

SURFACE WATER HYDROLOGY AND HYDRAULICS SECTION

The mission of the Surface Water Hydrology and Hydraulics section is to generate historical and spatial scientific data, investigate and understand watershed processes, and provide state-of-the-art scientific and engineering analyses to policymakers, planners, and resource managers in Illinois and beyond so that they can develop and implement sustainable watershed programs based on the best scientific and engineering analyses possible.

Illinois River Basin Research Program

The Illinois River Basin (IRB) continues to experience impacts that span from 19th century agriculture conversion and intensive land management to global climate change and variability. The IRB covers 44 percent of Illinois, and 90 percent of the state population lives within the basin. Therefore, the basin has enormous environmental and economic value to the state of Illinois. Excessive sediment and nutrient loading from major watersheds of the Illinois River Basin pose a significant threat to water quality in streams, lakes, rivers, and aquatic ecosystems. For example, the 2014 Illinois Nutrient Loss Reduction Strategy has identified priority watersheds for nutrient reduction efforts based on total nutrient loading and local water quality conditions, and many of these watersheds are part of the Illinois River Basin. The Illinois River Basin Research Program continues to provide scientific-based data and engineering for strategic planning and management of the Illinois River Basin from the headwaters to floodplains to stream channels.

Current Work: Current activities include updating and developing the watershed-scale hydrologic modeling framework for major watersheds of the Illinois River Basin to determine critical source areas of runoff and sediment and nutrient loadings in the Illinois River basin. A 35-year updated sediment budget for the Illinois River Basin was recently published. Previous budgets produced by the program were used to establish state/federal restoration goals. The impacts of various management programs, including the Conservation Reserve Enhancement Program (CREP), are being evaluated using field-based hydrologic, nutrient, and sediment monitoring data

used by hydrologic and hydraulic models and generating optimal scenarios of selected conservation practices. The Illinois River Basin Research Program continues to provide scientific-based data and engineering for strategic planning and sustainable management of the Illinois River Basin from the headwaters to floodplains.



Program Outcomes: The Illinois River Basin Research Program has leveraged GRF support and obtained funding over the past 30 years from a wide range of federal, state, and local agencies and organizations including the National Science Foundation, Illinois Department of Natural Resources, Illinois Environmental Protection Agency, the U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, The Nature Conservancy, National Great Rivers Research and Education Center, and others. It is estimated that outside grants for Illinois River Basin research and investigations have totaled more than \$5 million.

Erosion and Sedimentation Program

Excessive erosion and sedimentation is responsible for the loss of property and structure, reduced agriculture productivity, degradation of terrestrial and aquatic habitats and endangered threatened species, and reduced drinking water supplies. Understanding and quantifying the sediment transport processes associated with complex river hydraulic conditions improves the prediction of sediment yields through conducting numerical modeling, evaluating sediment

transport processes, and developing hydrologic, hydraulic, and sediment models to evaluate impacts of watershed and stream channel management scenarios on river hydraulics and transport of sediment was recently published.



Current Work: Recent investigations include watershed sediment fluxes related to land use management, sediment sources/sinks, sediment transport and deposition, and suspended sediment impacts to aquatic habitat, wetlands, reservoirs, and rivers. A 35-year updated sediment budget for the Illinois River Basin was recently published. Previous budgets produced by the program were used to establish state/federal restoration goals. Hydraulic modeling of flow under various ecosystem restoration scenarios have assisted in transforming floodplain farmland into a National Wildlife Refuge in the Illinois River, and extensive hydraulic modeling based on nearly 25 years of hydrologic and sediment monitoring have provided numerous restoration management alternatives for a RAMSAR Wetland of Importance in Southern Illinois. These types of research investigations have assisted and benefited several watershed resource management organizations and planning efforts, including but not limited to, the Integrated Management Plan for the Illinois River Watershed, Illinois River Basin Restoration Comprehensive Plan, and several restoration watershed planning efforts. The Erosion and Sedimentation Program provides the scientific data,

analysis, and tools to characterize and improve current understanding and prediction of watershed and riverine sediment transport and hydraulic processes for more effective resource management and planning by federal, state, and local agencies and stakeholders.

Program Outcomes: In recent years the program has received outside funding from the Illinois Department of Natural Resources, Illinois Environmental Protection Agency, The Nature Conservancy, Illinois-Indiana Sea Grant, City of Chicago, IDNR-Office of Water Resources, USEPA, and FEMA estimated to be \$1 million and capitalizes on the long history of this program for which grants totaled several million.

Surface Water Resources Program

Water resources planning, distribution, and management requires an understanding of the quantity and movement of water within the rivers, lakes, and other surface water bodies in a watershed. The impacts of various natural and human factors, such as climate, land use, urban growth, water use, and various water resource developments must also be analyzed as they can greatly affect the quantity, quality, and distribution of surface water resources. The Surface Water Resources Program combines basic research, problem-specific applied research, and public service for use in planning, decision making, and sustainable management of Illinois rivers, streams, and lakes.

