Impacts of streambed dynamics on nutrient and fine sediment transport in mountain rivers

Elowyn Yager[1*], Nicole Hucke[1], Rachel Watts[2], Andrew Tranmer[1], Janice Brahney[2], Joel Rowland[3], George Perkins[3] and Rose Harris[3]

[1]University of Idaho, Boise, ID

[2]Utah State University, Logan, UT

[3]Los Alamos National Laboratory, Los Alamos, NM

Environmental System Science Program

Summary

- The armor layer protects the finer bed subsurface from erosion, but when dislodged during high flow events it can release fine sediment enriched in Phosphorus (P) and Organic Carbon (OC).
- **Hysteresis and seasonal variations** in particulate and soluble reactive phosphorus (PP and SRP) and in particulate and dissolved organic carbon (POC and DOC) could be **controlled by armor layer motion**
- By monitoring summer monsoon and snowmelt flows and conducting field experiments in a mountain stream in NM, our preliminary results suggest that the **quantity of fine sediment in the riverbed is related to local hyporheic flux and flow velocity**.
- Particulate constituents such as POC and suspended sediment (SS) often show clockwise hysteresis, whereas DOC showed different hysteresis for different seasons, suggesting they are **coming from different sources.**
- We are currently investigating these sources and constraining the exact timing of armor layer motion in each event.

Methods

1. Capturing Hysteresis:

Study Site: La Jara Creek,
Valles Caldera National Preserve, NM

Turbidity and fDOM*
Collected using a YSI EXO2 Sonde

Water samples (SS, SRP, PP, DOC & POC)
Stage-triggered portable ISCO samplers

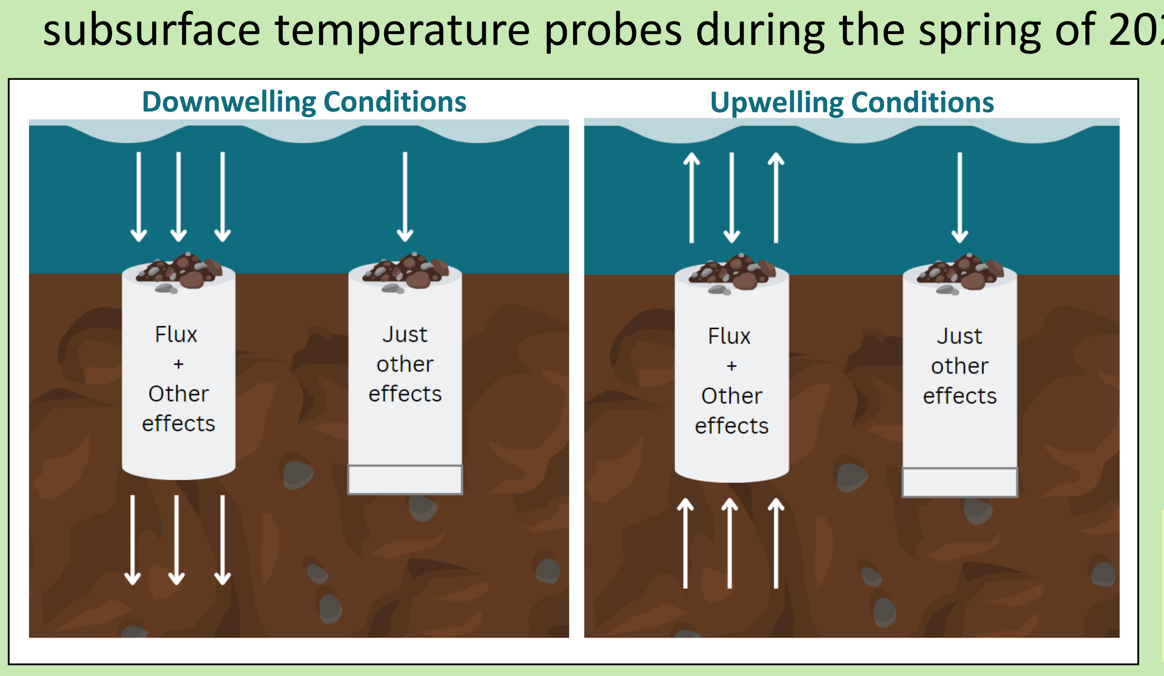
Flow depth and Discharge
Pressure transducers in stilling wells

