Phosphorus sequestration by oxidizing iron in groundwater fed lowland catchments

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Oxidation of Fe-rich groundwater → Fe oxyhydroxide particles

JUST AFTER SAMPLING

2 DAYS LATER

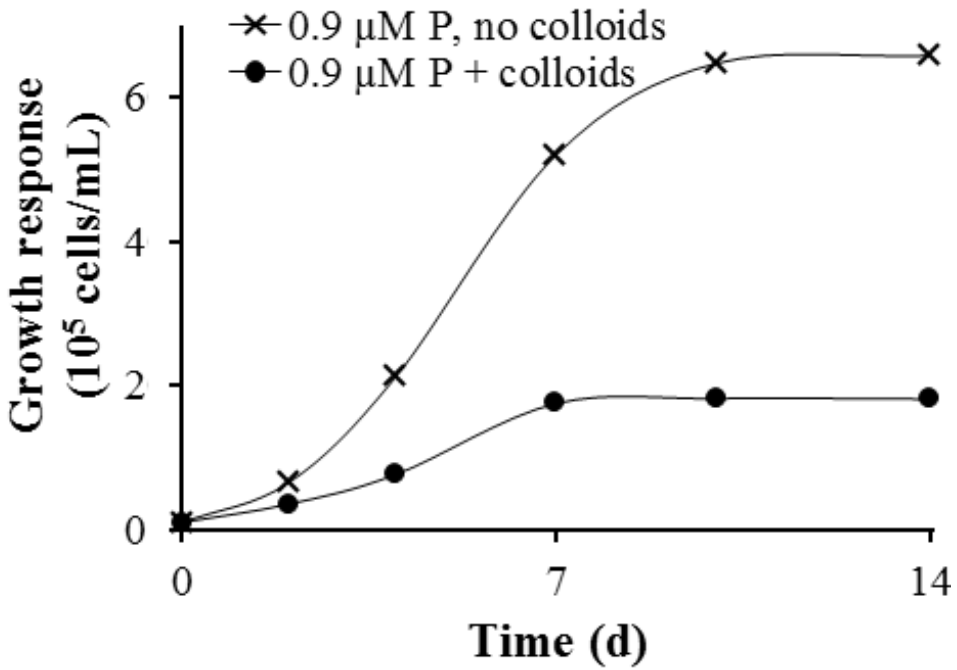
Reduced Fe(II) (soluble)

Oxidized Fe(III) (insoluble)

$$Fe^{2+} + 3H_2O \rightarrow Fe(OH)_3 + 3H^+ + e^-$$

- Oxidation rate at circumneutral pH: hours…days
- In the presence of PO_4
  - First, Fe hydroxyphosphate formation until near depletion of PO_4
  - Then, continued formation of Fe oxyhydroxides

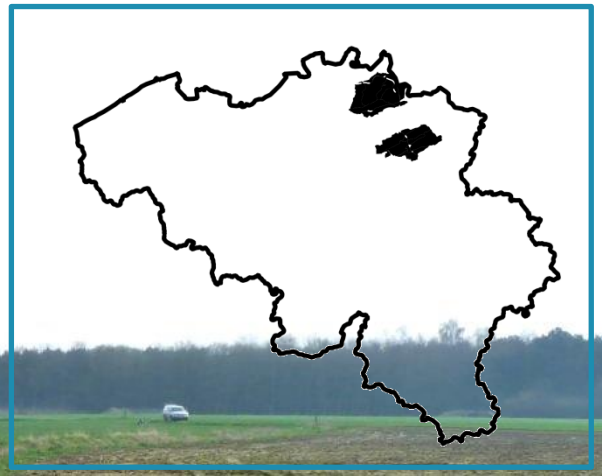
The P bound to Fe oxyhydroxides is poorly available to algae

