Water Resources Institute
Annual Technical Report
FY 2010

Introduction

The University of Wisconsin WRI serves as the gateway to federal WRRI grants for all Wisconsin colleges and universities. While the WRI s federal base funding from the U.S. Geological Survey totals less than $100,000 per year, every federal dollar is matched with at least two nonfederal dollars. All WRRI grants are awarded on a competitive, peer-reviewed basis. WRI funds are leveraged with additional funding from the UW System Groundwater Research Program, part of Wisconsin s Groundwater Research and Monitoring Program. Faculty members and research staff who have achieved PI status from any UW System campus are eligible to apply for this funding. Guided by the Wisconsin Groundwater Coordinating Council, this program is the mechanism whereby the UW System and the state departments of Natural Resources, Commerce, and Agriculture, Trade & Consumer Protection pool limited state and federal resources to support a coordinated, comprehensive and multidisciplinary response to the state s critical water resource issues. Together, these programs have helped establish the University of Wisconsin as a national leader in groundwater research.

The Wisconsin WRI funds an average of 15 short-term research projects of either a fundamental or applied nature that typically involve about 50 faculty, staff and students at a half-dozen campuses around the state each year. By supporting short-term projects, the institute is able to quickly respond to issues as they emerge. WRI annually provides about 25 graduate and undergraduate students in the UW System with opportunities for training and financial support while they work toward their degrees. During the current reporting period a total of 23 students/trainees (seven undergraduates, 10 master's degree students, three Ph.D. students and three post-doctoral students) received WRI support.

WRI research and other water-related information are readily accessible via a Web site (www.wri.wisc.edu) and the Water Resources Library (WRL), a nationally unique collection of documents covering every major water resource topic. The library s catalog is available online and searchable via the Internet, making the WRL a national and global resource. In 2003, the WRL became the first academic library in the state to make its collection available online to the public when it developed Wisconsin s Water Library (www.aqua.wisc.edu/waterlibrary), which permits Wisconsin residents to check out WRL books and other documents free of charge via their local libraries. WRI also helps organize and cosponsor state and regional conferences on water issues.

The WRI is housed in the Aquatic Sciences Center which also houses the UW Sea Grant Institute, part of another federal-state partnership of 30 university programs that promote research, education, and outreach on Great Lakes and ocean resources. This unique administrative union of Wisconsin's federal Water Resources Research Institute and Sea Grant programs enables the UW Aquatic Sciences Center to address the full range of water-related issues in Wisconsin, from surface water to groundwater, from the Mississippi River to the shores of Lakes Michigan and Superior.

Research Program Introduction

As established by Wisconsin s Groundwater Law of 1984, the state provides $300,000 annually to the UW System to support groundwater research and monitoring. In 1989, the WRI became the UW System s lead institution for coordinating the calls for proposals and peer reviews for distribution of the funds. To avoid duplication and better target groundwater research funding, several other state agencies (the departments of Commerce, Natural Resources, and Agriculture, Trade and Consumer Protection) agreed to partner with the WRI to establish an annual Joint Solicitation for Groundwater Research and Monitoring. This annual solicitation has funded more than 300 groundwater research and monitoring projects since its inception and has helped establish Wisconsin as a leader in groundwater research. The results of the Wisconsin Groundwater Research and Monitoring Program (WGRMP) are recognized internationally, and WRI plays an important role in coordinating project reporting and making all technical reports available through our institute s library and website.

Our priorities for groundwater research are established annually by the Wisconsin Groundwater Research Advisory Council (GRAC) and are included as part of the Joint Solicitation. The GRAC is our institute's advisory council and also convenes to make project funding decisions. All proposals submitted to the Joint Solicitation receive rigorous external peer review (coordinated by the WRI) and relevancy review by the Research Subcommittee of the state's Groundwater Coordinating Council.

Beginning in 2010, the annual 104(B) allocation was used to expand the scope of the joint solicitation to include research on the effects of climate change on Wisconsin s water resources. Priorities for climate change research were established through a partnership between the WRI and the Wisconsin Initiative on Climate Change Impacts (WICCI). Established in 2007, WICCI is a university-state partnership created to: (a) assess and anticipate the effects of climate change on specific Wisconsin natural resources, ecosystems and regions; (b) evaluate potential effects on industry, agriculture, tourism and other human activities; and (c) develop and recommend adaptation strategies that can be implemented by businesses, farmers, public health officials, municipalities, resource managers and other stakeholders.

We believe these partnerships with other state agencies provides WRI with the ability to fund highly relevant research and allows our limited funds for 104(B) to be leveraged to the fullest extent.

Award No. 08HQGR0148 The Transport, Fate and Cycling of Mercury in Watersheds and Air Sheds

Basic Information

Title:	Award No. 08HQGR0148 The Transport, Fate and Cycling of Mercury in Watersheds and Air Sheds
Project Number:	2008WI244S
Start Date:	9/15/2008
End Date:	9/14/2013
Funding Source:	Supplemental
Congressional District:	2nd
Research Category:	Water Quality
Focus Category:	Toxic Substances, Wetlands, Water Quality
Descriptors:	mercury, catchment processes
Principal Investigators:	Jim Hurley, David P. Krabbenhoft

Publications

1. Kolker, A., Olson, M., Krabbenhoft, D.P., Tate, M.T., and Engle. M.A., 2010, Patterns of mercury dispersion from local and regional emission sources, rural Central Wisconsin, USA, Atmos. Chem. Phys., 10, 1–10, 2010.
2. Engle, M.A., Tate, M.T., Krabbenhoft, D.P., Schauer, J.J., Kolker, A., Shanley, J.B., Bothner, M.H. 2010, Comparison of Atmospheric 1 Mercury Speciation and Deposition at Nine Sites across Central and Eastern North America, Geophysical Research (in press).
3. Engle, MA, MT Tate, DP Krabbenhoft, A Kolker, ML Olson, ES Edgerton, JF DeWild, and AK McPherson. 2008. Characterization and cycling of atmostpheric mercury along the centeral US Gulf of Mexico coast. Applied Geochemistry 23, 419-437
4. Geboy N, DP Krabbenhoft, MA Engle, and T Sabin. 2011. The Solubility of Mercury-Containing Aerosols in Fresh and Sea Water. In the Proceedings of the 10th International Conference on Mercury as a Global Pollutant, Halifax, Nova Scotia. 1 page.
5. Engle, M.A., Tate, M.T., Krabbenhoft, D.P., Schauer, J.J., Kolker, A., Shanley, J.B., Bothner, M.H. 2010, Comparison of Atmospheric Mercury Speciation and Deposition at Nine Sites across Central and Eastern North America, J. Geophys. Res., 115, D18306, doi:10.1029/2010JD014064

Annual Progress Report

Selected Reporting Period: 3/1/2010 - 2/28/2011

Submitted By: David Krabbenhoft
Submitted: 5/27/2011

Project Title

WR08R005: The Transport, Fate and Cycling of Mercury in Watersheds and Air Sheds

Project Investigators

James Hurley, University of Wisconsin

Progress Statement

This project looks at two mercury related questions: (1) mercury in watersheds; and, (2) mercury cycling and transport in the atmosphere. During reporting period the project completed its second year of "recovery" (i.e., no longer loading mercury to the study watershed) on the Mercury Experiment to Assesses Atmospheric Loadings in Canada and the US (METAALICUS) project. Our portion of the project is to monitor the watershed-scale response of the artificial load of mercury that was administered from 2001 through 2007 using three different stable isotopes (198Hg, 201Hg, 202Hg) to the study wetland, uplands and lake, respectively. During this phase of the project, we will quantify the response of the watershed to a mercury "load reduction" through continuous monitoring of the isotope concentrations and water flux from the terrestrial flows into the study lake. On the atmospheric studies, the project performed one assessment study of mercury deposition spanning time and space domain near a emission stack in central Wisconsin; and significantly enhanced our field monitoring system by securing the extra instrumentation needed to make "gradient" measurements (Eddy Correlation method) of mercury concentrations in the atmosphere above our study sites.

Principal Findings and Significance

Principal Findings and Significance

Description

Our results show that in coastal settings, the intersection of terrestrially based mercury emission sources interacting with chemical oxidants formed in the marine boundary layer result in exacerbated mercury deposition in the near coastal environments. These finds have direct implications for water-resource rich ecosystems along the East Coast of the US, and people who fish in those waters. Also, the application of the mercury depositon model developed by this project to these field settings provides a scientifically based explanation for why coastal areas in the southeastern US are among the highest mercury deposition zones.

Description

Results from the past year of data collection revealed that despite the cessation of loading the watershed on the METAALICUS project, concentrations in runoff continued to increase. This phenomenon reveals the inherent time lags that are part of the natural response to changes in loading watersheds. On the atmospheric studies portion of the project the assessment revealed the importance of the marine boundary layer for facilitating atmospheric mercury reactions and deposition.

Description

The expanded ability to measure mercury concentration in the atmosphere using the Eddy Correlation method will significantly improve our ability to understand the bi-directional nature of mercury fluxes between the atmosphere and the land/water surface.

