Ongoing research in geomorphology and hydrogeology at the Cooper Creek Collaborative Experimental Watershed, Cincinnati

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Abstract

The 2.9-km² Cooper Creek Collaborative Experimental Watershed in Cincinnati, OH was established in 2018 to assess mitigation strategies needed to restore a relatively natural hydrology to a headwater stream draining a densely developed urban area (48% impervious) in Hamilton County, Ohio. Cooper Creek is a natural tributary of Mill Creek, a strongly impacted urban watershed. The upper Cooper Creek catchment is shallowly underlain by Ordovician Bellevue Limestone. The natural soil of the catchment is developed from Illinoian-stage loess, glacial till and outwash. During individual heavy rain events, Cooper Creek and similar streams regionally exhibit very flashy behavior. The site offers substantial opportunities for both applied and basic research, including ongoing and planned projects in sediment transport, fluvial geomorphology, and hydrogeology.

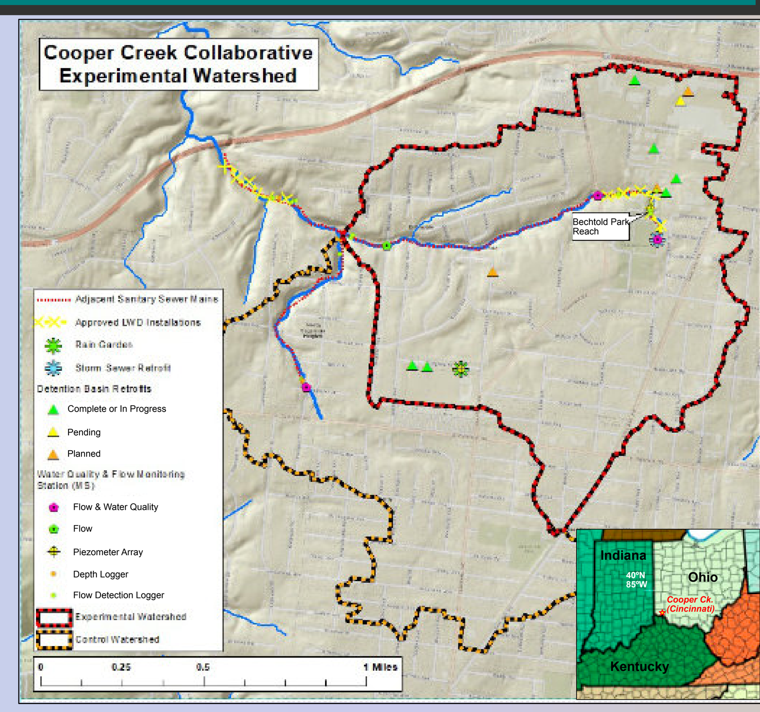
For example, an emerging question in bedload transport is how transport thresholds change based on particle shape, with implications for using typical metrics of e.g. Shields stress to assess sediment transporting flows. In the study area, Cooper Creek is mostly floored by partly-imbricated 10-50 cm limestone slab cobbles and boulders over in-place bedding planes of limestone. Over 300 PIT-tagged rocks across different size and shape classes have been deployed for particle tracking through the reach. This research directly relates to an ongoing applied study of streambed change and ecological health proxies in response to additions of large wood to experimental reaches of the stream.

Hydrogeologically, upper Cooper Creek is complex, with a mixed substrate of fractured bedrock, floodplain deposits, soil, and urban elements such as sewer lines and construction fill. Hyporheic exchange dynamics are poorly understood in these environments. We discuss first results from near-surface geophysical investigation of the subsurface heterogeneity structure and flow dynamics of the hyporheic zone; specifically seismic refraction tomography, spatial patterns of electrical conductivity, and time-lapse images of subsurface electrical resistivity. This work will further contribute data important for urban water management (e.g., mitigating baseflow problems related to urban karst).

