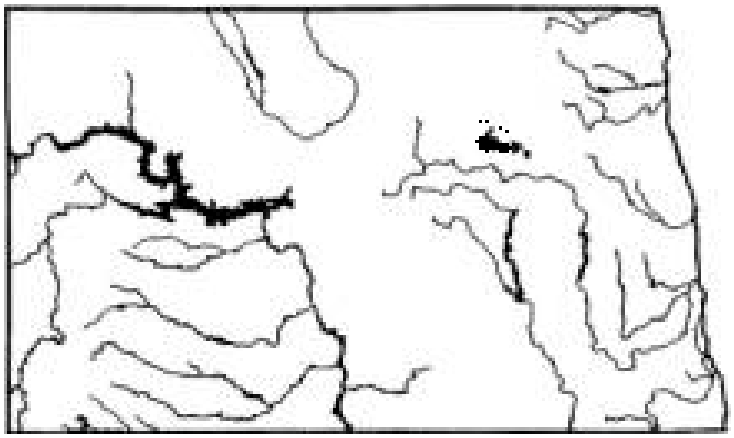

North Dakota
Water Resources Research Institute

North Dakota State University
University of North Dakota

ANNUAL REPORT

March 1, 2013 to February 28, 2014

Fiscal Year 2013 Report to the U.S. Geological Survey

June 2014

Annual Report

Fiscal Year 2013 Report to the U.S. Geological Survey

Award No. 06-HQ-GR-0104
U.S. Geological Survey

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June 2014

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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, 2013 to February 28, 2014.

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 communications 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.

Unfortunately, the sequestration and the government shut down affected adversely the USGS budget and correspondingly the WRRI budget was reduced to $55,525 from $92,335. The Fellowship amounts awarded had to be reduced accordingly.

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, is 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.

State Appropriation

The State Water Commission continued its support of 15% match ($13,850) to the 2013-2014 Graduate Research Fellowship program of NDWRRI under federal 104 (B) funding. This is tenth 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) 231-7043 Fax: (701) 231-6185 E-mail: G.Padmanabhan@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 2013-2014 Graduate Research Fellowship were posted on the Institute website in September 2012, and the request for applications was announced in the faculty news publications of the two university campuses by the middle of October.

The following is the request for application that was published on the UND and NDSU campus newsletters, and distributed by e-mail lists. October 15, 2012 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 Oct. 15 issue of IHaS:

2013 ND WRRI graduate research fellowship applications invited

The North Dakota Water Resources Research Institute (ND WRRI) invites applications for its 2013 Graduate Research Fellowship program.

North Dakota State University and University of North Dakota graduate students who are conducting or planning research in water resources may apply for fellowships of varying duration, 3 months to one year. Typically in the past fellowship awards for master's degree students have been in the range $800-$1,000 and for doctoral students it has been

$1,000-$1,400 per month. The fellowship funds must be applied between March 1, 2013, and Feb. 28, 2014. A technical completion report co-authored 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. Advisers of the applicant should co-sign the applications. 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. The proposals will be reviewed by a panel of state water resources professionals.

Announcement of awards will be made by early January subject to the appropriation of funds for the FY 2013 program by the federal government.

Consult the ND WRRI Web site, www.ndsu.edu/wrri, for background information on the program, and guidelines for preparation of applications.

Applications are due by 5 p.m., November 30, 2012.

Submit original and four hard copies of applications to Linda Charlton, Family Life Center (FLC 320), NDSU Department 2030, P.O. Box 6050, Fargo, ND 58108-6050 and an electronic copy in Word format to G.Padmanabhan@ndsu.edu.

For additional information, contact Padmanabhan at G.Padmanabhan@ndsu.edu or Charlton at Linda.Charlton@ndsu.edu.

NDWRRI GRADUATE RESEARCH FELLOWSHIPS

In total, fifteen applications were received. Eight are from NDSU and seven from UND. Out of fifteen, three (all Ph. D) are for renewal and twelve (2 Ph. D and 10 MS) are new applications. Fellowships ranging from $3000 to $11,500 were awarded to fourteen graduate students, five Ph.D. and nine MS, conducting research in water resources topics at NDSU and UND.
Funding for the Fellowship program comes primarily from the annual base grant and an additional support of 15 per cent of the base grant comes from the North Dakota State Water Commission. 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 review the proposals and select Fellows and award amounts are based on the quality of proposals and the priority of the proposed projects for the state and region.
Unfortunately, the sequestration and the government shut down affected adversely the USGS budget and correspondingly the WRRI budget. The Fellowship amounts awarded had to be reduced substantially.

2013-14 ND WRRI Fellows, Advisers, and Research Projects:

