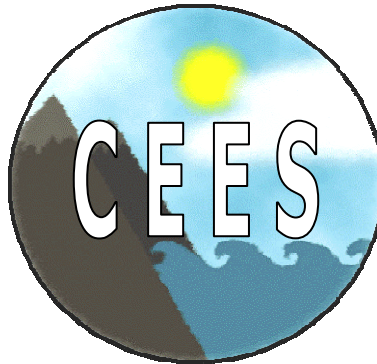


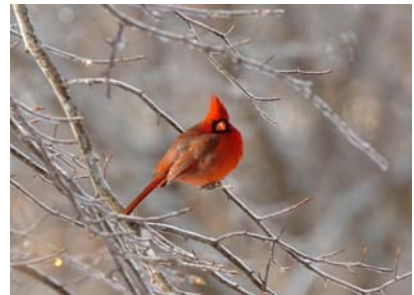
A Program of Excellence in Water Resources Research

Four Year Report



**Center for Earth and Environmental Science
Indiana University – Purdue University Indianapolis**

**With Significant Funding from
Veolia Water Indianapolis, LLC.**



***Providing Leadership and Answers for
Sustainable Water Resources***

A Note from the Director

The mission of the Center for Earth and Environmental Science at IUPUI is to provide applied interdisciplinary environmental solutions to translate research into action while promoting environmental stewardship through educational and public service programs. Applied research is important in bringing solutions to critical problems and gives CEES its uniqueness. CEES' vision is to grow into an international leader providing environmental solutions to both existing and emerging water resource issues and be a leader in environmental science education.

To move towards this vision, CEES works to bring research focus and pursue projects in the areas of:

- Water Resource Evaluation and Watershed Management
- Assessment of Environmental Constituents
- Stream and Wetland Assessment and Restoration
- Environmental Data Management and Visualization
- Science Education and Public Outreach

As an applied research and outreach center at IUPUI, CEES' programs seek to further the university's goals of pursuing excellence in 1) research, scholarship and creative activity, 2) teaching and learning, and 3) civic engagement while also enhancing the resource base of the university and community.

The 2007 designation of CEES as a Signature Center at IUPUI brings new



resources and additional focus to efforts to enhance water resources programs at CEES and build critical bridges between water resource research and human health. Our community partnerships, especially the long-term research and development program with Veolia Water Indianapolis, LLC., form the foundation from which these water resource research programs at CEES emerge.

As we move forward, we have taken the time to capture the results of CEES' efforts in water resources research excellence in the many facets that it is manifest. This report is a summary of efforts and in many ways a benchmark of our success. We also view this report as a foundational document to map our initiatives as we move forward.

CEES will continue to focus on four strategic objectives. The first strategic

objective is engaging in research targeted at sustaining and improving water quality in Indianapolis and worldwide through reservoir and watershed management. This objective requires placing a high priority on engaging in cutting-edge research and training for mixed agricultural and urban watersheds and evaluating and assessing Best Management Practices for atrazine, nutrients, and emerging pathogens. CEES continues to develop applied comparative research on sustainable integrated water resource management.

The second strategic objective is improving knowledge among leaders and the public regarding water resource and science education issues. In this regard, CEES places a high priority on establishing a K-12 technology-based science education program in water, air and energy. CEES also actively builds partnerships with local and state governments to support regional watershed initiatives throughout central Indiana.

The third strategic objective is becoming a center of competence in stream assessment and mitigation with emphasis on Midwestern systems. CEES will place a high priority on working with state and federal agencies in identifying watershed issues associated with new economic development initiatives. CEES will also work to facilitate a regional dialog to integrate stream and wetland assessment, mitigation, and rehabilitation efforts to enhance water resources and conduct cutting-edge research to address knowledge gaps.

The fourth strategic objective is to apply state-of-the-art techniques in environmental analysis to human health impacts related to potable water. CEES is working with collaborating research centers at IUPUI to bridge a gap that exists between water resources and human health. The January 2007 designation of CEES as an IUPUI Signature Center focuses new faculty and graduate student resources in water resources and human health risk.

Faculty, staff, and students working with CEES contribute to improving our understanding of the environment and have made great strides at enhancing the knowledge base for decision makers. The future is bright and we collectively look forward to new challenges and solutions.

Dr. Lenore P. Tedesco
Indianapolis, March 2007

“Faculty, staff, and students working with CEES contribute to improving our understanding of the environment and have made great strides at enhancing the knowledge base for decision makers. The future is bright and we collectively look forward to new challenges and solutions.”

