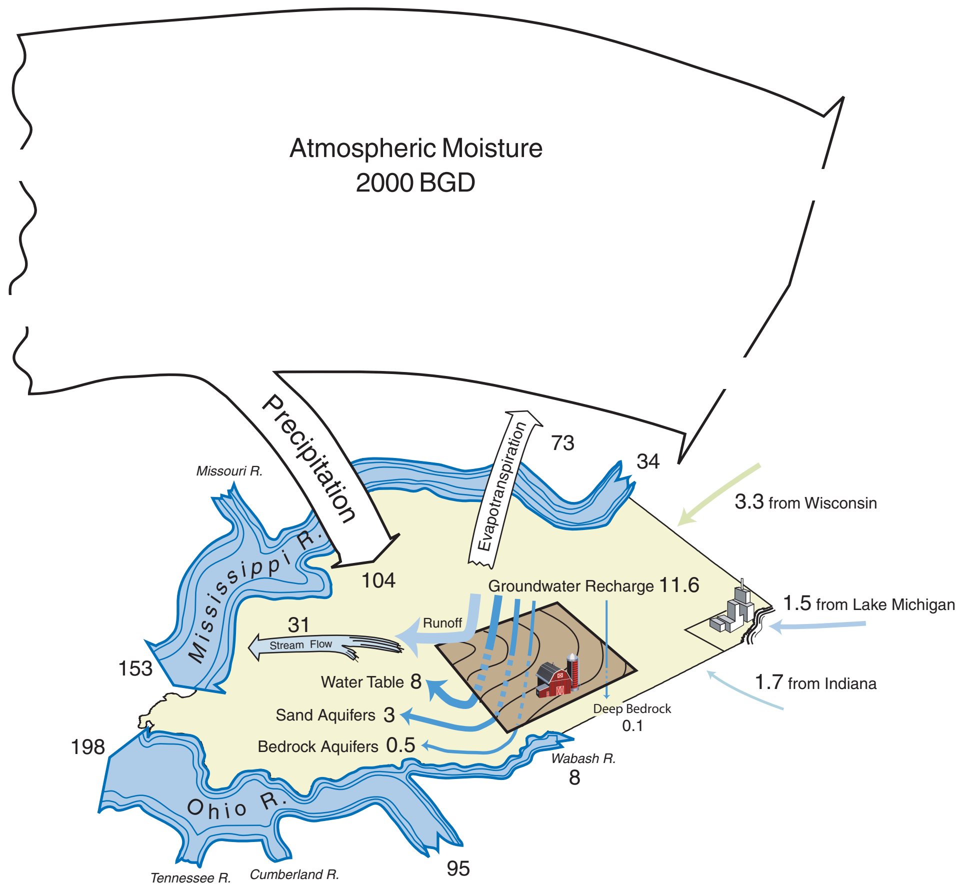
The Water Budget for Illinois
Water as an Integrated System



Illinois State Water Survey
Annual Report 2003-2004

Illinois State Water Survey Annual Report

July 1, 2003 – June 30, 2004

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2004

Editor: Eva Kingston
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Front Cover: This depiction shows water moving through the water cycle in Illinois and is based on 30-year (1971-2000) averages calculated by Illinois State Water Survey scientists (http://www.sws.uiuc.edu/docs/watercycle/picview.asp?p=hcycle2.gif). Values are in billions of gallons of water per day (BGD) and include: *atmospheric moisture* passing overhead (2000 BGD), *precipitation* (104 BGD), *evapotranspiration* (73 BGD), *surface water* flow (31 BGD), and *groundwater recharge* (11.6 BGD, of which 11.5 BGD is returned as groundwater discharge to surface streams). Additional surface water flows into Illinois from rivers in Indiana and Wisconsin, and water is imported into Illinois through the diversion from Lake Michigan at Chicago. Much of the water in the Mississippi, Ohio, and Wabash Rivers originates upstream of Illinois.

All uncredited photographs provided by Water Survey staff

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From the Chief's Desk

Providing an adequate supply of clean water at reasonable cost is important to all Illinois residents. Although the Illinois State Water Survey (ISWS) does not provide water to anybody directly and does not manage water resources, it does provide much scientific and engineering data that the public, resource managers, and policy makers need.

During the past 12 months, the ISWS has worked with other Illinois Department of Natural Resources (IDNR) offices, especially the Office of Water Resources (OWR), to fulfill the agency's responsibilities for planning and management of water supplies. In January 2004, the IDNR prepared a report that identifies the framework for administrative and housekeeping activities critical to the organization, management, and implementation of an Integrated Water Quantity Planning and Management team. With the Director of OWR, I serve as co-chair of this team, which meets quarterly and coordinates with personnel in other agencies through the State Water Plan Task Force and the Interagency Coordinating Committee on Groundwater.

The team has outlined several priority areas for water quantity planning and management for IDNR focus in the near-term, given the current limited resources (staff and funding). These priorities follow:

1. Develop a regional plan for northeastern Illinois, southeastern Wisconsin, and northwestern Indiana by working with the Northeastern Illinois Planning Commission and the Southern Lake Michigan Regional Water Supply Consortium. This includes developing a new regional groundwater model for the aquifer system in northeastern Illinois.

2. Develop a pilot or model aquifer management plan by working with local and regional authorities.

3. Develop a pilot management plan for the Fox River by working with the existing Fox River Study Group coalition, which includes the Fox River Ecosystem Partnership.

4. Update *Mitigative Measures for At-Risk Public Surface Water Supply Systems in Illinois*, an ISWS report prepared in 1990.

5. Continue to work on analyses of groundwater use to aquifer yield statewide.

Chief Derek Winstanley stands in front of the construction site of the Water Survey's new maintenance/ shop building.

6. Begin planning strategies and data collection that address the worst-case drought (100-year or worse).

Work continues or has been initiated on all these fronts, and some key results are presented in this *Annual Report*. In particular, the ISWS has developed and continues to populate its informational Web site on water supplies (http://www.sws.uiuc.edu/docs/wsfaq/). The Web site is intended to be the primary decision support site in the state for such information and includes a "hot button" to receive public input and comments specific to water planning issues. The diverse information on this Web site illustrates the complex nature of the water system, which necessitates consideration of scientific, engineering, legal, economic, public health, environmental, and societal issues.

For many years, the ISWS has had responsibility for floodplain mapping in Illinois. The OWR and others use the maps for floodplain management. Now, under the banner of Homeland Security, the U.S. Congress has appropriated funds to the Federal Emergency Management Agency (FEMA) to remap all floodplain areas in the nation. The ISWS and the OWR are working together to submit a multi-year proposal to FEMA to remap floodplains in Illinois using all recent data and up-to-date computer technologies and software. Such new floodplain maps would have great benefit for millions of Illinois residents through improved floodplain management, as well as for research, water and land management, and the private sector.

I am pleased to report that the ISWS continues to provide leadership in addressing topics that are important to the well-being of Illinois and the nation. Recognizing that the work of the ISWS embraces the entire water cycle, and research is coordinated across all Sections, the theme of this *Annual Report* is "Water as an Integrated System."

Derek Winstanley, Chief

ISWS and Chinese Scientists Collaborate on Modeling

Under the auspices of a long-standing agreement between China and the National Oceanic and Atmospheric Administration (NOAA), ISWS Chief Derek Winstanley, Kenneth Kunkel, and Xin-Zhong Liang traveled to China in October 2003 to further collaborative atmospheric science and technology research. The ISWS and NOAA established a Memorandum of Understanding in 2002 regarding ISWS involvement in this program.

The three scientists first visited Beijing's Appraisal Center for Environment & Engineering, State Environmental Protection Administration of China—their equivalent to the U.S. Environmental Protection Agency. Discussions there focused on the potential use of the ISWS regional modeling system to investigate potential environmental impacts of two major projects: diversion of water from water-rich areas in the south to more arid regions in northern China, and eastward transmission of natural gas from western portions of China.

Another stop on the itinerary was the Suzhou Meteorological Service (SMS) in Jiangsu Province, which also is interested in using the regional modeling system for typhoon (hurricane) forecasting. A three-month visit to the ISWS by the SMS Director in 2002 was the first step in this endeavor.

Kenneth Kunkel (left) and a guide climb a section of the Great Wall of China.

Chief Derek Winstanley, SMS Director Jian Ren, Kenneth Kunkel, and SMS Assistant Director Yang Jinbiao share a meal in Suzhou.

This time plans were finalized for further collaborations, including work on improving the regional climate modeling system during an upcoming U.S. visit by SMS scientists. The trio also discussed the possibility of future collaborations while visiting the Shanghai Meteorological Bureau. All participants have benefitted greatly from the three-way collaboration for which NOAA has provided thousands of hours in supercomputer time for related modeling experiments.

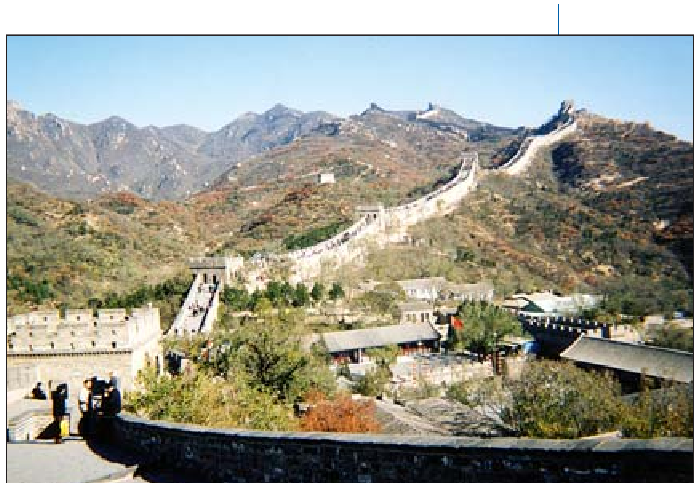
A sculpture is shown in the foreground of the Forbidden City in Beijing.

Zhouzhuang (Zhou township) is famous for its network of ancient canals.

This new city between Suzhou and Shanghai is being built for workers near a very large industrial park.

Chief Derek Winstanley created this plaque depicting Jiangsu Province and Illinois as a gift for the Assistant Mayor of Suzhou.

Xin-Zhong Liang, Jian Ren, and Kenneth Kunkel share a toast.



The Great Wall of China is north of Beijing.

Board of Natural Resources and Conservation

Board members, other Survey Chiefs, ISWS Section heads, and their spouses attend an evening reception and dinner at Chief Winstanley's home.

Derek Winstanley, Chip Zukokski, and Barbara Morgan.

Jene Robinson and Sue Key.

Betty Winstanley and Bill Shilts.

George VanderVelde.

Bob Inger and Joyce Changnon.

Sarah and Kent Smothers.

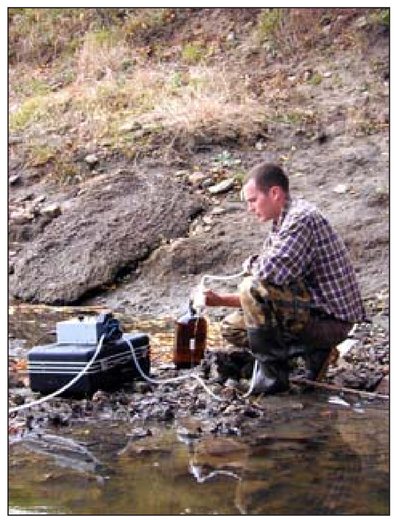
Damon Stotts, Jene Robinson, Deb Mitchell, and John Ebinger.

Jacque Sanders, Dave Thomas, and Bob Inger.

Water Survey Staff at Work

Staff members with 5–25 years service years measurable in 5-year increments are recognized annually at the ISWS Service Awards in February (top). Doug Ward and Kevin Merrifield conduct a network inventory (top left).

Jim Angel explains to student visitors how a hail pad records and measures hail.



Josh Stevens collects water samples on the Spoon River near Seville, Illinois for a C-FAR funded project designed to determine levels of bioavailable phosphorus within the watershed.

Al Williams adjusts the sampling inlet for aerosol analysis equipment housed inside this trailer.

Pam Lovett and Al Wehrmann finalize a report about monitoring networks in the Imperial Valley.

Extension and Education Activities

Staff continue to share their time, talents, and enthusiasm for the world of science with different activities at the State Fair. Most participants in the Groundwater Section's "Take the H_2O Challenge" preferred tapwater over distilled water. The public also tested pH, chlorine, hardness, and alkalinity of different types of water for the Analytical Chemistry & Technology Unit's "Test the Waters" interactive demonstration.

Throughout the year, staff also judged science fairs, spoke at career day fairs for students and teacher workshops, proctored tests for the Science Olympiad, and hosted field trips to the ISWS and its weather station for local science classes. Hundreds of publications, 1,500 raingages, watershed maps and postcards, magnets, and bookmarks also were distributed to teachers, private groups, and home school and other organizations interested in the environment and water resources. Two new outreach projects took ISWS staff into the classroom and students into the field or shared science information with students nationwide in conjunction with Earth Day 2004.