Current Work: Current program activities include collaboration with IDNR-Office of Water Resources to evaluate the availability and use of surface water resources in Illinois and the Midwest. The program investigates and assesses emerging water supply issues and the adequacy of public water supply systems which is a component of the current Illinois Water Supply Planning Program. Ongoing investigations of the frequency and occurrence of drought, and drought impacts on water supplies and instream flows contribute to the scientific data needed for the Illinois Drought Response Task Force and recently for the 2012 drought. Statistical and deterministic analyses of precipitation-runoff processes, flood hydrology, streamflow frequency, and hydrologic trends improves understanding of the effects that changes in land management and climate have on water availability. The Surface Water Resources Program continues to update and maintain the Illinois Stream Assessment Model (ILSAM) which is a water resources management tool that provides statistical estimates of flow quantities and simulates potential effects of hypothetical water resources projects for water resource managers. A

recent collaboration with campus faculty focused on estimating impacts of power plant cool water withdrawals on water quantity and quality in the Illinois River. Many hydrologic and hydraulic modeling studies have been performed in support of flood management and other water resources planning and management activities for state and local agencies. Evaluation and documentation of uncertainties in hydrologic data, models, and analytical methods is improving the program's ability to assess future surface water resources.

Program Outcomes: In recent years the program has produced reports summarizing recent droughts and floods in Illinois and has received G&C funds from the Illinois Water Supply Planning Program and the National Great Rivers Research and Education Center.

Stream & Watershed Monitoring, Assessment, and Restoration Program

Water and sediment movements are natural watershed and stream processes. Changes in land management practices and climate have a profound impact on the type and magnitude of water, sediment, and nutrient movement and channel adjustment mechanisms. Developing an understanding of these transport mechanisms and processes contributes to land and water resource management adaptations to preserve the environmental and economic viability of the state. The Stream & Watershed Monitoring, Assessment, and Restoration Program conducts analytical and field-based multi-scale, applied research supported by long-term and project-specific stream and watershed monitoring and assessments to evaluate land management and stream restoration impacts.



Current Work: Current activities include hydrologic, sediment, and nutrient watershed monitoring for the National Science Foundation – Critical Zone Observatory (CZO) and Illinois Department of Natural Resources (IDNR). The CZO investigation efforts contribute to the research efforts of researchers at multiple universities. The program coordinates the CZO site activities, conducts monitoring, mentors students in data collection techniques, and benefits

from national collaborations. IDNR needs scientific-based data and analyses to understand the impacts of federal and state conservation reserve programs on sediment and nutrient loadings in the Illinois and Kaskaskia River watersheds. The program also conducts geomorphic assessments and monitoring of both physical and in-channel habitat assessments for IDNR and IEPA in many watersheds over the years, but more recently in the Marseilles State Fish and Wildlife Area and Prairie Creek watershed, particularly to ameliorate total maximum daily load (TMDL) issues. A multi-scale geomorphic assessment protocol was developed to evaluate stream channel stability for particular use in the Upper Midwest glaciated watersheds. This systematic and rapid protocol determines landscape and stream channel instability at all scales combined with a determination of causative watershed and channel factors to assist in recommending restoration alternatives by investigating the hydrology, hydraulics, aquatic ecosystems, land use, and nutrient and sediment transport processes in Illinois watersheds.

Program Outcomes: The program has produced many reports on the analysis and restoration projects for the Sangamon River, Kaskaskia River, Embarras River, Cache River, Spoon River, Hall Creek, Waukegan River, Panther Creek, Cox Creek, Blue Creek, North Creek, Court Creek, Hickory Creek, and a host of other watersheds in Illinois. The Program has received grants from IDNR, IEPA, NSF, U.S. Fish and Wildlife Service, The Nature Conservancy and local governments estimated \$5 million in the last 10 years and support by GRF staff.

Watershed Systems Analysis Program

Nonpoint source pollution (NPS) resulting from agricultural sources is one of the major causes of impaired natural resources in the U.S., adversely affecting other ecosystem services. Seventy-five percent of nutrient delivery to the Gulf of Mexico comes from only nine Midwestern States, including Illinois, contributing to hypoxic zones in the Gulf of Mexico. The Watershed Systems Analysis Program provides solutions and management tools used to ameliorate the negative impacts of agriculture, contributing to improved ecosystem services such as regulation of nutrient cycling, soil and water retention, and pest control while maintaining provisioning services.