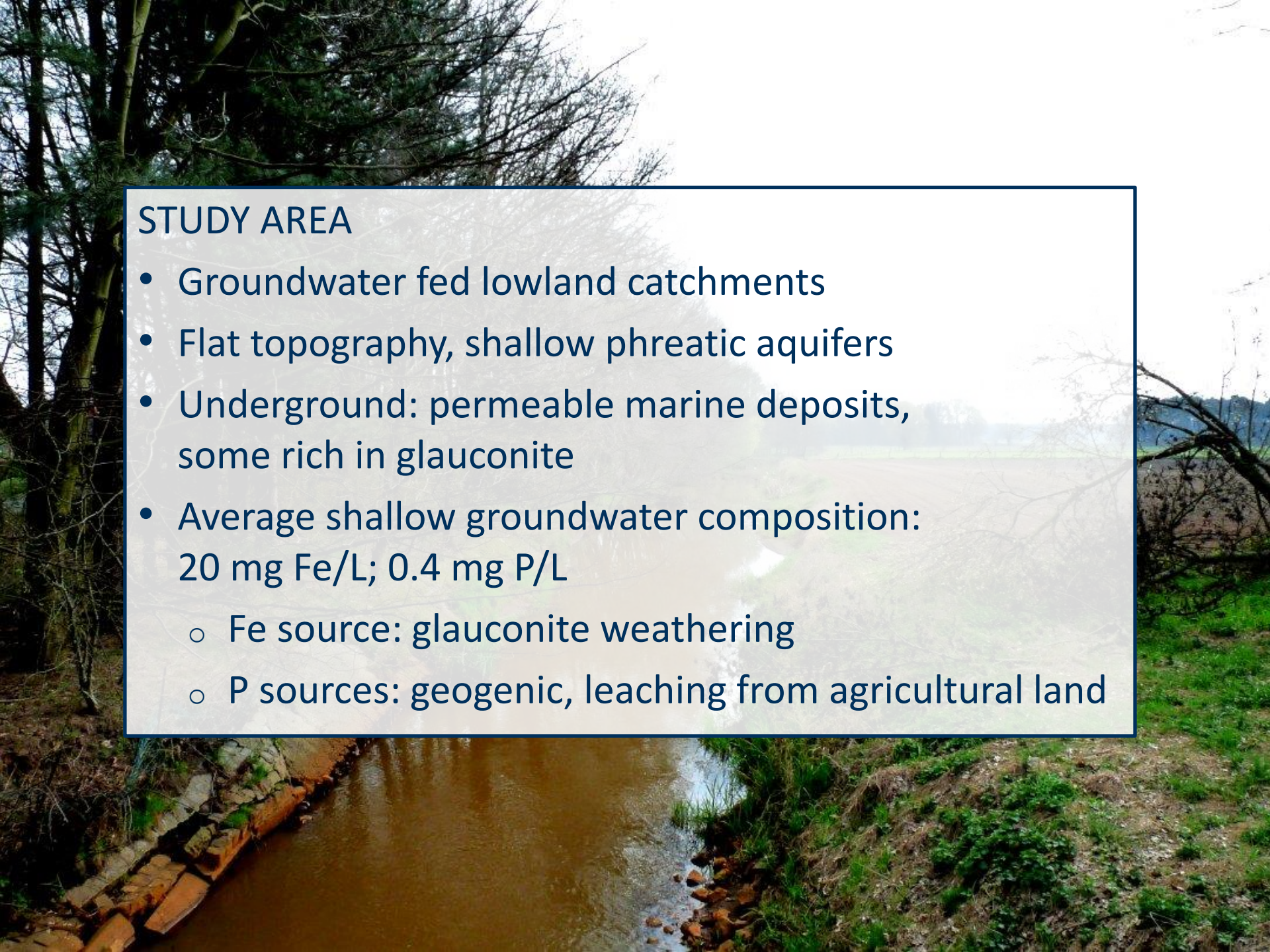


Algal growth and P uptake is reduced by adding Fe oxyhydroxide colloids.

After time, part of the P slowly becomes available.

