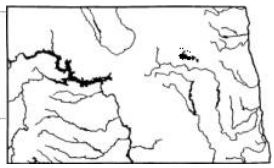
2019-2020

North Dakota Water Resources Research Institute

North Dakota State University, Fargo, ND 58108-6050



Newsletter

The National Institutes for Water Resources

https://www.ndsu.edu/wrri/

From the Director

Welcome to the 2019-2020 issue of North Dakota Water Resources Research Institute (NDWRRI) Newsletter. This newsletter introduces the nineteen 2020-2021 NDWRRI Fellows and highlights the 2019-2020 graduate fellowship research projects and the related findings and accomplishments achieved by the Fellows and their advisors. This issue features two Institute affiliated faculty in the section of "Meet Our Faculty," including Dr. Aaron Daigh (Department of Soil Science, North Dakota State University) and Dr. Benjamin Laabs (Department of Geosciences, North Dakota State University). Other sections include the information on the awards the Institute Fellows received and an introduction to the three members of the NDWRRI State Advisory Committee. The last section lists the recent publications and presentations by the Institute Fellows and their advisors, the Fellows' theses and dissertations, as well as the recent USGS ND-related publications and the ND State Water Commission reports and publications.

As the Director of the Institute, I would like to gratefully acknowledge the supplemental support for the graduate research fellowship program from the ND State Water Commission, in addition to the federal 104b funds. I also would like to take this opportunity to thank Steve Robinson for serving on the State Advisory Committee and also for his great support for the Institute and our students and faculty at NDSU and UND. Due to Steve's retirement, Joel Galloway, Hydrologic Studies Chief for the USGS Dakota Water Science Center, has taken over the position as a committee member from the USGS. The Institute has continuously received advice and support from the State Advisory Committee consisting of Joel Galloway (USGS Dakota Water Science Center), Andrew Nygren (ND State Water Commission), and Peter Wax (ND Department of Environmental Quality). Their guidance on the Institute's research priorities and graduate research fellowship program contributes to the success of the Institute.

Due to the COVID-19 pandemic, many Institute-funded research activities have been affected. Particularly, many faculty and graduate students have to postpone their research due to the restrictions of access to the essential research facilities and field sites. It has been challenging to conduct research online. To practice social distancing, some planned activities (e.g., conferences and seminars) have also been delayed or cancelled. The extension of both federal and state funds gave us more time to cope with this special situation. I would like to thank all Fellows and their advisors for their efforts in the funded research projects and their contributions to the Institute during the pandemic period.

Stay safe and healthy.

Xuefeng (Michael) Chu, Ph.D.
Professor, Civil & Environmental Engineering

Inside this issue:

The Institute Awarded Nineteen Graduate Fellowships for Year 2020-2021

The North Dakota Water Resources Research Institute announced its Graduate Research Fellowship recipients for the year 2020-2021. The fellowships were awarded to nineteen graduate students, including fourteen Ph.D. and five M.S. students, who will conduct water resources research at NDSU and UND. These nineteen graduate research projects are supported with the annual base (104b) federal grant, and an additional fund from North Dakota State Water Commission. The 2020-2021 NDWRRI Fellows, and their faculty advisors, academic programs, and research projects are listed as follows:

Fellow: Alicia Schlarb (M.S. student) **Advisor:** Dr. Matthew Smith
Program: Biological Sciences, North Dakota State University
Title: The ecotoxicological effects of saline water characteristics on amphibian survival and development

Fellow: Berkay Koyuncu (Ph.D. student) **Advisor:** Dr. Trung Bao Le
Program: Civil & Environmental Engineering, North Dakota State University
Title: Flood and Bathymetry Alteration Simulations Under Ice-Coverage in Red River

Fellow: Christine Cornish (Ph.D. student) **Advisor:** Dr. Jon Sweetman
Program: Biological Sciences/Environmental & Conservation Sciences, North Dakota State University
Title: Does wetland restoration affect the accumulation of glyphosate?

Fellow: Justin Waraniak (Ph.D. student) **Advisor:** Dr. Craig Stockwell
Program: Biological Sciences/Environmental & Conservation Sciences, North Dakota State University
Title: Assessment of agricultural impact on biotic components of North Dakota wetland resources using habitat suitability landscape genomics of amphibians

Fellow: Karthik Boregowda (Ph.D. student) **Advisor:** Dr. Yeo Howe Lim
Program: Civil Engineering, University of North Dakota
Title: Rejuvenation of Urban Streams in Cold Climate Regions Using Hydroponic Systems: A Case Study on English Coulee in Grand Forks, North Dakota

Fellow: Kristen Almen (M.S. student) **Advisor:** Dr. Xinhua Jia
Program: Agricultural & Biosystems Engineering/Environmental & Conservation Science, North Dakota State University
Title: Impact of Subsurface Drainage and Subirrigation on Water Quality in Richland County, North Dakota

Fellow: Kui Hu (Ph.D. student) **Advisor:** Dr. Jon Sweetman
Program: Biological Sciences/Environmental & Conservation Sciences, North Dakota State University
Title: Understanding intra-lake seasonal and spatial variability in shallow prairie lake diatom communities: implications for paleolimnological studies

Fellow: Lan Zeng (Ph.D. student) **Advisor:** Dr. Xuefeng Chu
Program: Civil & Environmental Engineering, North Dakota State University
Title: Development of a new depression-oriented watershed hydrologic model and its application in North Dakota

Fellow: Pavankumar Challa Sasi (Ph.D. student) **Advisor:** Dr. Feng "Frank" Xiao
Program: Civil Engineering, University of North Dakota
Title: Effectively and Practically Remove Per- and Polyfluoroalkyl Substances from Landfill Leachate and Groundwater

Fellow: Rebecca Jones-Bradley (M.S. student) **Advisor:** Dr. Matthew Smith
Program: Biological Sciences, North Dakota State University
Title: Influence of habitat characteristics on amphibian stress and reproductive success in North Dakota

Fellow: Stevie Holmes (Ph.D. student) **Advisor:** Dr. Taufique Mahmood
Program: Geology & Geological Engineering, University of North Dakota
Title: Hydrological Changes Due to Recent Wetting in a Cold Region Riverine Headwaters Environment

Fellow: Swetha Mallula (Ph.D. student) **Advisor:** Dr. Feng "Frank" Xiao
Program: Civil Engineering, University of North Dakota
Title: Soil Amendment for Reducing the Runoff of Nutrients from Agricultural Lands

The Institute Awarded Nineteen Graduate Fellowships for Year 2020-2021

Fellow: Tong Lin (Ph.D. student) **Advisor:** Dr. Zhulu Lin
Program: Agricultural & Biosystems Engineering/Environmental & Conservation Sciences, North Dakota State University
Title: Using Coupled Human and Natural Systems for Water Resources Management in the Bakken Region of Western North Dakota

Fellow: Tonoy K Das (Ph.D. student) **Advisor:** Dr. Achintya Bezbaruah
Program: Civil & Environmental Engineering/Environmental & Conservation Sciences, North Dakota State University
Title: Fabrication of Point of Use Treatment Systems for Aqueous Arsenic and their Evaluation

Fellow: Uday Bhanu Prakash Vaddevolu (Ph.D. student) **Advisor:** Dr. Xinhua Jia
Program: Agricultural & Biosystems Engineering, North Dakota State University
Title: Automatic sensor-controlled drip irrigation under mulches for tomato and watermelon productions

