42nd Indiana Water Resources Association Symposium
June 7-9, 2023
Purdue University
"An Isotopic Event: Use of Nuclear Science in Water Resources"

SYMPOSIUM ABSTRACTS

Sponsored by:

Wednesday, June 7, 2023

*Note: * = student presenter*

Time	Topic	Speaker
MODERATOR: Andrew Pappas, Indiana Department of Environmental Management		
1:00	**Opening and Welcome** Water Energy Nexus – Topic introduction	Andrew Pappas, IDEM, 2023 IWRA President; ATPappas@idem.in.gov
1:20	Water and Economic Development: Indiana data and policy gaps and opportunities revealed by the Lebanon LEAP proposed water transfer [INVITED]	Jane Frankenberger, Keith Cherkauer, Purdue University; frankenb@purdue.edu; cherkaue@purdue.edu
2:10	Testing for radionuclides in water and food [INVITED]	Jane Smith, Indiana Department of Health Laboratories; jesmith@health.in.gov
MODERATOR: David Lampe, U.S. Geological Survey		
3:00	Delineating the origin and transport mechanisms of contaminants or compounds of interest in the subsurface using isotopes to determine source and residence time [INVITED]	Myles Moore, U.S. Geological Survey; mtmoore@usgs.gov

Author: Myles T. Moore, U.S. Geological Survey, Ohio-Kentucky-Indiana Water Science Center
Abstract: As businesses and populations expand, there becomes a greater requirement to assess water resources' vulnerability to contamination. When assessing groundwater quality, crucial considerations should be undertaken especially in regions of the U.S. that are dependent on groundwater as a drinking water source. These considerations include assessing if groundwater is potable, and if it is contaminated, then determining the mechanism for the contamination and if other wells could be in danger of future contamination. A powerful tool in assessing groundwater vulnerability is using measurements of boron, strontium, tritium, noble gas abundance and isotopic composition as geochemical tracers. These tracers can be used to determine the residence time of contaminated and unaffected groundwater and the mechanisms and sources of contamination. In addition to describing the methodology in using geochemical tracers for determining groundwater residence time and source, this talk will review a study that determined residence time to source molybdenum (Mo) contamination in groundwater aquifers in southeast Wisconsin. Between 1988 and 2012, there were over 399 different construction projects that used more than 1 million tons of coal combustion reuse (CCR) as fill in Southeast Wisconsin. CCR is the leftover product after

coal has been burned for electrical generation that can contain Mo. Mo can be toxic at high concentrations in drinking water (EPA health advisory of 40 mg/L in drinking water) and has been linked to joint pain, anemia, tremors, and weakness. Concerns of drinking-water contamination due to groundwater migrating through CCR fill led to a field sampling campaign to determine which drinking water wells contained concentrations of Mo and what the age and source of that groundwater was. Results from the study indicated that groundwater with high Mo concentrations was naturally occurring due to water-rock interactions in an older underlying shale unit and that young groundwater (less than 80 years) associated with recent infiltration had lower Mo concentrations.

Another important scientific inquiry that hydrocarbon and noble gas isotopes can address is the source and migration pathways of methane. Methane is a vital resource for electrical generation and is considered a harmful compound regarding global climate change. A large reservoir of methane that the scientific community is working to better understand is gas hydrate. Gas hydrate is icelike substances that trap large volumes of methane in the subsurface and are intrinsically linked to the global carbon cycle. Gas hydrate can only exist within specific pressure and temperature regimes with natural dissociation of hydrate possibly being linked to major climatic events in the past. Therefore, determining the source of methane incorporated in hydrate can provide valuable insight into the mechanisms of hydrate formation. This talk will review a study that recovered pressurized core at in situ subsurface temperature and pressure conditions 424 meters below the sea floor in the Gulf of Mexico to determine the source and hydrogeological processes responsible for methane formation and incorporation into gas hydrate.

3:25	Using iodine-129 (^{129}I) to evaluate a conceptual model of groundwater/surface-water interactions in the Devil's Punch Bowl catchment in Shades State Park (Crawfordsville, IN)	Marty Frisbee, Purdue University; mdfrisbee@purdue.edu

Authors: Marty D. Frisbee[1], Srilani Wickramasinghe[1], Jon Ellingson[1,2], Marc W. Caffee[1,3,4], Greg Chmiel[4]
Affiliations:
[1] Department of Earth, Atmospheric, and Planetary Sciences, Purdue University
[2] Christopher B Burke Engineering, LLC, Indianapolis, IN
[3] Department of Physics and Astronomy, Purdue University
[4] PRIME Lab, Department of Physics and Astronomy, Purdue University
Abstract: Groundwater/surface-water interactions in agricultural and agriculturally-fragmented watersheds are very different than undisturbed watersheds. The hydrogeological behavior of many watersheds in the Midwestern U.S. has been altered by the installation of tile-drain systems and we do not fully understand how tile-drainage systems have impacted groundwater/surface-water interactions. In 2016, a study was undertaken in several small catchments in northern and central Indiana to quantify "background" or natural interactions between groundwater and surface water. One of the catchments, Devil's Punch Bowl (0.44 km2), in Shades State Park, Waveland, IN was chosen for the study because it offered a unique opportunity to see groundwater flow in the geologic units underlying the glacial sediment and some of the same units cropped out in catchments located closer to West Lafayette, IN. The drainage area for the catchment was comprised mostly of forested land adjacent, but it was adjacent to agricultural land. The previous research showed that springs in DPS were discharging groundwater that was recharged in the bomb-pulse era (1950s to 1960s) having mean residence times (MRT) ranging from 40 to greater than 70 years based on chlorofluorocarbons (CFCs) and chlorine-36 (^{36}Cl/Cl). The conceptual model that was developed from the dataset suggested that relatively old groundwater discharged from the deeper sections of the Mansfield Sandstone and through bedding-parallel fractures in the Borden Shale at lower reaches of the catchment. Recently, we interpreted tritium (3H) and iodine-129 (^{129}I) data that was collected contemporaneously with the previous dataset. Tritium residence times in the upper reaches of DPS ranged from 50 to 60 years supporting the previous interpretations. However, mixing models indicated that the residence times of the lower springs emerging from the sandstone/shale contact (Spring 2) and from the bedding-parallel fractures (Seep 2) likely exceed 150 to 200 years. 129I/I ratios of streamflow increase dramatically downstream of Spring 2 and Seep 2 suggesting that there is substantial contact time with old marine organic matter in the bedding-parallel fractures of the Borden Shale. These data provide additional support to the previous conceptual model with respect to the upper reaches of the catchment but also indicate that the fractured shale is capable of transmitting relatively large volumes of older groundwater.

