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HISTORY OF THE ILLINOIS STATE WATER SURVEY

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Abstract

The Illinois State Water Survey has provided leadership in establishing a scientific and engineering basis for water resources planning and management in Illinois and the nation since 1895. Although primary program areas have changed over time, some core programs remain. Program areas are monitoring, research, and public service, using the hydrologic cycle as the unifying framework. Major strengths of the Survey have been, and continue to be, partnerships with the other Scientific Surveys, the governing Board of Natural Resources and Conservation, the University of Illinois at Urbana-Champaign, Southern Illinois University, state and local government agencies, private companies, and professional organizations, especially the American Society of Civil Engineers. The Water Survey's contributions in the field of Civil Engineering are many and varied. These include river hydraulics, sedimentation and sediment transport, navigation impacts, hydraulic geometries of rivers and streams, urban runoff programs, groundwater evaluation analyses and modeling, wetland hydraulics, and water quality evaluations of streams, rivers and lakes. A goal is to make all of the Survey's major historical and current data sets and reports available via the Internet.

Introduction

Illinois is perhaps unique in the nation in having four Scientific Surveys to provide data and information and research results in the areas of water and atmospheric resources, natural history, geology, and waste management. In addition to meeting state needs, the Scientific Surveys participate in many regional, national, and international programs, and provide scientific and engineering data and information to a broad audience of researchers, professional organizations, governments, private companies, and individuals.

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The Scientific Surveys can be traced back to the motivation and far-sightedness of 19th century pioneers of the Midwest. Eminent scientists were successful in convincing public officials of the benefits of investing state funds in scientific institutions (Hays, 1980). The task of the Scientific Survey Chiefs and their staffs was "to require studies looking toward the future and not solely to solving the pressing needs of the present. Such long-term planning is quite unique among government agencies where the demands of the next election too often cause a concentration on short-term crises. The determination that these surveys should be devoted to study and analyses rather than regulatory administration is partly responsible for their uniqueness among state agencies" (William L. Everitt, in Hays, 1980, p. vii-viii).

When Illinois became a state in 1818, only 40,258 people lived in the state (Hays, 1980). By the end of the 20th century, the population had grown to more than 12 million and Chicago had mushroomed to become one of the major cities of the world. Such rapid development was not without its challenges and problems, however. Infrastructure in this frontier state was initially nonexistent and sanitary conditions were rudimentary. As late as the end of the 19th century, typhoid fever and other diseases plagued Illinois and other states in the Midwest. The annual typhoid death rate in Chicago in 1891 was 173 per 100,000 and 16 per 100,000 as late as 1910 – higher than in any city in the temperate zone. The highest death rate from typhoid, however, was in rural southern Illinois. Also, it was reported that "the state is not credited as recording as many as 90% of total deaths that occur within its limits" and "many typhoid deaths are not recorded" (Bartow, 1911, p.88). Waste from millions of people and animals were discharged directly into Lake Michigan, the Illinois River, and just about every other river in Illinois.

Founding of the Illinois State Water Survey

The Illinois State Water Survey (the Survey) was founded in September 1895 in Urbana as a unit of the University of Illinois Department of Chemistry. The Survey chemistry laboratory building was the only chemistry laboratory on campus at that time. In 1902, the Survey moved to the new Noyes Laboratory in Urbana. A plaque commemorating the pioneering work of Dr. Arthur W. Palmer, the first head of the Survey from 1895 to 1904, will be installed at the Noyes Laboratory this year. The Survey had its home in the Noyes Laboratory until 1951, when it moved to the newly constructed Water Resources Building in Champaign. In 1983, the Survey moved to its present home at the Water Survey Research Center on south campus. Regional offices are maintained in Peoria and Carbondale.