- Amanda Kreiger (Fellow), Geology and Geol. Engineering, UND; Scott Korom (adviser)
  Electron Donor Contributions to Denitrification in the Elk Valley Aquifer, ND
- Brian Mager, Civil Engineering, UND; Howe Lim
  Physical model evaluations of scour holes below a singular and multiple step rock weirs
- Jiexia Wu, Earth System Science and Policy, UND; Xiaodong Zhang
  Drought monitoring and prediction using NOAH land surface model and GRACE satellite observation
- Jun Yang, Civil Engineering, NDSU; Xuefeng Chu
  Improved Overland Flow Modeling for Hydrologic Connectivity Analysis of Potholes
- Kelsey Kolars, Ag and Biosystems Engineering, NDSU; Xinhua Jia
  Development of a Model for Subsurface Drainage and Subirrigation Water Management
- Kyle Horntvedt, Ag and Biosystems Engineering, NDSU; Xinhua Jia
  Measurement and modeling of soil moisture changes for subsurface drained and sub irrigated fields in the Red River Valley
- Melissa Wygant, Geography, UND; Paul Todhunter
  A Place Vulnerability Analysis of Flood Hazard Risk at Grand Forks: 1990-2010
- Mengqi Xiong, Civil Engineering, NDSU; Zulu Lin and G. Padmanabhan
  Application of Soil Water Assessment Tool (SWAT) Model for Estimating Nutrient Loads to Lake Ashtabula, ND, under Different Climate Scenarios
- Prosper Gbolo, Geology and Geologic Engineering, UND; Phillip Gerla
  The Cycling and Fate of Phosphorus at an Abandoned Feedlot
- Rick Thalacker, Geography, UND; Gregory Vandeberg
  Mapping Techniques for Soil Erosion using Digital Camera LiDAR and GIS
- Ruchi Joshi, ECS Program, NDSU; Eakalak Khan and John McEvoy
  Understanding the Survival of Cryptosporidium Oocysts in North Dakota under Winter Conditions
- Tanush Wadhawan, Civil Engineering, NDSU; Eakalak Khan and John McEvoy
  Investigation of Cryptosporidium oocysts in Influent and Effluent of the Fargo Water Treatment Plant
- Veselina Valkov, ECS, NDSU; Wei Lin
  Temporal-spatial distribution (dynamics) of phytoplankton and diversity in relation to lake physical and chemical condition
- Yangbo He, Soil Science, NDSU; Thomas DeSutter
  Sodic soil characterization and management on subsurface drainage

Electron Donor Contributions to Denitrification in the Elk Valley Aquifer, ND

Project Number: 2013ND273B
Fellow: Amanda Kreiger
Adviser: Scott Korom
Start Date: 3/1/2013
End Date: 2/28/2014

Publications

Kreiger, A., S. F. Korom, and W. Schuh, Electron donor contributions to denitrification in the Elk Valley aquifer, North Dakota, 58th Annual Midwest Ground Water Conference Program with Abstracts, Bismarck, ND, September 23-25, 2013.

Research

The data available through previous studies of the EVA near Larimore, ND and PHREEQC, a computer program developed by the U.S. Geological Survey for simulating geochemical reactions, have been used to model the changes in groundwater quality during the denitrification tracer tests in the ISMs to provide insights on the contributing electron donors. Cation exchange capacity of the sediments at the EVA has been evaluated.

The amount of nitrate that was lost beyond that explained by dilution of the bromide tracer, which could be attributed to denitrification, was determined. The amount of denitrification which is explained by the increase of sulfate, which could be attributed to the oxidation of pyrite, which was the only sulfide mineral found by x-ray diffraction in the EVA sediments was evaluated. The ratios of denitrification by organic carbon and ferrous iron were determined using PHREEQC, along with the saturation indices of the major minerals found in the EVA (Tesfay, 2006).

This research is the first to study the variation in the contributions of electron donors in aquifer sediments for such a long period of time, nearly eight years. This will be yet another step in the UND denitrification research group's progress in predicting aquifer denitrification parameters based on the electron donors present in aquifer sediment. Furthermore, this research will provide insights into which type of electron donor causes the greatest aquifer denitrification rates.

Physical model evaluations of scour holes below a singular and multiple step rock weirs

Project Number: 2013ND274B
Fellow: Brian Mager
Adviser: Howe Lim
Start Date: 3/1/2013
End Date: 2/28/2014

Research

During the last 15 years, rock weirs have become increasing popular hydraulic designs in the Red River Valley. However, very little research has been conducted as to the design parameters of rock weirs. Once constructed, rock weirs begin to form a scour hole downstream which if not properly designed will undermine the foundation of the rock weir, leading to failure of the site. Existing research has been limited to singular weir structures and doesn't evaluate the effects of stepped weirs to aid in downstream scour reduction.

Through a large scale sediment flume construction at the University of North Dakota a 1:5 scale model is being used to evaluate the severity of these scour holes. For this analysis a fine granular bed material was chosen that best represented local non-cohesive soil conditions. A typical U-shaped rock weir was evaluated for scour as a control and compared to multiple rock weirs of the same shape in series. The spacing between the weirs was varied and analyzed to determine optimum design parameters to reduce scour, given various volumes of flows and tailwater conditions. This will be vitally important to the small communities that compose the Red River Valley by providing the best design criteria at the most effective cost of construction. A GIS software will be used to visually analyze and mathematically calculate areas of scour to determine the optimum layout parameters.

Construction of a four thousand gallon concrete block flume, hydraulic conveyance piping and an XYZ measurement system are completed. The rock weir design has been choosen and a physical model has been constructed with a concrete base. Currently various simulations are being ran. Physical dimensions of the structure are 26 ft long 7 ft wide and 3 ft heigh. Dimensional analysis has been conducted on the variables responsible for rock weir erosion and theoretical research has also been completed.

Drought monitoring and prediction using NOAH land surface model and GRACE satellite observation

Project Number: 2013ND277B
Fellow: Jiexia Wu
Adviser: Xiadong Zhang
Start Date: 3/1/2013
End Date: 2/28/2014

Publications

Jiexia Wu and Xiaodong Zhang (2013) Agricultural drought monitoring and prediction using soil moisture deficit index and GRACE terrestrial water storage. Abstract and presentation. American Geophysical Union Conference, San Francisco, 9 – 13 December.

