WATER

IN A DYNAMIC PLANET

A Five-year Strategic Plan for Water Science

CUAHSI

CONSORTIUM OF UNIVERSITIES FOR THE
ADVANCEMENT OF HYDROLOGIC SCIENCE, INC.
WHY A WATER CONSORTIUM?

WATER IS CRITICAL FOR LIFE. The distribution and composition of water are equally important to ecosystems, climate, geologic processes, economies and human health. Water interacts with other components of the Earth in intricately connected ways. What are the multiple roles of water in climate change? How do ecosystems evolve relative to the availability of water and its variability over space and time? How do solutes and sediments mobilize, transform, and accumulate under different flow regimes? How is freshwater made available to different segments of society, and how are poverty, human health and development influenced by access? How is water linked to conventional and alternative energy production?

In all of these questions, a central challenge is scaling our measurements and models from the level of the lab or local field site to regional and global extents. In addition, fundamental science advancement will require new approaches, tools, and collaboration among diverse disciplines. There is general recognition that previous assumptions underlying our analytical methods, such as constant climate, static economic activities, models of population growth and land use change, in addition to the simple upscaling of processes to large, heterogeneous landscapes, are inadequate. Understanding water within the context of interacting physical, biological and social systems over the complex natural and built environment requires activities at the community level as well as at the investigator level because of the breadth of disciplines involved and the extensive infrastructure necessary to pursue interdisciplinary and multi-scale research. Advances in technologies to make measurements at hierarchy of scales from the pore to regional and modeling tools utilizing high performance computing provide tantalizing promise to revolutionize our understanding of water on earth, and its use and redistribution by humans (NRC 2008).

Rising to meet these challenges will require key advances in the next generation of theory and infrastructure to advance simulation capabilities, informatics, instrumentation, and observational strategies, designed to operate at levels up to regional, continental and global extents. Such broad and comprehensive activity requires a community approach based on collaboration and synthesis across disciplines and between university, government, and industry organizations that study, regulate, and utilize water.

The Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) was incorporated in 2001 following extensive discussion and recognition by the water science community of the need to organize and extend the national and international research portfolio, particularly to develop shared infrastructure for investigating the behavior and effects of water in large and complex environmental systems. CUAHSI has adapted and refined a set of strategies expressed in multiple reports (e.g., NRC 1991, 2001, USCGRP-WCSG 2001, WEB – Gupta et al 2000, Millennium Ecosystem Assessment 2005) advancing a community approach for basic and applied research on critical current and emerging questions in water science, including biological, physical, chemical and social aspects. The need for fundamental scientific advances and practical solutions for the environmental and social dimensions of water is widely recognized, and investment should not be delayed until crisis conditions force rapid and inadequately prepared responses to problems such as insufficient water availability, ecosystem collapse, and water-related disasters and disease.
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MISSION

CUAHSI enables the university water science community to advance understanding of the central role of water to life, Earth, and society. CUAHSI focuses on water from bedrock to atmosphere, from summit to sea and from the geologic past, through the present and into the future.

CUAHSI will support this community to advance water science and to improve societal well-being by:

- developing, supporting, and operating research infrastructure
- improving and promoting access to data, information and models
- articulating and advocating priorities for community level water-related research and observations
- facilitating interactions among the diverse water research community
- promoting interdisciplinary education centered in water science
- translating scientific advancements into effective tools for water management and policy.
Dear Colleagues,

The above mission statement reflects the conclusions of a community process to answer some fundamental questions about our consortium:

Who are we as a consortium?
Who do we serve?
What do we do?
How do we do it?

Over the past nine years since our inception, it has become clear that the university water science community encompasses all directorates of the National Science Foundation, many other governmental agencies, and a wide range of industries. Water engages many and varied disciplines including earth and atmospheric sciences, ecology, engineering, economics, geography and other social sciences. Although currently funded by the Hydrologic Sciences Program within the Earth Sciences Division of the Geosciences Directorate of NSF, CUAHSI serves all scientists and engineers with primary interest in water as a core Earth system research area, and interacts with all governmental agencies having responsibility for investigation and management of water. Indeed, one of the greatest services that CUAHSI can perform is to bring together diverse scientists and engineers from universities with their counterparts in private companies, NGOs and governmental agencies to develop a more comprehensive understanding of water and its interactions with the Earth, ecosystems, and society.

