Completed Projects Summaries

FY2017

Ohio Water Resources Center
https://wrc.osu.edu/

Dr. Justin Chaffin, Research Scientist at the Ohio State University and Ohio Sea Grant completed an Ohio Water Resources Center funded project via USGS 104(b) subaward. This project titled "**Effectiveness of Data Buoys as Early Warning Systems for cHABs (cyanobacterial Harmful Algal Blooms) in Lake Erie"** aimed to determine how accurate data buoys are at monitoring for cHABs.

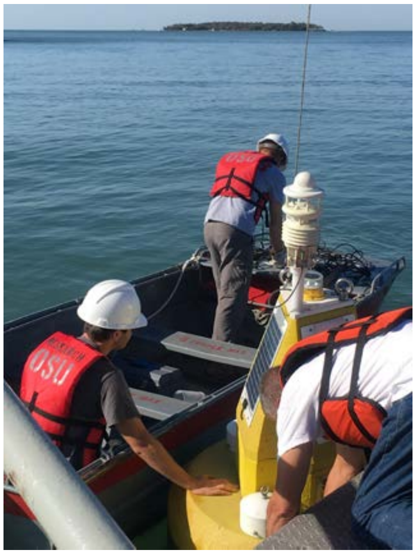


Figure 1 Dr. Chaffin with colleagues during deployment of data buoy

Real-time data buoys have become a valuable tool for lake managers, water treatment plant operators, and the public to monitor cyanobacterial (cHAB) abundance in Lake Erie. However, the sensors on the buoys are located about 1.0 m from the surface, whereas cHABs can regulate buoyancy and may be over or underestimated by the buoy sensors. Furthermore, the data buoys that are deployed in Lake Erie are able to measure only surrogates of these important parameters, such as chlorophyll a, phycocyanin and turbidity. Surface water samples were collected next to a data buoy located near Gibraltar Island throughout summers 2015, 2016 and 2017 (Figure 1) and analyzed for the cyanobacterial toxin microcystin and algal and chlorophyll concentrations. Additionally, on a subset of dates water was collected at every meter throughout the water column and analyzed with a FluoroProbe to determine cHAB-specific chlorophyll.

Overall, cyanobacterial biomass and microcystin concentration followed a very similar temporal pattern as buoy cyanobacteria phycocyanin concentrations (RFUs), suggesting the buoys can serve as an early warning system for cHABs. Buoy data averaged over a one hour before water sample collection had a better correlation with water sample data than the buoy data at the time of sample collection. A comparison of buoy RFU converted-cyanobacteria chlorophyll a (chla) to cyanobacteria chla measured throughout the water column showed that there were occurrences when the buoy both under and overestimated the cyanobacteria chla at specific depths (Figure 2). Overall, the buoy tended to underestimate cyanobacteria chla concentrations at 0 m while overestimating the deeper cyanobacteria chla concentrations. These inconsistencies between the buoy data and every-meter data that could potentially lead to inaccurate warnings and water treatment procedures.

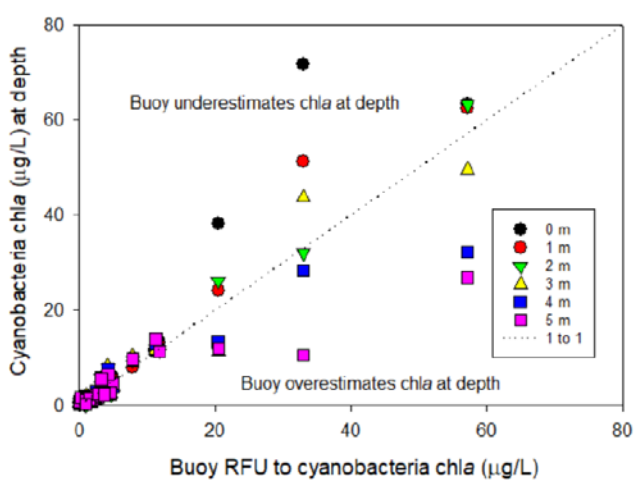


Figure 2 Comparison of measured chlorophyll a at various depths and buoys monitored chlorophyll a at 1 meter

<u>Researcher Profile:</u> Dr. Justin Chaffin is the research coordinator for Stone Laboratory and conducts his own research on cyanobacterial blooms in Lake Erie. His research interest is Lake Erie phytoplankton ecology with particular interest in cyanobacterial blooms (cHABs).