Research

For agricultural drought monitoring, soil moisture is the key indicator as such agricultural drought indices are often based on soil moisture deficit. For example Soil Moisture Deficit Index (SMDI) was developed to quantify drought severity. The SMDI was applied to drought monitoring for catchments in Texas, and it has never been used to large spatial scales. My research is applying SMDI to the entire continental U.S. to understand the spatial and temporal variability of 2010 to 2012 drought and develop drought prediction based on SMDI using soil moisture derived from Global Land Assimilation System (GLDAS) land surface model simulation and TSDI based on terrestrial water storage from (Gravity Recovery and Climate Experiment) GRACE. The performances of the two indices were evaluated temporally and spatially. Two methods were applied to predict climate variables and the drought prediction based on predicted climate variables matches with drought observations.

Improved Overland Flow Modeling for Hydrologic Connectivity Analysis of Potholes

Project Number: 2013ND279B
Fellow: Jun Yang
Adviser: Xuefeng Chu
Start Date: 3/1/2013
End Date: 2/28/2014

Publications

1. Yang, J., and Chu, X., 2013. Quantification of the spatio-temporal variations in hydrologic connectivity of small-scale topographic surfaces under various rainfall conditions. Journal of Hydrology. 505:65-77.
2. Chu, X., Yang, J., Chi, Y., and Zhang, J., 2013. Dynamic puddle delineation and modeling of puddle-to-puddle filling-spilling-merging-splitting overland flow processes. Water Resources Research. 49(6):3825-3829, doi: 10.1002/wrcr.20286.

Research

Surface topography is generally not smooth, and it influences overland flow generation, delays the initiation of surface runoff, and enhances the retention of runoff water. In the recent decade, research efforts have been made to quantify the hydrologic role of surface topography, analyze the dynamic behaviors of depressions, and investigate hydrologic connectivity. However, more efforts are needed to physically quantify the effects of depressions on surface runoff generation. Under the influence of surface topography, overland flow is generally characterized by a series of hierarchical puddle-to-puddle (P2P) filling, spilling, and merging processes. These processes are rarely simulated in overland flow models due to their complexity. Most of the widely used modeling software packages utilize depression-filled topographic surfaces. They are not capable of simulating the spatial and temporal dynamics of individual depressions and their interactions.

The Prairie Pothole Region (PPR) is located in northern United States and southern Canada. It covers the most part of the Red River basin in North Dakota. The potholes in the PPR have received an increasing attention due to their important roles in water retention, flood control, groundwater recharge and discharge, and water quality management. The variability and the dynamic hydrologic processes of these depressions have been identified as critical topics to improve the understanding of the hydrologic issues related to the PPR. However, hydrotopographic properties, hydrologic functions and behaviors of these potholes are poorly understood due to their spatially and temporally varied hydrologic processes.

Efforts have been made to investigate the aforementioned hydrologic issues in our research group. New methods have been developed to characterize surface topography with focus on delineating puddles in a “dynamic” fashion. In the 2012 fellowship project, a P2P overland flow model was developed to physically simulate the topography-influenced overland flow generation processes and the dynamic P2P processes.

The objectives of this study was set to improve the P2P overland flow model developed in 2012 and apply the model to investigate hydrologic connectivity of potholes for several sites selected in the PPR. Specific research tasks include:

In the current project, an improved, physically-based model has been developed to simulate the topography-controlled P2P dynamics and overland flow processes. This model can be used to improve the knowledge of: (1) how the water stored in depressions interacts with soil water and atmospheric water, and changes spatially and temporally, and (2) threshold behaviors and hydrologic functions of potholes. The proposed research and the developed model will potentially help address the following regional hydrologic issues: (1) understanding the hydrologic roles of potholes in the PPR, (2) predicting water levels in potholes for flood control, (3) understanding the chemical and biological characteristics of water bodies, and (4) managing natural resources.

Development of a Model for Subsurface Drainage and Subirrigation Water Management

Project Number: 2013ND272B
Fellow: Kelsey Kolars
Adviser: Xinhua Jia
Start Date: 3/1/2013
End Date: 2/28/2014

Publications

Kolars, K.A., X. Jia, D.D. Steele, T.F. Scherer, and T.M. DeSutter. 2013. Using eddy covariance, soil water balance, and photosynthetically active radiation methods for corn evapotranspiration measurements in the Red River Valley. ASABE Paper No: 131591426. Kansas City, Misso.: ASABE.

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. 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. 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. 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, but also allow for subirrigation when needed for watering the 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. 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 focuses 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, and 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 station have been set up in order to collect soil moisture, evapotranspiration, 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. The collection and processing of soil moisture, evapotranspiration, drainage and irrigation data is currently in progress for the 2012 growing season. Regular updates on field activities/progress can be found at http://aben-saregrant-ndsu.blogspot.com/

The use/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 such that an increase in yield is seen along with a decrease in nitrate loadings and soluble salts to surrounding surface waters. By incorporating net irrigation via a SI system and drainage via a SSD system in the Checkbook method the landowner is given a simple, familiar, and effective way to manage their system

Measurement and modeling of soil moisture changes for subsurface drained and sub irrigated fields in the Red River Valley

Project Number: 2013ND271B
Fellow: Kyle L. Horntvedt
Adviser: Xinhua Jia
Start Date: 3/1/2013
End Date: 2/28/2014

Publications

Horntvedt, K.L., X. Jia, D.D. Steele, T.F. Scherer, and T.M. DeSutter. 2013. Methods, techniques, and considerations for subirrigation practices in the Red River Valley of the North. ASABE Paper No. 131618357. Kansas City, Misso.: ASABE

Research

Agricultural drainage water management (DWM) is one of the biggest challenges producers face currently. During wet periods, excess water must be removed from fields to promote healthy plant development. Conversely, during drought periods, crops need additional water to be supplied in order to achieve desired yields. Through the removal or addition of water with subsurface drainage or subirrigation, producers will be able to effectively manage their water tables and available water content to their plants, adding security to crop yields regardless of weather conditions. It is estimated that 10 million ha in the United States and Canada are suitable for DWM, with their average land slopes being less than 0.5%. The majority of the RRV falls within these 10 million ha, making it a prime location for implementation of DWM practice.