In advancing our understanding of water, we must address organizational challenges as well as technological and intellectual ones. CUAHSI builds on core values of cooperation, collaboration, and scientific integrity to promote intellectual exchange among disciplines, and between academic and agency scientists to benefit science and society. We have made great progress in harnessing emerging technologies to improve data sharing, in bringing together disciplines such as near-surface geophysics and hydrology to assess the behavior and effects of water in novel ways, and in encouraging synthesis of hydrological, biogeochemical, social, and ecological data to address interdisciplinary questions. Given the importance of water to society, CUAHSI must enable the full spectrum of scientific development from basic discovery science through ultimate application. Our academic community spans that spectrum, and our consortium must reflect that diversity of approach. Thus, while basic research represents CUAHSI’s core focus, translational science—moving basic research results to practice—is also a key activity.
for the consortium. CUAHSI has worked closely with federal agencies, such as EPA, USGS and NOAA to identify and support national programmatic objectives and technical needs related to water, and will further engage the water resource community on an ongoing basis to identify emerging needs for development of tools, services, and standards. As a consortium, this engagement is at an organizational level different from member societies such as the American Society of Civil Engineers or American Water Resources Association as we are engaged at a broader community level across disciplinary boundaries (for example, developing services and standards facilitating integrated water science) rather than at the level of the individual or profession.

This strategic plan defines who CUAHSI is and what CUAHSI wants to do. This document outlines our vision for where we want to be several years from now, along with actions that will allow us to achieve that vision. The strategies we propose extend beyond current CUAHSI resources, and represent an ambitious growth trajectory which will require us to develop new funds and partnerships from multiple agencies. It is neither a science plan, which would address specific science questions, nor an implementation plan, which would address the details of how we would go about them. CUAHSI completed a science plan in 2007 (doi:10.4211/sciplan.200711). Here we articulate strategic objectives to achieve the science agenda.

Throughout the document, we have tried to simplify language to improve general readability and avoid redundancy. The terms used are meant to be inclusive: “scientists” means “natural scientists, engineers, and social scientists.” Everyone with a core research interest or educational focus in water and its interactions with the natural and built environment is included. Our strategic plan includes specific actions to diversify CUAHSI and engage the broader water science community.

We want to thank all those who have contributed to this strategic plan and to CUAHSI’s projects over the years, and look forward to welcoming more into the CUAHSI community. Together, we can accomplish great things.

Sincerely,

Richard P. Hooper
President and Executive Director

Lawrence E. Band
Chair of the Board, 2010
THE CUAHSI BOARD OF DIRECTORS met in April 2010 with a facilitator, Roy Savoian (Central Washington University) to draft this strategic plan. A subcommittee of the Board, together with the Executive Director, was responsible for editing the text that is contained in this report. Drafts of the strategic plan were reviewed first by members of CUAHSI’s six Standing Committees (Informatics, Instrumentation, Synthesis, Education and Outreach, Observations, and Research Applications), then by its Senior Advisory Council. This draft version was released for broader community comment, led by the representatives of the member institutions of CUAHSI. All comments were considered in the development of this document.

The strategic plan initiates an ongoing process of community review and input for all CUAHSI-led and CUAHSI-affiliated projects. CUAHSI staff develops status reports that contain planned activities for the coming year for review by each Standing Committee. Input from the standing committees is provided to the Board of Directors to assist them in prioritizing activities, including developing proposals for additional funding, in the succeeding year. The schedule for this review is coordinated with the annual cycle of NSF’s review of the Cooperative Agreement under which CUAHSI operates.
VISION

We envision a diverse and dynamic scientific community, enabled by shared infrastructure, developing an integrative understanding of interactions among water, earth, ecosystems, and society and the science necessary to achieve the sustainable management of water.