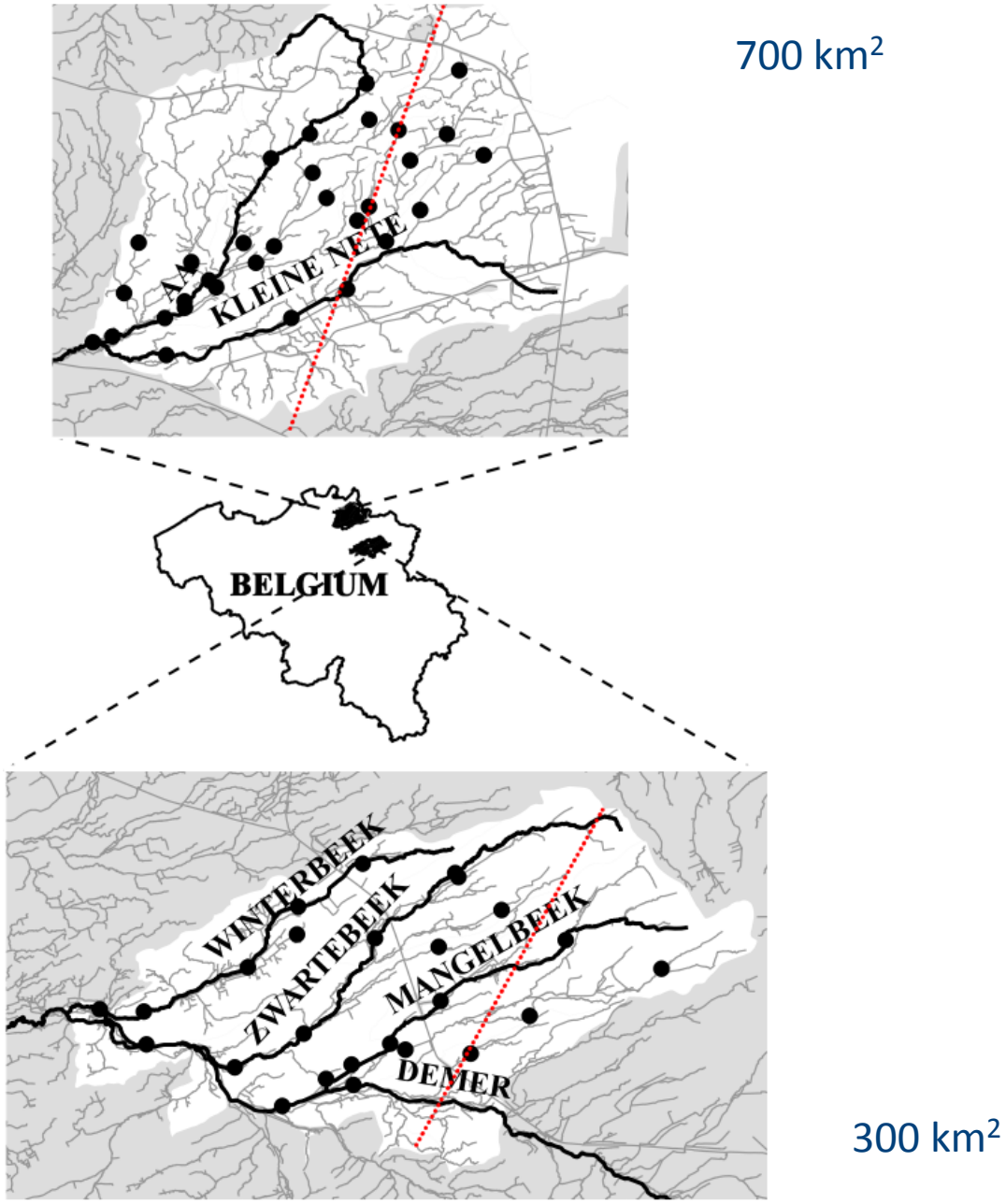
What if Fe-rich groundwater surfaces across a large area?