* Fluorescent dissolved organic matter – a reliable proxy for DOC

Laboratory Procedures
- **SS** – Laser diffraction method (LISST portable XR)
- **POC** – Eurovector elemental analyzer coupled to an Isoprime IRMS
- **DOC** – OI Analytical Aurora 1030 TOC Analyzer
- **SRP & PP** – SpectraMax M2e

2. Fine Sediment Deposition

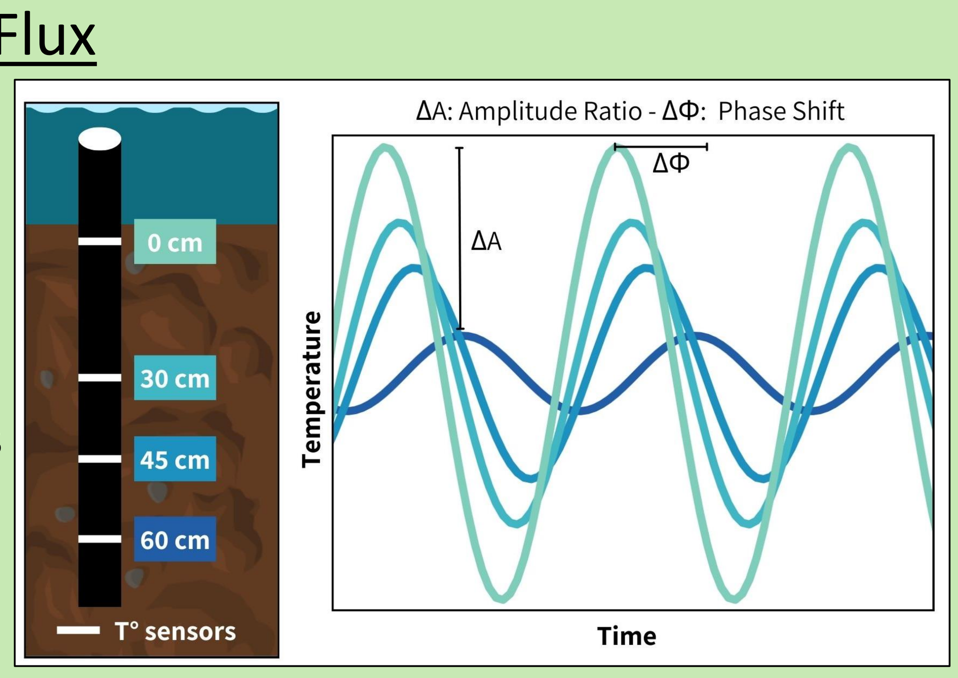
Sediment traps with open and closed bottoms were installed next to subsurface temperature probes during the spring of 2023



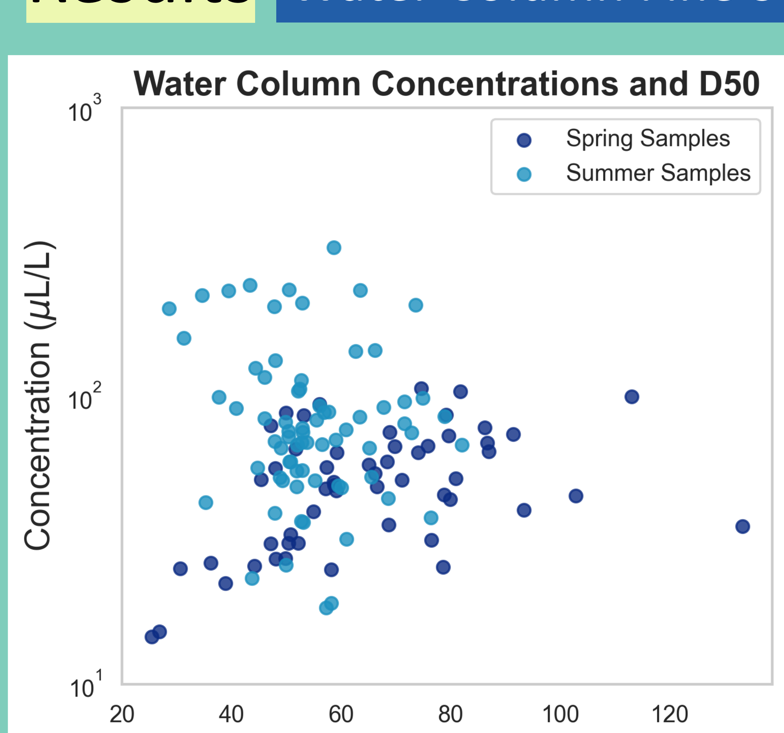
Other deposition effects:
- settling velocity
- stream turbulence effects

3. Computing Hyporheic Flux

Through diel substrate water temperature fluctuations, we can solve the vertical flux from the 1D advection-diffusion equation using *ΔA and ΔΦ*. Temperature-monitoring probes were installed at the locations of each basket group to estimate local hyporheic flux.