Table of Contents

<i>A Note from the Director</i>	3
<i>Table of Contents</i>	5
<i>Central Indiana Water Resources Partnership Overview</i>	7
<i>Watershed Research and Partnerships</i>	10
Stakeholder Partnerships and Grant Programs	10
Eagle Creek Watershed Alliance.....	10
The Upper White River Watershed Alliance ...	11
The USDA Conservation Effects Assessment Project	12
Watershed Student Research	13
Effects of Land Cover on Water Quality and Nutrient Loading	13
Leda Casey	13
Nutrient and Sediment Loading of Streams under the Influence of Agriculture, Urbanization and Residential Development in Eagle Creek Watershed Mary A. Campbell.....	14
Nutrient Specific Flow Paths during Storm Events in a Glaciated, Artificially Drained Landscape Laura Wagner.....	15
<i>Remote Monitoring and Remote Sensing Programs</i>	16
Remote Environmental Monitoring: Creating a Dynamic Network	16
Mapping Blue-Green Algae with Hyperspectral Imagery in Central Indiana Reservoirs.....	17
Remote Sensing Student Research	18
Remote Sensing of Phytoplankton Using Optically Active Pigments, Chlorophyll a and Phycocyanin Kaylan Randolph	18
Using Hyperspectral Remote Sensing To Estimate Chlorophyll a and Phycocyanin in Central Indiana Reservoirs Rebecca Sengpiel	19
<i>Reservoir Management</i>	20
Reservoir Assessment and Management Projects	20
The Relationship between Nutrient Limitation and Nuisance Blue-Green Algal Dominance Denise Lani Pascual	20
Nitrogen Dynamics in Sediment from Three Central Indiana Water Reservoirs Pierre-Andre Jacinthe, Ph.D.	20

Development of Time-Series Models for Water Quality Management in Eagle Creek Reservoir V. Kelson and J. Wittman.....	21
Three-Year Phosphorus Mass Balance of Eagle Creek Reservoir Denise Lani Pascual.....	22

Reservoir Assessment and Management Student Research

Internal Phosphorus Cycling in an Urban Drinking Water Reservoir Robyn Raftis	23
Multi-Reservoir Survey Showing the Relationship between Nitrogen Limitation and Nuisance Algal Bloom Formation Denise Lani Pascual.....	24
Effects of Zooplankton Growth on Nuisance Blue-Green Algae, <i>Microcystis</i> and <i>Anabaena</i> Annette Trierweiler	25

Ecosystem Restoration.....

Lilly ARBOR Project Riparian Restoration.....

Remote Monitoring Network at the Lilly ARBOR Project

Wetland Restoration: Scott Starling Nature Sanctuary

Ecosystem Restoration Student Research.....

Riparian Zone Hydrological Functioning in Glacial Till Valleys of the Midwest Andrew Smith	30
Assessing the Role of Geologic Setting on Water Quality of Temperate Fens in the Glaciated Midwestern United States Dustin Graves.....	31

Education and Outreach.....

Discovering the Science of the Environment

Central Indiana Watershed Enhancement Partnership – Expanding Environmental Service Learning and Water Quality Awareness

Environmental Service Learning Program.....

Experiential Learning	34
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<i>CEES Researchers.....</i>	<i>35</i>
<i>Affiliated Faculty</i>	<i>35</i>
<i>Research Staff</i>	<i>37</i>
<i>Graduate Students</i>	<i>38</i>
<i>Hosted Conferences</i>	<i>39</i>
Use of Long-Term Research for Enhancing Water Quality in the Great Lakes Region	39
Indiana Water Resources Association Fall Meeting: Regional Water Quality Research and Advanced Information Technologies to Assess and Enhance Indiana's Water Resources	39
2006 Emerging Issues in Source Water Management and Strategies for Addressing New Drinking Water Regulations	40
<i>Honors and Awards</i>	<i>41</i>
Honorary Membership in the Clean Stream Team February, 2007	41
President's Higher Education Honor Roll for Community Service October 2006	41
Chancellor's Faculty Award for Excellence in Civic Engagement April 2005	41
Honorary Membership in the Clean Stream Team October, 2003	41
Governor's Award for Environmental Excellence September, 2002	41
<i>Water Resources Publications.....</i>	<i>42</i>
<i>2007</i>	<i>42</i>
Papers.....	42
<i>2006</i>	<i>42</i>
Papers.....	42
Technical Reports	42
Conference Abstracts	42
<i>2005</i>	<i>44</i>
Technical Reports	44
Conference Abstracts	44

<i>2004</i>	<i>45</i>
Publications	45
Technical Reports	45
Conference Abstracts.....	45
<i>2003</i>	<i>46</i>
Technical Reports	46
Conference Abstracts.....	46
<i>Graduate Research Assistantships</i>	<i>47</i>
<i>Student Interns.....</i>	<i>48</i>
Graduate Students	48
Undergraduate Students.....	48
<i>Education and Outreach Events of Note.....</i>	<i>51</i>
<i>Invited Presentations.....</i>	<i>52</i>
<i>Community Partners.....</i>	<i>55</i>
CEES Partners in Research	55
CEES Community Partners in Education	55
CEES Signature Center	57
<i>CEES Financial Reports</i>	<i>58</i>

Central Indiana Water Resources Partnership Overview

In May, 2002, the City of Indianapolis purchased the assets of the Indianapolis Water Company and signed a 20-year management agreement with Veolia Water Indianapolis (then Vivendi). The contract called for the creation of a research and development partnership with IUPUI to conduct applied research on central Indiana's water resources to both protect and improve water quality. The Central Indiana Water Resource Partnership (CIWRP) is the partnership between Veolia Water Indianapolis, LLC. and the Center for Earth and Environmental Science at IUPUI born of this contract. Valued potentially at over \$5 million, CIWRP is managed by an eight member international Steering Committee comprised of university and Veolia representatives charged with guiding research programs.

The Central Indiana Water Resources Partnership program began in late 2002 with a comprehensive survey of the data and characteristics of Eagle Creek, Geist and Morse Reservoirs and their watersheds and created a preliminary report of analyses of water quality and nutrient cycling. This work helped us to understand the range of challenges

facing central Indiana's drinking water resources and set the stage for program research.