In order to accurately understand when water should be removed and added to the fields to optimally manage water tables and moisture content, researchers must gain an understanding of how water moves through each field and how the soil moisture changes in the root zone, in order to develop a water management plan for producers to follow. A large field experiment with four water management plans has been set up in the RRV and is scheduled to run in 2011 - 2014. Various instruments have been installed to measure the water balance components. To predict the effects of water management on water table position and soil moisture for a region, hydrological simulation models are required, such as Hydrus-2D and DRAINMOD. By measuring real-world moisture conditions in the field and comparing them to modeling results, a water management plan and irrigation schedule will be able to be developed to help producers make critical decisions throughout the year regarding the addition and abstraction of water in their fields.

The research project focuses on measuring the input parameters for DRAINMOD and Hydrus-2D models for four different DWM practices, and comparing the observed field response with the simulated field response for each practice. The specific objectives are

to gather field data to be inputted to the Hydrus-2D and DRAINMOD during 2012-2013 (Rainfall events, soil properties, tiling system specifications, irrigation water quantities, geographical features, etc.), simulate water movement in the field under different rainfall events and for the entire growing season, and conduct statistical analysis on the models' accuracy in modeling real field conditions, specifically the change in soil moisture in the root zone.

A Place Vulnerability Analysis of Flood Hazard Risk at Grand Forks: 1990-2010

Project Number: 2013SWC
Fellow: Melissa Wygant
Adviser: Paul Todhunter
Start Date: 3/1/2013
End Date: 2/28/2014

Research

Flooding is the most common and pervasive natural hazard in the United States, causing extensive damage and economic loss each year. Flood damages in the United States have continued to increase significantly over the past 200 years, causing loss of life, affecting untold millions of people, and inflicting billions of dollars in direct and indirect economic losses. Communities along the Red River Valley of North Dakota have a long history of flood damages. Grand Forks and the Fargo-Moorhead metropolitan area have experienced extensive flooding for over 100 years. In 1997 the Grand Forks community experienced a catastrophic flood and the Fargo-Moorhead metropolitan area narrowly escaped similar catastrophic flood damages on multiple occasions during the 2000s, while Minot and Bismarck suffered extensive flood damages in 2011. Avoiding a recurrence of a flood disaster similar to the 1997 flood at Grand Forks is crucial to the sustainability of all of North Dakota's major metropolitan areas. The purpose of this study is to evaluate flood hazard risk and vulnerability at Grand Forks, North Dakota from 1990-2010 prior to and following completion of their U.S. Army Corps of Engineers certified $420 million levee system to identify the extent to which flood risk has actually been reduced over time. A place vulnerability approach will be used as the organizing framework to provide a quantitative spatial assessment of flood risk over time.

Project Objectives:

• Develop georeferenced maps of flood risk in Grand Forks prior to and following the completion of the USACE levee system;
•Quantify and map social vulnerability at the census tract level for three U.S. Census periods;
•Use a GIS to quantify and map place vulnerability in Grand Forks for three time periods-1990,2000, and 2010;
•Identify the extent to which biophysical vulnerability, social vulnerability, and place vulnerability have changed in Grand Forks over the 20 year study period;
• Provide an objective and spatially-based evaluation of how actual flood risk changed following the 1997 flood disaster.

It is anticipated that the place vulnerability maps will show a reduction in flood risk over time due to the implementation of the dike system, and other various mitigation strategies, but reveal that substantial residual risk is still present within Grand Forks. This should be helpful to city leaders in Grand Forks and other North Dakota communities who are responsible for building more flood-resilient communities

Application of Soil Water Assessment Tool (SWAT) Model for Estimating Nutrient Loads to Lake Ashtabula, ND, under Different Climate Scenarios

Project Numer: 2013ND278B
Fellow: Mengqi Xiong
Advisers: G. Padmanabhan and Zhulu Lin
Start Date: 3/1/2013
End Date: 2/28/2014

Presentations

Mengqi Xiong, Zhulu Lin, and G.Padmanabhan. "Load estimation for nutrient TMDLs for Lake Ashtabula" North Dakota Water Quality Monitoring Conference, Bismarck, ND. March 4-6, 2014.

Research

Surface water quality impairment resulting from point and non-point sources pollution is of concern for watershed and water resource management. Therefore, Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations require states to identify and list the impaired and threatened surface waters within their boundaries, to prioritize them, and to develop Total Maximum Daily Loads (TMDLs) for the pollutants of concern. The 2012 Section 303(d) TMDL list for North Dakota has targeted 45 water bodies for completion by the end of 2014. Lake Ashtabula is listed as impaired due to excess nutrients and eutrophication (http://iaspub.epa.gov/tmdl_waters10/attains_impaired_waters.impaired_waters_list?p_state=ND&p_cycle=2012). Lake Ashtabula is a large impoundment on the main stem of the Sheyenne River. It is a U.S. Army Corps of Engineers multipurpose reservoir built for flood protection, recreation and irrigation.

Watershed modeling is an integral part of the TMDL development process of estimating nutrient loads from point and non-point sources to the receiving waters. Of all the suitable models for TMDL development, SWAT has been extensively applied for TMDL development and ArcSWAT provides a user-friendly GIS interface for developing site-specific SWAT models. SWAT is a semi-distributed watershed model and requires spatially explicit topographical, land use, soils, and meteorological data (such as precipitation, air temperature, and evapotranspiration, etc.) as model inputs. SWAT has also been applied to assess the impact of potential climate variability and change on nutrient loads to surface waters.