Results Water Column Fine Sediment Concentrations and D_{50}



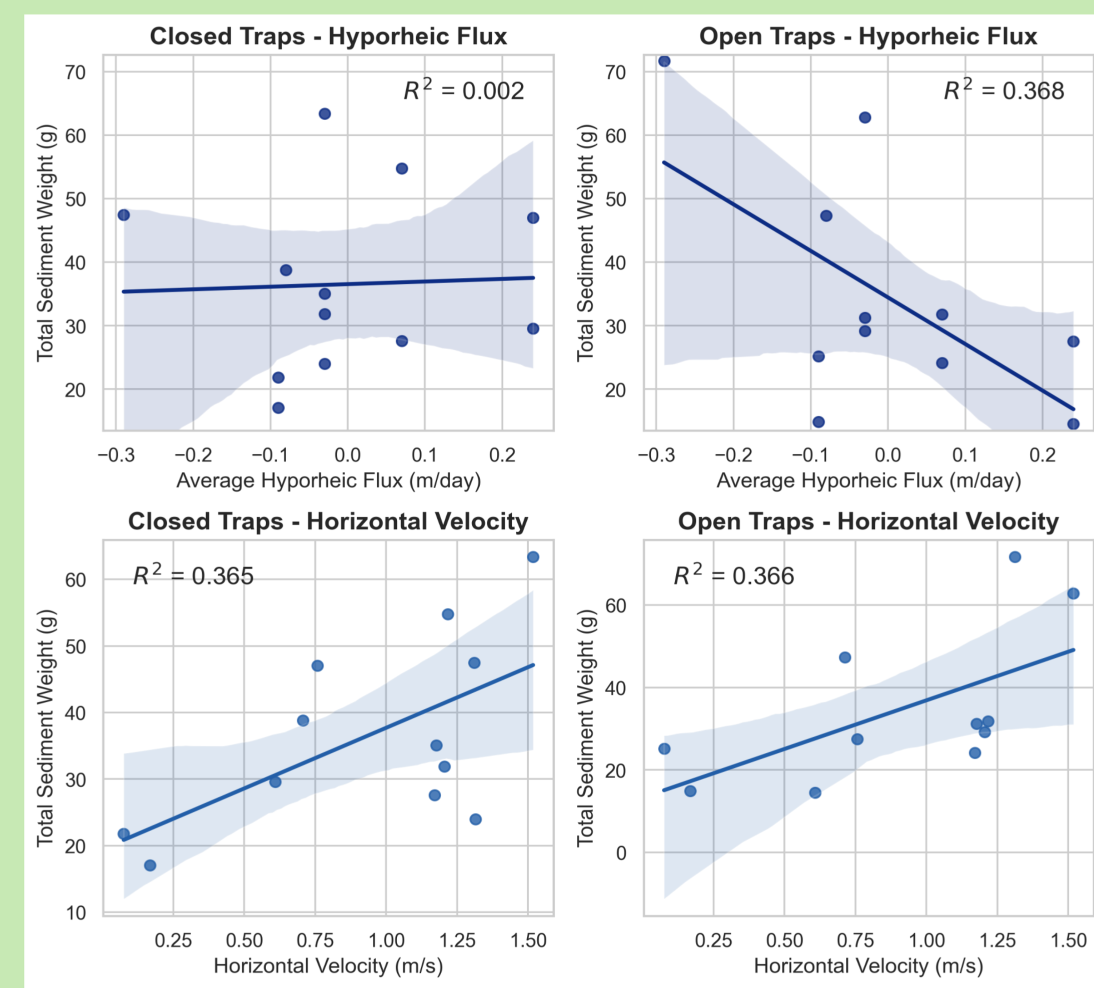
Summer high flow events displayed a wider range of concentrations and **higher peak concentrations on average** than the spring event concentrations.

Spring high flow events have a wider range of D50's and a **coarser grain size distribution on average** compared to the summer samples.