This vision is motivated by our recognition that a broad array of expertise is required to understand the behavior of water in the earth systems and the constituents it carries. The circulation of water influences the development of the physical, chemical, biological and social environment, which in turn strongly influences the distribution, flow, and composition of water. From a scientific perspective, each discipline—hydrology, ecology, atmospheric science, geomorphology, biogeochemistry, and the social sciences—brings its unique perspective to water but is insufficient in itself to answer fundamental questions of how water shapes the Earth, especially as the human footprint grows. Each discipline requires input from the others to make major advances. From an engineering perspective, traditional solutions, such as structural controls to prevent flooding or centralized waste treatment, each have both technological limitations and downstream consequences. Our ability to successfully manage engineered infrastructure while protecting health and the environment requires a more comprehensive understanding of interactions between water, humans, ecosystems, and the Earth. From a social science perspective, water is a critical resource for society, and provides a compelling subject for exploring basic aspects of human behavior, social organization, political stability, equity and decision making. Such inquiries can benefit from a more complete understanding of how natural and built systems operate and interact, and in turn provide insight into societal responses and constraints that influence engineering decisions. Ultimately, we seek a new water science that incorporates all of these disciplinary perspectives.

Our vision explicitly recognizes both the scientific questions associated with complex water systems and the societal benefits of developing comprehensive understanding of water in the Earth system. By achieving this understanding, our community will make important contributions to decisions that must be made to ensure reliable supplies of water for competing demands in the face of changing climate, land use, and population. Water—its quantity, composition, and the timing and intensity of its delivery—is a major aspect of global change. Yet, the prediction of precipitation and runoff patterns remains among the most uncertain in general circulation models used for prediction of weather and climate due, in part, to interactions among water, earth, ecosystems and humans that influence cycling between the land, ocean and atmosphere.

Critical water challenges, such as understanding and mitigating natural hazards, and predicting the long-term fate and effects of excess nitrogen inputs, require larger, longer, and more interdisciplinary investigations, and a higher degree of coordination between university and agency scientists than currently occurs in the United States. CUAHSI will strive to develop better integrated, longer term and more effective research capacity by expanding resources and leveraging existing programs to address these types of critical issues.
We envision CUAHSI taking a leadership role in uniting academic scientists to more effectively engage with scientists in government agencies and the private sector concerning all aspects of water in the natural and built environment. The behavior of water is governed by universal processes, but critical water issues have key elements that are often specific to sites or regions. Therefore, integration between academics and agencies may best be achieved by establishing a number of centers and/or consortia with regional or thematic focus, consisting of academic research groups and agency researchers and staff. The strategic long-term goals of the centers and consortia are to a) efficiently develop scientific and engineering advances in water science b) effectively transfer these advances into practice c) inform public policy makers, d) prepare the next cadre of specialists, and e) enhance scientific literacy of the general public. These goals will be accomplished through collaborative studies encompassing basic and applied research as well as implementation in practice. CUAHSI can facilitate the formation of regional consortia through enhancing communication among universities and agencies, topical prioritization, and sharing experiences in constructing such centers.

CUAHSI’s academic members have a great degree of diversity of expertise. Academic/agency partnerships would provide federal, state and local agencies with opportunities to more efficiently assimilate scientific and engineering advances in water science and will allow agencies to perform research and development in a flexible manner with direct engagement of a wide variety of academic experts and students.

Multidisciplinary centers and consortia will integrate scientific research, technology development, education, and knowledge transfer to increase the state of knowledge, public awareness, and governmental response to water issues.
ROLE OF CUAHSI

Scientific innovation often occurs through the focused activity and creativity of individuals and small teams of scientists, but is limited by the lack of community resources and interdisciplinary cooperation. CUAHSI’s role is to support the scientific community by facilitating the development of new ideas and tools, providing access to research infrastructure, coordinating community research efforts, disseminating research findings and products, and improving our ability to communicate with other scientists, with students and the public, and with public and private decision makers. CUAHSI will support individual researchers by developing and making available research infrastructure, and operating infrastructure for the benefit of the community. CUAHSI will work to articulate community priorities to science agencies, water management agencies, and the water practitioner community to facilitate collaboration, enhance the stature of water science, and to develop research objectives. We will disseminate the findings of academic research to managers, regulators and policy makers, and will foster the translation of research products into practical tools for engineering, decision making and management. CUAHSI will further support the academic community by developing educational material and modules, and improving effectiveness of communication with the public. These activities will augment the role of individuals and small academic teams by coordinating community activity, improving the accessibility and performance of large-scale and integrated research infrastructure, and providing a broad and ongoing platform for articulation of community objectives and communication with scientists from related disciplines, water managers and engineers, and scientific and mission agencies.

