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Using sediment texture to estimate infiltration rate at a managed aquifer recharge site

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Introduction

California and much of the western U.S. have experienced intense droughts and water shortages in recent decades; ongoing and future climate change will create additional challenges. Groundwater meets ~40% of freshwater demand in California during normal years, and ≥60% in dry years; some basins almost entirely depend on groundwater. Chronic groundwater overdraft has led to many problems, including disconnection and drying of streams and wetlands, loss of aquatic habitat, and subsidence.

WY21, diverted flow from the Cosumnes River. Photo: H. Dahlke.

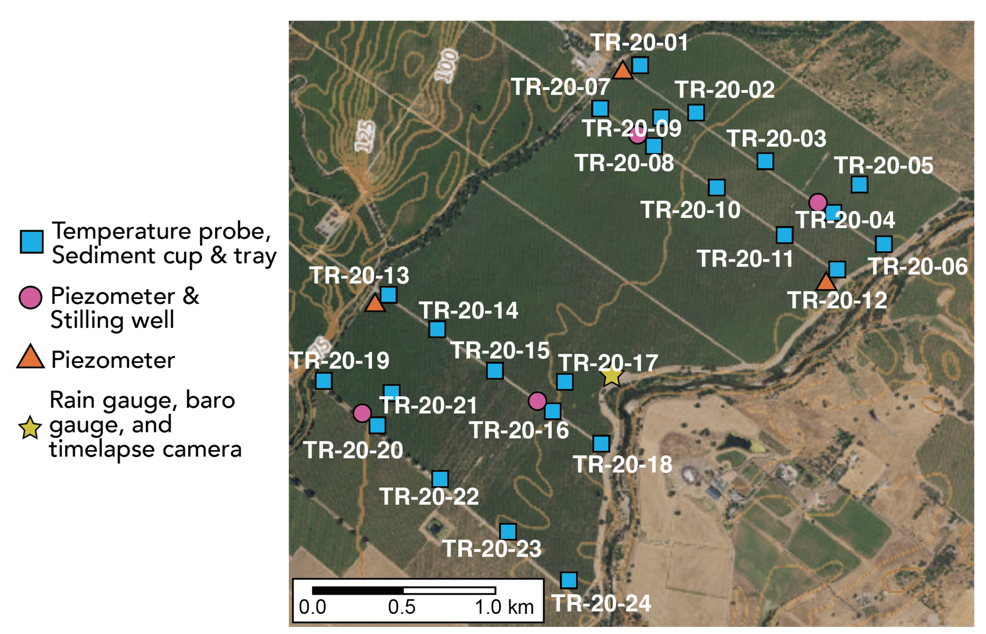
Sample Collection

We deployed instruments to measure flood and infiltration conditions, and collected soil samples, to assess properties that control infiltration rates and impacts on water quality. The first flood MAR diversion at the field site occurred in January of 2021. Laboratory experiments with intact cores recovered from the field site are being run to assess how flood MAR infiltration could influence water quality, particularly if soils are augmented with bioavailable carbon.

1 meter hand-augered sediment core.

Managed Aquifer Recharge

Managed aquifer recharge (MAR) is a set of methods used to enhance inflow to aquifers with excess surface water. Intense rainfall and snowmelt events can contribute to enhanced groundwater recharge, if this water can be infiltrated quickly into the ground. MAR often targets small areas using infiltration basins or wells. Another technique known as "flood MAR" uses excess flows to inundate large areas, including farms and rangeland. Members of the UCSC Hydrogeology group are participating in a pilot flood MAR project on a 785-acre vineyard near Elk Grove, CA to evaluate how much water can be infiltrated on the floodplain of the Cosumnes River.