Cooper Creek Collaborative

www.coopercreek.org

Partners



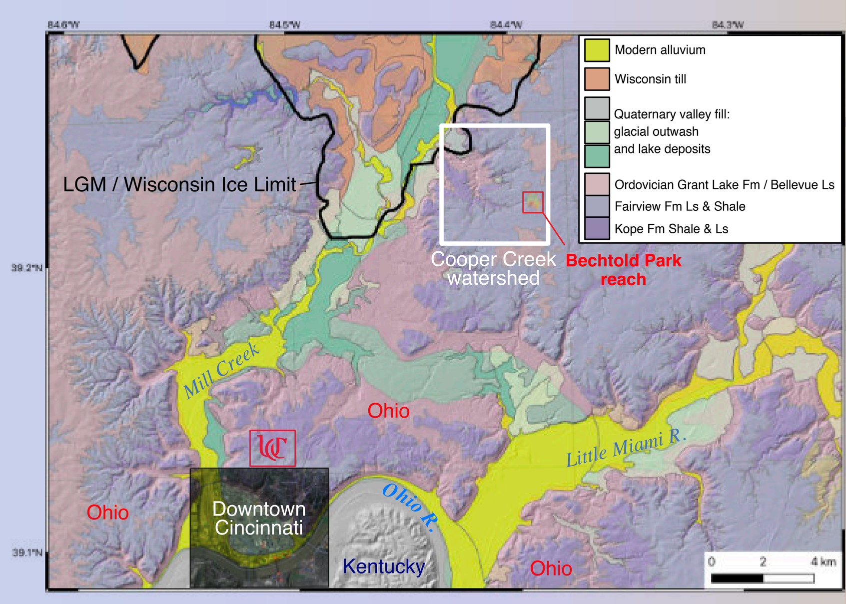
The Cooper Creek Collaborative Experimental Watershed

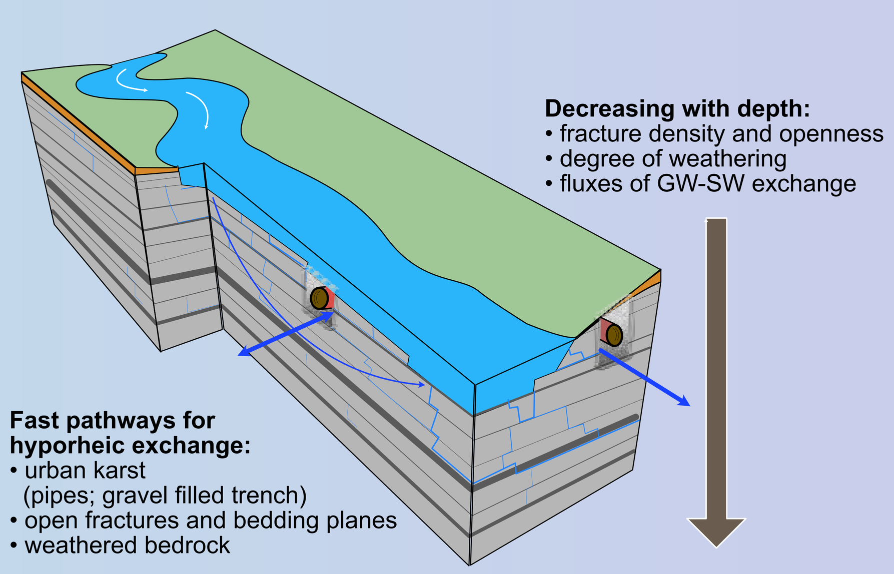
is a multi-partner project that enables applied and basic research as well as training, education, and outreach on urban stormwater management and hydrogeology.

Selected mitigation projects and monitoring locations are shown on the map at the right.

