



Understanding nitrate processing in agricultural stream corridors using electrical resistivity tomography (ERT) and salt tracer experiments in riparian aquifers.

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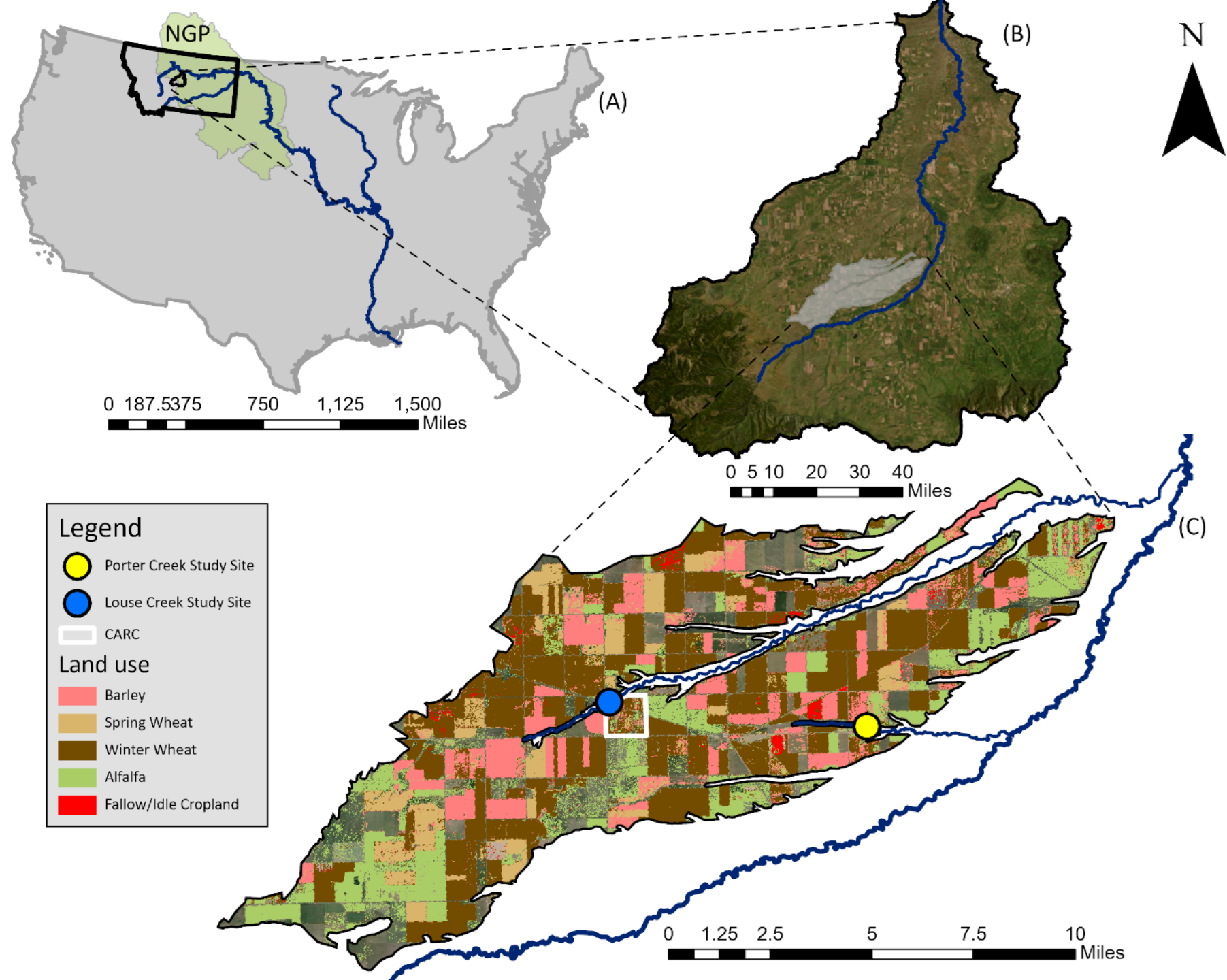
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Study area and previous work

- Consistently 20ppm nitrate N in the terrace aquifer over the past 15 years.
- Both upland soils and riparian corridors on the Moccasin terrace attenuate nitrate loading.
- Water-logged soils and anoxic shallow aquifers in riparian corridors are hotspots of nitrate removal.



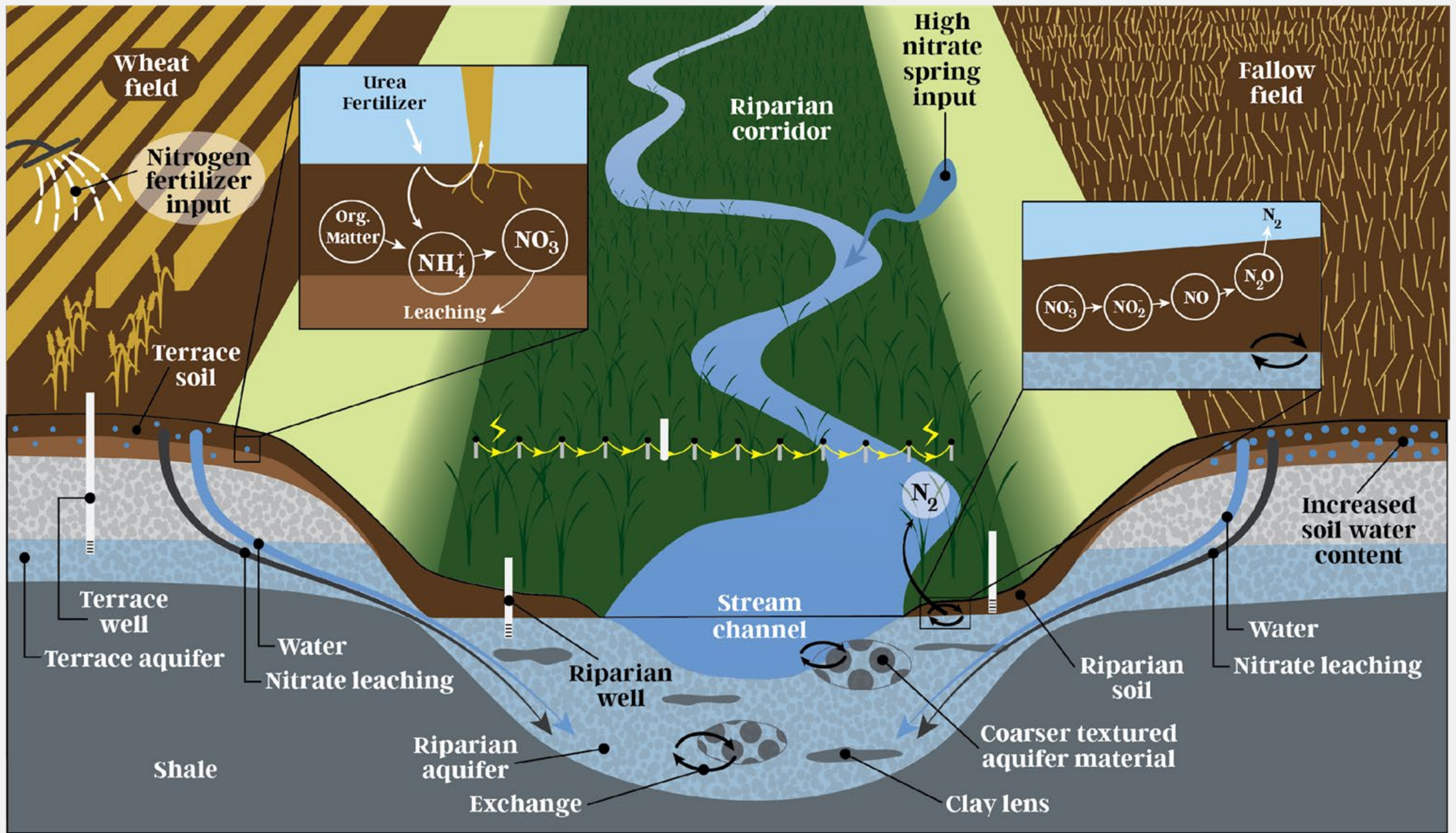
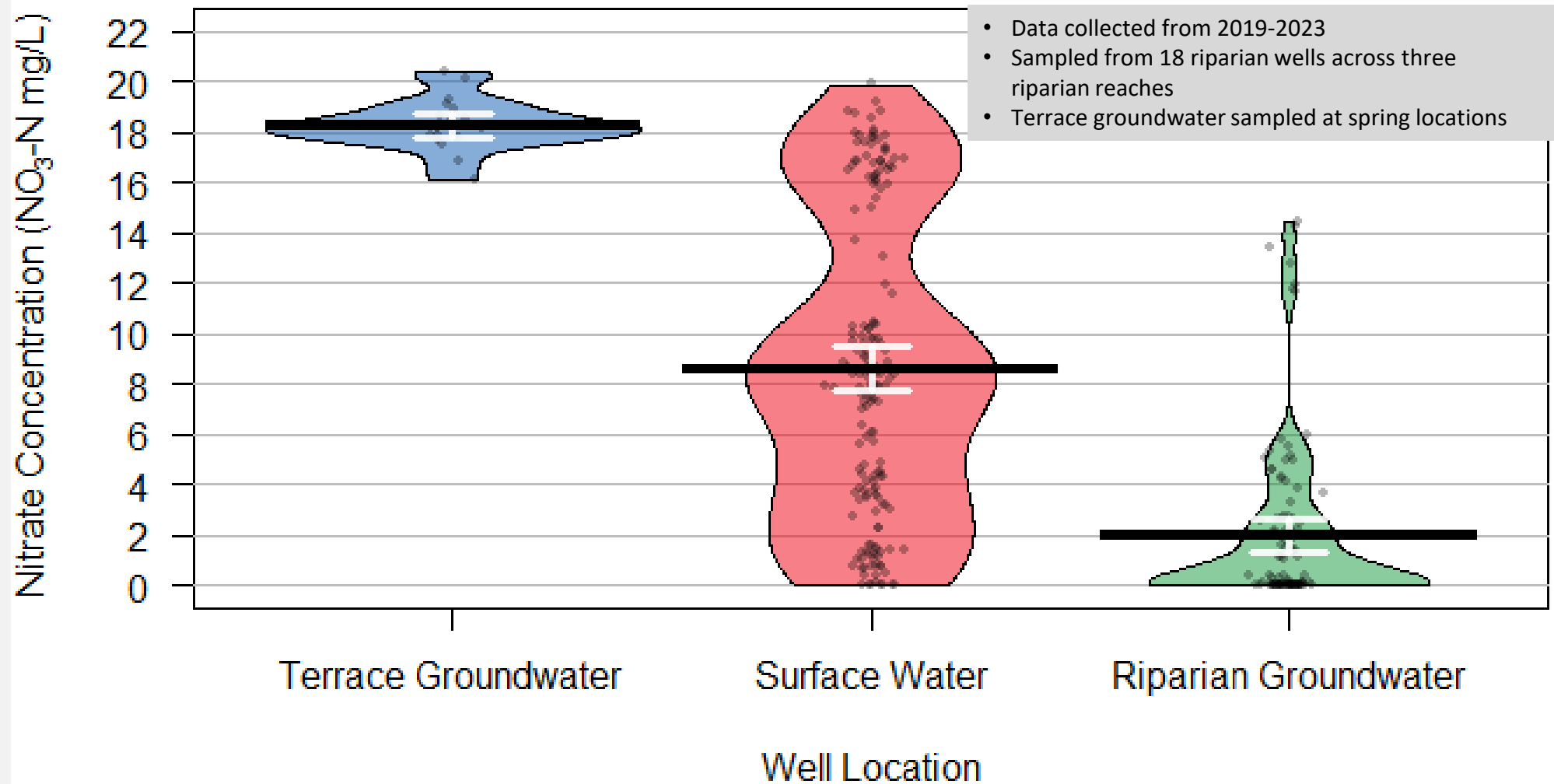