Palmer, a chemist, was meticulous and thorough. His detailed reports of water quality set a standard not only for the Survey, but also for the nation. His data for the Illinois River and the Mississippi River in the 1890s and at the start of the 20th century have been used, in conjunction with recent data, to establish century-long trends in nitrate concentrations in the Mississippi River basin as part of a national assessment of hypoxia in the Gulf of Mexico

(CENR, 2000). Palmer also used these early data in a U.S. Supreme Court case to resolve a dispute brought by St. Louis against Chicago after the Lake Michigan diversion was initiated in 1900. The diversion flushed sewage from Chicago and other towns down the Illinois River into the Mississippi River, from which St. Louis obtained much of its water supply. After 30 years of controversy with the lake states over the amount of water being diverted - in excess of 8,000 cubic feet per second (cfs) - the U.S. Supreme Court in 1930 limited the amount of water that Illinois could divert from Lake Michigan. The diversion controversy erupted again in the 1950s and 1960s, and the Survey played a major role in providing data and expertise to the Supreme Court, which set the diversion to 3,200 cfs. Today, some of the water diverted from Lake Michigan dilutes waste, supports barge transport on the Illinois River, and provides water to millions of residents in the Chicago Metropolitan Area. The Survey maintains a dense raingage network across the region to measure precipitation as one component of assessing the water diversion.

Palmer also was an early protagonist of interdisciplinary research, which is widely recognized today as a necessary step in addressing complex environmental problems. Specifically, he promoted chemistry, geology, bacteriology, and engineering research to address the many water quality problems in Illinois (Hays, 1980). Bacteriological and biological research was necessary in order to understand the links between water quality and microorganisms, which, for example, both fixed nitrogen in surface waters and removed nitrogen from surface waters and sediments. Palmer worked closely with Professor Stephen A. Forbes, who had succeeded John Wesley Powell as curator of the State's Natural History Society's museum in 1872. Forbes pioneered research on the biology and water quality of the Illinois River and set a solid foundation for ecological studies (Hays, 1980). "In later years, this pervading interest in the interactions of organisms earned Forbes recognition by many as the true "father of ecology" (Harlow B. Mills cited in Hays, 1980, p. 37).

Palmer was interested in solving problems, not just in studying them, and he recognized the importance of engineering as part of the solutions. Under Palmer's leadership, the Survey addressed water softening methods, sewage and wastewater treatment, water supply technology, and the establishment of sanitary standards for drinking water in the early years of the 20th century.

The original mission of the Survey was to survey the waters of Illinois to trace the spread of waterborne disease, particularly typhoid fever. By 1910, 21,715 water samples from 971 towns in all of the state's 102 counties had been tested. Many wells were condemned due to combinations of high bacteria levels, nutrients, and minerals: almost 80% of the wells less than 25 feet deep, 65% of those 25-50 feet deep, half of those 50-100 feet deep, and 20% of those over 100 feet deep (Bartow, 1911). "Every engineer employed by the State Water Survey since it was organized has had a part in the collection of data which appears in this bulletin, and every chemist at the Survey has had a part in the collection of data or in the analysis of waters"

(Bartow, 1911, p. iii).

The Board of Natural Resources and Conservation

In 1917, the Scientific Surveys were transferred to the State Department of Registration and Education, and each head accepted the title "chief" (Hays, 1980). The Board of Natural Resources and Conservation (the Board), composed of eminent scientists and professionals selected by the Governor, was established to guide the activities of the Scientific Surveys and to ensure that the Scientific Surveys' work could be done without undue political influence.

Scientific investigations were expanded in the 1930s, and the state's first inventory of municipal groundwater supplies was published. Activities also focused on methods to determine water levels in wells, yield testing, and establishment of an ongoing survey of the state's surface water resources. This survey included a cooperative streamgaging program with the U.S. Geological Survey. In 1931, the Survey conducted a sediment survey of Lake Decatur - the first such survey ever made by a state agency (Gottschalk, 1952).

Professor Noyes served as Secretary to the Board for many years, thus helping to cement an enduring relationship between the Scientific Surveys and the University of Illinois at Urbana-Champaign. Eighty-five years later, the Board still governs the Scientific Surveys. The Board is chaired by the Director of the Illinois Department of Natural Resources and has representatives of the Presidents of the University of Illinois and Southern Illinois University, and experts in the scientific disciplines of the Scientific Surveys.