Our study will develop a SWAT model for the Lake Ashtabula watershed that drains the upper Sheyenne River basin (SRB) and a portion of the middle SRB for nutrient TMDL development purpose. The SWAT model will also be used to investigate the impact of the Devils Lake diversion on the water quality in Lake Ashtabula under different climate scenarios.

The objectives of the study are to review the state-of-the-art of watershed modeling for TMDL purposes, to develop a SWAT model to estimate sediment and nutrient loadings to Lake Ashtabula, to link the watershed model with an in-stream water quality model to investigate the impacts of different future climate scenarios (e.g., dry and wet conditions) on water quality in Lake Ashtabula, and to compare SWAT results with those of AnnAGNPS to gain a better understanding of upland nutrient sources to Lake Ashtabula

This study can be divided into three stages: database development, model development, and evaluation of uncertainty of SWAT model for the Lake Ashtabula in North Dakota. The database development for model setup and calibration has been done. The input data include topographic, soil, land use, management, and weather data. The calibration data include daily streamflow observations and bi-weekly measurements of concentrations of water quality parameters. The model development is ongoing. We are currently using ArcSWAT, the GIS interface of SWAT, to setup the SWAT model. Efforts are also focused on separating the non-contributing drainage area and careful evaluation of curve numbers.

The Cycling and Fate of Phosphorus at an Abandoned Feedlot

Project Number: 2013SWC
Fellow: Prosper Gbolo
Adviser: Phil Gerla
Start Date: 3/1/2013
End Date: 2/28/2014

Publications

Gbolo, P, Gerla, P, and Vandeberg, G, "Using high-resolution, multispectral imagery to assess the effect of soil physical and chemical properties on vegetation reflectance at an abandoned feedlot (In-review for submission to the International Journal of Advanced Remote Sensing and GIS, 2014).

Gbolo, P, and Gerla, P, "Spatiotemporal distribution of nutrients from an abandoned cattle feedlot", 2014 (In Review for submission to the Journal of Soils and Sediments)

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

Gerla, P, and Gbolo, P., 'Mapping the fate of nutrients at the abandoned Crookston Cattle Company feedlot', Proceeding of the North Dakota Water Quality Monitoring Conference Poster Presentation, Bismarck State College, Bismarck, ND - March 2014.

Gbolo, P, and Gerla, P, 2013. Statistical analysis to characterize transport of nutrients in groundwater near an abandoned feedlot. Hydrology and Earth System Sciences 17:4897-4906.

Gbolo, P, and Gerla, P, "Spatial distribution of soil nutrients in an abandoned feedlot and adjacent wetlands", Proceedings of the North Dakota Geographic Information Systems (GIS) users conference, Alerus Center, Grand Forks, ND - September 2013.

Gbolo, P, and Gerla, P, 2013, 'Nutrient variability in soils and plants in an abandoned cattle feedlot', Proceedings of the North Dakota /South Dakota Engineering Research Summit, South Dakota State University, Brookings, SD - April 2013.

Research

Nutrients are 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. Currently, there are research gaps in the cycle, mobility, speciation, and sequestration of P in different environments. Nutrient quantification in runoff and nutrient leaching in groundwater systems have received attention lately. In view of this, this research examines the P cycle within a sandy ridge and adjacent wetlands. This

study will analyze groundwater, soils, surface water, plant tissues, and microorganisms as part of a larger study to test the hypothesis that when P is transported by runoff, it is sequestered and immobilized, with increasing abundance in wetlands. Objectives are to quantify the P fluxes within soil, groundwater, and vegetation, to investigate the variability of nitrogen, organic carbon, and trace elements on phosphorus concentration, to assess the seasonal dynamics of phosphorus, and to characterize the role of some invasive and native plants in nutrient uptake and phytoremediation.

The site has been instrumented with nested wells and soil pore-water samplers for monitoring groundwater nutrient. Grab soil samples and plant biomass were sampled during 2012 summer, but more sampling was done during 2013 summer to determine more thoroughly constrain nutrient variability. Drought conditions experienced in summer 2012 limited groundwater sampling; additional sampling was carried out during 2013 for water quality analysis and nutrient modeling. A manuscript has been submitted and accepted for publication in the journal Hydrology and Earth System Sciences (HESS). A second paper is in review.

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 trace elements. Result of this research will benefit feedlot management and mitigate pollution, and also help guide the development of regulations for protecting surface and groundwater quality without excessively restricting animal production

Mapping Techniques for Soil Erosion using Digital Camera LiDAR and GIS

Project Number: 2013SWC
Fellow: Rick Thalacker
Adviser: Gregory Vandeberg
Start Date: 3/1/2013
End Date: 2/28/2014

Research

Soil erosion is a worldwide problem that can negatively impact surface water through the introduction of sediment, nutrients (eg. nitrogen, phosphorus), pesticides, and other chemicals. These pollutants can be toxic to aquatic and terrestrial biota, as well as impact anthropogenic uses of surface water for drinking, agriculture, and industry. Soil erosion is often exacerbated by agricultural and other types of land use. In North Dakota, more than 28.1 million surface acres are in cropland, and 9.9 million in rangeland. The North Dakota State Water Commission has identified soil erosion as a concern in contributing to sedimentation in lakes and reservoirs. In particular, soil erosion in the Red River basin has been identified as a problem due to the loss of soil, and the pollution of lakes and streams. Local soil conservation districts work with local producers, the Natural Resource Conservation Service, and other state and federal agencies to implement best management practices to reduce the amount of soil erosion. Identifying locations prone to soil erosion can help agencies to prioritize their efforts for implementing best management practices.