Scientist David Gay works with some children at State Fair.

WaterWorks Program at Urbana Middle School

The innovative *WaterWorks* program used the Salt Fork watershed as the focal point for development of instructional modules for seventh-graders at Urbana Middle School (UMS). Students were introduced to the concept of a watershed; natural properties of water; monitoring for water pollutants; wastewater treatment; and how area farms and industries use, conserve, and protect water resources.

During a half-day field trip to the ISWS, students and their teacher Gary Apfelstadt learned about the scientific approach to rain chemistry as illustrated by National Atmospheric Deposition Program sample collection, shipping and handling techniques, and chemical analyses. Students used pH differences to identify unknown samples and learned about the range of pH values found in rain samples across the United States. Staff chemists also demonstrated and discussed different analytical techniques used for determining pH, which ranged from the first glass electrode pH meters in the 1950s to litmus paper to color indicator solutions.

Several staffers also visited the UMS classroom to provide follow-up information, introduce an assignment based on pH of solutions in the students' homes, and then help them with their journal entries about the earlier field trip.

Together with staff from the U.S. Geological Survey Illinois District, two ISWS Watershed Science Section scientists conducted a field demonstration for UMS students on streamgaging, flow measurements, and sediment sampling in the Boneyard Creek on the University of Illinois campus. Students received prior classroom training to familiarize them with the equipment used and later saw the results of their measurements as they graphed data.

As part of the UMS WaterWorks *program, students tested water and recorded data with chemist Sophia Lazovsky (far left) and sampled sediment in the Boneyard Creek with scientist Laura Keefer (left).*

Staff involvement with the UMS program continued all year. Keynote speaker ISWS Chief Derek Winstanley spoke to students and their parents about the hydrologic budget and community use of water resources at one of several program Open Houses. The final class project was a student-created film for use as public service announcement encouraging proper use of water resources. In addition to the ISWS, others who hosted field trips and provided support for this unique project included the Illinois Student Environmental Network, Champaign County Soil and Water Conservation District. University of Illinois at Urbana-Champaign College of Education, and Urbana Public Works Department.

ISWS and ACS Collaborate on National Outreach Project

Staff collaborated with the American Chemical Society (ACS) on activities for "What Do You Know about H_2O" for Earth Day 2004 and designed a unifying experiment that let students determine rainwater acidity by testing pH. As part of this water-related celebration, the ACS Web site (http://www.chemistry.org/earthday) provided complete instructions for the experiment, outlined additional resources for students and teachers, described further hands-on activities, and discussed water-related topics such as erosion, evaporation, and condensation, among others. A related ISWS-sponsored Web site (http://nadp.sws.uiuc.edu/earthday/) let students report their pH results, print a certificate of completion, or obtain a hydrologic cycle coloring sheet.

Publicity for this event focused national attention on the ISWS. The electronic ACS newsletter *Chemunity News* highlighted ISWS involvement in Earth Day activities and reached 33,000 ACS members. National ACS headquarters also distributed Earth Day information and ISWS publications to 187 ACS sections nationwide. Then Maryland area ACS members at the Capitol Children's Museum in Washington, DC distributed pH kits and information about the experiment, which had the potential for reaching thousands of schoolchildren across the nation as a result of promotional efforts and Web access.

This was the first ACS partnership with an outside agency to produce a science

Proud ISWS staffers show the plaque they received from the American Chemical Society in recognition of their Earth Day contributions.

activity on a national level. In appreciation of ISWS efforts, the ACS presented ISWS staff with a plaque. An accompanying letter stated: "The participation in the Chemists Celebrate Earth Day program tripled in comparison to last year, and credit for that increase is primarily due to your [NADP/ISWS] efforts. Please accept this 'Salute to Excellence' plaque on behalf of the American Chemical Society's Committee on Community Activities, and the Office of Community Activities. It is only a small way to recognize a large commitment, but we hope that you will know that it is heart felt. Thank you for sharing your talents, skills and time with the youth of America."

Geographic Information Systems

A three-dimensional, color plaster model suitable for display was created in collaboration with the Imaging Technology Group at the Beckman Institute for Advanced Science and Technology at the University of Illinois. The model shows the formation of Illinois' water resources as repeated glacial advance and retreat changed the topography of Illinois. The ISWS is one of the first agencies in the nation to apply cutting-edge printing tools to geographic information systems (GIS). More information about the process used is available on the Web (www.sws.uiuc.edu/chief/gis/).

Digital Elevation Models were used to generate this model of Illinois.

Cross-disciplinary maps help convey information about water resources. The most recent addition to the ISWS map series depicts community surface water supplies in Illinois and shows intake locations in the context of the respective watershed and river system.

Staff also are expanding Internet map services and creating computer-animated landscapes (www.sws.uiuc.edu/chief/gis/gallery.htm). On-line interactive maps allow users to pan the landscape; zoom in or out on specific areas; add, subtract, or view features; and hyperlink to informational Web sites related to the selected location. The maps depict groundwater resources, streamflows, alternative crops, and the Illinois River watershed.

Quality Management

The Quality Management Plan (QMP) is the central document for the quality management system at ISWS and is available on the ISWS Web site. The QMP underscores the elements of a good quality system; provides a policy for staff and management training; and outlines procedures for procurement, document records and control, planning processes, staff responsibilities, and development of standard operating procedures (SOPs).

An important facet of the quality management system at ISWS is the Quality Assurance/Quality Control (QA/QC) Committee, a staff resource on individual quality practices. The QA/QC Committee continues to use the Web to distribute information and provide guidance on developing quality systems. An expanded Web site contains a hot link listing all ISWS QMPs and regularly updated lists of 19 Quality Assurance Plans (QAPs) and 63 SOPs, including the Committee-developed SOP on pipettor performance verification.

WARM Program Integrates Data from ISWS Networks

By its very name and mandate, the Water and Atmospheric Resources Monitoring (WARM) Program (http://www.sws.uiuc.edu/warm/) integrates data from various ISWS data collection networks in a comparable format for dissemination to users. For nearly 25 years, long-term monitoring networks within WARM have compiled information on much of the hydrologic cycle in Illinois, including data on weather and soil moisture, flows in rivers and streams, reservoir heights, shallow groundwater levels, and in-stream suspended sediments.

The Illinois Climate Network provides hourly and daily weather observations of numerous atmospheric and soil surface variables. Such data provide valuable information on usual and extreme weather events in Illinois, and serve as a basis for assessing the impacts of short- and long-term climate trends on other water resources in the state.

Monitoring soil moisture pinpoints areas of excessively dry and wet soils in Illinois with implicit short- and long-term impacts on agriculture and other water-sensitive industries. Data from the Soil Moisture Network become especially important during prolonged periods of precipitation drought. Not only do these data quantify the level of dryness in soils, but they provide an early picture of regions where water resources may soon be in decline, and also give indications of the length of time that a subsequent recovery may require.

Monitoring of streamflows on Illinois' rivers, data extracted from U.S. Geological Survey observations, is important to Illinois in developing and maintaining successful surface water strategies in support of Illinois agriculture, industry, water supplies, navigation, and recreation.

Water-level information on Illinois' reservoirs provides a historical perspective on reservoir conditions by yielding indications of present water reserves. Fluctuations in water levels are normal, but levels much lower than those typical for a particular time of year serve as a warning of declining supply. Monthly monitoring provides vital insights during drought conditions and is essential for water budget analyses of historical and current drought events.

The Shallow Groundwater Network monitors the water table at wells sited in rural locations remote from pumping stations to define short- and long-term trends in water-table levels under natural conditions. These data help scientists understand the effects and extent of long-term droughts and floods in Illinois, and, in particular, their lingering impacts on groundwater resources.

Suspended sediment data collections on selected rivers and streams through the Benchmark Sediment Monitoring Program place long-term changes in sedimentation transport in Illinois waterways as a high-priority water resource issue. The data help staff to identify watersheds with high erosion rates, to evaluate the effectiveness of watershed protection programs, to pinpoint watersheds with potential degradation of surface water supplies, to estimate sediment loads in nearby unmeasured streams, and to determine long-term trends in sediment transport.

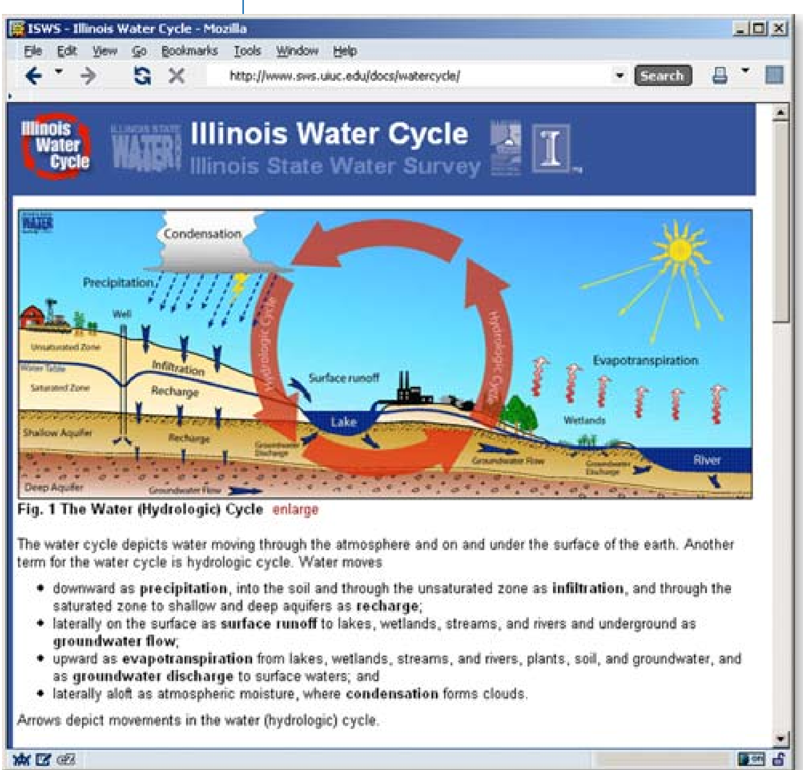
Integration of these regular monitoring networks provides high-quality information necessary to understand the natural variability of Illinois' water and atmospheric resources. They assist state officials with data needed to make adequate assessments of the current status of these resources, and the planning necessary to address potential impacts to Illinois as changes occur.

What's New on the Web

During the last year, almost 300,000 new users discovered the ISWS Web site (http://www.sws.uiuc.edu/), which contains press releases and other news items, publications, information, and downloadable data, and is included in more than 1,000 popular search engines. The ISWS Web group—the Illinois State Water Survey (http://www.sws.uiuc.edu/), the Midwestern Regional Climate Center (http://mcc.sws.uiuc.edu/), the National Atmospheric Deposition Program (http://nadp.sws.uiuc.edu/), and the Illinois Rivers Decision Support System (http://ilrdss.sws.uiuc.edu/), among other sites—experienced more than 19 million hits during Fiscal Year 2004, a new high for the sixth consecutive year.

A new link scroller on the ISWS home page unobtrusively highlights new and important Web site additions, without taking up valuable page space. The list of links is updated frequently.

For example, the new Illinois Water Cycle Web site (http://www.sws.uiuc.edu/docs/watercycle/) depicts water moving through the atmosphere and on and under the Earth's surface. Diagrams of this hydrologic cycle show water movement downward as precipitation into the soil, through the unsaturated zone as infiltration, and through the saturated zone to shallow and deep aquifers as recharge; laterally on the surface as surface runoff and underground as groundwater flow; upward as evapotranspiration, and as groundwater discharge to surface waters; and laterally aloft, where condensation forms clouds. Future expansion of this site is anticipated.



This informational Web site shows water movement.

A different search engine was added to the ISWS Publications Database, which includes new search criteria for users. An advanced search option (http://www.sws.uiuc.edu/pubs/advsearch.asp) now lets users find data and information quickly by title, author, feature, subject, year, or publication type, and also by combining the different search types.

Updates to many ISWS Web site pages reflect a recently redesigned new look (http://www.sws.uiuc.edu/hilites.asp). The new layout provides increased compatibility with newer browsers, while increasing the ease of site navigation because links to the major areas of the ISWS Web site now appear on every page. Phasing in of this redesign will continue, along with sitewide content update.

Content of the Watershed Science and Groundwater Section Web pages was updated. Many other ISWS programs already are working on project and information updates for the next phase of the site update.