Fellow: Umesh Acharya (Ph.D. student) **Advisor:** Dr. Aaron Daigh
Program: Soil Science, North Dakota State University
Title: Soil moisture mapping using Landsat data in a frigid glaciolacustrine landscape with agricultural production

Fellow: Vida Atashi (Ph.D. student) **Advisor:** Dr. Yeo Howe Lim
Program: Civil Engineering, University of North Dakota
Title: Hydraulic and hydrologic routing parameters in natural channels in North Dakota under spring snowmelt conditions

Fellow: Zachary Bartsch (M.S. student) **Advisor:** Dr. Thomas DeSutter
Program: Soil Science, North Dakota State University
Title: Imprinting and hydromulch for soil erosion reduction and plant establishment in semi-arid soils disturbed from oil and gas development

Fellow: Zachary Ranisate (M.S. student) **Advisor:** Dr. Feng "Frank" Xiao
Program: Civil Engineering, University of North Dakota
Title: Red Lake River and Red River Raw Water Quality Investigation

2019 — 2020 NDWRRI Fellowship Research Highlights

Understanding Escherichia Coli and water quality in stormwater retention ponds and detention basins as part of the Red River watershed

Erika Olson *(Fellow) &* ***Dr. Christina Hargiss*** *(Advisor), North Dakota State University*

Little is known about the spatial and temporal changes that occur with water quality and E. coli in urban stormwater systems. The goal of this project was to assess urban stormwater detention basins and retention ponds to: determine water quality differences and similarities between the two; assess E. coli levels during storms and normal water flows to see how it moves through the system; and determine genetic sources of the E. coli and pathogens to better understand potential impacts on humans. Surface water quality was sampled at three detention basins and five retention ponds during major storm events in the summers of 2018 and 2019. One week after each storm groundwater and surface water were sampled. Additionally, molecular source tracking samples were taken from storm events and normal flows, for both surface water and groundwater, to determine the genetic source(s) of the E. coli. Results indicate that E. coli quantities are often higher in detention basins than retention ponds, but other water quality parameters are not significantly different between the two. E. coli across all sites was found to be extremely high during storm events, especially if a significant amount of time has passed since the last precipitation event. This research is important to scientists and water managers seeking to understand water quality in urban systems. Special attention should be paid to water quality in urban areas where stormwater ponds are being utilized or retrofitted to meet recreational needs.

2019 — 2020 NDWRRI Fellowship Research Highlights

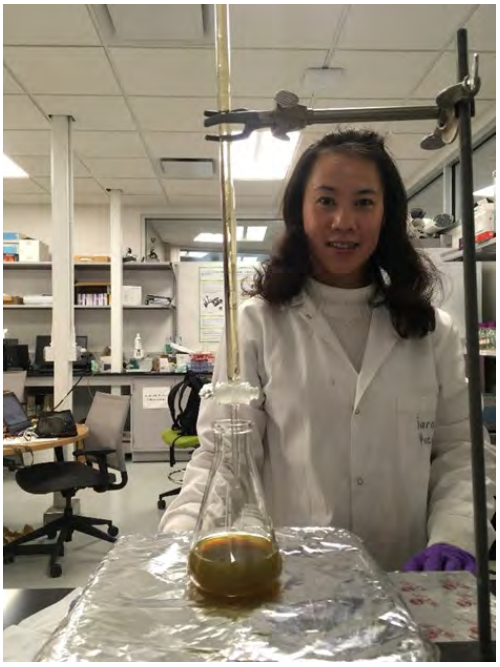
Effect of Different Water Table Levels on Canola Growth and Quality Parameters

Hakan Kadioglu *(Fellow) &* ***Dr. Halis Simsek*** *(Advisor), North Dakota State University*

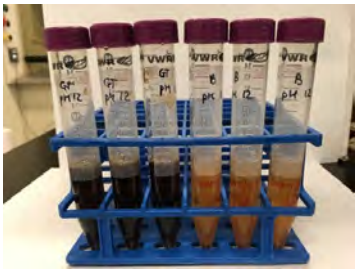
Groundwater is an important natural water source in North Dakota (ND) that is used for domestic, agricultural, and industrial purposes. About 37% of the irrigation water is supplied by groundwater in ND. Water table rise brings salts to the root zone through capillarity. Water table levels can be managed by using a tile drainage system. Therefore, knowing the optimum water table depth to provide optimum water use efficiency for canola plant (Brassica napus L.) will be an important finding for ND farmers. A lysimeter study is the simplest and tenable way to determine the optimum water use efficiency with high canola yield production. Lysimeter studies were conducted to investigate canola plant water use, growth, and yield parameters under three different water table depths (30, 60, and 90 cm). Additionally, control experiments were conducted and only irrigation was applied to these lysimeters without water table limitation. Results showed that groundwater contributions to canola plant were 97, 71, and 68%, while the average grain yields of canola were 4.5, 5.3, and 6.3 gr for the treatments of 30, 60, and 90 cm water table depths, respectively. These results demonstrated that 90 cm water table depth was the optimum depth for canola plant to produce high yield with the least amount of water utilization. In addition, monitoring the root-mass distribution of canola in the lysimeters for different water table depths provided valuable information for the related research.

Application of Green Iron Nanoparticles Synthesized using Barley Polyphenols to Combat Lake Eutrophication

Hoang Pham *(Fellow) &* ***Dr. Achintya Bezbaruah*** *(Advisor), North Dakota State University*



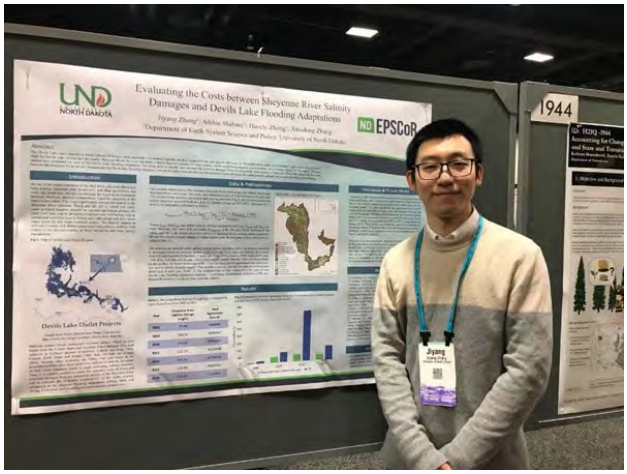
Phosphorus in surface water can be a concern as it leads to unwanted excess plant and algal growth and finally leads to the eutrophication of the waterbodies. Water quality becomes impaired when microorganisms consume dead algae and use dissolved oxygen contents, causing the suffocation of aquatic life. Barley (*Hordeum vulgare*), qualified as a mode plant, is a well-studied plant in terms of genetics, genomics, and breeding. We have developed a green iron nanoparticle (Green FeNPs) using barley extract as a reducing agent. Over 95% of PO_4^{3-}-P/g (5 mg/L) was removed in 60 minutes. The adsorption kinetics is best depicted by the pseudo-second-order reaction with a high correlation coefficient of one. The adsorption isotherm of phosphate on barley-FeNPs fits well with the Freundlich with the maximum adsorption capacity of 18.71 mg/g. This explains the phosphate adsorption onto barley-FeNPs, which is chemical adsorption in nature and happens on heterogeneous surfaces. There is not a significant difference in phosphate removal in different temperatures (10-45^{o}C) and ions (HCO^{3-}, SO_4^{2-}, and NO^{3-}). The kinetics, isotherms, interference, and pH studies showed that adsorption was governed by several mechanisms with various processes dominating different stages of the adsorption. The results indicated that the material had the potential application in removing phosphate phosphorus.