The 2004 research program focused on understanding nutrient delivery, cycling and algal community response in Eagle Creek Reservoir. A systems approach was used to develop a mass balance of the

3d model of Upper White River Watershed



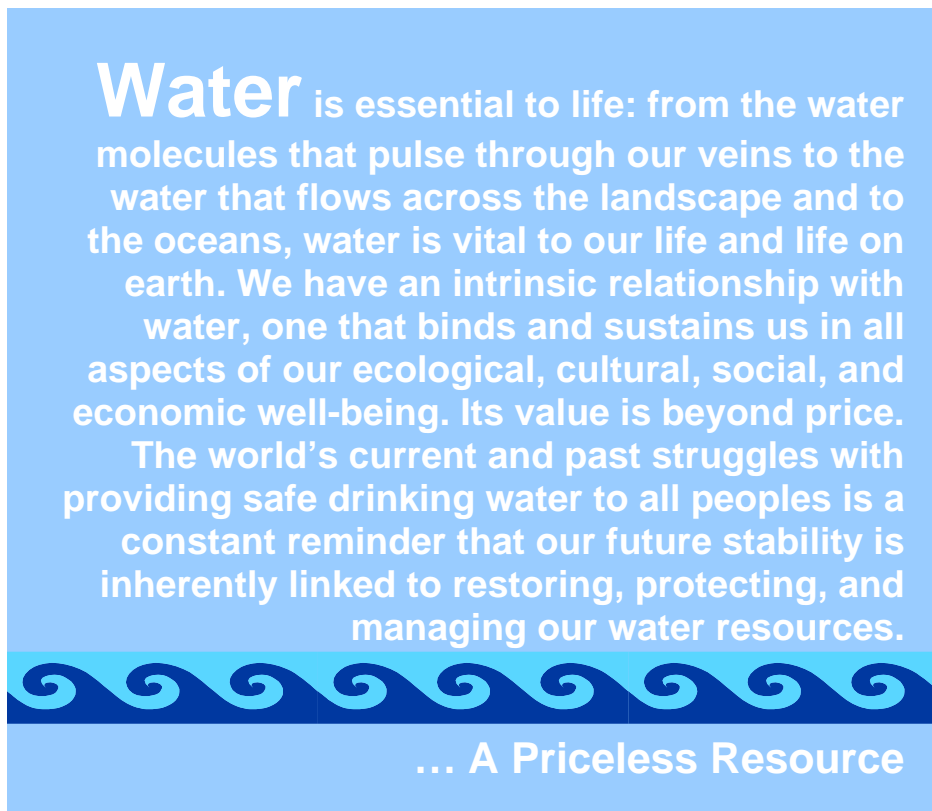
source of nutrients coming into the reservoir from watershed sources, the effect of different land uses on the magnitude and timing of that delivery, the fate of nutrients once in the reservoir (including burial in the sediments and release back to the water column for reuse), and the utilization of nutrients in the reservoir by blue-green algae to understand the causes and triggers for nuisance algal blooms that affect drinking water quality. Of particular concern were taste and odor caused by algae in Eagle Creek Reservoir. CEES research helped guide improved management approaches that resulted in both cost savings to Veolia Water and drinking water

customers and enhanced environmental stewardship.

The 2005 research program focused on reducing degradation of source water quality by implementation and analysis of strategies for watershed best management practices and the development of rapid assessment tools to aid in determining conditions in source waters. 2005 projects included finalizing the nutrient mass balance study on Eagle Creek, documenting nutrient utilization by blue-green algae to refine efforts to predict nuisance algal blooms in the reservoir, refining nutrient and sediment stream budgets in areas of land use change in watersheds undergoing development, and developing new tools to rapidly map blue-green algae with remote sensing.

The 2006 research program targeted continued understanding of both watershed and reservoir resources. Efforts were focused on understanding the transport pathways and timing of delivery of nutrients and other contaminants to streams. This work is important for understanding appropriate management tools to limit stream contamination as well as provide

information to water resource managers regarding the risk associated with this transport and delivery. The remote sensing research program continued to develop and refine tools for the rapid mapping of blue-green algal blooms on central Indiana reservoirs. This tool was tested in June 2006 and provided timely information to Veolia managers to help



improve the effectiveness of algal bloom management on Eagle Creek Reservoir.

CIWRP has been a major focus for watershed and water resource program development for both CEES and Veolia Water Indianapolis, LLC. and has benefited the central Indiana community in many ways. Nine graduate students had thesis support and conducted research as part of this program with two starting research within the next year. Twenty three undergraduate students

and four additional graduate students have worked as research interns at both IUPUI and Veolia Water research labs. CIWRP is helping to train tomorrow's scientists and providing highly trained scientists to the central Indiana work force. The partnership funding has also enabled CEES to build faculty and staff resources. Watershed studies and water quality programs have been a focus for proposal development. CEES and affiliated faculty have obtained funding from the Indiana Department of Environmental Management Clean Water Act Section 319 Nonpoint Source Pollution Management Program for the Eagle Creek Watershed Alliance, USDA's Cooperative State Research, Education and Extension Service, the Lake and River Enhancement Program of the Indiana Department of Natural Resources, and the Indiana Water Resource Research Center at Purdue University. Since program inception, CIWRP has leveraged more than \$1.4 million in research funding and \$465,000 in education and outreach funding to improve central Indiana water resources.