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CORE VALUES

As a community and science support organization, we hold these values:

- Technical excellence
- Objectivity
- Service to society
- Collaboration
- Transparency
- Democratic governance
- Support of individual and team research
- Community action

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STRATEGIC OBJECTIVES AND ACTIONS

TO MEET THE MISSION OF CUAHSI and to achieve the vision outlined above, we have identified five strategic objectives: Community and Governance, Service Development, Service Delivery, Outreach and Education, and Translational Science. These objectives reflect the development stage of the four programmatic areas of observatories, synthesis, informatics, and instrumentation that CUAHSI identified in 2002. Translational Science has been added as an additional objective in recognition of the barriers that exist to the incorporation of research results into operational tools. The objective of translational science is to overcome those barriers and make research results more useful to society.

Each strategic objective includes a set of actions with the overarching goal of achieving the CUAHSI vision over the coming years. Implementing these actions will require both significant growth of the resources available to the water science research community and leveraging resources through partnerships among federal agencies, private companies, and academia.

COMMUNITY AND GOVERNANCE

CUAHSI’s core constituency is academic scientists and engineers with primary research activity in water and its interactions within the Earth system, including biota and humans. As such, its governing structure must reflect the diversity of this constituency. CUAHSI is in a unique position to integrate the academic water science community, and to promote interactions with other scientific disciplines, government agencies, and policy makers. Building on our values of community action, objectivity, and scientific integrity, CUAHSI will enable a significantly more synthetic and effective approach to water science than exists today.

CUAHSI will:

1. Build community to achieve the major objectives outlined below through meetings, working groups, and web-based interactions
2. Diversify its membership and leadership to represent the broad interests and composition of the water research community
3. Advocate that key agencies make sustained, major investment in and access to community-level water research infrastructure
4. Enhance training opportunities to assist the membership in communicating with government and the public
5. Foster communication and develop community priorities through workshops, web tools, presentations and multiple media.
SIMULATION MODELS, SCIENCE AND PREDICTION

Computational codes that can accurately represent myriad interacting processes at high resolution are needed, along with the data required to use them anywhere across the continent. Ultimately, a package of codes and data that can simulate water everywhere at all times is needed. Significant advances over current capability will require academics, government researchers, and the private sector to come together and develop community models—this challenge is too big to be tackled by any one group alone, but it is too important to avoid.

A coordinated continental-scale water modeling capability developed as a suite of community codes and benchmark data sets is a goal of the CHyMP project. Meeting this goal would represent a major scientific achievement in integrating our understanding of water cycle dynamics, and it would have immediate value for water resources management. Such capability would also have great utility as a benchmark against which we would measure future progress. Innovations and new data that outperform the benchmark would be incorporated through a peer-review process, so the simulation capability would continuously improve through input from the community.

Progress on simulation capabilities will also require improvements in understanding the reasons why predictions deviate from observations. A community model would provide a common platform for testing hypotheses about sources of uncertainty, up- and downscaling, process representation, inaccurate forcing data, numerical issues, and other factors affecting prediction accuracy. These insights would be the basis for developing a community-wide focus on key areas for improvement. They would also provide an objective assessment of the need for directed field investigations and observations, both at selected locations and distributed over an observation network.
SERVICE DEVELOPMENT

Community services require extensive piloting and testing before a service can be precisely defined. This strategic objective reflects the need to continue to explore and prioritize new services for the water science community, and provide methods to incubate their conceptualization and development.

Community Modeling

There is a clear need to improve the efficiency of the development of hydrological models, and the use of models to advance understanding. Improved models will lead to more reliable and more precise predictions. A community modeling activity, similar to that in other fields such as the atmospheric sciences, would be a great benefit to the water research community. CUAHSI has organized a series of open workshops to define the scope and requirements of a Community Hydrologic Modeling Platform (CHyMP) to develop, disseminate and support community modeling tools and simulation models.

CUAHSI will:

1. Articulate benchmarks and standards for model development, testing, intercomparison and use
2. Provide specifications and evaluate a national spatial data infrastructure required for model parameterization, calibration and testing
3. Help to coordinate regional and national water modeling activities and advocate for the establishment of regional and national modeling centers
4. Organize open workshops to obtain community input and feedback for the further development of CHyMP
5. Enable community access to high-performance computing.