2019 — 2020 NDWRRI Fellowship Research Highlights

Evaluation of the Costs between Devils Lake Flooding Adaptations and Sheyenne River Salinity Damages resulted from Devils Lake Outlet Operations

Jiyang Zhang *(Fellow) &* ***Dr. Haochi Zheng*** *(Advisor), University of North Dakota*



The Devils Lake (DL) outlet projects in North Dakota have been effective in mitigating regional flooding over the past decade. However, with the highly saline water pumped from Devils Lake into the nearby Sheyenne River, the water quality degradation has caused societal concerns in surrounding communities. This study aims to estimate the monetary costs of the increasing water salinity in the Sheyenne River as the consequence of mitigation measures in combating DL flooding. By comparing the costs of the salinity damages in the Sheyenne River and the benefits received from flooding adaptations in DL, we further evaluate the economic trade-offs of the outlet projects and provide insights for future regional policymaking. Using the benefit transfer method, we monetized the potential impact of DL outlets in the middle and lower Sheyenne River subbasins to be ranging from $2,389 to $7,765 per year with every 1 mg/L increase of river salinity. As a tradeoff, reducing the capacity of the outlets to avoid the 1 mg/L increase in the Sheyenne River salinity would have caused an increase of 0.012 ft in the DL's maximum level, which can lead to a cost of $62,796 in protecting the surrounding infrastructures. Thus, our results show that the benefits of the DL outlet project significantly outweigh its costs. While our results support the operations of the Devils Lake outlets, Policymakers should consider population growth and recreational values in future scenarios to better assess the economic trade-offs of the Devils Lake outlet projects.

Assessment Of Agricultural Impact On Biotic Components Of North Dakota Wetland Resources Using Landscape Genomics Of Northern Leopard Frog (Rana Pipiens)

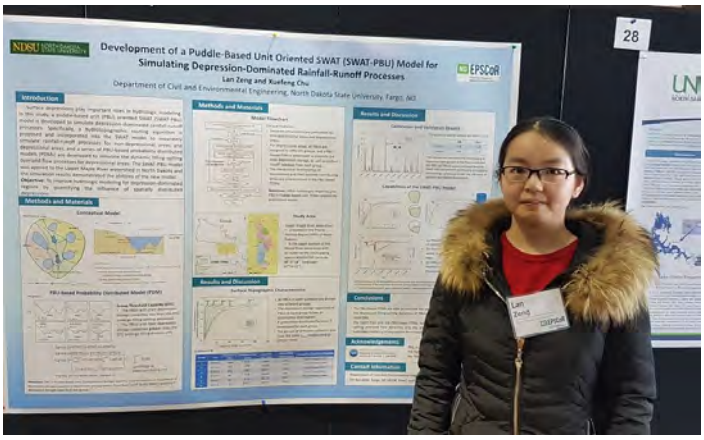
Justin Waraniak *(Fellow) &* ***Dr. Craig Stockwell, Dr. David Mushet*** *(Advisors), North Dakota State University*

We collected northern leopard frogs from 28 samples sites (20 frogs per site) in the Lake Oahe and James River basins for genomic analysis. After quality filtering of genomic data, frogs were genotyped at over 2400 biallelic SNP (single nucleotide polymorphism) loci. Initial analyses indicated that there was no obvious effect of the amount of nearby agriculture on the measures of genetic diversity, as the proportion of land use for cultivated crops in a 5-km buffer around the sample site wetland did not explain a significant amount of variation in estimates of heterozygosity or inbreeding coefficients. However, analyses of genetic connectivity among our sites suggest that agricultural areas may be acting as a barrier to movement for frogs. This analysis suggests that areas of interconnected grassland and wetland are necessary to maintain biological connectivity in the Prairie Pothole ecosystem. Additionally, the habitat suitability models were updated by using the land use data from 2019 and the occurrence of five anuran species was predicted for the study area near Jamestown, ND. Despite the increases in agricultural land use (particularly corn and soybeans) in the study area, several species were expected to expand their range since 2010 due to the increased amount of water on the landscape. Field work should be conducted in the future to test the results of this habitat suitability model.

2019 — 2020 NDWRRI Fellowship Research Highlights

Development of a puddle-based-unit oriented SWAT (SWAT-PBU) model and its application in North Dakota

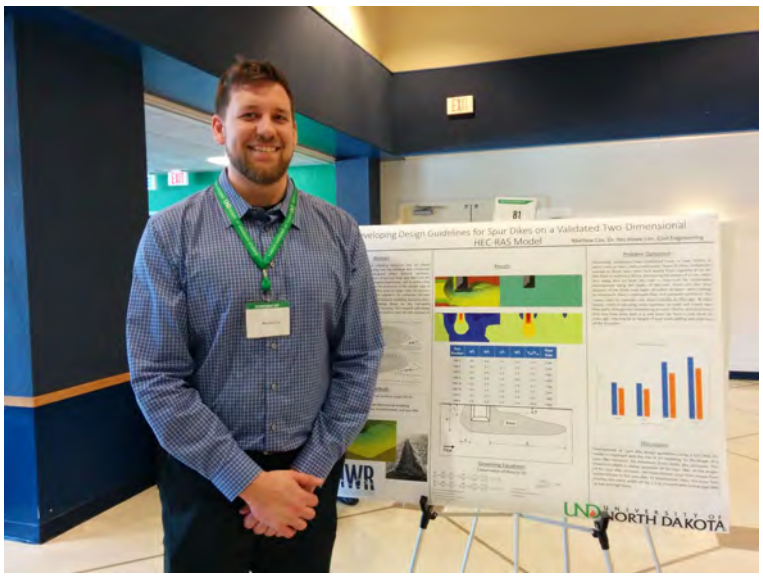
Lan Zeng *(Fellow) &* ***Dr. Xuefeng Chu*** *(Advisor), North Dakota State University*



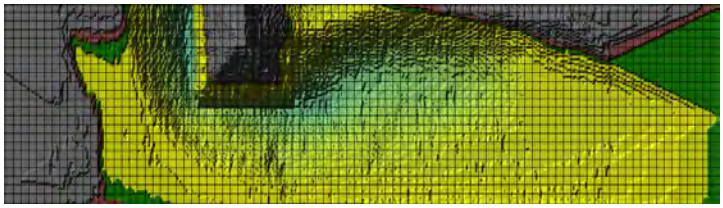
A new puddle-based unit probability distributed model (PBU-PDM) is developed and coupled with the existing Soil and Water Assessment Tool (SWAT) for improved watershed-scale hydrologic modeling in depression-dominated regions. In the PBU-PDM, PBUs are conceptualized as basic modeling units for depressional areas to account for the potential merge of depressions, which avoids underestimating the total maximum depression storage and overestimating surface runoff. The contributing area, depression storage, and surface runoff of depressional areas are simulated by using the probability distribution functions of depression storage capacities. Specifically, the PBU-PDM tracks the filling-spilling process and storage variations of depressions, which facilitates the simulation of variable contributing area and threshold-controlled overland flow dynamics. The PBU-PDM enhanced SWAT was applied to the upper Maple River watershed in the Prairie Pothole Region of North Dakota, and simulation results demonstrated its capability in simulating the depression-controlled surface runoff generation processes. The model also provided the seasonal variations in surface runoff and the probabilities of overflows from depressions. It was found that there was a higher possibility for depressions to be fully filled, generating surface runoff in March - May. The PBU-PDM can be used to evaluate the influences of changing climate and land use and land cover on hydrology. It can also be integrated with other watershed-scale models to improve water quantity and quality modeling, especially in depression-dominated areas.