Journal Articles & Other Publications

Publication Type	Journal Article/Book Chapter (Peer-Reviewed)
Title	Characterization and cycling of atmospheric mercury along the central U.S. Gulf of Mexico Coast
Author(s)	Engle, M.A., Tate, M.T., Krabbenhoft, D.P., Kolker, A., Olson, M.L., Edgerton, E.S., DeWild, J.F., and McPherson, A.K.
Publication/Publisher	Applied Geochemistry 23 (2008), pp. 419–437.
Year Published	2008
Volume & Number	23
Number of Pages	19
Description	
Any Additional Citation Information	

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Publication Type	Journal Article/Book Chapter (Peer-Reviewed)
Title	Patterns of mercury dispersion from local and regional emission sources, rural Central Wisconsin, USA
Author(s)	Kolker, A., Olson, M., Krabbenhoft, D.P., Tate, M.T., and Engle. M.A.,
Publication/Publisher	Atmos. Chem. Phys.,
Year Published	2010
Volume & Number	10, 1–10
Number of Pages	10
Description	Abstract. Simultaneous real-time changes in mercury (Hg) speciation- reactive gaseous Hg (RGM), elemental Hg (Hg°), and fine particulate Hg (Hg-PM2.5), were determined from June to November, 2007, in ambient air at three locations in rural Central Wisconsin. Known Hg emission sources within the airshed of the monitoring sites include: 1) a 1114 megawatt (MW) coal-fired electric utility generating station; 2) a Hg-bed chlor-alkali plant; and 3) a smaller (465 MW) coal-burning electric utility. Monitoring sites, showing sporadic elevation of Hg°, Hg-PM2.5, and RGM were positioned at distances of 25, 50 and 100 km northward of the larger electric utility. Median concentrations of Hg°, Hg-PM2.5, and RGM were 1.3–1.4 ng m−3, 2.6–5.0 pg m−3, and 0.6–0.8 pg m−3, respectively. A series of RGM events were recorded at each site. The largest, on 23 September, occurred under prevailing southerly winds, with a maximum RGM value (56.8 pg m-3) measured at the 100 km site, and corresponding elevated SO2 (10.4 ppbv; measured at 50 km site). The finding that RGM, Hg°, and Hg-PM2.5 are not always highest at the 25 km site, closest to the large generating station, contradicts the idea that RGM decreases with distance from a large point source. This may be explained if: 1) the 100 km site was influenced by emissions from the chlor-alkali facility or by RGM from regional urban sources; 2) the emission stack height of the larger power plant promoted plume transport at an elevation where the Hg is carried over the closest site; or 3) RGM was being generated in the plume through oxidation of Hg°. Operational changes at each emitter since 2007 should reduce their Hg output, potentially allowing quantification of the environmental benefit in future studies.
Any Additional Citation Information	

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Publication Type	Journal Article/Book Chapter (Peer-Reviewed)
Title	Comparison of Atmospheric Mercury Speciation and Deposition at Nine Sites across Central and Eastern North America
Author(s)	Engle, M.A., Tate, M.T., Krabbenhoft, D.P., Schauer, J.J., Kolker, A., Shanley, J.B., Bothner, M.H.
Publication/Publisher	Geophysical Research
Year Published	In Press
Volume & Number	
Number of Pages	
Description	
Any Additional Citation Information	

Publication Type	Proceedings/Symposium (Not Peer-Reviewed)
Title	The Solubility of Mercury-Containing Aerosols in Fresh and Sea Water
Author(s)	Geboy, N., Krabbenhoft, D., Engle, M., and Sabin, T.
Publication/Publisher	Proceeding of the 10th International Conference on Mercury as a Global Pollutant
Year Published	2010
Volume & Number	1
Number of Pages	1
Description	Abstract presented at this international meeting
Any Additional Citation Information	

Students & Post-Docs Supported

Student Name	Nicholas Ostrowski
Campus	University of Wisconsin-Madison

Advisor Name	Kenneth Bradbury
Advisor Campus	University of Wisconsin-Madison

Degree	Masters
Graduation Month	August
Graduation Year	2012
Department	IES
Program	Letters and Science
Thesis Title	
Thesis Abstract	

Grant No. G09AP00068 Influence of Coupling Erosion and Hydrology on the Long-Term Performance of Engineered Surface Barriers

Basic Information

Title:	Grant No. G09AP00068 Influence of Coupling Erosion and Hydrology on the Long-Term Performance of Engineered Surface Barriers
Project Number:	2009WI245S
Start Date:	5/15/2009
End Date:	8/31/2012
Funding Source:	Supplemental
Congressional District:	WI-2
Research Category:	Engineering
Focus Category:	Management and Planning, Models, Hydrology
Descriptors:	
Principal Investigators:	Anders W. Andren, Craig H Benson

Publications

There are no publications.

Annual Progress Report

Selected Reporting Period: 3/1/2010 - 2/28/2011

Submitted By: Craig Benson
Submitted: 5/30/2011

Project Title

WR09R007: Influence of Coupling Erosion and Hydrology on the Long-Term Performance of Engineered Surface Barriers

Project Investigators

Craig Benson, University of Wisconsin-Madison

Progress Statement

OBJECTIVE

The objective of this project is to evaluate erosion control strategies for waste containment systems that balance erosion control and hydrologic performance (primarily percolation into the underlying waste). The tasks involved in completing this objective include:

Conduct a literature review regarding erosion control strategies being employed for waste containment facilities in both humid and arid regions.

Select a combination of models that can predict erosion and hydrological performance of covers in humid and arid regions and compare/validate the models with field data.

Perform model simulations to identify strategies likely to be effective in managing erosion and hydrology of covers.

LITERATURE REVIEW AND MODEL SELECTION

Our literature review has shown that erosion control strategies for LLW facilities consist of controlling surface texture (e.g., riprap barriers, gravel-amended soil layers) and geometric control (e.g., slope length, slope shape, benching, intermittent energy barriers). We are evaluating these strategies in our modeling studies.

We have also reviewed erosion and hydrologic models. Models were evaluated based on their capabilities, mechanistic vs. empirical methodology, simulation time, ease of use, calibration capabilities, and validation with field data. Erosion models that were evaluated including RUSLE 2, WEPP, and EPIC, as well as the landform evolution models SIBERIA, CHILD, CAESAR, and GOLEM. The following are key highlights of these models:

RUSLE 2, EPIC, and WEPP are well documented and widely used codes, especially in agriculture. They provide an average annual erosion rate and are highly empirical. These models are relatively easy to use, but do not provide detailed erosion patterns or mechanisms that may be important to a long-term waste containment strategy.

The landform evolution models SIBERIA, CHILD, CAESAR, and GOLEM are physically based models that use digital elevation models to describe the landscape. They rely on a mechanistic description of erosion processes to simulate sediment yield and erosion patterns. Landform models are more difficult to parameterize and deploy.
SIBERIA was chosen for use in this project because of its mechanistic basis, channel initiation function to describe the transition point between the hillslope and channel, and coupling of fluvial and diffusive erosion processes (e.g., soil creep and rain splash). SIBERIA is also well documented and has been used to evaluate long-term containment systems. SIBERIA has been calibrated with RUSLE 2 using average annual erosion rates as the main calibration factor, and has been validated with experimental and field geomorphological data at the ERA Ranger Mine in Australia.

Hydrologic models that were considered include UNSAT-H, HYDRUS, SVFlux, and VADOSE/W. Each of these models is based on Richards' equation, includes an atmospheric surface boundary to simulate soil-plant-atmosphere interactions, and has been used successfully to simulate the hydrology of

earthen covers used for long-term waste containment. UNSAT-H is a 1D model, VADOSE/W is 1D or 2D, and SVFlux and HYDRUS are available in 1D, 2D, and 3D versions. We chose SVFlux because it has capability for 3D simulation and a stronger surface boundary module than HYDRUS. The developer of SVFlux is also interested in adapting the code for more diverse cover applications, including erosion modeling.

SIMULATION STRATEGIES

We are using two UMTRA disposal facilities to create base cases for simulation: the Grand Junction Uranium Mill Tailings disposal site (near Grand Junction, CO) and the Canonsburg Mill Site disposal site near Canonsburg, PA. The US Department of Energy's Office of Legacy Management has provided geometric data for these sites (e.g., topographic maps) as well as construction document reports. These sites represent semi-arid (Grand Junction) and humid climates (Canonsburg) that employ traditional cover designs with an unvegetated riprap layer overlying a clay radon barrier. We are also using the cover profile from the Monticello disposal site (Monticello, UT) as the base case for an alternative profile with a vegetated gravel-soil mixture.

Our simulations conducted to date have been based on the as-built conditions at the Grand Junction site and the gravel admixture used at Monticello as an alternative. We are also studying combinations of riprap and a gravel admixture on the top desk and side slopes. For each scenario, only layers above the protection layer (450 mm) and radon barrier layer (450 mm) are being varied (i.e., the protection and radon barriers are being used in all of the simulations).

We are also evaluating how re-shaping side slopes reduces erosion and promotes long-term stability. The intent is to create naturally shaped slopes and to avoid the sharp grade breaks that are typical of man-made slopes. We are also evaluating mound-type covers with gradual breaks in grade and intermitted energy dissipation breaks in longer slopes.

PATH FORWARD

We plan to continue our literature review on erosion control strategies in both humid and arid regions as the project proceeds to ensure that we cover as many practical and creative strategies as practical. We will continue using the codes SIBERIA and SVFlux in tandem for modeling erosion and percolation. Our emphasis to date has largely focused on erosion modeling. However, in the next year we anticipate more emphasis on sequential modeling of erosion and unsaturated hydrology to understand how erosion control strategies affect percolation into the underlying waste.

Principal Findings and Significance

Principal Findings and Significance

Description This project is still in its early stages and thus significant applications and impacts have not yet been realized. However, this project will result in design methodologies for more sustainable and effective cover systems. New cover system profiles will be developed as an outcome of this study. These profiles will be more resistant to erosion and more effective in limiting percolation into underlying waste. As a result, they will require less maintenance and be more effective in protecting groundwater.

Awards, Honors & Recognition

Title Diplomate Geotechnical Engineer
Event Year 2009
Recipient Craig H Benson
Presented By Academy of Geoprofessionals
Description Inducted as a diplomate

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Title Academy of Distinguished Alumni
Event Year 2009
Recipient Craig H Benson
Presented By University of Texas at Austin
Description Inducted into academy of distinguished alumni in Civil & Environmental Engineering.

Title	Award of Merit
Event Year	2011
Recipient	Craig H. Benson
Presented By	ASTM
Description	

Partners

Name/Organization Affiliation	US Department of Energy/CRESP
Affiliation Type	Federal
Email	
Description	

Name/Organization Affiliation	US Department of Energy/Legacy Management
Affiliation Type	Federal
Email	
Description	

Students & Post-Docs Supported

Student Name	Crystal Smith
Campus	University of Wisconsin-Madison

Advisor Name	Craig Benson
Advisor Campus	University of Wisconsin-Madison

Degree	Masters
Graduation Month	December
Graduation Year	2010
Department	Geological Engineering
Program	Geological Engineering
Thesis Title	NA
Thesis Abstract	NA

Development and Application of a User-Friendly Interface for Predicting Climate Change Induced Changes in Evapotranspiration

Basic Information

Title:	Development and Application of a User-Friendly Interface for Predicting Climate Change Induced Changes in Evapotranspiration
Project Number:	2010WI246B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	2nd
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Hydrology, Methods
Descriptors:	
Principal Investigators:	Steven Loheide

Publications

There are no publications.