Current Work: The Watershed Systems Analysis Program conducts research that promotes effective and efficient use of water resources in terms of

quantity and quality in agricultural and urban watersheds. The program utilizes systems approaches for mathematical modeling of water resources, promoting informed decision-making processes. It specifically focuses on: (1) investigating agricultural NPS pollution and identifying landscape hotspots in Illinois and beyond, (2) identifying mitigating practices and their efficiency, (3) developing decision support tools required for selection and placement of land management practices, and (4) investigating impacts of climate change on hydrologic and water quality processes and mitigating practices for future adaptation and quantifying uncertainties associated with it. The program uses current capabilities in hydrologic and water quality modeling, state-of-the-art optimization algorithms such as evolutionary algorithms, and data mining methods to effectively conduct research. In addition, it relies on other programs at ISWS for observational data such as climate and watershed monitoring (e.g., stream flows, sediment, nutrients, etc.).

Program Outcomes: The program has received grants from The Nature Conservancy and Illinois EPA totaling \$160,000 in the past couple of years and also leveraged GRF support. The program has participated in several other ISWS projects and produced several reports and papers. The program supports stakeholders, non-governmental organizations (e.g., The Nature Conservancy), and the IEPA/IDOA/USEPA/USDA in watershed TMDL implementation plan preparation through the application of systems analysis in generating optimal scenarios of management and conservation. This program developed a decision support tool for evaluating best management practices in agricultural watersheds.

Statistical Hydrology and Hydroclimatology Program

Climate variability and climate change have critical impacts on hydrologic, urban, biotic, and agricultural systems. The goal of this program is to improve our understanding of the interactions between climate and hydrologic processes in the Midwest and the Great Lakes region using cutting-edge science. The program develops and applies research methods using statistical and stochastic analysis and data analytics to interpret and analyze observed climate, hydrologic, and water quality data which ultimately contribute to solving real-world water-related issues.

Current Work: Current activities include updating rainfall frequency maps in the Chicago area based on both past observed and future projected climate data. This program has contributed to the Urban

Flooding Awareness Act (Illinois Public Act 098-0858), a key document for safety of citizens in Chicago and other urban areas in Illinois; and to FEMA flood mapping efforts within the National Flood Insurance Program. The recent research and publications of this program provide innovative approaches to predict future projected floods in rural and urban areas.

Several projects carried out by this program improved the accuracy of predictions of riverine nutrients leaving Illinois, reaching the Gulf of Mexico, and causing the hypoxia. These efforts contribute to nationwide efforts to reduce pollutants in rivers and the receiving water bodies. The program also predicts future water quality impairment in the Great Lakes, based on agricultural fertilizers and climate change. This program also provides education and training, which is demonstrated through teaching at various departments, training graduate students working at ISWS, and mentoring graduate students seeking M.S. and Ph.D. degrees.



Program Outcomes: The program has leveraged GRF support for the lead scientist to receive several grants, totaling approximately \$800,000, including grants from NOAA, EPA, University of Illinois, National Great Rivers Research and Education Center, National Center for Supercomputing Applications, Environmental Change Institute, and Illinois-Indiana Sea Grant. In addition, the program lead scientist executed a number of other state-funded projects, and served as a scientific advisor in a number of projects at ISWS.

Water Supply Planning

Scientific studies supporting water supply planning is one of the core activities of the ISWS, going back at least 100 years. Having adequate supplies of good quality water is critical for the state's economy and wellbeing of its citizens. Recent and current droughts in the Midwest, the Southwest, and California underscore the critical need for a robust water supply planning

program.



Several legislative mandates charge the ISWS with water supply planning responsibilities, including the Water Use Act of 1983 (and amendments). Water supply planning activities at the ISWS are performed in almost all of its scientific sections, including Groundwater Science, Surface Water Hydrology and Hydraulics, Water Resources Data & Information, Climate and Atmospheric Science, Water Quality, and the Public Service/Analytical Services Laboratory, as well as at other state agencies, including the Illinois State Geological Survey, Illinois Department of Natural Resources, and the Illinois Environmental Protection Agency.

Current Work: The ISWS conducts research on both groundwater and surface water resources, on multiple scales (state, regional, local), and for multiple

purposes (drinking water supply, ecological flows, and agricultural and industrial needs). Scientific activities include: (1) many types of data collection and interpretation (groundwater levels, stream discharges, water chemistry, and water use); (2) estimations of future water demand; (3) physical testing of aquifers; and (4) numerical models of groundwater flow and surface water flow. Scientists meet frequently with various stakeholder groups and government agencies, including counties, municipalities, regional planning committees, and agricultural, industry, and mining interests. Considerable effort is made to coordinate activities and share information among the various agencies and stakeholders.

Program Outcomes: A recent example of how water supply planning at ISWS benefits Illinois citizens is the determination that deep groundwater use by some communities in Northeastern Illinois is unsustainable over the next 25 to 50 years. Findings resulted from developing a complex groundwater model and collecting and interpreting large amounts of hydrogeological data. Analysis of surface water availability and the impact of potential water use on streamflow in the Fox River assisted Montgomery, Oswego, and Yorkville to revamp their public water supply systems. The ISWS is providing scientific support to these and several other communities as they develop strategies to obtain sustainable water supplies into the future.

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