Recognizing the Importance of Water Resources Planning

Over the years, the work of the Survey has changed to meet changing needs while still providing some of the original services. The Public Service Laboratory, for example, continues to provide free analysis of water samples submitted by Illinois residents. The latest addition to the suite of analytes is arsenic, which was added in 2002 in response to the U.S. Environmental Protection Agency tightening of the arsenic drinking water standard.

By the 1930s, no authoritative data on groundwater supplies were available. Continuing the tradition of looking forward, Chief Arthur M. Buswell, who succeeded Dr. Edward Bartow in 1920, proposed "a comprehensive survey of the volume of groundwater available in Illinois" (Hays, 1980, p. 122). Twelve years later, Buswell broadened his proposal to include all the state's water resources and to estimate future demand. This program was "aimed at securing the information needed for the most beneficial development of the state's water resources" (Hays, 1980, p. 145). "Although this project was included in the budget requests for several years, it was not funded by the legislature" (Hays, 1980, p. 203). Buswell also stressed water quality for industrial purposes, with particular emphasis on corrosion problems and newer

water-softening methods (Buswell, 1952).

After the resignation of Arthur Buswell, whose leadership spanned nearly four decades, William C. Ackermann was appointed Chief in 1956. Ackermann, a civil engineer, had worked with the Tennessee Valley Authority's water control planning department before heading the Watershed Hydrology Section of the U.S. Department of Agriculture's Agricultural Research Service. Working closely with John C. Frye, the new Chief of the Illinois State Geological Survey, the two Chiefs opened a joint regional office in Naperville to work on groundwater studies in the Chicago Metropolitan Area (Hays, 1980). "But no consistent progress had been made toward comprehensive mapping of the groundwater resources of the state" (Hays, 1980, p. 164).

Returning to Washington, D.C. in 1963, on leave from the Survey, Ackermann became "the first technical assistant for water resources in the Office of the President" (Hays, 1980, p. 170). "He put together, among the federal agencies, the first coordinated water resources research budget, first coordinated water research plan in the federal government ..." (Donald Hornig, cited in Hays, 1980, pp. 170-171). Building on this experience, "Ackermann organized and served as first Chairman of the Committee on Water Resources Research, with members from various government agencies dealing with water resources... Of all the needs in national water policy, Ackermann found the need for more advanced planning in regard to water resources to be among the most pressing.... It also led to Ackermann's increased concern for better planning at the state level, ... In 1965, Illinois Governor Otto Kerner designated Ackermann as director of a task force to formulate a comprehensive state plan for water resources" (Hays, 1980, p.171). In 1967, an ambitious state water plan was released, but was not implemented due to budget constraints (Illinois Technical Advisory Committee, 1967).

Ackermann was very active in various activities of the American Society of Civil Engineers (ASCE). He served in various capacities and held several offices, including the Director of Zone III of ASCE. During his lengthy tenure as Chief of the Survey, he contributed significantly to water resources planning and management in the state and the nation.

Recognizing a central scientific role in the evolving environmental movement, Ackermann developed "a strong advisory and supporting role with the newly created state environmental agencies." "The Water Survey itself was now organized in five principal sections: water quality, chemistry, atmospheric sciences, hydrology, and hydraulic systems. Increasingly, investigations were crossing section lines" (Hays, 1980, p. 179).

Population growth in the late 1950s and 1960s created the need for expanded water resources throughout the state, and the Survey attempted to identify and increase usable supplies. Studies addressed reservoir development and maintenance, new methods for evaluating wells and aquifers, and the effects of future development. A statewide network of

observation wells was established, and investigations of groundwater resources in the Chicago and East St. Louis areas were important contributions to an inventory of the state's principal groundwater formations.

Contributions in Hydraulics, Rivers, Streams, Lakes, Wetland Dynamics, and Groundwater Modeling

Over the last 70 years or more, the Survey's civil engineers have made significant contributions in the areas of open channel flow, sediment transport, groundwater modeling, and wetland dynamics. Many lakes in the nation, and especially in the central part of the country, are filling up rapidly with excessive sediment deposition. Since the original sedimentation survey of Lake Decatur, more than 170 lake sedimentation surveys have been completed by the Survey. These surveys, supported by yield analyses, have provided extremely valuable information to local communities and state agencies in predicting and managing their water supply availability and recreational opportunities.