Annual Progress Report

Selected Reporting Period: 3/1/2010 - 2/28/2011

Submitted By: Steve Loheide
Submitted: 5/24/2011

Project Title

WR10R001: Development of a User-Friendly Interface for Predicting Climate Change Induced Changes in Evapotranspiration

Project Investigators

Steven Loheide, University of Wisconsin-Madison

Progress Statement

We have developed and calibrated an evapotranspiration (ET) model using a modified Penman-Monteith approach to predict daily ET for nine Wisconsin (WI) regions and five vegetation communities for the periods of 1981-2000, 2046-2065, and 2081-2100 using three global climate models (GCMs). The ET model has been packaged into a user-friendly graphical user interface (GUI) which is freely available online for interested users (http://hydroecology.cee.wisc.edu/research/WisconsinET/index.htm). Daily ET output from the GUI can be used to understand the expected changes to ET by region and by vegetation type and to understand the range of possible changes, which can be used in subsequent hydrologic modeling efforts.

The model is based on the modified Penman-Monteith approach put forth by the FAO which is a combination of the energy balance and mass transfer approaches to estimating ET. This physically based approach allows for computation of daily ET using readily available climate data. The model initially calculates a daily reference ET for a hypothetical uniform surface using daily net radiation, ground heat flux, wind speed, temperature, and relative humidity data. This reference ET is then adjusted using an evaporation reduction coefficient and a basal crop coefficient for specific vegetation communities to account for differences in vegetation height, leaf area index, aerodynamic and surface resistance, and soil water availability.

An important factor in the rate at which plants transpire is the size of a plant's stomatal openings. Plants are able to open and close their stomata in response to environmental factors to regulate the exchange of water vapor and CO2. To account for this, we have incorporated the Jarvis-Stewart model of stomatal conductance in our ET model, which describes how plants respond to temperature, radiation, vapor pressure deficit, and atmospheric CO2 concentration. The resulting stomatal conductance term is applied to the surface resistance term of the Penman-Monteith approach and accounts for stomatal factors that can serve to limit transpiration rates.

The Ameriflux network of eddy flux covariance towers provides long term measurements of vertical water vapor flux (equivalent to actual ET), temperature, relative humidity, wind speed and precipitation. Although the sites are largely focused on researching CO2 exchange in ecosystems, the records of actual ET along with many other climate parameters makes eddy flux data ideal for developing and calibrating ET models. We applied the climate parameters recorded at each of five Ameriflux sites to our ET model and compared our daily predicted ET with the actual ET measurements at the same site. The dominant vegetation types at the five sites are corn, soybeans, tallgrass prairie, shrubs, and hardwood forests. By adjusting the model parameters affecting stomatal conductance and the rate and onset of growth for each vegetation community, we minimized the root mean squared error between the two datasets and obtained sets of Jarvis-Stewart parameters for the vegetation types at each location.

The IPCC Coupled Model Intercomparison Project Phase 3 included fifteen GCMs that predict future radiation, wind speed, humidity, temperature and precipitation globally for the periods of 1961-2000, 2046-2065, and 2081-2100. We applied a subset of three of these models from the Special Report on Emissions Scenarios A1B for use in predicting future ET: cccma_cgcm3_1_t63, cnrm_cm3, and miroc3_2_medres. These three models provide the same spatial resolution of future climate predictions of approximately 2.8 by 2.8 degrees latitude and longitude which corresponds to six GCM cells covering the entire state of WI. However, because the National Climate Data Center has designated nine climate divisions in WI which are defined as "areas of the state that have relatively uniform climate characteristics" we divided the state into nine regions for use in predicting future ET. We used statistically downscaled predictions of daily maximum and minimum temperature and precipitation provided by WICCI for each climate region, but we used non-downscaled data for radiation, wind speed, and relative humidity.

After completing the model calibration and parameterization and obtaining future climate predictions for each of the nine WI climate divisions, we

developed the model with a user-friendly GUI created using Matlab software to allow interested users to predict how ET will change in the future. The GUI allows users to select from three climate models, three climate periods, nine WI regions, five vegetation types, and nine soil types to obtain future ET estimates specific to a given region. For users with knowledge of plant phenology, advanced options are available that are used to adjust how plants respond to environmental factors with regard to stomatal conductance and the onset and rate of growth in the spring. The GUI is freely available online and does not require Matlab software to operate.

Results of this project indicate that increasing temperatures as a result of climate change increase the energy available to drive ET while also acting to increase the length of the growing season, both of which lead to substantial increases in potential ET (PET) in the coming decades. While the effects of increasing CO2 concentration on water use efficiency and changing cloud cover patterns can offset an increase in actual ET (AET) to some degree, the most important factor acting to limit an increase in AET is a decrease in precipitation observed in some models. Results obtained using cccma_cgcm3_1_t63, a wetter-than-average GCM, show an expected increase in future AET of about 5 centimeters annually by 2100. Over the same period, precipitation is shown to increase over 12 centimeters, far outpacing any increase in AET. Spatial differences in ET changes are subtle relative to the absolute ET increase over time, but in this scenario, southwest WI is likely to see the smallest increase in ET, while the largest increase in precipitation occurs in the northwest. In contrast, results obtained using miroc3_2_medres, a hotter-than-average GCM, suggest AET will increase very little on average by 2100, with any expected increases being limited by average precipitation declining 7 centimeters annually over the same period. Spatially, eastern WI sees the highest relative increase in AET combined with smaller precipitation declines than the state average. These results highlight the uncertainty inherent in future climate modeling and show that although PET is certain to increase, the changes in AET or, more importantly, the changes in the difference between AET and precipitation are less clear.

Although changes in AET are important, it is the change in the difference between annual precipitation and AET that will most strongly impact WI hydrology. If precipitation increases at a faster rate than AET, as in the cccma_cgcm3_1_t63 case, the amount of precipitation partitioned to surface runoff and groundwater recharge could increase. In southern WI, where high groundwater has been an issue of concern over the last several years, this could mean continued flooding problems in the future. Conversely, if ET rates increase faster than precipitation rates, as in the miroc3_2_medres case, the amount of water available for recreation, agriculture, ecosystems, and numerous other functions will decrease. Observed water table declines in much of northern WI could be amplified if the evaporative demand of the regional climate increases. Additionally, as plants use more soil water during the growing season, agriculture may become more dependent on irrigation to offset the relative decrease in natural precipitation. AET from these irrigated lands would more closely follow the clear increasing trends in PET as water stress is no longer an important factor impacting AET.

Principal Findings and Significance

Principal Findings and Significance

Description

As the second largest component of WI's water budget after precipitation, ET is a key determinant in water availability across the state. Considering the economic importance of water-based industries in WI such as lake tourism and agriculture, understanding whether dependable and abundant water supplies can be relied on in the future is a high priority. Municipalities and land-use decision makers also depend on accurate hydrologic forecasts to improve water allocation and land use zoning decisions. For those relying on accurate information about the changing water landscape in WI, understanding the potential impacts of changing ET is vital.

Our analysis shows that potential ET will be increasing substantially in the future. This is due in large part to increasing average temperatures which provide more energy to drive ET and which increase the length of the growing season. In irrigated areas, water stress does not inhibit a rise in actual ET compared to non-irrigated areas, so we can expect that irrigated croplands will see a sharp increase in future actual ET, regardless of future precipitation rates. Under non-irrigated conditions, however, any increases in actual ET will depend on how precipitation changes over the same time period. Using one climate model, we predicted that although ET will be increasing by nearly 5 cm annually, any increase will be negligible relative to increasing precipitation, which is expected to rise nearly 12 cm per year. Results from this scenario indicate that the amount of water partitioned to surface storage, runoff, and recharge will increase in the future. However, another climate model leads to modest increases in actual ET, but a decrease in precipitation of about 7 cm per year. Under this scenario, less water will be partitioned for overland flow, storage, and groundwater recharge, which could lead to much drier conditions in the future across the state. Thus, a large increase in potential ET is certain to occur in the future, but whether this results in an increase or decrease in water available for recreation, agriculture, and other uses is unclear and is largely dependent on how precipitation changes over the same period.

The user-friendly GUI developed as part of this project can be applied to help reduce uncertainty as to how precipitation will be allocated among ET, runoff, and groundwater recharge in the future. It provides a simple way for users interested in ET to better understand how climate change will impact them. The model provides three different sets of future climate data which allows for a range of possible changes to ET and accounts for the uncertainty inherent in the GCMs themselves. The inclusion of three climate periods from 1981-2000, 2046-2065, and 2081-2100 allows for a better understanding of how ET is expected to change temporally. The model also divides WI into nine different climate regions, which is useful in better understanding how ET will change in different areas of the state. The five broad vegetation categories in the model allow

users to investigate the importance of land cover in determining any ET changes. Finally, the inclusion of nine separate soil types helps explain the impact of soil characteristics on transpiration rates in a future climate.

This project benefits interested parties in WI and the midwestern United States that recognize the importance of the impacts of climate change on the hydrologic cycle. While many are familiar with the direct impacts of increasing temperatures such as melting glaciers and rising sea levels, the impacts of climate change on the way precipitation is partitioned among surface runoff, storage, groundwater recharge, and ET aren't as often considered. Water is an important economic resource in WI and fully understanding how our water supplies will be affected in the coming decades is crucial to ensure appropriate decisions are made at the state and local government level to maintain this essential resource.

Committees, Memberships & Panels

Group Name	Wisconsin Initiative on Climate Change Impacts - Water Resources Working Group
Description	
Start Date	
End Date	

Partners

Name/Organization	Ankur Desai
Affiliation	University of Wisconsin - Madison
Affiliation Type	Academic Institutions
Email	desai@aos.wisc.edu
Description	Dr. Desai has assisted us with data collection and data filtering from his eddy flux covariance sites as part of the Ameriflux network. He has provided his expertise in ecosystem-atmosphere exchange of energy and water fluxes.

Name/Organization	Ameriflux
Affiliation	Ameriflux Network
Affiliation Type	Federal
Email	
Description	The Ameriflux network of eddy flux covariance towers provides long-term measurements of evapotranspiration, radiation, wind speed, relative humidity, temperature, and precipitation. This public-access network provides an ideal source of data for developing and calibrating an ET model.

Presentations & Public Appearances

Title	Predicting Climate Change Induced Changes in ET
Presenter(s)	Steven Loheide
Presentation Type	Other
Event Name	Water Resources Working Group Meeting
Event Location	UW-Madison
Event Date	6/28/2010
Target Audience	Scientific audience
Audience Size	12
Description	Presented early work developing and calibrating an ET model to predict future ET trends using global climate model data.

