



**North Dakota  
Water Resources Research Institute**

**North Dakota State University  
University of North Dakota**

**ANNUAL REPORT**

March 1, 2014 to February 28, 2015

**Fiscal Year 2014 Report to the U.S. Geological Survey**

June 1, 2015

# **Annual Report**

## **Fiscal Year 2014 Report to the U.S. Geological Survey**

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## **INTRODUCTION**

This report describes the activities of the North Dakota Water Resources Research Institute (NDWRRI) during the period of March 1, 2014 to February 28, 2015.

The ND WRRI is one of the 54 institutes known collectively as the National Institutes for Water Resources (NIWR). The NDWRRI was founded in 1965, by authority of Congress (Water Resources Research Acts of 1964, 1972, 1984, and 1990), and is administrated through the United States Geological Survey. Section 104 of the Water Resources Research Act requires the NDWRRI to apply its Federal allotment funds to:

1. Plan, conduct or otherwise arrange for competent 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 public.
2. Cooperate closely with other college and universities in the state that have demonstrated the capability for research, information dissemination and graduate training, in order to develop a statewide program designed to resolve State and regional water and related land problems.
3. Cooperate closely with other institutes and other organizations in the region to increase the effectiveness of the Institute and for the purpose of promoting regional cooperation.

This year, NDWRRI once again allocated its 104(B) resources to fund Graduate Fellowship research projects. The institute also continued its efforts to enhance communication between the State and Federal agency personnel and university faculty and students. NDWRRI also worked closely with the Environmental and Conservation Sciences program of North Dakota State University (NDSU), Natural Resources Management program of NDSU, and the International Water Institute, Fargo, ND on water related research issues and collaboration.

The annual base grant amount received by the WRRI was \$92,335. The amount was used for administration and Fellowship awards. The Fellowship program was supported by the North Dakota State Water Commission with an additional amount of \$13,850.

### **Program Management**

The Institute continued the same administrative mechanism with a director managing the institute program with the help of a State Advisory Committee. Dr. G. Padmanabhan, Professor of Civil Engineering, continued as the director. Linda Charlton, a NDSU employee, has been working part-time for the Institute to assist the director with Institute finances, communications and information transfer. The State Advisory Committee consists of three members representing the three principal water agencies in North Dakota: State Water Commission, State Department of Health, and the USGS North Dakota District. In addition, the Institute also seeks advice from the faculty of the two research universities of the State: North Dakota State University and University of North Dakota.

Dr. G. Padmanabhan stepped down from the directorship at the end of the funding cycle effective February 28, 2015. Dr. Eakalak Khan, Professor of Civil and Environmental Engineering and the Director of NDSU Environmental and Conservation Sciences Graduate Program, assumed charges as the director from March 1, 2015.

## **State Appropriation**

The State Water Commission continued its support of 15% match (\$13,850) to the 2014-2015 Graduate Research Fellowship program of NDWRRI under federal 104 (B) funding. This is eleventh year the SWC provided support to the Fellowship program.

## **University Support**

North Dakota State University and the University of North Dakota administrations consider the NDWRRI activities important and are supportive of its efforts.

## **Institute Location**

The Institute continues to operate from the Administrative Building of the College of Engineering and Architecture of North Dakota State University in Fargo, North Dakota. The director may be reached at: ND Water Resources Research Institute, North Dakota State University, Civil and Environmental Engineering, Dept. # 2470, Fargo, ND 58108-6050  
Phone: (701) 231-7717 Fax: (701) 231-6185 E-mail: [Eakalak.Khan@ndsu.edu](mailto:Eakalak.Khan@ndsu.edu)

## **State Advisory Committee**

The State Advisory Committee provided guidance on water resources research priorities in the State and region, and participated in the review and evaluation of research proposals and projects. The current committee members are:

Gregg Wiche, District Chief, U.S. Geological Survey, Water Resources Division, Bismarck, North Dakota

William Schuh, Water Appropriation Division, North Dakota State Water Commission, Bismarck North Dakota

Peter Wax, Water quality Special Projects, ND Department of Health, Bismarck, North Dakota

The committee members are senior officials in the three major agencies in North Dakota responsible for much of the water resources research done outside of NDSU and UND in North Dakota.

## **RESEARCH PROGRAM**

### ***ANNUAL BASE GRANT (104-B)***

In the past several years NDWRRI has offered competitive fellowships to NDSU and UND graduate students for research on water resources topics under a Graduate Research Fellowship (GRF) program effectively using the modest amount of the 104(B) annual base grant. The program meets the requirements of Section 104 of the Water Resources Research Act of 1984.

- The fellowship program encourages entry of young university faculty and new research scientists into the water resources field;
- provides training and education to future water resource scientists and engineers;
- promotes exploration of new ideas that address water problems or expand understanding of water quantity, quality and related phenomena; and
- engages university faculty in collaborative research programs seeking supports from entities concerned with water problems.

This year also, the NDWRRI continued the GRF program and applied bulk of the federal allotment to it. The GRF program is administrated and monitored by the director. Applications are invited from the graduate students and their advisors of the two research universities of the State, NDSU and UND. A rigorous review by the State Advisory Committee and other water professionals in the state determines the awards. Active participation of the academic advisors of the students in meeting matching requirement and seeking co-funding from local, state and other sources is another positive aspect of the program. Periodical review of the progress of the students in meeting the fellowship expectations is ensured by seeking reports from the students and by encouraging them to make presentations in local, regional, and national technical seminars and conferences.

Guidelines for the 2014-2015 Graduate Research Fellowship were posted on the Institute website in September 2013, and the request for applications was announced in the faculty news publications of the two university campuses by the first week of November, 2013.

The following is the request for application that was published on the UND and NDSU campus newsletters, and distributed by e-mail lists. November 7, 2013 Issue of It's Happening at State (IHaS) (NDSU Publication) carried it. An announcement similar in content was also published in the University of North Dakota campus publication University Letter.

As it appeared in November 7, 2013 issue of IHaS:

### **ND Water Resources Research Institute seeks fellowship applicants**

The North Dakota Water Resources Research Institute invites applications for its 2014 Graduate Research Fellowship program.

NDSU and University of North Dakota graduate students who are conducting or planning research in water resources may apply for fellowships of varying duration, ranging from three months to one year. Typically, fellowship awards range from \$800 to \$1,000 per month for master's degree students and \$1,000 to \$1,400 per month for doctoral students. The fellowship funds must be applied between March 1, 2014, and Feb. 28, 2015. A technical completion report co-written by the fellow and the adviser is expected of each fellowship research project.

Research proposed for fellowship support should relate to water resources issues in the state or region. Regional, state or local collaborations or co-funding will strengthen an application. Fellowships have a matching requirement of two non-federal dollars to one federal dollar. At the time of applying, applicants should have a plan of study filed and/or should have a thesis research topic selected. Applications need to be prepared in consultation with advisers. The applications should be co-signed by the applicants' advisers.

Applications from students and advisers who have not met the reporting requirements of their previous fellowship projects will not be considered for funding.

The general criteria used for proposal evaluation include scientific merit, originality, research related to state or region, and extent of regional, state or local collaboration and/or co-funding. A panel of state water resources professionals will review the proposals.

Award announcements will be made by early January, subject to the appropriation of funds for the fiscal year 2014 program by the federal government.

For more information about the program and guidelines for preparation of applications, visit [www.ndsu.edu/wrri](http://www.ndsu.edu/wrri).

Applications are due Friday, Nov. 29, by 5 p.m.

Submit original and four hard copies of applications to Linda Charlton, Family Life Center (FLC 320), NDSU Department 2030, PO Box 6050, Fargo, ND 58108-6050 and an electronic copy in Word format to [g.padmanabhan@ndsu.edu](mailto:g.padmanabhan@ndsu.edu).

For additional information, contact G. Padmanabhan, professor of civil and environmental engineering, at [g.padmanabhan@ndsu.edu](mailto:g.padmanabhan@ndsu.edu) or Linda Charlton, ITS tech coordinator, at [linda.charlton@ndsu.edu](mailto:linda.charlton@ndsu.edu).

## **NDWRRI GRADUATE RESEARCH FELLOWSHIPS**

In total, seventeen applications were received. Twelve were from NDSU and five from UND. Out of seventeen, three (2 Ph. D and 1 MS) are for renewal and fourteen (6 Ph. D and 8 MS) are new applications. Approximately \$70,000 was available for Fellowship projects from the annual base grant. An additional support of \$13,850 came from ND SWC. Fellowships ranging from \$1,000 to \$10,000 were awarded to fifteen graduate students, 8 Ph.D. and 8 MS, conducting research in water resources topics at NDSU and UND. Selection of student Fellows and the award amounts were based on competitive proposals prepared by the students with the guidance of their advisers. A panel of state water resource professionals and the director reviewed the proposals and selected Fellows. The award amounts are based on the quality of proposals and the priority of the proposed projects for the state and region.

## **2014-15 ND WRRI Fellows, their advisers, and Fellowship research projects:**

Dasuni Arachchige (Fellow), Geography, UND; Gregory Vandenberg (adviser)  
*Flash Flood Potential Mapping Using GIS and Flash Flood Potential Index (FFPI) in Turtle River and Forest River Watersheds, North Dakota*

Abbie Beaudry, Civil Engineering, UND; Howe Lim  
*Nutrient Loading Reduction and Water Quality of Best Management Practices in Grand Forks, North Dakota*

Derrick Deering, Civil Engineering, UND; Howe Lim  
*Three Dimensional Analyses of Flow Dynamics & Chlorination of Ground Water Supply Reservoir in a Cold Region*

Heather Dose, Soil Science, NDSU; Ann Marie Fortuna  
*Where is fertilizer nitrogen going, up in smoke or down the pipe? An assessment of nitrogen transformations and water quality impacts on a tile drained sodic soil*

Prosper Gbolo, Geology and Geologic Engineering, UND; Phillip Gerla  
*The Cycling and Fate of Phosphorus at an Abandoned Feedlot*

Noah Habtezion, Civil and Environmental Engineering, NDSU; Xuefeng Chu  
*Quantification of Spatio-temporal Distribution of Surface Ponding and the Related Dynamic Processes*

Yangbo He, Soil Science, NDSU; Thomas DeSutter  
*Sodic soil characterization and management on subsurface drainage*

Mohammad Hossain, Civil and Environmental Engineering, NDSU; Achintya Bezbaruah  
*Biopolymers for Phosphate Removal from Eutrophic Lakes*

Kelsey Kolars, Ag and Biosystems Engineering, NDSU; Xinhua Jia  
*Development of a Model for Subsurface Drainage and Subirrigation Water Management*

Navaratnam Leelaruban, Civil and Environmental Engineering, NDSU; G. Padmanabhan  
*A Study of the Spatial and Temporal Characteristics of Drought and its Impact in North Dakota*

Debjit Roy, Ag and Biosystems Engineering, NDSU; Xinhua Jia  
*Snowmelt water infiltration into frozen soil in Red River of the North Basin*

Jingyi Sun, Ag and Biosystems Engineering, NDSU; Halis Simsek  
*Evaluation of Bioavailable Dissolved Organic Nitrogen Using Various Algal Species*

Mitchell Swanson, Civil and Environmental Engineering, NDSU; Eakalak Khan  
*The Role of Algal Species on Phosphorus Bioavailability*

Anthony Wamono, Ag and Biosystems Engineering, NDSU; Dean Steele  
*Effects of calcium based surface amendments on the hydraulic conductivity and selected physical properties of subsurface drained sodic-saline soils*

Lucas Wandrie, Biological Sciences, NDSU; Wendy Reed  
*Bird-mediated transport of toxic heavy metals and selenium from marine and terrestrial sources to freshwater wetlands in North Dakota.*

# **Nutrient Loading Reduction and Water Quality of Best Management Practices in Grand Forks, North Dakota**

**Project Number:**  
**Fellow:** Abbie Beaudry  
**Adviser:** Howe Lim  
**Start Date:** 3/1/2014  
**End Date:** 2/28/2015

## **Publications**

Abbie, B. and Lim, Y.H. (2014). "Performance of Pervious Concrete on Runoff Reduction in Grand Forks, ND." Proc., World Environmental and Water Resources Congress 2014- Water Without Borders, p 135-144, Environmental and Water Resources Institute, ASCE, Portland, Oregon, June 2014

## **Presentation**

Yeo Howe Lim, Abbie Beaudry. "What, When, and Where in Studying the Best Management Practices (BMP's) in Grand Forks, ND." North Dakota Water Quality Monitoring Conference, Bismarck, North Dakota, March 2014.

