Program of Research and Scholarly Excellence designation was conferred to water programs. Also, the university's "Water Plaza" was built and "Water Archives" initiated in the Morgan Library during his tenure.

Hunter Rouse, former Dean at the University of Iowa and the engineer for whom ASCE's Hunter Rouse Hydraulic Engineering Lecture is named, gave his first summer course at Colorado State in 1940. Rouse observed the rapid growth of Colorado State's water programs and decided that the factors behind the growth should be documented before the information was lost (Rouse, 1981). Rouse continued to teach his summer course and inspired several generations of faculty and students.

After joining the USGS staff in Fort Collins in 1957, Daryl B. Simons became a Professor and Associate Dean at Colorado State. He contributed to and established a well–known program in sedimentation and river engineering. The hydraulics team at the Engineering Research Center, including other professors such as Everett Richardson and Hsieh-Wen Shen, completed many model studies and research investigations.

Vujica Yevjevich joined Colorado State in 1957, after a research career in his native Yugoslavia. He established a well–known program in hydrology and stochastic hydrology, and advised a number of graduate students who went on to distinguished careers in the US and other countries. In 2002, one of his students, Ignacio Rodriquez–Iturbe, won the Stockholm Water Prize. In that same year, another student, Francisco Gomide, was named Brazil's Minister of Mines and Energy. Another Yevjevich student from Brazil, Jerson Kelman, had earlier been named Director of Brazil's national water agency.

Colorado State's groundwater faculty also made important contributions. Art Corey established a Groundwater Laboratory at the Engineering Research Center. Another key program that spun out of the engineering water program was the university's Atmospheric Sciences Department, a national leader among atmospheric science departments.

Although this short account does not do justice to non–engineering work, it would be remiss not to mention the fertile climate for interdisciplinary work that emerged on the campus after the 1960s. This enabled Colorado State to attract scientists who had already achieved highly in public sector work. For example, Henry C. Caulfield, former Director of the US Water Resources Council, served as a Professor of Political Science and interacted regularly with the engineers and natural scientists.

International work

Colorado State's international water programs began in the mid-1950s, when the university helped develop graduate-level water programs at the University of Peshawar in Pakistan, where the university's influence is still felt more than 30 years later, especially for irrigation systems and on-farm water management. Similar projects were conducted in Afghanistan. In 1959, Colorado State helped establish the Southeast Asia Treaty Organization graduate school in Thailand. The school is now known as the Asian Institute of Technology. In the early 1960's Colorado State researchers, under Maurice Albertson's leadership, had an active part in creating the Peace Corps.

Colorado State has been active in international training and in 1967 established the International School for Water Resources. In the 1970s, Victor Koelzer retired from his post as Chief Engineer of the National Water Commission and assumed the directorship. Koelzer introduced a course on water resources planning, modeled after his experience with USBR and Harza Engineering Company. Later, Warren A. Hall, a pioneer in water resources systems engineering and former Director of the Office of Water Resources Research, joined the faculty and took over the school. In its first 25 years, the ISWR organized training programs for over 350 professionals from 57 nations.

Colorado State faculty assisted with several irrigation management projects in Egypt's Nile Valley. Everett Richardson and Dan Sunada directed key projects in the series. A $25 million contract awarded by the Egyptian government was the culmination of over two decades of work. About 40 Colorado State faculty members provided technical assistance to the project. About 55 Egyptian students enrolled in graduate programs in the United States; 30 at Colorado State University. Colorado State was also active in Pakistan irrigation research, and operated projects for the Agency for International Development. One of these, the Water Management Synthesis Project, was directed by Wayne Clyma and produced many reports about irrigation technology and management.

The Colorado Water Resources Research Institute

After over 125 years of work in the field of water, Colorado State's programs have diversified to the point where 25 departments participate in multi–disciplinary activity, much of which is coordinated by units such as the Water Center and the Colorado Water Resources Research Institute. CWRRI was one of the state institutes established by Congress in 1964. The Colorado Legislature authorized it in 1981 and again in 1997. It began as the Natural Resources Institute with Stephen Smith as the first director. Later, Norman A. Evans was director until 1988. He was followed by Neil S. Grigg and then Robert C. Ward. Colorado State created the Water Center to take on integrating functions within the university, and now CWRRI and the Water Center are combined. CWRRI has published over 300 research reports, and is a valuable entity to the state's water managers. Colorado State's annual partnership with water utilities and districts has sponsored the Children's Water Festival and several other outreach events. One of these, Hydrology Days, was started by Hubert Morel–Seytoux in the 1980s and continues under Water Center sponsorship.