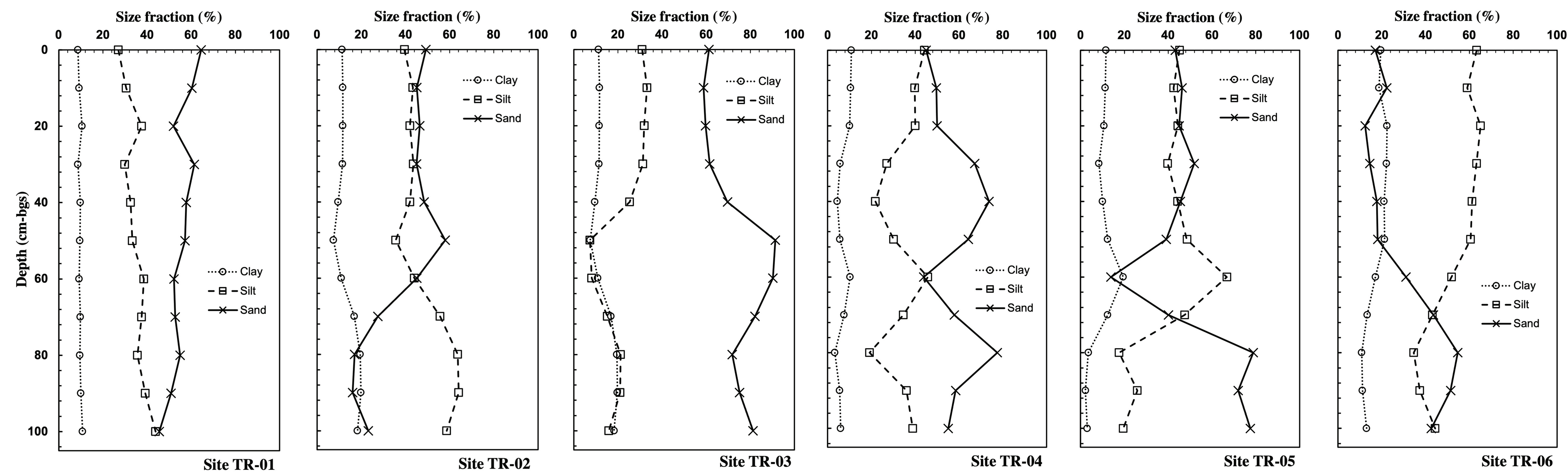


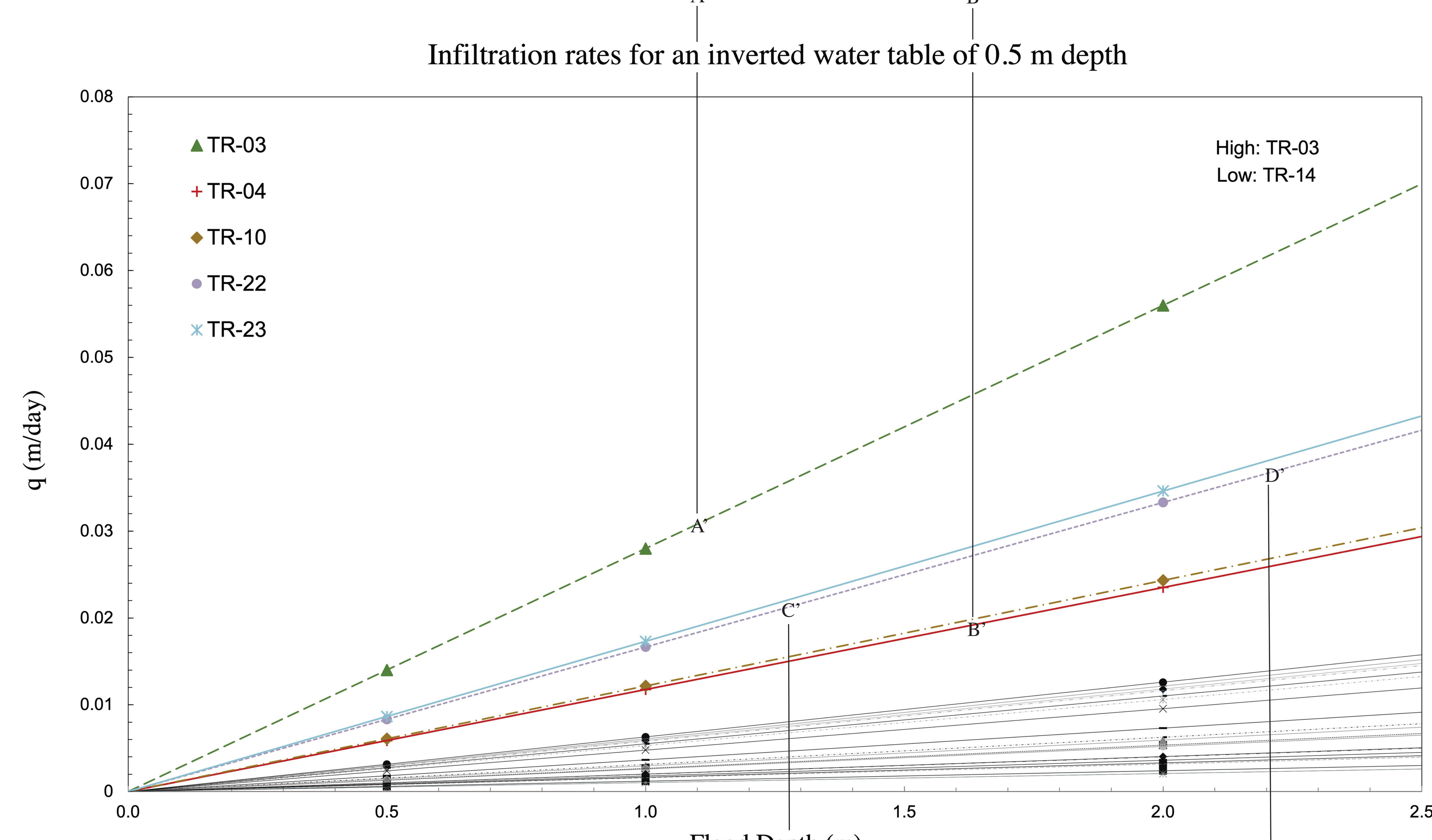
785-acre vineyard outside Elk Grove, Calif.