3:45	Water storage, mixing, and fluxes in tile-drained agricultural fields inferred from stable water isotopes	Mark Williams, USDA Agricultural Research Service, National Soil Erosion Research Laboratory; mark.williams2@usda.gov

Authors: Mark R. Williams and Scott J. McAfee
Abstract: Quantifying hydrological processes that control the upper critical zone water balance and contaminant transport in drained landscapes is needed, especially as precipitation patterns driving water balance dynamics continue to shift due to climate change. Here, hydrometric data are integrated with stable isotope signatures to quantify water storage, mixing, and fluxes to subsurface tile drainage at an agricultural field located in Indiana, USA. Over a 2-yr period, precipitation, soil water sampled with suction lysimeters (10–80 cm depth), groundwater (below tile depth; >1 m), and subsurface tile discharge were sampled 97 times. Results showed that isotopic variability in near-surface soil water (10–20 cm) reflected the seasonality of the precipitation input signal, while groundwater values were relatively consistent indicating that water stored below tile drain depth was recharged during winter. Soil water between 20 and 80 cm depth was a mixture of near-surface water and groundwater that varied seasonally depending upon groundwater hydrodynamics. Mean transit time of water ranged from 12 to 20 d for 10-cm soil water to 225–334 d for groundwater, with tile drainage exhibiting a mean transit time of 245 d. Both two- and three-component hydrograph separation indicated that groundwater was the primary source of water to the tile drain followed by soil water. Tile drain hydrograph response (i.e., celerity) was largely controlled by antecedent wetness. Comparison of tile drain celerities and velocities revealed however varying mechanisms controlling hydrograph response across a range of environmental conditions. Data sets of both water and tracer flux were, thus, useful to track the spatiotemporal variability of water fluxes within and from the critical zone. Such data provide valuable information to improve the representation of critical zone processes in these landscapes within spatially distributed hydrological models.

4:05	Remote sensing of water quality of Indiana waterbodies	Andrea Slotke*, Purdue University; aslotke@purdue.edu

Authors: Andrea Slotke [Purdue], Nate Bosch [Grace], Matthew Burlingame [Grace], and Keith Cherkauer [Purdue]
Abstract: In the North-Central United States, thousands of inland lakes and reservoirs provide critical ecosystem services, however, the health of these systems is experiencing increasing environmental and anthropogenic pressures. One major stress on these systems is from harmful algae blooms (HABs), which threaten the use of waterbodies for recreational enjoyment among other uses. Within Indiana, many lakes of similar topography, origin, and surrounding land use experience different severities of algal blooms each year. This study analyzes one subset of these lakes within Kosciusko County, Indiana to provide a quantitative understanding of the mechanisms which influence onset and occurrence of harmful algal blooms. Analysis of water samples, balanced by imagery from satellite remote sensing platforms, are used to quantify the biogeochemical state of these water systems and better understand the mechanisms involved in formation of HABs. This presentation will provide an overview of trends identified in historic water samples and discussion of how this information will be paired with remote sensing imagery to extend the relationship between optical properties and the biogeochemical state of waterbodies throughout Indiana.

Poster Presentations:		
MODERATOR: Laura Esman, Purdue University		
POSTER 1	Algal-bacterial consortia in treatment of fish wastewater and resource recovery of aquaculture water system	Yolanys Aranda Vega*, Purdue University; yaranda@purdue.edu

Authors: Yolanys Aranda-Vega, Karthik B. Shivaram, Pankaj Bhatt, Halis Simsek, Purdue University

Abstract: Aquaculture is a controlled aquatic farming sector and one of the important human food sources. Fish farming is one of the predominant and fast-growing sectors that supply seafood products. Along with the benefits, aquaculture practices can release large quantities of nutrients from poorly treated wastewater into the environment. Nutrients and organic matter released from aquaculture farm effluents affect the ecosystem by creating oxygen depletion and high phosphorus, nitrogen, and ammonia concentrations. In the present study, wastewater collected from a fish farming industry was treated using an algal-bacterial consortium as an alternative to other high-cost wastewater treatment methods. The cyanobacteria and algae species used in the experiments include *Chlorococcum minutum*, *Porphyridium cruentum*, Chlorella vulgaris, Microcystis aeruginosa, *Chlamydomonas reinhardtii*, and *Fischerella muscicola*. As bacterial inoculum, mixed-culture bacteria were used. All the samples were incubated for 21 days, and parameters, including chemical oxygen demand, dissolved inorganic and organic nitrogen species, and phosphate, were measured weekly. The results showed that M. aeruginosa greatly reduced inorganic nitrogen species (>99%). Similarly, *C. reinhardtii* was the most effective at removing COD, DON, and phosphate. The result of the present study suggested that algae-bacterial consortiums are helpful to treat aquaculture wastewater. The algae-bacterial consortium is beneficial to achieve the sustainable environmental goal from the wastewater.

POSTER 2	2D Modeling using diffusion wave transform methods: A pilot study using Wildcat Creek near Kokomo, Indiana	Gillian Gallagher*, Purdue University; gallaghg@purdue.edu

Authors: Merwade, V. Ph.D., Gallagher, G., Dey, S., Purdue University

Abstract: The Indiana Climate Change Impacts Assessment (IN CCIA) is a research effort led by the Purdue Climate Change Research Center (PCCRC). Its primary goal is to quantify and describe the impact of climate change in Indiana. Significant or extreme precipitation intensifies the risk of flooding and related damage. According to a report published by the PCCRC, statewide precipitation is anticipated to increase by 5% by 2100.