Dr. Daryl Dwyer, Associate Professor in the Department of Environmental Sciences at University of Toledo completed a small Ohio Water Resources Center funded project via Ohio Water Development subaward. The project, "**Determining Components for a Phosphorus Interceptor to Reduce Harmful Algal Blooms in the Western Lake Erie Basin**", investigates a way to capture phosphorous from agricultural tile drainage prior to entering ditches and tributaries.

Figure 1 Austin Bartos, student intern at the Lake Erie Center, the University of Toledo, setting up his nutrient interceptor.

Harmful Algal Blooms in Lake Erie appear closely linked to agricultural nutrients, specifically nitrogen (N) and soluble phosphorus (SP) within agricultural tile drainage. Dr. Dwyer's students investigated local and cheaply sourced materials that may be used in a simple nutrient interceptor for tile drainage, including zebra mussel shells, quarry-derived limestone and water treatment plant residuals. Water treatment plant residuals showed the fastest sorption capacity in batch experiments and therefore were chosen for flow through trials. In 300-minute trials, water treatment plant residuals allowed for continuous removal of phosphorous (Figure 1) and a 10 – 15% reduction in phosphorous levels (Figure 2).

<u>Researcher Profile:</u> Dr. Daryl Dwyer's research objectives encompass modeling and understanding the interactions of soil, water, and plants and restoring converted or degraded sites to native habitat with sustainable design as a remediation goal.

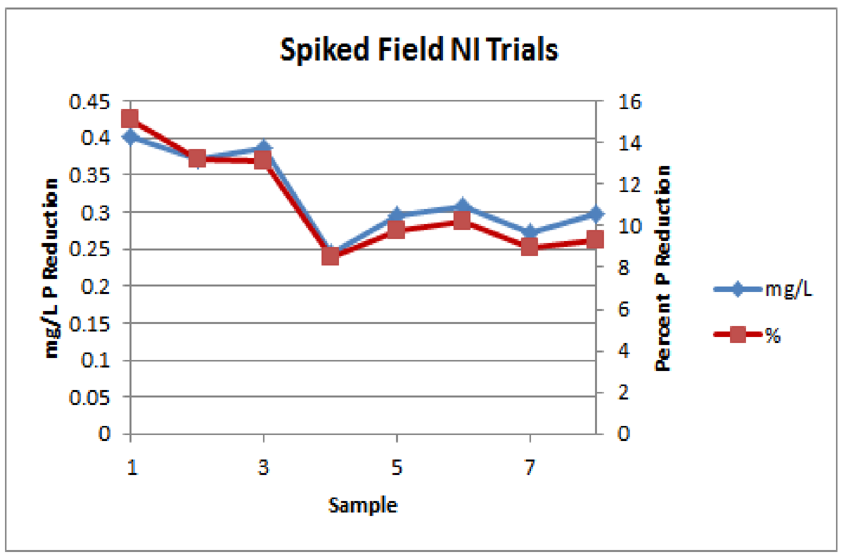
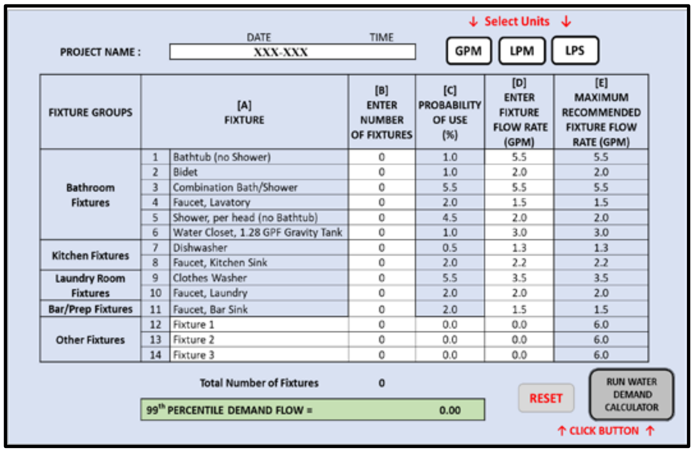