Title	Modeling Evapotranspiration in Wisconsin Under a Changing Climate
Presenter(s)	Douglas Joachim
Presentation Type	Seminar
Event Name	Water Resources Seminar - UW-Madison Course
Event Location	UW-Madison
Event Date	10/25/2010
Target Audience	University students
Audience Size	15
Description	Presented early work detailing the development and calibration of an ET model to predict future ET in WI.

Title	Evaluating Changes to Wisconsin Evapotranspiration Under a Future Climate
Presenter(s)	Douglas Joachim
Presentation Type	Professional meeting
Event Name	American Water Resources Association - WI Section - 2011 Annual Meeting
Event Location	Appleton, WI
Event Date	3/4/2011
Target Audience	Scientific audience
Audience Size	30
Description	Presented model description and early results of our evaluation of future ET in WI.

Title	Modeling Future ET Trends in Wisconsin
Presenter(s)	Douglas Joachim
Presentation Type	Professional meeting
Event Name	Second Mini ET Conference - ET Trends Along the Western Great Lakes
Event Location	Madison, WI
Event Date	4/29/2011
Target Audience	Scientific audience
Audience Size	20
Description	Presented modeled future ET results for WI. Particular focus on how actual ET will change relative to precipitation under different climate models.

Students & Post-Docs Supported

Student Name	Douglas Joachim
Campus	University of Wisconsin-Madison
Advisor Name	Steven Loheide
Advisor Campus	University of Wisconsin-Madison
Degree	Masters
Graduation Month	December
Graduation Year	2011
Department	Civil and Environmental Engineering
Program	Civil and Environmental Engineering
Thesis Title	
Thesis Abstract	

Response of Ice Cover, Lake Level and Thermal Structure to Climate Change in Wisconsin Lakes

Basic Information

Title:	Response of Ice Cover, Lake Level and Thermal Structure to Climate Change in Wisconsin Lakes
Project Number:	2010WI248B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	2nd
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Models, None
Descriptors:	
Principal Investigators:	Chin H Wu

Publication

1. Hsieh, YF, DM Robertson, RC Lathrop, and CH Wu. 2011. Influences of air temperature, wind, and water clarity on 100-year trends in ice cover and water temperature in a dimictic lake. Limnology and Oceanography (In Press).

Annual Progress Report

Selected Reporting Period: 3/1/2010 - 2/28/2011

Submitted By: Chin Wu
Submitted: 5/24/2011

Project Title

WR10R002: Response of Ice Cover, Water Level and Thermal Structure Climate Change in Wisconsin Lakes

Project Investigators

Chin Wu, University of Wisconsin-Madison

Progress Statement

We are investigating the physical responses of ice cover and water temperature in Wisconsin lakes to climate change. During the project period, we have been looking at lakes in southern Wisconsin (Madison area) and lakes in northern Wisconsin (Vilas County) to analyze temporal and spatial trends in long-term lake variables in response to climate changes. Specific lakes researched were Lake Mendota, Lake Wingra, and Fish Lake in Dane County, and Trout Lake, Crystal Lake, and Allequash Lake in Vilas County. During the course of the year, we (i) developed a hydrodynamic lake model for use investigating past and present climate-induced changes to lakes, (ii) looked at the influence of air temperature, wind speed, and water clarity on Lake Mendota, (iii) investigated the coherence of lake responses to climate changes in the northern and southern study lakes, and (iv) investigated the effect of lake morphometry on response to changing climate.

Model Development:
A one dimensional lake-ice model, called DYRESM-I, was developed to simulate vertical distribution of water temperature and ice cover in the study lakes. This model can continuously simulate lake hydrodynamics during open water and ice cover using thermodynamic principals. Addition of the ice component and calculations of sediment heat flux in the model are improvements over previous hydrodynamic lake models. The final model was calibrated to each of the study lakes to thoroughly investigate the response of thermal structure and ice cover. In addition, the one-dimensional model was used to project lake ice cover, lake level, and water temperature for use through the Interactive Nowcast/Forecast Operation System for Yahara Waters (INFOS) website. This website allows users to see real-time information on water temperature, ice cover, and water level of the Yahara Lakes (Madison, Monona, Waubesa, Kegonsa).

Influence of air temperature, wind speed, and water clarity on Lake Mendota:
This portion of the project validated and employed the DYRESM-I model to simulate 100 years (1911-2010) of ice cover and water temperature in Lake Mendota, Madison, WI. The overall purpose was to investigate how long-term changes in air temperature, wind speed, and water clarity have affected ice cover and thermal structure in lake Mendota during the last century. Results of model simulation and field measurements show that during the past century significant changes have occurred to ice cover and thermal structure of the lake. Ice cover on Lake Mendota has developed later, breaking up occurs earlier, duration has been decreasing, and ice thickness has also been decreasing. Model simulation shows that thermal stratification of the lake is occurring earlier, breaking down later, and lasting longer. Hypolimnetic temperatures have been decreasing, while epilimnetic temperatures have been decreasing. Additionally, it was determined that air temperature is the driving force for changes in ice cover dates, ice thickness, onset of stratification, and epilimnetic temperature. Wind speed, however, is the driving force for hypolimnetic temperature, summer hypolimnetic heating, fall overturn date, and freeze-over water temperature.

Coherence of Lake Response:
The spatial coherence of monthly and yearly variation and long-term trend of thermal regime and ice cover pattern were determined by investigating the coherence of climatic pattern between Northern (Trout Lake) and Southern (Lake Monona) lakes of Wisconsin. There is a strong coherent pattern of air temperature between Trout Lake and Lake Monona that ranges from monthly to yearly scale. Additionally, there is coherence in extreme years with extreme variability of air temperature, such as the anomaly of warm year as a result of periodical El Niño oscillation. However, the observed coherent in air temperature does not present in wind intensity between the two regions. Climatic drivers also exhibit a decadal trend, marked by a coherent trend of increasing mean annual air temperature and decreasing annual wind intensity between Trout Lake and Lake Monona. Using one dimensional model DYRESM-I, the ice cover variables (e.g. lake ice freeze and breakup, ice phenology) and lake thermal regime (e.g. epilimnion and hypolimnion

temperature, onset of stratification and fall turnover date) have been validated for both lakes for the selected study period (1989-2009). A Pearson product-moment correlation has been used to determine the coherence of lake ice cover and thermal regime variables between Trout Lake and Lake Monona under the climatic change.

Effect of Lake Morphometry on Response to Climate Change:
We believe that lakes may have dampened or heightened response to changing climate based on differences in lake morphometry. To investigate this aspect of lake response, we looked at Lake Mendota, Lake Wingra, and Fish Lake in Dane County, as the three lakes have experienced the same climate over the past 100 years, but have differing surface area and depths. Trends, variability, and periodic cycles for the three lakes were compared to each other and to air temperature and wind speed data. Results show that there are the same statistically significant increasing and decreasing trends for ice cover and water temperature variables in all three lakes, but the inter-annual variability and significant periodic cycles differ. For all three lakes there have been decreasing ice cover duration and ice thickness over the past 100 years in addition to increasing stratification duration, increasing epilimnetic temperature, and decreasing hypolimnetic temperature. The fact that each lake is experiencing the same trend of increasing or decreasing lake variables indicates that the climate has been causing significant changes in the lake's physical structure. Differences in magnitude of trend, variability, and periodic cycle indicate that morphometric differences among the lakes also plays a significant role in determining the exact physical response of lakes to changing climate.

Principal Findings and Significance

Principal Findings and Significance

Description

The most direct benefit of the project is the development of the DYRESM-I lake-ice model for use in investigation of past and future changes in climate. DYRESM-I has been validated for Wisconsin lakes, and is applicable for use in lakes throughout the world. Use of the model allows researchers and lake managers to simulate lake variables under specific possible climate conditions. This allows for increased preparedness to climate changes. Use of the DYRESM-I model within the INFOS system has direct, positive benefits to the Madison, Wisconsin area, as it provides easily accessible lake information to the public.

Results of the investigation of the impact of changing climate to Wisconsin lakes provides quality information to lake managers and other researchers. Understanding the change of water temperature may allow regulatory agencies to determine which lakes may become at risk for invasive species. This allows agencies to direct their manpower to a few specific lakes to prevent species spread rather than having to monitor a variety of lakes, some of which may not be at risk to invasive species. Additionally, as water temperature greatly affects fish species within the lakes, understanding which lakes may be at risk for fish kills due to increasing stratified period or increasing water temperatures may allow for mitigation efforts to protect important fish populations

Committees, Memberships & Panels

Group Name	WICCI Water Resources and Coastal Community Working Group
Description	he Wisconsin Initiative on Climate Change Impacts (WICCI) assesses and anticipates climate change impacts on specific Wisconsin natural resources, ecosystems and regions; evaluates potential effects on industry, agriculture, tourism and other human activities; and develops and recommends adaptation strategies that can be implemented by businesses, farmers, public health officials, municipalities, resource managers and other stakeholders.
Start Date	8/1/2010
End Date	12/31/2011

Journal Articles & Other Publications

Publication Type	Journal Article/Book Chapter (Peer-Reviewed)
Title	Influences of air temperature, wind, and water clarity on 100-year trends in ice cover and water temperature in a dimictic lake
Author(s)	Hsieh, Y.F., Robertson, D.M., Lathrop, R.C., and Wu, C.H.
Publication/Publisher	Limnology and Oceanography
Year Published	In Review
Volume & Number	Accepted under minor revision

Number of Pages	~10
Description	A one-dimensional hydrodynamic model (DYRESM-I) is validated and employed to simulate a continuous 100-year (1911-2010) of ice cover and water temperature in a dimictic lake, Lake Mendota, WI, USA. Both measured data and modeled results indicate that during the past century ice cover on Lake Mendota has been developing later (7.4 days), breaking up earlier (13.1 days), decreasing in duration (20.7 days), and decreasing in thickness (13.6 cm; based on model results). Model results also show that thermal stratification is developing earlier (10.0 days), breaking down later (10.3 days), and lasting longer (20.9 days) over the 100-yr period. For the summer stratified period, hypolimnetic temperatures are decreasing (about –1.4oC/100yr), but no significant trend is observed in epilimnetic temperatures. Correlation analyses demonstrate the relative importance of the three dominant drivers (air temperature, wind speed, and water clarity): air temperature is most related to changes in ice-on and ice-off dates, maximum ice thickness, onset of stratification, and epilimnetic temperature; whereas wind speed is most related to changes in freeze-over water temperature, hypolimnetic temperature, summer hypolimnetic heating, and fall turnover date. Features strongly driven by variability in wind speed demonstrate a regime shift around 1993, when wind speeds decreased rather abruptly.
Any Additional Citation Information	