Geologic Setting

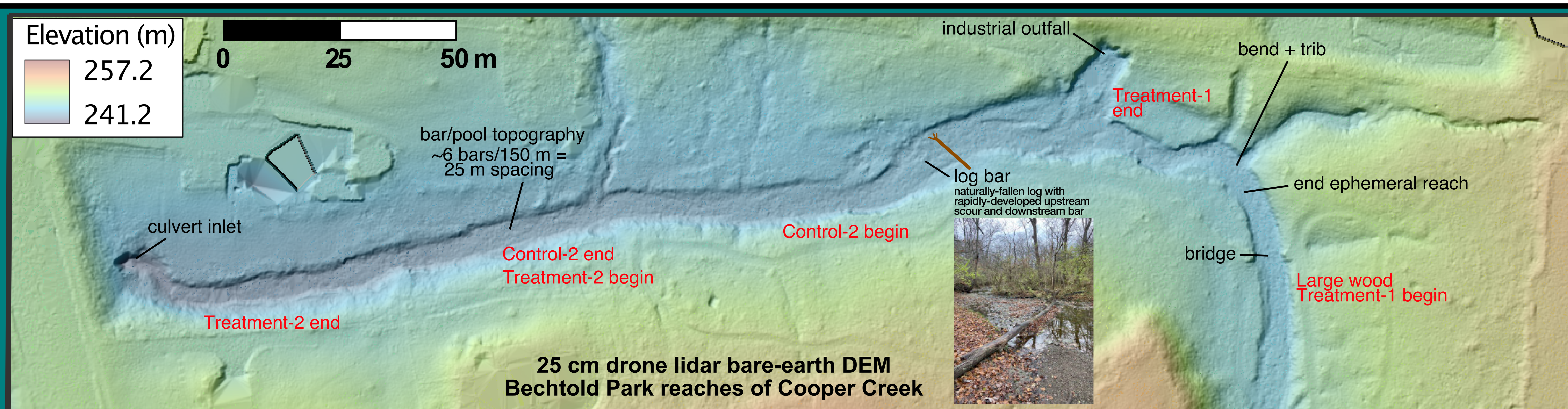
Cooper Creek's watershed lies just outside the 19 ka Wisconsin ice limit of the Laurentide Ice Sheet, and well within the Illinoian limit; the creek enters Mill Creek valley at the former ice margin. The upper Cooper Creek catchment is shallowly underlain by typical Cincinnatian stratigraphy, predominantly the Ordovician Grant Lake Limestone, which contains limestone beds of 2-15 cm thickness intercalated with 1-8 cm mudstone layers. The natural soil of the upper catchment is developed from Illinoian-stage loess, glacial till and outwash. In the study reach, the streambed is mostly floored by imbricated 10-50 cm limestone slab cobbles and boulders over in-place bedding planes of limestone. The banks typically expose 0-50 cm of bedrock overlain by a mix of construction backfill and natural floodplain deposits.