Toward the future

Today, water activity at Colorado State is even more extensive than the past. The university has over 100 courses related to water, and over 900 scientists work in government natural resource research agencies in Fort Collins. The university's water programs address more complex issues than in earlier times. Roles of public universities have blended into a more complex society with more and different institutions plying their knowledge to solve problems of water. Colorado State's water programs remain vibrant and continue to evolve in response to the demands of a changing world.

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The Iowa Institute of Hydraulic Research[1]: Seventy-Plus and Still Going Strong

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Abstract

This paper presents a overview of the Iowa Institute of Hydraulic Research (IIHR). The overview outlines IIHR's beginning as a single-room hydraulics laboratory in 1920, charts its growth, and describes its current research and educational prospects. Periods of development are discussed briefly in terms of IIHR's sequence of directors. Over time, the range of IIHR's research and educational activities has widened. It is intriguing, though, to observe that many of the opportunities IIHR currently faces are intrinsically the same opportunities that led to IIHR's founding. In particular, IIHR's research and educational activities continue to be motivated by the overall need to understand and simulate water flow, as well as to design diverse structures that influence water flow. A recent book, *Flowing Through Time*, provides detailed coverage of IIHR's founding, its development, and its present prospects.

Introduction

The Hydraulics Laboratory, administrative center for the Iowa Institute of Hydraulic Research (IIHR), rises as an imposing red-brick edifice on one of the busiest corners of the Midwestern college town of Iowa City, Iowa (Fig. 1). Located alongside the Iowa River near the downtown area on The University of Iowa's central campus, this building is seen by thousands every day. Only the initiated, those who are hydraulicians, hydrologists, or fluid mechanicians with some inside association, are likely to realize that the building's walls, if they could talk, would tell the ageless story of people attempting to understand and control that most common of the earth's constituents, water.

Part of that story is told in a recent book on IIHR's history, *Flowing Threw Time* (Mutel, 1998). IIHR, like other hydraulics laboratories, has performed research crucial to the workings of modern society. That research dated from early in the century to present times. As the activities and personalities that have energized this

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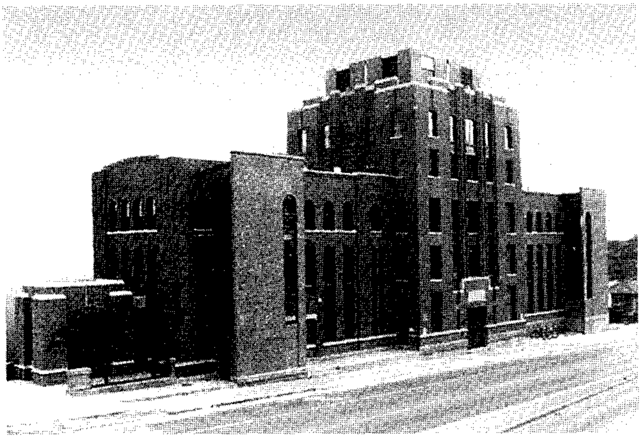

Figure 1. IIHR's Hydraulics Laboratory following its 2001 renovation.

organization since 1920 took hold, IIHR grew into of one of the U.S.'s major hydraulics laboratories.

This paper sketches out IIHR's creation, development, and present prospects for advancement. A common feature throughout the outline is IIHR's leadership by directors known internationally for their contributions to hydraulics research and education. The birth of IIHR is largely attributable to one man, Director Floyd Nagler. IIHR was his brainchild. IIHR's growth to maturity was guided and motivated by Directors Hunter Rouse and John F. Kennedy, both of who were internationally prominent hydraulicians. Its current development is presided over by Director V.C. Patel, an internationally known fluid mechanician. Since it is often asked how IIHR began and what IIHR's future holds, this article focuses on the first and current directors (Nagler and Patel). Detailed information about Directors Rouse and Kennedy is presented elsewhere (e.g. in the book *Flowing Through Time*).

Another common feature of IIHR's research is its inclusion of the diverse facets of water resources. From its creation, IIHR undertook research into water flow in rivers, water movement through the hydrologic cycle, the design and performance of various hydraulic structures, and the fundamentals of fluid flow. The breadth of IIHR's interests in water and fluid flow recently led IIHR to adopt a new name – IIHR–Hydroscience & Engineering – to reflect the scope of its research and educational activities.