Other Project Support

Source	NSF Long Term Ecology Research
Dollar Value	$48,500
Description	Research Assistant for supporting a Ph.D. student
Start Date	3/1/2009
End Date	2/28/2010

Presentations & Public Appearances

Title	Future Scenarios of Water Level and Ice Cover in Two Northern Wisconsin Lakes
Presenter(s)	Hsieh Yi-Fang, Chin Wu
Presentation Type	Professional meeting
Event Name	Sciences in the Northwoods
Event Location	Camp Manitowish, Boulder Junction Wisconsin
Event Date	9/30/2010
Target Audience	Scientific audience
Audience Size	200
Description	The responses to future climate scenarios for two northern Wisconsin lakes (i.e. Trout Lake and Crystal Lake, located in Vilas County) with distinct hydrologic features are studied. A physically-based lake ice/snow (DYRESM-IS) model is developed and calibrated using the data during the period of 1989-2009. For the future climate scenarios we use the downscaled A1B future climate projection provided by Wisconsin Initiative on Climate Change Impacts, WICCI. For Trout Lake, the results suggest that the projected ice duration is shortened by 31.5 days and the maximum ice thickness is reduced by 6.7 cm. Nevertheless the projected change in water level is insignificant. For Crystal Lake, the projected water level decreases substantially up to 4.5 m (24%). Similar to those in Trout Lake, the ice duration and the maximum ice thickness are shorted by 30.2 days and 6.9 cm, respectively. Overall the projected decreasing water level for seepage lakes in temperate regions (e.g., Crystal Lake) suggests that the projected changes in precipitation with climate warming may not compensate for increased evaporation from the lake surface and likely alteration in groundwater flows.

Title	Response of Wisconsin Lakes I(Ice Cover, Water level, and Thermal Structure) to Climate Change
Presenter(s)	Chin Wu and Yi-Fang Hsieh
Presentation Type	Seminar
Event Name	WICCI Science Meeting
Event Location	UW-Sea Grant
Event Date	9/1/2010

Target Audience	Scientific audience
Audience Size	40
Description	The response of lake ice cover, water level, and thermal structure to the WICCI's future climate projections in Wisconsin will be obtained. Specifically we examine how the ice characteristics will change and how the change will affect the water level and lake thermal structure due to the changing climate. We also address how much water would evaporate during the period when losing ice cover due to the warming air temperature, which may help understand processes of the current declining lake water level in the northern Wisconsin. For this talk we attempt to answer the following questions: Whether/how and to what degrees are the thermal structures of Wisconsin lakes in response to the climate condition? Would there be the point of no-return, i.e. thermal structure shift and ice-free winters, under the WICCI's climate projection? What would be the difference between the northern and southern lakes associated with changing climate variables (e.g. air temperature, snowfall, and snow depth) and the ocean-atmospheric anomalies (e.g. ENSO, PDO, and SOI)?

Students & Post-Docs Supported

Student Name	Anastasia Gunawan
Campus	University of Wisconsin-Madison
Advisor Name	Chin Wu
Advisor Campus	University of Wisconsin-Madison
Degree	Masters
Graduation Month	
Graduation Year	
Department	Civil and Environmental Engineering
Program	Civil and Environmental Engineering
Thesis Title	Coherence of Lake Response
Thesis Abstract	The spatial coherence of monthly and yearly variation and long-term trend of thermal regime and ice cover pattern were determined by investigating the coherence of climatic pattern between Northern (Trout Lake) and Southern (Lake Monona) lakes of Wisconsin. There is a strong coherent pattern of air temperature between Trout Lake and Lake Monona that ranges from monthly to yearly scale. Additionally, there is coherence in extreme years with extreme variability of air temperature, such as the anomaly of warm year as a result of periodical El Niño oscillation. However, the observed coherent in air temperature does not present in wind intensity between the two regions. Climatic drivers also exhibit a decadal trend, marked by a coherent trend of increasing mean annual air temperature and decreasing annual wind intensity between Trout Lake and Lake Monona. Using one dimensional model DYRESM-I, the ice cover variables (e.g. lake ice freeze and breakup, ice phenology) and lake thermal regime (e.g. epilimnion and hypolimnion temperature, onset of stratification and fall turnover date) have been validated for both lakes for the selected study period (1989-2009). A Pearson product-moment correlation has been used to determine the coherence of lake ice cover and thermal regime variables between Trout Lake and Lake Monona under the climatic change.

Student Name	Yi-Fang Hsieh
Campus	University of Wisconsin-Madison
Advisor Name	Chin Wu
Advisor Campus	University of Wisconsin-Madison
Degree	PhD
Graduation Month	August
Graduation Year	2011
Department	Civil and Environmental Engineering
Program	Civil and Environmental Engineering
Thesis Title	MODELING ICE COVER AND WATER TEMPERATURE OF LAKE MENDOTA
Thesis Abstract	The goal of this work is to build lake physical templates, i.e., ice cover, thermal structure, and transport processes through modeling approaches. Knowledge of lake physics can be further used for ecosystem and climate change studies. Specifically,

the following two sciencequestions are addressed using the lake physical template developed in this study:
(1) How do lake temperate and ice cover vary in response to long-term (~ 100 years) changing climate, and what are physical drivers.
(2) At a short-term scale (~ less than 1 year), what is the spatial and temporal variation when lake experiencing natural (e.g. meteorological inputs) and/or manmade (e.g. effluent discharge) disturbances.
Both one-dimensional (1D) and three-dimensional (3D) lake hydrodynamic-ice models were developed to have continuous simulations over the course of the year. The models were applied to a dimictic lake, Lake Mendota, Madison, Wisconsin. The 1D hydrodynamic-ice model was firstly validated by simulating a continuous 100-year period (1911–2010) of ice cover and water temperature. Measured data and model results indicate that during the past century ice cover on Lake Mendota has been developing later (7.4 days), breaking up earlier (13.1 days), decreasing in duration (20.7 days), and decreasing in thickness (13.6 cm; based on model results). Model results also show that thermal stratification is developing earlier (10.0 days), breaking down later (10.3 days), and lasting longer (20.9 days) over the 100-yr period. For the summer stratified period, hypolimnetic temperatures are decreasing (about –1.4oC/100yr), but no significant trend is observed in epilimnetic temperatures. Correlation analyses demonstrate the relative importance of the three dominant drivers: air temperature, wind speed, and water clarity. Air temperature is most related to changes in ice-on and ice-off dates, maximum ice thickness, onset of stratification, and epilimnetic temperature; whereas wind speed is most related to changes in freeze-over water temperature, hypolimnetic temperature, summer hypolimnetic heating, and fall turnover date. Features strongly driven by variability in wind speed demonstrate a regime shift around 1993, when wind speeds decreased rather abruptly.
The 1D ice module was extended to a 3D framework and coupled with an existing 3D hydrodynamic model. The 3D hydrodynamic-ice model was used to simulate both temporal and spatial distributions of ice cover for the winter 2009–2010 when the extensive spatial data for ice and snow cover are available. Simulated ice and snow cover are compared well with the satellite image and field data. Model results show distinct spatial patterns of the ice cover. The ice tended to be thinner towards the lake center because the initial ice appeared from the shore; the earlier appearance of nearshore ice was mainly due to the less heat storage of water column and boundary heat flux at lake's perimeter. The deviation of ice thickness across the lake converged until ice reached its maximum thickness. In the melting period, nearshore ice decayed more rapidly mainly due to the boundary heat flux although the influence was local and limited to a short-time period before the lake resumed to open water condition.
A study of transport of buoyant effluent plume in Lake Mendota during the summer stratified season is also included in this thesis. The customized FLUENT model with two major modifications made through the user-defined functions was applied to have complete modeling of buoyant plumes in both near and far fields. The model was validated by comparing with plume models, i.e., CORMIX and Visual Plume for near-field predictions in ideal flow conditions. Sensitivity analysis shows that the near-field plume characteristics (i.e., rise height and initial dilution) can be predicted well using a non-uniform mesh containing fine grids in the near field and coarse grids in the far field when the ambient water is strongly stratified. In addition, water temperature and current velocity that greatly affect plume behaviors agree well with the measurements conducted in both near and far fields in the study lake. With the strength of simulating flow dynamics, the hydrodynamic model shows capability in predicting buoyant plume transport in real lakes.

Student Name	Madeline Madgee
Campus	University of Wisconsin-Madison
Advisor Name	Chin Wu
Advisor Campus	University of Wisconsin-Madison
Degree	Masters
Graduation Month	
Graduation Year	
Department	Civil and Environmental Engineering
Program	Civil and Environmental Engineering
Thesis Title	Effect of Lake Morphometry on Response to Climate Change
Thesis Abstract	We believe that lakes may have dampened or heightened response to changing climate based on differences in lake morphometry. To investigate this aspect of lake response, we looked at Lake Mendota, Lake Wingra, and Fish Lake in Dane County, as the three lakes have experienced the same climate over the past 100 years, but have differing surface area and depths. Trends, variability, and periodic cycles for the three lakes were compared to each other and to air temperature and wind speed data. Results show that there are the same statistically significant increasing and decreasing trends for ice cover and water temperature variables in all three lakes, but the inter-annual variability and significant periodic cycles differ. For all three lakes there have been decreasing ice cover duration and ice thickness over the past 100 years in addition to increasing stratification duration, increasing epilimnetic temperature, and decreasing hypolimnetic temperature. The fact that each lake

is experiencing the same trend of increasing or decreasing lake variables indicates that the climate has been causing significant changes in the lake's physical structure. Differences in magnitude of trend, variability, and periodic cycle indicate that morphometric differences among the lakes also plays a significant role in determining the exact physical response of lakes to changing climate.

Implications of Climate Change and Biofuel Development for Great Lakes Regional Water Quality and Quantity

Basic Information

Title:	Implications of Climate Change and Biofuel Development for Great Lakes Regional Water Quality and Quantity
Project Number:	2010WI253G
Start Date:	9/1/2010
End Date:	8/31/2013
Funding Source:	104G
Congressional District:	WI-002
Research Category:	Climate and Hydrologic Processes
Focus Category:	Models, Water Quality, Water Quantity
Descriptors:	
Principal Investigators:	Anita Thompson, Bruno Basso, Mike Fienen, David Hyndman, Randall Jackson, K. G. Karthikeyan, Anthony Kendall, Brian J Lepore

Publications

There are no publications.