Grain-size Analysis

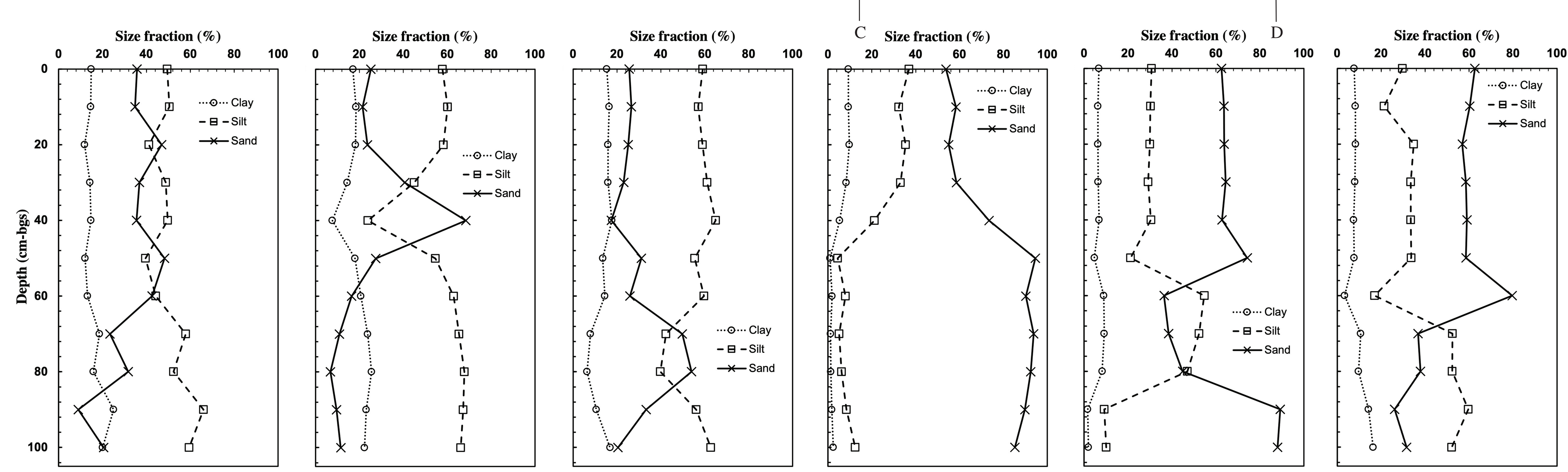
The upper 1 meter of sediment was collected at 24 locations, with measurements made every 10 cm. Samples were processed with 30% hydrogen peroxide to remove excess organic material. Samples were analyzed using scattered laser light diffraction to determine texture. Results were analyzed to determine the sand, silt, and clay fractions, and calculations were made to determine key metrics from the size distributions: d_{10}, d_{20}, d_{50}, d_{60}, and d_{80} (where d_{XX} = diameter of grains finer than the XX percentile).

Sediment Texture & Infiltration Estimates





Infiltration estimates depicting high sand fractions.