Leveraged Funding

\$1.2 Million from Veolia Water

\$1.4 Million in Additional Research Grants

\$485,000 in Educational and Outreach Funding

Recent Grants

✚ **\$271,200** - Use of Remote Sensing Hyperspectral Imaging to Map the Spatial Distribution of Blue-green Algal Blooms

✚ **\$33,250** - Development of a Restoration and Management Plan for a Portion of the Scott Starling Sanctuary, Eagle Creek Park

✚ **\$343,254** - Eagle Creek Watershed Alliance: Watershed BMP Implementation, Education and Public Outreach

✚ **\$20,000** - Trace Gas Fluxes in Riparian Buffers along an Urban-Rural Gradient

✚ **\$650,000** - Watershed-scale Evaluation of BMP Effectiveness and Acceptability: Eagle Creek Watershed

Watershed Research and Partnerships

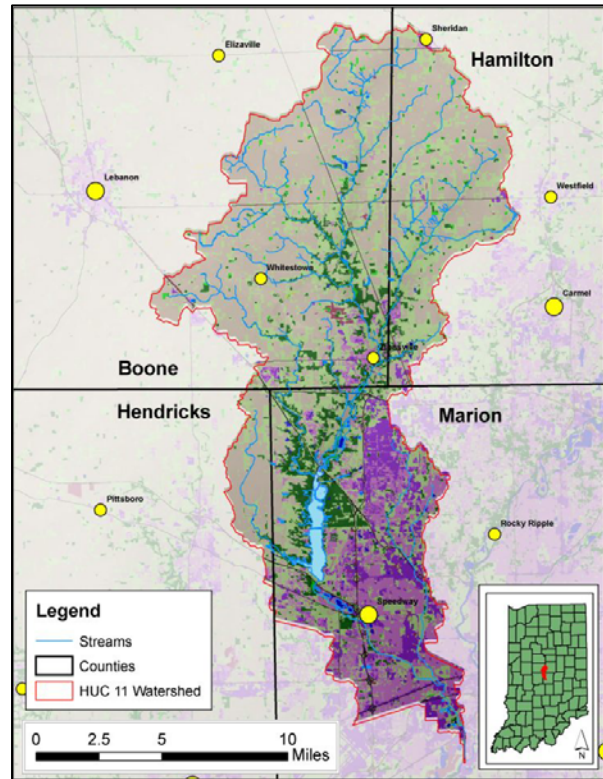


Stakeholder Partnerships and Grant Programs

Eagle Creek Watershed Alliance

CEES and partners in the Eagle Creek Watershed Alliance (ECWA) completed a Watershed Management Plan for Eagle Creek Watershed, which received approval from the Indiana Department of Environmental Management in September 2005. As a result of the approved Management Plan, CEES acting as a sponsor for the ECWA, was awarded more than \$345,000 for an Environmental Protection Agency Section 319 Implementation Grant. The Implementation Grant will focus on installation and/or adoption of Best Management Practices (BMPs) to alleviate nonpoint source pollution in the Eagle Creek Watershed. This collaborative program provides a great opportunity for CEES to work with several partners including Veolia Water Indianapolis, Eagle Creek Watershed Task Force, Boone, Hendricks, Marion, and Hamilton Soil and Water Conservation Districts and Health

Departments, Hoosier Heartland Resource Conservation and Development Council Inc., Eagle Creek Park, Indiana Department of Natural Resources, Indiana Department of Environmental Management, Central Indiana Land Trust, and citizen volunteers, among others.



Eagle Creek Watershed Landuse

Eagle Creek Watershed is the catchment basin draining into Eagle Creek Reservoir. Pressures from agriculture, urban development, and increasing population demands threaten the sustainability of Eagle Creek Watershed for recreational use, aquatic life and drinking water. The watershed is negatively impacted by sedimentation from eroding streams, ditches, construction sites and agricultural land. Excessive nutrients from agricultural production, inadequate septic systems, animal waste, urban runoff, point source discharges and uncontrolled storm water

also degrade water quality in tributary streams and in the reservoir.