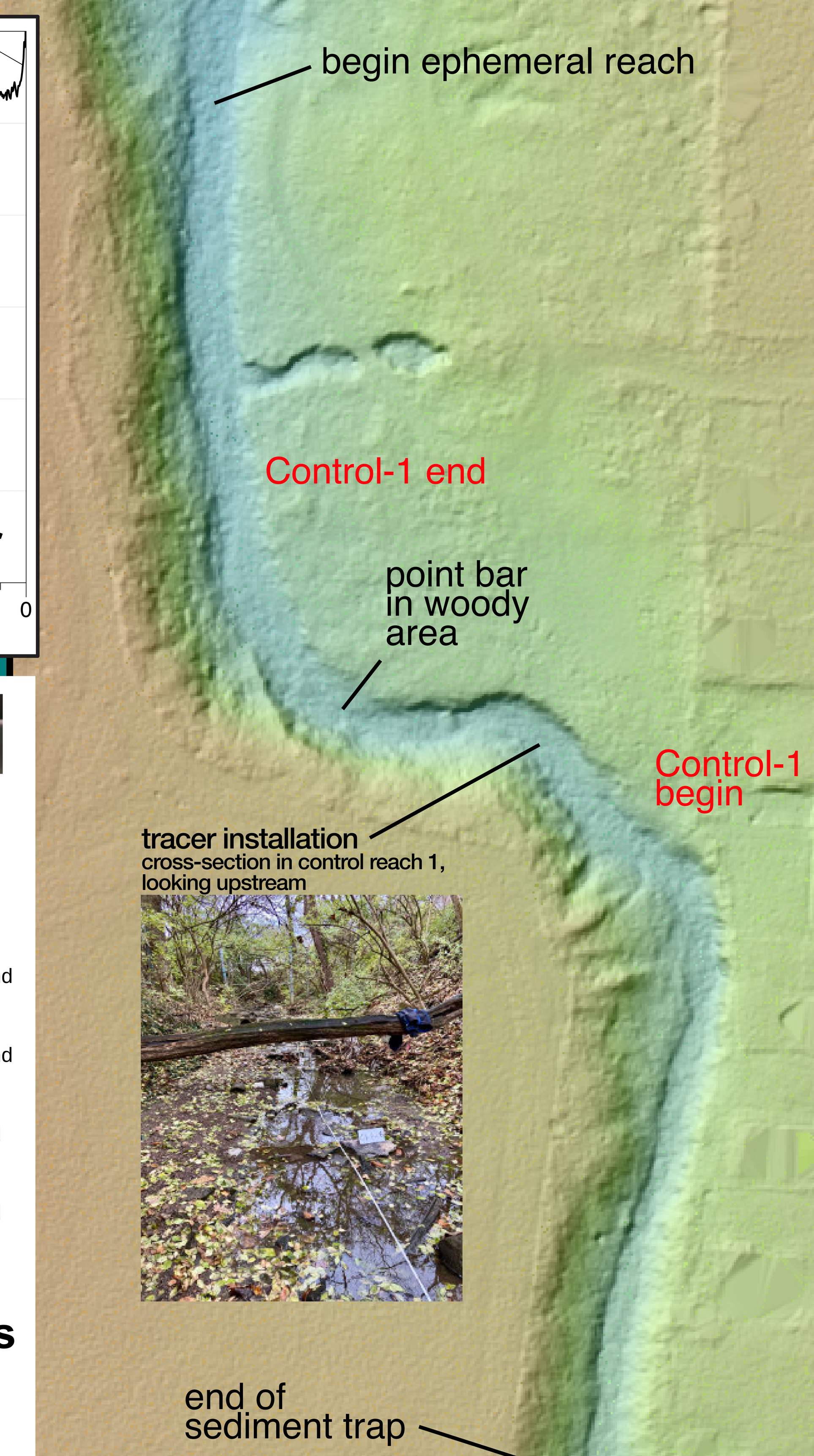




Complex urban hydrology

During individual heavy rain events, the study reach exhibits flashy behavior, rising as much as 50 cm over a few hours and then falling to near baseflow within a day. Upstream of the upper study reach, the stream is fed by stormwater infrastructure, emerging from a culvert that maintains some baseflow year round. Many headwaters reaches are locally ephemeral, as a result of the fractured limestone and shale bedrock, the regional flow of groundwater, and/or the interaction with urban infrastructure (e.g., sanitary sewer lines and the trenches surrounding them).