Many kinds of software are available for modeling advanced water issues. Hydrologic models, sometimes called rainfall-runoff models, are used to study the behavior of real systems to water fluxes. These simulations can be used for different applications including flood, drought, and watershed studies. Models are an important resource for simulating flooding events and can be used to extract important information such as geospatial files, animations, or maps. Created by the Hydrologic Engineering Center (HEC), HEC-HMS and HEC-RAS offer a variety of different features for creating one-dimensional and two-dimensional models. Although similar, both platforms have subtle differences in setup, availability of features, and visualization techniques.

The city of Kokomo experiences flooding because of its proximity to Wildcat Creek. This study simulates flooding along Wildcat Creek near Kokomo using 2D Diffusion Wave; it is a transform method that pulses excess rainfall across a basin using momentum and continuity equations. As a newer feature in HMS, the accuracy of its output relative to existing diffusion wave features available in the River Analysis System (HEC-RAS) was assessed.

This presentation will discuss the methodology, limitations and results of two-dimensional modeling using HEC-RAS and HEC-HMS diffusion methods. In the context of climate modeling, information will be provided about which approaches are most suitable for characterizing specific simulation events. Further applications of numerical and visual results within sustainable engineering will also be provided using prior historical precipitation events.

POSTER 3	Investigating the impacts of alpine glacier meltwater on mountain groundwater flow processes using environmental isotopes	Ayobami O. Oladapo*, Purdue University; aoladap@purdue.edu

Authors: Ayobami O. Oladapo[1], Marty D. Frisbee[1], and Trinity L. Hamilton[2]
Affiliations:
[1] Dept. of Earth, Atmospheric, and Planetary Sciences, Purdue University
[2] Department of Plant & Microbial Biology and The BioTechnology Institute, University of Minnesota
Abstract: Alpine glaciers are vital sources of freshwater for high-mountain communities and ecosystems globally. Recent work by Miller et al. (2021) shows that glacier meltwater is an essential component of the alpine water cycle, contributing recharge that supports groundwater flow processes in the mountains. In the face of drastic climate change, knowledge of residence times of glacial meltwater in mountain aquifers and response times of these aquifers to loss of glacial ice are critical in evaluating the sustainability of alpine water resources for human communities and ecosystems. However, we lack information on the residence times of the mountain aquifer and the response times of these aquifers to loss of glacial recharge. An important step toward addressing these questions is to identify the rock units that host flow paths and how these flow paths are connected across scales. Therefore, my research is focused on identifying water-bearing units, calculating groundwater residence times, and calculating aquifer response times in Glacier National Park (GNP) and Mount Hood National Forest (MH). In this presentation, I use strontium isotopes ($^{87}Sr/^{86}Sr$) and geochemical tracers to identify the rock units hosting the flow paths, and provide insight into where groundwater is stored in the high mountains.

MH is comprised of mostly young, reworked volcanic rocks. There have been 3 eruptions in the past 2 Ma; thus, there is not much variability in the $^{87}Sr/^{86}Sr$ of springs across spatial scales. In comparison, for GNP, we see that springs are supported by groundwater flow that is hosted in either bedrock, mixed alluvium, and possibly younger volcanic sills. Springs with high $^{87}Sr/^{86}Sr$ ratios represent waters flowing through much older rocks associated with old sedimentary rocks that have been thrust over younger sedimentary rocks. Springs with relatively low $^{87}Sr/^{86}Sr$ represent waters that flow through a young volcanic sill that crosscuts the strata. Finally, springs flowing from the alluvium have $^{87}Sr/^{86}Sr$ ratios that are intermediate between the two other groups. These springs are likely discharging a mixture of recharge sources: modern recharge from precipitation (rain) and snow mixed with glacial recharge. The impacts of alpine meltwater on mountain groundwater flow processes have important implications for global water resource management and conservation efforts. Glacier National Park (GNP) and Mt. Hood (MH) are important mountainous regions that show different responses to climate change since their glaciers are in different states of retreat. GNP glaciers are in advanced stages of retreat compared to Mount Hood glaciers. My future research will be focused on residence times and response times with an overall goal of determining the vulnerability of groundwater in these high mountains to an ice-free future.

POSTER 4	Algal–bacterial consortia to treat high-strength shell egg processing wastewater	Karthik B. Shivaram*, Purdue University; kshivara@purdue.edu

Authors: Karthik B. Shivaram, Pankaj Bhatt, Yolanys Aranda-Vega, Bernard A. Engel, Halis Simsek, Purdue University
Abstract: Egg-washing wastewater contains high amounts of phosphate and organic nitrogen, which could potentially pollute the natural waters when discharged without appropriate treatments. Using phosphate-rich wastewater as a fertilizer in an agricultural field has potential; however, excess irrigation will eventually seep into groundwater and cause contamination. Hence, egg-washing wastewater must be treated properly before being discharged into the environment. Co-cultivation of microalgae and bacteria is becoming an attractive alternative for wastewater treatment due to its cost-effectiveness and potential biomass extraction opportunities. This study has investigated the application of an algal-bacterial consortium to observe the effectiveness of egg-washing wastewater treatment in a laboratory-scale setup. The wastewater treatment was performed using mixed culture bacteria combined with six different pure culture algal strains. The results showed that the treatment method achieved 81.07% of reductions in phosphorous while 67.4% of reductions in total nitrogen concentrations. Algae combined with bacteria is observed to increase the treatment efficiency due to the mutual relationship between algae-bacteria. The findings of this study will be helpful for farmers in designing a cost-effective on-site wastewater treatment plant for egg-washing wastewater treatment.

POSTER 5	A rapid one-step field-based detection method for nanoplastics in wastewater samples	Vidhatri Iyer*, University High School; vid2008mp@gmail.com

Author: Vidhatri L. Iyer, University High School of Indiana, Carmel

Abstract: The widespread use of plastics has raised concerns about their persistence in aquatic and terrestrial environments. Tiny plastic particles, microplastics, and nanoplastics which are generated by degradation cause real environmental problems. Rapid identification of potential hotspots of nanoplastics contamination has been challenging due to lack of field-based detection methods. The purpose of this study was to develop a single-step field-based method to detect nanoplastics in wastewater samples. Using a custom-designed single channel fluorometer, several parameters such as linearity of signal, sample incubation times and effects of sample shaking were optimized using Nile Red dye. A one-step Nile Red based method was successfully developed to detect nanoplastics in filtered wastewater samples within 10 min. The limit of detection of nanoplastics detection was 35 mg/mL. Clarification of treated wastewater samples during the treatment cycle resulted in significant reduction of nanoplastics levels. Nanoplastics load was always higher in influent wastewater samples compared to effluent water when samples were monitored from monthly collections over a 6-month period. This method can be broadly used to monitor nanoplastics levels in different water streams which drain into urban watersheds.