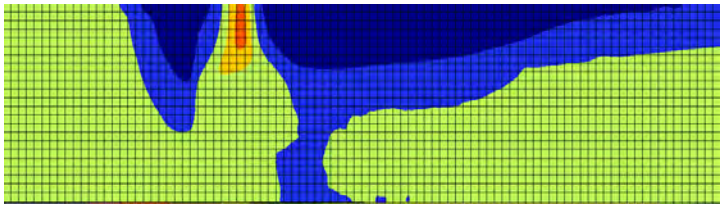
Developing Design Guidelines for Spur Dikes in Curved Trapezoidal Channels based on a Validated Two-Dimensional HEC-RAS Model

Mathew Cox *(Fellow) &* ***Dr. Yeo Howe Lim*** *(Advisor), University of North Dakota*



Spur dikes are commonly used as hydraulic structures to protect erodible bank areas. While spur dikes help protect the riverbank downstream, they change the flow pattern along the centerline of the channel, which can cause erosion and scour in previously stable locations. Historically, downscaled physical models were used to model channel sections for possibility of scour and erosion around hydraulic structures. The increased accuracy and efficiency of two-dimensional numerical models have allowed for numerical computer models to begin to take place of physical models. Numerical models are quicker to setup, simulate, and tweak than physical models. Instead of direct simulation of sediment transport using a numerical model, a relationship of maximum flow velocity, upstream flow velocity, and upstream Froude number was developed in this study to determine maximum scour depth. The developed relationship proved to be more accurate than the past relationships using the data from physical models. Further development of such relationships could allow for scour modeling of additional hydraulic structures.



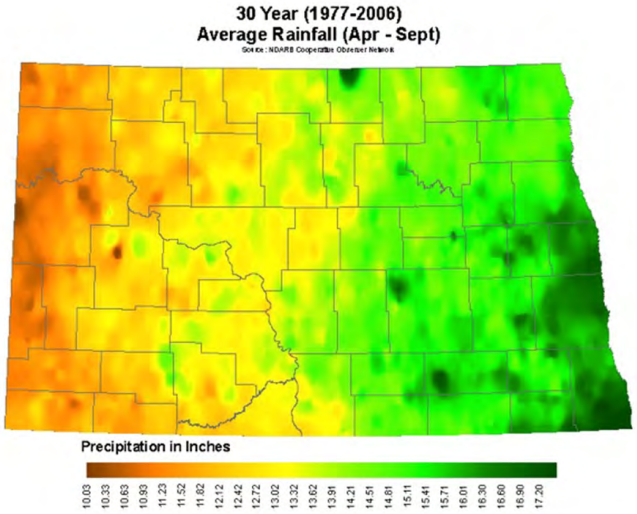


2019 — 2020 NDWRRI Fellowship Research Highlights

Precipitation Evaluation of the North Dakota Cloud Modification Project (NDCMP) using Rain Gauge and Radar Observations

Matt Tuftedal *(Fellow) &* ***Dr. David Delene*** *(Advisor), University of North Dakota*

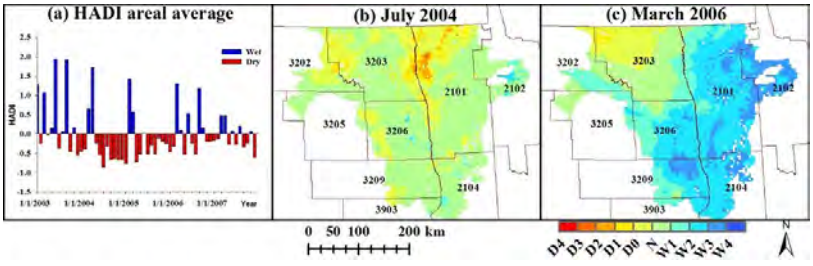
The effectiveness of the North Dakota Cloud Modification Project (NDCMP) at increasing precipitation is evaluated from 1977 through 2018 using rain gauge observations. Monthly and seasonal (June-August) precipitation is averaged to create county-wide target and control area rain amounts. The McKenzie and Bowman operational areas have 7 of 8 double ratios above 1.0 and rainfall increases of up to 12%. Additionally, 2 of the 8 double ratios have a 95% significance of being greater than 1.0. The statistical analysis is constrained by the lack of a robust control due to sparse rain gauge measurements before the start of NDCMP and the lack of a totally independent control area with a similar precipitation pattern. The main conclusion of the research is that even without a carefully designed control, the statistical analysis of 41 years of rain gauge observations indicates that the NDCMP operational weather modification program increases rainfall by up to 12%. With most target/control pairings indicate some rainfall increase, some tests providing 95% confidence in the increase. The software used for data analysis in this project is available at https://sourceforge.net/projects/evaluationofndcmp-tuftedal2019/ and the project's data collection is available in the University of North Dakota Scholarly Commons.



Drought Identification and Prediction in Cold Climate Regions

Mohammad Hadi Bazrkar *(Fellow) &* ***Dr. Xuefeng Chu*** *(Advisor), North Dakota State University*

A new drought identification, categorization, and prediction (DIC-Predict) model was developed. In this model, the hydroclimatic aggregate drought index (HADI) was used. Furthermore, a joint probability distribution function of drought frequencies and classes as well as conditional expectation were used for drought categorization. The new customized drought categorization based on variable threshold levels accounted for the variations in both time and geographical locations. For drought prediction, the non-stationary time series of the selected predictors were divided into stationary time series by using a change point detection technique. Then, the canonical correlation analysis (CCA) was performed to increase the correlation between the predictors and the predictands. Support vector regression was applied on each stationary time series to predict the HADI. The model was applied to the Red River of the North Basin (RRB) and its performance was evaluated by comparing with the Palmer Drought Severity Index (PDSI) and the U.S. Drought Monitor (USDM) products. Based on the impacts of drought on agriculture, the HADI outperformed the PDSI in identification of droughts in the RRB. Although the HADI and USDM showed a good agreement in identification of drought periods, the drought area coverages for each drought category from the two methods differed. The DIC-Predict model is able to provide more accurate drought identification and early warnings of drought development, especially for cold climate regions.



2019 — 2020 NDWRRI Fellowship Research Highlights

Enhanced removal of Poly- and Perfluoroalkyl substances from water

Pavankumar Challa Sasi *(Fellow) &* ***Dr. Feng (Frank) Xiao*** *(Advisor), University of North Dakota*

To get a better understanding of PFAS decomposition, we studied five perfluoroalkyl carboxylic acids (PFCAs) and one perfluoroalkyl ether carboxylic acid (PFECA) in three different conditions (PFAS only, PFAS with GAC, and PFAS adsorbed on GAC) in a closed system. We found that the destabilization of studied compounds during thermal treatment followed the first-order kinetics. The temperature needed for thermally destabilizing PFCAs increased with the number of perfluorinated carbons (nCF2) when PFAS were adsorbed on to GAC. Decomposition of PFCAs such as perfluorooctanoic acid (PFOA) on GAC initiated at temperatures as low as 200 °C. The PFECA was even more readily decomposed than PFCA with the same nCF2. The degradation temperature of PFAS decreased with the presence of GAC and on PFAS laden GAC compared to its absence. In addition to the volatile organofluorine species identified in previous studies, we found evidence for the formation and then decomposition of short-chain compounds during thermal degradation of four PFCAs. Efficient mineralization to fluoride ions (>80%) of PFOA and PFOS on GAC occurred at 700 °C or higher, accompanied by near complete PFOA and PFOS decomposition (>99.9%). Thermal decomposition pathways of PFOA were proposed. We have also identified that ammonium acetate is the most suitable amendment for methanol to achieve higher PFAS extraction efficiencies. Organofluorine and short-chain compounds generated from thermal decomposition of PFAS at low to moderate temperatures (≤600 °C) warrant studies on the exposure to these compounds during cooking, baking, firefighting, and other relevant thermal processes involving PFAS.