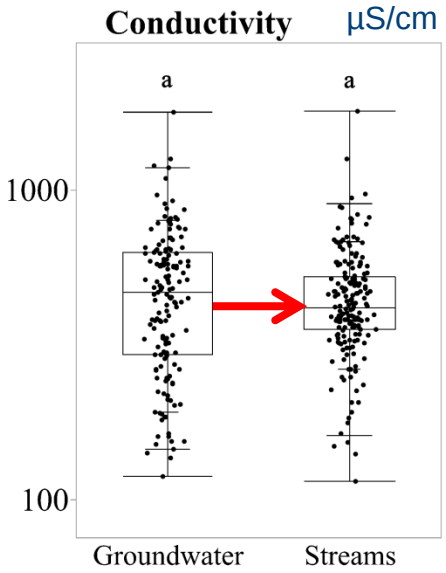


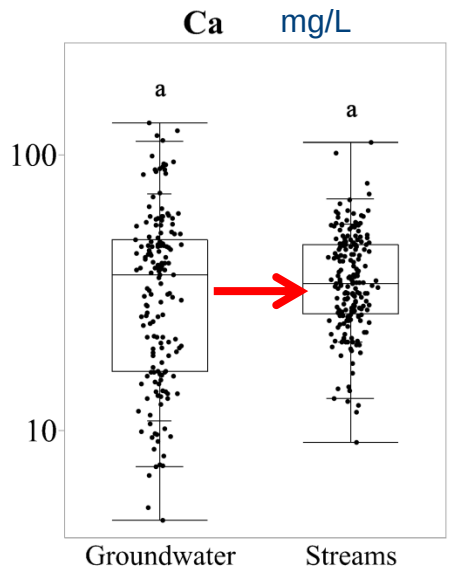
STUDY AREA

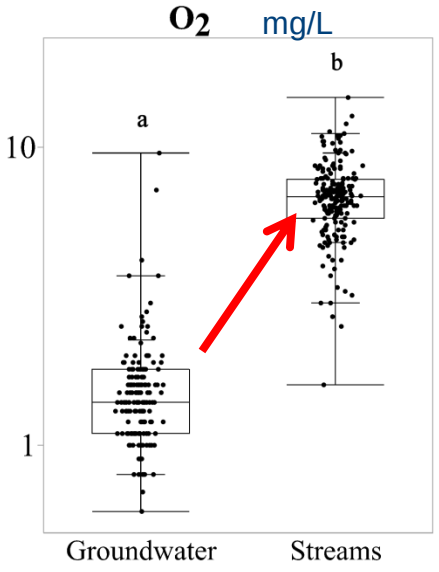
- Groundwater fed lowland catchments
- Flat topography, shallow phreatic aquifers
- Underground: permeable marine deposits, some rich in glauconite
- Average shallow groundwater composition: 20 mg Fe/L; 0.4 mg P/L
  - Fe source: glauconite weathering
  - P sources: geogenic, leaching from agricultural land

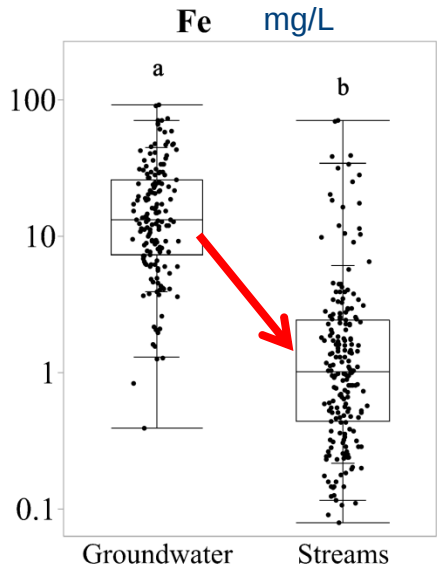

700 km²
KLEINE NETE
BELGIUM
WINTERBEEK
ZWARTEBEEK
MANGELBEEK
DEMER
300 km²

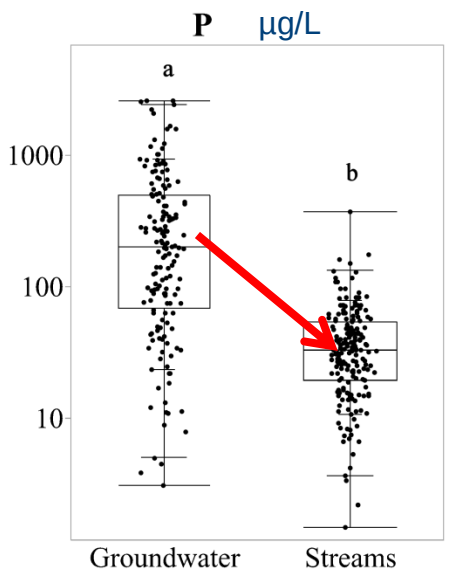
Composition of filtered groundwater and surface water