POSTER 6	Barium and sulfur isotope exchange between Barite and 137Ba- and 32S-enriched solutions at Barite solubility equilibrium	McKailey Sabaj, Indiana University and Indiana Geological and Water Survey; msabaj@iu.edu

Author: McKailey Sabaj, Indiana University

Abstract: Chemical reaction rates and isotope fractionation at chemical equilibrium are critical to Earth sciences, but only scant data are available. Because many geological and environmental processes of interest span thousands to millions of years, most geochemical reactions proceed at or near chemical equilibrium. This study uses the state-of-art multiple collector inductively coupled plasma mass spectrometry to analyze non-traditional barium stable isotopes and sulfur isotopes in milliliter-sized samples. The experiments generated a valuable set of isotope data for a total of 165 samples.

The reactions between a natural barite crystal and aqueous solutions at chemical equilibrium were studied with 12 series of laboratory experiments, with the initial solutions doped with barium, sulfur, and oxygen isotopes. The sharp contrast of isotope compositions between barite and aqueous solutions illuminated the continuous attachment and detachment of Ba^{2+} and SO_4^{2-} onto and from barite crystal surfaces, which is otherwise invisible in experiments without isotope doping.

The data showed that (1) the rates of mass transfer between aqueous solutions and barite surfaces are the same for sulfur and barium isotopes, which supports a reaction mechanism of simultaneous detachment and attachment of oppositely charged ions from and to the barite surfaces; (2) barium isotope exchange is reversible; and (3) several stages of reactions occur after barite surfaces are contacted with aqueous solutions. These stages represent different types of reactions and different reactivities of surface functional groups on barite surfaces.
The oxygen isotope analysis was not successful at present, but it can be pursued in the future. More quantitative analysis of the experimental data with molecular level and process-based models can be interpreted in terms of the reaction rates and isotope fractionation.

POSTER 7	Lake Michigan shoreline monitoring, evaluation, and modelling using high resolution multispectral satellite images	Hazem Abdelhady*, Purdue University; abdelhah@purdue.edu

Authors: Hazem U. Abdelhady and Cary D. Troy, Purdue University,

Abstract: Water level fluctuations in Lake Michigan are increasingly frequent, leading to significant alterations along Lake Michigan's coastal areas. Notably, from 2013 to 2020, Lake Michigan experienced a remarkable water level rise of 2 meters, encompassing the entire historical range of water levels. This swift shift in water level resulted in widespread coastal transformations, such as the retreat of shorelines, habitat modifications, erosion of bluffs and dunes, infrastructure and property destruction, coastal flooding, and failures of coastal protection structures.

Hydrological predictions indicate that Lake Michigan will continue to experience more frequent water level extremes in the coming decades, suggesting that similar events of rising water levels and associated shoreline changes are likely to reoccur in the near future.

In this presentation, our focus will be on utilizing high-resolution multispectral satellite images to effectively monitor the fluctuations in Lake Michigan's shoreline. We aim to establish connections between these shoreline changes and various hydrodynamic and morphological factors in order to predict future alterations. To achieve this, we have developed an innovative shoreline detection algorithm that makes use of high-resolution multispectral imagery obtained from satellites like Planetscope and RapidEye. To ensure consistent and highly accurate shoreline detection from the imagery, we have created a fully automated framework. This framework relies on a novel water-land index known as the Direct Difference Water Index (DDWI). Additionally, our model employs a transect-free method that automatically detects shoreline changes and generates a comprehensive time series based on the input satellite images. By utilizing this shoreline time series, we have developed a model that establishes a connection between shoreline changes and variations in water level, wave climate, and sediment characteristics.

POSTER 8	Lake Michigan turbulence mixing: a data-driven approach	Nhu Hoang Van Pham*, Purdue University; pham69@purdue.edu

Authors: Nhu H.V. Pham and Cary D. Troy, Purdue University
Abstract: Lake Michigan is the largest freshwater resource for the state of Indiana with over 45 miles of shoreline, including the Indiana Dunes and several municipal facilities that offer scenic and recreational opportunities for the public. The past few decades have been one of the most dynamic and challenging periods for our coastal communities, from environmental changes such as rising water levels and prolonged extreme weather conditions to invasive benthic filter-feeders (e.g., quagga mussels) that have direct causal effects on the water clarity and the dynamics of the local food web at lower trophic levels. However, it also presents research opportunities for scientists to gain insights on how the lake is responding to these elemental changes and allow us to develop appropriate management plans to protect Lake Michigan's waters and shorelines.

A combination of moored instruments, including acoustic wave and current profiler (AWAC) and buoy deployment, along with meteorological data from local harbors and intermittent microstructure sampling has been utilized to monitor the health and behavior of Indiana-Lake Michigan waters. The data not only serves as a long-term historical record of wind-wave-current-temperature conditions but is also used to forecast seasonal stratification and lake overturning as well as simulating turbulence mixing at varied temporal and spatial scales. Furthermore, using a data-driven approach, we can accurately derive the wind forcing and wave-induced effect of these dynamics and successfully overcome the challenges of representing the Indiana-Lake Michigan nearshore waters in 1-D hydrodynamic models due to its complex nature.