## **Research:**

When an urban area develops over time, an increase in impervious land surface occurs, which impacts the stormwater runoff within the drainage basin. Developers and engineers are many times required to have post-development stormwater impacts to be the same, if not better, than prior to development. This is accomplished by installation of structures such as retention ponds, detention ponds, infiltration beds, etc. that are commonly known as Best Management Practices (BMP's).

Grand Forks, ND has many in-situ BMP's located throughout the city. Until now, these structures have been assumed to be functioning the way they were intended to when designed: to increase water quality and decrease runoff quantity. In reality, however, there is currently no comprehensive data collection scheme in place to accurately assess the effectiveness of the BMP's in general, and the structures in particular. This research combines the current attention to nutrient loading reduction by federal and state agencies with a local city's curiosity of how effective its stormwater structures are at providing better water quality.

The main objective of this research is to assess the effectiveness of select stormwater BMP's in Grand Forks, ND. This is to determine a baseline study, as well as develop a sampling plan that can be used in future continuation of the research.

The specific objectives include:

- Development of a long term BMP monitoring program – includes forecasting and frequency analysis of storm events, analysis of parameters tested for insignificance, modeling for appropriate time of concentration
- Cost-analysis of BMP structure based on effectiveness – provide recommendations to city officials

Storm event frequency analysis for precipitation events greater than 0.10 inches from 1994-2013 has been completed. In-situ BMP structures are being prioritized for sampling and water quality parameters to be tested have been decided. The sampling plan is currently being developed, as well as a Quality Assurance Project Plan (QAPP) that will outline all measures taken to ensure that the analysis is done accurately without bias. The logistics of items such as sample storage, access to laboratory equipment, and city of Grand Forks aid in sampling have been developed. Current progress puts sample collection beginning in May 2014 as planned.

**Significance:**

The U.S. Environmental Protection Agency (EPA) has begun efforts to expand regulations and strengthen the current program for individual states regarding stormwater. A new rule focusing on stormwater discharges from newly developed and redeveloped sites is expected to be finalized by December 2014 (Copeland, 2012). They also released a memo in March of 2011 that addressed how development of nutrient loading criteria is best handled at the state and local level (North Dakota Department of Health). In response to the EPA's request, the North Dakota Department of Health (NDDH) published the State of North Dakota Nutrient Criteria Development Plan in 2007 (Deutschman & Saunders-Pearce, 2007). The NDDH has recently put together a Nutrient Reduction Stakeholder group that has been working at creating the nutrient loading criteria to be applied throughout the state in year's to come. Major sources of nutrients are municipality point sources and stormwater runoff in urban areas, among others. Pollution from nutrients, such as phosphorus and nitrogen, in waterways leads to eutrophication, which causes degradation of wildlife habitat and leads to concerns for public health. The city of Grand Forks aims to use the collected data from this research as a comparison to the nutrient criteria being developed at the state level.

# **Three Dimensional Analyses of Flow Dynamics & Chlorination of Ground Water Supply Reservoir in a Cold Region**

**Project Number:** 2014ND283B

**Fellow:** Derrick Deering

**Adviser:** Howe Lim

**Start Date:** 3/1/2014

**End Date:** 2/28/2015

## **Publications**

Deering, D. and Lim, Y.H. (2014). "Identification of Safe Navigation Routes in a Remote Watershed under Extreme Storm Events Utilizing GIS and Hydrologic Models." Proc., World Environmental and Water Resources Congress 2014- Water Without Borders, p 2286-2295, Environmental and Water Resources Institute, ASCE, Portland, Oregon

## **Research**

Storage tanks are designed to supply water demand as well as provide storage for fire-fighting. Generally, when operating under normal conditions a fraction of the water within the tank is utilized. Since chlorine decay occurs in relation with time, a combination of extended water age and unmixed tank conditions generates varying water quality throughout the tank. Previous literature documents water entering the storage tank with sufficient concentration and exiting with a chlorine concentration that is extremely low. When chlorine concentration is extremely low the possibility of bacterial growth increases impacting human health.

East Grand Forks, MN has experienced chlorine depletion in a particular storage tank in the past. To resolve the issue a tank mixer was installed to achieve completely mixed conditions. However, it is believed that if hydraulic conditions are taken into account during the design process, completely mixed conditions with higher water quality throughout may be efficiently achieved.

The main objective of this research is to create an accurate three-dimensional, multiphase, free surface, CFD model, utilizing ANSYS CFX software.

Water temperature and chlorine concentration have been measured within the storage tank from January through April 2013. Soil temperatures were collected from North Dakota State Climate Office. CFD models have been created and initial conditions have been set. Currently, model computations are underway for the actual geometry of the tank in East Grand Forks as well as an alternative tank to geometry. Potential flow conditions for each geometry are considered and modeled separately. Based on completed outcomes, modeling three-dimensional, multi-phase, free-surface flow has been accomplished.

## **Significance:**

Generally, water quality has been analyzed under the assumption that storage tanks are completely mixed. However, previous literature indicates otherwise based on field test. With the advancement of technology CFD software has begun to be implemented into the field of hydraulics. Previously, CFD analysis of storage tanks were modeled as steady state because of the extensive computation time and memory. This research considers unsteady flow conditions with fluctuating water levels as well as temperature interactions during the winter season.

# **Where is fertilizer nitrogen going, up in smoke or down the pipe? An assessment of nitrogen transformations and water quality impacts on a tile drained sodic soil**

**Project Number: 2014ND284B**

**Fellow:** Heather Dose

**Adviser:** Ann Mary Fortuna

**Start Date:** 3/1/2014

**End Date:** 2/28/2015

## **Publications**

Matthees-Dose, H.L., A.-M. Fortuna\*, L.J. Cihacek, J. Norland, T.M. DeSutter, D.E. Clay and J. Bell. 2015. Biological indicators provide short term soil health assessment during sodium soil reclamation. *Ecological Indicators*. Accepted.

## **Presentations**

Calderon, F.J., A.-M. Fortuna, H. Matthees-Dose, L.J. Cihacek, K.A. Anderson, T.M. DeSutter and J. Bell. 2015. Using infrared spectroscopy to predict soil health indicators in sodic soils. SSSA, Long Beach, CA.

Matthees-Dose, H.L., A.-M. Fortuna\*, L.J. Cihacek, J. Norland, T.M. DeSutter, D.E. Clay and J. Bell. 2014. Identifying Soil health indicators for management of a sodic soil. SSSA, Long Beach, CA.

Dose, H. and A.-M. Fortuna\*. 2014. Development of soil health indicators for management of a sodic soil. North Dakota EPSCoR Annual Meeting. Grand Forks, ND.

Dose, H. and A.-M. Fortuna\*. 2014. Development of soil health indicators for management of a sodic soil. American Water Works Association Chapter Meeting. Fargo, ND.

Dose, H. and A.-M. Fortuna\*. 2014. Development of soil health indicators for management of a sodic soil. North Dakota State University Graduate Research and Arts Forum. Fargo, ND.

## **Research**

Tens of thousands of ha have been tiled annually, many of which are located on soils having a high risk for salinity or sodicity (i.e. Calciaquolls and Natraquolls). Yet, the effects of tile drainage on losses of reactive nitrogen (N) are largely unknown for these types of soil. Sodic soils, due to the structural limitations of excess sodium, have a high potential of being saturated. Tile drainage has the potential to improve nitrogen use efficiency, net primary productivity of row crops, and reduce gaseous losses of reactive N by eliminating saturated anoxic zones. However, tile drainage has been linked to greater nitrate leaching losses and reduced water quality. In sodic soils, leaching rates may be overestimated, while gaseous losses underestimated.

This work will measure nitrogen losses and plant uptake under tile drained and undrained conditions. Specifically, we will determine potential leaching rates of nitrate-N on a common sodic soil series.

The main objective of this study is to investigate the interactions between tile drainage, nitrogen uptake and losses on a sodic soil. Specific objectives include:

- Determination of plant nitrogen uptake from a sodic soil
- Assess whether tile drainage on a sodic soil increases nitrate leaching potential

Field plots with a tile drainage treatments (tile drained, controlled tile drained, and undrained control) were established in the fall of 2012 on an Exline soil (fine, smectitic, frigid Leptic Natrudolls) in Richland County, ND. Data on soil penetration resistance, soil enzyme activity levels for nutrient cycling, and soil chemical properties have been collected throughout the 2013 growing season.

### **Significance**

Soil sodicity impacts over 4 million ha in North Dakota. Increases in salt affected areas are associated with elevated groundwater tables and precipitation patterns over the last 20 years. Agricultural producers in eastern North Dakota are installing subsurface tile drainage to aid in the removal of excess soil water with a secondary benefit of removing salts. Increases in tile drainage have been linked to water quality concerns as nitrates are easily leached through the tile drain. This work will assess nitrogen uptake in crops and nitrogen leaching potential in sodic soils.

# **Quantification of Spatio-temporal Distribution of Surface Ponding and Related Dynamic Processes**

**Project Number:** 2014ND285B

**Fellow:** Noah Lebassi Habtezion

**Adviser:** Xuefeng Chu

**Start Date:** 3/1/2014

**End Date:** 2/28/2015

## **Publications**

Chu, X, and Habtezion, N, 2014. Applications of the Green-Ampt method across scales, p282-291. In: Water without Borders, Proceedings of the 2014 ASCE World Environmental and Water Resources Congress edited by Wayne C. Huber. American Society of Civil Engineers.

## **Presentations**

Noah Habtezion and Xuefeng Chu. "Effects of multiple rainfall events on soil water dynamics and surface hydrologic response" ASCE World Environmental and Water Resources Congress, Austin, TX. May 17-21, 2015.

Xuefeng Chu and Noah Habtezion. "Applications of the Green-Ampt method across scales" ASCE World Environmental and Water Resources Congress, Portland, OR. June 1-5, 2014.

Noah Habtezion and Xuefeng Chu. "Surface microtopography and its significance on spatial distribution of hydrologic processes" ND EPSCoR/IDeA State Conference, Grand Forks, ND. April 29, 2014.

## **Research**

Surface depressions and the relevant surface ponding dynamics have unique hydrologic features and play important roles in overland flow generation, the occurrence of floods and droughts, the hydrodynamics and ecological functions of the associated wetlands, and the sustainability of the related agricultural systems in North Dakota. Thus, the knowledge of temporal and spatial distributions of depressions and the quantitative methods of surface ponding dynamics would improve the understanding of such problems and help identify effective strategies and solutions.

This study will focus on the important water resources topics with broad practical implications in North Dakota associated with surface ponding, depression filling-spilling-merging processes, and discontinuous overland flow. The specific objectives of this study are:

- to quantify surface depressions and surface ponding across temporal and spatial scales using the puddle-to-puddle (P2P) modeling system developed in our group, and
- to examine surface ponding dynamics and overland flow generation under the influence of a number of factors, including surface microtopography, rainfall features, soil properties, and initial soil moisture contents.

## **Significance**

Specifically, the P2P model will provide detailed simulation outputs for all the scenarios, including puddles and their microtopographic characteristics, spatial and temporal variations in surface ponding, P2P filling-spilling-merging-splitting dynamics, outlet hydrographs, infiltration and unsaturated flow, soil moisture distributions, and hydrologic connectivity.

This study is expected to improve our understanding of the critical role of surface ponding and overland flow dynamics. Modeling of surface ponding has broad practical implications and application potentials across different fields. Particularly, such a detailed study on surface ponding and overland flow generation would potentially help identify better solutions for flood prediction and control.

# **Sodic soil characterization and management on subsurface drainage**

**Project Number:** 2014ND286B and SWC

**Fellow:** Yangbo He

**Adviser:** Thomas DeSutter

**Start Date:** 3/1/2014

**End Date:** 2/28/2015

## **Publications**

He, Y., T. DeSutter, F. Casey, D. Clay, D. Franzen, D. Steele. 2015. Field capacity water as influenced by Na and EC: Implications for subsurface drainage. *Geoderma* 245-246:83-88.