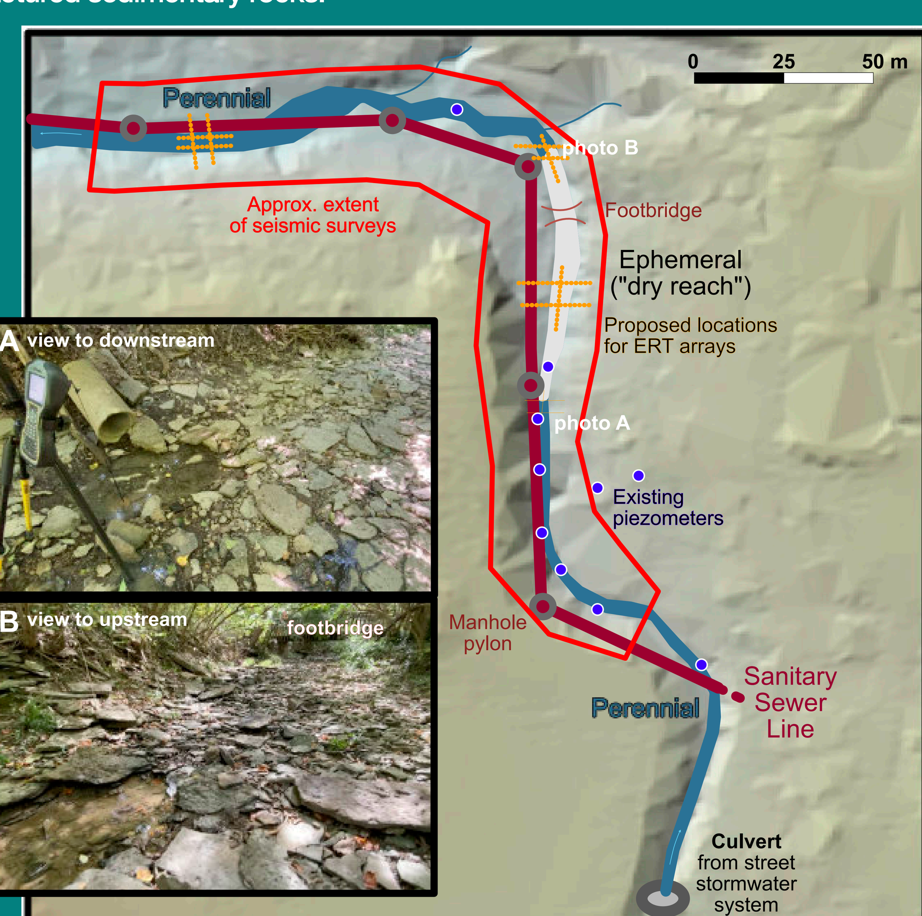
Near-surface geophysics

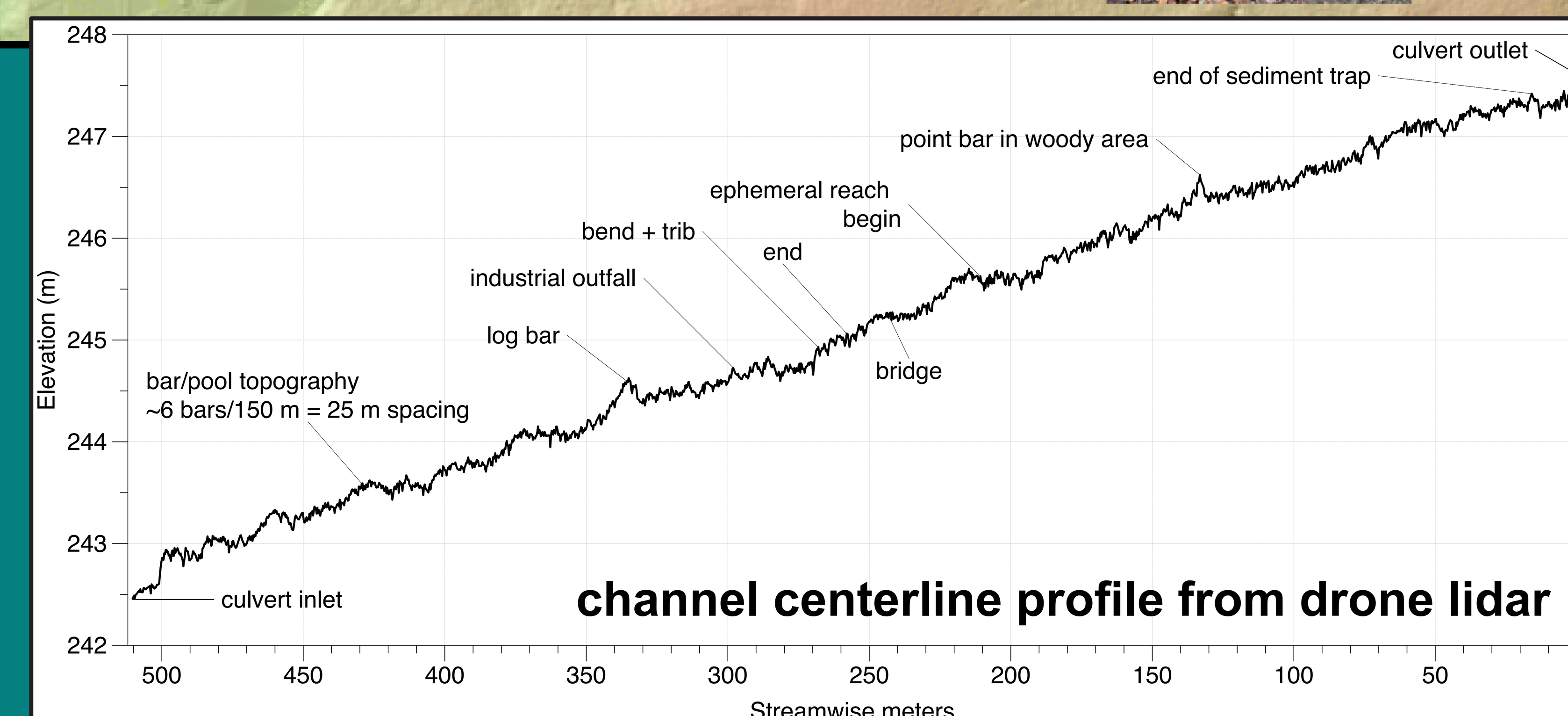
The major aim of our geophysics work is to diagnose transient dynamics of flow in the subsurface and its relationship to natural and artificial dominant flow pathways. The work will facilitate ongoing applied research in the Cooper Creek watershed by Cooperative members; see related presentations:

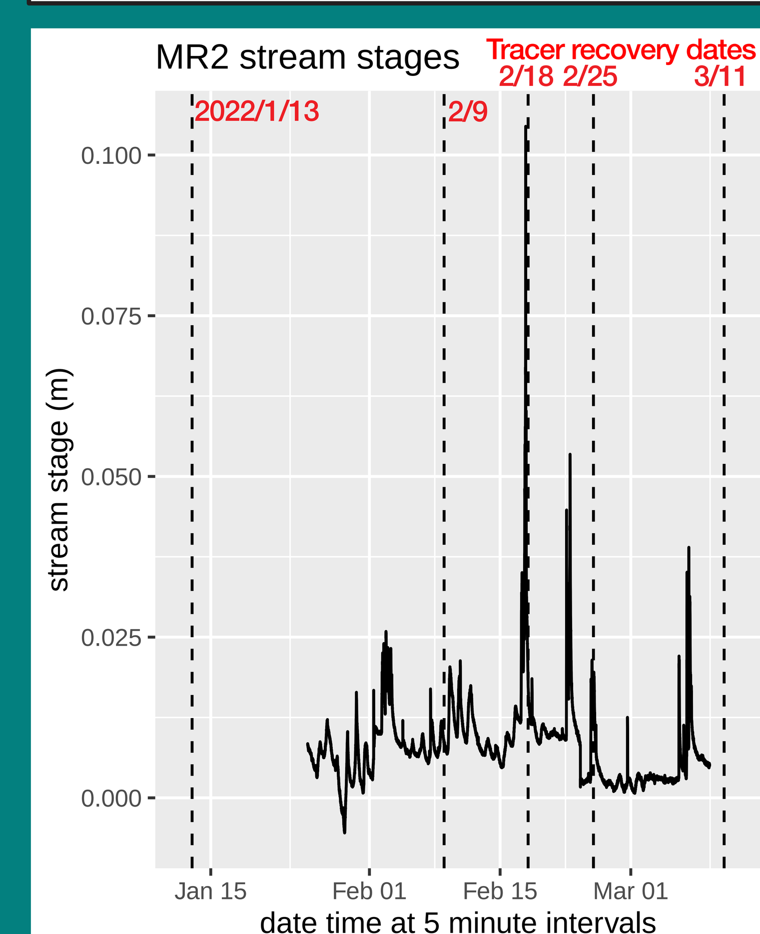
Ford et al., 11-5 - ASSESSING THE INFLUENCE OF URBAN KARST ON THE SUSTAINABILITY OF STREAM FLOW