POSTER 9	Estimating water quality parameters in the midwestern reservoirs through radiative transfer theory-guided deep learning	Shuo Chen*, Purdue University; chen4371@purdue.edu

Authors: Shuo Chen, Keith Cherkauer, and Zhi Zhou, Purdue University
Abstract: Environmental and anthropogenic activities are posing increasing pressure on inland water quality in the Midwestern U.S. This has led to increasing interest in improving the assessment of water quality using remote sensing data products. Recent efforts have started to explore the potential for deep learning to improve the prediction of optical active constituents (OACs) in inland waters using remote sensing. Deep learning (DL) models are empirical in nature, which lacks scalability and transferability across a diverse range of real-world reservoir conditions. To achieve accurate retrieval of OAC concentration, DL models usually require massive data for model training. Unfortunately, field sampling is labor-intensive and costly. In contrast, a physical model based on radiative transfer theory (e.g., HydroLight) can be used to retrieve the OAC concentration in a more robust and transferable way. However, the radiative transfer model has weaker predictive performance than DL models since it usually uses simplifying assumptions (e.g., cloud cover, wind speed) about the water body that may not hold in the real world. It is also hard to be applied to large-scale monitoring.

To address the above issues, our research transfer radiative transfer theory into the DL model. Firstly, we carried out 1,000,000 simulations using different concentrations of Chlorophyll-a (Chl-a), non-algal particles (NAP), and colored dissolved organic matter (CDOM) with Hydrolight 6.0 radiative transfer software. This synthetic dataset was used to pre-train a deep learning model to predict these constituents from remote sensing imagery. Then, this pre-trained model was fine-tuned with 213 field samples collected from the Wabash River and the Tippecanoe River in 2014 summer to transfer the knowledge from the physical-based model (Hydrolight) to improve the prediction accuracy for local applications. In this way, a radiative transfer theory-guided neural network was built to predict the concentration of Chl-a, NAP, and CDOM from satellite imagery. If successful this research could improve the transferability of DL models and reduce the amount of field data required for water quality prediction research in the Midwestern U.S.

Thursday, June 8, 2023

Time	Topic	Speaker
MODERATOR: Jane Frankenberger, Purdue University		
8:30	Near proximal and proximal LiDAR mapping for fine-resolution quantification of shoreline regression	Yi-Ting Cheng*, Purdue University; cheng331@purdue.edu

Authors: Raja Manish, Yi-Ting Cheng, Tian Zhao, Hazem Abdelhady, Cary Troy, and Ayman Habib, Purdue University

Abstract: Coastal areas, which are heavily populated, are vulnerable to natural hazards in the form of water level rise, waves, shoreline erosion. Therefore, high temporal and spatial resolution monitoring of these areas is necessary for establishing proper management practices to ensure their resilience against these hazards. For example, the Great Lakes are experiencing high water levels after a 15-year period of low water levels. With the persistently high-water level, storms have much more potential to erode shorelines. A well-developed understanding of complex shoreline movement, i.e., their spatial distribution at local, regional, and national scale, as well as their temporal distribution at event, seasonal, and decadal scales, serves as the foundation for effective coastal management. Remote sensing modalities from satellite and airborne platforms have been used to provide geospatial data of coastal areas. However, the low spatial and/or temporal resolution of acquired geospatial data by these platforms is a limiting factor. In this regard, near proximal and proximal sensing platforms (e.g., Uncrewed Aerial Vehicles – UAVs – and Backpack Systems, Figures 1 and 2) equipped with imaging and ranging modalities are emerging as a promising option for the acquisition of high spatial and temporal geospatial data.

This research provides an overview of multi-year data acquisition campaigns at the shoreline of southern Lake Michigan using both UAV and Backpack systems. A custom-built UAV-based mobile mapping system is used in this study for simultaneously collecting both LiDAR and imagery data. The system consists of a DJI M600 Pro hexa-copter, which carries a laser scanner (Velodyne VLP-32C), a camera (Sony Alpha ILCE-7R), and an integrated GNSS/INS unit (APX-15 UAV V2) for direct georeferencing, as shown in Figure 1. At a flying height of 50 m, the expected horizontal and vertical accuracy values are in the ±5-6 cm range at nadir position. At the edge of the full swath, the horizontal precision is in the ±8-9 cm range, and the vertical precision is in the ±5-6 cm range. Another in-house developed backpack Mobile Mapping System (Backpack MMS) is also used for data acquisition, Figure 2. The Backpack MMS comprises a Velodyne VLP-16 Hi-Res LiDAR and a Sony α7R II 43.6 MP full-frame camera with a 35 mm lens. A Novatel SPAN-CPT GNSS/INS is used for direct georeferencing of the LiDAR and camera. The expected accuracy of the point cloud is ±3 cm at a range of 50 m by considering the specifications of the individual components.

The UAV and Backpack surveys took place at two sandy beaches along the Indiana shoreline of Lake Michigan, USA in 2018, 2019, and 2021. The two beaches are located in the towns of Dune Acres and Beverly Shores, both of which are small, private residential communities. Figure 3 shows the locations and the survey area within the two sites. The research will present the potential of using such systems to evaluate regression of the shoreline through UAV and Backpack surveys of the study area as shown in Figure 4. For example, the ridge points (orange diamonds in Figure 4) were manually identified and their coordinates were recorded. The foredune ridge recession amounts are between 2 m and 9 m over the entire survey period, and between 0 m to 6 m within the storm-induced period (November, 2018 to December, 2018). The total volume of eroded sand within one-year period is 3998.6 m3, equating to an average volume loss of 18.2 cubic meter per meter of beach shoreline (the length of the ROI is 220 m). For the storm-induced period, the volume change is 2673.9 m3, equating to an average volume loss of 12.2 cubic meter per meter of beach shoreline.

