2019-2020 NDWRRI Annual Report – General Information

Products

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 Proceeding Papers

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.

Dissertations and Theses

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.

Information Transfer Program

Information dissemination was mainly done through the Institute's website, the annual newsletter, as well as a variety of publications and conference presentations. The major information transfer activities supported with the 104b annual base grants and required matching funds include:

1) Maintaining the Institute's website as an effective way to disseminate all Institute-related information and communicate to the public. Particularly, a new NDWRRI homepage is currently under construction.
2) Publishing the annual Institute newsletter to highlight the graduate research fellowship program and the impacts of the funded projects, profile the Institute researchers and their accomplishments, and provide information on water issues in the State.
3) Publishing the research findings by the Institute's Fellows and their advisors (PIs of the funded projects) in peer-reviewed journals, proceedings, book chapters, as well as theses and dissertations.
4) Presenting research results by the Institute's Fellows and their advisors at various conferences.

5) Sponsoring or co-sponsoring local or regional conferences (note that due to the COVID-19 pandemic, all conferences have been postponed, cancelled, or changed to an online conferences).

Student Support

The NDWRRI continued its Graduate Research Fellowship (GRF) program supported with the annual base (104b) and required matching funds (including the funds from the North Dakota State Water Commission). It provided competitive funds for graduate students and their advisors (PIs) at North Dakota State University and the University of North Dakota to conduct water resources research and particularly, to address the water issues in the State. In the 2019-2020 funding period, the fellowships were awarded to 15 graduate students, including 9 Ph.D. students and 6 M.S. students from the two universities. The fellowships ranged from $1,500 to $13,440 over a period of 3, 7.5, or 12 months.

Notable Achievements and Awards

In the 2019-2020 funding period, fifteen projects were funded through the Institute's GRF program to address various water resources issues in North Dakota. Thirty graduate students and faculty have been involved in these projects. They have published 9 peer-reviewed journal papers and 1 proceeding paper, and given numerous conference presentations at various conferences. Two Ph.D. students and four M.S. students supported by the 104b federal funds and required matching funds have successfully received their degrees and published their theses/dissertations. The awards the Institute's Fellows received in this funding period are listed as follows:

- Lan Zeng (Ph.D. student, Civil and Environmental Engineering, North Dakota State University) received an Outstanding Student Presentation Award from the American Geophysical Union (AGU), as one of the top 5% of student participants. She presented a paper, entitled "Modeling of Dynamics of Runoff Contributing Areas in Depression-dominated Areas" at the 2019 AGU Fall Meeting held on December 9-13, 2019 in San Francisco, California.
- Erika Olson (M.S. student, Natural Resource Management, North Dakota State University) was a recipient of the 2019 North Central Chapter of Society of Wetland Scientists (SWS) Student Travel Award ($500).
- Justin Waraniak (Biological Sciences/Environmental & Conservation Science, North Dakota State University) 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 (Ph.D. students, Civil and Environmental Engineering, North Dakota State University) received the 2019-2020 Student Travel Awards from the ND EPSCoR ($2000).

Understanding E. Coli And Water Quality In Stormwater Retention And Detention Basins In Fargo As Part Of The Red River Watershed

Project Type: Annual Base Grant
Project ID: 2019ND199B

Project Impact:

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.

Drought Identification And Prediction For Cold Climate Regions

Project Type: Annual Base Grant
Project ID: 2019ND200B

Project Impact:

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 nonstationary 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.

Effect Of Different Water Table Levels On Canola Growth And Quality Parameters

Project Type: Annual Base Grant
Project ID: 2019ND201B

Project Impact:

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

Project Type: Annual Base Grant
Project ID: 2019ND202B

Project Impact:

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 PO4^(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 °C) and ions (HCO^(3-), SO4^(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.

Evaluation Of The Costs Between Devils Lake Flooding Adaptations And Sheyenne River Salinity Damages Resulted From Devils Lake Outlet Operations

Project Type: Annual Base Grant
Project ID: 2019ND203B

Project Impact:

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)

Project Type: Annual Base Grant
Project ID: 2019ND204B

Project Impact:

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.

Development Of A Puddle-based-unit Oriented SWAT (SWATPBU) Model And Its Application In North Dakota

Project Type: Annual Base Grant
Project ID: 2019ND205B

Project Impact:

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.

Enhanced Removal Of Poly- And Perfluoroalkyl Substances From Water

Project Type: Annual Base Grant
Project ID: 2019ND206B

Project Impact:

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

Project Type: Annual Base Grant
Project ID: 2019ND207B

Project Impact:

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.

Using UAV And Thermal Imaging To Determine Soil Moisture In Red River Valley

Project Type: Annual Base Grant
Project ID: 2019ND208B

Project Impact:

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.

Fabrication Of Point Of Use Treatment Systems For Aqueous Arsenic And Their Evaluation

Project Type: Annual Base Grant
Project ID: 2019ND209B

Project Impact:

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-glaciolacustrine Meandering Rivers: A Case Study Of The Red River

Project Type: Annual Base Grant
Project ID: 2019ND210B

Project Impact:

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.

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

Project Type: Graduate Fellowship Project

Project ID: N/A (fully funded by the matching fund from ND State Water Commission)

Project Impact: 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.

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

Project Type: Graduate Fellowship Project

Project ID: N/A (fully funded by the matching fund from ND State Water Commission)

Project Impact: 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.

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

Project Type: Graduate Fellowship Project

Project ID: N/A (fully funded by the matching fund from ND State Water Commission)

Project Impact: Project Impact: 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.