Annual Progress Report

Selected Reporting Period: 3/1/2010 - 2/28/2011

Submitted By: Anita Thompson
Submitted: 5/25/2011

Project Title

WR10R008: Implications of Climate Change and Biofuel Development for Great Lakes Regional Water Quality and Quantity

Project Investigators

Anita Thompson, University of Wisconsin-Madison

Progress Statement

This 3 year project was initiated September 1, 2010. The field component of this project is being conducted in Great Lakes Bioenergy Research Center (GLBRC) biofuel cropping system plots located at the Arlington Agricultural Research Station (AARS), Arlington, WI. A randomized complete block design experiment with 8 cropping system treatments planted in 5 replicated blocks was established Spring, 2008. During the first 7 months of the project (September 1, 2010 – February 28, 2011), progress was made in the installation of instrumentation to monitor subsurface water and nutrient dynamics in 4 of the biofuel cropping system treatments in the GLBRC biofuel plots. A detailed topographic survey of the area comprising all 5 treatment blocks was conducted. Instrumentation was purchased and eight subsurface Equilibrium Tension Lysimeters (ETLs) were installed during October and November 2010 in the following treatments: continuous corn (3; between and within plot duplication), corn-soybean-canola rotation (1), monoculture switch grass (3; between and within plot duplication), and monoculture Miscanthus (1). Volumetric soil moisture reflectometers and soil temperature probes were installed at each lysimeter location. Data logger programs for controlling the operation of the ETLs were written and debugged and equipment troubleshooting continued through February, 2011. Planning for installation of surface runoff monitoring plots was conducted. Three project meetings were held during which the P.I.s from the collaborating institutions (University of Wisconsin – Madison, Ball State University, Michigan State University, and the U.S. Geological Survey) discussed project planning, data requirements for the hydrologic models and data collection, formatting and distribution.

Year 1 activities at Michigan State University have thus far consisted of model development and coupling activities. The SALUS and ILHM models are being coupled as part of other externally-funded projects. This coupling is expected to be complete by the end of Year 1. Along with this, the development of new capabilities to track and simulate nutrient transport from the field to the stream is expected to be complete by the end of Year 1 as well. As part of this process, a detailed nutrient source database for regional modeling is being developed for the Lower Peninsula of Michigan. The methods and data sources used for this database will be applied to the regional models developed for Wisconsin as well.

Principal Findings and Significance

Principal Findings and Significance

Description The significance of efforts during the past reporting year include: 1) the majority of field equipment required to successfully complete our project was installed and 2) two graduate students were trained in the installation and operation of subsurface water and nutrient dynamics monitoring equipment.

Students & Post-Docs Supported

Student Name	Jack Buchanan
Campus	University of Wisconsin-Madison

Advisor Name	Anita Thompson
Advisor Campus	University of Wisconsin-Madison
Degree	Masters
Graduation Month	
Graduation Year	
Department	Agroecology
Program	Agroecology
Thesis Title	
Thesis Abstract	

Student Name	Anthony Kendall
Campus	Other
Advisor Name	David Hyndman
Advisor Campus	Other
Degree	Post Doc
Graduation Month	
Graduation Year	
Department	Geological Sciences
Program	
Thesis Title	
Thesis Abstract	

Student Name	Damodhar Mailapalli
Campus	University of Wisconsin-Madison
Advisor Name	Anita Thompson
Advisor Campus	University of Wisconsin-Madison
Degree	Post Doc
Graduation Month	
Graduation Year	
Department	Biological Systems Engineering
Program	
Thesis Title	
Thesis Abstract	

Student Name	Ryan Stenjem
Campus	University of Wisconsin-Madison
Advisor Name	Anita Thompson
Advisor Campus	University of Wisconsin-Madison
Degree	Masters
Graduation Month	
Graduation Year	
Department	Biological Systems Engineering

Program Biological Systems Engineering

Thesis Title

Thesis Abstract

Information Transfer Program Introduction

None.

University of Wisconsin Water Resources Institute - Information Transfer

Basic Information

Title:	University of Wisconsin Water Resources Institute - Information Transfer
Project Number:	2010WI281B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	WI-2
Research Category:	Not Applicable
Focus Category:	Education, Groundwater, Water Quality
Descriptors:	
Principal Investigators:	Moira Harrington

Publications

1. Moynihan, DP, R Gray, G Galloway, R Burby, S McLellan, T Anderson, K Lang, T Leece, D Alesch, J Ballweg, L Larson. 2010. From Sandbags to Sanity: Dealing with Flood Risk in Wisconsin. Water Resources Institute, University of Wisconsin, Madison, WI. 56p. Final_WR09R001.pdf
2. White, Elizabeth, ed. 2010 Aquatic Sciences Chronicle, Spring issue. Madison: University of Wisconsin Aquatic Sciences Center, 5 pages.
3. White, Elizabeth, ed. 2010 Aquatic Sciences Chronicle, Summer issue. Madison: University of Wisconsin Aquatic Sciences Center, 5 pages.
4. White, Elizabeth, ed. 2010 Aquatic Sciences Chronicle, Fall/Winter issue. Madison: University of Wisconsin Aquatic Sciences Center, 5 pages.
5. White, Elizabeth, ed. 2011 Aquatic Sciences Chronicle, Winter issue. Madison: University of Wisconsin Aquatic Sciences Center, 5 pages.
6. Bocast, Chris. 2010. Water, Wisconsin, and the Mercury Cycle. Audio Podcast on iTunes U from the University of Wisconsin-Madison. http://itunes.apple.com/WebObjects/MZStore.woa/wa/viewPodcast?id=430421609 .
7. Karl, John. 2010 Testing Well Water for Microorganisms. Video on the YouTube channel for the UW Aquatic Sciences Center. www.youtube.com/watch?feature=player_profilepage&v=ey-xqU0i9PI
8. Karl, John. 2010 A New Measure of Groundwater Flow. Video on the YouTube channel for the UW Aquatic Sciences Center. www.youtube.com/watch?feature=player_profilepage&v=gOBCnZGpSiU

Annual Progress Report

Selected Reporting Period: 3/1/2010 - 2/28/2011

Submitted By: Moira Harrington
Submitted: 5/24/2011

Project Title

WR06A001: Information Transfer - 104B FY 2006-2010 Program

Project Investigators

James Hurley, University of Wisconsin
Stephen Wittman, University of Wisconsin

Progress Statement

The University of Wisconsin Water Resources Institute Information Transfer Program is multi-platform and targeted to researchers, professionals and resource managers, along with members of the general public to build science literacy. It is an ongoing project.

In this reporting period, the program produced and distributed publications, messages through social media outlets, news releases, a quarterly newsletter, videos and a seven-part audio podcast series; maintained a website; co-sponsored, planned and presented at a major statewide conference on water resources; maintained and expanded a library on water resources that also conducts outreach through presentations.

More details are provided below:

Information and Outreach Activities

The University of Wisconsin Water Resources Institute website, wri.wisc.edu, is the main portal into the information and outreach activities of the program. It was launched in 2008 in a user-friendly format.
In this reporting period, the site attracted 18,503 unique visitors who were responsible for 61,302 views. The site orients visitors to the Wisconsin program and includes a variety of information for those interested in water-related issues. One of the site's main audiences is researchers. To that end, the site provides a clear navigational path to the WRI project listing, project reports, groundwater research database, funding opportunities and conference information sections. The areas are updated on a regular basis to ensure currency of information transfer.

The site is slated for some additional design and functionality updates in 2011-12, planning for which took place during this reporting period.

Additionally, the Wisconsin Water Resources Institute established a presence on Twitter and Facebook in January 2011, late in this reporting period. The initial numbers in this reporting period are therefore low. However, traction started to build thanks to an average of 50 tweets a month. Additionally, in January and February 2011, there were a combined 86 posts that included a combination of video, photos, news and sharing links.

Wisconsin Water Resources Institute Publications

In recognition of the manner in which people increasingly access information – through the Internet – the Wisconsin Water Resources Institute is part of an online publications store featuring a number of relevant Wisconsin groundwater publications. Staff has produced print publications that can be mailed at request. Free PDF downloads are also available and allow for the maximum convenience of information transfer to interested audiences. Through both methods – print and electronic – some of the most popular publications in this reporting period have been "Design Guidelines for

Stormwater Bioretention Facilities," with more than 1,035 downloads and a distribution of 12 print copies; a fact sheet on groundwater drawdown with a total of 679 downloaded copies and 20 mailed copies; and a booklet, "Climate Change in the Great Lakes Region," appealing to 513 people who downloaded it and another 8 people who requested a mailed copy.

During this reporting period, an additional brand-new publication was added to the online store. "From Sandbags to Sanity: Dealing With Flood Risk in Wisconsin" is available only as a download. It synthesizes a daylong seminar on Wisconsin flooding and mitigation and adaptation strategies. The publication was posted in September 2010 and from then until Feb. 28, 2011, there had been 60 downloads.

A seven-part audio podcast series ("Water, Wisconsin, and the Mercury Cycle") on mercury in the environment and the Wisconsin Water Resource Institute's lead role in research was also produced. The material can be accessed through the University of Wisconsin-Madison's iTunes University chapter as well as through the site prx.org.

For the first time in 2010-11, two specific short videos posted to You Tube to build science literacy have been produced. The subject matter has included WRI-sponsored research on tracking groundwater flow ("A New Measure of Groundwater Flow") using distributed temperature sensing and identifying pathogens in groundwater ("Testing Well Water for Microorganisms").

Extensive production work was done on a third video related to nitrate cycling in streambed sediments during the period, although the video was not publically available until shortly after the reporting period concluded. Plans are in place to continue expanding this catalog of videos as a means to transfer information on the work the Wisconsin Water Resources Institute does.

Finally, during this reporting period, the Wisconsin Water Resource Institute's information transfer project distributed eight news releases to media outlets. The topics were Groundwater Awareness Week, the mercury podcast series and the federal recertification of the Wisconsin Water Resources Institute.

Water Resources Research Highlighted in Newsletter

The Aquatic Sciences Chronicle is published quarterly and distributed to nearly 6,000 electronic and print subscribers. Chronicle readers include local and state water management agencies; academic faculty, staff and students; water-related non-governmental organizations; peer WRI personnel; and members of the news media. During this reporting period, Chronicle news stories have highlighted research on groundwater flooding, movement of groundwater, pathogens in groundwater, climate change, and news and announcements about water-related meetings.

