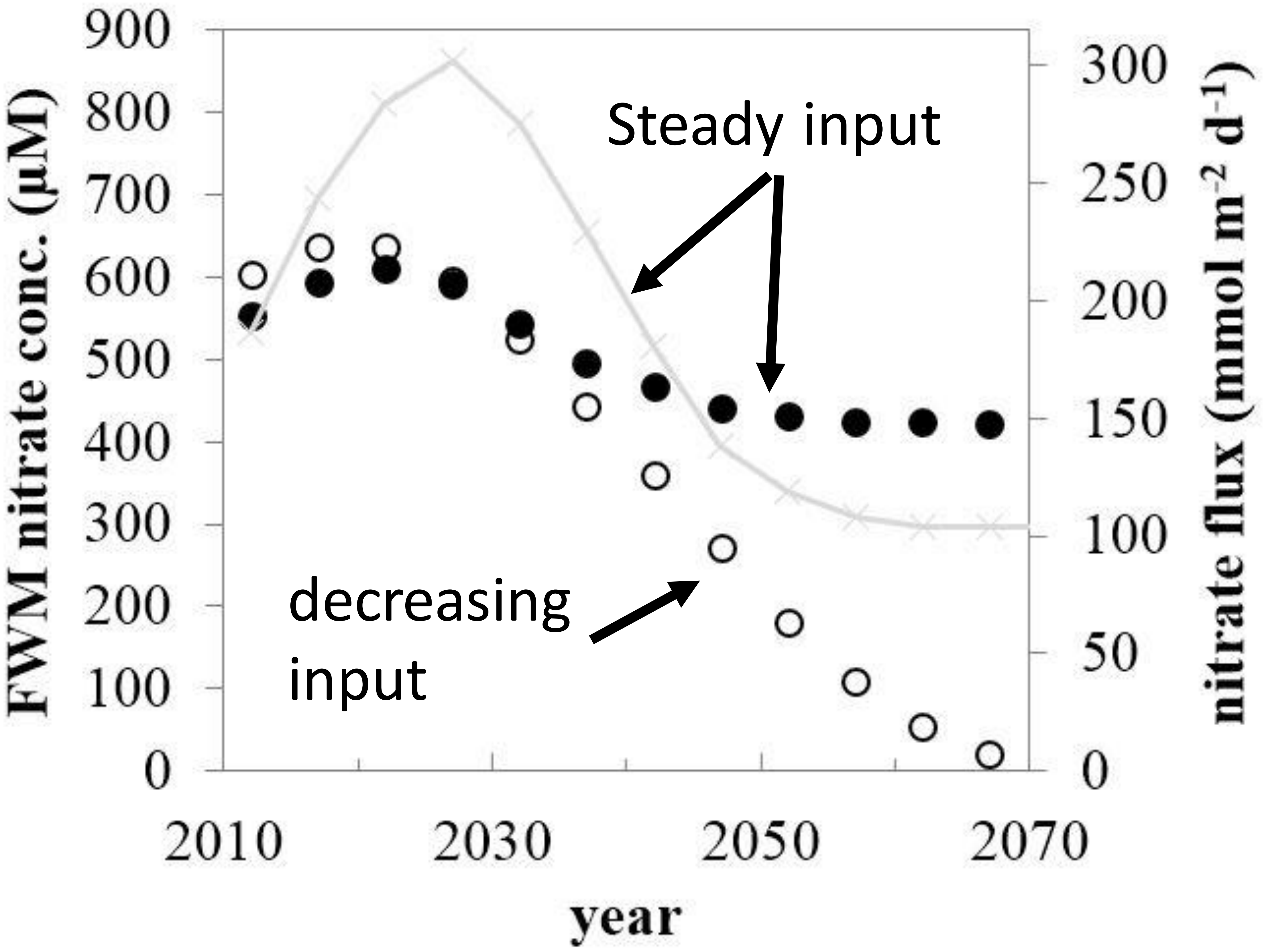
(d) Two future management scenarios



Constant inputs, at current levels

Steady decrease to zero

Future nitrate concentration in aquifer discharge (adjusted for denitrification)



Research Conclusions

- GW age and N used to reconstruct contamination history (4-day field campaigns)
- Predictions possible with simple spreadsheet model (no numerical GW flow model)
- NO_3^- fluxes are likely to increase in some reaches (need both patience and persistence in watershed management)

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