He, Y., T.M. DeSutter, D. Hopkins, D. Wysocki, and D. E. Clay. 2014. The relationship between SAR1:5 and SARe of three extraction methods. *Soil Sci. Soc. Am. J.* doi:10.2136/sssaj2014.09.0384.

## **Presentations**

He, Y., T. DeSutter, L. Cihacek, D. Clay, F. Casey, D. Franzen, S. Clay, and D. Steele. "Behaviors of Na-affected soils: implications for subsurface drainage". ASA, CSSA, &SSSA International Meeting, Long Beach, CA. Nov. 2-5, 2014.

He, Y., and T.M. DeSutter. "Advances in our Knowledge of Dispersion and Swelling with Soil Sodium and the Interaction of Sodium Chemistry with Soluble Salts". Presented at North Dakota Agricultural Association, Annual meeting. January, 2014. Fargo.

## **Research**

Many soils in ND are being drained through the use of subsurface tiles. The purpose of subsurface drainage is to 1) decrease excess soil water, specifically at times of planting and harvesting and 2) remove soluble salts from the root zone (Chatterjee and DeSutter, 2012; Franzen, 2007). However, as noted by Cihacek et al. (2012), many of the soils may be negatively impacted because sodium is part of the exchange complex. Sodium is known a dispersant and this dispersion or swelling is accelerated when the concentration of soluble salts is reduced, which will likely occur in tile-drained soils (Cihacek et al., 2012; Curtin et al., 1994a). Dispersion and or soil swelling can lead to decreased Ksat, water percolation, and increased runoff, and finally a decrease in drainage performance. Currently there are no management strategies that have been developed for tile-drained soils in to help combat the effects of high sodium and low electrical conductivity or to prevent these phenomena from occurring. Detailed interpretation of chemical factors involved in sodic soils during tile drainage is incomplete.

The main objective of this study is the characterization and management of sodic soils for tile drainage. The specific objectives include:

- Determine physical and chemical properties (Ksat, dispersion, swelling, and pore volumes of water) of sodic soils
- Develop management guidelines and treatment options for sodic soils that will be or have been subsurface drained

Investigation of how pure clay minerals react under different sodicity and salinity levels was completed and paper with title of “Dispersion of pure clay minerals as influenced by Ca to Mg ratios, SAR, and EC” was published by Soil Science Society of America Journal (77:2014-2019). For the project for which I am seeking funding, the effect of solution electrical conductivity and sodicity levels on sodic soil water holding capacity has been completed. The manuscript is being prepared and plans to be submitted to the Journal of Soil and Water Conservation for review. The characterization of the spatial distribution of sodium as related to topography will be started in May 2014.

### **Significance**

The disruptive effect of sodicity on the soil structural stability is a function of swelling and dispersion. Both of these processes may lead to a reduction of water infiltration and movement. Swelling commonly occurs in 2:1 dominant type of clays (like the clays we have in North Dakota) when water enters into their interlayer region. In sodic soils, high  $\text{Na}^+$  exists compared to divalent cations ( $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$ ). The size of  $\text{Na}^+$  has little disruption on the water within the clay's interlayer close to clay surface and thus as the soil is wetted, water moves from the solution phase to these interlayers, causing swelling. When  $\text{Na}^+$  is present the interlayer water is “rigid” and does not easily flow. Swelling is maximized when the concentration of  $\text{Na}^+$ , expressed as SAR (sodium adsorption ratio), is high and the EC is low, conditions that are typical of the Btn horizon in most sodic soils. This condition may also occur as salts are moved through the soil profile via gravimetric water in tile-drained systems. Therefore, improving our understanding of how subsurface drainage impacts soil chemical and physical properties is required for improved management of both sodium-affected soils and subsequent soil water.

# Biopolymers for Phosphate Removal from Eutrophic Lakes

**Project Number:** 2014ND287B

**Fellow:** Mohammad Hossain

**Adviser:** Achintya Bezbaruah

**Start Date:** 3/1/2014

**End Date:** 2/28/2015

## Publications

1. Mohammad Enayet Hossain, Talal Almeelbi, Harjyoti Kalita, Cody Ritt, and Achintya N. Bezbaruah. Phosphate Removal by Metal Cross-Linked Biopolymers. Proceedings of the ASCE/EWRI World Environmental and Water Resources Congress, Portland, Oregon, June, 2014. pp. 222-226 (5 pages)

## Presentations

1. **Hossain, M.E.**, Ritt, C., Bezbaruah, A.N. Iron Cross-linked Biopolymer for Aqueous Phosphate Removal, Surface Water Treatment Workshop, American Water Works Association, Fargo, North Dakota, April, 2014. (Poster)
2. **Hossain, M.E.**, Ritt, C., Bezbaruah, A.N. Iron Cross-linked Biopolymer for Aqueous Phosphate Removal, North Dakota Water Quality Monitoring Conference, Bismarck State College and National Energy Center of Excellence, Bismarck, North Dakota, March, 2014. (Poster)

## Research:

Phosphorus (P) is important for the growth of plants and microorganisms in most ecosystems. However, excess phosphorus present in aquatic bodies leads to the overgrowth of algae and plant species (an indicator of eutrophication of the waterbodies). While eutrophication is a natural process, it is accelerated through anthropogenic activities. Accelerated eutrophication not only impacts the aquatic life but indirectly hampers the economic progress of communities that rely on aquatic food and other resources. Dissolved phosphate as low as ~0.02 mg/L is known to cause profuse algal growth in waters, thereby posing a host of problems. Eutrophication of lakes is a major problem in North Dakota. According to the North Dakota Department of Health (NDDH), ~52% (87 lakes) are eutrophic and ~17% (29 lakes) are hypereutrophic among the lakes surveyed. Further, ~56% of the lakes are considered threatened indicating that the continuation of current water quality and/or watershed trends would make it unlikely that these waterbodies will continue to support aquatic life and the water will be fit for human uses. The amount of P-compounds in waters should be reduced to prevent eutrophication of lakes and other surface waters. It is imperative to devise effective methods to remove excessive phosphate from water and wastewater. Presently, there is a significant gap in technology to remove low concentration P from waters, specifically from eutrophic lakes. There is another aspect to the P issue. Phosphorus for fertilizer production is mined chiefly from select phosphate mines from Morocco, Western Saharan region, Peru, and China. The United States' phosphate imports come from Morocco and Peru. Phosphorus is a nonrenewable resource and a recent assessment indicated that natural phosphate deposits will last for approximately 60-240 years. The present NDWRRI research involves the use of novel biopolymer beads for phosphate removal and reusing the beads (with sorbed phosphate) for agricultural purposes as source of phosphate for plants. The research, if successful, will provide a robust and sustainable technology (or technologies) to remove and recover aqueous phosphate.

The main objective of this research is to determine if biopolymer beads can be used to remove aqueous phosphate and then use the phosphate as a plant fertilizer. The specific objectives of this work are:

1. To investigate the phosphate sorption characteristics of the beads
2. To identify the sorption and desorption mechanisms
3. To determine the feasibility of using the beads in eutrophic lakes
4. To measure the bioavailability of bead removed P for agriculture uses

**Significance:**

This research work will enable us to alleviate the problem of eutrophication of lakes. In addition to dealing with eutrophication, this research will contribute towards generating a new source for phosphorus for agricultural uses and, thus, contribute towards better crop production in North Dakota and improve global food security.

# **A Study of the Spatial and Temporal Characteristics of Drought and its Impact in North Dakota**

**Project Number:** 2014ND288B

**Fellow:** Navaratnam Leelaruban

**Advisers:** G. Padmanabhan and Adnan Akyuz

**Start Date:** 3/1/2014

**End Date:** 2/28/2015

## **Publications**

Odabas. M., Leelaruban. N., Halis Simsek, and G. Padmanabhan (2014) Quantifying Impact of Droughts on Barley Yield in North Dakota, USA Using Multiple Linear Regression and Artificial Neural Network. *Neural Network World*, Vol. 24, No.4, pp. 343-356.

Halis Simsek, Bilal Cemek, Leelaruban, N, G. Padmanabhan., An assessment of drought impact on barley yield using a county wide drought Severity and Coverage Index and Adaptive Network-based Fuzzy Inference System (ANFIS) Model. Proceedings of the 2nd International Symposium on Innovative Technologies in Engineering and Science (ISITES), 18-20 Jun 2014, Karabuk, Turkey.

## **Presentations**

Leelaruban. N., Odabas. M., Halis Simsek, and G. Padmanabhan , 2014. Application of Artificial Neural Network to study the Barley yield under different Drought Conditions. North Central ASABE/CSBE Intersectional Meeting, March 28-29, 2014, Brookings, SD [Podium Presentation]

Halis Simsek, Bilal Cemek, Leelaruban, N, G. Padmanabhan., An assessment of drought impact on barley yield using a county wide drought Severity and Coverage Index and Adaptive Network-based Fuzzy Inference System (ANFIS) Model. 2nd International Symposium on Innovative Technologies in Engineering and Science (ISITES), 18-20 Jun 2014, Karabuk, Turkey.

## **Research:**

Drought is a complex phenomenon, and difficult to accurately describe because of its complex characteristics. It is well known that drought is a spatially and temporally varying natural hazard. Understanding drought severity, frequency, duration, and spatial extent is critical in drought mitigation and planning. It is crucial to understand how drought propagates in space and time for effective management and mitigating measures. Also, it is well known that drought significantly impacts agriculture, environment, and society. A clear understanding of drought impact on these sectors will help address planning for future droughts. Quantifying drought impact is difficult because of the complex characteristics of drought and also the impacted sectors.

Various drought indices are used to identify and monitor drought situations, and to decide the timing and level of drought responses. The most commonly used indices include (i) Palmer Drought Severity Index (PDSI) (ii) Standardized Precipitation Index (SPI) (iii) Crop Moisture Index (CMI) and (iv) U.S Drought Monitor Index. All except the last one are severity indicators and do not reflect the spatial extent of droughts. Each index has its own advantages and disadvantages from the users' perspectives. A composite index which will reflect the severity and spatial coverage corresponding to that severity together, particularly at the county level will be useful for resource allocation for drought mitigation purposes.

It is estimated that drought costs the United States \$6–8 billion annually. Drought creates stress on water sources (i.e., surface water, groundwater), and on soil moisture. This will impact water-dependent industries including agriculture, water supply, and recreation. Researchers have developed several techniques to understand the drought impact.

There is still a need for comprehensive drought study to understand the drought and its impact in North Dakota. Especially, the recent development and availability of computational tools can help develop better understanding of drought. The recent drought events in this region emphasize the need for a rigorous drought study.

Objectives of the study are:

1. To study the drought propagation mechanism based on the geospatial and temporal characteristics of droughts to gain a better understanding of the phenomenon
2. To study the impact of drought on water resources and agriculture in North Dakota

A refined county-level drought Severity and Coverage index is developed for drought management based on U.S Drought Monitor (USDM) drought severity and coverage values. The spatial variation of drought severity and frequency within North Dakota are analyzed and mapped. Based on the relationship between crop yield and USDM severity coverage values a crop specific county-wide drought Index is proposed. Transition probabilities are derived for crop yield categories from state of less severe drought year to more severe drought year using Markovian process. Impact of drought on barley yield is studied using Multiple Linear Regression and Artificial Neural Network. Responses of groundwater level to drought are being investigated based on drought severity and duration.

### **Significance:**

North Dakota has experienced several drought events in the past. The impact of drought in this region has significant influence on the economy, social, and environmental sector of North Dakota. This study will analyze the characteristics and impact of drought in this region. The results of this study will be useful for state agencies, and water dependent industries to plan and manage the future drought events. In addition, this study will propose potential actions to be taken in order to improve the drought monitoring and mitigation in the state of North Dakota. Though this study focuses on the state of North Dakota, the methodologies used in this study can be adopted for other places. In general, this research will contribute to understand the propagation mechanism of drought, and assess the impact of drought on agriculture and groundwater resources using novel approaches.