Time	Topic	Speaker
8:50	Quantification of Lake Michigan shoreline changes with historical LiDAR imagery	Tasmiah Ahsan*, Purdue University; ahsan3@purdue.edu

Authors: Tasmiah Ahsan and Cary Troy, Purdue University

Abstract: Recent high-water levels in Lake Michigan caused extensive shoreline changes along the Indiana coastline. To evaluate recent shoreline changes of Indiana coastline along Lake Michigan, topographic LiDAR surveys available for the years 2008, 2012, 2013, 2018 and 2022 were analyzed. This study included LiDAR data of over 400 cross-shore transects, generated at 100 meter spacing. Beach profiles were generated to detect the shoreline position and

quantify beach width and nearshore volume change. The analysis revealed accretion of both shoreline and beach width from 2008 to 2012 during low water level period. It was also found that shoreline and beach width receded during the period of water level increase from 2013 to 2018. In response to the water level changes, the shoreline moved with a median of 18m landward exhibiting erosion from 2008 to 2022. The shoreline movement varied spatially between 63m recession to 29m accretion. Similarly beach profiles showed loss of median sand volume of 13.5m3/m. The volume change ranged from 613.5m3/m loss to 296.4m3/m accumulation varying spatially along the shoreline. The bulk loss was experienced downdrift of Michigan city harbor near Mt. Baldy. In addition to the spatial variation, the recession also varied slightly with shoreline type. The natural beaches were mostly recessional whereas buffered beaches, characterized by a swath of vegetation or dune, experienced the least erosion. The results suggest that LiDAR surveys can provide useful information in monitoring beach condition and coastal management.

9:10	Hydrology, geology, and history of Hudson Lake, Indiana	Garth Lindner, IDNR; glindner@dnr.in.gov

Authors: Garth A. Lindner, Kristiana Cox, Glenn Grove, Randy Maier, Indiana Department of Natural Resources, Division of Water, Resource Assessment

Abstract: Hudson Lake is a Public Freshwater Lake with an established Legal Lake Level located in northeast LaPorte County, Indiana. Hudson Lake is a kettle lake with no natural inlet or outlet located at the interface of multiple glacial landforms. The surrounding landscape is composed of non-dendritic, depressional features with highly permeable soils. Due to this landscape setting, lake levels fluctuate on long-term cycles, defined by multi-year to decadal periods of high and low lake levels. Furthermore, preliminary investigations indicate complex groundwater flow paths, with Hudson Lake 1) acting as a flow-through or hinge lake during periods of normal to wet conditions and 2) vertically losing water to deeper subsurface aquifers during periods of dry conditions. The outward flow of groundwater from Hudson Lake is radial in nature, with flow directions partitioned between the Kankakee River Valley and Lake Michigan. Here, we present an overview of the hydrology, geology, and history of Hudson Lake to promote improved understanding and interest of this unique lake system to support long-term management strategies.

9:30	Eco-intensification using recycled drainage water for fertigation	Dongseok Yang*, Purdue University; yang2309@purdue.edu

Authors: Dongseok Yang, Laura C. Bowling, and Keith A. Cherkauer, Purdue University

Abstract: Rainfall has traditionally been sufficient in Indiana and Illinois to support agriculture and replenish groundwater. However, the 2012 drought highlighted sobering limitations of the current infrastructure to address water shortages. Despite increasing annual precipitation, short-term droughts are projected to increase due to shifting seasonality. Farmers are being asked to increase production with fewer inputs, while minimizing downstream impacts. This results in a need to advance insights in terms of climate adaptive practices, such as irrigation and fertigation based on agronomic, hydrologic, and economic research that promotes sustainable intensification of crop production. Practices like drainage water recycling (DWR) and fertigation, using recaptured drainage water to irrigate and fertilize fields, show promise in increasing the efficiency of specific inputs. And practices such as settling ponds or wetlands are well known as efficient non-point source controllers and water storage for agricultural fields which help sustainable agriculture.

The overall goal of this research is to ecologically intensify corn and soybean management using existing isolated agricultural wetlands for storage of drainage water for irrigation and fertigation to maximize crop production and profitability while enhancing nutrient use efficiency and minimizing downstream impacts. This presentation will provide an overview of our field site including the experimental design, infrastructure, sensors and data. And the challenges involved with an assessment of the results of the first full year of operations from in-situ and remote sensing measurements, as well as quantification of water quality, water use and yield for both soybean and corn crops.

9:50	Water quality sampling provides insight into nutrient sources and pathways within the St. Mary's River Watershed	Noah Rudko*, Purdue University; nrudko@purdue.edu

Authors: Noah Rudko[1], Sara McMillan[2], Jane Frankenberger[1], Dani Lay[1], and Mandy Limiac[1]
Affiliations:
[1]Agricultural and Biological Engineering, Purdue University
[2]Agricultural and Biosystems Engineering, Iowa State University
Abstract: Understanding where agricultural nutrients originate in the landscape can help prevent their transport downstream. A monitoring dataset collected at two very similar watersheds in northeastern Indiana provides the opportunity to try and better understand the hydrology and water quality of intensive agricultural watersheds. This dataset was collected from 2017 – 2021 at the Nickelsen and Weber-Gerke HUC12 subswatersheds. Because storm events are responsible for significant nutrient export, automatic samplers were installed that allowed for high frequency nutrient samples throughout a storm. Metrics that quantify the change in nutrients during a storm event, such as the change in concentration on the rising limb of the hydrograph compared to the recession limb and the difference between concentration at peak discharge and baseflow (hysteresis and flushing indices, respectively) can provide valuable information about the sources of nutrients. These storm event metrics together with nutrient grab samples from tiles and agricultural ditches collected throughout the watershed shed insight into how nutrients are transported through typical agricultural watersheds in Indiana. The analysis from this water quality dataset indicates that nutrients have different source areas, while C-Q relationships indicate how much of the constituent is available for transport and identifies at which discharge concentrations begin to increase. These results can be used by watershed managers to understand nutrient delivery mechanisms, their factors driving movement, and also set reasonable expectations for when nutrient concentrations and loads will decrease after practices have been implemented.

MODERATOR: Martha Clark Mettler, Indiana Department of Environmental Management

10:30	Policy: State rule and federal changes that will impact water resources [INVITED]	Drake Abramson, IDEM; DAbramso@idem.IN.gov

Author: Drake Abramson, Indiana Department of Environmental Management
Abstract: Overview of how the legislative process works at the state level and then will touch on three bills that impacted the IDEM Office of Water Quality this session.

10:55	USDA Inflation Reduction Act Funding – The benefits of targeted climate-focused efforts on water quality and quantity	Tony Bailey, USDA, Natural Resources Conservation Service; tony.bailey@in.usda.gov

Author: Tony Bailey, Natural Resources Conservation Service
Abstract: Funding levels will be increasing for conservation practices that target Climate Smart Agriculture and Forestry. These Programs and many of the conservation practices, including those soil health management system practices that sequester carbon and minimize GHG emissions, are also impactful on water quality and quantity. We'll briefly explore these best management practices along with lessons learned plus questions on impacts and improvements to make them work better.