Several integrative data sites were added, including two new live data feeds on the Water & Atmospheric Resources Monitoring Web site, a Web site with downloadable data from one site, and another that estimates flow quantity in Illinois streams. The Pest Degree Days (http://www.sws.uiuc.edu/warm/pestdata/) and Growing Degree Days (http://www.sws.uiuc.edu/warm/cropdata/) pages feature tabular data and isobar maps of Illinois that are updated daily. The Arcola Data Station Web site offers downloadable data (http://www.sws.uiuc.edu/data/stations/arl/). The Illinois Streamflow Assessment Model (ILSAM) Web site uses real-time graphing and produces estimates of flow quantity in Illinois streams with GIS technology to assist in the input process (http://gismaps.sws.uiuc.edu/ilsam/).

Program Planning and Management

Planning and management of programs, facilities, equipment, budgets, and staff are accomplished through the Water Survey's Strategic Plan. An annual update of the plan, including current year action items, has been completed. This plan will be coordinated with the Department of Natural Resource's Strategic Plan as it is developed under Governor Blagojevich's administration.

The University of Illinois' five-year initiative for an integrated business and student services system on all three campuses has been completely activated. This suite of integrated products operates from a common database and will provide real-time access to vital information for University departments. The new system has made it necessary to implement comprehensive changes and has required some level of training for all staff members dealing with University accounts and extensive training for the business staff at the Water Survey.

Mercury in the Environment

The presumption of naturally low and environmentally insignificant amounts of mercury in the environment has influenced scientific and public perception about the effects of human activities on mercury in the environment. For example, the U.S. Environmental Protection Agency and others assume no widespread geologic sources of mercury and conclude that mercury in Illinois and U.S. soils and watersheds comes mainly from atmospheric mercury pollution.

Using data from the Illinois State Geological Survey, U.S. Geological Survey, and the Mercury Deposition Network of the National Atmospheric Deposition Program, ISWS scientists observed that soils typically contain on the order of 10,000 years of mercury at present rates of atmospheric mercury deposition. Thus, the amounts of mercury present in Illinois and U.S. soils are too great to be caused mainly by atmospheric mercury pollution.

This finding does not mean that there is no atmospheric mercury pollution. Nor are there situations where conditions are such that most mercury does come from atmospheric mercury pollution. It does indicate, however, that because environmentally significant amounts of natural mercury generally are found in soils, further research should investigate the mobility and fate of both natural mercury and mercury added to terrestrial and aquatic environments by human activities. For additional information, refer to E.C. Krug and D. Winstanley. 2004. "Comparison of Mercury in Atmospheric Deposition and in Illinois and USA Soils." *Hydrology and Hydrology and Earth System Science* **8**(1):98–102.

ANALYTICAL CHEMISTRY & TECHNOLOGY UNIT

Water as an Integrated System

Analytical Chemistry & Technology Unit (http://www.sws.uiuc.edu/chem/) programs provide support for the analytical needs of researchers at the ISWS and at the University of Illinois for projects on groundwater, surface water, public drinking water systems, private wells, and heating/cooling systems at state facilities. They also help private citizens, state facilities and departments, and small public drinking water systems solve water-related problems in Illinois and throughout the Midwest.

Public Service Laboratory

The Public Service Laboratory (PSL) was established in 1895 to monitor the water quality in Illinois' waters in response to typhoid outbreaks around the country in 1893. Since then, the ISWS has continued to offer Illinois residents free analyses of minerals in their water—more than 230,000 samples to date—but the original focus has changed to address current needs. Today arsenic analysis is a major concern of private well owners due to the lowered federal drinking water standard from 50 micrograms per liter (µg/L) to 10 µg/L. Many public water supplies and hundreds of private wells in Illinois are potentially susceptible to high arsenic concentrations.

Private well owners and others contact the PSL to request a sample kit and instructions on how to collect the sample depending upon what is being tested. Some samples are submitted purely for information sought by well owners, but more typically to find answers to corrosion, staining, mineral scale formation, or taste and odor problems. In addition to samples of water used for drinking, farmers also may submit samples of well or surface water used to supply livestock or water crops.

Typical analyses performed include determinations of metals, anions, pH, dissolved solids, and alkalinity. Last year, the PSL analyzed 532 samples and responded to more than 500 informational requests. Clients receive a report detailing results and an explanatory letter that also includes staff recommendations on addressing the problems. If the analysis indicates a potential health hazard, clients are referred to the appropriate state agency or assistance provider.

This truly unique program provides a valuable resource, continues to be a cornerstone of the ISWS public service component, and meets the needs of Illinois' residents by proactively addressing new issues.

Ted Snider drops off some samples from the CREP project for nutrient analyses by Lauren Sievers.

Analytical Services

The Analytical Services group provides chemical analyses in support of research conducted by ISWS staff and at the University of Illinois. Analyses routinely include metals, anions, pH, alkalinity, dissolved solids, nonvolatile organic carbon, and various organic constituents. Staff also help researchers with sample collection/preservation methodology and quality assurance protocols.

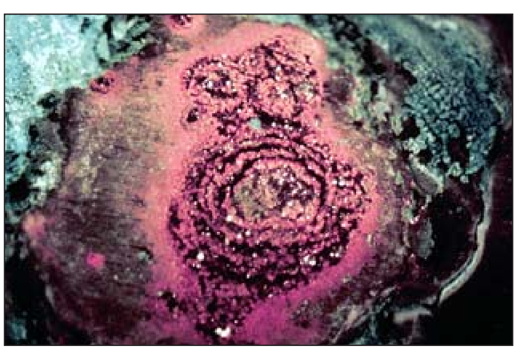
During the past year, the Analytical Services group contributed to a wide range of projects, including sediment and nutrient monitoring to evaluate the Illinois River Conservation Reserve Enhancement Program, watershed monitoring for Lake Decatur, dewatering well assessment for the East St. Louis highway drainage system, hot springs water quality in Yellowstone National Park, shallow groundwater studies and fen water quality in Kane County, arsenic in the Mahomet Aquifer in central Illinois, solar phototransformation of nutrients in Illinois' lakes, bioavailability of phosphorus in the Spoon River and nutrient contributions to surface water by groundwater for projects sponsored by the Illinois Council of Food and Agricultural Research, and metals analysis for the Institutional Water Treatment Program. This group is an essential part of the many diverse water-quality-related projects ongoing at the ISWS.

By helping design and specify water treatment systems such as this state-of-the-art cooling water treatment system, IWTP staff help participating state facilities.

Institutional Water Treatment Program

The Institutional Water Treatment Program (IWTP) was established in 1949 at the request of the Illinois Department of Mental Health to help handle problems in water used for drinking and for heating/ cooling systems. The program was such a success that other state departments and facilities soon began using IWTP services and paying a nominal fee to support some costs associated with program administration.

The IWTP continues to help more than 100 state facilities, including Department of Central Management Services, Department of Corrections, Department of Human Services, Department of Natural Resources, Department of Transportation, Department of Veterans Affairs, and the Office of the Secretary of State. More than a dozen state universities and some community colleges also participate.



This active corrosion on a copper pipe surface was photographed under magnification using a stereoscope.

Staff provide advice on the proper application and specification of chemical treatment to control mineral scale and corrosion in water-using systems. Effective water treatment results in dollar savings and conservation of valuable natural resources through reduced water usage and energy and maintenance costs.

Additional services provided include laboratory analysis of samples, on-site training and seminars, detailed written recommendations and reports, corrosion monitoring, equipment recommendations and specifications, and ongoing evaluation of treatment programs. Staff also write specifications for water treatment chemicals and testing supplies for the annual state chemical bid administered by the Department of Central Management Services, to ensure products supplied meet specifications.

During the last year, staff visited 470 sites and analyzed nearly 4,000 samples in the field. The laboratory analyzed 963 water samples and almost 200 corrosion coupons of various types. Staff also responded to requests for assistance and information with nearly 1,200 phone calls and more than 1,500 letters and reports.

Midwest Technology Assistance Center

Through a combination of competitive grants, outreach, and information dissemination, the Midwest Technology Assistance Center (MTAC) for Small Public Water Systems (http://mtac.sws.uiuc.edu) works with university researchers, technical assistance providers, and regulatory officials to help small public drinking water systems meet fiscal, managerial, and technical challenges. This U.S. Environmental Protection Agency-funded program cooperates with other similar Centers around the country to build the capacity of small water systems to provide safe drinking water at a reasonable cost.

An important issue facing many public groundwater supplies and private well owners in Illinois is high arsenic concentrations. This toxic chemical is indicated as a causative agent in cancers of the skin, bladder, kidney, liver, and lung due to chronic exposure to arsenic-contaminated drinking water over a long period. Arsenic has been the focus of several MTAC-sponsored educational workshops for small system operators and administrators over the last two years. Three separate major MTAC-funded projects also address this issue.

"Arsenic Removal in Water Treatment Facilities: Survey of Geochemical Factors and Pilot Plant Experiments" sought to identify critical factors related to improved arsenic removal using existing plant equipment, as well as geochemical factors that may influence the arsenic concentration in groundwater wells. Improving oxidation efficiency and the ratio of iron to arsenic were determined to be the most critical parameters related to arsenic removal efficiency. Researchers also concluded that most arsenic in these wells came from the main aquifer, not bedrock as previously thought, and many wells had extensive temporal variability of arsenic concentrations.

"Arsenic in Illinois Groundwater: Implications for Non-community Water Supplies" involved sampling noncommunity supplies in Illinois not sampled previously to determine any supplies in which arsenic concentrations may pose a health concern to those consuming the water. A complete water-quality analysis of each sample was performed to determine any other water-quality parameters related to high arsenic concentrations. Well construction and geological information were collected, when available, to try to correlate these factors with variable arsenic concentrations in Illinois' groundwater supplies.

"Development of Low Cost Treatment Options for Arsenic Removal in Water Treatment Facilities" is attempting to use innovative methods to improve the oxidation of arsenic and its co-precipitation with iron oxide to result in increased arsenic removal efficiency. Preliminary studies are encouraging, and in-plant trials are proceeding.

Other MTAC projects are studying source water protection, water-supply-and-demand projections, terrorism vulnerability assessment, nitrate removal, and information technology security. Next year studies will be initiated on drought preparedness and planning, and additional efforts to address the arsenic problem. New program areas being launched include implications and effects of organizational changes such as consolidation and partnership on small systems, security issues for water distribution systems, and developing recommendations on monitoring technology and cyberinfrastructure to address homeland security concerns.

ATMOSPHERIC ENVIRONMENT SECTION

Studies of Atmospheric Aspects of the Hydrologic Cycle

The atmospheric portion of the hydrologic cycle plays a significant role in the fluctuations of water supply and quality that affect society and the environment. For example, persistent anomalous large-scale atmospheric circulation patterns are the major cause of widespread, serious floods and droughts. The atmosphere is not simply the cause of other features of the cycle, however; surface hydrologic processes also affect the atmosphere through mass and energy fluxes at the surface. Thus, atmospheric and surface hydrologic processes are a truly coupled system that must be studied in an integrated manner.

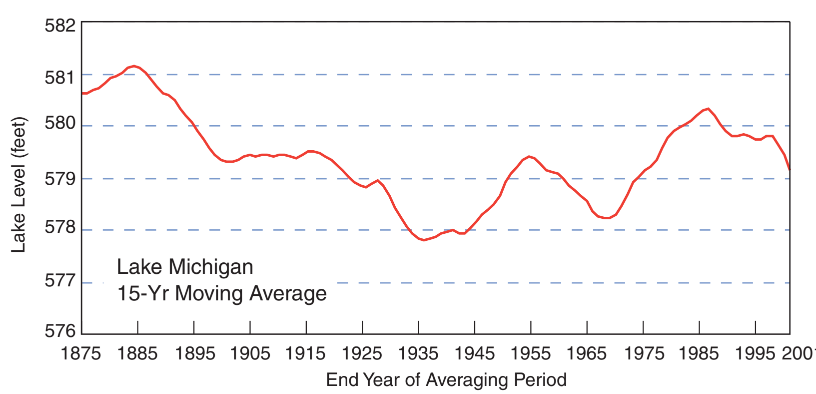
Weather and Climate

A long-term objective of the multi-component ISWS atmospheric sciences program is to assess weather and climate fluctuations to better understand the hydrologic cycle and to better anticipate future conditions. Study of basic processes in the atmosphere increases the fundamental understanding of the cycle and provides a solid scientific foundation for other program aspects. Experimental studies that include field measurements are a powerful complement to basic research and modeling, and also increase scientists' understanding of physical processes.