Instrumentation Technology

Advancements in sensors, wireless networking, and data communications hold the potential to provide data at unprecedented spatial and temporal resolution, contributing to the capacity to observe new patterns and to discover new processes. However, for the promise of advanced instrumentation to be realized, instrument development from an integrated circuit on the bench to a field-robust sensor package must be accelerated, and field scientists need to be continually training on new technologies. Delivering both of these services to the water science community has been identified as critical. CUAHSI will pursue several mechanisms for meeting these needs:

1. Evaluate priorities for new instrument development each year through support of the Instrument Node Model
2. Foster communication between academic researchers and technical groups for the development and testing of prototype instrumentation
3. Expedite translation of new technologies to widespread availability by providing forums for interactions between researchers, private companies, and public institutions

4. Communicate technological advances through short courses, workshops and other mechanisms for dissemination and technology transfer

5. Explore the development of an Instrument Facility to accelerate instrument access in collaboration with agencies, private industry or other partners.

**Observational Strategies**

Water science has long relied on a spectrum of observations from the laboratory, the field plot, the hillslope, the aquifer, and the experimental catchment to test theory. The need to develop more comprehensive understanding and predictive capabilities of water dynamics in Earth systems requires comparing observations across field sites, and scaling observations to regional and global extent. Such comparisons have been challenging to do systematically because they require coordination at a level above a project managed by an individual scientist or small groups of scientists. Specifically, investment in multiple field sites does not provide a network observational capacity without a mechanism of coordinating observations, informatics and analysis. CUAHSI will meet this challenge by:

1. Developing programs for community field campaigns geared to key interdisciplinary water science themes. Past examples include the BOREAS and FIFE projects, focusing on northern forest and grassland water, carbon and energy cycling. The resulting data sets have proven very valuable to a much larger science community than the active participants.

2. Improving accessibility to existing observational networks (e.g., CZO, NEON, LTER, ARS), including data and facilities access, improving comparability of datasets from disparate sites, and providing long-term maintenance of datasets

3. Exploring the utility of linking multiple observational networks into a broader environmental observation super-network

4. Evaluating the efficiency and completeness of existing observational networks, and recommending needs for new observation facilities to supplement existing capabilities

5. Enhancing the value and utility of data by assisting in the development of measurement standards.

**Synthesis**

Synthesis refers to the analysis of data to draw conclusions beyond the scope of the initial or local data collection effort, particularly to integrate findings to large scales (regional or national assessments), to evaluate new theory or models, and to assess interactions between disparate types of processes. Synthesis of disparate
OBSERVATIONS: THE FOUNDATION OF SCIENTIFIC UNDERSTANDING

Advances in our ability to predict hydrologic systems are predicated on observations to enhance understanding, test theories, and inform models. Advances that transcend specific sites require networks of long-term observatories across diverse climate, land use, ecosystems and geomorphology. Such observations must be accessible to the broad water science community from the outset; collected, processed, disseminated and archived with community access as a primary goal. CUAHSI has been advancing efforts to create community datasets since its inception. External initiatives including the Critical Zone Observatories, WATERS Testbeds, Water Sustainability and Climate sites, and the well-established Long Term Ecological Research sites are also taking great strides towards this goal. CUAHSI should take an active role in assisting these ongoing efforts to make relevant observations available to the community, while continuing to design strategies for new initiatives.

While keeping a grand vision of networked hydrologic observatories at the forefront, CUAHSI must also pursue observation strategies that yield community products in the near term. These include targeted field campaigns designed to create benchmark datasets, and grassroots efforts to organize the observation platforms that already exist. Benchmark datasets refer to those generated by targeted campaigns that are typically beyond the scope of individual PIs, that elucidate essential processes or properties, and that are disseminated widely for open interpretation and model development. Such benchmarking efforts should capitalize on the wealth of information that has been generated by decades of experimental watershed research. If we inspire researchers who are conducting ongoing site-specific field research to share data through the Hydrologic Information System, we will build and contribute to the backbone of an observatory network. At a minimum, such a grassroots network can be used to test principles of top-down observatory design, to assess the value of shared data, and to identify gaps and successes in observing platforms.
The Role and Need for Research Centers

The study of water cuts across multiple traditional disciplines and strongly influences ecosystems, economies, climate and human well being. In recognition of the cross-disciplinary nature of water, a number of universities are establishing centers and institutes for water research. The water science community has repeatedly called for dedicated facilities to support synthesis, thematic and regional activities in both fundamental water science and in critical applications, and to leverage and integrate academic and agency research.