Figure by Maggie Druckenmiller

Variable nitrate loading in Louse and Porter Creeks

Nitrate concentration by water type



How does the architecture of soil and sediment influence groundwater quality in riparian corridors?

Hypothesis: Coarser textured zones of riparian soil and sediment promote more rapid groundwater movement and solute transport while fine textured zones hold up water, promoting anoxia and solute transformation.

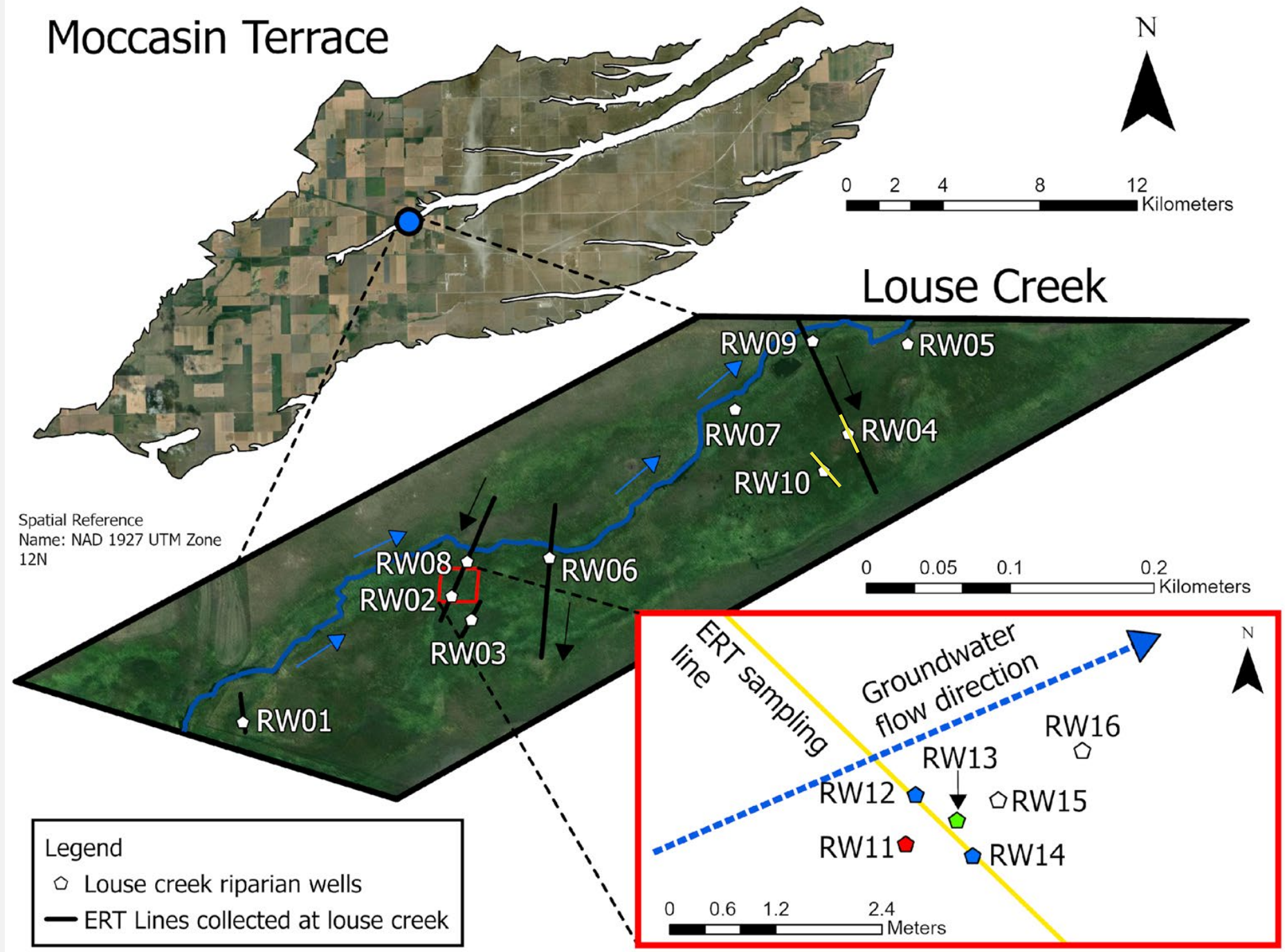
Approach:

- Use slug tests in riparian wells to assess hydraulic conductivity.
- Use a salt tracer experiment to track groundwater movement.
- Use simple simulation to show how contrasting materials dictate solute transport, and likely reaction, dynamics in this riparian aquifer.