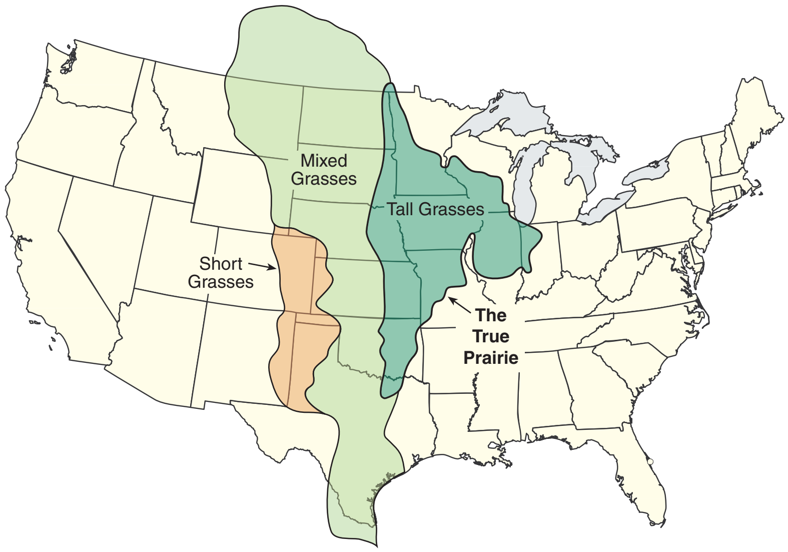
Investigation of past climate changes and fluctuations that have affected our physical environment provide information about the potential range of future conditions and the types of physical impacts that future climate shifts could bring to Illinois. Environmental conditions are quite adaptable to a certain range of weather shifts that last for a relatively short period, up to a few years in duration, but atmospheric changes that last a decade, a century, or longer may be sufficient to alter essential environmental conditions so it is crucial to identify those changes. Sophisticated models have been developed and are powerful tools to better understand what the future may bring.

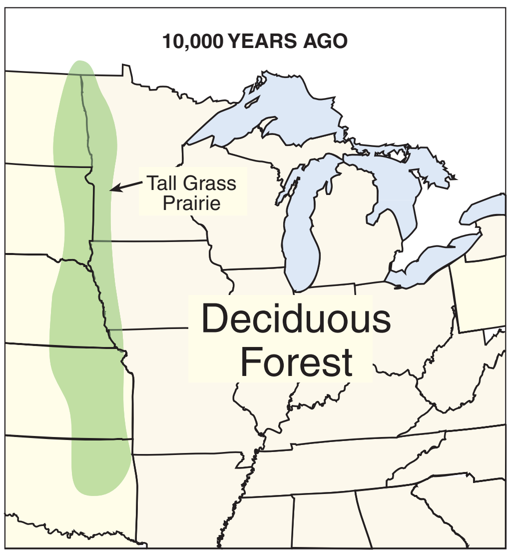
Lake Michigan is an important source of water for the Chicago metropolitan area and a key environmental resource. The ISWS has conducted considerable basic research to better understand interactions between weather/climate and the Great Lakes when no ice was present. Although pack ice floating on the Great Lakes plays an important role in atmospheric modification, little is known about its influence. The ISWS helped lead a field experiment using an instrumented aircraft over the Great Lakes to investigate these interactions during periods of ice cover in February 2004. Initial findings indicate that the lakes modify the overlying atmosphere even when their surface is covered almost completely with pack ice.

Studies of past climate variability and change extend back thousands of years. Scientists at ISWS re-examined the end of the Pleistocene Epoch as the ice age ended in Illinois 11,500 years ago. The Wisconsin ice sheet melted and retreated as a much warmer climate with temperatures five degrees higher returned to the Midwest after a 140,000-year absence. This new warmer climate of the Holocene interglacial era led to the development of a boreal forest across Illinois 10,000 years ago. A warmer, drier climate about 9,000 years ago, together with extensive burning of vegetation by Native Americans and lightning,



Moving average levels for Lake Michigan are based on 15-year periods.





Much of what is prairie today (top map) was once forest (bottom map).

replaced Illinois' forests with tall grass prairie that spread across most of Illinois and the Midwest. Another climate change about 7,500 years ago to the drier Hypsithermal period, with continued burning, caused prairie expansion eastward across Indiana and Ohio, into Pennsylvania, and farther into southern Illinois.

This warm, dry climate lasted until 4,700 years ago when a cooler, wetter regime emerged. The prairie retreated westward and northward, followed by forests from Indiana eastward. Primary climatological conditions that determined the extent of the prairie included occasional severe droughts, relatively little precipitation and occasional thunderstorms during the cold season, and relatively high precipitation compared to potential evapotranspiration during the warm season.

Study of Great Lakes levels over the past 140 years revealed two important climate conditions affecting these valuable water resources. Precipitation and evaporation due to temperature and winds varied considerably between lakes in most years such that the levels of Lakes Michigan and Huron behaved very differently than those of Lakes Superior or Erie. The levels of all the Great Lakes reflected large-scale weather fluctuations that created extremely high and low lake levels during 1923–1941 and again during 1971–2000. Both periods were sufficiently different to other periods and dramatically affected shorelines with increased exposure and extensive erosion that also impaired water quality in the lakes.

Investigations of Illinois' precipitation levels over the past 120 years defined another series of conditions with significant environmental impacts. The first 30-year period (1880–1910) had precipitation amounts near the 120-year average, followed by much below average amounts (1911–1940), near average amounts (1941–1970), and much above average amounts (1971–2000). Of course, each period had years with anomalous amounts, such as the dry 1988 and the wet 1936–1937 with record floods amidst the major drought of the 1930s.

Studies of Illinois' corn growing season weather conditions over the 20th Century revealed this sequence of average–dry–average–wet periods has had profound effects on corn yields, with much higher than average yields beginning in 1970 than in any past period. An ever wetter regime since 1940 also has resulted in higher streamflows and more frequent floods, including major floods in 1993, 1996, and 1997. Over the past 30 years, Illinois, Iowa, and Missouri have experienced more flood damage with extensive erosion and floodplain damage than any other states in the nation.

Water cycle impacts of long-term changes in temperature have changed evaporation rates over water surfaces, evapotranspiration rates over land, snowfall, and snowmelt. Careful reconstruction of temperatures since the 1850s showed generally cooler temperatures than at present during the second half of the 19th Century before warming by about two degrees through the mid-20th Century. Thereafter temperatures cooled by one degree, culminating in cold winters in the late 1970s. Temperatures have warmed slightly since then, but are not as warm as the decades of the 1930s, 1940s, and 1950s. Most of these changes occurred in winter (December–February). Current research is extending temperature records back to the earlier half of the 1800s.

With the publication of the definitive *Climate Atlas of Illinois*, a diverse audience now has access to 50 years of ISWS climate research. The 10-chapter atlas includes nearly 300 maps and graphs, more than 80 photographs, an extensive bibliography, a glossary, and appendices of climatological data for 11 locations.

Droughts

A study of drought during the 20th Century found that temporal and spatial variability appear to be strongly influenced by patterns of sea-surface temperatures in the Pacific and Atlantic Oceans, findings that may make it possible to predict periods of elevated drought risk in Illinois. More than 52 percent of the spatial and temporal variance in multi-decadal drought frequency over the conterminous United States is attributable to the Pacific Decadal Oscillation (PDO) and the Atlantic Multidecadal Oscillation (AMO). The PDO represents a sea-surface temperature pattern that varies in opposite sign in the eastern tropical Pacific Ocean and the northwestern Pacific Ocean, and is thought to be related to the frequency and magnitude of El Niño events. The AMO is derived from the average sea-surface temperature departure from normal of the Atlantic Ocean north of 10°N latitude.

Recent droughts with broad impacts over the conterminous United States in 1996 and 1999–2002 were associated with North Atlantic warming (positive AMO) and northwestern Pacific warming and eastern tropical Pacific cooling (negative PDO). Much of the long-term predictability of drought frequency may reside in the multi-decadal behavior of the North Atlantic Ocean.

Another project considered the worst-case drought from the instrumental record since the 1850s and earlier tree-ring records for Illinois. Precipitation was only 67 percent of normal statewide in the driest year in the instrumental record, 1901. Some sites were even drier, with values 50–60 percent of normal. Although multi-year droughts occurred in the 1930s and 1950s, tree-ring analysis over the past 400 years identified a megadrought with precipitation departures estimated at 12 percent below normal from 1565 to 1574. These worst-case drought conditions, along with newly updated drought return periods, will help define the bounds of the natural variability in the water cycle.

Modeling

An ISWS program is developing a state-of-the-art regional modeling system to study climate, air quality, and impacts associated with natural and human-induced changes. The model's present version is being used for these studies while improvements are made. A 20-year simulation of the recent past climate was completed and analyzed, a necessary validation step to assessing model ability to simulate major climate characteristics. The model accurately simulated Illinois' precipitation and temperatures. Significant model improvements included incorporating better geophysical data for the land surface. Work to couple crop models with the regional model also began.

Continuous flux measurements of carbon dioxide, water vapor, and energy balance over corn and soybeans are providing valuable information for validation of these models, and to better understand the impacts of short-term weather events on crop yields. Flux measurements have shown that a 10- to 16-day dry spell during soybean pod set and fill will reduce daily photosynthesis approximately 50 percent. A 12-day dry spell compounded by a severe soybean aphid infestation reduced daily photosynthesis by 92 percent, however, with only a small recovery after rains in late August and early September 2003.

The ISWS-developed regional climate model requires global climate model (GCM) input data. Evaluation of 30 GCMs focused on their accuracy in simulating precipitation amounts and atmospheric processes responsible for precipitation variability in the Midwest. No single model was shown to be superior to all others after comparing data from 21 atmospheric GCMs and 9 coupled ocean–atmosphere GCMs. The study examined GCM seasonal precipitation and temperature averages, atmospheric water vapor content, and flow patterns near the surface and at the upper level of the jet stream.

Several models simulated many climate features, but all models evaluated were deficient in some respect. Satisfactory simulation of fall precipitation patterns poses a particular problem: all models but one produced too little fall precipitation. The National Center for Atmospheric Research Parallel Climate Model (PCM) accurately simulated many aspects of the Midwest's climate, and the Hadley model calculated fall precipitation successfully but was not as good as the PCM in other respects. Both complementary models will be used to drive the ISWS regional climate model.

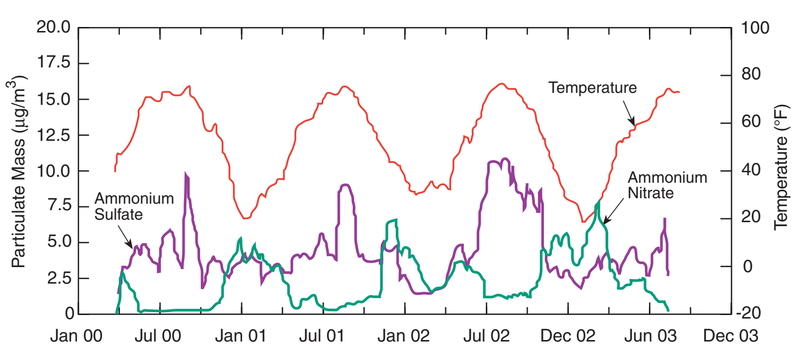
Atmospheric Pollution

Fine particulate matter (PM) in the atmosphere is significant as a health concern, a primary cause of visibility impairment, and as a factor in the Earth's radiation balance. Intensive ISWS field measurement campaigns continue to increase knowledge about PM properties that produce complicated emissions, transformations, and meteorological interactions. Multi-year project support from the Lake Michigan Air Directors Consortium is funding measurements every 30 minutes of ammonium, sulfate, and nitrate in atmospheric particulate matter smaller than 2.5 millimeters ($PM_{2.5}$). Few other long-term, high-frequency aerosol composition datasets even exist.

Last summer, more than 2,500 measurements of three major $PM_{2.5}$ ions were made at an established rural monitoring site near Bondville, Illinois. The ionic composition data showed that mixed sulfate and nitrate aerosols occur at night, and that nitrate concentration decreases sharply and sulfate predominates during the day. These observations are consistent with other literature, suggesting sulfate from air masses aloft mixes downward during the morning, shifting the near-surface aerosol towards sulfate.

These data also were examined from the standpoint of wind direction during collection. In general, the average inorganic aerosol mass at Bondville was twice as large when the wind was from the southeast as from the northwest. The $PM_{2.5}$ aerosol proportionately had much higher sulfate concentrations with southeasterly winds and proportionately higher nitrate concentrations with northwesterly winds, implications for aerosol source apportionment and emission control regulations. These temporal and spatial trends could not be discerned previously using 24-hour-total filter-based monitors operated on one day in three or longer schedules. Scientists are using the results to correlate parallel 30-minute measurements of $PM_{2.5}$ precursor gases (e.g., ammonia, nitric acid and sulfur dioxide).

This instrument at Bondville, Illinois, and others from Oklahoma to Ohio measure air samples for gas and particulates, especially ammonia.



The ISWS has long-term ammonia data for Bondville, Illinois.