Conductivity & Infiltration Calculations

Coefficient of grain uniformity:

$$U = \frac{d_{60}}{d_{10}}$$

Empirical equation for porosity:

$$n = 0.255(1 - 0.83^{U})$$

Kozeny-Carmen equation for conductivity:

$$K_i = \frac{g}{v} C_{Ko} \frac{n^3}{(1-n)^2} d_{10}^2$$

K: hydraulic conductivity; g: acceleration due to gravity; v: kinematic viscosity; C_{Ko}: Kozeny sorting constant (8.3×10^{-3}); n: porosity; d_{10}: grain diameter

Harmonic mean conductivity for vertical flow:

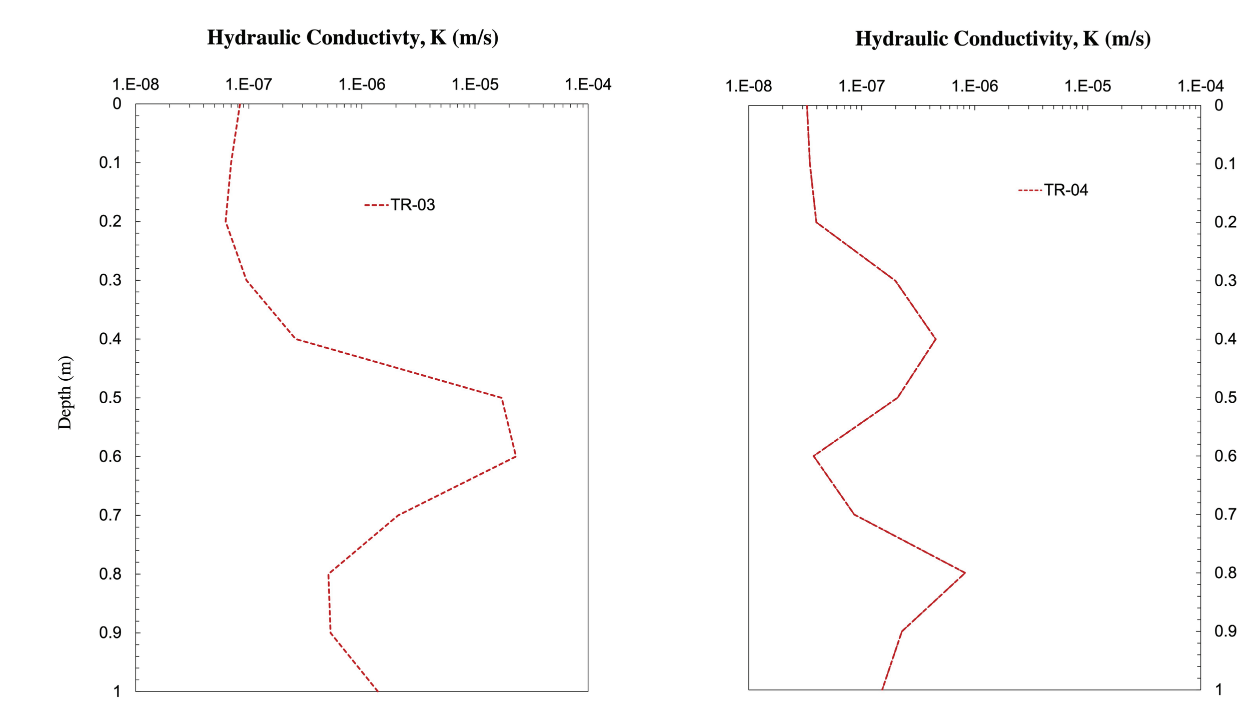
$$K_{vert.} = \frac{\Delta Z_T}{\sum_{i=1}^{n} \frac{\Delta Z_i}{K_i}}$$

ΔZ_T: total depth; ΔZ_i: spacing depth; ΔK_i: conductivity at spacing depth

Darcy's Law for infiltration:

$$q = -K_{vert.} \frac{\Delta h}{\Delta z}$$

q: infiltration rate; Δh: head difference; Δz: elevation difference



Highly variable conductivity at depth.

Next Steps

This study yields conservative estimates of infiltration rates from grain-size. We expect in-field infiltration rates to be greater because of root systems, rodent burrows, and other high permeability pathways. Additional studies will explore soil variability at greater depths.

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