Figure 2 Average reduction of phosphorus (mg/L; red line) and average percent reduction of phosphorus (%; blue line) of spiked tile drainage water (2.5 mg P/L) calculated for each effluent sample for the nutrient interceptor trials.

Dr. Steven Buchberger, Professor and Head of the Department of Civil Engineering, Architectural Engineering, and Construction Management at the University of Cincinnati completed an Ohio Water Resources Center funded project via Ohio Water Development sub-award. The project, **"Improved Estimates of Peak Water Demand in Buildings: Implications for Water-Energy Savings"**, aims to quantify water and energy savings resulting from hot water use in residential plumbing systems serving households with efficient fixtures. A key step in the analysis involved development and application of a novel Water Demand Calculator (WDC, see Figure 1) by graduate student Toritseju Omaghomi.



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PROJECT NAME : DATE XXX-XXX TIME

GPM LPM LPS

FIXTURE GROUPS		[A] FIXTURE	[B] ENTER NUMBER OF FIXTURES	[C] PROBABILITY OF USE (%)	[D] ENTER FIXTURE FLOW RATE (GPM)	[E] MAXIMUM RECOMMENDED FIXTURE FLOW RATE (GPM)
Bathroom Fixtures	1	Bathtub (no Shower)	0	1.0	5.5	5.5
	2	Bidet	0	1.0	2.0	2.0
	3	Combination Bath/Shower	0	5.5	5.5	5.5
	4	Faucet, Lavatory	0	2.0	1.5	1.5
	5	Shower, per head (no Bathtub)	0	4.5	2.0	2.0
	6	Water Closet, 1.28 GPF Gravity Tank	0	1.0	3.0	3.0
Kitchen Fixtures	7	Dishwasher	0	0.5	1.3	1.3
	8	Faucet, Kitchen Sink	0	2.0	2.2	2.2
Laundry Room Fixtures	9	Clothes Washer	0	5.5	3.5	3.5
	10	Faucet, Laundry	0	2.0	2.0	2.0
Bar/Prep Fixtures	11	Faucet, Bar Sink	0	2.0	1.5	1.5
Other Fixtures	12	Fixture 1	0	0.0	0.0	6.0
	13	Fixture 2	0	0.0	0.0	6.0
	14	Fixture 3	0	0.0	0.0	6.0

Total Number of Fixtures 0

99th PERCENTILE DEMAND FLOW = 0.00

RESET

RUN WATER DEMAND CALCULATOR

↑ CLICK BUTTON ↑

Figure 1 Input Template for Water Demand Calculator

An estimate of peak water demand is the most crucial factor for sizing a building's water distribution system. Hunter's design curve has been used for this estimation since 1940. However, with changes in fixture performance and consumer water use habits over time, Hunter's iconic design curve significantly over-estimates peak water demand for indoor hot and cold-water uses. Buchberger and Omaghomi compared peak water demand in a 2-bath home and the resulting pipe sizes from the WDC against the traditional Hunter's curve. They simulated instantaneous indoor hot water use and evaluated the energy delivered and lost within the household distribution system for a one-year operating period. Results show that premise plumbing systems with efficient water fixtures can be substantially smaller in scale (i.e., reduced pipe diameters, meters, heaters, softeners) than the plumbing systems serving standard less efficient water fixtures. Simulation of instantaneous water and energy consumption in a typical 2-bath residential unit shows that annual savings for both water and energy can approach 30 percent each when rightly-sized plumbing is coupled with efficient fixtures (Figure 2).