AWRA 2011 Annual Conference

WRI cosponsors the annual conference of the Wisconsin Section of the American Water Resources Association, which is attended regularly by approximately 200 water resource managers, professionals and students from throughout the state. In 2011, the conference was held in Appleton, Wis., on March 3 and 4 and featured more than 60 oral and poster presentations – just beyond this reporting period. The plenary session topics focused on the American Water Resources Association, Wisconsin Chapter's role in restoring the Great Lakes.

Other conference sponsors were the University of Wisconsin-Stevens Point Center for Watershed Science and Education, Wisconsin Department of Natural Resources, Wisconsin Geological and Natural History Survey and the U.S. Geological Survey's Wisconsin Water Science Center.

Wisconsin's Water Library Outreach Activities

Wisconsin's Water Library provides outreach by answering many in-depth reference questions on a wide range of water-related topics. Some examples of reference queries answered in this reporting period include: researching an inquiry from a NASA engineer on the number of gallons of wastewater discharged into fresh and salt waters in the U.S. via municipal wastewater outfalls, assisting a student from a local technical college learn about how to measure magnesium in water, helping a University of Wisconsin-Milwaukee graduate student with information on surface and groundwater flowing through Fredonia, Wis., and answering an inquiry from high school students on what Wisconsin as a whole has done for water conservation.

During the reporting period, in partnership with the Wisconsin Department of Natural Resources and the Wisconsin Wastewater Operator's Association (WWOA), the library continued its outreach to current and future wastewater operators of Wisconsin. The library cataloged the essential technical manuals into the library catalog and provided loans to WWOA members around the state in support of their required state license examinations as well as in support of the educational needs of their daily work.

Wisconsin's Water Library continues to catalog all groundwater research reports from projects funded by the Water Resources Institute into WorldCat and MadCat, two library indexing tools that provide both worldwide and statewide access to WRI research. By having this information permanently indexed, the research results are easily available to other scientists throughout the University of Wisconsin System as well as across the nation and throughout the world.

The library applied for and won a Friends of the UW Madison Libraries grant. It is funding material acquisition related to water and climate change, expanding the titles the library owns on this important topic and creating a substantial collection for use by researchers.

The library conducted 13 story hours at libraries in southern Wisconsin during the summer of 2010. And, the library forged a positive literacy- and water-literacy-building ongoing relationship with the Ho-Chunk Nation of Wisconsin, which meant four different presentations.

Library Websites

The library maintains several information transfer tools to reach library patrons and the most frequently accessed is the library's website, aqua.wisc.edu/waterlibrary. The library's site serves as an outreach site for those who want to know more about state water resources. The site's design ensures books and other materials in the library easily accessible to any Wisconsin resident. There are three areas of the site, each set up to address the needs of the library user groups: There is an area for UW system faculty, staff and students; a section just for Wisconsin residents; and an area dedicated to just children, and their guardians and parents. Library staff continually update the site with new topical reading lists, new links to useful water-related websites, and pages with the library's new books. These frequent updates encourage users to return to the site often.

During the past 12 months, the library site has had 66,588 visitors. In addition to its website, Wisconsin's Water Library uses other technology tools to reach library patrons. Using e-mail, the library sends out a bimonthly Recent Acquisitions List to close to 500 contacts. The message also includes recent updates to the library website and contact information for users to ask any water-related question. The library also supports an e-mail inquiry process at askwater@aqua.wisc.edu, which is monitored daily.

The library also employs web 2.0 tools to reach new library users and raise visibility. The library has a blog, AquaLog, aqualog2.blogspot.com, where library staff reports on news, publications and resources about water and the Great Lakes. The blog has seen increased usage over the time it has been active, including an average of 40 visitors per day.

The library is also using the social media tools Facebook and Twitter. Users of both technologies can become followers of both and get the latest on water-related information instantly. Facebook (facebook.com/pages/Madison-WI/UW-Wisconsins-Water-Library/92090121028?ref=nf) is used often to announce events and display interesting links to its "fans." Twitter (twitter.com/WiscWaterLib) is an excellent way to communicate in a timely manner. Both tools have seen increased use by library patrons and both have loyal and an increasing numbers of followers.

Principal Findings and Significance

Principal Findings and Significance

Description Some notable accomplishments in this time period are the production of seven audio podcasts and two videos. For the first time, these accessible and informative channels are being used to convey scientific WRI information to broader audiences. They are posted at the popular You Tube site and the iTunes site.

Description Wisconsin's Water Library undertook an important collaborative archival step – signing an agreement to digitize the entire collection of Wisconsin Department of Natural Resources Groundwater Research and Monitoring Program reports. The University of Wisconsin Digital Collections Center will complete the archival process by September 2011, ensuring a permanent and accessible electronic record of Wisconsin groundwater-related activities since 1984. Paper copies of the reports will continue to be a part of the library.

Committees, Memberships & Panels

Group Name Planning Committee for the Annual Conference of the Wisconsin Section of the American Water Resources Association,

Description The Wisconsin Section of the American Water Resources Association annual meeting is attended regularly by approximately 200 water resource managers, professionals and students from throughout the state.

Start Date 8/1/2010

End Date 3/7/2011

Journal Articles & Other Publications

Publication Type Electronic Publication

Title	From Sandbags to Sanity: Dealing With Flood Risk in Wisconsin
Author(s)	Moynihan, Daniel
Publication/Publisher	
Year Published	2010
Volume & Number	
Number of Pages	63
Description	In April 2009 a conference was held in Madison to consider what could be learned from the severe Wisconsin floods of 2008. This book summarizes key contributions from that conference. It covers a broad range of relevant topics about flooding in Wisconsin such as hydrology, climate change, water quality, health impacts, mitigation options, human services and economic consequences. Experts who spoke at the symposium emphasized stronger leadership, more communication, better research, greater education and stiffer laws to help control food damage and reduce the loss of property and lives. They also identified a need to fundamentally reconsider how policymakers ask residents to share risk and responsibility, and the role of government in shaping those choices.
Any Additional Citation Information	

Publication Type	Newsletter/Periodical (Not Peer-Reviewed)
Title	Aquatic Sciences Chronicle - Spring 2010
Author(s)	
Publication/Publisher	Aquatic Sciences Center
Year Published	
Volume & Number	
Number of Pages	5
Description	
Any Additional Citation Information	

Publication Type	Newsletter/Periodical (Not Peer-Reviewed)
Title	Aquatic Sciences Chronicle - Summer 2010
Author(s)	
Publication/Publisher	
Year Published	
Volume & Number	
Number of Pages	5
Description	
Any Additional Citation Information	

Publication Type	Newsletter/Periodical (Not Peer-Reviewed)
Title	Aquatic Sciences Chronicle - Fall/Winter 2010
Author(s)	
Publication/Publisher	
Year Published	
Volume & Number	
Number of Pages	5
Description	
Any Additional Citation Information	

Publication Type	Newsletter/Periodical (Not Peer-Reviewed)
Title	Aquatic Sciences Chronicle - Winter 2011
Author(s)	
Publication/Publisher	
Year Published	
Volume & Number	
Number of Pages	5
Description	
Any Additional Citation Information	

Publication Type	Other
Title	Water, Wisconsin and the Mercury Cycle
Author(s)	Bocast, Chris
Publication/Publisher	
Year Published	2010
Volume & Number	
Number of Pages	
Description	Seven-part series of audio podcasts
Any Additional Citation Information	

Publication Type	Video/CD/DVD
Title	Testing Well Water for Microorganisms
Author(s)	Karl, John
Publication/Publisher	
Year Published	2010
Volume & Number	
Number of Pages	
Description	
Any Additional Citation Information	

Publication Type	Video/CD/DVD
Title	A New Measure of Groundwater Flow
Author(s)	Karl, John
Publication/Publisher	
Year Published	
Volume & Number	
Number of Pages	
Description	
Any Additional Citation Information	

Publication Type	Other

Title	aqua.wri.wisc.edu
Author(s)	
Publication/Publisher	
Year Published	
Volume & Number	
Number of Pages	
Description	program website
Any Additional Citation Information	

Publication Type	Other
Title	aqua.wisc.edu/waterlibrary/
Author(s)	
Publication/Publisher	
Year Published	
Volume & Number	
Number of Pages	
Description	library website
Any Additional Citation Information	

Publication Type	Other
Title	http://www.facebook.com/UWiscSeaGrant
Author(s)	
Publication/Publisher	
Year Published	
Volume & Number	
Number of Pages	
Description	Facebook page for both WRI and SG
Any Additional Citation Information	

Publication Type	Other
Title	@UWiscSeaGrant
Author(s)	
Publication/Publisher	
Year Published	
Volume & Number	
Number of Pages	
Description	Twitter handle for both WRI and SG
Any Additional Citation Information	

Partners

Name/Organization Affiliation	University of Wisconsin-Stevens Point Center for Watershed Science and Education
Affiliation Type	Academic Institutions
Email	
Description	Co-sponsor of the annual conference of the Wisconsin Section of the American Water Resources Association.

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Name/Organization Affiliation	Wisconsin Department of Natural Resources
Affiliation Type	Local & State
Email	
Description	Co-sponsor of the annual conference of the Wisconsin Section of the American Water Resources Association.

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Name/Organization Affiliation	Wisconsin Geological and Natural History Survey
Affiliation Type	Local & State
Email	
Description	Co-sponsor of the annual conference of the Wisconsin Section of the American Water Resources Association.

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Name/Organization Affiliation	U.S. Geological Survey's Wisconsin Water Science Center.
Affiliation Type	Federal
Email	
Description	Co-sponsor of the annual conference of the Wisconsin Section of the American Water Resources Association.

Presentations & Public Appearances

Title	Conserving Wisconsin's Buried Treasure
Presenter(s)	
Presentation Type	
Event Name	
Event Location	
Event Date	
Target Audience	
Audience Size	
Description	News release distributed on Feb. 28, 2011. As part of Groundwater Awareness Week, we helped coordinate a Wisconsin Public Radio statewide hour-long interview.

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Title	New Free, Downloadable Podcast Series Explores the Properties/Dangers of Mercury
Presenter(s)	
Presentation Type	
Event Name	
Event Location	
Event Date	
Target Audience	
Audience Size	
Description	News release distributed on Feb. 4, 2011.