One of the pioneering works on hydraulic geometries of streams and rivers was completed by John B. Stall and Dr. Yu Si Fok in the mid 1960s. Stall also served in various capacities for the ASCE, including a term as the Chairman of the old Hydraulics Division. The hydraulic geometry concept was further expanded by Dr. Nani Bhowmik and Stall to include floodplains. Dr. Ted Yang and Stall later developed the Unit Stream Power concept, which is used by various entities for modeling sand transport in streams and rivers. Stall also was instrumental in the development of the Illinois Urban Drainage Area Simulator model, which is used all over the world to evaluate and model urban runoff.

The 7-day, 10-year low flow concept for the determination of minimum flows and assimilative capacities of streams and rivers essentially was developed at the Survey by Stall and Dr. Krishan P. Singh. This concept is now used widely for managing low stream flows for a variety of purposes.

The Survey's contributions in river hydraulics are many and varied. Bhowmik was the first engineer in the nation to conduct a scientific evaluation of the physical impacts of navigation in large rivers, including the upper Mississippi, Illinois, and Ohio Rivers. These research activities started in the early 1980s and have provided valuable information for potential navigation improvements and ecosystem-based management of the upper Mississippi and Illinois Rivers. Bhowmik and Dr. Mike Demissie also worked on the Long Term Ecological Research of Large Rivers, a multidisciplinary endeavor by engineers, biologists, and geologists, supported by the National Science Foundation. The concept developed from this project formed the basis for the establishment of the Environmental Technical Management Center in Onalaska, Wisconsin, for research and data collection on the upper Mississippi River. Bhowmik contributed significantly to the understanding of waves generated by recreational boats in lakes

and rivers. Also, he has served in various capacities for ASCE, including chairman of a Task Committee, control and contributing member of several Task Committees, and as an Associate Editor of the *Journal of Hydraulic Engineering*.

The Survey's contributions on the effects of wetlands in flood peak attenuation received national attention, including the deliberations of a Task Force appointed by President Bill Clinton during the 1993 flood on the upper Mississippi, Missouri and Illinois Rivers. That report prepared by Demissie and Dr. Abdul Khan was cited in numerous publications as a significant contribution to the effects of wetlands in flood peak attenuation for smaller watersheds. Contributions by Demissie and Bhowmik in the basic determination of sediment load transport and sedimentation of the Illinois River, Kankakee River, and other rivers and streams of Illinois have assisted and will continue to assist the state, and federal and local government in the technical evaluation and development of management alternatives for these streams and rivers for many years to come.

Contributions by Survey engineers in the modeling and evaluation of groundwater resources also are many and varied. Bill Walton's groundwater book has been a standard for many years. Tom Prickett and Carl Lonnquist prepared a classic groundwater modeling report for the Survey in the mid 1960s that has been a standard modeling report for numerous state, federal, international, and private entities worldwide.

Over the years, Survey engineers have played and continue to play a very active role in numerous ASCE activities. These included Director of Zone III (Ackermann), chairing of a Division (Stall), co-editing national conference proceedings (Bhowmik), chairing and participating in ASCE Task Committees (Bhowmik, Demissie, Stall, and Singh), chairing technical sessions, and presenting numerous papers at ASCE conferences.

The Emergence of Atmospheric Sciences and Long-Term Monitoring

During World War II, Survey chemists cooperated with the University of Illinois and the federal government in studies on the detection of chemical warfare agents in water and methods for their removal. Meteorological efforts expanded in the postwar years, including the investigation of atmospherics for cloud seeding to induce rainfall, use of radar to measure rainfall and track severe storms, and the establishment of networks of densely spaced raingages (Changnon and Huff, 1997). The U.S. Weather Bureau transferred the State Climatologist to the Survey, and computerization of the Survey's historical weather records began. In 1953, the Survey gained national prominence when "radar observers were able to view and record on radar photographs for the first time the development, growth, and partial disintegration of a severe central Illinois tornado" (Hays, 1980, p. 158). In 2001, the magnetron from that early radar was preserved and put on display at the Survey.