Measurements at a wide range of concentrations from an 11-station network have shown the existence of an east–west ammonia gradient as thought. These data are being used to build a large database of atmospheric ammonia and other components to help understand rural aerosol chemistry and allow further development of regulatory modeling programs that protect visibility and health. The network was established to monitor and study atmospheric ammonia and other gaseous and aerosol components across the Midwest.

Still another study nearing completion is describing the emission, deposition, and background levels of aerosol-emitted road salt from treated roads at five instrumented sampling sites near Lemont in anticipation of a tollway extension that since has been put on hold. These data are being used to develop a salt deposition model to estimate salt deposition for planned roadways. The model's geographic information system format will be applicable for existing roadway networks and all estimate salt deposition on other mapped overlays such as forest preserves.

Groundwater as an Integrated Component of the Hydrologic Cycle

Most people reading this *Annual Report* probably have an appreciation for the hydrologic cycle (the water cycle) and a basic understanding of the interrelationships among precipitation, surface runoff and streamflow, and groundwater recharge, storage, and discharge. Perhaps, the least understood of these relationships—by the lay public and even by the scientific community—are those involving groundwater recharge, storage, and discharge.

Much like a checkbook balance reflects spending, a water budget seeks to balance inputs and outputs for a groundwater system. Such a balance can be expressed as:

$$R_{gw} = D_{gw} + ET_{gw} + U + S_{gw} + Q$$

In other words, over a given time period within a basin or aquifer system, groundwater input or recharge (R_{gw}) is balanced by groundwater outputs that include groundwater discharge to the surface (D_{gw}), evapotranspiration (ET_{gw}), groundwater underflow (U) to other basins or aquifer systems, the change in groundwater storage (S_{gw}), and groundwater withdrawals or pumpage (Q). Rearranging the terms, as follows,

$$S_{gw} = R_{gw} - D_{gw} - ET_{gw} - U - Q$$

describes the change in groundwater storage as being equal to groundwater input minus groundwater outputs. The change in groundwater storage is measured directly as the change in groundwater levels.

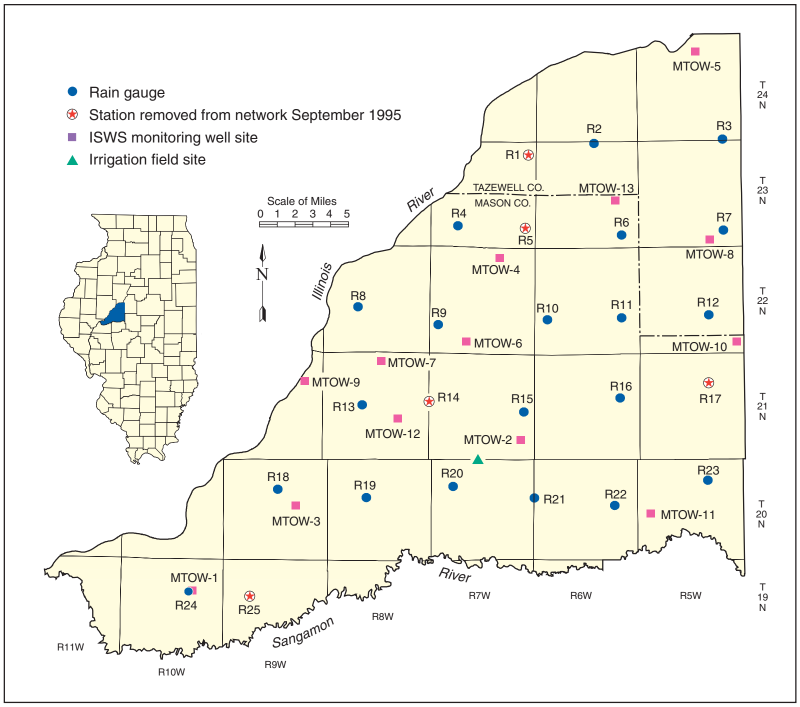
When groundwater outputs are less than recharge, groundwater levels rise, just as the balance does in the checkbook example. Conversely, when outputs exceed recharge, the change in groundwater storage is negative and is reflected by a fall in groundwater levels, or a negative balance in the checkbook example. Groundwater Section and other ISWS scientists are examining the components of the hydrologic cycle to improve the understanding of these complex interrelationships.

Examining Groundwater Inputs and Outputs in the Imperial Valley

There is no better example of how ISWS scientists are working together to examine the hydrologic cycle interrelationships than in the operation of two observational networks in the Imperial Valley in Mason and Tazewell Counties. The area overlies the confluence of the ancient Mississippi and Mahomet–Teays bedrock valleys. Sandy soils and rolling dunes stand in stark contrast to the typically flat topography and silt loam soils elsewhere in central Illinois. Sand-and-gravel deposits associated with these two valleys contain an abundant groundwater resource that is used to irrigate various row and specialty crops. Crops grown on the well-drained, sandy soils demand tremendous amounts of water, approximately 46 billion gallons provided by 1,867 irrigation systems in 2003.

Knowledge of precipitation variability and its relationship to groundwater recharge over this extensively irrigated region will be useful for managing the region's groundwater resources. Long-term monitoring of precipitation and groundwater levels has been undertaken through funding from the Imperial Valley Water Authority to better understand how their groundwater resource responds to precipitation, particularly drought, and seasonal irrigation. Because the soils are so sandy, essentially no overland runoff occurs, simplifying the water balance equation and making this aquifer system ideal for study.

A network of 25 raingages at 5-mile grid spacing was established in 1992, reduced to 20 gages in 1996, and now contains almost 12 years of precipitation data, including digital records at 10-minute intervals since 1997. A groundwater network of 11 observation wells, established in 1994, was expanded to 13 wells by 1996, and most wells now have monthly measurements of groundwater levels covering a 10-year span. Locations of both networks are shown (see map).



The Imperial Valley raingage and observation well networks are located in Mason and Tazewell Counties.

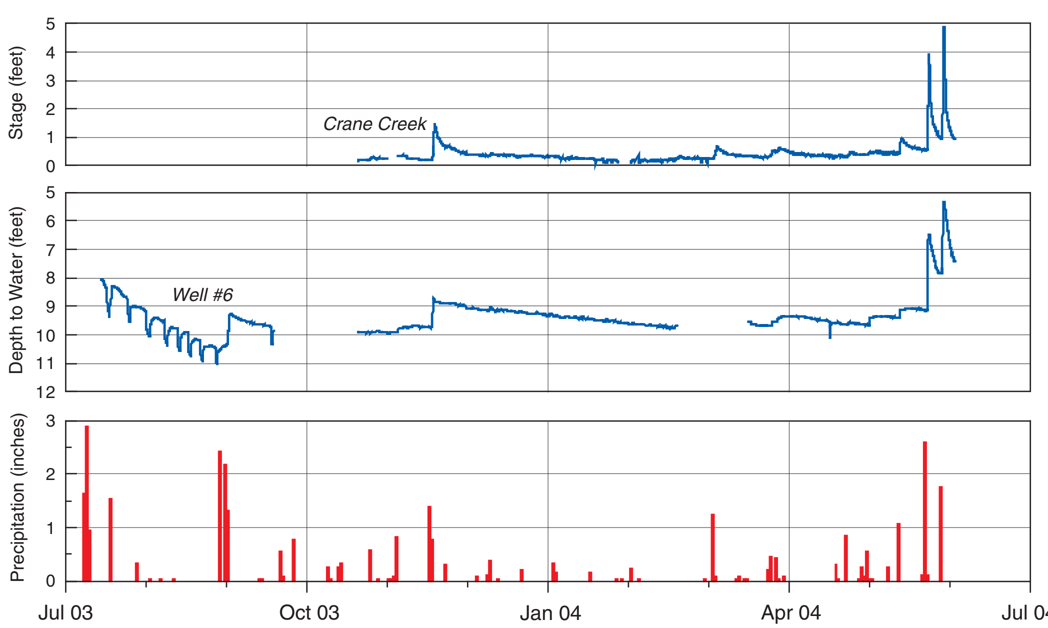
A closer examination of the interactions among precipitation, groundwater, surface water, and irrigation was the objective for creating a third network of nine observation wells on an irrigated field site in 2003 (see map). Pressure transducers connected to dataloggers were installed in two wells and on the bottom of Crane Creek to measure hourly groundwater levels and stream stage. The data (see graph) clearly show interrelationships between the major components of the water cycle.

Operation of the local irrigation system a few hundred feet away caused the sawtooth pattern of groundwater levels in July and August 2003. The downward trend resulted from a lack of precipitation throughout most of July and August, local and regional irrigation groundwater withdrawals, and groundwater discharge to Crane Creek after earlier spring recharge.

Heavy rainfall at the end of August and beginning of September resulted in a distinct upward spike of groundwater levels. Water levels rose slightly from late August into November, followed by a sharp water-level increase after more than 2 inches of rain over a two-day period. A spike in Crane Creek also is seen.

Frozen ground and only slight precipitation along with continuous groundwater discharge to Crane Creek caused a long downward water-level trend in winter 2003–2004. A gap in the datalogger record occurred during a significant precipitation event, but shortly returned to the downward slope seen previously. Water levels climbed slightly at the end of March and fell through April 2004, with a very short, severe downward spike as the farmer tested his irrigation system one day. Water levels jumped in stair-step fashion after precipitation events in late April and May and then spiked dramatically at the end of May. Simultaneous spikes in Crane Creek stage also were a result of the high groundwater levels that increased discharges to Crane Creek.

Such nearly continuous data collection at this scale only now is revealing its true value. As longer records for these sites and the region are accumulated and assessed, they can be used to make informed decisions about managing this valuable groundwater resource.



This graph depicts the groundwater level in well 6, precipitation, and Crane Creek stage at the irrigation field site.

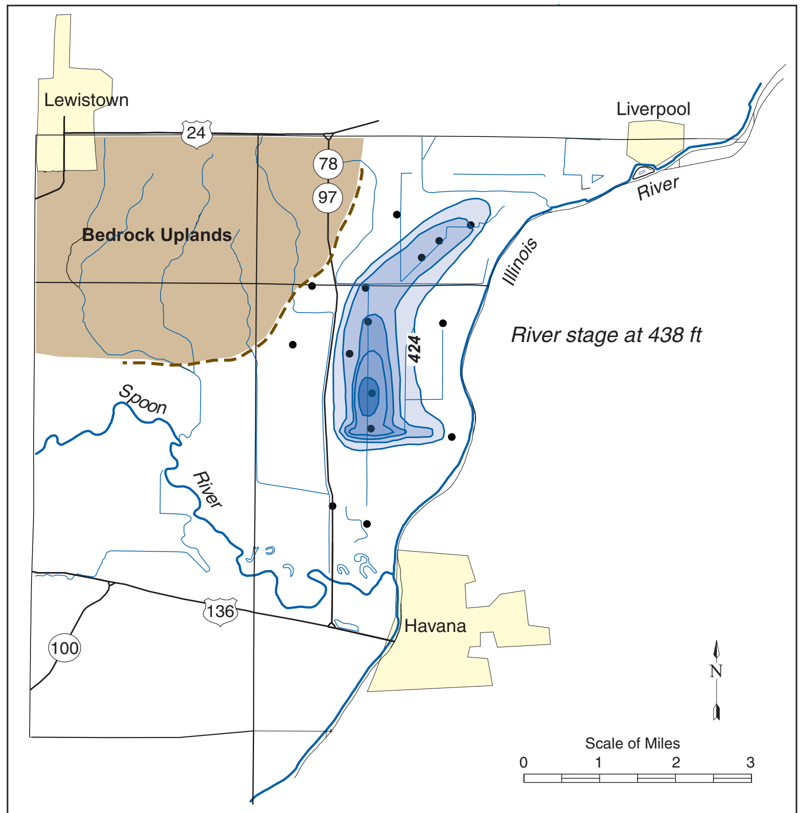
Groundwater–Surface Water Interactions in the Emiquon Area

About 40 miles southwest of Peoria, just north of the confluence of the Spoon and Illinois Rivers in Fulton County, Illinois, lies a 7,500-acre tract of land that has been protected from flooding by an encircling levee system for more than 80 years. Native Americans named this area the Emiquon, which once nurtured diverse and abundant communities of native plants and animals in a complex system of backwater wetlands and lakes of the Illinois River. The Nature Conservancy (TNC) purchased the tract expressly to restore natural ecological processes and habitat that support native species along the Illinois River. The TNC then approached ISWS scientists to collect hydrologic data and develop a sediment transport model for the Illinois River in the Emiquon area to assist with planning restoration activities.

The land surface of the Emiquon area lies at elevations commonly below the Illinois River stage and is kept arable by the levee, a dewatering system of drainage tiles and canals, and a pumping station that discharges canal drainage to the river. Restoration activities likely will include some suspension, even cessation, of dewatering system pumping and may also include periodic flooding of the area through a managed reconnection to the Illinois River.