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Title	Water-Themed Story Hours Make a Splash Around Baraboo
Presenter(s)	
Presentation Type	

Event Name	
Event Location	
Event Date	
Target Audience	Media
Audience Size	
Description	A news release distributed on Jan. 27, 2011. Was printed by the Baraboo News Republic and the Ho Chunk Nation newspaper.

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Title	Spring is a Good Time to Test Well Water
Presenter(s)	
Presentation Type	
Event Name	
Event Location	
Event Date	
Target Audience	
Audience Size	
Description	A news release on March 10, 2010.

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Title	Conserving Wisconsin's Buried Treasure
Presenter(s)	
Presentation Type	
Event Name	
Event Location	
Event Date	
Target Audience	
Audience Size	
Description	A news release that was distributed on March 10, 2010.

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Title	Meeting to Examine Emerging Challenges for Wisconsin's Water
Presenter(s)	
Presentation Type	
Event Name	
Event Location	
Event Date	
Target Audience	
Audience Size	
Description	A news release that was distributed on March 4, 2010.

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Title	Meeting to Examine Emerging Challenges for Wisconsin's Water
Presenter(s)	
Presentation Type	
Event Name	
Event Location	
Event Date	
Target Audience	
Audience Size	
Description	A media advisory that was distributed on March 4, 2010.

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Title	Water Resources Institute Praised, Recertified
Presenter(s)	
Presentation Type	
Event Name	
Event Location	
Event Date	
Target Audience	
Audience Size	
Description	A news release that was distributed on Jan. 7, 2011.

Students & Post-Docs Supported

Student Name	Amy De Simone
Campus	University of Wisconsin-Madison

Advisor Name	Anne Moser
Advisor Campus	University of Wisconsin-Madison

Degree	Masters
Graduation Month	May
Graduation Year	2011
Department	School of Library and Information Studies
Program	library and information studies
Thesis Title	
Thesis Abstract	

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	0	0	0	0	0
Masters	4	2	1	2	9
Ph.D.	1	0	1	0	2
Post-Doc.	0	2	0	0	2
Total	5	4	2	2	13

Notable Awards and Achievements

In 2011, Professor Craig Benson received an Award of Merit (Soil and Rock) from the American Society for Testing and Materials (ASTM). The Award of Merit was established in 1949 by the ASTM International Board of Directors and is the highest society award granted to an individual member for distinguished service and outstanding participation in ASTM International committee activities. Recipients also receive the honorary title of Fellow.

UW-Madison professor Craig Benson was inducted into the Academy of Geoprofessonals as a Diplomate Geotechnical Engineer, 2009

UW-Madison professor Craig Benson was inducted into the Academy of Distinguished Alumni in Civil & Environmental Engineering at the University of Texas Austin, 2009.

Publications from Prior Years

1. 2005WI154O ("Validation of transport of VOCs from Composite Liners") - Water Resources Research Institute Reports - Park, M.G., T.B. Edil, and C.H. Benson. 2007. Validation of Transport VOCs from Composite Liners. Water Resources Institute, University of Wisconsin-Madison, Madison, WI. 113p.
2. 2005WI155O ("Arsenic Species (III,V) Distribution in Wisconsin Groundwaters: Field Measurements and Prediction Using Multivariate Analysis of Geochemical Data Prediction Using Multivariate Analysis of Geochemical Data") - Dissertations - Kerr, S. 2007. Trace Metal Cycling in a Northern Wisconsin Watershed. Ph.D. Dissertation, Environmental Chemistry and Technology Program, College of Engineering, University of Wisconsin, Madison, Wisconsin, 260 pages
3. 2005WI150S ("Grant No. 04HQGR0034 The Role of Dissolved Organic Carbon in Aquatic Mercury Cycling The Transport, Fate and Cycling of Mercury in Watersheds and Air Sheds") - Book Chapters - Krabbenhoft, D., D. Engstrom, C. Gilmour, R. Harris, J. Hurley, and R. Mason. 2007. Monitoring and Evaluating Trends in Sediment and Water. In: R. Harris, Ed., Ecosystem Responses to Mercury Contamination: Indicators of Change, Boca Raton, Florida, CRC Press. pp. 47-86
4. 2005WI158O ("Nitrate and Pesticide Penetration into a Northern Mississippi Valley Loess Hills Aquifer") - Water Resources Research Institute Reports - Kraft, G.J. and D.J. Mechenich. 2008. Nitrate and Pesticide Penetration into a Northern Mississippi Valley Loess Hills Aquifer. Water Resources Institute, University of Wisconsin, Madison, Wisconsin. 10p.
5. 2006WI189O ("Application of LSQR to Calibration of a Regional MODFLOW Model: Trout Lake Basin, Wisconsin") - Dissertations - Muffels, C. 2008. Application of the LSQR algorithm to the calibration of a regional groundwater flow model: Trout Lake Basin, Vilas County, Wisconsin. MS Dissertation, Department of Geology and Geophysics, College of Letters & Sciences, University of Wisconsin, Madison, Wisconsin, 212p.
6. 2005WI155O ("Arsenic Species (III,V) Distribution in Wisconsin Groundwaters: Field Measurements and Prediction Using Multivariate Analysis of Geochemical Data Prediction Using Multivariate Analysis of Geochemical Data") - Articles in Refereed Scientific Journals - Kerr, S.C., M.M. Shafer, J. Overdier, and D.E. Armstrong. 2008. Hydrologic and biogeochemical controls on trace element export from northern Wisconsin wetlands. Biogeochemistry 89, pp273-294.
7. 2008WI192B ("A Thermal Remote Sensing Tool for Mapping Spring and Diffuse Groundwater Discharge to Streams") - Water Resources Research Institute Reports - Deitchman R.S. and S.P. Loheide II. 2009. A thermal remote sensing tool for mapping spring and diffuse groundwater discharge to streams. Water Resources Institute, University of Wisconsin, Madison, WI. 16p.
8. 2007WI212O ("Transport and Survival of Pathogenic Bacteria Associated With Dairy Manure in Soil and Groundwater. ") - Water Resources Research Institute Reports - Li, J. and C.H. Yang. 2009. Transport and Survival of Pathogenic Bacteria Associated With Dairy Manure in Soil and Groundwater. Water Resources Institute, University of Wisconsin, Madison, Wisconsin. 17p.
9. 2008WI192B ("A Thermal Remote Sensing Tool for Mapping Spring and Diffuse Groundwater Discharge to Streams") - Dissertations - Deitchman, R.S. 2009. Thermal remote sensing of stream temperature and groundwater discharge: Applications to hydrogeology and water resources policy in the state of WI, MS Dissertation, Environment and Resources, Nelson Institute for Environmental Studies, University of Wisconsin, Madison, Wisconsin. 256p
10. 2008WI192B ("A Thermal Remote Sensing Tool for Mapping Spring and Diffuse Groundwater Discharge to Streams") - Articles in Refereed Scientific Journals - Deitchman R.S. and S.P. Loheide II. 2009. Ground-based thermal imaging of groundwater flow processes at the seepage face. Geophysical Research Letters, Vol. 36, L14401, doi:10.1029/2009GL038103
11. 2006WI146G ("Identifying High-Infiltration and Groundwater Recharge Areas") - Water Resources Research Institute Reports - Arrington Ka, S Ventura, J Norman. 2010. Identifying High-Infiltration

and Groundwater Recharge Areas. Water Resources Institute, University of Wisconsin, Madison, Wisconsin. 15p.

12. 2009WI215B ("From Sandbags to Sanity: Lessons from the Midwest Floods of 2008") - Water Resources Research Institute Reports - Moynihan, DP, R Gray, G Galloway, R Burby, S McLellan, T Anderson, K Lang, T Leece, D Alesch, J Ballweg, L Larson. 2010. From Sandbags to Sanity: Dealing with Flood Risk in Wisconsin. Water Resources Institute, University of Wisconsin, Madison, Wisconsin. 56p.
13. 2009WI217B ("The Lethal and Sublethal Effects of Elevated Groundwater Nitrate Concentrations on Infaunal Invertebrates in the Central Sand Plains") - Water Resources Research Institute Reports - Stelzer R, M Muldoon, S Eggert. 2010. Nitrate toxicity and nitrate removal in a Central Sand Plain stream. Water Resources Institute, University of Wisconsin, Madison, Wisconsin. 15p
14. 2007WI202O ("Controls on Methylation of Groundwater Hg(II) in Hyporheic Zones of Wetlands. ") - Dissertations - Creswell J.E. 2010 Biogeochemical controls on mercury methylation in a riparian wetland. PhD Dissertation, Environmental Chemistry & Technology Program, College of Engineering, University of Wisconsin, Madison, Wisconsin.
15. 2006WI135B ("Measuring and Modeling Macroporous Soil Water and Solute Flux Below the Root Zone of a Plano Silt-Loam Soil") - Articles in Refereed Scientific Journals - Lepore, B.J., J.M. Norman, B. Lowery and K.R. Brye. 2011. Soil compaction above long-term lysimeter installations. Soil Sci. Soc. Amer. J. 75:30-34.
16. 2009WI217B ("The Lethal and Sublethal Effects of Elevated Groundwater Nitrate Concentrations on Infaunal Invertebrates in the Central Sand Plains") - Articles in Refereed Scientific Journals - Stelzer, R.S., L.A. Bartsch, W.B. Richardson, and E.A. Strauss. 2011. The dark side of the hyporheic: nitrogen processing and profiles in deep stream sediments. Freshwater Biology, (In Press).
17. 2008WI193O ("Use of the 2009 Behavioral Risk Factor Surveillance Survey to Assess the Safety of Private Drinking Water Supplies") - Water Resources Research Institute Reports - Knobeloch L. 2010. Use of the Behavioral Risk Factor Surveillance Survey to Assess the Safety of Private Drinking Water Supplies. Water Resources Institute, University of Wisconsin, Madison, Wisconsin. 14p.
18. 2009WI222O ("DTS as a Hydrostratigraphic Characterization Tool ") - Water Resources Research Institute Reports - Bahr, J, and D Hart. 2010. DTS as a Hydrostratigraphic Characterization Tool. Water Resources Institute, University of Wisconsin, Madison, Wisconsin. 18p.
19. 2009WI222O ("DTS as a Hydrostratigraphic Characterization Tool") - Dissertations - Leaf, A.T. 2010. Distributed temperature sensing in the Sandstone Aquifer system of Wisconsin: New possibilities for characterizing hydraulic heterogeneity. MS Dissertation, Department of Geology, College of Letters & Sciences University of Wisconsin, Madison, Wisconsin. 152p.