Influence of wetland water quality on amphibian stress and reproductive success in Eastern North Dakota

Rebecca Jones/Bradley *(Fellow) &* ***Dr. Matthew Smith*** *(Advisor), North Dakota State University*

As amphibians continue to decline globally, conservation efforts are necessary for the development of future management plans. Understanding the correlation between amphibian presence and various habitat characteristics within North Dakota wetlands is essential for amphibian conservation. Larval and visual encounter surveys were conducted and environmental data were collected in Wildlife Management Areas (WMAs) across the east-central and southeast parts of North Dakota. Water quality measurements of phosphate, nitrate, nitrite, lead, iron, copper, and ammonia were collected from each site, once a month, during the May to July field season. Surveyed WMAs can be separated into two distinct groups: sites with tadpoles present and sites without tadpoles. WMAs with tadpoles present had average (min, max) measurements (mg/l) of: 1 (0, 5) phosphate, 0.26 (0, 8.3) nitrate, 0.01 (0, 4) nitrite, 0.39 (0, 4) copper, 0.13 (0, 0.5) ammonia, 0.16 (0, 1.7) iron, and 2.08 (0, 20) lead. WMAs without tadpoles had average (min, max) measurements (mg/l) of: 0.58 (0, 1) phosphate, 0.48 (0, 6.7) nitrate, 0.01 (0, 0.3) nitrite, 0.19 (0, 1) copper, 0.31 (0, 4) ammonia, 0 (0, 0) iron, and 2.72 (0, 20) lead. A multivariate analysis of variance was conducted to assess significant differences between the water characteristic levels of these two groups. Results showed a p-value of 0.054, a borderline statistically significant difference between phosphate levels in the two groups, with higher levels found in the tadpoles present group. Ultimately, this project will assess how North Dakota wetland condition influences amphibian presence.

2019 — 2020 NDWRRI Fellowship Research Highlights

Using UAV and Thermal Imaging to Determine Soil Moisture in Red River Valley

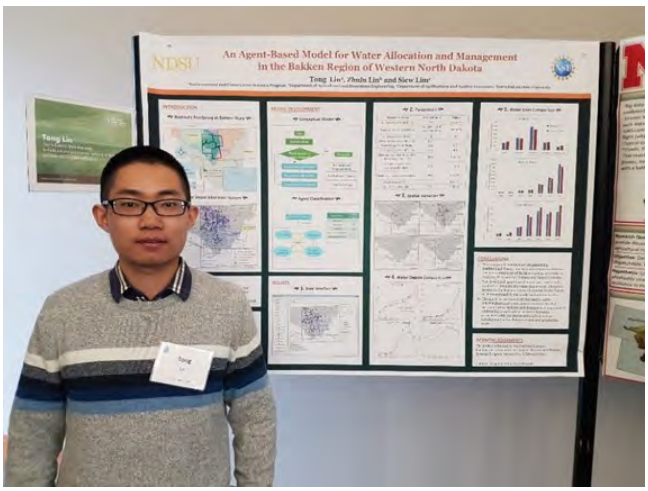
Talon Mack *(Fellow) &* ***Dr. Xinhua Jia*** *(Advisor), North Dakota State University*

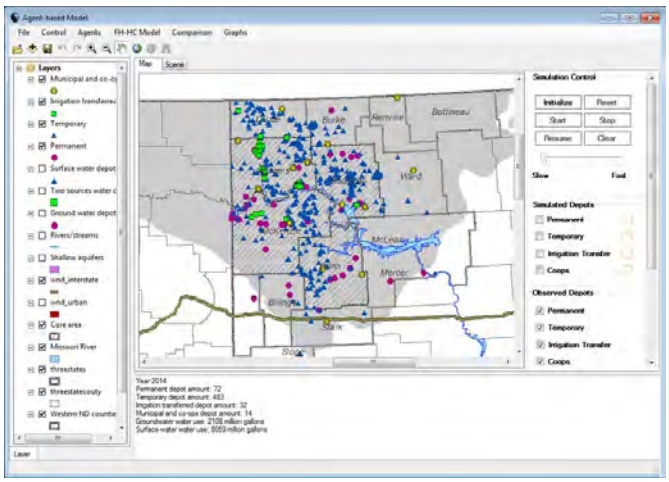
Using remotely sensed images collected by an unmanned aerial vehicle (UAV), a soil water content map was created for a field in the Red River Valley, which explored/expanded the possibility/potential of using UAV in water resources discipline. In 2019, several UAV flights were conducted to collect multispectral and thermal images. During the flights, soil water contents were also measured on the ground using a time domain reflectometer (TDR) at depths of 5 and 15 cm. The TDR was calibrated in the laboratory using the gravimetric method. Using the near infrared (NIR) and red bands, soil water content maps were developed for the field. The estimated and the measured soil water contents using the UAV and the TDR were in good agreement with a coefficient of determination greater than 0.7. However, the processing time and computing power needed to produce such soil water maps were challenging and difficult for a producer. Future research should focus on developing programs to help on the map development. With some of the experience gained from this first UAV project, more research can be conducted to further explore the use of UAVs for other purposes in the field of water resources.

Water Resources Impacts and Management in the Bakken Region of Western North Dakota

Tong Lin *(Fellow) &* ***Dr. Zhulu Lin*** *(Advisor), North Dakota State University*

To investigate the impact of the hydraulic fracturing (HF) water use on streamflow in the Bakken region of western North Dakota, we developed a SWAT model for simulating the hydrological processes of the Little Muddy River. The SWAT model was calibrated using the observed streamflows from 2004 to 2011 and validated from 2012 to 2014. The calibration and validation results showed that the SWAT model simulated the streamflows in the Little Muddy River fairly well. We then integrated the calibrated SWAT model and the agent-based model to predict streamflow changes under different precipitation conditions and HF water use scenarios. The simulation results indicated that the streamflow in the Little Muddy River was not much influenced by the HF water use at the Bakken. Instead, precipitation was a more influencing factor than the HF water demand in reducing the streamflows in the Little Muddy River. When the total HF water demands in the Bakken region increased 100 times, the streamflow in the Little Muddy River would decrease 4.7 ft3/s (approximately 6.1% of the annual average streamflow). We plan to further couple the agent-based model with the calibrated Fox Hills-Hell Creek MODFLOW model (provided by the ND State Water Commission) to study the impact of the HF water use on the Fox Hills-Hell Creek aquifer under different future scenarios.