Focal sites and initial ERT line locations

- ERT imaging collected transecting riparian wells
- Tracer experiment diagram located within red square

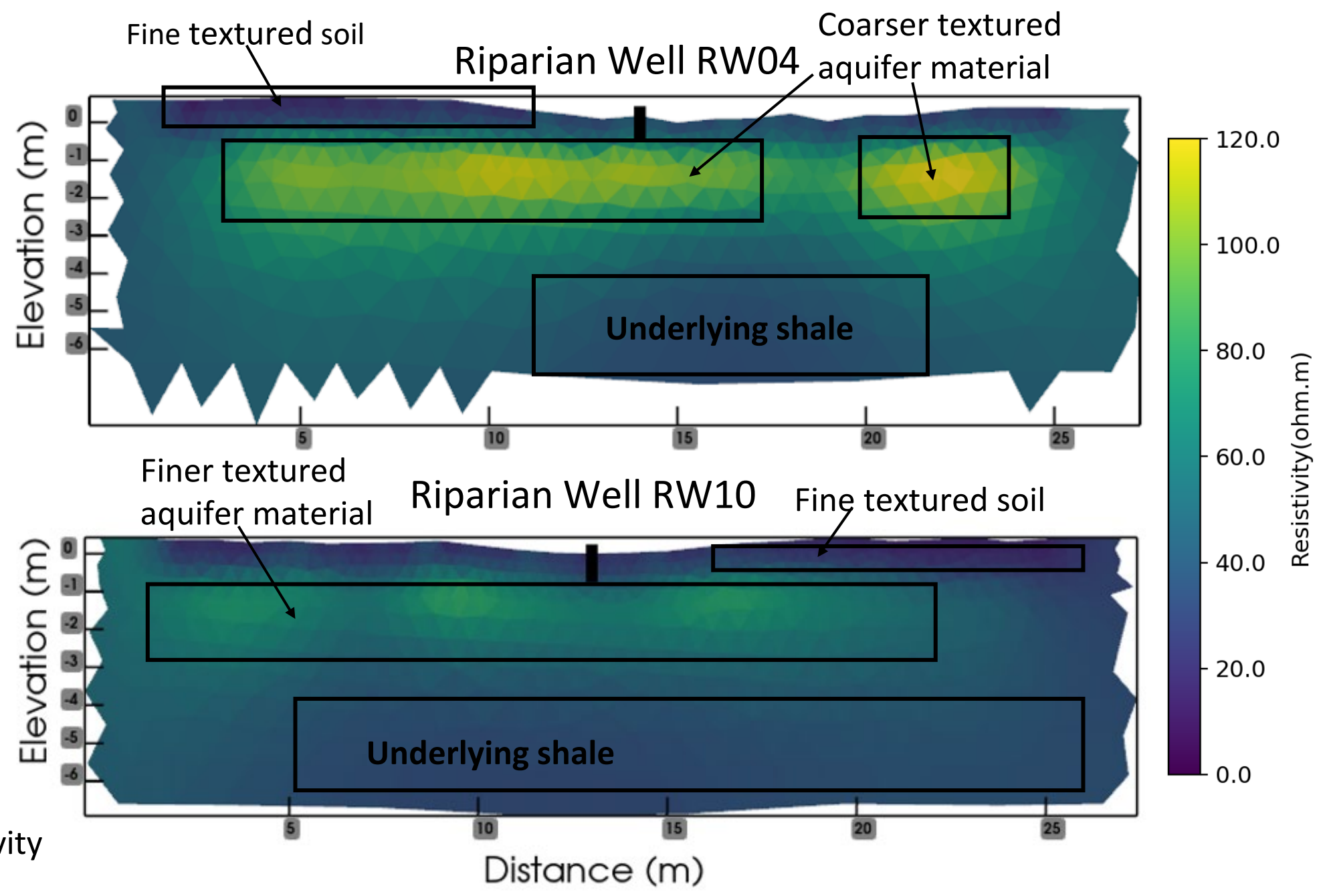


Riparian corridor ERT

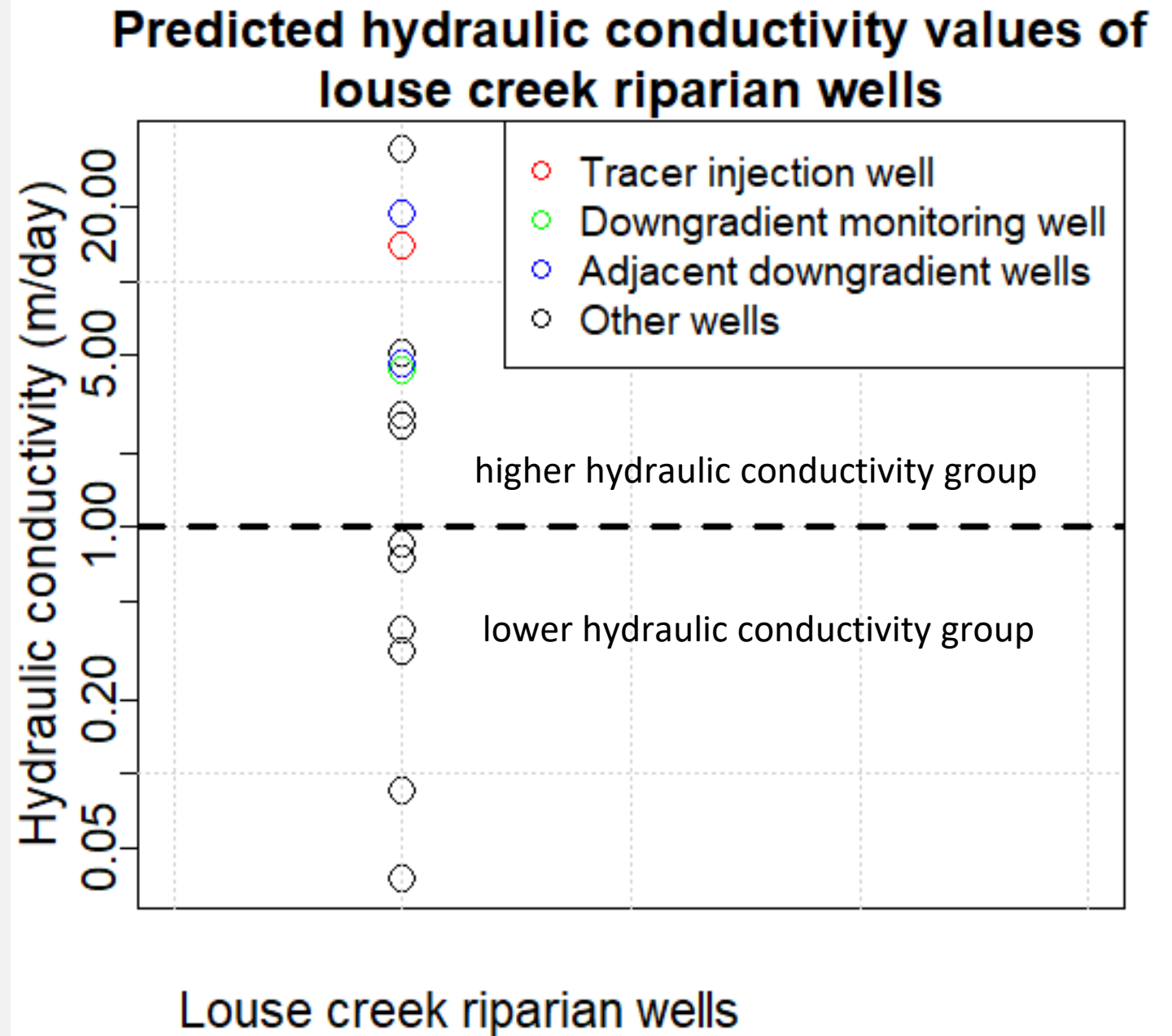
Resistivity data reflect:

- Substrate
- Water content
- Ion content of water

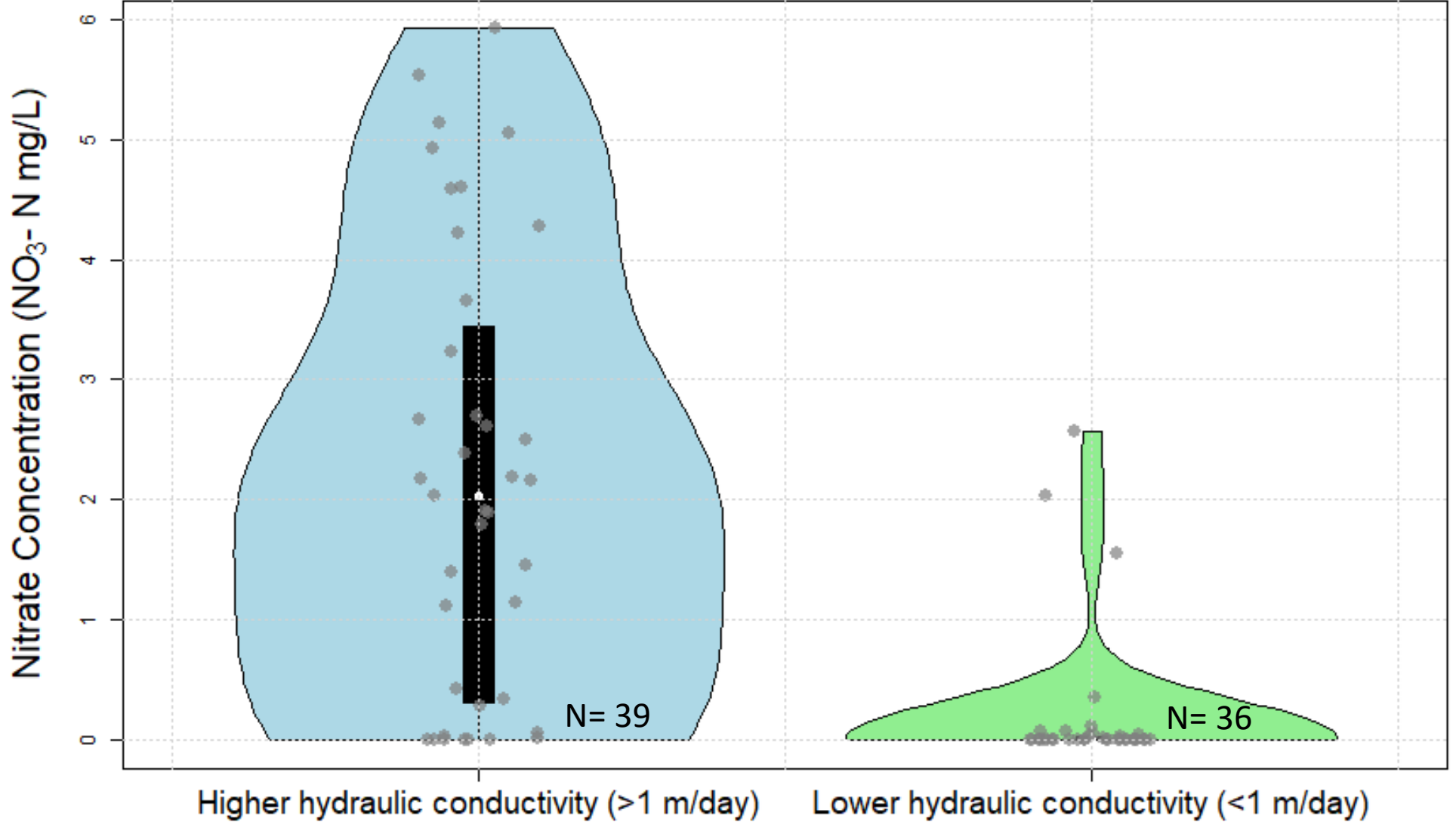
Riparian aquifers have components of highly resistive coarse textured material and lower resistivity finer textured material



- Riparian well hydraulic conductivity values are variable.
- Higher hydraulic conductivity values refers to faster recovery well, resulting from water pulled from coarser substrate.



Riparian well nitrate concentrations based on hydraulic conductivity grouping



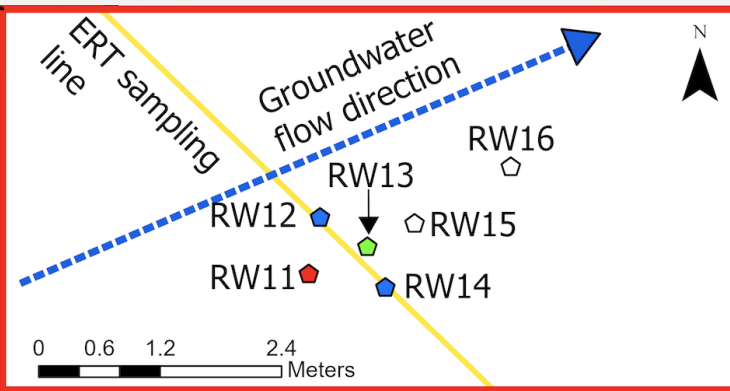
- Data from riparian wells
- Wells with higher hydraulic conductivity values have higher and more variable nitrate concentration values.

Assessing substrate using salt tracer

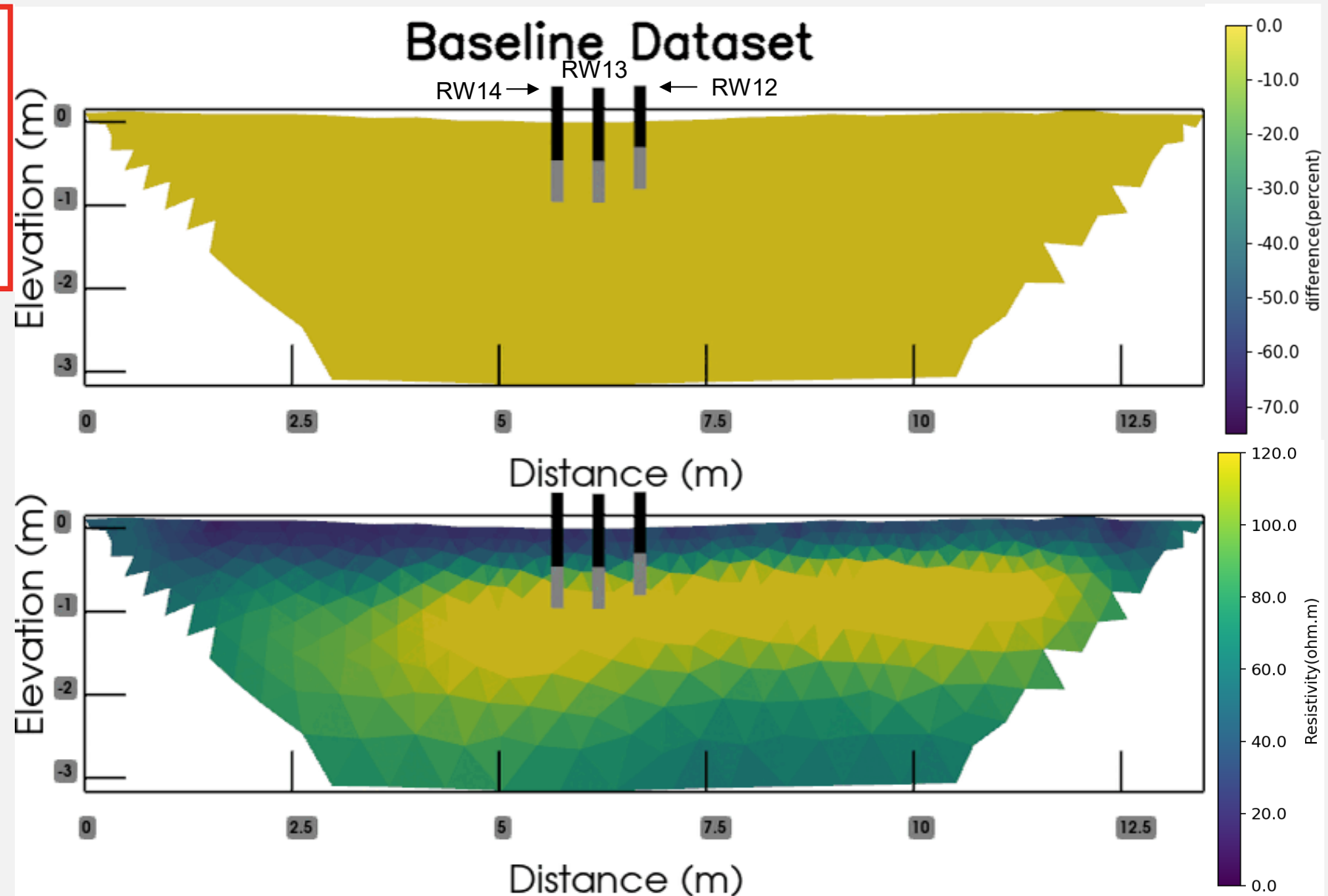
- Total input of 24 kg NaCl in 300 liters water
- NaCl injection solution, 110,000 ms/cm
- Injection for 6.5 hours
- Monitored using:
 - ERT Imaging
 - Conductivity probes