Several questions were posed by TNC: "If we cease pumping, how deep will the water be and how long will water remain at those levels? What influence will Illinois River levels have on water levels behind the levee, and how quickly will Emiquon water levels respond to river-level changes? Finally, what are the likely outcomes of reconnecting the area to the Illinois River?" Thus, principal objectives were to initiate groundwater and other hydrologic data collection efforts within the Emiquon and to provide preliminary answers to TNC questions regarding the location, depth, and period of natural and managed flooding of the Emiquon.

An investigation of groundwater conditions at the site began in 2002 with installation of 24 wells at 15 sites within and just west of the Emiquon property. During the course of drilling, a continuous layer of sand, thought to be part of the Sankoty sand aquifer, was found beneath a confining bed of very fine-grained alluvium and lakebed sediments. Measurements of groundwater levels within the sand revealed a distinct and elongated depression in artesian head or groundwater elevation nearly 20 feet below Illinois River stage in the deepest part of the depression. Just as a pumped well creates a cone of depression in groundwater levels around it, this depression is a reflection of groundwater connections to surface drainage ditches that are periodically pumped to the Illinois River.



A distinct cone of depression occurred on the groundwater surface within the Emiquon in July 2003.

Decades of pumping of what was believed to be surface water from the drainage ditches apparently has caused a large cone of depression in the artesian head of the Sankoty aquifer beneath the Emiquon (see map above). If pumping of the drainage ditches were to cease under TNC plans to restore the Emiquon to a more natural wetland environment, groundwater levels likely will rise to pre-pumping conditions, an elevation of 430–434 feet above mean sea level, potentially causing permanent surface flooding over a large portion of the site. Such a permanent pool would be detrimental to the goals of TNC restoration.

Collection of groundwater data has provided a new understanding of the effects of groundwater on the surface hydrology of the Emiquon area, which would have had tremendous consequences on TNC restoration decisions had they been overlooked. New studies during summer 2004 will examine the potential for isolating the groundwater–surface water connection at Emiquon.

NATIONAL ATMOSPHERIC DEPOSITION PROGRAM

Precipitation Chemistry Data Contribute Important Information about Hydrologic Cycle

A goal of the National Atmospheric Deposition Program or NADP (http://nadp.sws.uiuc.edu/) is to provide scientists, resource managers, and policy-makers with high-quality information on the exposure of managed and natural ecosystems to biologically important chemical deposition and other stressors from changes in the nation's chemical climate. The NADP Program Office, housed at the ISWS, is responsible for overall management and coordination of the project and for the NADP Central Analytical Laboratory (CAL), which provides chemical analysis, site support, and data management services for NADP sites.

The NADP provides data and information on the chemicals in precipitation from three networks of co-located sites that collect precipitation samples. These data are available on-line (http://nadp.sws.uiuc.edu) in various formats (tables, graphs, maps, map animations, and trend plots), in addition to reports, brochures and other program-related information.

An important element in understanding the biogeochemical cycling of chemicals in our environment is atmospheric deposition, which deposits airborne particles and gases on water (streams, lakes, reservoirs, and ponds), land (forests, fields, and soils), and structures (buildings, statues, and other structures). These air pollutants come from natural sources, such as forest fires, volcanoes, and oceanic salt, or from power plants, newly plowed fields, motor vehicles, and other human activities. Wet deposition occurs during precipitation—predominantly rain and snow. Dry deposition occurs during dry weather through gravitational settling, impaction with surfaces, and adsorption on surfaces. Deposition of acidic particles and gases is called acid deposition, and acidic wet deposition is called acid rain.

NTN

The NADP measures the wet deposition of inorganic nutrients, sulfate, base cations, and free acidity as pH at 256 National Trends Network (NTN) sites across the United States, including six sites in Illinois, and one site each in Canada, Puerto Rico, and the Virgin Islands. Site samples collected weekly are sent to the CAL for chemical analysis of inorganic nitrogen as nitrate and ammonium. Both forms can serve as plant nutrients. Nitrate and sulfate are the principal sources of acidic precipitation. High-temperature combustion processes, the principal sources of nitrogen oxides, lead to nitrate formation in precipitation in most of North America, including Illinois. Manure, agricultural fertilizers, human waste, and automobile exhaust are important sources of ammonium in precipitation. Total inorganic nitrogen, the combination of nitrogen from nitrate and ammonium, is a measure of the nutrient nitrogen in precipitation. The NTN does not measure organic nitrogen in precipitation, although the presence and forms of atmospheric organic nitrogen is an area of active research.

Sulfate is another major inorganic chemical measured in NTN samples. Sulfate deposition provides sulfur, a plant nutrient for agricultural crops, and is the most important contributor to precipitation acidity. Sulfate is also a major component of airborne particles smaller than ~2.5 microns in diameter. Combustion of sulfur-containing fossil fuels such as coal in industrialized nations is the largest source of sulfur oxides, leading to sulfates in precipitation.

AIRMoN

The NADP measures the same chemicals as at NTN sites at the eight Atmospheric Integrated Research Monitoring (AIRMoN) sites, including an ISWS-operated site at Bondville, Illinois. The AIRMoN samples are collected every day that rain or snow was observed in the previous 24 hours, whereas NTN samples are collected once a week, independent of precipitation amount or timing.

All AIRMoN samples are refrigerated after collection and until analysis at the CAL. Refrigeration retards microbiological activity that can degrade certain chemicals, such as ammonium. These data are used to track chemical and meteorological processes related to individual storms and for model development and verification.

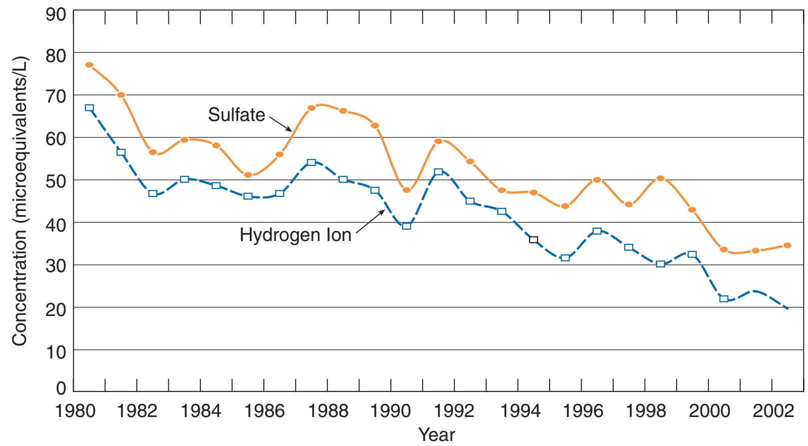
MDN

The NADP measures the total mercury content of precipitation samples at the 82 Mercury Deposition Network (MDN) sites, including the ISWS-operated site at Bondville. Samples are collected every Tuesday, just as at NTN sites, and are especially preserved to prevent mercury losses. Mercury, a persistent toxic pollutant, is extremely slow to degrade or change into nontoxic forms. Indeed, it is deposited mostly in a toxic inorganic ionic form that can be transformed into an even more toxic organic form, methyl mercury, under certain anaerobic conditions. Principal human sources of atmospheric mercury in the continental United States are burning coal, incinerating medical and municipal waste, and certain chemical manufacturing processes.

Acidic Atmospheric Deposition in Illinois

Most soils, crops, watersheds, and forests in Illinois are not particularly sensitive to acidic atmospheric deposition. These soils generally are well buffered and rich in organic matter, which imparts resistance to chemical changes from exposure to long-term deposition over years and decades or episodic deposition during heavy rains. Agricultural soils of Illinois are carefully managed to ensure fertility and pH balance, but sulfate deposition is closely linked to acid rain and to related air-quality concerns, such as reduced visibility and high fine particle concentrations.

Acidic precipitation can speed the corrosion of exposed metals and the weathering of unprotected stone buildings and statues. Sulfate and hydrogen ion concentrations, the two chemicals most closely tied to acidic precipitation, have changed in parallel at the NTN site at Bondville (see graph). Sulfate concentrations have decreased by about 55 percent and hydrogen ion concentrations by nearly 70 percent from 1980 levels. The annual average pH of precipitation in central Illinois has risen from about 4.1 to 4.7 since 1980.



Sulfate and hydrogen ion concentrations at the NTN site at Bondville, Illinois.

Decreases in sulfate concentrations and related precipitation acidity also are reflected in decreases in the amount of sulfate deposited by precipitation. Sulfate deposition at the Bondville site in Champaign County has decreased by 50 percent from an average of 30 kilograms per hectare (kg/ha) in 1980 to 15 kg/ha in 2002. This is a decrease in the amount of sulfur deposited by precipitation from 8.9 pounds per acre (lb/acre) in 1980 to 4.5 lb/acre in 2002.

Corn, Illinois' principal grain crop, requires ~0.12 lb of sulfur per bushel, and the 1980–2002 Champaign County yield averaged 128 bushels/acre. Precipitation supplied about 57 percent of the average corn crop sulfur needs in 1980, but only 29 percent in 2002. Similarly, the fraction of sulfur supplied for Champaign County soybeans by precipitation dropped from 61 percent in 1980 to 31 percent in 2002.

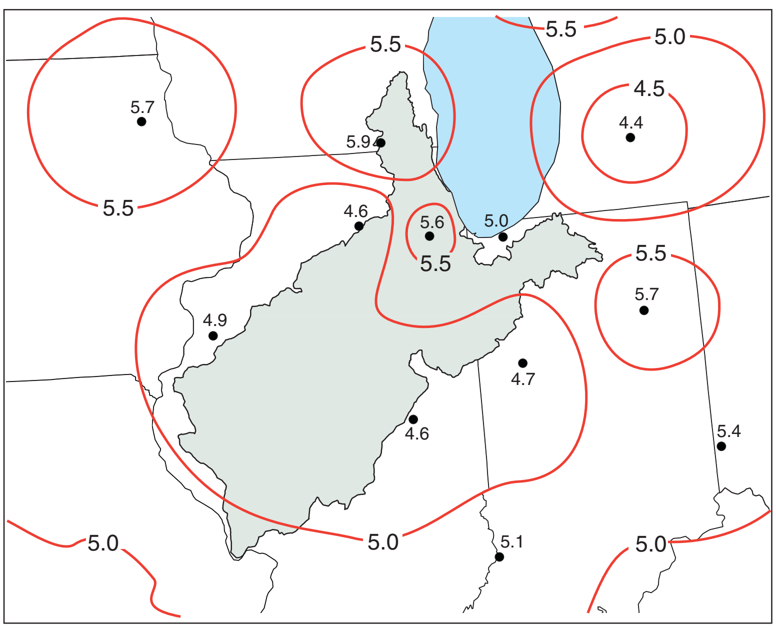
Routine measurements of the dry deposition of sulfur were not available for the Bondville site until 1989. Combining the estimates of dry deposition fluxes of sulfur from the Clean Air Status and Trends Network (CASTNet) with measurements of wet deposition fluxes of sulfur from the NTN, the atmospheric (wet plus dry) sulfur deposition was ~7.5 lb/ acre at the Bondville site in 2000, about 50 percent of the average corn and soybean sulfur requirements (~14–15 lb/acre). Atmospheric sulfur deposition at the DeKalb County CASTNet and NTN sites at the Northern Illinois Agronomy Research Center was ~6.4 lb/acre in 2000, only about 40 percent of the average corn and soybean requirements in 2000. Atmospheric sulfur deposition at the Madison County CAST-Net and NTN sites near Alhambra in west-central Illinois was 9.1 lb/acre, 65–79 percent of the average corn and soybean requirements in 2000.

Clearly, these data show that atmospheric sulfate deposition no longer can meet most sulfur requirements of Illinois' corn and soybean crops. Because sulfur is not routinely applied when Illinois fields are fertilized, crops must obtain the additional sulfur they require from organic and inorganic soil sources.

Water Quality

The Illinois River is a focus of state and federal agencies and other organizations interested in integrated watershed management. Among the issues of interest is water quality, particularly nutrient sources, transport, and transformation in the river and its watershed. The Illinois Rivers Decision Support System (ILRDSS), maintained by ISWS scientists, was designed to provide information that can assist decision-makers on issues related to Illinois Rivers and their backwaters. Data from the NADP were used to calculate dissolved inorganic nitrogen (DIN) delivered to the Illinois River watershed by precipitation. Nitrogen from nitrate and ammonium together with precipitation data were used to calculate DIN inputs.

Maps of annual nitrate, ammonium, and nitrogen inputs to the watershed are accessible from the ILRDSS Web site (http://nadp.sws.uiuc.edu/ilrdss). The three-year (2000–2002) annual DIN deposition in and around the Illinois River watershed averaged 4,626 tons, 50 percent from nitrate and 50 percent from ammonium (see map). The 1985–2002 annual DIN input was 3,960–5,457 tons. Statewide, DIN input during that period was 74,754–106,726 tons, averaging 93,668 tons or about 12.8 lb/acre annually, far less than the amount of nitrogen applied in fertilizers.