# **Snowmelt water infiltration into frozen soil in Red River of the North Basin**

**Project Number: 2014ND289B**

**Fellow:** Debjit Roy

**Advisers:** Xinhua Jia

**Start Date:** 3/1/2014

**End Date:** 2/28/2015

## **Presentations**

Debjit Roy, Xinhua Jia, Dean Steele and Thomas DeSutter. “Soil water release curve development by field and laboratory setups” ASABE Intersectional Meeting, Brookings, SD. March 28-29, 2014.

Xinhua Jia, Joel Ransom and Debjit Roy. “ Prediction of phenological development and maturity of two corn hybrids in eastern North Dakota” 2014 ASABE Annual International Meeting, Montreal, Canada. July 12-16, 2014

Debjit Roy, Xinhua Jia and Dean D. Steele. “HYDRUS model simulation of infiltration rates into undrained and tile drained soils” North Central ASABE Conference, Fargo, ND. April 10-11, 2015.

Debjit Roy, Xinhua Jia, Dean Steele and Xuefeng Chu. “ Measurement and simulation of infiltration rates into undrained and subsurface drained soils” 2015 ASABE Annual International Meeting, New Orleans, LA. July 26-29, 2015.

## **Research:**

Snowmelt water infiltration into frozen soil is an important but complicated process that can affect surface water runoff and groundwater recharge. Many factors, such as soil moisture, soil temperature, water release rate from the snow cover, energy content of infiltrating water, porosity, soil cracks, presence or absence of macropores and also complex processes of heat and mass transfer through the frozen soils affect the total infiltration process into frozen soils. In northern hemisphere, nearly 60 percent of the land surfaces are seasonally frozen and North Dakota is a part of that area. There is no simple and clear answer on how water infiltrates into frozen soil. The lack of understanding of the infiltration process into frozen soil is the major limiting factor affecting spring flood forecasting. In recent years, during the spring flood events in the Red River of the North Basin (RRB), flood forecasting cannot be estimated accurately due to lack of data on infiltration into frozen soil. Any error in flood prediction can cause significant financial losses and threaten 200,000 people lives in the Fargo-Moorhead metro area as well as people and animals in the entire basin. The proposed research project will focus on snowmelt infiltration characteristics into frozen soils. A snowmelt water infiltration model will be developed which can help to overcome the current obstacles in order to accurately predict spring flood.

The research project will focus on snowmelt infiltration characteristics into frozen soil. The specific objectives of the research study are:

- To measure infiltration amount/rate into frozen soil at field and laboratory conditions.
- To develop a snowmelt water infiltration model based on historic, laboratory and field data.
- To evaluate model outputs with other available infiltration models.

Hydra Probe II sensors for soil moisture and temperature measurement, SR50A Sonic ranging sensor for monitoring snow depth, and modified TE525 rain gage for rainfall and snow fall measurement are installed in the field. Three wireless weather stations were also set up in the research site to collect weather parameters like air temperature, relative humidity, solar radiation, wind speed and direction. A Cornell sprinkler infiltrometer is now being calibrated and tested in field for infiltration measurement.

**Significance:**

Understanding the infiltration process into frozen soils could have a broad impact to the hydrological field for the entire and especially in permafrost regions. It would help to better understand the runoff processes and flooding events in winter and spring. Properly adjusted numerical infiltration model could be used to predict actual runoff peaks to prevent damage from floods or to prevent overestimation of runoff. The benefit from this proposed study will be several million dollars each year in flood preparation.

# Evaluation of Bioavailable Dissolved Organic Nitrogen Using Various Algal Species

**Project Number:** 2014ND290B

**Fellow:** Jingyi Sun

**Advisers:** Halis Simsek

**Start Date:** 3/1/2014

**End Date:** 2/28/2015

## Presentations

Sun, J., Kasi, M., Khan, E., Simsek, H., 2014. Nitrogen removal in municipal wastewater using pure cultured algae. Poster presented at the 86th Annual North Dakota Water and Pollution Control Conference (NDWPCC), October 14-16, Fargo, North Dakota.

Sun, J., Kasi, M., Khan, E., Simsek, H., 2014. Bioavailability of organic nitrogen in wastewater to two different pure culture algal species. Presented at American Society of Agricultural and Biological Engineers (ASABE) intersectional Meeting. March 28-29, Brookings, South Dakota.

## Research

Dissolved organic nitrogen (DON) from final effluent of WWTPs and animal feedlots from agricultural areas are important nutrient sources for bacterial and algal communities in surface waters such as rivers, lakes, and estuaries. Excess amount of DON in surface waters can cause excess algal growth and dissolved oxygen depletion and ultimately cause eutrophication in water ecosystem. Bioavailable DON (ABDON) is a fraction of DON that is directly or indirectly available as a nitrogen source for algal species through hydrolysis process. ABDON is calculated as the differences of DON initial and DON final during the incubation period. This research will provide the data that both plants may expand their effluent qualities by reducing DON and TDN and may reduce the treatment cost by using algae in the WWTPs. Algal usage in WWTPs will provide a basis for protecting aquatic ecosystems from cultural eutrophication.

The main scope of this study is to collect DON and ABDON data from three locations of two different WWTPs and two locations from animal feedlots in order to achieve the following objective:

1. To investigate DON and ABDON for four different algae species in a two-stage trickling filter and an activated sludge WWTPs, and in an animal feedlots.
2. To examine mixed culture algae and algae + bacteria interactions for 4 different algal species to determine the best algal species to utilize ABDON.

Two sets of experiments determining ABDON using algae *Chlamydomonas reinhardtii*, and *Chlorella vulgaris* has been completed with different stages of wastewater from Fargo WWTP. Algae will be used in animal wastewater samples from feedlot to evaluate the ABDON under high nutrient conditions.

**Significance**

This research will provide important outcomes to improve the quality of surface waters (rivers, lakes, etc.) in North Dakota by minimizing the nutrient entrance to water ecosystem either from WWTPs or from animal feedlots. Using algae to treat the wastewater is a natural and cost effective way. For the first time, different algal species will be used to examine the bioavailability of dissolved organic nitrogen in a two-stage trickling filter WWTP. Determining the best treatment condition for per pure-cultured and/or mixed cultured algae will help us to understand nutrient removal potential of algae very well.

# The Role of Algal Species on Phosphorus Bioavailability

## Project Number:

**Fellow:** Mitchell Swanson

**Advisers:** Eakalak Khan

**Start Date:** 3/1/2014

**End Date:** 2/28/2015

## Research

Eutrophication of waters is one of the major issues society faces, it degrades water quality and can lead to dead zones such as in the Gulf of Mexico. Phosphorus is one of the key nutrients that lead to eutrophication when sufficient concentrations are present in water bodies. However it is the bioavailable phosphorus (BAP) that is of real concern, because this is the phosphorus algae use to grow. *S. capricornutum* has been the standard algal species utilized to estimate BAP. This study will utilize two additional species, *C. vulgaris* and *C. reinhardtii*, for the comparison of BAP estimates.

It is hypothesized that BAP differs between different algal species as organisms fill different niches in ecosystems. There is little research concerning BAP especially in the area of environmental engineering. This research will further our understanding of phosphorus and how it is utilized by algae after being discharged and can impact how future nutrient standards are managed.

The main objective of this study is to investigate phosphorus bioavailability when examined from multiple algal species. The following objectives have been developed:

- Determine BAP from three different species when present individually and as a group.
- Analyze P-species distribution before and after bioavailability assays.
- Investigate the effect of enzymatic activity on BAP
- Evaluate the effect of pretreatment of samples with UV radiation on BAP.

Methods to measure the different phosphorus fractions have been determined and standards curves replicated successfully. Various methods of measuring algal growth for the determination of BAP have been explored and a method selected. Standard curves comparing algal growth to BAP will be created shortly. Samples incubated with the mixed algal inoculum will be examined through a microscope at the end of the incubation period in order to determine algal species ratios and to determine which algal species compete for nutrients more efficiently. After the replication of standard curves for algal growth and therefore BAP, secondary effluent samples will begin to be examined.

## Significance:

Results will show whether BAP estimates vary between different algal species. If results vary this research will show that the current standard algal species of *S. capricornutum* is not necessarily a reliable estimate of BAP and that other algal species may provide a higher estimate of BAP. The research will also show how the algal species affect the concentration of the different P-species from multiple WWTP effluents.

The effects of enzymes and UV light on P-species and their potential to convert non-BAP to BAP will also be determined. This provides further understanding on how algae and other physical factors are converting the P-species into usable forms that can be taken up by algae.

# **Effects of Calcium Based Surface Amendments on the Hydraulic Conductivity and Selected Physical Properties of Subsurface Drained Sodic-Saline Soils**

**Project Number:** SWC

**Fellow:** Anthony Wamono

**Advisers:** Dean Steele and Zhulu Lin

**Start Date:** 3/1/2014

**End Date:** 2/28/2015

## **Presentations**

Anthony Wamono, Dean Steele, Zhulu Lin, Thomas DeSutter, and Xinhua Jia. "Effects of calcium based surface amendments and cover crops on the penetration resistance of subsurface drained sodic-saline soils." American Society of Agricultural and Biological Engineers 2014 Annual International Meeting, Montreal, Quebec Canada. July 13-16, 2014.

Anthony Wamono, Dean Steele, Zhulu Lin, Thomas DeSutter and Xinhua Jia. "Penetration resistance measurements to evaluate the effects of calcium amendments and water management strategies in sodic-saline soils." American Society of Agricultural and Biological Engineers 2014 North Central Intersectional Meeting, Brookings, SD. March 28-29, 2014.

Dean Steele, Thomas Scherer, F. Adnan Akyuz, Anthony Wamono, and Thomas DeSutter. 2014. Evaluation of a low-cost optical rain sensor. American Society of Agricultural and Biological Engineers 2014 North Central Intersectional Meeting, Brookings, SD. March 28-29, 2014.

## **Research**

The installation of tile drainage to remove excess moisture in the fall and spring poses a risk of transforming saline-sodic soils to sodic soils in the Northern Great Plains. Yet, leaching of sodic soils with low EC water results in the swelling of the soil, dispersion of clay particles and consequently the breakdown of soil structure. Changes in soil hydraulic and physical properties ensue, such as reduced hydraulic conductivity and increased soil hardness when the soil is dry.

In this study, the cone index (CI), a measure of penetration resistance, will be determined for the plots at Wyndmere and Grand Forks sites in North Dakota using a hand held penetrometer. Soil water content measurements will augment the CI data. Statistical analyses of CI relationships with depth, moisture content, drainage state, and surface treatments will be determined. A Cornell sprinkler infiltrometer will be used to measure the changes in hydraulic conductivity of the plots. The effectiveness of calcium based surface amendments and cover crops under drainage and non-drainage options on improving the hydraulic and mechanical properties soil will be evaluated.

The main objective of this study is to evaluate effectiveness of calcium based surface amendments and cover crops under drainage and non-drainage options on improving the hydraulic and mechanical properties of the soil.

The penetration resistance represented by the cone index was measured for each plot of the 45 plots at Wyndmere and at Grand Forks. A hand held penetrometer was used to take readings at 2.5 cm depth intervals from 0 to 45 cm. A total of ten readings were taken for each plot. In contrast to trafficability, higher CI relates to higher bearing capacity of the soil to support heavy equipment, therefore an increase in the values of penetration resistance for soils treatments indicate improvement of trafficability of the soil. Given that CI is sensitive to moisture content, soil samples from 0-15 cm, 15-30 cm and 30-45 cm

depth were taken and gravimetric moisture content was determined. A relation to account for the influence moisture on the CI was pursued.

A Cornell sprinkle infiltrometer was used to determine the gypsum treatments' effects on the water infiltration properties of a field with tile drainage. Three infiltration tests were carried out on each of three 10 t ac<sup>-1</sup> gypsum and check split plots under tile-drained main plots with free outflow. Infiltration rate curves have been developed for these plots. Additionally, key soil hydraulic parameters derived from the infiltration curves will be used as input data for Hydrus 1D modeling. Soil samples for moisture content determination were taken weekly during the corn growing season; these too will serve as key input data for Hydrus 1D modeling.