The identification of soil erosion or soil erosion potential has been addressed using many different techniques. Erosion surveys allow for on the ground mapping and/or the use of aerial photos to map erosion. These surveys can be time consuming and expensive. Erosion indexes and rainfall intensity have also been used to map erosion, or erosion potential. Empirical and process-based models such as the Universal Soil Loss Equation (USLE), Revised Universal Soil Loss Equation (RUSLE), Water Erosion Prediction Project (WEPP) and Surface and Water Assessment Tool (SWAT) allow for the prediction of sediment runoff as well as changes to runoff and water quality based on different management and cropping scenarios. These methods evaluate overall erosion, or loading to local surface water, but do not pinpoint locations of increased erosion potential.

The purpose of this study is to identify and model soil erosion or potential soil erosion using Digital Camera LiDAR to create high resolution Digital Elevation Models (DEM's) in a GIS.

Project Objectives:

1. Identify critical areas of surface erosion identified by gullies, and inlets from agricultural ditches to the upper Turtle River and Forest River watersheds of North Dakota using SPI. The identification of these critical areas will allow for the implementation of precision conservation techniques to decrease impacts to surface water quality. The results of this pilot study can be translated to the greater Red River valley area to identify critical areas of erosion.
2. To investigate soil erosion and how to best identify, model and represent soil channelization using a new and exciting remote sensing technique referred to as "digital camera LiDAR" using "Structure from Motion" (SfM) techniques and software.
3. The results of this study will be used to compare data between airborne LiDAR and digital camera based LiDaR data of the Red River Valley. This research promises to be a new and economical approach to creating field-scale LiDAR data sets for erosion and other studies using free open source software and digital cameras. The proposed study areas are the upper Turtle River and Forest River watersheds in Grand Forks and Walsh County, ND.

Anticipated results and benefits:

Stream Power Index's (SPI's) created from Digital Elevation Models (DEM's) will be produced to identify potential critical erosion areas adjacent to the Turtle and Forest Rivers above Larimore and Fordville dams. As part of this study, the models produced from the airborne vs. digital camera LiDAR will be compared. SPI's at or above critical erosion levels can be used to target precision conservation in individual fields adjacent to the Turtle and Forest Rivers. This information can be used by landowners, the local Soil Conservation District as well as the Red River Resource Conservation and Development Council. A comparison between the airborne LiDAR and digital camera LiDAR will help to determine the viability of using digital camera LiDAR for applications such as this. The results of this research will be submitted to a journal such as Catena or the Journal of Environmental Quality.

Understanding the Survival of Cryptosporidium Oocysts in North Dakota under Winter Conditions

Project Number: 2013SWC
Fellow: Ruchi Joshi
Adviser: Eakalak Khan and John McEvoy
Start Date: 3/1/2013
End Date: 2/28/2014

Research

Cryptosporidium is an infective protozoan which is one of the most important contaminants found in drinking water and is associated with high risk of waterborne illness. Cryptosporidium causes a parasitic gastrointestinal disease called cryptosporidiosis in mammals. Cryptosporidiosis is potentially lethal for mammals which have suppressed immune systems. An infected mammal can shed up to 107 oocysts per ml of its fecal matter which can contaminate soil and water. Severity of the public health concerns can be estimated by the fact that ingestion of contaminated water containing as few as 10 oocysts can lead to cryptosporidiosis. The mechanism of Cryptosporidium transport in the environment remains poorly understood. Cattle and other livestock are reservoirs of human pathogenic Cryptosporidium species. Application of liquid manure to the fields is a common practice in many North American farm operations. Fertilizing agricultural lands with manure contaminated with Cryptosporidium can result in cryptosporidiosis outbreaks.

Considering both, the climate conditions in North Dakota and survival conditions of Cryptosporidium, it is apparent that Cryptosporidium oocysts can survive in North Dakota. Besides these conditions, data has been provided by the Centre for Disease Control & Prevention (CDC) reflecting a gradual increment in the number of Cryptosporidiosis cases within North Dakota. Therefore, taking in account the capability of Cryptosporidium of causing a public health outbreak, it is very important to understand the effect of low temperature on Cryptosporidium.

Project Objectives:

The main objective of this study is to investigate the excystation of Cryptosporidium parvum. The specific objectives include investigating the survival of Cryptosporidium parvum oocysts by subjecting them to different temperatures and determining their viability, determining the infectivity of the Cryptosporidium parvum oocysts by an in vivo method, and studying the morphological changes in the Cryptosporidium parvum oocysts before and after exposing to different temperatures.

Investigation of Cryptosporidium oocysts in Influent and Effluent of the Fargo Water Treatment Plant

Project Number: 2013ND276B
Fellow: Tanush Wadhawan
Adviser: Eakalak Khan and John McEvoy
Start Date: 3/1/2013
End Date: 2/28/2014

Research

Since 1999, the Center for Disease Control has been monitoring the number of reported cases of cryptosporidiosis in the United States. The average annual number of reported cases for North Dakota 23 with 2007 being the year with the highest number of cases (78 cases). The majority of the cases for 2007 were reported in June and July, of those, 6 people reported swimming in lakes in North Dakota. Studies have been conducted to determine the presence of *Cryptosporidium* in the Red River and its tributaries during the flooding of 2009 and 2010. Sixty nine percent of water samples collected during the flood of 2009 and 82% sample of 2010 were found to be positive for *Cryptosporidium*. This high prevalence of *Cryptosporidium* in water samples can be accounted for the presence of animals in or around the sampling area. Two studies concluded the prevalence of *Cryptosporidium* in 20.3% and 8.9% of the animals tested in North Dakota. The high prevalence of *Cryptosporidium* in North Dakota and their high potency to infect humans requires us to understand transport of *Cryptosporidium* into surface waters during spring thaw. This information will help in risk assessment and development of control practices.