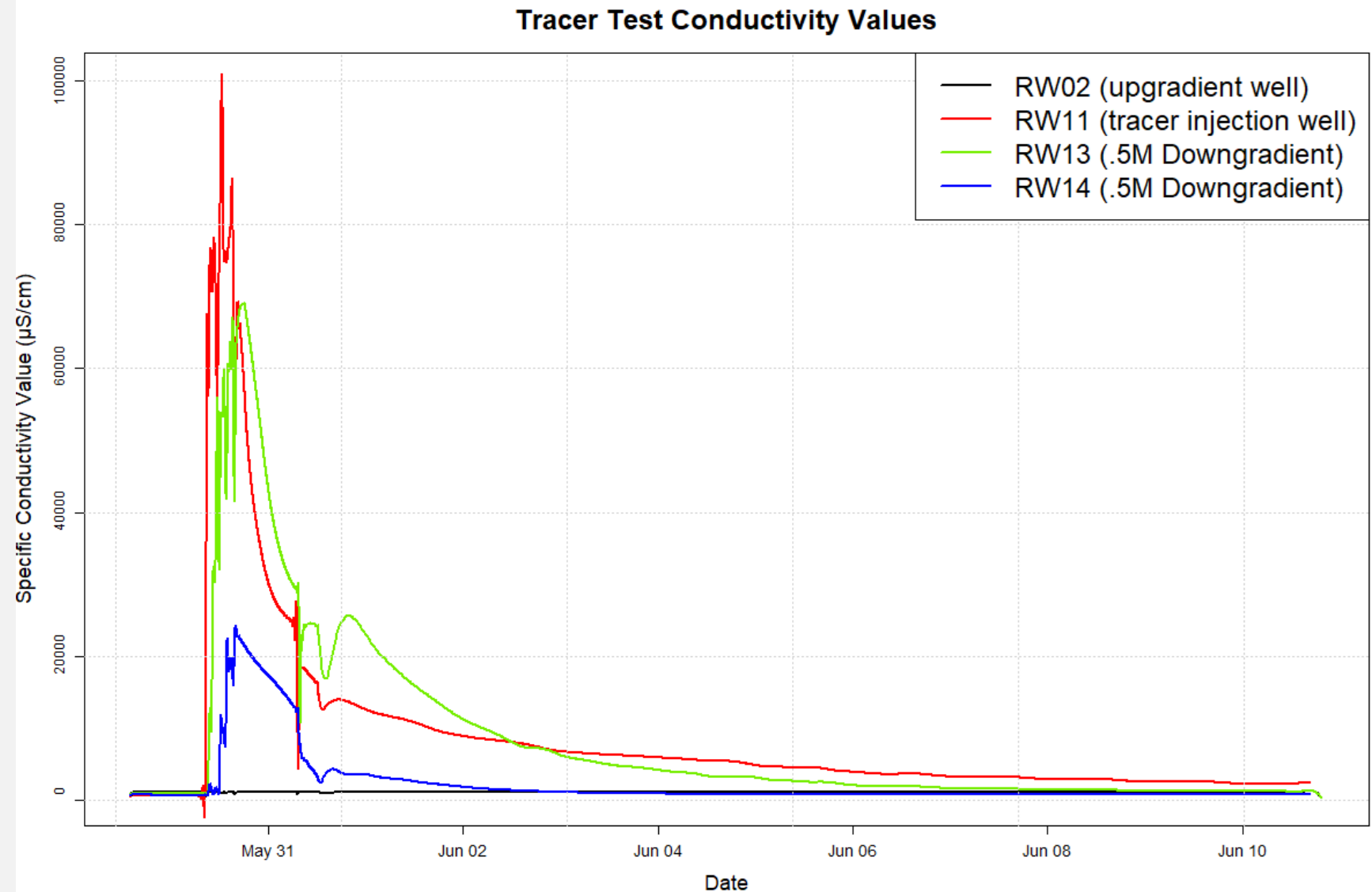
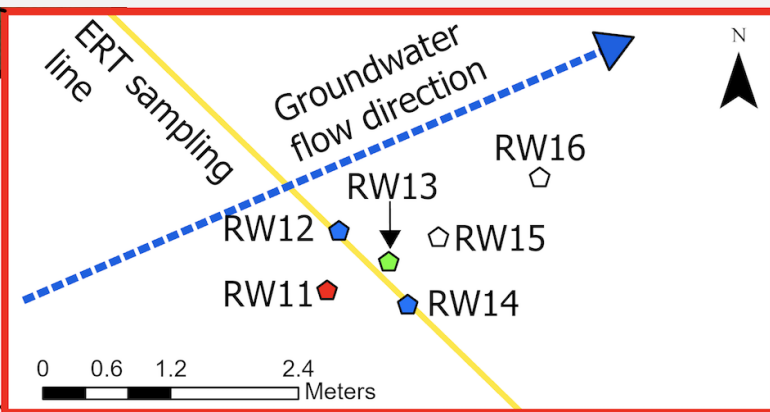
Tracer test ERT results 0.5m downgradient of salt injection



Tracer shows primary groundwater flow through the coarse textured material.