### **Significance**

Maintaining productive and sustainable agriculture on poorly drained soils depends on understanding the risk of hard setting posed by draining saline-sodic soils. The results of this study will help develop guidelines and recommendations for removing excess water, thereby improving the trafficability and workability of sodic-saline soils.

# **Flash Flood Potential Mapping Using GIS and Flash Flood Potential Index (FFPI) in Turtle River and Forest River Watersheds, North Dakota**

**Project Number:** SWC

**Fellow:** Dasuni Arachchige

**Advisers:** Gregory Vandeberg

**Start Date:** 3/1/2014

**End Date:** 2/28/2015

## **Presentations:**

Ranapathi Arachchige, D.J. and G. Vandeberg. "Mapping Flashflood Potential Using GIS and the Flash Flood Potential Index in the Turtle River and Forest River Watersheds, North Dakota," Annual Meeting of the Association of American Geographers, Chicago, IL. April 23, 2015.

## **Research:**

Flash flooding is one of the most disastrous weather related natural hazards causing extensive damages and death. As it occurs rapidly and within a very short period of time, proper flash flood risk assessments, predictions and warnings are extremely important to make community resilient to flash flooding.

Historically flash flood hazards have been addressed in many ways in the United States. The commonly used applications are based on hydrologic and meteorological data. Flash Flood Guidance (FFG) and Gridded Flash Flood Guidance (GFFG) are two examples that have been used to monitor and predict imminent flash flooding by National Weather Service (NWS). In this research, the focus is on physiographic parameters that can help to predict the occurrence and intensity of flash floods. Flash Flood Potential Index (FFPI), designed by Gregory Smith in 2003, looks at four physiographic parameters (slope, soil, land use, and vegetation) that influence hydrologic response and flash flood potential. Mainly, FFPI is going to be applied to the selected study area.

North Dakota has experienced severe flood events throughout the history including flash flooding. Turtle River and Forest River located in upper Red River Basin, are two watersheds, which have been subjected to significant flash flooding. Digital Elevation Models (DEM) are the primary elevation datasets in this study. The DEMs have resolutions of 30 meter and 3 meters (LiDAR based data set). Arc GIS is the primary tool that will be used to produce hydrologic models and the FFPI for these watersheds.

## **Project Objectives:**

- Identify critical areas of the Turtle River and Forest watersheds of the upper Red River basin that have a high potential for flash flooding using FFPI
- Evaluate the sensitivity of this index to different resolutions of digital elevation models (e.g. 30m and 3 m) as well as ruggedness of landscape.
- Evaluate the effectiveness and applicability of the FFPI model compared with historical flash flood events that have occurred in the two watersheds using storm datasets.
- Conduct a standard hydrologic analysis of a subbasin of the study area and compare to FFPI

**Significance:**

Flash flooding is second to heat waves in weather related natural hazards causing extensive damages and deaths. These types of floods occur rapidly with significant impacts. Rapidly moving water, only a few centimeters deep, can lift people off their feet, and only a depth of a 0.3-0.6meters, is needed to sweep cars away. According to a 20 year National Weather Service Study ending in 2006, an average of 150 people per year perished due to hundreds of significant floods that occurred in the United States. Use of an effective and accurate potential assessment index will benefit emergency managers, planning boards, and other local officials and groups who are responsible for making communities more flash flood resilient.

# Quantifying Phosphorus Cycling and Fate within an Abandoned Feedlot

**Project Number:** SWC

**Fellow:** Prosper Gbolo

**Advisers:** Phil Gerla

**Start Date:** 3/1/2014

**End Date:** 2/28/2015

## Publications

Gbolo, P, and Gerla, PJ, 2015. Spatiotemporal distribution of soil nutrients from an abandoned cattle feedlot. *Journal of Soils and Sediments* 15(1):71-80. DOI: 10.1007/s11368-014-0971-8

Gbolo, P, Gerla, PJ, and Vandenberg, GS, 2015. Using high-resolution, multispectral imagery to assess the effect of soil physical and chemical properties on vegetation reflectance at an abandoned feedlot. GeoCarto International. DOI: 10.1080/10106049.2014.985746

Gbolo, P, and Gerla, PJ, 2014. Harnessing sequestered phosphorus from abandoned feedlots: A feasible alternative to depleting phosphorus. *SCOPE Newsletter* 106 (All Contributions: Visions for Sustainable Phosphorus Tomorrow), pp. 34-35.

Gerla, PJ, Gbolo, P, and Gorz, KL, 2014. Large-Scale prairie restoration: managing for resilience”, Technical Report for the collaborative project between the Red Lake Watershed District, U.S. Fish and Wildlife, and the University of North Dakota (March, 2014), 150 pp.

## Presentations

Gerla, PJ, and Gbolo, P, 2014. Mapping the fate of nutrients in wetlands adjacent to an abandoned feedlot. Proceedings of the Joint Aquatic Sciences Meeting 2014, Abstract No. 14855, P 325. (Oregon Convention Center, Portland, OR - May 2014).

Gbolo, P, and Gerla, PJ, 2014. Plants, soils, and waters’ role in mitigating environmental problems associated with an abandoned feedlot, University of North Dakota Scholarly Forum (Grand Forks, 2014).

Gerla, PJ, and Gbolo, P, 2014. Mapping the fate of nutrients at the abandoned Crookston Cattle Company feedlot: Proceedings of the North Dakota Water Quality Monitoring Conference (Bismarck, ND - March 2014).

Gerla, P., Gbolo, P., and Gorz, K.L., “Large-Scale prairie restoration: managing for resilience”, Technical Report for the collaborative project between the Red Lake Watershed District, U.S. Fish and Wildlife, and the University of North Dakota (March, 2014).

## **Research**

Nutrients are very important chemical species that play important roles in soils, water, and living organisms, and are transformed from one species to another through different biogeochemical processes and cycles in different environments. Currently, there are gaps that remain in our knowledge of the cycle, mobility, speciation, and sequestration of P in different environments. Nutrient quantification in runoff and nutrient leaching in groundwater systems has received attention recently. In view of this, Gbolo's research will address the aspects of the P cycle within a heterogeneous beach ridge and wetland environment. This study will involve groundwater, soils, surface water, plants tissue, and microorganism analyses as part of a larger study to test the hypothesis that when P is transported by infiltration, it is sequestered and immobilized within natural sinks. Objectives include:

- Evaluate the phosphorus budget of the feedlot system
- Investigate the variability of some nutrients and trace elements associated with P immobilization
- Quantify the amount of phosphorus within the natural plant community and how important they can be for phytoremediation
- Determine the lithologic units in the area and the role they play in the transportation and sequestration of nutrients

The site has been characterized using monitoring wells, nested wells, and soil pore water samples for groundwater nutrient monitoring. Grab and composite soil samples from various soil horizons and plant tissues have been sampled and analyzed during the 2012 and 2013 field season. Preliminary results of the groundwater have been published in the journal *Hydrology and Earth System Sciences (HESS)* and presently, the results of the soils and vegetation are in the final stage of review for submission.

## **Significance:**

This research will bridge some of the research gaps concerning nutrient pathways in surface and subsurface systems, and the relationship between nutrients, organic matter, soil physiochemical properties, and some chemical species. Result of this research will have an implication for feedlot management and pollution control, and also help develop regulations for protecting surface and groundwater quality without placing undue hardship on animal production.

# Development of a Model for Subsurface Drainage and Subirrigation Water Management

**Project Number:** SWC

**Fellow:** Kelsey Kolars

**Advisers:** Xinhua Jia

**Start Date:** 3/1/2014

**End Date:** 2/28/2015

## Research

In the Midwest, shallow water tables caused by excess precipitation and poor drainage conditions have the potential to increase soil salinity and water logging, and make field trafficability difficult (Guitjens et al., 1997; Skaggs et al., 2010). Lately, the negative impacts of shallow water tables have been seen in the Red River Valley (RRV), which is in large part due to a wet weather cycle since 1993 (Jia et al., 2012). This wet weather cycle has encouraged the installation of subsurface drainage systems (SSD), which help to remove excess water from the soil profile and make trafficability with heavy machinery easier during planting and harvest.

However, these SSD systems have been shown to have a negative impact on water quality by increasing the amount of nitrates and soluble salts in the outflow compared to surface runoff alone (Jia et al., 2012; Skaggs et al., 2010). Thus, an emphasis has been put on controlled drainage (CD) and subirrigation (SI) systems for their ability to not only reduce outflow by keeping water in the field in late spring, but also allow for subirrigation when it is needed by crops. Even though a CD + SI system has many benefits, its success relies heavily on proper management. One potential management option involves the inclusion of SSD, CD, and SI in the Checkbook Method for Irrigation Scheduling.

The Checkbook Method for Irrigation Scheduling is a popular and relatively simple method developed at NDSU and used in the upper Midwest to help with irrigation management decisions (Steele et al., 2010). However, the Checkbook Method is meant for use with an above ground sprinkler irrigation system and does not consider drainage outflow through a SSD system. Thus, the development of irrigation efficiency for a SI or CD + SI system would be helpful when it comes to determining the time and amount of irrigation water needed to reach field capacity. The introduction of SI and SSD in the Checkbook Method would allow the landowner to better manage the soil moisture deficit so that the field remains at optimal moisture conditions. In the end, the results of this study will allow a better understanding on the effects of a shallow water table on crop water consumption and, as a result, assist in the development of better management plans using the modified Checkbook method for a CD + SI system. Benefits of a better management plan for a CD + SI system consist of increased yields, improved water quality, and reduced pumping costs.

The research project will focus on subsurface drainage and subirrigation water management by modifying the Checkbook irrigation method. The specific objectives of the study are to:

- Determine the relationships between shallow water tables and crop water consumption.
- Develop net irrigation amount using field measured water table, soil moisture, irrigation/drainage, and weather data.
- Incorporate SI and SSD into the modified Checkbook method to develop a best water management practice for SSD and SI systems.

A CD and CD + SI system was installed in the spring of 2012 and both systems were used over the 2012 growing season. In the CD and CD + SI fields, 12 piezometers were installed in the fall of 2011 and water level loggers have been placed in each well during the 2012 growing season. In the CD + SI field, an eddy covariance and wireless weather stations have been set up and collect soil moisture, ET, wind speed, soil temperature, relative humidity, air temperature, and rain/snowfall data. In the CD field soil moisture sensors have been installed at six different depths to record soil moisture changes with respect to different water management practices and varying weather conditions. In 2013, the CD and CD+SI fields switched (i.e. the CD field became CD + SI and the CD + SI field became CD) as well as their associated instruments.

Over the summer of 2013, Kelsey presented a poster and wrote a conference paper titled “Using eddy covariance, soil water balance, and photosynthetically active radiation methods for corn evapotranspiration measurements in the Red River Valley” for the 2013 ASABE Annual International Meeting in Kansas City, MO. The paper not only presents comparisons among the three evapotranspiration (ET) methods (Photosynthetically Active Radiation (PAR), Eddy Covariance (EC), and Soil Water Balance (SWB)), but also ET comparisons among four water management practices (WMP) and two corn varieties. It was found that ET estimates through PAR and EC methods were well correlated with a coefficient of determination ( $R^2$ ) of 0.94 and root mean square error (RMSE) of 0.02 mm/30min. On the other hand, the ET estimates through SWB and EC methods showed little to no correlation. When comparing ET estimates among four different WMP’s it was found that ET rates were similar over all WMP’s. This was partially due to the abnormally dry growing season in which the water table remained below 6 ft the entire season, hence subsurface drainage systems had little effect on the water balance. In addition, no visible difference was seen among ET estimates for the two corn varieties.

Currently, the research has continued through the 2013 growing season. There has already been markedly different field conditions between the 2012 and the 2013 growing seasons, with 2013 being much wetter than 2012. Hence, 2013 data should provide good comparisons between dry and wet growing seasons along with varying WMP’s.

Regular updates on field activities/progress can be found at <http://aben-saregrant-ndsu.blogspot.com/>

### **Significance:**

The application and installation of SSD, CD, and SI systems in the RRV has dramatically increased over the last decade. With this increase also comes an increased need for a better understanding of how to optimally manage these systems. An increase in yield is seen along with a decrease in nitrate loadings and soluble salts to surrounding surface waters with these systems. By incorporating net irrigation and drainage into the Checkbook method, the landowner is given a simple, familiar, and effective tool to manage their system.