Average:	Spring	Summer
Concentration (μL/L)	53.76	95.00
Median Grain Size (μm)	65.74	54.65

Peak discharges for these high flow events were higher during the spring than the summer.

Results Spring and Summer Fine Sediment Deposition



Settling velocities and different grain sizes are yet to be added to this analysis

The sediment traps demonstrated that the **total captured sediment weight was higher for the spring samples.**

Preliminarily, we also found that the spring sediment particle size distribution (PSD) is coarser than the summer sediment PSD

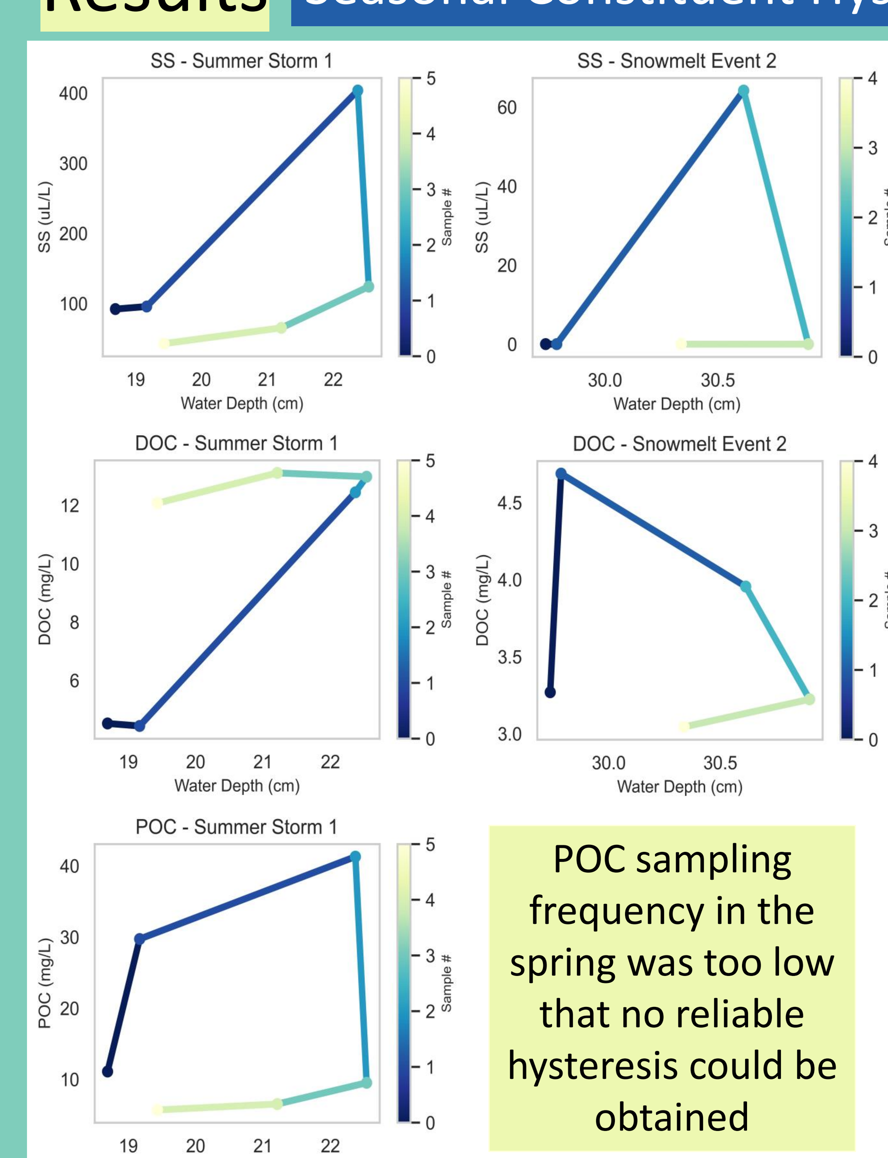
Total deposited **sediment weight correlates better with hyporheic flux for the open traps** than the closed trap.