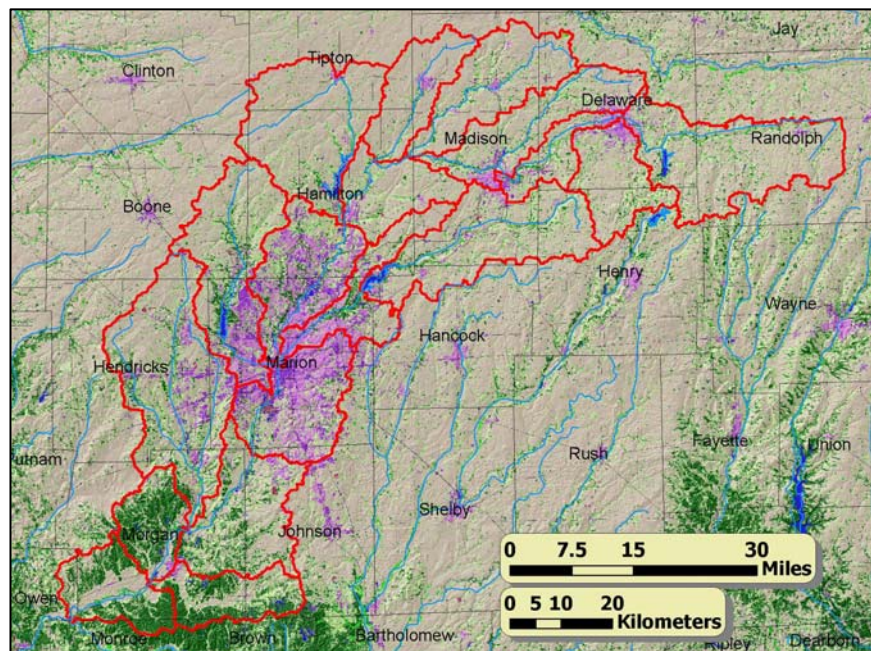
The 319 Implementation Project is addressing the impairments of Eagle Creek Watershed and working towards improving and restoring the natural structure and function of the stream ecosystem. Project initiatives include a cost-share program for the implementation of BMPs, such as woody riparian buffers, grassy buffer strips, fencing livestock from streams, stream bank restoration, wetland restoration, and other conservation practices. It also includes a water quality monitoring program; watershed education; and public information and outreach components. A watershed coordinator and farm promoter are funded through the EPA Section 319 Implementation Grant to ensure coordination, progress and success of the Implementation Project.

The Eagle Creek Watershed Alliance completed numerous projects related to outreach and technical programs during the Fall of 2006. Members of ECWA staffed a booth at the Zionsville Fall Festival September 9 and 10. CEES staff and ECWA volunteers organized and led a tour as part of the Indiana Conservation Alliance "Fall into Nature Days" on September 16. ECWA offered a boat and bus tour of Eagle Creek Reservoir and watershed. On Friday,

September 29th, 190 5th grade students from Zionsville West Middle School participated in a Water Quality Awareness Day festival at Zionsville Lions Park. Citizens had the opportunity to experience some of the festival's water activities at the Saturday, September 30th Water Quality Awareness Day at Eagle Creek Park Marina. The ECWA has developed a website and published a watershed specific nonpoint source pollution brochure and quarterly newsletters.

The Upper White River Watershed Alliance

The Upper White River Watershed Alliance (UWRWA) was formed in 1999 and immediately got to work after a substantial fish kill occurred as a result of a pollution incident along the White River near Anderson, Indiana. Public and municipal concern regarding overall water quality in the river continued, and continues to rise. Current urban development pressures, concern for the



Upper White River Subwatersheds, Central Indiana

quality of area drinking water supplies, and other use impairments drive the Alliance's activities.

The Alliance's projects, partnerships, and stakeholders are defined by the geographic boundaries of the Upper White River Watershed. The watershed encompasses a 2,718 square mile area within central Indiana extending across sixteen counties including significant portions of Hancock, Marion, Hendricks, Johnson, Hamilton, Morgan, Boone, Tipton, Madison, Henry, Delaware, and Randolph Counties, as well as smaller portions of Owen, Monroe, Brown, and Clinton Counties.

After a significant decline in activity and effectiveness of the organization, CEES, Veolia Water Indianapolis, LLC., and the City of Indianapolis began in 2006 to work to revitalize the UWRWA. With a vision to become the principle regional watershed leader by creating resources, educational programs and partnerships that promote, protect, and enhance the biological, chemical, and physical integrity of the White River ecosystem, the UWRWA is a key organization in our efforts to enhance water resources for central Indiana.

With significant leadership efforts from CEES, Veolia Water, the City of Indianapolis, and Hamilton County, the

Scott Starling Nature Sanctuary Eagle Creek Watershed, NW Indianapolis



UWRWA is growing and making great strides. With a new watershed coordinator, revitalized membership, a five-year strategic plan, and a series of new programmatic goals, the UWRWA is poised to provide structure and support for regional watershed planning critical to a water resources protection and enhancement framework for central Indiana.

The USDA Conservation Effects Assessment Project

Purdue University and IUPUI CEES have teamed up to investigate how well various water resource conservation practices work, how much they cost, and how landowners feel about implementing the practices through a project funded with a \$650,000 grant from the USDA's Cooperative State Research, Education and Extension Service (CSREES). The Conservation Effects Assessment Project (CEAP) is concentrating on the Eagle

Creek watershed to evaluate the long and short-term effects of practices such as tillage, nutrient management, pesticide management, conservation buffers and water management. The project is also studying the social and economic factors that affect decisions about water quality management alternatives.

CEES and Veolia Water Indianapolis, through the Central Indiana Water Resources Partnership, have collected and managed historical data and ongoing analysis of the Eagle Creek watershed that will be utilized in CEAP. This information will be used to develop models in order to project the watershed's future and recommend alternative management practices. The analyzed information will be provided to conservation agencies that can then plan and put in place strategies to correct problems. Real data will be used to drive scenario modeling to use in educational programs for policymakers and implementers of best management plans to influence water quality practices in the Eagle Creek watershed.

Watershed Student Research

Watershed research forms a core of CIWRP programs. The watershed team is led by Dr. Lenore P. Tedesco, and Dr. Philippe Vidon and includes CEES research scientists Bob E. Hall, D. Lani Pascual, Eileen Hack, and Robert C. Barr.