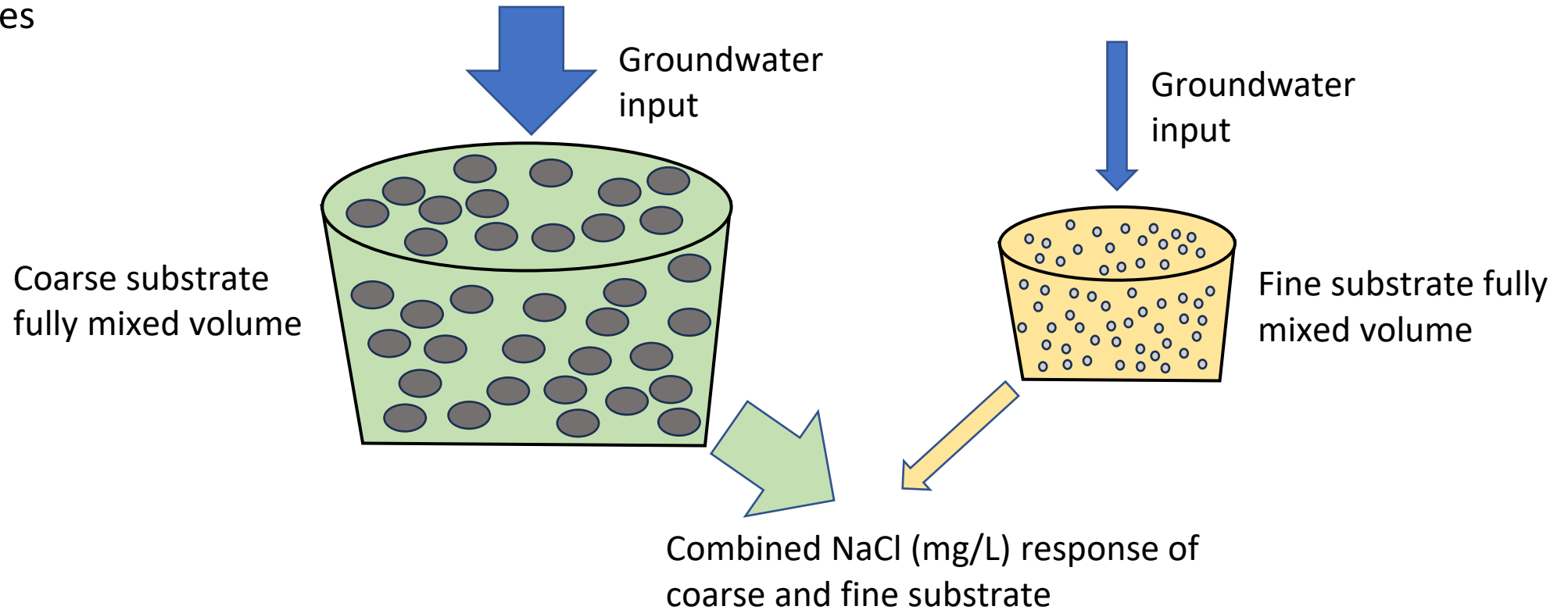
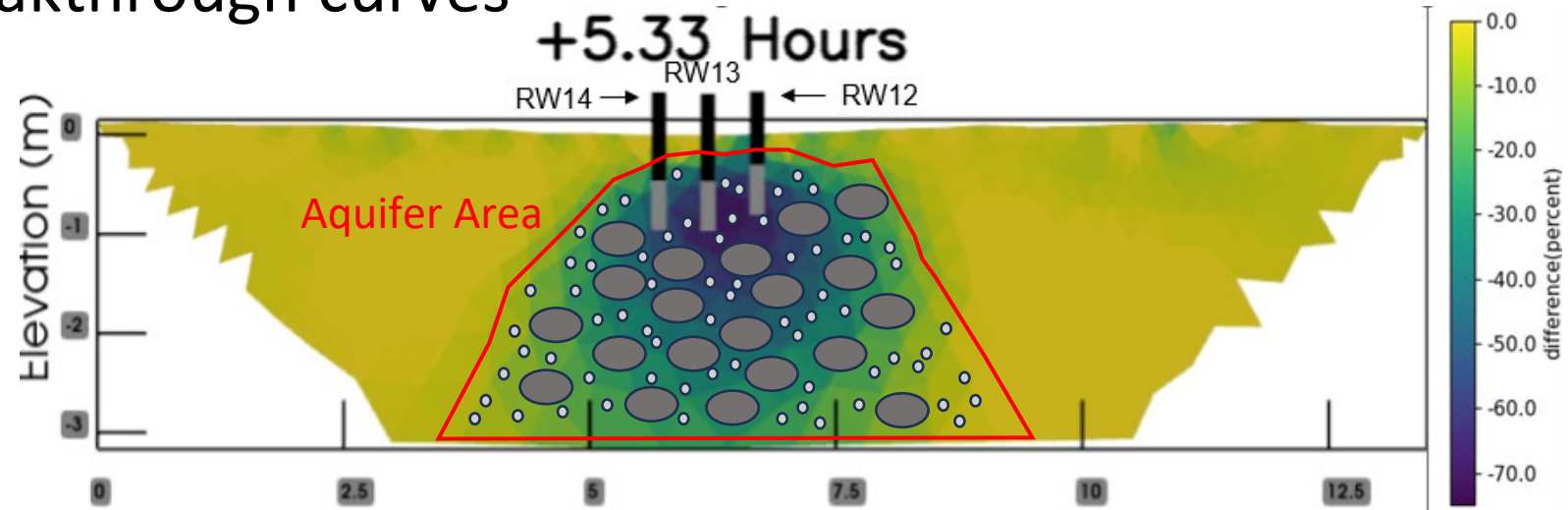
Watching the salt tracer using conductivity sensors



- Solutes in groundwater move on the timescale of days with tailing.
- Interbedded fine textured material within the riparian aquifer.
- Can we simulate these curves using a combination of coarse and fine textured material?

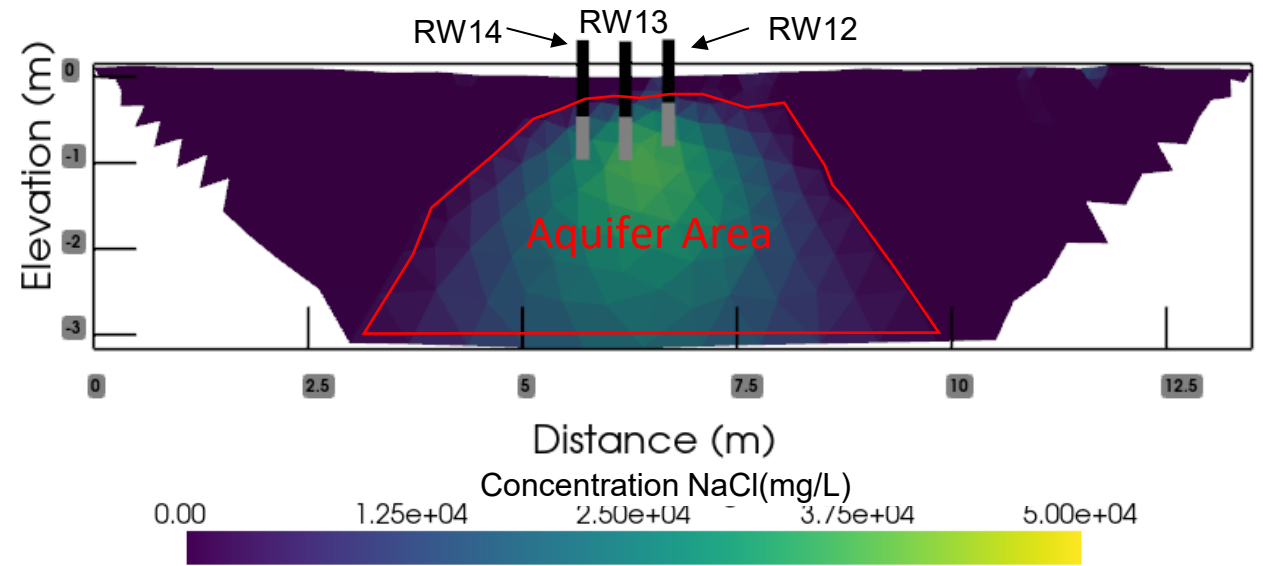
Simulating salt breakthrough curves

- Bucket model with two kinds of substrate
- Steady state groundwater flow based on hydraulic gradient and low/high hydraulic conductivities