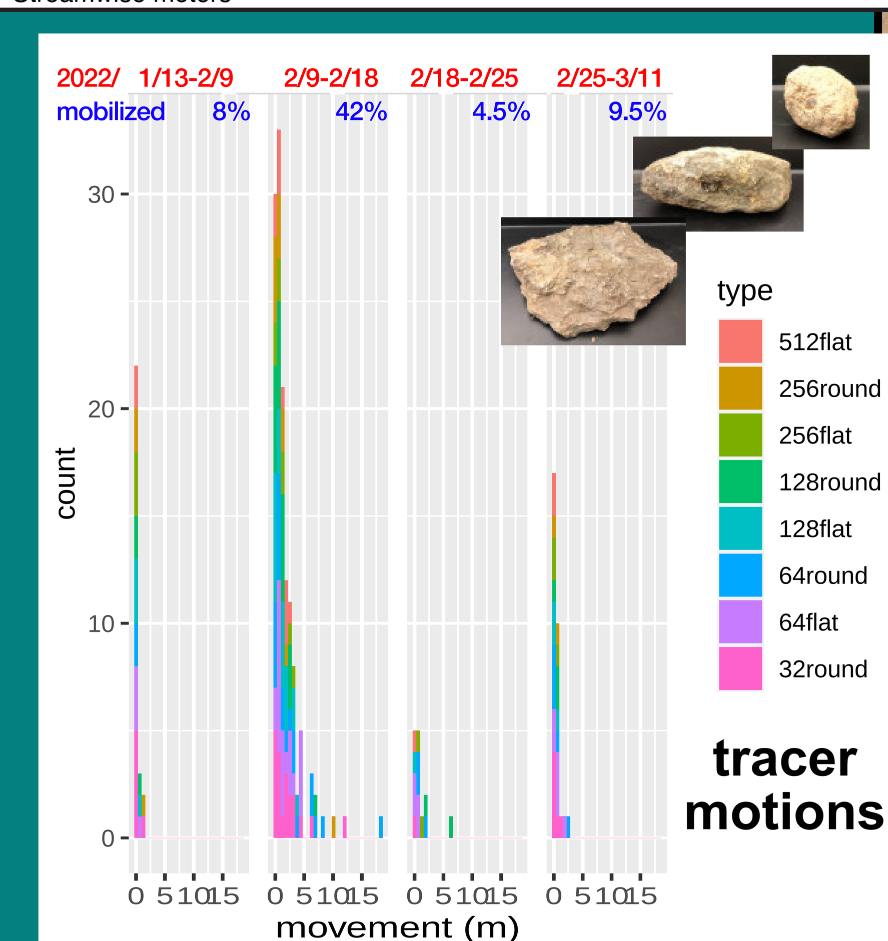
Brase et al., 17-2 USING A RAIN GARDEN TO TEACH HYDROGEOLOGICAL CONCEPTS IN A HIGH SCHOOL SCIENCE CLASSROOM).

During 2022-23, this project will generate three key new geophysical datasets: 1) seismic refraction tomography of the shallow subsurface; 2) spatial patterns of electrical conductivity, and 3) time-lapse images of subsurface electrical resistivity. These data will complement a host of existing stage, chemistry, and temperature measurements currently being collected at the Cooper Creek Collaborative Experimental Watershed. Integrating these multiple datasets will advance fundamental understanding of hyporheic exchange dynamics in altered, complex, mixed-substrate environments, with important implications for the exchange of water, solutes, and pollutants through the critical zone in fractured sedimentary rocks.









Wood and tracer stones

As part of a treatment-control study to evaluate the impact of large wood additions on the creek's hydrology and bed structure, various measurements of suspended sediment and bedload transport are ongoing. This includes over 300 rocks in four size and two shape classes that were sampled from the stream, drilled, tagged with RFID passive inductive transponder (PIT) tags, and replaced in cross-sectional transects at the upper 50% of each wood-addition treatment and control reach (see lidar map). The tags enable near-field radio recovery of tracers without disturbing their position in the bed, even if they are shallowly buried. The current recovery strategy focuses on longitudinal movements, enabling rapid re-survey after observed flow events. Initial results suggest substantial mobility even during small floods.

Acknowledgements:

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