Effects of Land Cover on Water Quality and Nutrient Loading

Leda Casey

M.S. Geology, IUPUI, 2007

Geologist, Office of Land Quality
Indiana Department of Environmental
Management

The IUPUI Department of Earth Sciences Master's thesis research by Leda Casey focused on understanding the influence of land cover on the amount and timing of water and nutrient delivery to streams in Eagle Creek Watershed.



**Continuous Water Monitoring Station,
Eagle Creek Watershed**

Research was completed in Fishback Creek and School Branch Creek on the northwest side of Indianapolis. Both watersheds are rapidly developing from agricultural to residential land use and flow directly into Eagle Creek Reservoir, a source of drinking water for the City of Indianapolis. Increased nutrient input from the watersheds is believed to be a cause of increased algal blooms observed in the reservoir. The study utilized a holistic approach to watershed research and management, combining in-stream water sampling, continuous monitoring, and remote sensing technologies.

Results of the study indicated that the influences of different land cover types on water delivery to streams and in-stream water quality vary seasonally and with respect to flow conditions. Additionally, study results suggested that a land cover change from agriculture to development will affect the concentration and loading of some water quality parameters (nitrogen) while others will likely remain the same (phosphate).

This research, in conjunction with 2003/2004 CIWRP research, is in the process of being

published in the journal Science of the Total Environment.

Nutrient and Sediment Loading of Streams under the Influence of Agriculture, Urbanization and Residential Development in Eagle Creek Watershed

Mary A. Campbell

M.S. Candidate, Department of Earth Sciences, IUPUI

Research by Abby Campbell focused on determining changes in water quality during low flow and event flow in streams as land use changed from agricultural to urban. Special attention was given to the characterization of the impact of areas currently transitioning from agricultural to residential land-use.

This project is an outgrowth of the project completed by Leda Casey in Fishback Creek and School Branch.



Results indicate that the increase in urbanization from less than 3% in the upstream areas to 10% lower in the watersheds led to a decrease in atrazine and total nitrogen in the stream. However, the moderate increase in urban land-use observed in the downstream direction did not strongly impact phosphorus, nitrate or suspended sediments in the watersheds studied.



Automated Water Quality Sampling Eagle Creek Watershed

This research is in the process of being published in the journal *Agricultural Water Management*.

Nutrient Specific Flow Paths during Storm Events in a Glaciated, Artificially Drained Landscape

Laura Wagner

M.S. Candidate, Department of Earth Sciences, IUPUI

The Master's thesis research conducted by Laura Wagner is determining variations in nitrate, phosphorus, and dissolved organic carbon concentration in two small catchments in Eagle Creek watershed during spring and summer storm events and identifying the specific ways these nutrients are moved from the land into streams. Two independent techniques are used to determine the specific flow paths and include use of oxygen isotopes and major cations as change in their concentrations throughout a storm event indicate whether the water is sourced from

precipitation, shallow groundwater, or surface runoff. Identifying changes in water sources during events using these two independent approaches allows for a better characterization of nutrient export processes in the two watersheds. This work will aid in our understanding of both where and when nutrients are being exported into streams in both agricultural and developing areas of the Midwest that can guide nutrient management decisions to improve water quality.

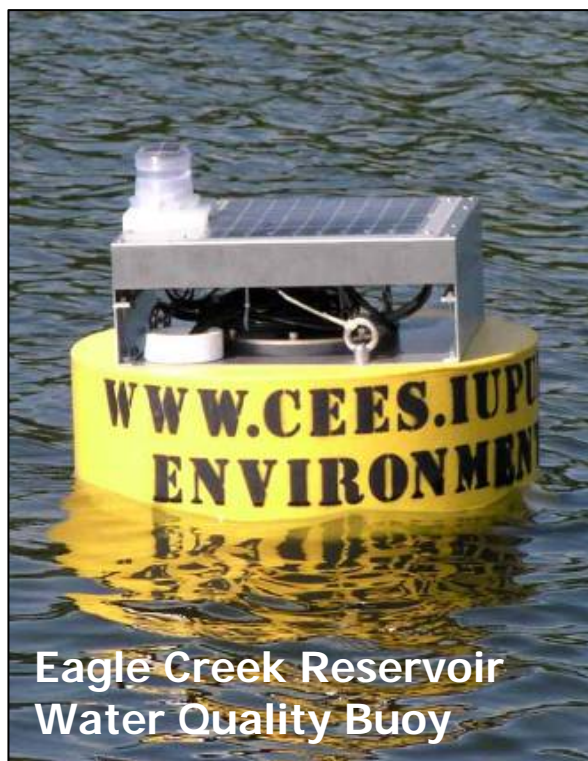
***Providing opportunities
for students to conduct
applied research and
work with community
partners on water
resources issues.***

Remote Monitoring and Remote Sensing Programs

Remote Environmental Monitoring: Creating a Dynamic Network

CEES launched an environmental monitoring buoy in the southern portion of Eagle Creek Reservoir in 2004. Equipped with a radio transmitter, the buoy measures physical, chemical and biological parameters near the surface, middle and bottom of the reservoir every 15 minutes. Data output includes water temperature, dissolved oxygen, chlorophyll and a suite of other parameters. In 2005 a temperature string buoy was added. These buoys are integral to the Central Indiana Water Resources Partnership and studies of algal blooms in Eagle Creek Reservoir.