# **Bird-mediated Transport of Toxic Heavy Metals and Selenium from Marine and Terrestrial Sources to Freshwater Wetlands in North Dakota**

**Project Number:** SWC

**Fellow:** Lucas Wandrie

**Advisers:** Wendy Reed

**Start Date:** 3/1/2014

**End Date:** 2/28/2015

## **Research**

Toxic heavy metals and selenium are being transported from marine and terrestrial sources to freshwater wetlands in North Dakota by a migratory bird. Environmental levels of heavy metals and selenium are a cause for concern because of the potentially toxic effects for humans and wildlife and as such are often regulated and monitored. This study evaluates the role of Franklin's gull (*Larus pipixcan*), a bird that migrates long-distances, in moving heavy metal and selenium among aquatic habitats. This is accomplished by estimating organic contributions (e.g., feathers and guano) by Franklin's gulls to wetlands in North Dakota, via feathers and guano, and measuring heavy metal concentrations in the water, sediment, vegetation, aquatic invertebrates, and eared grebe (*Podiceps nigricollis*). The focus of this study is on cadmium and selenium concentration in the ecosystem as previous studies in Minnesota found elevated levels of selenium and cadmium in Franklin's gulls and eared grebes. Of special concern are cadmium levels because it is a known carcinogen. Currently, it is unknown as to whether cadmium levels in Franklin's gulls are still higher than that of other seabird species or if they have changed from levels found in the historic populations. It is also unknown as the whether historic levels differed between feathers made from South American and North American resources.

We collected feathers from juvenile and adult bird as concentrations of metals vary between life stages (i.e., eggs, juveniles, and adults) and from different breeding populations as metals concentrations also vary by region. We compared heavy metal levels in Franklin's gull feathers made from North and South American resources and between juveniles and adults. Furthermore, we collected eggs from Franklin's gulls and eared grebes to compare concentration differences between a species that forages in terrestrial and wetland environments (e.g., Franklin's gull) and one whose food sources are restricted to within the wetland (e.g., eared grebe). These analyses will complement our current data set of heavy metal levels found in Franklin's gull eggs. Additionally, we are interested in how the metals move throughout the environment once the feathers are degraded. This will be determined from elemental analysis of water, sediment, vegetation and aquatic invertebrates within the wetlands.

## **Significance**

Previous studies of metals and selenium in Franklin's gull and eared grebe have documented the concentration in tissues and eggs but have not attempted to use them as sentinels of environmental health. Additionally, by comparing heavy metal and selenium concentrations found in control wetlands to wetlands, we will be able to estimate the allochthonous inputs that is contributed by Franklin's gulls and determine if the wetland systems where they breed are impaired. Elemental analysis of *Typha* and aquatic invertebrates will provide information on the level of heavy metal and selenium exposure that occurs in organisms that complete their life-cycle within the wetland.

## Information Transfer Program Introduction

Information dissemination is done through an annual newsletter, and presentations and publications by grant and fellowship recipients. A web site also helps disseminating institute research information. The institute's website address is <http://www.ndsu.edu/wrri>.

Past newsletters can be accessed through the institute web site. Technical reports of Fellowship projects authored by the Fellows and advisers are also placed on the institute web site.

## Information Dissemination and Communication

**Project Number:** 2014ND292B

**Start Date:** 3/1/2014

**End Date:** 2/28/2015

**Principal Investigator:** G. Padmanabhan

Activities to disseminate institute and other research under this project included:

1. Maintaining web site as an effective way communicating to the public
2. Publishing the annual institute newsletter
3. Publishing Fellowship and other research done through the Institute
4. Hosting the annual "Distinguished Water Seminar"
4. Presenting research results to state and federal water agencies
5. Sponsoring or co-sponsoring local or regional conferences

The website of the Institute was updated at least quarterly, and more often when a research project wished to provide updates or when a Fellow graduates. The website provides additional details on the research. The list of Institute Affiliate Faculty with their expertise was updated. Research reports published by the institute were placed on this web site as and when they became available. The institute web site is: <http://www.ndsu.edu/wrri> .

The Institute continued its annual newsletter, which highlighted the graduate research fellowship program, the research grants associated with it, and general summaries of ongoing research. The newsletter profiled institute research and researchers and published other newsworthy water issues in the State.

The Institute continued its off-campus seminar series, designed to enhance communication between the State and Federal agency personnel and university faculty and students. Advisors and fellows present their research results to State and Federal professionals in Bismarck, the state capital. The Institute also encouraged its Fellows and faculty to attend seminars and conferences held in the region. Modest support to Fellows for travel was provided by the institute.

## 2014 North Dakota Water Quality Monitoring Conference

The institute partnered with North Dakota Department of Health, N.D. State Water Commission, N.D. Game and Fish Department, U.S. Geological Survey and U.S. Department of Agriculture to host 2014 North Dakota Water Quality Monitoring Conference March 4-6 in Bismarck, N.D. which was attended by more than 100 water professionals from North Dakota and surrounding states. G. Padmanabhan, professor of civil and environmental engineering and director of the institute, served on the conference planning committee. Francis Casey, professor and director of the NDSU School of Natural Resource Sciences was one of the keynote speakers. His talk was titled “Estrogenic Hormones in the Environment.” Casey is an affiliate faculty of the Institute.



From left to right: Dr. Padmanabhan, Mohammad Hossain, Achintyamugdha Sharma, Amanda Grosz, Priyanka Deka, Anthony Wamono, Debjit Roy, and Mengqi Xiong

Several past and present North Dakota Water Resources Research Institute graduate fellows, and their advisers presented at the conference. Podium presentations included:

- “Under the radar: Nanoparticles and rare earth elements as emerging pollutants” Marinus Otte, NDSU professor of biological sciences, and Donna Jacob, NDSU research assistant professor of biological sciences
- “What, When, and Where in Studying the Best Management Practices (BMPs) in Grand Forks, N.D.” Yeo Howe Lim, UND associate professor of civil engineering
- “Prioritizing aquifer monitoring in North Dakota: Geochemistry is important too” Scott F. Korom, UND associate professor of geology and geological engineering, and William Schuh, North Dakota State Water Commission
- “Plant Phosphorus, Nitrogen, and Carbon and Soil Phosphorus in North Dakota Wetlands” NDSU student Lindsey Meyers
- “The National Wetland Condition Assessment in North Dakota: Preliminary Results” Shawn DeKeyser, NDSU associate professor of range science
- “Three Discovery Farms...Three Unique Water Quality Stories” Rochelle Nustad, institute fellow
- “Remediation of Nutrients from Feedlot Runoff by Plants” Arjun Thapa, NDSU student
- “Monitoring tile drainage and subirrigation water quality using electrical conductivity” Xinhua Jia, NDSU associate professor of agricultural and biosystems engineering
- “Nitrate-Nitrogen in Soil Water as Affected by Nitrogen Management in Sugarbeet under Subsurface Drainage Condition” NDSU student Rakesh Awale
- “Monitoring water quality in Devils Lake in real time” Xiaodong Zhang, UND associate professor of earth systems science and policy
- “Waste Load Allocation Modeling of an Intermittent Stream” Jayme Klecker, NDSU BS '98, civil engineering

Poster presentations included:

- “Multi-Elements in Pothole Wetlands – investigating the trace and rare earth elements” Donna Jacob, NDSU research assistant professor of biological sciences

- “Ecotoxicity of Single-Walled Carbon Nanotubes and Zinc Oxide Nanoparticles Suspended in Water”  
NDSU student Amanda Grosz
- “Iron Cross-linked Biopolymers for Phosphate Removal” NDSU student Mohammad Hossain
- “Uncertainty analysis of load estimation for the nutrient TMDLs for Lake Ashtabula” NDSU student Mengqi Xiong, Zhulu Lin, and G. Padmanabhan
- “Mapping the Fate of Nutrients at the Abandoned Crookston Cattle Company Feedlot” Phil Gerla, UND associate professor of geology and UND student Prosper Gbolo
- “Nanoparticles in Water and Interaction in Plants” NDSU student Priyanka Deka
- “Nanoparticles for Remediation and Disinfection of Water” NDSU student Achintyamugdha Sharma
- “Coating Nanoscale Zero Valent Iron with Modified Food Starch for Improved Colloidal Stability”  
NDSU student Mary Pate

## Fourth Annual Distinguished Water Seminar



The annual 4<sup>th</sup> Distinguished Water Seminar sponsored by the Institute was held on February 19, 2015. The featured speaker was Dr. Gregory V. Lowry, Water J. Blenko Sr. professor of civil and environmental engineering at Carnegie Mellon University in Pittsburgh. Dr. Lowry, is also the deputy director of the Center for Environmental Implications of Nanotechnology of CMU. The topic title was "Nanotechnology in Water Science and Engineering: Sustainably Harnessing the Power of Nanotechnology."

Dr. Lowry presented an overview of the history of the Environmental Nanotechnology field, and recent advances in applications and implications of engineered nanomaterials in water science.

## **INSTITUTE PUBLICATIONS**

Technical Report No: ND14-01

SODIC SOIL SWELLING AND DISPERSION AND THEIR IMPLICATIONS FOR WATER MOVEMENT AND MANAGEMENT

Yangbo He and Thomas DeSutter

## **2014-15 PUBLICATIONS BY PREVIOUS NDWRRI FELLOWS**

Bezbaruah, A.N., Kalita, H., Almeelbi, T., Capeocchi, C.L., Jacob, J.L., Agrinov, A.G., and Payne, S.A., 2014. Ca-Alginate Entrapped Nanoscale Iron: Arsenic Treatability and Mechanism Studies, *Journal of Nanoparticle Research*, 16:2175, 2014.

Lim, Y.H. and Mager, B. (2015). "Model Studies of Singular and Multiple Step Rock Weirs: the Influence of Design Parameters on Scour Depths." *Proc., World Environmental and Water Resources Congress 2015- Floods, Droughts, and Ecosystem*, p 1760-1768, Environmental and Water Resources Institute, ASCE, Austin, Texas.

Mohammed M. Rahman, Zhulu Lin, Xinhua Jia, Dean D. Steele, and Thomas M. DeSutter, 2014. Impact of subsurface drainage on streamflows in the Red River of the North basin, *Journal of Hydrology*, <http://dx.doi.org/10.1016/j.jhydrol.2014.01.070> 0022-1694/\_ 2014 Elsevier

Mehmet Serhat Odabas, Navaratnam Leelaruban, Halis Simsek, and G. Padmanabhan, 2014. Quantifying Impact of Droughts on Barley Yield in North Dakota, USA using Multiple Linear Regression and Artificial Neural Network. *Neural Network World*, 4/14, pp 343-355

Shoghli, B. and Lim, Y.H. (2015). "Predictive Scheme for Failures of Embankment Dams with High Overtopping Potential: Case Studies Using Remote Sensing Data." *Proc., World Environmental and Water Resources Congress 2015- Floods, Droughts, and Ecosystem*, p 1332-1340, Environmental and Water Resources Institute, ASCE, Austin, Texas.

Halis Simsek, Bilal Cemek, Navaratnam Leelaruban, and G. Padmanabhan, 2014. An Assessment of Drought Impact on Barley Yield using a County wide Drought Severity and Coverage Index and an Adaptive Network based Fuzzy Inference System Model, *Proceedings of 2nd International Symposium on Innovative Technologies in Engineering and Science*, Karabuk, Turkey, June 18-20, 2014, pp 1725-34.

Thalacker, R.J. and G. Vandenberg. "Mapping Techniques for Soil Erosion: Modeling Stream Power Index Using High Resolution LiDAR Datasets in the Red River Valley of North Dakota," *ND EPSCoR/IDeA 2014 State Conference ND EPSCoR*, Grand Forks, ND. April 29, 2014.

Thalacker, R.J. and G. Vandenberg. "Mapping Techniques for Soil Erosion: Modeling of Stream Power Index in Eastern North Dakota Using LiDAR Data" *Annual Meeting Prairie Division of the Canadian Association of Geographers*, Riding Mountain National Park, Manitoba, Canada. September 27, 2014.