Average 2000–2002 nitrogen deposition (lb/acre) from NADP/NTN nitrate and ammonium measurements at sites in and around the Illinois River watershed.

Mercury in Illinois

The Illinois Fish Contaminant Monitoring Program issued a statewide advisory for predator fish in Illinois waters due to methyl mercury (http://www.idph.state.il.us/envhealth/fishadv/fishadvisory_qa.htm). Consumption advisories due to high methyl mercury in fish flesh identify particular fish species in four lakes and two reservoirs in Cook and McHenry Counties; six southern Illinois lakes; a west-central Illinois lake; and the Chicago, Illinois, Ohio, Rock, and Wabash Rivers.

Accumulations of mercury in the food chain reach part-per-million levels in predator species, such as largemouth bass, white bass, white crappie, sauger, and flathead catfish. The physical, chemical, and biological mechanisms by which mercury is transformed into methyl mercury and enters the food chain are only poorly understood so additional data and research are necessary.

Potential sources of mercury in Illinois' surface waters include soils, geological formations, industrial waste, and atmospheric deposition. The NADP measures total mercury in precipitation samples at one MDN site in east-central Illinois. Mercury concentrations between 1999 and 2002 averaged 10–11.6 parts per trillion annually, and deposition of mercury during this period averaged 90–96 milligrams per hectare annually. Though very small by comparison with sulfur and nitrogen deposition, mercury accumulates by more than a millionfold in the food chain, persists in the environment, and is highly toxic. These factors make it important to measure and understand the cycling and fate of even these small amounts of mercury.

Using Watersheds To Understand and Analyze the Hydrologic Cycle

The Watershed Science Section (WSS) is using watersheds as natural units to integrate hydrologic processes, an effort made challenging and exciting by complex internal watershed processes and variable physical and climatic conditions, and land-use practices throughout Illinois. This watershed-based approach includes developing and applying tools and methods that provide integrated, ongoing evaluation and feedback about watershed assessment, monitoring, modeling, and restoration implementation.

For example, it would be impossible to establish appropriate monitoring stations without some form of watershed assessment to identify problem areas and processes. It would be impossible to develop reliable watershed models without data from a monitoring network for model calibration/validation. It also would be very difficult to implement appropriate restoration projects without benefit of watershed assessments, monitoring data, and models. Staff continuously evaluate how best to use these methods and tools to address watershed issues in Illinois.

Josh Stevens collects water samples on the Spoon River near Seville, Illinois, for a C-FAR-funded project designed to determine levels of bioavailable phosphorus.

Watershed Assessment

Although watershed and stream assessments long have been used to identify problem areas and potential restoration sites, such efforts are now more organized and comprehensive. For example, the WSS, the Illinois State Geological Survey (ISGS), and the Illinois Natural History Survey (INHS) have been assessing watersheds as part of a joint effort by the U.S. Army Corps of Engineers and the State of Illinois to enhance and restore ecosystems in the Illinois River basin. Potential priority or target restoration sites are being identified in an innovative approach that uses synchronized aerial images from a global positioning system aboard a helicopter.

Watersheds of potential restoration sites are examined spatially using global information system backdrops to help explain the evolution of streams, landscapes, and their potential responses to different restoration designs. For the first time, the ISWS systematically is combining collection of geomorphological field data and biological information to help select and prioritize restoration sites, to help select restoration designs, and to monitor project performance.

Watershed Monitoring

One of the major efforts in an integrated approach to water resources investigations is planning and implementing well-designed monitoring networks for projects at various scales and with diverse data requirements. The WSS has established numerous stations throughout Illinois to monitor precipitation, streamflow, sediment, and water quality. The Benchmark Sediment Monitoring Network has provided suspended sediment concentrations and loads at 15 monitoring sites in Illinois since 1980. Sources of nitrate into Lake

Decatur in the upper Lake Decatur watershed have been monitored since 1993. Although that program has been maintained at a reduced level for more than 10 years, it provides valuable data on trends in nitrate concentrations over different periods of climatic conditions.

In cooperation with the Illinois Department of Natural Resources (IDNR) under the Pilot and Illinois River Conservation Enhancement Program (CREP), 13 stations were established in 10 small watersheds to monitor hydrology, sediment, and water quality. Biological data being collected by the INHS for the same watersheds complement ISWS hydrology, sediment, and water-quality data. Budget constraints have reduced the number of stations, but existing stations provide valuable data for use in model development to evaluate the effects of different conservation programs in Illinois. A comprehensive hydrologic and sediment monitoring program for the Illinois River basin also has been developed.

Modeling Watershed Processes

Understanding watershed and other hydrologic processes requires accurate monitoring data, adequate data for numerical modeling, and, ultimately, the ability to test watershed responses to various physical conditions. Ideally, the analysis of hydrologic changes in a watershed would be based entirely on observed data that would allow changing one particular environmental factor and then observing watershed, water-quality, or streamflow response. Watershed systems are rarely simple enough to allow easy isolation of the effect of a single factor or even between two hydrologic events or experiments. However, numerical modeling provides the tool to separate the effects of multiple factors in watershed hydrology. Because it is unfeasible to monitor every location, modeling also allows transfer of results from gaged to ungaged sites in the same or similar watersheds.

Even though watershed models simulate complex relationships between multiple factors, their mathematical formulas still simplify natural phenomena and interactions. Acquisition of adequate data on watershed characteristics and streamflow quantity and quality ensures that simulations accurately reflect watershed responses to hydrometeorological inputs.

Evaluating the effects of best management practices (BMPs) and other watershed changes does not stop with model development and prediction of hydrologic change based on algorithms and assumptions built into model structure and parameters. For example, many applications may have a certain tendency or outcome built into the model when predicting land-use or climate change impacts. To be certain that the desired affect has been achieved, scientists must be able to observe predicted hydrologic changes using monitoring data collected after BMP implementation. In some cases, those data may not verify model predictions, and model adjustments may be necessary.

Using an Acoustic Doppler Profiler, Kip Stevenson and Ted Snider collect discharge measurements on the Illinois River near Kingston Mines, Illinois.

Developing and Applying Models for the Illinois River Basin

The WSS has identified the Illinois River and its watershed as a major focus area and has committed resources to provide the best scientific information and analyses in developing and implementing restoration plans that improve hydrology, water quality, and habitats along the river and its watershed. A major challenge is to understand watershed hydrology and river hydraulics so that watershed and river management promote and sustain the river's ecological function and also maintain its economic functions. In support of this effort, the WSS is developing models to guide and evaluate impacts of proposed or ongoing restoration efforts in the Illinois River basin. A hydrologic model of the entire Illinois River watershed and hydraulic models of the Illinois River Waterway, developed as part of the Illinois Rivers

Decision Support System, eventually will be expanded to include sediment transport and water quality.

A preliminary hydrologic model for the 29,000-square-mile Illinois River watershed uses the Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) modeling system supported by the U.S. Environmental Protection Agency (USEPA) and the Hydrologic Simulation Program–Fortran (HSPF) watershed model. Parameters for the HSPF model were calibrated for watersheds of three major tributaries of the Illinois River: the Kankakee–Iroquois, Spoon, and Vermilion Rivers. Analyses concluded that calibration of additional tributary watersheds would be necessary before regional sets of parameters could be developed for the entire Illinois River watershed.

Completing the calibration of the Vermilion River represents a detailed approach that identifies separate parameters for major soil associations, using more detailed land-use and soils databases, and is the prototype for future calibration efforts. Calibration of more tributary watersheds will facilitate development of regional parameter sets to evaluate ungaged basin areas.

In addition to providing a useful tool for analyzing broad restoration issues for the entire Illinois River basin, it is envisioned that the Illinois River BASINS model will provide an expansion framework for more detailed modeling within each sub-watershed. Streamflow and water-quality data collected on smaller watersheds for CREP provide an excellent resource for modeling and understanding the hydrology of these watersheds, and to examine modeling issues of transferring information gained for use in improving accuracy and detail of the Illinois River watershed model.

Additional BASINS model improvements addressed in on-going efforts include importing the latest datasets for the Illinois River basin and developing more detailed land-use and soil parameters for portions of the watershed. Sediment and water-quality simulation capabilities are being developed for selected sub-watersheds. Coupling the HSPF model and the unsteady flow routing model for the Illinois River (UNET) provided modeling ability to describe flow dynamics associated with lakes and pooled areas for most of the Illinois River and greater capability for using both models for river management.

The WSS is committed to maintaining and improving expertise with advanced multi-dimensional unsteady flow hydraulics models that address channel stability, sedimentation, and aquatic habitat of rivers. Experience gained in this area and in study of Illinois River hydrodynamics have established the ISWS as a leader in assessing important issues pertaining to large rivers in Illinois. To date, the ISWS has developed two-dimensional models for two sections of the Illinois River: the Peoria Lake area to investigate impacts of island construction on flow dynamics and sedimentation rates, and the Emiquon/Chautauqua area to simulate flow patterns in river and floodplain areas under different management alternatives.

Mike Machesky and Kip Stevenson collect Spoon River sediment samples for laboratory analyses related to phosphorus bioavailability.

Assessing Climate Change Impacts on Watershed Hydrology

One of the basic uncertainties concerning assessment of future water resource availability and water supply is potential climate change and/or future variability. A common approach uses watershed or hydrologic simulation models to estimate the effects of climate variability on surface water resources. The Fox and Iroquois River watersheds were modeled to evaluate responses of simulated streamflows to various climate scenarios based on simulations from two global climate models (GCMs), the Japan and Hadley models that represent comparatively dry and wet future climate conditions, respectively. Considerably different climate simulations by various GCMs are reflected in the selected scenarios and the range of streamflow conditions simulated.

In terms of average precipitation and temperature, the Japan GCM produces conditions more typical of southwestern Oklahoma, whereas the Hadley GCM produces conditions typical of southeastern Illinois. The simulated streamflow for the driest scenario, an 80-percent reduction in average flow amounts, differs drastically from present conditions. That simulation also indicates that the Fox and Iroquois Rivers potentially would dry up.

The wet scenario, however, produces relatively small change in simulated streamflows, with changes in most flow parameters for the Fox and Iroquois Rivers less than 15 percent different than those at present. Results indicate that predicted precipitation increases for the wet scenario may not necessarily mean noticeable increases in flooding if also accompanied by warmer temperatures.

Although soil moisture values used in the watershed models were not analyzed, lower soil moisture resulting from warmer temperatures and increased evapotranspiration could reduce the chance of high runoff, thereby offsetting effects of increased precipitation. Additional modeling should investigate more thoroughly possible changes in frequency and impacts of heavy rainfall, and effects of changes in other climate parameters on the water budget.

Clearly, the dry climate scenario would have substantial impacts on streamflows and, likely, create a water-supply crisis in Illinois; but broader impacts for agriculture, land use, and ecosystems substantially would change expectations related to water resource management. In contrast, the wet climate scenario would modify streamflows only slightly, with water resources management more likely driven by other societal changes, such as those associated with population growth. Thus, overall impacts on future water resources will become clearer with improved ability to model climate change and climate variability.

Implementing Restoration Projects

The WSS also implements restoration projects to demonstrate and learn about technique effectiveness and any shortcomings. Lessons learned have a significant influence on watershed and stream restoration practices throughout Illinois. The WSS is working with the IDNR Office of Resource Conservation to install riffles/pools that control channel incision and provide improved water quality and habitat in the Cache River while helping protect a highly valued wetland. Controlling streambed and bank erosion and addressing sediment transport issues using innovative stream habitat restoration is one component of overall watershed management that helps guide local partnerships for watershed planning and restoration efforts throughout Illinois and the United States.

Personnel from the ISWS and IDNR and a landowner discuss the multiple benefits of riffle pool structures at North Creek in the Court Creek watershed.

The WSS assessed habitat conditions and demonstrated the effectiveness of restoration techniques for naturalizing a stream environment in Lake County. Streamflow and biological monitoring indicated several biological improvements due to added habitat.