In contrast to interdisciplinary panels formed by such groups as NSF and NAS/NRC to issue reports synthesizing current knowledge and recommending next steps, these facilities would support and execute synthesis research, yielding broad cross-comparisons of hydrologic systems and processes, and developing new integrated theories and quantitative models for the flow and distribution of water, its use by society, its interaction with ecosystems, and its role in shaping the Earth’s surface. These types of integrative activities are typically not well supported by individual research projects, which lack the infrastructure to solicit and leverage contributions by interdisciplinary groups of scientists. Dedicated staff is needed to harness the creativity of small groups of PIs working collaboratively on novel projects. Logistical support is needed to coordinate working meetings and facilitate communication, technical support is needed to assemble, manipulate, and integrate data, and staff researchers are needed to execute exploratory studies under the direction of groups working between disciplines. Ongoing, flexible support is needed to encourage and cultivate innovative initiatives at the interface of traditional fields. Academia offers a comprehensive scope of expertise and organizational flexibility extending well beyond those of any single agency. These factors position CUAHSI to take a leadership role in integrating hydrologic research in the United States.
information is essential to obtain comprehensive understanding of freshwater systems and the links between inland, coastal, and marine waters, as well as to evaluate outcomes that are critical to society. Examples of critical problems include short- and long-term variability in the availability and quality of water resources, and the integrity and resilience of ecosystems subject to changing climate and intensive human manipulation. Synthesis efforts typically involve diverse teams of scientists, and require extensive communication and coordination between people with different backgrounds. Synthesis in the water sciences can be achieved by both small and large consortia of investigators, but requires long-term effort and substantial logistical support. The National Center for Ecological Analysis and Synthesis (NCEAS) is one model involving a physical center where visiting working groups of scientists meet over a period of a few years on a specific topic, supported by resident post doctoral fellows. Additional synthesis efforts are needed to engage a wider array of water scientists using this or similar models. New synthesis centers in federal agencies with a major water focus (e.g., USGS, NOAA) provide strong potential to elevate interaction between academic and government scientists. To foster ongoing and emerging synthesis efforts, CUAHSI will:

1. Develop resources for sustained support for a broad range of synthesis activities, including exploratory efforts by small groups and coordinated efforts with governmental agencies
2. Facilitate interaction between disparate scientists interested in synthesis through venues such as focused workshops
3. Provide logistical support for investigator-initiated synthesis efforts
4. Pursue national and thematic research centers in collaboration with federal agencies and other institutions.

Regional Centers and Consortia

Major water science problems are often regional in nature, and require focused, interdisciplinary collaboration leveraging the strengths of different groups. In addition to working towards national synthesis and thematic water science centers, CUAHSI will work to connect universities with state and local agencies, NGOs and communities to develop or extend regional centers and consortia to provide integrated, long term capacity to study and solve critical environmental and societal water issues:

1. Develop regional workshops with university, agency and other public and private partners to identify and prioritize critical water science and management questions, the skills and resources necessary to develop solutions, and provide communication and coordination with national scale activity
2. Work with multiple agencies to develop the resources to effectively connect university faculty and students with federal, state and local agencies and stakeholders in well defined centers or consortia focused on water issues of particular local and regional importance.
SERVICE DELIVERY

Data Access
Data about water come from many sources—government agencies at all levels, academic sources, and non-governmental organizations. Understanding interactions between water and environmental systems requires many kinds of data including information on vegetation, soils, geology, built infrastructure and water use. Advancing water science requires discovering, integrating and analyzing data from multiple sources. In support of this strategic plan, CUAHSI will:

1. Develop and maintain search services for diverse sources of data and the underlying metadata catalogs (building on and extending from the Hydrologic Information System – HIS), including an access portal and coordination with providers of water-related information
2. Develop a mechanism for citation and use tracking to provide professional recognition for contributions to community data archives
3. Solicit community input on emerging data needs and facilitate access to new types of data
4. Coordinate development, promotion, and adoption of metadata standards between universities, governmental agencies, and the private sector for interpreted data products (e.g., potentiometric surfaces, areal estimations of precipitation, and input-output budgets).