Birth of an Institute

IIHR's origins lie in the foresight of the faculty of The University of Iowa's Department of Mechanics and Hydraulics who influenced the design of the Burlington Street dam on the Iowa River. They enabled the construction in 1919 of a small hydraulics laboratory with a 40-m-long and 3-m-wide open-channel flume. The small, one-room laboratory expanded very rapidly, and the basic structure of the current Hydraulics Laboratory was completed in 1932. It featured, in addition to the previously mentioned large-scale open-channel flume, a large constant-head tank in the top story and a recirculating water system permitting small-scale model and laboratory testing on all floors of the building. The scope and complexity of the problems undertaken by the laboratory soon received national attention. They prompted the formal organization of IIHR in 1931 as "an agency for the coordination of talent, facilities and resources available through The University of Iowa to be brought to bear on problems in hydrology and hydraulic engineering."

It is said that IIHR's first director, Floyd Nagler, was a man of boundless energy and drive, capable of balancing ten activities simultaneously and keeping them all going. Nagler's primary legacy before his premature death at age 41 was the establishment of the physical and organizational structure of the Iowa Institute of Hydraulic Research. He had been brought to Iowa to foster the research of a tiny laboratory with under 500 square feet of floor space; he left a five-storied laboratory well over 50 times as large. He guided the transition of this Hydraulics Laboratory to the full-blown IIHR and served as the founding director of both the laboratory and the institute. As the first to steer the vessel, he set IIHR on its course and established the traditions that were to become its hallmark: traditions of high productivity, excellence, innovation in research, and engineering service.

His drive led to an amazing proliferation of research that exceeded even his expectations. At first, research work at the Hydraulics Laboratory was synonymous with work completed by Nagler: he was, after all, the only researcher present. As his staff grew, Nagler remained involved in the Hydraulics Laboratory's research as well as its administration, and he seemed to have a thorough grasp of IIHR's diverse efforts and their import. His own efforts in later years focused on surveys regarding the water-resource potential and flow characteristics of the Mississippi River and its watershed. This research was performed for the Army Engineers (now the U.S. Army Corps of Engineers) and for Iowa's Fish and Game Commission and Board of Conservation.

Early Development, 1920–1933

During Nagler's tenure, the field of hydraulics rapidly expanded in importance and breadth of activity. Hydraulics-related problems were abundant and obvious. As Nagler himself wrote, "The field open to hydraulic research is almost unlimited." Laboratories were popping up across the country at major universities, encouraging the assemblage of collaborating researchers, and enabling the evolving use of small-scale models, which in turn stimulated an attack on basic problems that had not previously been investigated. Spin-off projects were attacked with zest, for hydraulic research was providing useful and necessary answers to basic questions and thus was well funded. All these factors combined to feed one another, the funding permitting the expansion of laboratories and personnel, which jointly fostered the more sophisticated use of models, resulting in a recognition of additional research problems that beckoned the researchers ever onward. Even the most straightforward problems commanded a sense of excitement and energy.

Research during this period focused on questions that until then had remained largely unaddressed. During Nagler's tenure, IIHR attacked all these questions, typically under contracts from a government agency, private company, or engineering firm that desired their applied results (although IIHR graduate students remained engaged in more theoretical challenges or, as Nagler explained, "in the study of more academic problems"). Nagler and his colleagues examined the water-carrying capacity of various culvert shapes and materials. They tested the performance of meters that measured current, assessed characteristics of the hydraulic jump, and investigated how metal flap gates affect water flow. They observed how bridge piers and abutments of various shapes block or constrict water, causing local scouring of the riverbed. Sometimes the most basic questions revealed surprising results; for example, Nagler's team discovered that in a given period, almost twice as much water could pass through a smooth concrete culvert as through a corrugated metal culvert with the same inner diameter. Or (as Nagler pronounced with pride), the 57 unlikely solutions that had been proposed to abate flood problems at Milan, Illinois, had been reduced at the Hydraulics Laboratory into a single successful resolution.

Model testing for the Army Engineers' Mississippi River locks and dams would become one of the Hydraulics Laboratory's major focuses in the 1930s, bringing in a substantial portion of its consulting revenue. Thus, Floyd Nagler and IIHR, in its early years, were instrumental in the massive restructuring of the Upper Mississippi that today characterizes the river and its use.