11:20	Impact of various eras of the Great Lakes Water Quality Agreement Act (GLWQA) on Rust Belt manufacturing sustainability	James Tanoos, Purdue Polytechnic Institute; jtanoos@purdue.edu

Author: James J. Tanoos, Purdue Polytechnic Institute
Abstract: The Great Lakes of North America are a vital natural resource for the region. They contain 21% of the earth's entire freshwater supply and 84% of North America's surface fresh water (The 71percent, 2020). Of the 40 million gallons of freshwater consumed daily from the Great Lakes, more than half is utilized for industrial power production (Environmental Law and Policy Center, 2019). However, the region's industrial output has had negative unintended consequences on the Great Lakes, including degraded water quality. This presentation addresses this dilemma by assessing industrial production against water pollution records for this region's American states vis-à-vis various enforcement eras of the Great Lakes Water Agreement Act (GLWQA).

This study used a cross-sectional analysis to assess industrial sustainability related to water pollution resulting from industrial productivity/output in terms of several different GLWQA milestones, utilizing total on-site and off-site disposal or release of chemicals (total pollution) data from the US Environmental Protection Agency's Toxic Release Inventory (EnviroEPA, 2021) and economic data specific to industrial output from the US Bureau of Economic Analysis. Quantitative tests of significance including the Welch Test, f-test, and Mann-Whitney U test show that Rust Belt producers were manufacturing efficiently in terms of water pollution during different GLWQA enforcement eras as compared to non-Rust Belt states.

11:45	Water supply planning as a framework for estimating regional water availability [INVITED]	Jack Wittman, INTERA; jwittman@intera.com
MODERATOR: Mark Basch, Indiana Department of Natural Resources		
1:30	Lessons and discoveries from the Norfolk Southern chemical spill and chemical fires disaster [INVITED]	Paula Coelho* and Andrew Whelton, Purdue University; awhelton@purdue.edu
2:10	Using $\delta^{15}N$ isotopes to disentangle nitrogen sources and processes in the Wabash River, Indiana	Srilani Wickramasinghe*, Purdue University; swickra@purdue.edu

Authors: Wickramasinghe WMS, Frisbee MD, and Michalski G, Purdue University

Abstract: The sources, cycling processes, and dynamics of nitrogen in large watersheds remain incompletely explored. Anthropogenic impacts such as agricultural inputs to large watersheds only adds to the complexity. In this study we attempt to fill the gaps in our understanding on how nitrogen inputs from diverse sources change the water chemistry of large agricultural rivers and how the processes contributing to these nitrogen fluxes change with increasing scale, land-use and land-cover type, and geology using a Midwestern agricultural watershed, namely the Wabash watershed, as a case study. The watershed is largely agricultural, but there are other sources of nitrate which may impact spatial trends in nitrate and overall nitrate export from the watershed. Amidst the growing body of literature on the nitrogen processes of the Wabash, there is still uncertainty in how different sources of nitrogen affect the overall nitrate load of the river. We hypothesize that denitrification in the field-soils of the riparian one may have a more significant role in the consumption of nitrates leading to loss of nitrogen from the system. We use $\delta^{15}N$ and $\delta^{18}O_{NO3}$ data accompanied by solute concentrations and other isotopic data such as $^{36}Cl/Cl$, $^{87}Sr/^{86}Sr$, to quantify nitrogen sources, spatial trends and processes along the Wabash River, and how anthropogenic factors such as land-use, water treatment plants and residential areas impact these processes. We observe a zig-zag pattern of variation in $\delta^{15}N$ and $\delta^{18}O_{NO3}$ and NO_3^{2-} concentrations with increasing distance from the headwaters. Our $\delta^{15}N$ and $\delta^{18}O_{NO3}$ source apportionment biplot identified manure and septic waste as the predominant source of nitrogen in the headwaters and at specific locations downstream. This observation is supported by the presence of poultry and swine farms and wastewater treatment plants in close proximity to the river. Soil nitrogen and nitrates from fertilizers were also nitrogen sources at other sampling sites. We observed a clear denitrification trend indicated by a strong positive relationship between $\delta^{15}N$ and $\delta^{18}O_{NO3}$ ($R^2 = 0.9$) with a O:N fractionation ratio (slope) of 0.7. Having confirmed that denitrification is a critical part of the Wabash River's nitrogen budget we plan to expand our study further to answer the important question: Does denitrification occur in-stream or in the soils of riparian zone? In future work, we aim to improve our understanding of the nitrogen sources and cycling processes within the Wabash River which will help to better regulate nitrogen inputs and contamination of the river waters which is critical to preserve the water quality and health of the river.

2:30	Remediating salt and heavy metal occurrence via desalination	David Warsinger, Purdue University; dwarsing@purdue.edu

Author: David Warsinger, Purdue University

Abstract: Many dissolved ions in our water resources are present in quantities high enough to be hazardous. These include outright toxic heavy metals like arsenic, but also "safe" compounds like NaCl that are often concentrated enough to cause negative impacts on blood pressure and related diseases. To remove small ions, "desalination" technologies are available, but face drawbacks with costs, energy, and brine disposal needs. In this talk, I will give a brief broad background to saline contamination issues in surface and groundwaters, cover basics of salt in solutions, and give a broad introduction to desalination technologies suitable for different regions and salinities. Then I will go into detail about particular solutions my lab has been working on, including batch reverse osmosis variants, and thermal desalination for high salinities.

MODERATOR: Joe Schmees, The Nature Conservancy

3:10	PFAS Sampling of Public Water Systems [INVITED]	Kevin Spindler, IDEM; kspindle@idem.in.gov

Author: Kevin Spindler, Indiana Department of Environmental Management

Abstract: Per- and polyfluoroalkyl substances (PFAS) are a class of synthetic organic chemicals that consist of carbon-fluorine chains of varying length. More than unique 3,000 PFAS compounds have been manufactured since the 1940s. Many PFAS compound have useful chemical properties that have resulted in their use in both industrial and consumer products. Though U.S. production of some of these chemicals has declined, PFAS are highly resistant to degradation, and they have earned the moniker “forever chemicals” for their persistence in the environment. The United States Environmental Protection Agency (U.S. EPA) considers PFAS compounds to be emerging contaminants in the environment.