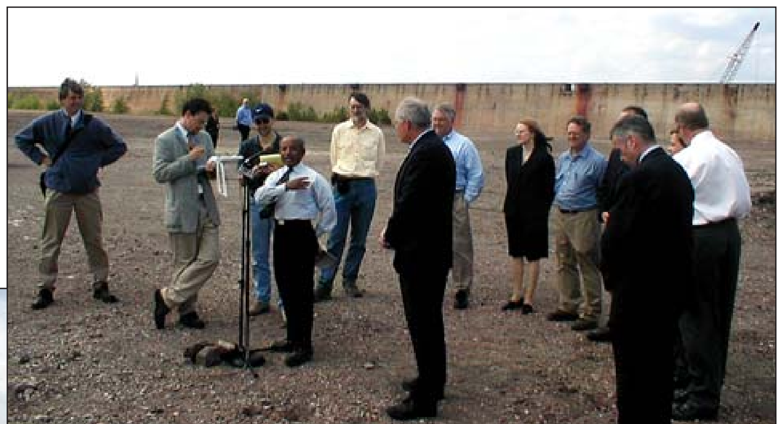
Consideration is being given to addressing other limiting factors associated with ecosystem restoration, such as water quality and flow diversity at this urban site. Staff are continuing to collect and disseminate scientific information to the IEPA, the City of Waukegan, and other local partners to help facilitate integrated watershed and stormwater planning and to use adaptive management and innovative conservation designs that further naturalize the watershed and improve the overall quality of life for watershed residents.

The WSS actively has addressed rural nonpoint pollution and sedimentation in Lake Pittsfield, the source of water supply for the City of Pittsfield in the Blue Creek watershed in Pike County. Some watersheds in Illinois, particularly those in older glaciated landscapes of western Illinois, have exhibited consistently high sediment yields from erosion, and portions of Blue Creek and its watershed occur in one of these geologically steep, erosive areas.

The USEPA and IEPA asked the ISWS to determine the effectiveness of land management strategies in reducing erosion and sediment delivery, and to examine innovative ways to improve water quality and biological diversity at Lake Pittsfield. Watershed monitoring documented the effects of traditional erosion control practices, and the ISWS implemented innovative restoration techniques to see how well combinations of practices improved water quality and habitat. Flow gaging, sampling suspended sediment transport, and lake sedimentation surveys documented the effectiveness of water and sediment control basins (WASCOBs) that retained substantial sediment. Erosion increased downstream, an expected stream channel response, and an overall increase in sediment yield occurred initially after WASCOB installation in geologically unstable or steep watershed areas.

This clearly showed that some actions to control erosion and sediment transport can upset the balance of flow, slope, sediment transport, and channel morphology in a stream system. Constructing riffles/pools in stream segments just downstream stabilized any potential further disequilibration or disruption of the existing balance inherent in a fluvial system due to WASCOB construction.

Restoration monitoring documented that WASCOBs controlled channel morphology changes (incision and bank erosion), oxygenated water, provided habitat, and added aesthetical appeal. The resulting geomorphological understanding and evidence acquired helped clarify the physical nature of the fluvial system and helped determine the effectiveness of erosion control efforts to reduce sediment input and delivery and improve habitat and water quality.



Hydrologist Nani Bhowmik (top) discusses the multi-Survey Lake Calumet project at a press conference. A barge docked at U.S. Steel in Chicago (bottom) carries some of the 105,000 tons of sediment from Peoria Lake to be used as topsoil at this brownfield site. Plantings of native grasses then will transform the site into a park on the Lake Michigan shore.

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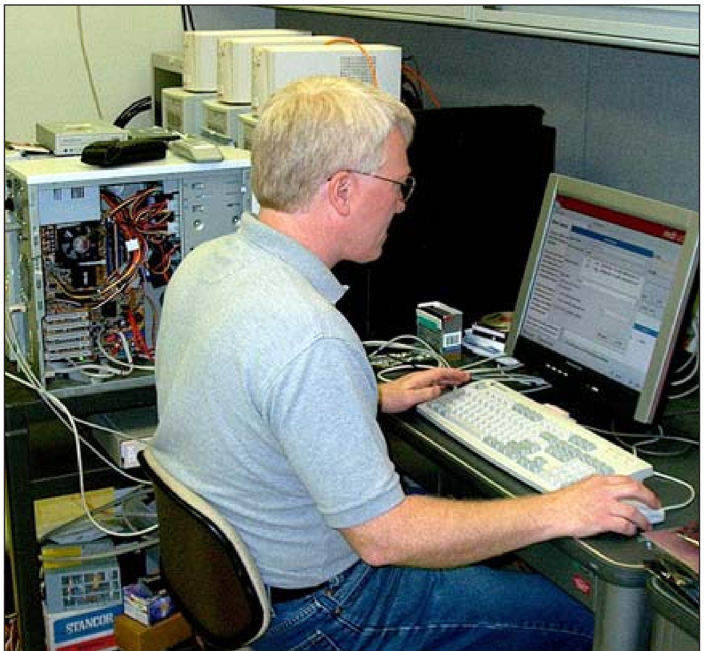

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Watershed Science Section

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Breaking Ground for Building 11

Members of the Board of Natural Resources and Conservation and Water Survey staff joined Director Joel Brunsvold and Deputy Director Leslie Sgro for the groundbreaking ceremony marking the start of construction of a 14,000-square-foot maintenance/shop building west of the current Water Survey Research Center (WSRC) on the University of Illinois at Urbana-Champaign campus. The dedication ceremony was held on May 27, 2004.

The new building will house repair shops (electrical and machine), research laboratories, field staging area, offices, mail room, storage, and a loading dock. There will also be a major renovation of the WSRC's boiler and chiller system. Completion of all work is expected within 11–12 months.

HONORS

Kingsley Allan
Member, Illinois GIS Association Board, and Chair, Conference Planning and Awards Committees

Van Bowersox
Invited Presenter, "Monitoring Chemical Climate Change in America - The Case for Ammonia," National Atmospheric Deposition Program Ammonia Workshop, Washington, DC, October 2003

Mark Brooks and Chuck Curtiss
Conference Co-Chairs, 56th Annual Illinois Institutional Chief Engineers workshop, October 2003

Joyce Changnon
Vice Chair, State Universities Retirement System Members Advisory Committee

Stan Changnon
Recipient, American Meteorological Society special award for advancing applied climatology

Karen Harlin
Recipient, 2003 award in recognition of valuable contributions to American Chemical Society *National Chemistry Week*; Recipient, 2003 award in recognition of significant contributions as Chair, Methods Committee on Environmental Quality, AOAC International; and Vice Chair, National Atmospheric Deposition Program Network Operations Subcommittee

Ken Kunkel
Elected Fellow, American Meteorological Society; and Member, Advisory Committee, Program for Climate Model Data and Intercomparison (Lawrence Livermore National Laboratory)

Mary LeFaivre
Treasurer and Coordinator, Off-Campus Educational Outreach Programs, East Central Illinois Local Section, American Chemical Society

Randy Locke
Chair, Illinois Groundwater Association

National Atmospheric Deposition Program
Recipient, Salute to Excellence award, *2004 Chemists Celebrate Earth Day Program* and long-standing commitment to children's science education, American Chemical Society, Washington, DC

Jane Rothert
Chair, Atmospheric Deposition Subcommittee on Sampling and Analysis of Atmospheres, ASTM International

Doug Walker
Member, Steering Committee, and Chair, Technical Program Committee, Straddling the Divide: Water Supply Planning in the Southern Lake Michigan Region

Dan Webb
Coordinator, Water Quality section of 2005 National Science Olympiad, with assistance of ISWS chemists

Derek Winstanley
Appointed Chair, Technical Committee of the Southern Lake Michigan Regional Water Supply Planning Consortium, December 2003; Invited Reviewer, National Oceanic and Atmospheric Administration, Cooperative Institute for Mesoscale Meteorological Studies, Norman, Oklahoma, September 2003; and Co-Chair, DNR Integrated Water Quality Planning and Management Team

CONTACTS

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Lake Sedimentation Surveys: Bill Bogner, (217) 333-9546
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Surface Water Supply: Vern Knapp, (217) 333-4423
Water and Wastewater Treatment: Gary Peyton, (217) 333-5905
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Watershed Hydrology: Vern Knapp, (217) 333-4423
Watershed Monitoring: Laura Keefer, (217) 333-3468
Watershed Processes: Mike Demissie, (217) 333-4753

ADJUNCT & EMERITUS APPOINTMENTS

Adjuncts to University of Illinois at Urbana-Champaign

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Derek Winstanley, Department of Geography

Atmospheric Environment Section
James Angel, Department of Geography
Stanley Changnon, Department of Geography and Department of Atmospheric Sciences
Steven Hollinger, Department of Natural Resources and Environmental Sciences
David Kristovich, Department of Atmospheric Sciences and Department of Geography
Kenneth Kunkel, Department of Atmospheric Sciences

Adjuncts to Illinois State Water Survey

Dr. Geoffrey Hewings
Regional Economics Applications Lab
Department of Geography
University of Illinois at Urbana-Champaign
Urbana, IL

Dr. Scott Isard
Department of Geography
University of Illinois at Urbana-Champaign
Urbana, IL

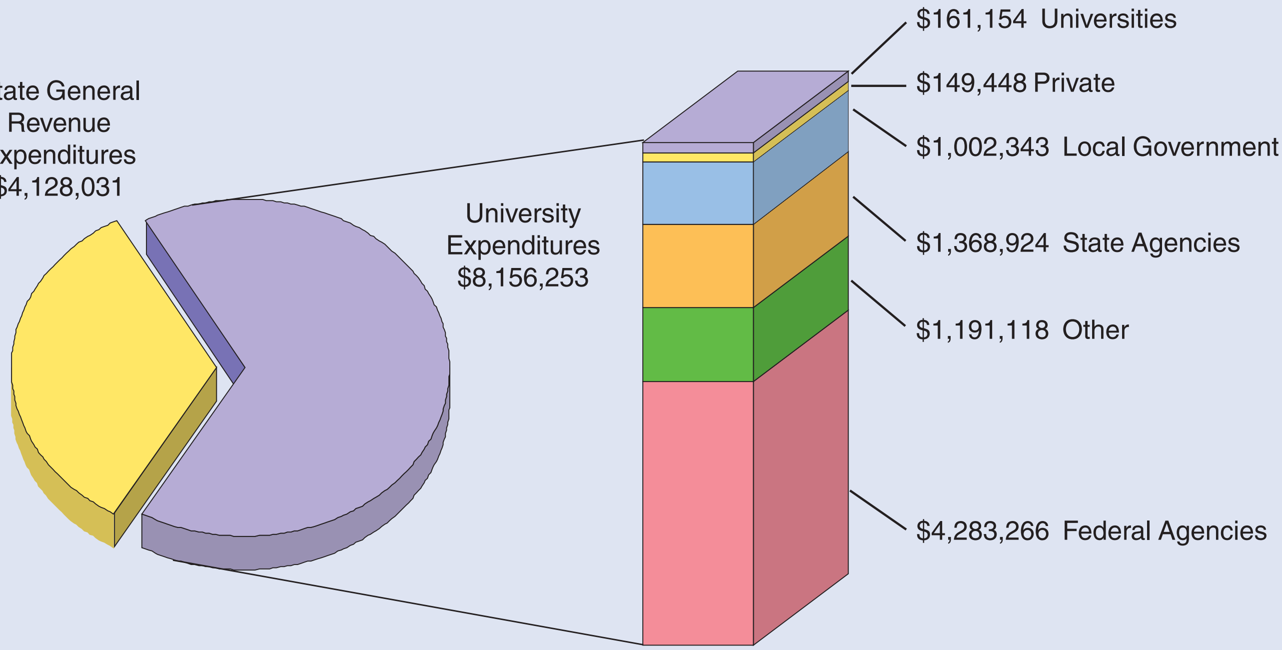
Dr. Roger A. Pielke, Jr.
Environmental & Societal Impacts Group
National Center for Atmospheric Research
Boulder, CO

Thomas A. Prickett
Thomas A. Prickett & Associates
Urbana, IL

Emeritus Appointments

Russell Lane, Principal Scientist Emeritus, 1981
Ralph Evans, Principal Scientist Emeritus, 1984
Stanley Changnon, Chief Emeritus, 1985
Robert Sasman, Professional Scientist Emeritus, 1987
Richard Schicht, Principal Scientist Emeritus, 1989
Eugene Mueller, Principal Scientist Emeritus, 1990
Donald Staggs, Professional Scientist Emeritus, 1990
Richard Semonin, Chief Emeritus, 1991
Chester Neff, Principal Scientist Emeritus, 1992
Michael Terstriep, Principal Scientist Emeritus, 1993
Krishan Singh, Principal Scientist Emeritus, 1996
Wayne Wendland, Principal Scientist Emeritus, 1996
Thomas Butts, Senior Professional Scientist Emeritus, 1998
Raman Raman, Principal Scientist Emeritus, 1998
Donald Gatz, Principal Scientist Emeritus, 1999
Nani Bhowmik, Principal Scientist Emeritus, 2001
Shundar Lin, Senior Professional Scientist Emeritus, 2001
Harry Ochs, Principal Scientist Emeritus, 2002
Mark Peden, Senior Professional Scientist Emeritus, 2002
Kenneth Beard, Principal Scientist Emeritus, 2003

FINANCIAL STATEMENT, FY 04



Total Expenditures $12,284,284

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