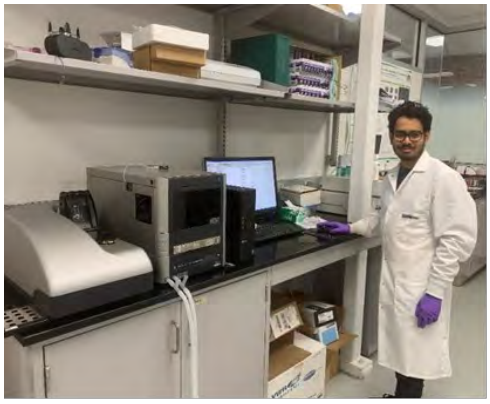




2019 — 2020 NDWRRI Fellowship Research Highlights

Fabrication of Point of Use Treatment Systems for Aqueous Arsenic and their Evaluation

Tonoy Kumar Das *(Fellow) &* ***Dr. Achintya Bezbaruah*** *(Advisor), North Dakota State University*



Arsenic contamination of drinking water is a threat to public health due to its carcinogenicity, and affects more than 200 million people worldwide. We have developed a novel graphene-oxide iron-nanohybrid (GFeN) for aqueous arsenic removal (removal capacities of 306/431 mg/g for As(III)/As(V) and fast reaction kinetics). Graphene-oxide sheets play an important role in the removal process. We proposed an arsenic removal mechanism where graphene-oxide sheets were used in the nanohybrid work as electron storage units to help in reactivating the iron as well as reducing the arsenic species to the final zero-valent state. There were negligible interferences by co-existing ions, pH, temperature, and organic matters on arsenic removal by GFeN. High adsorbing GFeN poses a risk of release of the adsorbed arsenic, so we evaluated the stability of adsorbed arsenic. In the presence of competing anions and different pH, the nanohybrid showed minimal release. The adsorbed arsenic remained stable, and only ~6% of the adsorbed arsenic was released over a two-year period. Ultra-high arsenic adsorption capacity, quick removal, and stability of adsorbed arsenic make our nanohybrid a reliable and robust candidate for possible field application (as an adsorption medium). To ease the application of powdered GFeN in point-of-use treatment systems, we have synthesized polyethersulfone (PES) and cellulose nanofiber (CNF) based composite, which can successfully entrap the GFeN for efficient arsenic removal. This research is developing a feasible and sustainable arsenic treatment system that will be able to supply safe drinking water to the stakeholders.

Interdisciplinary Approach to Understanding Fluvial Geomorphology of Post-glaciolucustrine Meandering Rivers: A Case study of the Red River

Zachary Phillips *(Fellow) &* ***Dr. Stephanie Day*** *(Advisor), North Dakota State University*

This project contributed to developing the geomorphic history of the Red River Basin. There are several reasons that this basin provides an ideal case study for understanding river evolution and response to post glacial isostatic rebound, but perhaps the most significant are the well documented timing of river initiation and the presence of high-resolution topographic data for the entire basin. Taking advantage of these factors, we have made two significant findings related to river evolution. The first finding is related to the impacts of subsurface geology on river erosion. In the case of the Red River, buried glacial moraines have a clear impact on river erosion, driving more movement in close proximity to these features despite having little to know surface expression. The second finding is related to river avulsion, finding not only that isostatic rebound can be a driving force in avulsions, but that these happen early in the river evolution history. Beyond these two findings, this research also contributed new tools that can be used for geomorphic observations on rivers around the world. This project also examined processes on the modern Red River, specifically looking into the effects of river ice on erosion. Through both field and laboratory analyses it was found that in the rivers with higher sinuosity river ice impacts can be expected to occur more often and may contribute to bank erosion on the outside of meander bends.

Meet Our Faculty

Dr. Aaron Daigh is an Associate Professor of Soil Physics and Hydrology in the Soil Science Department, North Dakota State University (NDSU), where he has a 90% research appointment in the North Dakota Agricultural Experiment Station and 10% teaching appointment in the Collage of Agriculture, Food Systems, and Natural Resources. He completed his Bachelors of Science (2007) in Environmental, Soil and Water Sciences and his Masters of Science (2009) in Crop, Soil and Environmental Sciences at the University of Arkansas. He then completed his PhD (2013) in Soil Science and Environmental Science at Iowa State University. After his PhD, he was a post-doctoral Research Associate of Water Quality (2013) in the Agricultural and Biosystems Engineering Department at Iowa State University. He then joined the faculty at NDSU in December, 2013.

Dr. Daigh currently directs research on satellite remote sensing of soil moisture with the use of machine learning algorithms, methods to extend soil moisture representation from weather mesonets, plant survival and tolerance in harsh storm-water systems, agricultural water management via tillage and cover crop systems, characterization of slope failures in North Dakota, naturally hydrophobic capillary barriers, plant and soil responses to hexacyanoferrate, and the occurrence and economic costs of deep wheel-traffic compaction. His previous research has included brine spill remediation, subsurface drainage dynamics and water quality, coalmine reclamation, crops and cover crop effects on soil moisture, salinity and sodicity effects on soil hydraulic properties, nitrogen dynamics in floodwaters of flood-irrigated cropping systems, temporal fluctuations of soil microbial communities, spatial and temporal dynamics of soil carbon dioxide emissions, and flipped-classroom modes of bolstering calculus skills in soil physics courses. Dr. Daigh teaches two classes at NDSU, including Soil Ecohydrology and Physics (for graduate and undergraduates) and Advanced Soil Hydrology and Physics (for PhD students). He also currently serves on the Board of Directors for the Soil Science Society of America and is the Chair of the Program Planning Committee that oversees the International Annual Meetings of the Joint Tri-societies of American Society of Agronomy – Crop Science Society of America – Soil Science Society of America.

Dr. Benjamin Laabs is an Associate Professor at North Dakota State University (NDSU) in the Department of Geosciences. He earned his B.S. and Ph.D. in Geology at the University of Wisconsin-Madison and his M.S. in Geology at Northern Arizona University. Prior to joining NDSU, he served on the faculty at SUNY Geneseo and Gustavus Adolphus College.

Dr. Laabs' research interests include glaciology, paleoclimate, and geochronology. His research explores the geologic record of glaciations through Earth history with the goal of reconstructing the pace and timing of regional climate change. Students in Dr. Laabs' research group use numerical models to simulate the mass balance and flow of past glaciers and the water budget of nearby lakes, which help to infer how climate changed as these ancient bodies of water expanded and retracted through time. Recently, he has been awarded research grants from the U.S. National Science Foundation, NASA EPSCoR, and the Geological Society of America. He has recently published papers in Quaternary Science Reviews, the Journal of Quaternary Science, and the Geological Society of America Bulletin. Dr. Laabs teaches a variety of classes at NDSU, including The Earth Through Time, Climate Change and Energy, Environmental Geology, Glacial Geology, and Structural Geology and supervises graduate students in the Environmental and Conservation Sciences program. He directs the Cosmogenic Nuclide Preparation Lab in the Department of Geosciences and serves as the Chair-Elect for the Rocky Mountain Section of the Geological Society of America.

Awards Received by Institute Fellows

- **Lan Zeng** received an Outstanding Student Presentation Award from the American Geophysical Union (AGU). She presented a paper, entitled "Modeling of Dynamics of Runoff Contributing Areas in Depression-dominated Areas" at the 2019 AGU Fall Meeting in San Francisco, CA.
- **Erika Olson** was a recipient of the 2019 North Central Chapter of Society of Wetland Scientists (SWS) Student Travel Award.
- **Justin Waraniak** was a finalist of the 2020 North American Congress for Conservation Biology Student Presentation Award. The title of his presentation was "Population Connectivity in Agricultural Landscapes: Land Use Effects on Gene Flow in Northern Leopard Frogs in the Prairie Pothole Region."
- **Lan Zeng, Mohammad Hadi Bazrkar, and Ning Wang** received the 2019-2020 Student Travel Awards from the ND EPSCoR.