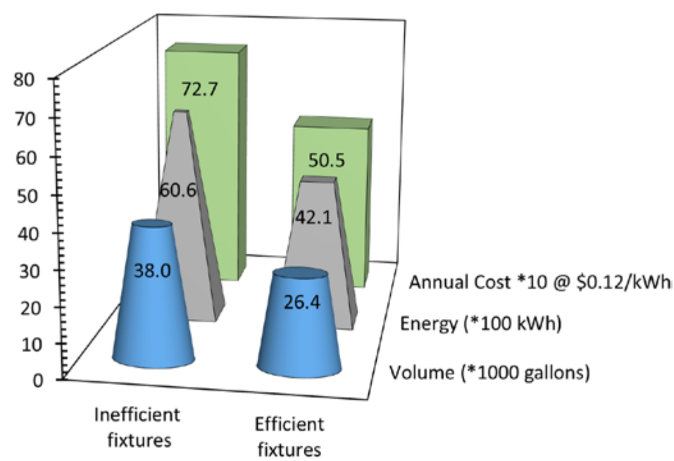

Figure 2 Annual hot water volume, energy consumed and energy cost in a 2-bath home with inefficient and efficient water fixtures

The overriding importance of this project is the verification that reduced pipe sizes provide safe, sustainable and efficient premise plumbing to complement water conservation and promote energy savings in modern buildings. It is expected that results from the new approach of estimating peak water demand will lead to significant water and energy savings without loss of performance in the water delivery system. The WDC has been incorporated into the 2018 Uniform Plumbing Code. The WDC app is available free of charge from IAPMO: http://www.iapmo.org/Pages/WaterDemandCalculator.aspx

Researcher Profile: Professor Buchberger's teaching interests include surface water hydrology and reliability-based design. His research interests include mathematical modeling of water demands and water quality in municipal distribution systems; estimating peak water demands in buildings; characterization and control of nonpoint pollutants; water and energy management for sustainable urban environments.

Dr. Gil Bohrer, Professor at the Department of Civil, Environmental and Geodetic Engineering at the Ohio State University completed an Ohio Water Resources Center funded project via USGS 104(b) and OEE subaward. This project titled **"Baseline measurements of methane emissions from Piedmond Lake - current and future fracking area"** aimed to provide baseline measurements of methane emissions from natural and agricultural aquatic ecosystems around the proposed locations of a hydrofracking site. These observations allow for development of an empirical model for the natural methane emissions from the water system at the site and will allow determining whether these emissions increase due to diffused methane release into the ground water after the drilling operations started.

Figure 1 Installation of flux tower on proposed hydrofracking site

Methane is an important green house gas that affects the global climate. A large uncertainty surrounds both the quantity and mechanisms of natural methane emissions from lakes and wetlands, and fugitive methane emissions during hydrofracking. Therefore, there is a strong need for baseline observations of the natural emissions, which will be used to distinguish those from additional emissions, if present, related to fracking. There are several hypothetical sources and pathways for fugitive methane emissions during the hydrofracking process. One possible and understudied pathway for fugitive methane emissions is methane that is diffusively emitted from soil and waters surrounding the shale development sites. We conducted methane chamber measurements and flux tower measurements on an alternative site due to the original site unavailability (Figure 1). This site started fracking few months after we started baseline measurements and analysis. Our preliminary results showed that the grass field produces no methane, although some very low rate of methane oxidation occur in the soil. As expected, some methane emission occurred from the river (Figure 2). Nonetheless, the emissions from the river were very low. For example, they are about two orders of magnitude lower than emissions we typically observe in natural wetlands. Measurements on this site will continue on NSF funded project to comprehensively quantify methane emissions.

<u>Researcher Profile:</u> Dr. Gil Bohrer develops and uses physical and empirical models of the interactions between individual, biological organisms and atmospheric and hydrological processes.