The Eagle Creek Reservoir buoys are just two instruments in CEES' rapidly expanding remote environmental monitoring network. The Center also has added water level and water quality probes to the White River, Fishback Creek, Eagle Creek and School Branch Creek. Additional probes are installed in groundwater wells at the Lilly ARBOR Project riparian restoration site and the Starling Nature Sanctuary wetland restoration site. Additional monitoring sensors are embedded throughout central Indiana at wetland research sites. Many of these probes are reporting conditions in near real-time and are accessible on-line at www.cees.iupui.edu.



Ecological studies depend on our ability to monitor an environment, collect data, and analyze that data from diverse viewpoints. That's why CEES has partnered with the IU Visualization and Interactive Spaces Lab, under the direction of Dr. Polly Baker, to create the integrated environmental monitoring network. Our network of environmental sensors provides real-time data of real environments that is translated into visual components. Visualization allows researchers to thoroughly study data from a particular site, but it also provides an array of educational opportunities for K-12 students and teachers. The instrumented sites will be used to create analysis and presentation applications to foster community interest and participation in ecosystem restoration and water quality improvement projects.

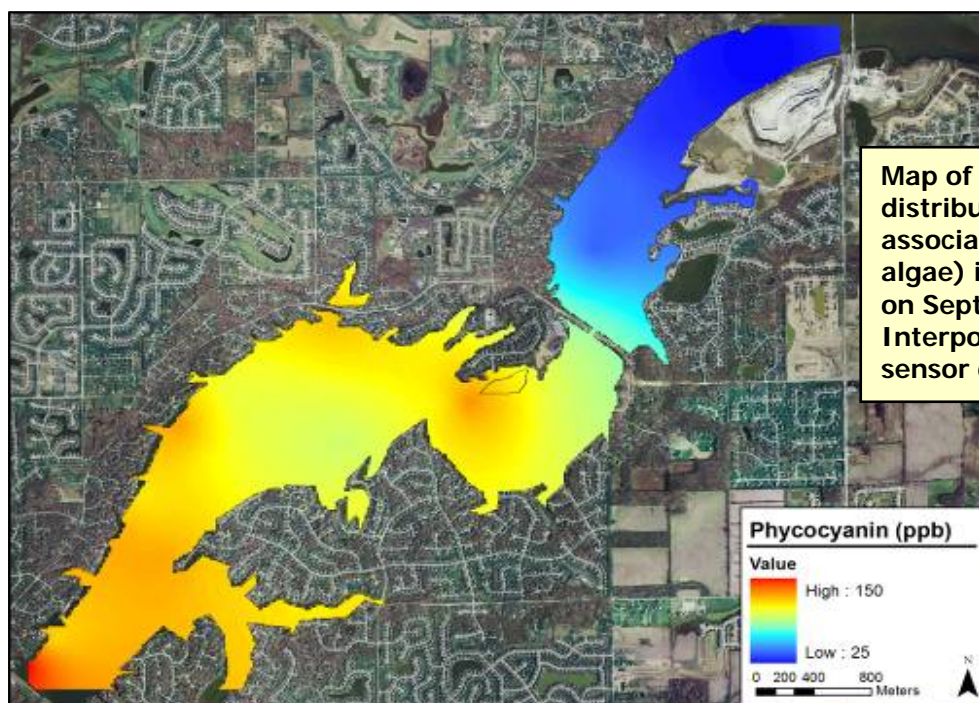
Mapping Blue-Green Algae with Hyperspectral Imagery in Central Indiana Reservoirs

In 2005, CIWRP and the Lake and River Enhancement Program of the Indiana Department of Natural Resources funded a research project to develop an assessment tool to map nuisance blue-green algal blooms in Central Indiana reservoirs that are part of the Indianapolis drinking water system. These nuisance and sometimes harmful algal blooms can result in degradation of lakes and reservoirs due to the production of surface scum, earthy smells from taste and odor causing compounds, recreational use degradation, and possibly human health concerns. Using the optical properties of phytoplankton pigments such as chlorophyll *a* and phycocyanin, a pigment unique to blue-green algae, CEES researchers were able to develop methods to rapidly map blue-green algae using light reflectance data.

Reflectance data collected both by boat-based and airplane-based sensors on Eagle Creek, Geist, and Morse Reservoirs have resulted in maps of blue-green algae distribution in all three reservoirs. This assessment tool is currently being tested as a real-time tool for tracking the distribution of blue-green algae in the reservoirs and allowing researchers and managers to better understand how to manage blooms and more effectively target reservoir sampling and treatment.

The research team is led by Dr. Lin Li, Dr. Jeffery Wilson, and Dr. Lenore P. Tedesco and CEES research scientists D. Lani Pascual, Kate Randolph, and Bob E. Hall. This research program remains an important part of the applied work that is the focus of CIWRP programs. Program focus continues to refine applications of algorithms to increase accuracy of predictions as well as allow for the transfer of this work to other lakes and reservoirs both throughout Indiana as

well as potentially in Europe and Australia.



Map of phycocyanin distribution (a pigment associated with blue-green algae) in Geist Reservoir on September 6, 2005. Interpolated from field sensor data.