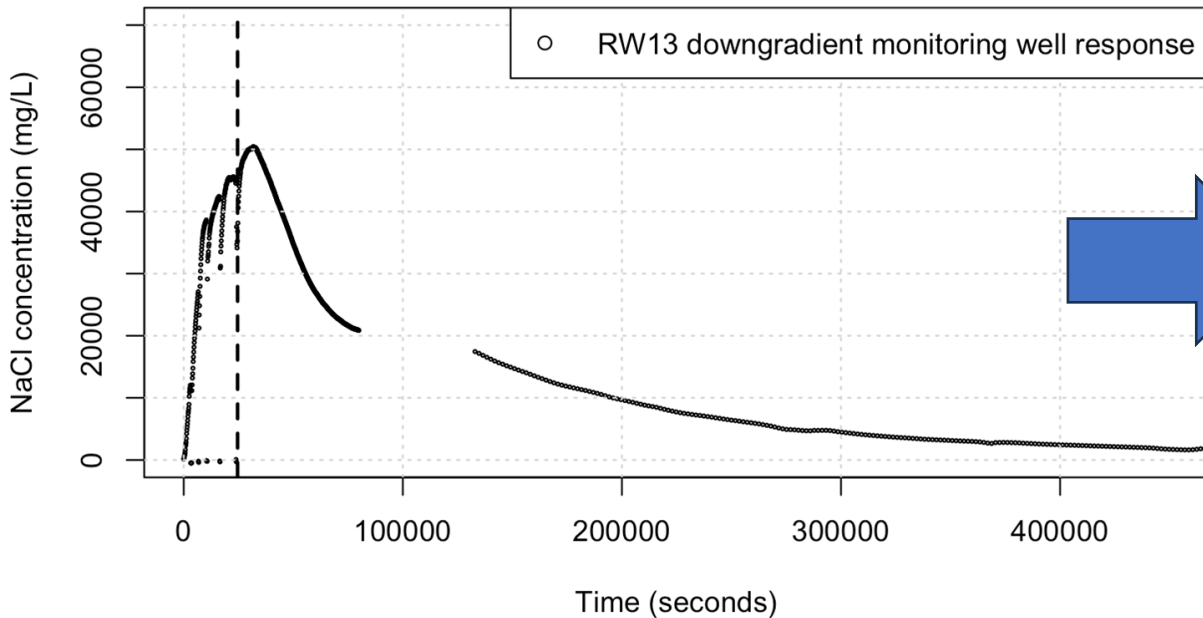


Model parameters

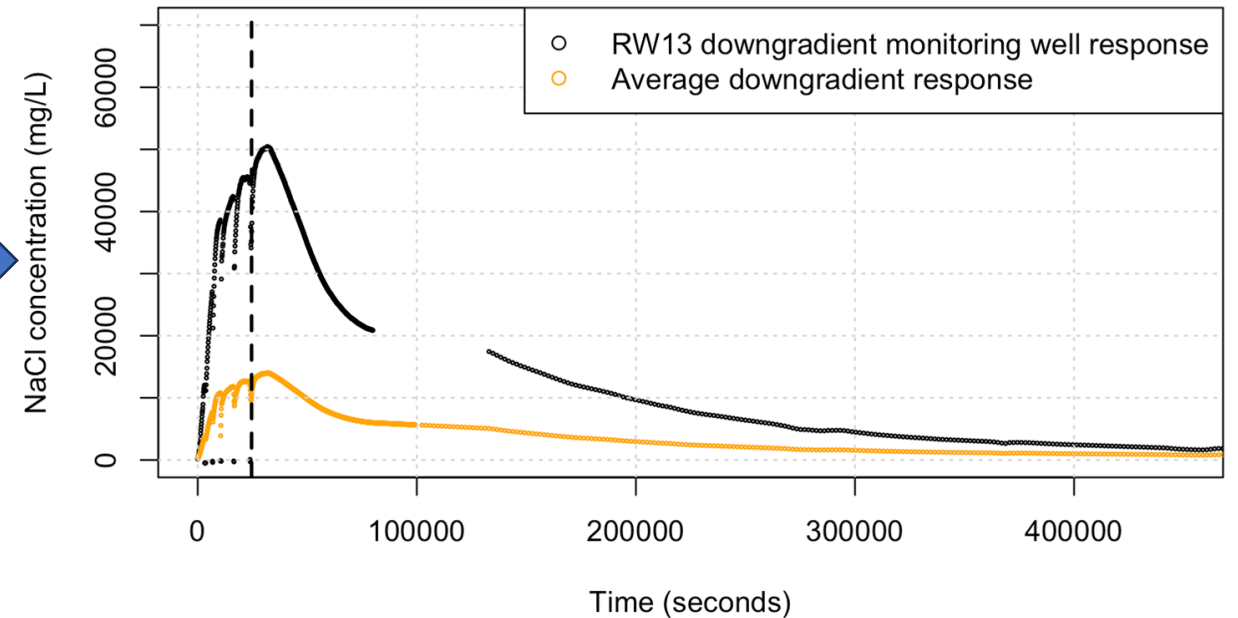
- Fraction of coarse and fine textured material
- Hydraulic conductivity values of both the coarse (K_{coarse}) and fine (K_{fine}) textured substrate



Modeled flow response of salt concentrations with different fraction of coarse substrate, $K_{coarse} = 10$, $K_{fine} = 0.5$

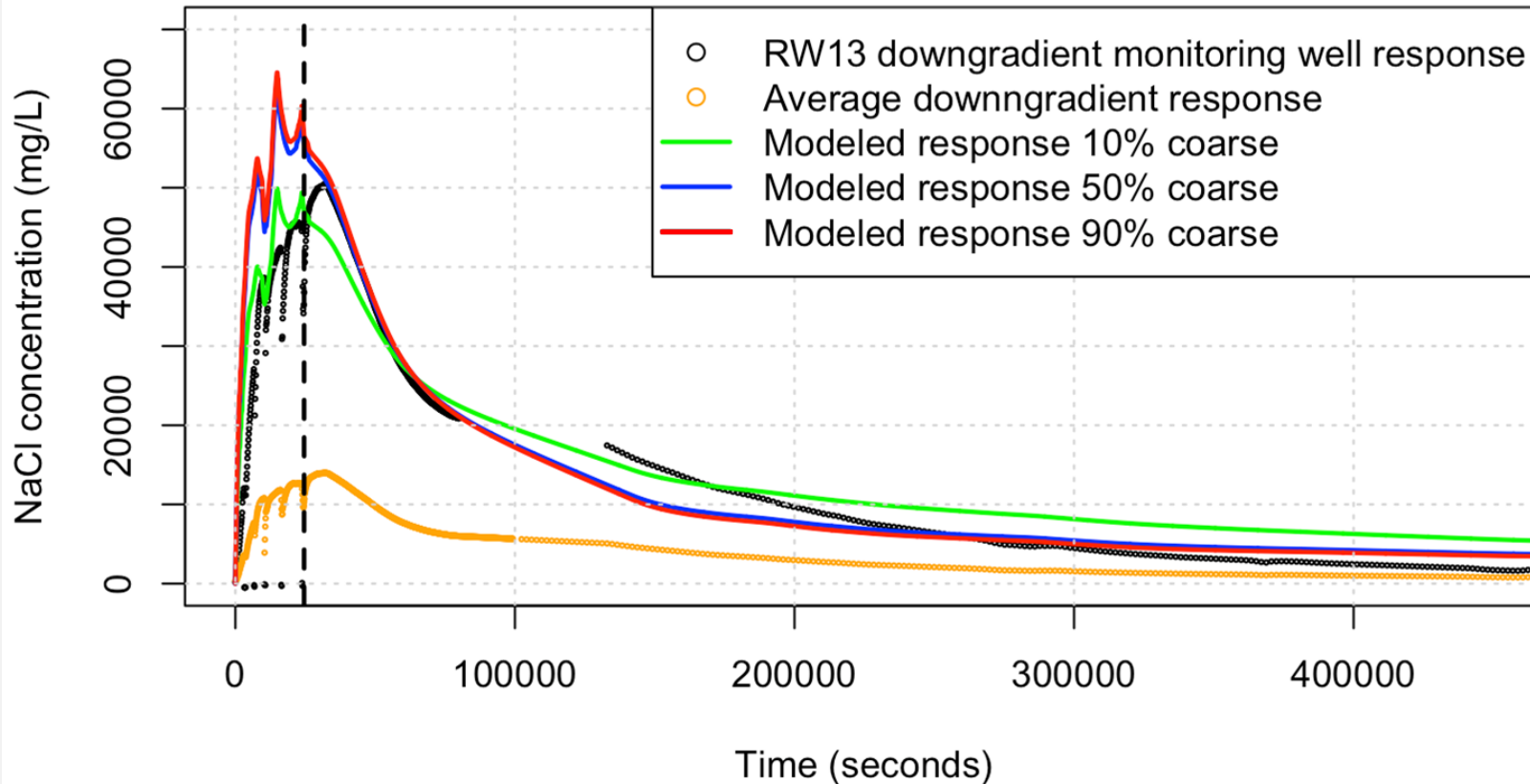


Modeled flow response of salt concentrations with different fraction of coarse substrate, $K_{coarse} = 10$, $K_{fine} = 0.5$



Model results

**Modeled flow response of salt concentrations
with different fraction of coarse substrate, $K_{coarse} = 10$, $K_{fine} = 0.5$**



- Modeled results return higher concentration values
- Issues with average data set across aquifer can arise from:
 - Conversion from conductivity to concentration of NaCl
 - Converting ER imaging to conductivity values and then NaCl concentrations(mg/L)

Takeaways

- Finer textured soils drive nitrate removal, exchange low nitrate water with higher riparian groundwater in the aquifer.
- Modeled responses mimic values more similar to downgradient well specific conductivity response as compared to average aquifer response.