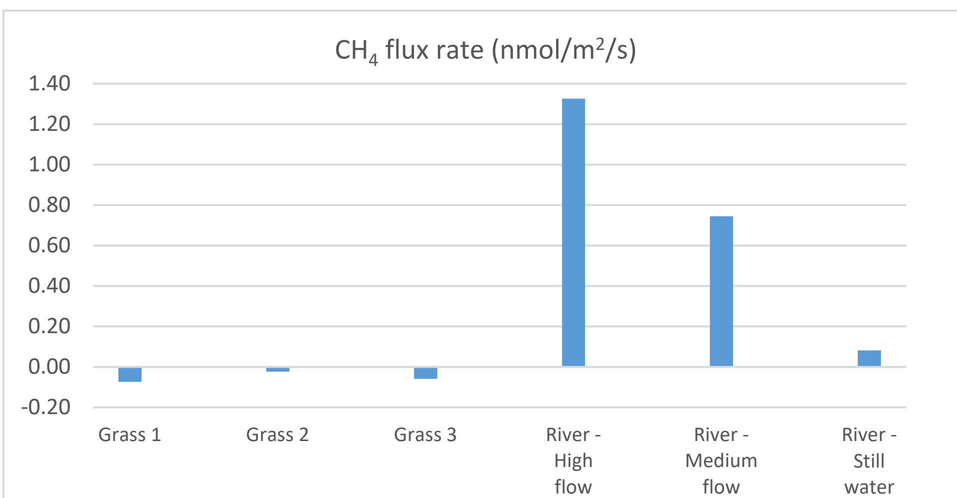

Figure 2 Methane fluxes from grass field and river near flux tower location and fracking site. All measurement are done in duplicate and site locations in triplicate

Dr. Audrey Sawyer, Assistant Professor in the School of Earth Sciences at The Ohio State University completed an Ohio Water Resources center funded project through the USGS 104(b) subaward. The project, "**Quantifying direct groundwater discharge to Lake Erie and vulnerability to hidden nutrient loads**," examined the contributions of dissolved nutrients in groundwater to nutrient loading in Lake Erie. Produced maps of direct groundwater discharge rates and identified coastal areas that are vulnerable to groundwater-borne nutrient loads can be used as a tool for implementation of low-coastal development strategies.

Harmful algal blooms (HABs) have proliferated in Lake Erie and are proving to be one of the largest environmental challenges. The discharge rates of streams and rivers into lakes are easily measured, and the concentration of nutrients can be quantified. However, groundwater, which seeps from the lakebed over broad areas, also contains dissolved nutrients and is a more difficult source to measure. Dr. Sawyer used a combination of geospatial analysis (water budget method) and field measurement (Figure 1) of groundwater seepage rates and nutrient concentrations to identify coastal areas that are vulnerable to nutrient inputs from groundwater.

Figure 1 A student captures groundwater in bags using seepage meters along Lake Erie's coast.

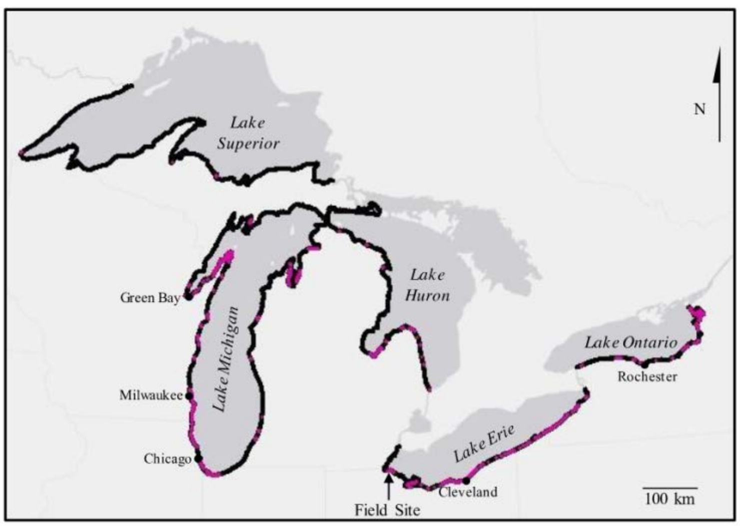

Figure 2 Vulnerability of Great Lakes to contaminant inputs from ground water. Bright color represent vulnerable areas.