Beginning in February 2021, the Indiana Department of Environmental Management (IDEM) facilitated PFAS monitoring at all Community Public Water Systems (CWS) throughout the state of Indiana. The purpose of the sampling program is to evaluate the occurrence of 18 common PFAS compounds in CWSs across the state and determine the efficacy of conventional drinking water treatment for PFAS. IDEM partnered with labs (the Indiana Department of Health and Pace Analytical) to distribute PFAS sampling bottles and kits to the operators at the CWSs that have agreed to participate in the program. This project is funded by an Emerging Contaminant grant from the U.S. EPA.

The PFAS sampling project is being implemented in three phases. Phase 1, the sampling of CWSs that serviced between 3,300 and 10,000 people, was completed in 2021. Phase 2, the sampling of systems serving less than 3300 people, was completed at the beginning of 2023. Phase 3 sampling of systems serving more than 10,000 people is currently underway. Samples are collected by the drinking water operator at all raw water (i.e. wells and intakes) and finished (after treatment) water points in a CWS’s supply and shipped overnight to the contract lab.

Sampling results will be shared with the CWSs and posted on the project’s website for public viewing.

3:40	Web-based GIS and source water protection management: A Marion County example	Rachel Walker, Mundell and Assoc.; rwalker@mundellassociates.com

Authors: Rachel Walker and Julie Reyes, Mundell & Associates, Inc.

Abstract: The Marion County Wellfield Education Corporation (MCWEC) is tasked with documenting known and potential groundwater contamination sources within Marion County, Indiana, wellfields and providing that information to stakeholders including utilities, businesses operating in the wellfields and the public. Historically, the information was manually compiled, documentation was arduous and resulted in a static year-end report, which, while still valuable to stakeholders, had many limitations. Over the last three years, MCWEC has migrated to a fully digital approach utilizing ArcGIS online tools to provide interactive web maps and dashboards for utility use and a publicly facing interactive Story Map for disseminating information to the public. This approach allows for the integration of the high-quality GIS data sources available in Indiana and provides for better mapping of potential

contaminant concerns in a way that is more immediately useful to utility planning. The rise of relatively low-cost GIS technology can provide great value for water resource protection and planning, as well as an avenue for communicating with the public.

4:00	A New Springs Online Database at the Indiana Geological and Water Survey	Tracy Branam, IGWS; tbranam@indiana.edu

Authors: Tracy Branam, Benjamin Romlein, and Casey Jones, Indiana Geological and Water Survey
Abstract: Springs have historically been an important source of water for various uses throughout the world. Indiana experienced a period of economic growth related to interest in mineral springs as a source of healing and health maintenance in the late 1800s through the early 1900s. In addition, early pioneer villages were centered around large springs capable of generating sufficient energy to power grist and lumber mills. Many smaller springs were a major factor in where settlers, seeking domestic water supplies for consumption and a means of refrigeration for perishable goods, located their homesteads. While the dependence on springs as a primary source of water for energy and domestic uses has diminished over time due to the development of modern energy-generation technology and an extensive network of public water supplies, springs are still an important natural resource that serve several purposes. Some of the more common uses include tourism, roadside public water sources, domestic water uses, agriculture, recreation, and as a central component of unique ecosystems.

Because of the continued and growing interest in spring water, the Indiana Geological and Water Survey (IGWS) has recently collected data for more than 100 perennial springs in the Uplands region of south-central and southern Indiana through funding provided by the Indiana University Center for Rural Engagement. The primary purpose has been to build an online, searchable database of springs in Indiana. The data collected include field chemistry, flow estimates, anion and cation chemistry, selected trace elements, coliform bacteria screening, and some stable isotope values for oxygen, deuterium, sulfate-sulfur, and dissolved inorganic carbon. Data were loaded into an enterprise geodatabase, which allows for existing records to be updated as well as new records added. This database powers a web-based front-end application where users can search and filter data (both textually with forms and drop-downs, and spatially with a map) to learn more about the springs near them. The application also directs users to a Survey123 form where they can submit the location of a spring and request a field check from IGWS researchers. If it is a previously unrecorded spring, it will be added to the database and could be included in future measurements and studies. As time and interest allow, researchers plan to regularly monitor water quality and chemistry, the measurements of which will be added to the database to create a growing and dynamic resource for researchers and the community.

A brief demonstration of the application will be presented along with examples of how the data can be used to help interpret spatial and chemical relationships for this data set using maps, cluster analyses, and Durov diagrams.

4:20	Beach rebuilding period buffers Indiana beach erosion in Lake Michigan	Cary Troy, Purdue University; troy@purdue.edu

Authors: Ben Nelson-Mercer, Hannah Tomkins, Tasmiah Ahsan, and Cary Troy, Purdue University
Abstract: Recent high water levels in the Laurentian Great Lakes caused widespread shoreline damage to beaches, homes, and coastal infrastructure. To quantify these recent shoreline changes and place them in historical context, historical shoreline imagery was analyzed to determine the magnitude, rates, and spatial variability of shoreline changes along the Indiana shoreline of Lake Michigan. The analysis shows that over the recent period of water level increase from 2013 – 2020, during which the water level rose nearly 2 m, the median shoreline recession along the Indiana coastline was 57.8m +- 17.8m. This recent shoreline recession was highly variable spatially, but not strongly correlated with shoreline type or position relative to littoral barriers. Comparisons with other historical high water years and periods of water level increase show that while the recent shoreline erosion was large, it was consistent with previous recession rates. Analysis of water level records and available wave hindcasts for the coastline suggest that while large, the erosion associated with the recent water level increase was tempered by a prolonged beach rebuilding period of low water levels and waves that resulted in an accreted shoreline that largely buffered the water level increase. The results suggest that future Indiana coastal planners should be cautious given the uncertainty in future lake levels.