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- Stephanie A. Ewing
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- Trevor P. Irons
- Caitlin M. Mayernik

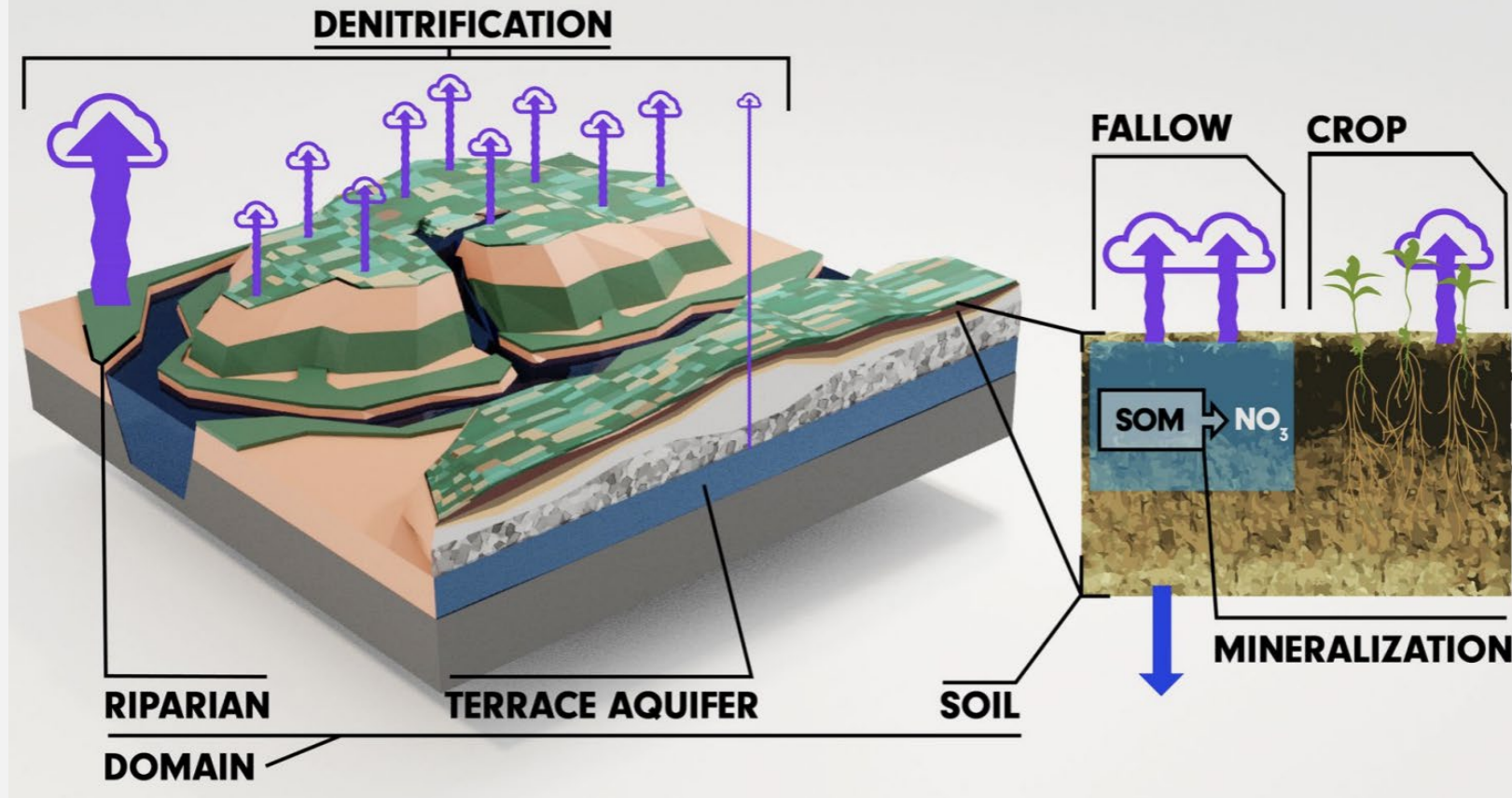


Works Cited

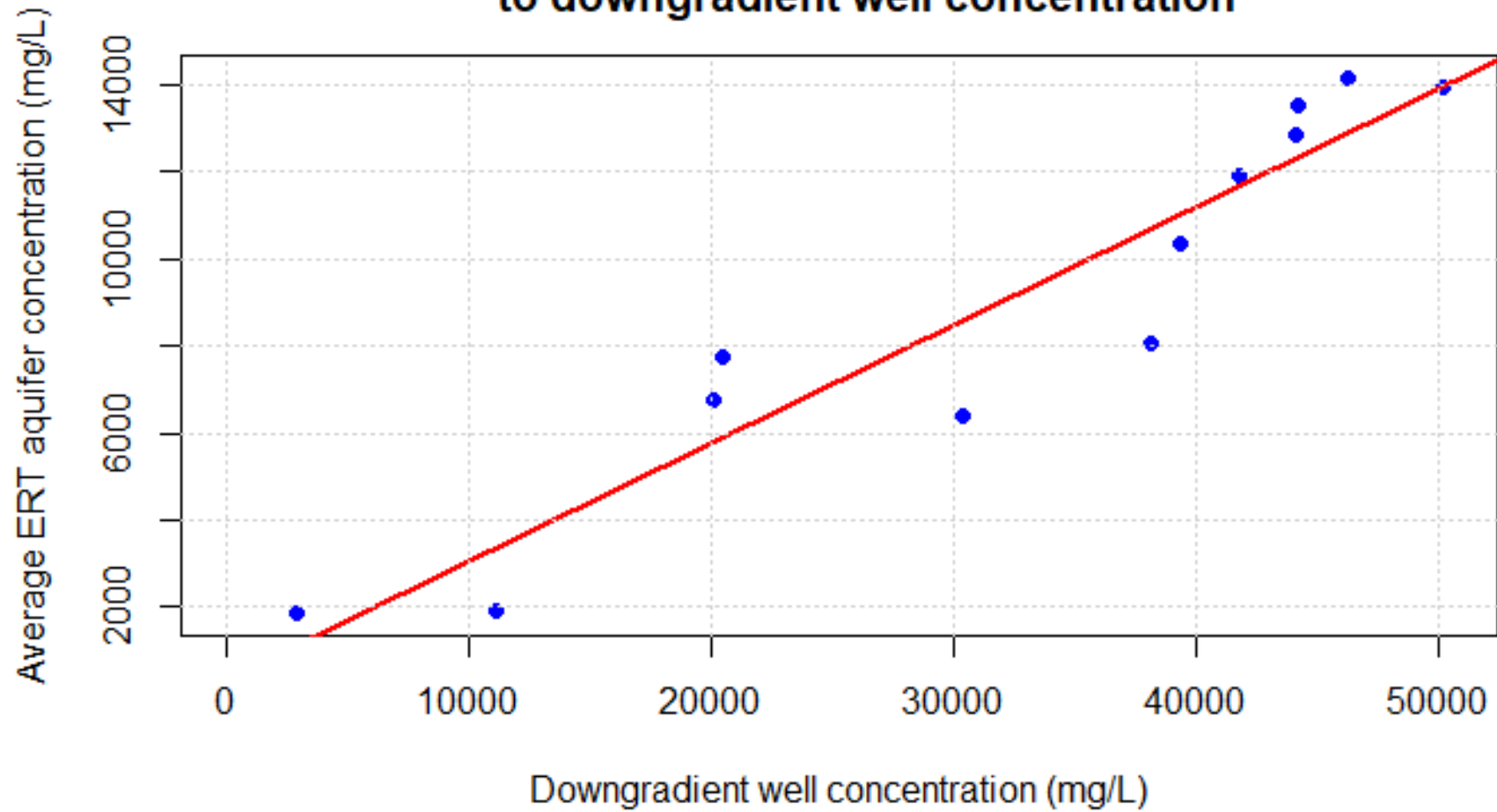
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Motivation

- Current use of nitrogen fertilizers, at inefficient rates that now exceed crop uptake, has led to leaching loss of nitrate (NO_3^-) to surface and groundwaters (Houlton et al., 2013), including in Montana (Sigler et al., 2018).
- Rising levels of nitrate in groundwater in the Judith River watershed of Central Montana have been linked to soil management practices that facilitate nitrate leaching (John et al. 2017, Sigler 2020/2022)



**Average ERT concentration compared
to downgradient well concentration**



P-value = 3.277 e -06

R-squared = 0.8846