The principle findings of this study show that 43% of the U.S. Great Lakes' coast is vulnerable to groundwater-borne nutrients and Lake Erie has the greatest fraction of vulnerable shoreline (Figure 2). Furthermore, lakebed sediments are a source of dissolved phosphorous at discharge zones and some nitrate removal occurs along groundwater flow paths prior to discharge.

The map developed during this research project is freely available and may help tailor strategies aimed toward reducing nutrient loading in Lake Erie and other lake systems.

To access map data, go to https://zenodo.org/record/1011074#.W4hb585KiUk.

Researcher profile. Dr. Audrey Sawyer is a hydrogeologist focused on two themes: 1. Understanding interactions between surface water and groundwater in streams, rivers, estuaries, and coasts, and 2. Determining hydrologic controls on the movement of nutrients, contaminants, and heat in watersheds.

Figure 1 MS student Brindha Murugesan (University of Cincinnati) is optimizing a bench-scale membrane bioreactor system with the carbon nanotube composite membrane.

Dr. Soryong Chae, Assistant Professor at the Department of Chemical and Environmental Engineering at the University of Cincinnati completed an Ohio Water Resources Center funded project via OWDA subaward. This project titled **“Design of a self-cleaning membrane-assisted bioreactor for enhanced removal of nutrients from wastewater”** aims to fabricate a self-cleaning membrane for the efficient use in wastewater treatment.

Due to the continuously increasing occurrence of HABs in Ohio’s lakes and rivers and the inefficient or impractical technologies for the elimination of nutrients, there is a critical need to develop an effective solution for a satisfactory removal of nutrients from wastewater sources in order to achieve clean and safe drinking water supplies and protect human health. Dr, Chae and students build a bench-scale membrane bioreactor (MBR) with self-cleaning carbon nanotube (CNT) membrane (Figure 1). They fed the MBR with synthetic wastewater to investigate organic compounds, total nitrogen and total phosphorous removal and evaluate the membrane durability and fouling potential when heating is used for membrane cleaning. Typical removal efficiencies of chemical oxygen demand, total nitrogen, and total phosphorus by the MBR during 60 days of operation were 95~96%, 83~84%, and 63~65%, respectively. As shown in Figure 2, the CNT composite membrane was able to treat wastewater for 9-10 days without cleaning, while a commercial polytetrafluoroethylene (PTFE) membrane in the same setting could be operated only for 6-7 days before cleaning/replacement. Furthermore, the membrane was effectively recovered from fouling using electric heating. During this period, any physical damage of the CNT composite membrane was not found by the electric heating. The results allow for development of novel engineering solutions for the mitigation of membrane fouling and/or recovery from membrane fouling that eventually increase performance of MBR systems and also reduce HABs’ risks to public health and the environment.

<u>Researcher Profile:</u> Dr. Soryong Chae received his Ph.D. from Korea Advanced Institute of Science and Technology (KAIST) in 2004 and he pioneered research in the application of nanotechnology for membrane, water and energy. His research interest includes environmental implications and applications of engineered nanomaterials; membrane technology for drinking water production; and MBR for municipal and industrial wastewater recycling.