## **THESES AND DISSERTATIONS**

Fellow: Amanda Kreiger, M.S. in Geology and Geological Engineering, graduated in May, 2014

Adviser: Scott Korom, Associate Professor, Geology and Geological Engineering, UND

Title: Electron Donor Contributions to Denitrification in the Elk Valley Aquifer, North Dakota

Abstract:

Six denitrification tracer tests were performed over eight and a half years in insitu mesocosms (ISMs) in the Elk Valley Aquifer (EVA) in east-central North Dakota. Groundwater samples were analyzed to determine how much nitrate was lost beyond that explained by dilution of the bromide tracer. Additional losses were attributed to denitrification. The denitrification rates varied from 0.10 to 0.23 mg N/L/day for the six tests. In general, the major electron donors for denitrification are organic carbon (OC), pyrite (FeS<sub>2</sub>), and ferrous iron silicate minerals. In the EVA tracer tests, increases in sulfate indicated that the oxidation of pyrite explained a significant of the denitrification. The contributions of the three electron donors varied between tests and from test to test with pyrite, ferrous iron from silicate minerals, and OC apparently contributing 38-84%, 1-3%, and 14-59% to denitrification, respectively.

Fellow: Brian Mager, M.S. in Civil Engineering, graduated in May, 2014

Adviser: Howe Lim, Associate Professor, Civil Engineering, UND

Title: Physical Model Studies of Scour Holes below Singular and Multiple Step Rock Weirs

Abstract:

An investigation into the effects of spacing between multiple step rock weirs was evaluated. By having a better understanding of the relationships between weir spacing, flow, and tailwater, future weir designs will be both structurally stable and environmentally friendly. Increased popularity of rock weirs in recent years for environmental concerns of aquatic habitat and mitigation of water quality pollution has driven the need for proper design. To better understand the design requirements, physical models were constructed and studied in the hydraulics laboratory located at the University of North Dakota over the timespan of January through August of 2013. By compiling all the collected data from laboratory worksheets into excel for data management; analysis was conducted on the information to determine relationships. By using dimensional analysis based upon sixteen key variables measured in the laboratory, scour conclusions and weir stability were concluded. Through manipulation of the variables, and execution of the experiments, dimensionless plots statistically showed that weir spacing was not a factor in downstream scour. However as the number of weirs increased, the scour depth downstream also increased. Leading the design of future rock weirs to be independent of one another will minimize the compounding effects of converging stream velocities.

Fellow: Jixia Wu, M. S. in Earth System Science & Policy, University of North Dakota, Graduated May 2014

Adviser: Xiaodong Zhang Assoc. Professor, Dept. of Earth System Science and Policy, UND

Title: Agricultural drought monitoring and prediction using soil moisture deficit index

Abstract:

The purposes of this study are: 1) to evaluate the performance of an agricultural drought index, Soil Moisture Deficit Index (SMDI) at continental scale; 2) to develop an agricultural drought prediction method based on precipitation, evapotranspiration and terrestrial water storage. This study applied multiple linear regression (MLR) with the inputs of precipitation from Parameter-elevation Regressions on Independent Slopes Model (PRISM), evapotranspiration from Moderate Resolution Imaging Spectroradiometer (MODIS) MOD 16 product and terrestrial water storage (TWS) derived from the Gravity Recovery and Climate Experiment (GRACE) to predict soil moisture and SMDI. The inputs of the MLR model were chosen based on the mass conservation of the hydrological quantities at the near surface soil layer (two meters). In addition, the model also accounts for seasonal and regional variations. Comparisons with the US drought monitor (USDM) showed that SMDI can be used as a proxy of agricultural drought. The model exhibited strong predictive skills at both one- and two-month lead times in forecasting agricultural drought (correlation  $>0.8$  and normalized root mean square error  $<15\%$ ).

Fellow: Jun Yang, Ph. D in Civil Engineering, North Dakota State University, graduated May 2014

Adviser: Xuefeng Chu, Assoc. Professor, Civil and Environmental Engineering, NDSU

Title: Microtopography-dominated Discontinuous Overland Flow Modeling and Hydrologic Connectivity Analysis

Abstract:

Surface microtopography affects a series of complex and dynamic hydrologic and environmental processes that are associated with both surface and subsurface systems, such as overland flow generation, infiltration, soil erosion, and sediment transport. Due to the influence of surface depressions, overland flow essentially features a series of progressive puddle-to-puddle (P2P) filling, spilling, merging, and splitting processes; and hydrologic systems often exhibit threshold behaviors in hydrologic connectivity and the associated overland flow generation process. It is inherently difficult to realistically simulate the discontinuous overland flow on irregular topographic surfaces and quantify the spatio-temporal variations in dynamic behaviors of topography-dominated hydrologic systems. This dissertation research aims to develop a hydrologic model to simulate the discontinuous, dynamic P2P overland flow processes under the control of surface microtopography for various rainfall and soil conditions, and propose new approaches to quantify hydrologic connectivity.

In the developed P2P overland flow model, the depressions of a topographic surface are explicitly incorporated into a well-delineated, cascaded P2P drainage system as individual objects to facilitate the simulation of their dynamic behaviors and interactions. Overland flow is simulated by using diffusion wave equations for a DEM-derived flow drainage network for each puddle-dominated area. In addition, a P2P hydrologic connectivity concept is proposed to characterize runoff generation processes and the related spatio-temporal dynamics. Two modified hydrologic connectivity indices, time-varying connectivity function and connectivity length of the connected areas and ponded areas, are proposed to quantitatively describe the intrinsic spatio-temporal variations in hydrologic connectivity associated with overland flow generation. In addition, the effects of DEM resolution, surface topography, rainfall distribution, and surface slope on hydrologic connectivity are also evaluated in this dissertation research.

The developed model can be applied to examine the spatio-temporally varying P2P dynamics for hydrologic systems. This model provides a means to investigate the effects of the spatial organization/heterogeneity of surface microtopography, rainfall, and soil on overland flow generation and infiltration processes. In addition, the two proposed hydrologic connectivity indices are able to bridge the gap between the structural and functional hydrologic connectivity and effectively reveal the variability and the threshold behaviors of overland flow generation.

Fellow: Rick Thalacker, M.S. in Geography, University of North Dakota, graduated in May 2014

Adviser: Gregory Vandeberg, Associate Professor in Geography, UND

Title: Mapping Technics for Soil Erosion: Modeling Stream Power Index in Eastern North Dakota

Abstract:

Soil erosion is a worldwide problem that can negatively affect surface water through the introduction of sediment, nutrients (eg. nitrogen, phosphorus), pesticides, and other chemicals. Soil erosion is often exacerbated by agricultural and other types of land use. The objective of this study was to identify gully locations in agricultural fields adjacent to the Turtle and Forest rivers in eastern North Dakota that accumulate surface flow resulting in areas of critical surface erosion in a GIS using the Stream Power Index (SPI). A field survey was conducted to verify the accuracy of the terrain analysis at identifying 391 gully and inlet locations. Sediment samples were collected from 44 inlets/gully locations and analyzed for soil texture, pH and conductivity to characterize the material being eroded and transported. The pH levels for the soil samples ranged from neutral to moderately alkaline and the EC values represented soils that were either non-saline or slightly saline. Sand was the dominant separate for both study areas. This study found that SPI signatures at or above critical erosion levels can be used to target precision conservation in individual fields adjacent to the Turtle and Forest rivers.

Fellow: Ruchi Joshi, M.S., Environmental and Conservation Sciences Program, College of Graduate and Interdisciplinary Studies, North Dakota State University, graduated in April 2014.

Advisers: Eakalak Khan, Professor, Civil and Environmental Engineering and Dr. John McEvoy,

Title: In Vitro Enrichment of Phosphorylated Proteins from Synchronously Excysted *Cryptosporidium parvum*.

Abstract:

*Cryptosporidium* is an enteric protozoan parasite that infects all major vertebrate groups. It is a major waterborne parasite of humans, causing the diarrheal disease cryptosporidiosis, which can become chronic and life-threatening in malnourished children and the immunocompromised. Diarrheal disease is responsible for more deaths each year worldwide than malaria and AIDS combined. According to a recent study by UNICEF, the majority of water related deaths occur in underdeveloped countries due to a dearth of safe drinking water, sanitation, education, hygiene, and nutrition. In developing countries, *Cryptosporidium* is the leading non-viral cause of death from diarrheal disease in children. There is no effective drug treatment for cryptosporidiosis, and a poor understanding of *Cryptosporidium* biology impedes the search for novel targets.

Two studies were conducted. In the first, a novel protocol was developed for the rapid in vitro excystation of *Cryptosporidium parvum*, a species infectious for humans and cattle. Rapid excystation (release of infectious sporozoites from the environmental oocyst stage) is necessary to study molecular dynamics during the early stages of *Cryptosporidium* development. The developed excystation assay (Joshi assay) used an HCl (pH 2.5) oocyst pretreatment instead of the bleach pretreatment that is more frequently used in excystation assays. The Joshi assay resulted in an excystation rate of 27% per min, and achieved >90% excystation in 10 min. In comparison, a standard excystation protocol with bleach pretreatment requires 60 min to achieve > 90% excystation. This rapid, reproducible, and synchronous in vitro excystation assay mimics the in vivo conditions in a mammal.

In the second study, phosphorylated and non-phosphorylated proteins were selectively enriched from non-excysted and excysted *C. parvum* oocysts and separated using 2 dimensional gel electrophoresis. This is the first study that enriched phosphorylated proteins from *C. parvum*.

Fellow: Spencer Gbolo, Ph. D, Geology and Geological Engineering, graduated in December, 2014.

Advisers: Associate Professor, Geology and Geological Engineering, UND

Title: Quantifying phosphorus cycling and fate within an abandoned feedlot and adjacent wetlands

Abstract:

Feedlot operations over the years have increased revenue and boosted economies of states and countries, but these operations have resulted in elevated concentrations of nutrients in soils, surface water, and groundwater. Feedlot operations generate large quantities of manure and other waste, which when not managed properly can result in environmental problems.

It is hypothesized that nitrogen can cause a short-term contamination of soils and groundwater beneath abandoned feedlots, but phosphorus can cause both short- and long-term contamination, especially in well-drained carbonate and iron-rich soils associated with the confined animal holding areas. It is also hypothesized that spectral vegetation index can be used as an effective indicator of plant-available soil nutrients and optimum soil conditions for precise decision-making in fertilizer application. To test these hypotheses, analysis of soils, graminoid tissues, aerial spectral images, surface water, and groundwater samples from a former feedlot in northwest Minnesota was used to quantify the phosphorus budget, characterize nutrients movement and plant vigor, and determine the fate of nutrients.

Soil analysis revealed elevated concentrations of sequestered phosphorus at the confined animal holding areas, in contrast to varying concentrations of nitrate in the wetlands. Groundwater analysis indicated a steady decline in nitrate concentration due to denitrification, leaching, and plant uptake, with sequestered phosphorus released in soluble form due to oxidation-reduction conditions. These nutrients are transported into the wetlands for consumption by plants and microbes. Although there was no relationship observed between spectral vegetation indices and plant tissue nutrients, the indices correlated with soil-available nutrient and soil properties. Modified soil-adjusted vegetation index (MSAVI) was the best index for characterizing plant vigor and soil relationships due to its reduced sensitivity to atmospheric conditions and the changes in vegetative cover as compared to the other indices. The lack of any relationship between plant tissue and the spectral indices suggests that acid digestion approach used in plant tissue nutrient analysis may be problematic due to the volatility of some of the nutrients.

This research provides insight into the viability of feedlots abandoned more than a decade as a source of phosphorus to supplement the primary sources of phosphorus used in fertilizer. It is estimated that crops remove approximately 2 to 15 mg kg<sup>-1</sup> of phosphorus for growth. Phosphorus concentrations on the beach ridge exceed 50 mg kg<sup>-1</sup>, which implies no soil phosphorus fertilization is required for plant growth. Agronomists and stakeholders in agriculture and food security should take a holistic approach and conduct feasibility studies on using sequestered phosphorus in abandoned feedlot soils as alternative source of phosphorus fertilizer.