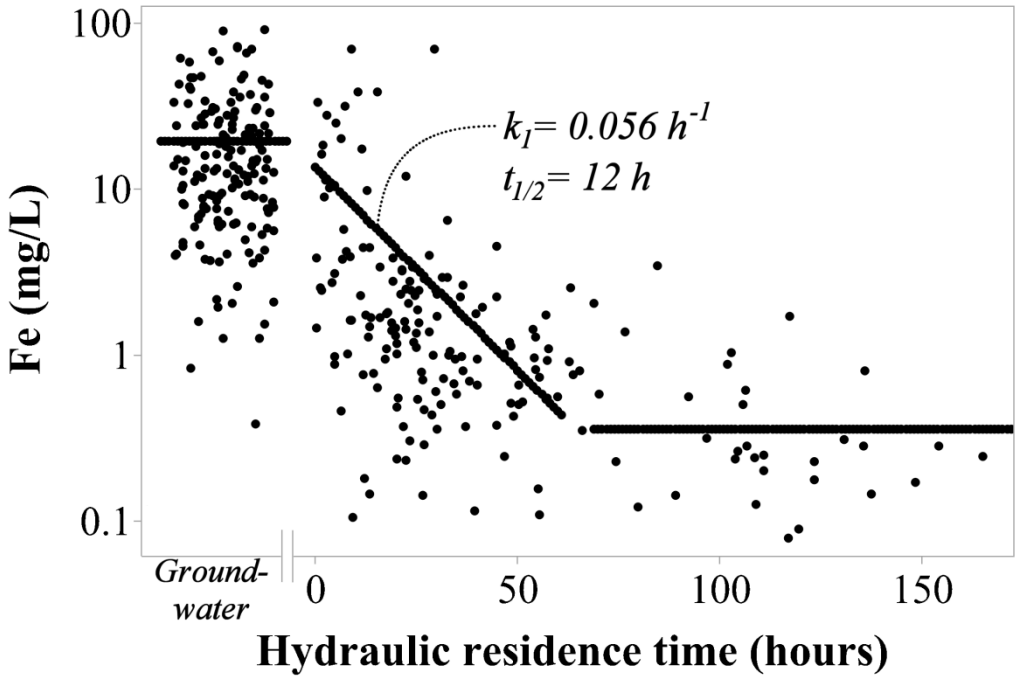




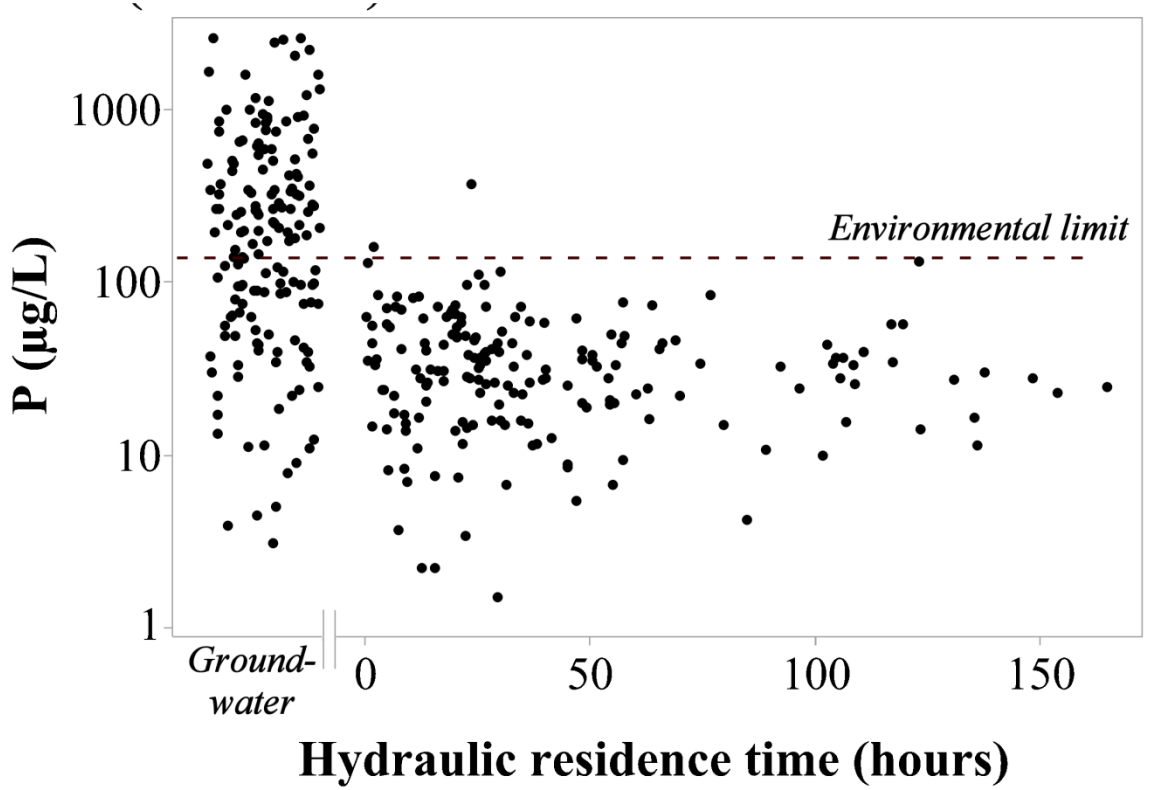








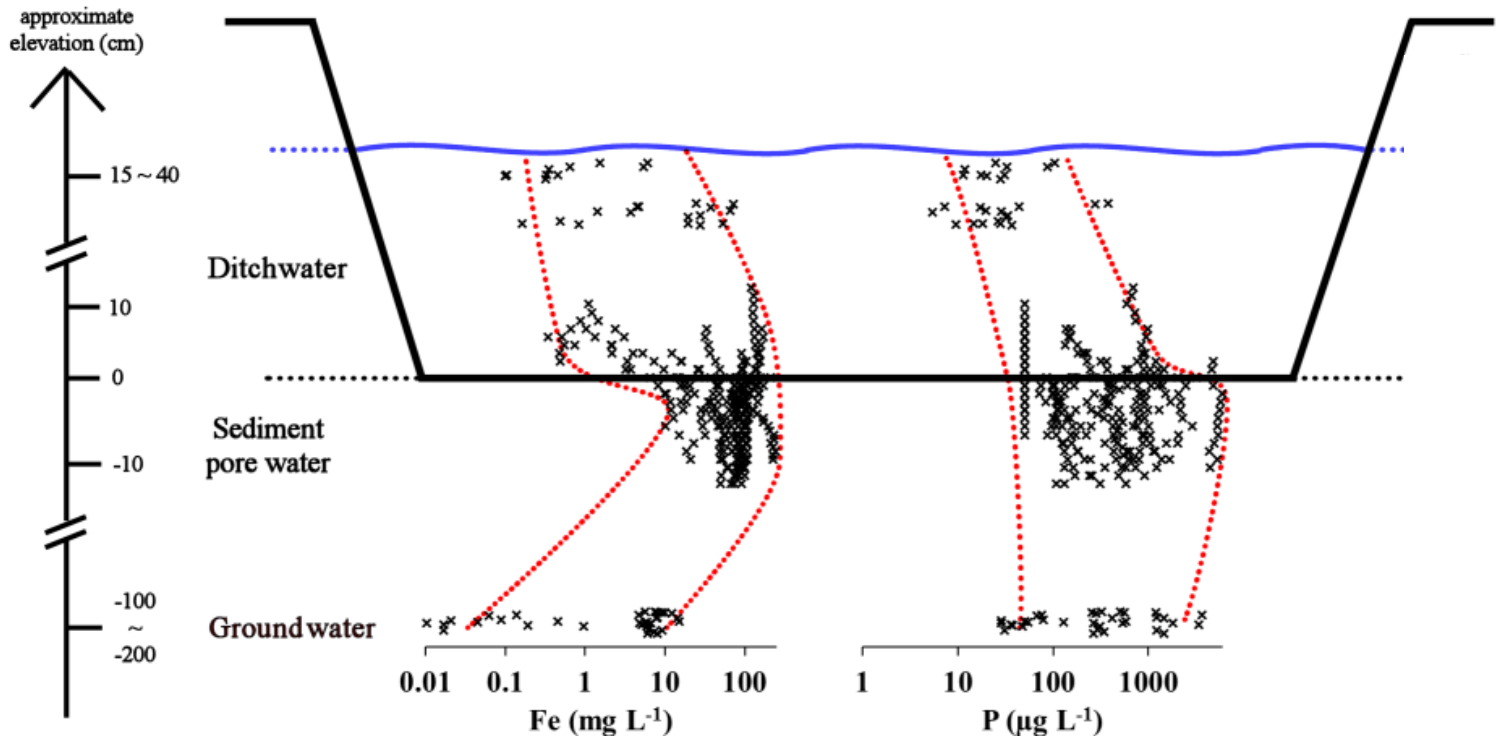
The Fe(II) is oxidized and removed from solution (<0.45 µm) as the groundwater surfaces and flows through the catchment into increasingly larger streams



Before the water reaches the headwater streams, 90% of the P is removed from the <0.45 µm fraction

Drainage ditches with Fe-rich sediments seasonally evacuate groundwater

What happens as Fe and P bearing groundwater flows through Fe-rich sediments and into drainage ditches?



- As groundwater surfaces and flows through the catchment, the Fe is oxidized and Fe oxyhydroxide particles and colloids are produced.
- These particles strongly bind P, and thereby remove it from solution
- This study area is extreme in terms of its low P:Fe ratio
  - to what extent does this process occur in other lowlands?