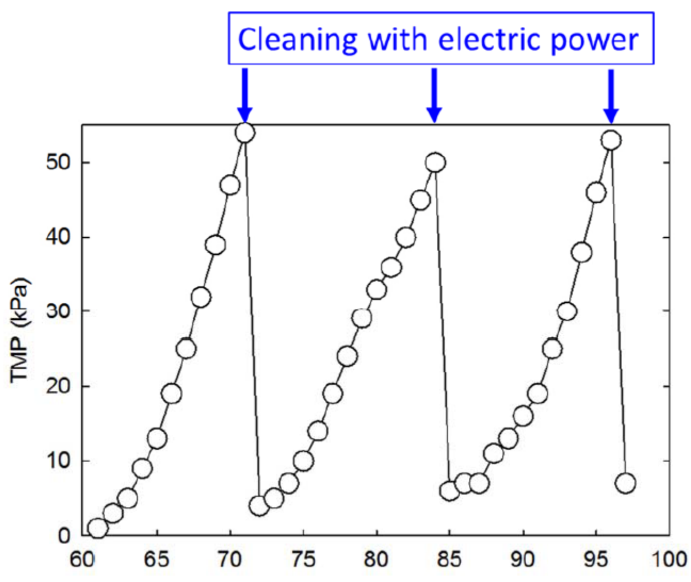

Figure 2 Changes in carbon nanotube membrane fouling (transmembrane pressure) during the experimental period.

Dr. Elizabeth Herndon, Assistant Professor in the Department of Geology at Kent State University completed an Ohio Water Resources center funded project through the Ohio Water Development Authority subaward. The project, "**Concentration-discharge behavior of dissolved and particulate metals in a mining impacted stream**," examined metal dynamics in the Huff Run watershed, an AMD-impacted watershed in northeast Ohio. Evaluating the relationship between discharge and metal transport at Huff Run will enable responsible parties to assess the long-term economic benefits and viability of stream restoration projects.

The HR25 tributary in the Huff Run Watershed is relatively pristine above a beaver dam (the grassy area in the middle of the photo) but receives inputs of AMD-contaminated water below the beaver dam (left of photo).

Acid mine drainage is a common cause of water impairment in eastern Ohio and the Appalachian coal region. Huff Run watershed is an example of an area with reduced water quality due to AMD (photo left). Oxic limestone treatment has decreased some of the stream acidity, but parts the stream stay impaired. Dr. Herndon and her students installed velocity meter on small tributary to Huff Run and collected water samples during the storms and dry weather to evaluate dissolved and particulate metals and other anions. They determined that limestone constructed treatment system can act as ephemeral tributary to the stream and control concentration discharge behavior at the stream outlet. Overall, the treatment system effectively neutralized acidity and reduced contaminant loads in the tributary, but only under high flow conditions. In the stream, the base cations and sulfate behaved chemostatically when exiting the catchment while AMD-derived metals (Fe, Mn, Al) showed dilution behavior. Chemostatic behavior was explained by the mixing of chemically similar waters. Particle transport increased at high discharge, possibly due to scouring of iron oxides from the stream bed during high flow conditions (Figure right). This study highlights both the significance of metal speciation with regard to watershed export of contaminants, and flow conditions with regard to treatment design and the necessity to examine the hydrology of the area further to create treatment systems.

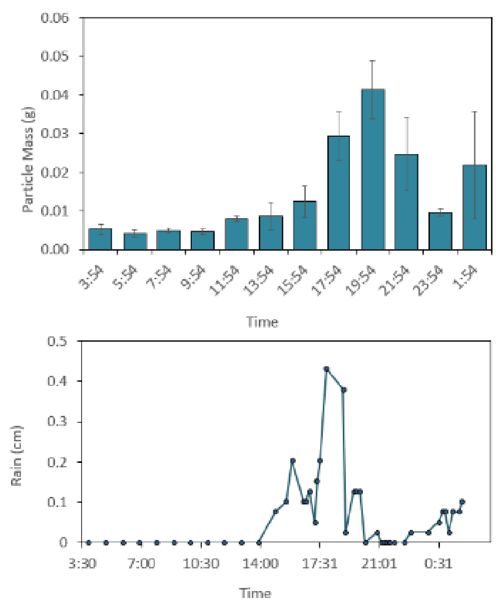

Figure 5. *(top panel)* Particle mass contained within 60 ml of stream water collected once every two hours by the ISCO autosampler and injected into the gravity filtration system. (bottom panel) Rainfall recorded during the storm event.

<u>Researcher profile</u>: Dr. Elizabeth Herndon is an environmental geochemist, with research interests that includes the interaction between minerals, water, and biota with a focus on human perturbation of the environment through changes in land use.