Other deposition effects such as **horizontal velocity** (obtained through ADV measurements) and **Turbulence Kinetic Energy (TKE)** were used to compute multivariate regressions

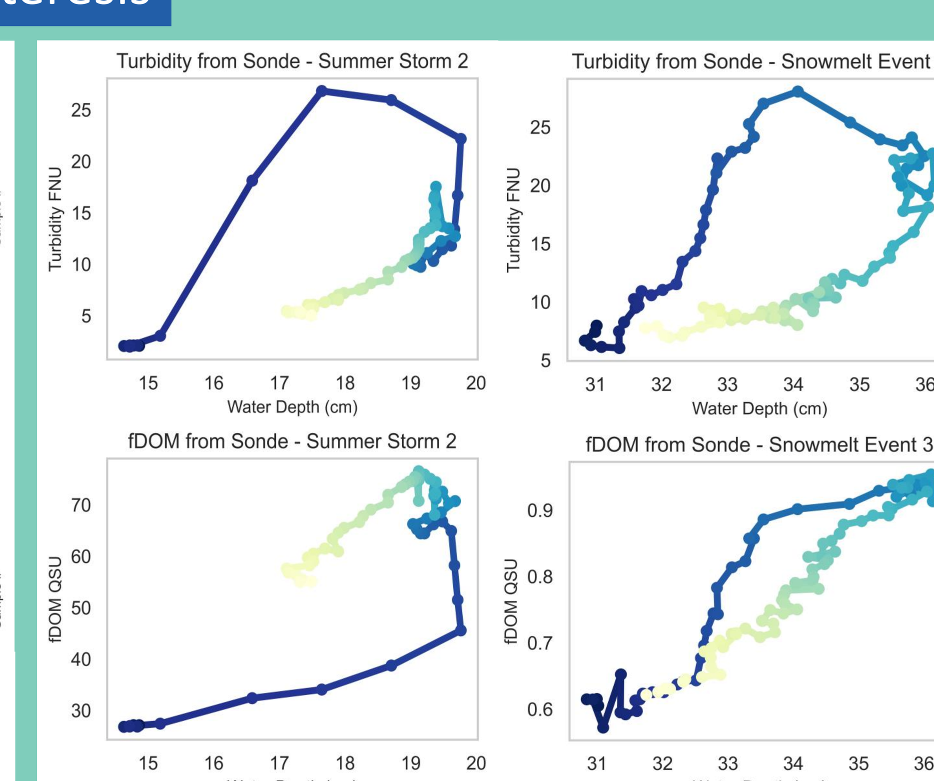
Preliminary results show that **hyporheic flux and horizontal velocity can potentially explain the amount of deposited sediment in open traps**. Closed traps showed little to no relation with hyporheic flux, as expected, but was related to the horizontal velocity and TKE.

Regression Variables:		Hyporheic Flux, Horizontal Velocity and TKE		Hyporheic Flux and Horizontal Velocity		Hyporheic Flux and TKE	
Type of traps:		CLOSED	OPEN	CLOSED	OPEN	CLOSED	OPEN
R^2 values	R^2	0.413	0.791	0.375	0.677	0.310	0.791
	Adjusted R^2	0.192	0.702	0.236	0.597	0.156	0.739
Coefficients	Hyp. Flux	19.621	-6.556	9.708	-67.069	28.416	-5.177
	Hor. Vel.	13.139	0.693	18.505	21.704	-	-
	TKE	22.304	67.457	-	-	47.032	69.052
P values	Hyp. Flux	0.524	0.865	0.711	0.024	0.355	0.845
	Hor. Vel.	0.270	0.958	0.046	0.025	-	-
	TKE	0.493	0.092	-	-	0.076	0.004

Results Seasonal Constituent Hysteresis



POC sampling frequency in the spring was too low that no reliable hysteresis could be obtained



A total of 7 summer and 4 snowmelt high flow events were captured for hysteresis

Particulate constituents (SS, POC and TP) exhibited clockwise hysteresis in all events for both seasons.

Dissolved constituents (DOC and SRP) differed in their behavior. Hysteresis for SRP changed for different summer storms. Hysteresis for DOC was consistently counter-clockwise in the summer and consistently clockwise in the spring. This suggests that these constituents might come from different sources

Discussion and Further Work

- Coarser deposited grain sizes in the spring traps might be due to the transport of larger particle sizes, but the lower concentrations might be a result of dilution and constant exposure to high flows compared to the summer storms.
- Settling velocities for water column suspended sediment samples are yet to be calculated. A more comprehensive analysis of the deposition of each grain size class (sand, silt and clay) with hyporheic flux is in development.
- Different summer hysteresis patterns for DOC and particulate constituents suggest they are coming from different sources. The different degree of hysteresis (related to the peak lag times) could be explained by the timing of armor layer motion.
- The timing of armor layer motion is currently being explored to better understand our results

For questions, please contact huck4481@vandals.uidaho.edu or eyager@uidaho.edu