NDWRRI State Advisory Committee

Joel Galloway Section Chief, U.S. Geological Survey, Dakota Water Science Center, Bismarck

Joel has worked for the U.S. Geological Survey for 27 years in North Dakota, Arkansas, South Dakota, Iowa, and Wyoming and is currently a Hydrologic Investigations Chief for the USGS Dakota Water Science Center and is located in Bismarck. He has a Master of Science degree in environmental/civil engineering from the South Dakota School of Mines and Technology and a Bachelor of Science degree in geology from the University of North Dakota. Joel has authored or coauthored over 50 scientific reports and journal articles on different water-quality, groundwater, and surface-water topics.

Andrew Nygren Hydrologist, Water Appropriation Division, North Dakota State Water Commission

Andrew has worked for the North Dakota State Water Commission (NDSWC) for 16 years initially as a Water Resource Engineer with the NDSWC Development Division Investigations Section, and for the past 15 years as a Hydrologist with the NDSWC Water Appropriation Division. He has a Master of Science and Bachelor of Science in Geological Engineering from University of North Dakota.

Peter Wax Environmental Scientist, North Dakota Department of Environmental Quality

Wax is an Environmental Scientist with 32 years of experience monitoring, assessing, and protecting the nations surface waters. The last 30 years have been spent in the state of North Dakota supporting multiple Sections of the Clean Water Act and the Standards of Quality for Waters of the State. A graduate of Minot State University with a B.S. in Environmental Science, Wax is proficient at designing and implementing the collection of biological, geomorphologic, and water quality data for standards compliance, special projects, pollution releases, oil extraction spills, remediation, and cleanup. The additional responsibilities of supporting Section 303 of the Clean Water Act and State Century Code through rulemaking and enforcement give Wax an uncommon skill set linking law and science to the benefit of aquatic and human communities.

Recent Publications and Presentations by Institute Fellows and PIs

Peer-reviewed Journal Papers

Bazrkar, M. H. and X. Chu. 2020. A new standardized baseflow index for identification of hydrologic drought in the Red River of the North Basin. *Natural Hazards Review*, 21(4), 05020011, 1-8, https://doi.org/10.1061/(ASCE)NH.1527-6996.0000414.

Bazrkar, M. H., J. Zhang, and X. Chu. 2020. Hydroclimatic aggregate drought index (HADI): A new approach for identification and categorization of drought in cold climate regions. *Stochastic Environmental Research and Risk Assessment*, 34(11), 1847-1870, https://doi.org/10.1007/s00477-020-01870-5.

Das, T. K. and Bezbaruah, A. N. 2020. Comparative study of arsenic removal by iron-based nanomaterials: Potential candidates for field applications. *Science of the Total Environment*, 764, 142914. https://doi.org/10.1016/j.scitotenv.2020.142914.

Das, T. K., Sakthivel, T. S., Jeyaranjan, A., Seal, S., Bezbaruah, A. N. 2020 Ultra-high arsenic adsorption by graphene oxide iron nanohybrid: Removal mechanisms and potential applications. *Chemosphere*, 253, 126702, https://doi.org/10.1016/j.chemosphere.2020.126702.

Kadioglu, H., Hatterman-Valenti, H., Jia, X., Chu, X., Aslan, H., and Simsek, H. 2019. Groundwater table effects on the yield, growth, and water use of canola (*Brassica napus* L.) plant. *Water*, 11(8), 1730, https://doi.org/10.3390/w11081730.

Lin, Z., Lim, S. H., Lin, T., and Borders, M. 2020. Using agent-based modeling for water resources management in the Bakken region. *Journal of Water Resources Planning and Management*, 146(1), 05019020, https://doi.org/10.1061/(ASCE)WR.1943-5452.0001147.

Xiao, F., Challa Sasi, P., Yao, B., Kubátová, A., Golovko, S. A., Golovko, M. Y., and Soli, D. 2020. Thermal stability and decomposition of perfluoroalkyl substances on spent granular activated carbon. *Environmental Science & Technology Letters*, 7(5), 343-350, https://doi.org/10.1021/acs.estlett.0c00114.

Zeng, L., Shao, J., and Chu, X. 2020. Improved hydrologic modeling in depression-dominated areas. *Journal of Hydrology*, 590, 125269, 1-12. https://doi.org/10.1016/j.jhydrol.2020.125269.

Zhang, J., Zheng, H., Zhang, X., and VanLooy, J. 2020. Changes in regional snowfall in central North America (1961–2017): Mountain versus plains. *Geosciences*, 10, 157. https://doi.org/10.3390/geosciences10050157.

Conference Proceedings

Lim, Y. H. and Cox, M. L. 2020. Enhancing maximum scour depth determination for spur dikes using a validated two-dimensional model. Proc. ASCE World Environmental and Water Resources Congress 2020, Hydraulics, Waterways, and Water Distribution Systems Analysis, p84-98, https://doi.org/10.1061/9780784482971.009.

Data Publications

Tuftedal, M. E. and Delene, D. J. 2020. Precipitation evaluation of the North Dakota Cloud Modification Project (NDCMP) using rain gauge observations, University of North Dakota Scholarly Commons, Grand Forks, ND, https://doi.org/10.31356/data017.

Conference/Seminar Presentations

Bazrkar, M. H. and Chu, X. 2019. Application of joint probability distribution function to customize drought categorization based on spatial and temporal distributions of drought. AGU Fall Meeting, December 9-13, 2019, San Francisco, CA.

Das, T. K., Hazra, R. S., Quadir, M., Jiang, L., and Bezbaruah, A. N. 2020. Graphene oxide iron nanohybrids loaded polyethersulfone-cellulose nanofiber beads for arsenic removal. 8th Sustainable Nanotechnology Conference (Virtual), November 12-13, 2020.

Das, T. K., Sakthivel, T. S., Seal, S, and Bezbaruah, A. N. 2019. Mechanism(s) of arsenic desorption from graphene oxide-metal oxide nanohybrids. 8th Sustainable Nanotechnology Conference, November 7-10, 2019, San Diego, CA.

Recent Publications and Presentations by Institute Fellows and PIs

Conference/Seminar Presentations

Rashid, U. S, Das, T. K., Sakthivel, T. S., Seal, S, and Bezbaruah, A. N. 2019. Rapid kinetics of fluoride removal by CeO_2-GO nanocomposite. 8th Sustainable Nanotechnology Conference, November 7-10, 2019, San Diego, CA.

Das, T. K. and Bezbaruah, A. N. 2019. Practical relevance of graphene oxide supported iron nanohybrid in arsenic remediation. Association of Environmental Engineering and Science Professors (AEESP) Distinguished Lecture. November 1, 2019, University of Minnesota, MN.

Das, T. K. and Bezbaruah, A. N. 2019. Arsenic removal by graphene-oxide iron nanohybrid: Spectroscopic and microscopic studies. ND EPSCoR State Conference, Fargo, ND.

Kadioglu, H., Jia, X., Chu, X., Daigh, A.L.M., and Simsek, H. 2019. The impact of groundwater depth on the yield and some quality parameters of canola (*Brassica napus L.*). ICSAE 6th International Conference on Sustainable Agriculture and Environment, October 3-5, 2019, Konya, Turkey.