Attaining Stature, 1940s – 1980s

Following the death of Professor Nagler in 1933, Director and Associate Director positions, respectively, were filled by Dean C.C. Williams and Professor F. T. Mavis until 1936, then by Dean F. M. Dawson and Professor E.W. Lane until 1942. During these two periods, graduate student involvement in research increased significantly. Also, IIHR initiated the sponsorship of a national hydraulics conference, setting a tradition which continued over twenty years with seven conferences, and ultimately leading to the Hydraulics Specialty Conference series, now run as the Annual Water-Resources Engineering Conference by the American Society of Civil Engineers (ASCE).

Professor H. Rouse became Associate Director in 1942, then Director in 1944. He reorganized IIHR to consist of an active research staff, drawn from Engineering College faculty. He redirected IIHR toward basic research and graduate study, and he wrote several textbooks, some with the cooperation of IIHR's staff. These activities coincided with the emergence of hydraulics and hydrology as separate scientific disciplines through adaptation of advances being made in fluid mechanics in general, and hydrodynamics and aerodynamics in particular, and with the expansion of research funding by government agencies brought on by World War II. In 1947, IIHR again expanded with the addition of a laboratory annex and wind tunnel (IIHR's former West Annex). Rouse is credited widely with considerably enhancing IIHR's national and international prestige as a premier fluids-engineering laboratory.

Professor J.F. Kennedy became director in 1966. In response to the challenge of operating IIHR during a period when research funds were becoming considerably more difficult to obtain (primarily because of the formation of other laboratories, often staffed by IIHR graduates), he broadened IIHR's research scope to maintain a fertile balance of basic and applied research. As a result of Kennedy's leadership and his own technical reputation, IIHR thrived and expanded to its current level of activities and facilities. Upon Kennedy's resignation as director in July 1991, Professor R. Ettema was appointed Acting Director.

IIHR's Research and Educational Challenges in the Years 2000-Plus

Professor V.C. Patel was appointed as IIHR's director in June, 1994, at a time when the scope of IIHR's activities was broadening in response to evolving societal interests, new technologies and new insights, and coincident interests and expertise among the people comprising IIHR. That broadening of scope drew IIHR further into advanced aspects of hydrology and hydrometeorology, computational fluid dynamics, biofluid mechanics, and environmental concerns, and also kept IIHR busy with hydraulics research. In response to these and other developments, Patel encouraged both the renaming of IIHR as "IIHR - Hydroscience & Engineering" and further broadened its research and educational focus. In 2002, together with Associate Director Tatsuaki Nakato, Patel established an IIHR field laboratory on the Mississippi River near Muscatine, Iowa. Through Patel's leadership, IIHR has been readied to further address evolving and new societal needs and basic hydraulics questions, as discussed below.

Evolving Societal Interests. IIHR has long been attuned to changing societal interests and needs, and from them has created new possibilities for research and education. Doing so has proved crucial to society because the relevance and importance of hydraulics – that is the practical and pervasive role of water in human affairs – has never diminished. Over the years, IIHR has provided national and worldwide leadership in areas such as thermal pollution in water bodies, power-plant cooling, river control structures, ice engineering, and viscous ship hydrodynamics.

Presently, for instance, hydraulics has progressively turned "green" in response to concerns about environmental well-being. Traditionally, hydraulics has been associated with manipulation of natural water bodies (rivers, aquifers, and coasts in particular) to meet societal demands. Though these activities remain critically important, society perceives them a little skeptically -- especially those societies whose water needs have by-and-large been met. In response to public perception and to real needs, contemporary hydraulics is placing heightened emphasis on understanding and enhancing the natural environment. Research and teaching in the areas of environmental hydraulics (or environmental fluid mechanics), habitat hydraulics, and ecological hydraulics have become topical in response to concerns about environmental well-being.

Increased interests in efficient water use compel research and education in water-resources engineering. Population growth, together with concerns for environmental well-being, are placing increasing demands on water supply. The term "water stress" signifies the limiting influence of water availability on the expansion of human communities, especially mega-cities like New York, Los Angeles, Tokyo, and Cairo. Water's abundance or scarcity is even felt in much smaller communities like Iowa City, which faces difficult decisions concerning the feasibility of expansion. For hydraulics, water stress implies a host of research prospects including new types of conveyance and hydraulic structures (particularly for large cities and arid areas); improved flow-control and flow-regulation systems; greater efficiencies in power-production systems using water (as most do); water recycling; and innovative integration of natural water systems (e.g. wetlands) into human wastewater systems.