Remote Sensing Student Research

Remote Sensing of Phytoplankton Using Optically Active Pigments, Chlorophyll *a* and Phycocyanin

Kaylan Randolph

M.S. Geography, IUPUI, 2007
Research Associate, CEES

Nuisance blooms of blue-green algae are seasonally prevalent in Indianapolis' three reservoirs: Geist, Morse, and Eagle Creek. These blooms can lead to aesthetic degradation of drinking water resources (e.g., surface scums on the water and taste and odor in drinking water). Some blue-green algae are able to produce toxins which can lead to adverse human health effects. Current methods for detecting blue-green algae are both costly and time consuming, which can lead to delayed management decisions. However, remote sensing techniques that utilize the optical properties of blue-green algal pigments (chlorophyll *a* and phycocyanin) can meet the need for rapid detection and assessment of blue-green algal distribution. Several previously developed algorithms were applied to boat-collected field reflectance spectra to predict the phytoplankton pigment concentrations in the reservoirs. Preliminary results show that the algorithms are able to predict up to 90% of the variability in phycocyanin concentration and thus blue-

green algae distribution. While the algorithms are robust, data will be analyzed to further optimize their applicability to Indianapolis' water reservoirs, thus, providing water quality managers with a survey tool for the rapid delineation and quantification of nuisance blue-green algae.

This research is in the process of being published in the journal *Remote Sensing of the Environment* in a Special Issue on *Application of Remote Sensing to Monitor Freshwater and Estuarine Systems*.

Spectral Sampling in Morse Reservoir



Using Hyperspectral Remote Sensing To Estimate Chlorophyll *a* and Phycocyanin in Central Indiana Reservoirs

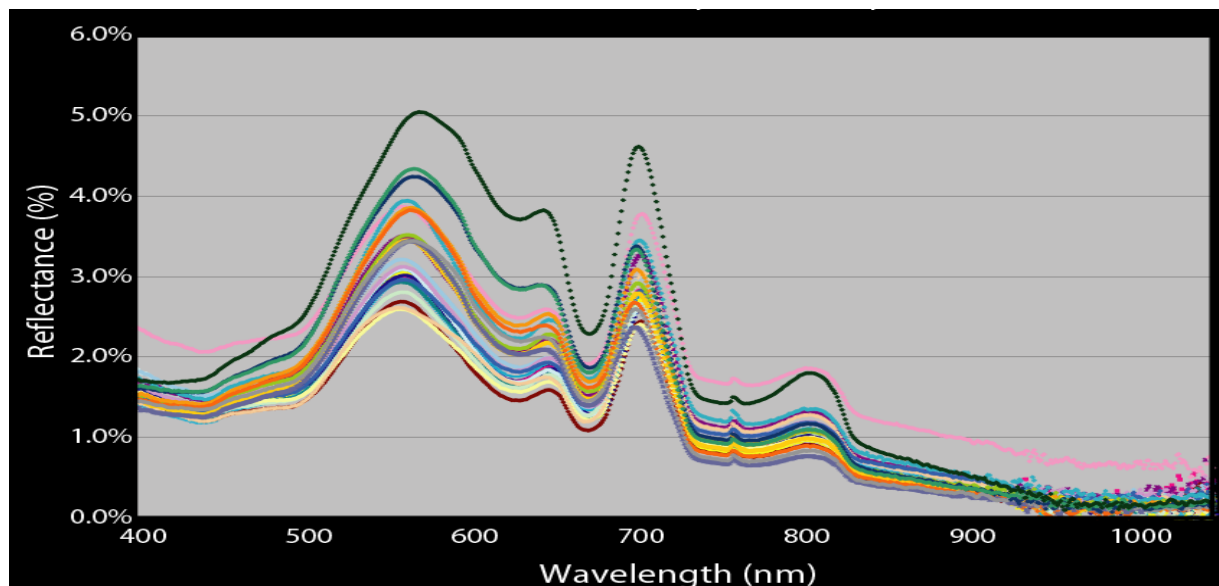
Rebecca Sengpiel

M.S. Candidate, Department of Earth Sciences, IUPUI

Through funding provided by the Indiana Department of Natural Resources LARE Grant and Veolia Water Indianapolis LLC., Rebecca Sengpiel is working on the development of a more efficient survey tool to determine blue-green algae concentration and spatial distribution in drinking water reservoirs. The approach of the research utilizes the spectral characteristics, i.e. the changes in how light from the sun is absorbed, of chlorophyll *a* and phycocyanin, as captured by the Airborne Imaging Spectrometer for Applications (AISA) airplane-based sensor. Chlorophyll *a* and phycocyanin are light absorbing pigments that are used by blue-green algae

photosynthesis, thus changes in light absorption and reflection indicates the presence of blue-green algae. The image data from one of the three reservoirs in the study, Geist Reservoir, has been processed. Preliminary results from this Reservoir have yielded two successful algorithms for the prediction of chlorophyll *a* and phycocyanin. The algorithms can then be applied to the data collected to generate high spatial resolution (1 m²) maps of chlorophyll *a* and phycocyanin distribution in Geist Reservoir. Additional work is also mapping Morse and Eagle Creek Reservoirs.

This research is currently in the process of being published in the International Journal of Remote Sensing.



Field Spectral Response for Geist Reservoir Sampling