Kadioglu, H., Hatterman-Valenti, H., Daigh, A.L.M., and Simsek, H. 2019. Determining water stress condition of canola plant in three different groundwater depths. 111th Annual Meeting, North Dakota Academy of Science, March 8, 2019, Grand Forks, ND.

Kadioglu, H., Kadioglu, I., and Simsek, H. 2019. Quantifying growth, yield and water use of canola plant in different water table depths. ND EPSCoR State Conference, March 27, 2019, Fargo, ND.

Mack, T., Jia, X., Flores, P., and Sun, X. 2019. Using UAV images to determine soil moisture in the Red River Valley. ASABE 2019 Annual International Meeting, July 7-10, 2019, Boston, MA.

Olson, E., Hargiss, C., and Norland, J. 2019. Understanding water quality and genetic source tracking of E. coli in urban ponds. Society of Wetland Scientists 2019 Annual Meeting, May 28-31, 2019, Baltimore, MD.

Pham, H. and Bezbaruah, A. N. 2020. Iron nanoparticles synthesis using green routes and its application. 8th Sustainable Nanotechnology Conference (Virtual), November 12-13, 2020.

Pham, H. and Bezbaruah, A. N. 2019. Mechanisms of iron nanoparticles synthesis using green routes and its application. Association of Environmental Engineering and Science Professors (AEESP) Distinguished Lecture, November 1, 2020, University of Minnesota, MN.

Phillips, Z. and Day, S. S. 2020. Experimental investigation of river ice dynamics in sinuous channels. Upper Midwest Stream Restoration Symposium, February 23-26, 2020, Stillwater, MN.

Waraniak, J., Mushet, D. M., and Stockwell, C. A. 2020. Population connectivity in an agricultural landscape: Land use effects in northern leopard frog (Rana pipiens) in the Prairie Pothole Region. North Dakota Wildlife Society Chapter Meeting, February 12-14, 2020, Bismarck, ND.

Waraniak, J., Mushet, D. M., and Stockwell, C. A. 2020. Conservation genomics in the northern Great Plains: Assessments of genetic diversity, population structure, demographic history, and anthropogenically mediated selection in the northern leopard frog. Invited symposium at Northern Prairie Wildlife Research Center, February 27, 2020, Jamestown, ND.

Waraniak, J., Mushet, D. M., and Stockwell, C. A. 2020. Population connectivity in agricultural landscapes: Land use effects on gene flow in northern leopard frog (Rana pipiens) in the Prairie Pothole Region. North American Congress for Conservation Biology Virtual Conference, July 27-31, 2020 (online).

Zeng, L. and Chu, X. 2019. Development of a puddle-based unit oriented SWAT (SWAT-PBU) model for simulating depression-dominated rainfall-runoff processes. ND EPSCoR State Conference, March 27, 2019, Fargo, ND.

Zeng, L. and Chu, X. 2019. Modeling of dynamics of runoff contributing areas in depression-dominated areas. AGU Fall Meeting, December 9-13, 2019, San Francisco, CA.

Zhang, J., Shabani, A., Zheng, H., and Zhang, X., 2019. Evaluation of costs between Devils Lake flooding adaptations and Sheyenne River salinity damages. ND EPSCoR State Conference, March 27, 2019, Fargo, ND.

Theses and Dissertations

Cox, Mathew Lee. 2019. Determination of Maximum Scour Depth for Spur Dikes Based on a Validated Two-Dimensional HEC-RAS Model. M.S. Thesis. Civil Engineering, University of North Dakota, Grand Forks, ND.

Kadioglu, Hakan. 2019. Groundwater Table Effects on Yield, Growth and Water Use of Canola (Brassica napus L.) Plant. M.S. Thesis. Natural Resource Management, North Dakota State University, Fargo, ND.

Olson, Erika Leigh. 2020. Understanding Escherichia Coli and Water Quality in Stormwater Retention Ponds and Detention Basins in Fargo as Part of the Red River Watershed. M.S. Thesis. Natural Resource Management, North Dakota State University, Fargo, ND.

Phillips, Zachary Rockford. 2020. Holocene Postglacial Fluvial Processes and Landforms in Low Relief Landscapes. Ph.D. Dissertation. Environmental and Conservation Sciences, North Dakota State University, Fargo, ND.

Tuftedal, Matthew Erik. 2019. Precipitation Evaluation of the North Dakota Cloud Modification Project (NDCMP) Using Rain Gauge Observations. M.S. Thesis. Atmospheric Sciences, University of North Dakota, Grand Forks, ND.

Zeng, Lan. 2020. Improved Hydrologic Modeling for Characterizing Variable Contributing Areas and Threshold-Controlled Overland Flow in Depression-Dominated Areas. Ph.D. Dissertation. Civil Engineering, North Dakota State University, Fargo, ND.

Recent USGS Publications

Lundgren, R. F. and Iorio, M. J. 2020. Characterization of surface-water and groundwater quality on the Fort Berthold Reservation, North Dakota, 2014–17. U.S. Geological Survey Scientific Investigations Report 2020–5020, 37 p., https://doi.org/10.3133/sir20205020.

Medler, C. J. and Eldridge, W. G. 2021. Spring types and contributing aquifers from water-chemistry and multivariate statistical analyses for seeps and springs in Theodore Roosevelt National Park, North Dakota, 2018. U.S. Geological Survey Scientific Investigations Report 2020–5121, 48 p., https://doi.org/10.3133/sir20205121.

Nustad, R. A. and Vecchia, A. V. 2020. Water-quality trends for selected sites and constituents in the international Red River of the North Basin, Minnesota and North Dakota, United States, and Manitoba, Canada, 1970–2017. U.S. Geological Survey Scientific Investigations Report 2020–5079, 75 p., https://doi.org/10.3133/sir20205079.

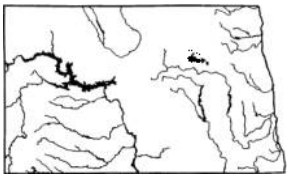
Vecchia, A. V. and Nustad, R. A. 2020. Time-series model, statistical methods, and software documentation for R–QWTREND—An R package for analyzing trends in stream-water quality. U.S. Geological Survey Open-File Report 2020–1014, 51 p., https://doi.org/10.3133/ofr20201014.

Vining, K. C. 2020. Water-balance techniques for determining available soil-water storage for selected sandy and clay soil study sites in Cass County, North Dakota, 2016–17. U.S. Geological Survey Scientific Investigations Report 2019–5141, 39 p., https://doi.org/10.3133/sir20195141.

Williams-Sether, T. and Wheeling, S. L. 2020. Small basin annual yield and percentage of snowmelt runoff in North Dakota, 1931–2016. U.S. Geological Survey Scientific Investigations Report 2019–5144, 37 p., https://doi.org/10.3133/sir20195144.

Recent ND State Water Commission Reports and Publications

North Dakota Water Commission & State Engineer, Reports and Publications
https://www.swc.nd.gov/info_edu/reports_and_publications/



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North Dakota Water Resources Research Institute (NDWRRI)

The Institute was founded in 1965 by authority of Congress as one of the 54 Institutes throughout the nation and is administered through the United States Geological Survey. The NDWRRI receives funding through section 104 of the Water Resources Research Act of 1984 and it applies its Federal allotment funds to research that fosters: A) the entry of new research scientists into the water resources field, B) training and education of future water resources scientists, engineers, and technicians; C) the preliminary exploration of new ideas that address water problems or expand understanding of water and water-related phenomena; and D) the dissemination of research results to water managers and the public.