Periodic heavy storms and flooding always have been a concern in Illinois, and

precipitation frequencies issued by the Survey provide an important basis for civil engineering design and planning. Precipitation has increased since about 1970, and the Survey has reanalyzed the data and issued modified precipitation frequencies. Major field studies conducted by the Survey 25 years ago under the leadership of Stanley A. Changnon, an atmospheric scientist who was appointed Chief of the Survey in 1980, identified that heat islands over large urban centers such as Chicago and St. Louis increase temperature and stimulate heavier precipitation.

In the 1970s, the issue of acid rain emerged as an important environmental concern and an energy-related problem. The chemical composition of the atmosphere became a major focus of activities at the Survey. The National Atmospheric Deposition Program (NADP) was established in 1978 to monitor the chemical composition of precipitation across the nation. For 24 years, the Survey has analyzed the chemistry of weekly samples from the NADP network, now numbering more than 240 sites nationwide. Since 1992, the Survey has performed similar measurements for 10 sites collecting daily samples. Results of the chemical analyses show that the concentrations and amounts of sulfate in precipitation have decreased substantially since enactment of the acid rain controls under the 1990 Clean Air Act Amendments. Since 1997, all the other components of NADP, including an emerging mercury deposition network, data storage and analysis, and education have been transferred to the Survey.

For about two decades, the Survey has monitored a number of environmental variables statewide under its Water and Atmospheric Resources Monitoring program: weather and climate, radiation, soil moisture, sediment concentrations, and groundwater levels. Long-term monitoring of these variables will continue. The State Water Plan Task Force uses these records, in combination with data on river discharge and reservoir levels, for water resources planning and management, especially during droughts and floods. Scientists throughout the world use the soil-moisture data to study terrestrial-atmospheric moisture fluxes and budgets. Wind and radiation data from the program provide a foundation for evaluating the potential for wind and solar energy in Illinois.

The Midwestern Regional Climate Center, housed at the Survey, is a cooperative program with the National Climatic Data Center of the National Oceanic and Atmospheric Administration and provides many climate services to residents throughout the Midwest. The State Climatologist, still housed at the Survey, provides data and information on Illinois weather and climate to the news media, government agencies, private companies, and Illinois residents.

The Survey Now and in the Future

Since 1995, the Scientific Surveys and the State Museum have been Divisions of the Illinois Department of Natural Resources. The Scientific Surveys remain affiliated agencies of

the University of Illinois at Urbana/Champaign. Support for scientific programs at the Survey includes a state appropriation and income from grants and contracts with various Illinois state agencies, municipal groups, universities, private organizations and businesses, and many federal agencies. The Survey has a diverse, multidisciplinary staff of 200, including 25 Ph.Ds. The Survey's major activities continue to be resource monitoring, research, and services in five Sections: Watershed Science, Groundwater, Atmospheric Environment, the National Atmospheric Deposition Program, and Analytical Chemistry and Technology.

Following a tradition of success and innovation for more than a century, the Survey continues to adapt to changing priorities and implement new programs while providing traditional services, all within the framework of the hydrologic cycle.

Climate change and its possible influence on state water resources are important to the state, the nation, and the world. Unfortunately, precipitation scenarios for the Midwest for the 21st century range from an increase in mean annual precipitation of about 10 inches to a decrease by the same amount. Such uncertainty makes water resources planning very difficult. To reduce this uncertainty, Survey scientists are starting to conduct diagnostic studies of computer models which simulate the climate system in an attempt to understand the reasons for the divergent climate scenarios. They also are developing a new regional climate model embedded in a global climate model. Linked to the climate model is a regional air quality model and a hydrologic model. The results from this research could provide an improved scientific basis for making policy decisions about climate change, air quality, and water resources.