Our previous studies showed that clayey soils and manure applied to soil drastically increased the adsorption of *Cryptosporidium*. In addition, we also found higher transport of oocysts occurred during a snowmelt event compared to a rain fall event.

Our data from a different project suggested that there might be seasonal changes in the concentration and type of *Cryptosporidium* oocysts present in the Red River of the North. Water samples collected during 2009 and 2010 spring flooding were 69.23% and 82.35% positive for *Cryptosporidium*, respectively. It is important to know the concentration and types of oocysts entering the Fargo Water Treatment Plant.

The main scope of this project is to investigate the prevalence of *Cryptosporidium* oocysts in a drinking water system. The specific objectives of the proposed studies are as follows:

1. To quantify the amount of *Cryptosporidium* oocysts in the influent and effluent of the Fargo Water Treatment Plant.
2. To perform molecular characterization of *Cryptosporidium* oocysts in the influent and effluent of the Fargo Water Treatment Plant.

Temporal-spatial distribution (dynamics) of phytoplankton and diversity in relation to lake physical and chemical condition

Project Number: 2013ND275B
Fellow: Veselina Valkov
Adviser: Wei Lin
Start Date: 3/1/2013
End Date: 2/28/2014

Presentations/Posters

Veselina Valkov “Impacts of artificial destratification on water quality and phytoplankton growth in an eutrophic lake” 85th Annual ND Water Pollution Control conference, Grand Forks, 2013

Veselina Valkov “The effect of artificial aeration on phytoplankton growth in a small eutrophic lake in North Dakota” presentation at River Watch Spring Workshop, Kathryn, North Dakota, 2013

Research

Eutrophication is a process by which lakes and reservoirs become more productive as a result of increased concentrations of nutrient, especially nitrogen (N) and phosphorus (P). Eutrophication occurs naturally; however, human activities that cause increased nutrient release accelerate eutrophication. This process is defined as cultural eutrophication. The high concentrations of N and P stimulate growth and blooms of phytoplankton, periphyton, and macrophytes. The common consequences of water quality changes related to eutrophication, and particularly to an increase of phytoplankton growth, include a decrease of water transparency, increase of diurnal dissolved oxygen (DO) variation, anoxic condition in water bottom layer, and shifts of phytoplankton composition to bloom-forming species of certain classes, such as Cyanobacteria. Species such as Aphanizomenon sp., Anabaena sp. and Microcystis sp. are among the most common Cyanobacteria in eutrophic lakes and reservoirs. As reported in the “North Dakota 2012 Integrated Section 305(b) Water Quality Assessment Report”, 45% of assessed lakes and reservoirs are eutrophic making eutrophication a serious water quality concern in North Dakota.

Artificial aeration is one of the methods used as a management technique to increase DO concentration in the water column and to prevent thermal stratification. On one hand, the introduced air become dissolved in the water, and on the other hand, lake circulation caused by artificial aeration reduces, or prevents the stratification and increases natural mixing of oxygen rich surface waters with oxygen poor bottom water. Improved DO concentrations in turn prevent fish kill and loss of suitable habitats for aquatic biota. Recently, artificial aeration has been an adopted method to control algal and especially Cyanobacteria blooms.

The remediation of water quality problems, including reduction of Cyanobacteria blooms, using an aeration system requires an understanding of the factors favoring Cyanobacteria dominance in lakes. The two most competitive advantages of Cyanobacteria are their ability to regulate buoyancy and the capability of some species to fix atmosphere nitrogen N2. Buoyancy regulation of many Cyanobacteria through the production of gas vesicles is an ecologically important mechanism enabling them to adjust their vertical position in the water column. The rate of sinking and upward movement, however, depends on colony size and cell density of the species. In addition to buoyancy regulation, nitrogen fixation influences the growth of Cyanobacteria such as Aphanizomenon sp. and Anabaena sp. In fact, the N2-fixation capability provides N2-fixing species with a competitive advantage over the other phytoplankton species when the nitrogen concentrations in water are limited.

Sodic soil characterization and management on subsurface drainage

Project Number: 2013ND270B
Fellow: Yangbo He
Adviser: Thomas DeSutter
Start Date: 3/1/2013
End Date: 2/28/2014

Presentations

He, Y., and T. DeSutter. Advances in our knowledge of dispersion and swelling with soil sodium and the interaction of sodium chemistry with soluble salts. Soil and Soil/Water Training, Jan. 22, 2014, Fargo, ND.

DeSutter, T., and Y. He. Chemistry of sodium-affected soils. Presented at the What is Successful Reclamation? Second annual North Dakota Reclamation Conference. February 24 and 25, 2014, Dickinson, ND.

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. However, many soils may be negatively impacted because sodium is part of the exchange complex. Sodium is known a dispersant and this dispersion is accelerated when the concentration of soluble salts is reduced, which will likely occur in tile-drained soils. Dispersion can lead to decreased Ksat, water percolation, and increased runoff, and finally decrease drainage performance. Currently, there are no management strategies that have been developed for ND to help combat the effects of dispersion or to prevent dispersion from occurring within tile-drained soils.

The main objective of this study is to characterization sodic soils and produce management guidelines for sodic soils that have been tile drained. The specific objectives include:

1. Determine physical and chemical properties (Ksat, dispersion, swelling, and pore volumes of water) of sodic soils from that have the potential to be subsurface drained
2. Develop laboratory and simulation experiments (equations and computer-based models) to determine calcium requirements for remediation of sodic soils within tile drained soils.