New Technologies, New Insights. Technological innovations facilitating new insights into fundamental aspects of fluid flow are creating opportunities for hydraulics research and practice. At IIHR, hydraulics is becoming increasingly sophisticated and rigorous, progressing substantially beyond the hydrodynamicist Theodore von Karman's somewhat derisive characterization as "the science of variable coefficients." Substantial improvements in the design and control of numerous hydraulic and hydrologic systems undergirding social infrastructure (e.g. those for handling storm-sewer flows, hydropower generation, or irrigation) are in the wind or already underway. Hydraulics is abuzz with "hydroinformatics." Advances in computational hydraulics and computational fluid-dynamics (the two are merging), augmented by instrument development, are facilitating those improvements. Ultimately, they will supercede present-day, often empirical and seat-of-the-pants approaches used to design and operate hydraulic systems.

Several current projects at IIHR illustrate the opportunities presented by technological developments and by advances in the understanding and modeling of fluid flow. One project involves application of multi-component laser-Doppler velocimetry (LDV) to obtain detailed information on flow within hydropower intakes and turbines. The project is motivated by two concerns: fish passage through hydropower plants, and the occasional need to re-aerate oxygen-deficient flows released from reservoirs. This project also involves application of advanced computational fluid dynamics (CFD) modeling of the sort originally developed by fluid dynamicists for simulating and investigating flow around airfoils and ship hulls. In a similar vein, LDV instrumentation and CFD simulation are being used at IIHR to investigate flow in dune-bed channels (albeit still with two-dimensional dunes) and flow in water-intake pump sumps. Another promising tool, particle-image velocimetry (PIV), is beginning to make possible, in virtually the twinkling of an eye, flow imaging and measurement that until now have been extremely arduous. In the long run, application of powerful CFD methods and convenient instrumentation will completely change the way nonstandard hydraulic structures are designed. Those innovations already are occurring in the design of ships, planes, and hydromachines. The change will entail collaboration among engineering disciplines.

Coincident Interests and Expertise. An issue of growing significance is the importance of professional interaction among disciplines with interests and expertise that coincide. Such interaction, applied to larger problems and processes, is not easily facilitated with today's tendency toward increased specialization. It is an issue, therefore, with implications concerning the ways hydraulics and related topics are taught. In this respect, a strength of IIHR has been its capacity to blend personnel, facilities, and activities that elsewhere are found in diverse departments with little or no interaction or shared goals among them. A faculty and research staff drawn from diverse backgrounds, dedicated to basic research and the solution of real-world problems, is the hallmark of IIHR. Joint projects and innovative approaches to research are readily conceived and executed in this environment.

Present Prospects

IIHR's research expertise lies in core fluids-engineering disciplines that will be relied upon to solve problems of the air and water environment. With renewed national emphasis on human wellness and related research in health, biofluid dynamics offers vast research opportunities for IIHR. IIHR has been involved in this area only on a limited basis in the past.

A growing number of emerging projects engaging IIHR are multidisciplinary in nature. Because water and fluid dynamics play major roles in diverse aspects of human affairs and the natural environment, IIHR will have to become increasingly engaged in research and development efforts that are primarily multi-faceted and multidisciplinary.

IIHR has long enjoyed a worldwide reputation for its educational and research programs. This is a fortunate circumstance as problems related to water and the environment are receiving increased attention around the globe, and IIHR is in a unique position to provide leadership at the international level. The problems are particularly acute in the so-called Rapidly Developing Countries where rampant industrialization has strained water resources and quality, and also in the Third-World Countries aspiring to increase industrial production in fragile environments with limited water resources. Moreover, these problems are not confined by international boundaries. With its extensive international connections, its expertise in hydraulic engineering and water resources, and its growing capabilities in mathematical modeling of complex systems, IIHR is uniquely qualified to develop an international program of research and education in these areas. IIHR has become a world leader in the development of mathematical models of river networks and associated hydraulic structures. These models incorporate state-of-the-art computing and data-processing methods as well as modern developments in hydrology, hydrometeorology, and remote sensing with ground-, air-, and space-based instrumentation, resulting in tools that are needed to attack large-scale international water-related problems.

Concluding Remarks

Ongoing changes in national and international priorities, developments in technology and knowledge, and the coincidence of people's interests have enabled IIHR to configure effectively its research and educational programs over time. Presently, IIHR's prospects reflect increased emphasis on multidisciplinary research in fluid dynamics, water-resources engineering, and the hydrosciences. Additionally, IIHR intends to strengthen its partnerships with industry. These actions position IIHR to