Working with the U.S. Army Corps of Engineers, the Survey has modeled hydrology and hydraulics to evaluate design options for constructing islands in the Illinois River near Peoria. Construction of these islands, announced by the Corps in June 2002, will remove large quantities of sediment from the Illinois River, help reduce sedimentation problems, and improve biological habitat. A related major project in partnership with the Corps is restoration of Illinois rivers. The Scientific Surveys are developing the Illinois Rivers Decision Support System to inventory all related activities and data, and to provide analytical tools for evaluating restoration options.

In many cases, it is difficult for small water suppliers in rural communities to keep pace with aging systems, new regulations, and increasing demands. To assist small water supply systems throughout the Midwest, the Survey, in cooperation with the Water Resources Center at the University of Illinois in Urbana/Champaign, heads the new Midwest Technology Assistance Center sponsored by the U.S. Environmental Protection Agency.

In summary, the following is a brief characterization of Survey history:

Era I:	1895 to1930: a primary focus on water chemistry
Era II:	1930s to 1960: a primary focus on hydrology (water quantity)
Era III:	1960 to 1990: an increasing focus on atmospheric resources

Era IV-present: a uniform focus on environmental issues in water resources and weather/climate.

Conclusions

For more than a century, the Survey has been a leader in water resources studies and in atmospheric studies for 60 years. There are many reasons for the agency's longevity and numerous successes. A significant reason is that generations of political leaders and constituents throughout Illinois, and especially in Springfield, have recognized the economic, environmental, and human health benefits to Illinois and the nation of investing in science. Based on extensive scientific data and analytical tools produced by the Survey, private individuals, government agencies, private companies, and nongovernmental organizations have made hundreds of thousands of decisions to protect human health, locate and protect water supplies, stimulate economic growth, protect the environment and ecosystems, and enact science-based policies and regulations. Other reasons include the diverse scientific backgrounds of the Chiefs and Survey staff and their ability to form partnerships with many national programs and professional organizations. The Survey has had only eight directors or chiefs in 108 years, thus providing a great deal of continuity and stability to the organization.

The Survey has achieved national and international recognition as a unique source of data and information on water and atmospheric resources. Survey scientists and staff participate in and lead national programs with benefits that far transcend state boundaries.

However, a major challenge that has faced Illinois and the Survey for 70 years still remains - developing and implementing a comprehensive survey of state water resources and a statewide water resources management plan. A key unresolved question, asked by L.R. Howson of Chicago in 1951 is "... to what extent that interest [state interest in its water resources] should be expressed in control legislation?" (Howson, 1952, p.145). Howson's view was that "... the regulation of many so-called water shortages in a state such as Illinois, which has abundant water resources, in many localities a choice of resources is quite largely an economic question" (Howson 1952, p.147).

Debate between a free-market approach based on the riparian doctrine of reasonable use and a regulatory approach to allocating water resources has been renewed in recent years. In April 2002, Governor George Ryan signed an Executive Order requiring the Department of Natural Resources to take the lead in preparing an integrated groundwater and surface-water resources agenda and assessment report, and to submit this report to the Interagency Coordinating Committee on Groundwater. In turn, the Committee shall report to the Governor by January 1, 2003, and establish a water-quantity planning and management procedure for Illinois. Whatever the outcome, the Survey, working closely with the State Geological Survey and the Office of Water Resources, is committed to providing an improved scientific basis for water resources planning and management (ISWS, 2001). Currently, the Survey is undertaking

a multi-year project with the State Geological Survey to characterize water resources in Kane County in the Chicago Metropolitan Area, and with the Mahomet Aquifer Consortium in central Illinois.

One of the greatest assets of the Survey is its collections of data and reports. It is a Survey goal to make all its major reports and data sets dating back to 1895 available via the Internet. Substantial progress already has been made in this endeavor (www.sws.uiuc.edu). By next year, the Survey also plans to have more than 300,000 groundwater well records digitized and available via the Internet.

Throughout its history, the Survey has enjoyed and benefitted from close professional ties with the American Society of Civil Engineers. The Survey salutes the American Society of Civil Engineers in celebrating its first 150 years of achievements. We look forward to continuing the productive partnership.

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