Investigation of how pure clay minerals react (disperse or flocculate) under different sodicity and salinity levels was finished the 2012 summer. Since then soil samples have been collected, air-dried, and ground, but laboratory assessment and computer modeling have yet to be completed.

Significance:

Excessive levels of salts occur in large areas around the world and profoundly affect land use. Usually, these problematic soils are defined into two major types, namely, saline and sodic soils. When saline soils are dominated by sodium salts, soils are termed “sodic.” Estimates of the globe that are covered by sodium-affected soils are about 581.0 million ha, which occupy a large proportion of a total 932.2 million ha of salt-affected soils (Szabolcs, 1989; Sumner and Naidu, 1998). Sodic soils occur in many areas of Northern Great Plains, and in North Dakota, about 4.7 million acres are negatively affected by sodium (Brennan,

Personal communication, North Dakota USDA-NRCS, 2008). One of the main concerns that NDSU soil scientists have about the draining of these sodium-affected soils is the potential of decreased soil water hydraulic conductivity (Ksat) due to the factors that control soil swelling and dispersion: (1) sodium on the exchange sites and (2) decreased electrical conductivity (EC) of the soil solution due to drainage. This concern has resulted in the publication of a tile-drainage Extension bulletin by Cihacek et al. (2012) so that tile-drainage installers and landowners can become more aware of this concern and have a tool by which they can learn more about their soils. However, this publication only addresses the soils that might be affected and does not inform landowners of how to manage, in particular, sodium-affected soils.

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: 2013ND280B
Start Date: 3/1/2013
End Date: 2/28/2014
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.

The annual "Distinguished Water Seminar" could not be hosted because of the budget cut. However, the Institute partnered with the US Geological Survey, ND Department of Health, and the ND Water Commission to host the 58th Annual Midwest Groundwater Conference in Bismarck, September 23-25, 2013.

MIDWEST GROUNDWATER CONFERENCE

Several North Dakota Water resources Research Institute (NDWRRI) Fellows and affiliated faculty presented at the 58th Annual Midwest Groundwater Conference, September 23-25, 2013 in Bismarck, ND. Approximately 140 researchers and practicing professionals from government agencies, industries, and universities from the Midwestern states attended the conference. A tour of the Bakken oil country was a highlight of the conference. The tour included an oil drilling site, production well, water depots and transport, wastewater handling, and a man camp. An intake tower with horizontal wells on the Missouri river for Bismarck water supply was also a part of the tour.

The Midwest Groundwater Conference is a forum in which individuals, universities, industry, and government agencies of the Midwestern states come together annually to share research and case studies related to all aspects of groundwater. The conference began in 1956 in Illinois and has been held at one of the member states ever since.

G. Padmanabhan, Director, NDWRRI, served on the Planning Committee and chaired a session.

Scott Korom, Associate Professor of Geology and Geological Engineering, UND, an NDWRRI affiliate faculty, and also a planning committee member was the banquet speaker. His talk was about nitrogen issues in the Lake Taupo Catchment in New Zealand. He also chaired a session.

Other NDWRRI affiliate faculty members who chaired sessions are Francis Casey, Professor of Soil Science and Director of School of natural resources, NDSU, and Xinhua Jia, Assistant Professor, Agriculture and Biosystems Engineering, NDSU.

Presentations by Fellows (F) and affiliate faculty (AF) included:

1. Underground Coal Gasification: What is it? What role does hydrogeology play?- Scott Korom (AF)
2. Stationarity Revisited: A Physical Geographer's Perspective – Paul Todhunter (AF)
3. Surface Modification of Nanoparticles with Food Starch for Groundwater Remediation Applications – Achintya Bezbaruah (AF)
4. Fate and Transport of Estrogenic Hormone in Subsurface Waters – Francis Casey (AF)
5. 5.Electron Donor Contributions to Denitrification in the Elk Valley Aquifer – Amanda Krieger (F), Scott Korom (AF), and William Schuh
6. Groundwater Level Response to Droughts in North Dakota – Navaratnam Leelaruban and G. Padmanabhan (AF)
7. Groundwater Bioremediation for Alternating Contaminants using Enricher Reactor – Entrapped Cell Permeable Reactive Biobarrier – Murthy Kasi (F)

Dr. Achintya Bezbaruah, NDWRRI research faculty presenting at the MGW conference, Bismarck, September 23-25, 2013

NDWRRI participants in Banquet dinner at the MGW conference

NATIONAL COMPETITIVE PROGRAM (104-G)

No submission.

Institute Publications

Technical Report No: ND13-01
Toward Understanding the Hydrologic Processes on Topographic Surfaces with Depressions – Modeling and Applications
Jun Yang and Xuefeng Chu

Technical Report No: ND13-02
Tile drain water: identification of sources and quality improvement by a constructed wetland
Alex Stalboerger, Donna Jacob and Marinus Otte

Technical Report No: ND13-03
EFFECTIVE DELIVERY OF IRON NANOPARTICLES BY AMPHIPHILIC POLYSILOXANE GRAFT COPOLYMERIC VEHICLES FOR GROUNDWATER REMEDIATION
Sita Krajangpan, Bret J. Chishlom, and Achintya N. Bezbaruah

Technical Report No: ND13-04
COMPARISON OF DENITRIFICATION POTENTIAL AROUND A TILE DRAIN AND IN AQUIFER SEDIMENTS: OAKES, ND
Chase J. Christenson and Scott F. Korom

Technical Report No: ND13-05
Impact of Subsurface Drainage on Stream Flows in the Red River of the North Basin
Mohammed M. Rahman and Zhulu Lin

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 (FeS2), 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:

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: Jiexia 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.

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.