Fellow: Yangbo He, Soil Science, graduated in December, 2014.

Advisers: Thomas DeSutter, Associate Professor, Soil Science, NDSU

Title: Sodic soil swelling and dispersion and their implications for water movement and management

Abstract:

North Dakota has over 1.9 million ha of sodium-affected soils, influencing water movement and crop production. This dissertation consists of four studies examining different aspects of sodic soils. The first study surveys sodium adsorption ratio (SAR) methods to determine which is the most reliable. The second and third studies investigate the dispersion and swelling functions of sodic soils. The final study examines field spatial distribution of Na in order to propose management strategies.

Analytical approaches for converting alternative to standard approaches are needed. The SAR was determined from many non-standard techniques. One hundred soils were used, SARE and 1:5 soil/water SAR1:5 determined using shaking, stirring, and a USDA-NRCS method were compared. Three of the methods influenced the SAR1:5 values.

Electrical conductivity (EC), SAR, and Ca/Mg ratios influence dispersion. Three pure clay minerals (montmorillonite, kaolinite and illite) were pretreated by variable Na and cation ratios and absorbance was determined using spectrophotometer for dispersion. Calcium-Mg ratios across the same SAR did not influence clay dispersion. Dispersion increased with higher SAR and reduced EC whereas no dispersion for kaolinite.

Swelling is associated with hydration of clays, which forces clay tactoids to separate. Four soil series from North Dakota field sites were used. To assess swelling, field capacity (FC) was used as proxy. The study found that soil Na and soluble salt concentrations were two important chemical factors influencing FCW. The FCW increases with increased SAR and lower levels of EC. These results indicate that maintaining an EC level above 4 dS m<sup>-1</sup> may mitigate swelling, which is an issue considered in tile drainage.

Over- and under-application of amendments in sodic soils was studied in a 8.1 ha sodic soil field. At each site, samples were taken from two depths; electromagnetic (EM38) and elevation readings were done. Elevation was significantly correlated with soil variables except for Na%. The EM38 was reliable to express soil EC and was correlated with Na% and dispersion. Therefore, conducting the EM38 and RTK may allow site-specific management of Na. Improved knowledge of sodic soils dispersion, swelling, and field distribution will benefit researchers and farmers in managing their fields.

Fellow: Noah Lebassi Habtezion, MS in Civil Engineering, graduated in December, 2014.

Advisers: Xuefeng Chu, Associate Professor, Civil Engineering, NDSU

Title: Modeling of Surface Microtopography and Its Impacts on Hydrologic Processes

Abstract:

Understanding the impacts of surface microtopography on hydrologic processes is critical. The objectives of this thesis research are: (1) to evaluate the effects of DEM resolution on microtopographic characteristics, hydrologic connectivity, and modeling of hydrologic processes; and (2) to assess the influences of multiple rainfall events on surface and subsurface hydrologic processes with the use of a puddle-to-puddle (P2P) modeling system. The change in DEM resolution has a significant effect on how surface microtopography is depicted, which in turn alters the hydrologic response of a topographic surface. The smoothing of reduced DEM resolution tends to enhance hydrologic connectivity, reduce the depression storage and infiltration, and increase surface runoff. Temporal rainfall distribution results in spatio-temporal variations in soil water dynamics, depression storage, infiltration, hydrologic connectivity, and surface runoff. The reduction in ponding time and infiltration, and the enhancement of hydrologic connectivity further caused earlier and greater surface runoff generation.

Fellow: Tanush Wadhawan, Ph.D in Civil Engineering, graduated in December, 2014.

Advisers: Eakalak Khan, Professor, Civil and Environmental Engineering, NDSU  
John McEvoy, Associate Professor, Vet and Microbiological Sciences, NDSU

Title: Investigating Biodegradability of Dissolved Organic Nitrogen in Oligotrophic and Eutrophic Systems.

Abstract:

Dissolved organic nitrogen (DON) in water and wastewater is a major public concern. In drinking water treatment plants (WTP), DON and biodegradable DON (BDON) may form carcinogenic by-products during disinfection and might also serve as a nutrient for microbiological growth in distribution systems. BDON in treated wastewater can promote algal growth in receiving water bodies. Understanding biodegradability of DON is important to develop strategies and processes capable of minimizing DON impact on the wastewater effluent receiving water bodies and drinking water. WTPs are nutrient-poor oligotrophic systems that receive source water with DON of about  $\leq 2$  mg N/L. Wastewater treatment plants (WWTPs) are nutrient-rich eutrophic systems which receive raw wastewater with DON of  $\geq 8$  mg N/L. At WWTPs, sidestream deammonification is a highly eutrophic system employed to treat highly concentrated streams of DON ( $\geq 100$  mg N/L) and ammonia ( $\geq 1,500$  mg N/L) generated from filtrate from anaerobically digested sludge dewatering. DON characteristics including biodegradability for different trophic levels could differ. The main goal of this dissertation is to investigate biodegradability of DON in these oligotrophic and eutrophic systems.

Three research tasks were performed. In the first task, a method to measure BDON in oligotrophic systems was developed and applied to determine the fate of BDON along four treatment stages of a WTP with ozonation prior to filtration. Optimum dose of inocula and incubation time were identified for the BDON measurement. The Moorhead WTP, Moorhead, MN on average removed 30% of DON and 68% of BDON. The second task involved investigating the role of four biological wastewater treatment processes in removing DON from eutrophic systems. Nitrification process biodegraded 70, 54, and 57% of DON in influent, primary effluent, and secondary effluent, respectively. Heterotrophic DON removal was less (1.7 to 38%) while denitrification and deammonification did not remove DON. For the third task, BDON biodegradability in highly eutrophic system was investigated using nitrifying sludge. About 45 to 90% of DON in sidestream effluent was biodegradable. Information from this dissertation provides a better understanding on DON and BDON fate through water and wastewater treatment processes representing different trophic levels.

Fellow: Dasuni Arachchige, M.S. in Geography, University of North Dakota, graduated in May 2015

Adviser: Gregory Vandeberg, Associate Professor in Geography, UND

Title: Mapping Flash Flood Potential Using GIS and the Flash Flood Potential Index (FFPI) in the Turtle River and Forest River Watersheds in North Dakota

Abstract:

Flash flooding is a rapid onset natural hazard and can cause extensive property and crop damages as well as deaths. The National Oceanic and Atmospheric Administration storm database reports 464 flash flood events from 1996 to 2013 in North Dakota causing two deaths, more than \$145 million in property damage and \$14 million in crop damage. The main purpose of this study is to identify the critical areas of flash flooding within two selected watersheds in eastern North Dakota. The research method relies on the use of a GIS-based model, the Flash Flood Potential Index that incorporates physiographic characteristics from the watershed. This Flash Flood Potential Index has been used for predictions at various geographic locations from Colorado to Iowa. The index has not been used, to our knowledge, in a flat-lying region such as the Red River Valley of North Dakota and Minnesota. In this study, digital elevation models at 30 m and 3 m resolutions were used to evaluate the sensitivity of the index. Three different scenarios were used with changes for the original FFPI equation. The preliminary results include maps showing areas susceptible for flash flooding in the watersheds. Notably, the highest values of the index for this study correspond to urbanized areas and impervious surfaces such as roads and built spaces, and high slopes reflecting an increased vulnerability to floods and inundation of the watersheds. The correlation between historical events and index results was also tested. Some modifications of the index for flat-lying landscapes might have to be considered in future studies.

Fellow: Melissa Wygant, M.S. in Geography, University of North Dakota, graduated in June, 2014

Adviser: Paul Todhunter, Professor in Geography, UND

Title: A Place Vulnerability Analysis of Changing Flood Risk for Grand Forks, North Dakota 1990-2010

Abstract:

Floods are the most common natural hazard in the U.S.; each year they leave communities in destruction and despair. Despite the efforts of emergency managers, local government officials, and scientists, flood damages in the U.S. have increased significantly over the past 100 years. It is increasingly important to evaluate a community's risk and vulnerability to flooding in order to develop efficient emergency operation plans, and to improve upon flood management practices. Communities in the Red River Valley of North Dakota have dealt with flood hazards for a very long time. In particular, Grand Forks, North Dakota, Fargo, North Dakota, Moorhead, Minnesota, and East Grand Forks, Minnesota have experienced extensive flooding for more than 100 years. The Grand Forks community experienced one of the worst floods in the Red River Valley in the spring of 1997. The purpose of this study is to evaluate flood risk and vulnerability at Grand Forks from 1990-2010 prior to and following completion of the \$420 million levee system constructed by the U.S. Army Corps of Engineers. This study identifies the extent to which flood risk has actually been reduced over time. A place vulnerability approach is used as the organizing framework to provide a quantitative spatial assessment of flood risk. To date, few research studies have examined place vulnerability for non-coastal communities and for flood hazard applications. Existing place vulnerability studies have also been static and not considered changes in vulnerability over time. This study aims to fill multiple gaps in the literature by providing a quantitative and dynamic analysis of flood hazard risk and vulnerability over time in a community that has experienced catastrophic loss to flooding in the past. Results show that there has been an increase in place vulnerability of flood risk from 1990-2000 but a slight decrease from 2000-2010. This suggests that various structural and nonstructural strategies have been helpful in reducing flood hazards. However, there continues to be residual risk, and areas throughout Grand Forks are still at risk from flooding. As Grand Forks increases in population in the coming years, various social factors could increase social vulnerability and place vulnerability.

Fellow: Abbie Beaudry, M.S. in Civil Engineering, University of North Dakota, graduated in June, 2014

Adviser: Howe Lim, Associate Professor in Civil Engineering, College of Engineering and Mines, University of North Dakota

Title: Removal Efficiency of Water Quality Pollutants in a Wet Detention Basin in Grand Forks, ND

Abstract:

It is hypothesized that the applied sampling techniques, water quality analysis, and statistical analysis predict pollutant removal efficiencies of the project site. Current practices in urban stormwater runoff are the design of systems that limit the developed peak discharge to less than or equal to the peak discharge of the pre-developed conditions. This is many times accomplished with the installation of stormwater retention, detention, or attenuation facilities that store the generated runoff from the drainage area. These are commonly known as structural Best Management Practices (BMPs). The City of Grand Forks, ND (City) implements BMPs into the stormwater management plans for all new developments. Design of these facilities for water quality is volume based, and considerations for removal efficiency are not currently integrated.

The City is interested in determining the pollutant removal efficiency of their current in-situ Structural BMPs. This research is used to develop a sampling plan and parameter list for potential future expansion of the project. To determine an accurate sampling plan and parameter list, a baseline study on one operational wet detention pond located within the City was completed to prove the hypothesis. Since this is a baseline study, water quality parameters included the analysis of total suspended solids, nutrients of various forms, heavy metals, bacteria, and other chemical properties used to assess the current quality of stormwater influent and effluent going through the system. The sample collection includes both single grab samples for instantaneous water quality analysis and manual flow-weighted composite samples for analysis of event mean concentration (EMC). The EMC influent and effluent results are compared to determine intra-event removal efficiency and a statistical analysis is performed to determine if the sample sets are statistically significantly different between the influent and effluent concentrations.

Acceptance of the hypothesis is proven for the nutrients, total phosphorus and nitrate as nitrogen, and conductivity. The average removal efficiency of the nutrients is 73 percent for total phosphorus and 40 percent for nitrate as nitrogen. Conductivity was determined to increase between the influent and effluent concentrations. Other analytes that exhibited removal efficiency, but were not proven to be statistically significant, were total suspended solids (TSS) at 76 percent removal, phosphate as orthophosphate at 71 percent removal, and bacteria as E. Coli at 83 percent removal. The remaining parameters of ammonia as nitrogen, nitrite as nitrogen, total copper, total lead, total zinc, chloride, pH and dissolved oxygen did not suggest effective removal trends throughout the BMP.

Continued analysis of the site is required to better define the statistical difference between the influent and effluent concentrations for these parameters. The removal of the nitrite from the parameter list is suggested based on low to non-detection of the analyte throughout the monitored sampling events. TSS and conductivity were observed to be potential surrogates for total phosphorus and chloride, respectively.