Instrumentation Node Model
CUAHSI has successfully supported individual investigators in sharing their equipment and in providing hands-on workshops for others to learn about instrumentation. These services will be continued and expanded.

1. Support and expand the Hydrologic Measurement Facility (HMF) Distributed Node model for instrumentation access to scientists. Through the Instrumentation Committee, the Board will recommend priorities for new or expanded instrument nodes each year, and work to develop resources for implementation. We set a goal of building from the three current nodes to at least five, in the next five years.
2. Coordinate deployment of HMF node instrumentation, as well as instrumentation available from other sources (USGS, PASSCAL, UNAVCO, NEON, etc.) in CUAHSI-supported field campaigns
3. Evaluate alternatives (e.g., distributed nodes, centralized facility, other) for improving access to instruments.

OUTREACH AND EDUCATION
The next generation of water scientists must be well-educated in order to confront the complexities of future water issues. Our members are directly involved with graduate and undergraduate education and can also contribute content for K-12
The Hydrologic Information System (HIS) project is a collaborative effort involving several universities. It has pioneered the development of a services-oriented architecture for publishing, discovering, and managing time-series data collected at fixed points, such as records of stream discharge or water chemistry collected at gages. One critical element of this system is a standard transmission language for data, called WaterML, which is an XML-based scheme developed by David Valentine at the San Diego Supercomputing Center.

To be effective, a standard has to be adopted widely. CUAHSI fostered the development of a consistent standard for water data by requesting that key federal agencies, such as the USGS, consider using WaterML. CUAHSI provided a venue for the university water research community to approach these agencies in a coordinated manner. Furthermore, by sequentially requesting the assistance of USGS, EPA, NCDC and other agencies on using a services-based approach for publishing their data, CUAHSI catalyzed the formation of a standard much more quickly than would have occurred otherwise. WaterML has now been included in commercial software packages, such as the Kisters WISKI package used by many of the Florida Water Management Districts, the Australian Bureau of Meteorology, numerous European water agencies, and is under review as an international standard by a joint working group of the Open Geospatial Consortium and the World Meteorological Organization.
CUAHSI has successfully prototyped two “nodes” of a distributed, virtual Hydrologic Measurement Facility (geophysics and distributed fiber optic temperature sensing) and has a third node under development (mobile X-band radar), each supported by the National Science Foundation. Each instrumentation node is developed and championed by an individual researcher or team of researchers. CUAHSI supports access to this equipment through publicizing the service or by establishing a more formal allocation committee, if so desired. Deployment cost for the equipment is handled by the Node PI.

The Geophysics Node is primarily a ‘matchmaking’ service between geophysicists with potential solutions and field hydrologists with a problem. A key barrier to the use of geophysics by hydrologists has been the difficulty of assessing whether a given technique will work in a specific field setting. The Geophysics node provides travel grants for geophysicists to visit hydrologic field sites to assess the feasibility of a proposed technique. Unlike the other nodes, there is no cost for this service to the field scientist.

CUAHSI wishes to develop more such nodes, and, as we evaluate these nodes, identify barriers to use of services offered and develop solutions. We have a target of developing 5 new nodes in the next 5 years.
education. In addition, given the societal importance of water, key results from the academic water science community must be conveyed to the general public and policy makers at all levels of government.

1. Host and organize learning materials for all education levels, including courses, topical modules, laboratory exercises, and videos, that incorporate new research and encourage broad interest in environmental science.

2. Support member university workshops for local water science teacher training.

3. Survey, document, and articulate national needs for education on water science and sustainability.

4. Participate in international capacity-building activities in water science.

5. Build an online directory for access to local water experts.

6. Provide training for water scientists to communicate more effectively with the public and with policy makers.

7. Raise public awareness of water issues by communicating objective, scientific findings to non-academic audiences, including Congress, government agencies, citizen's groups.

**TRANSLATIONAL SCIENCE**

Given the dual challenges of population growth and climate change, there is a critical need to improve the ways in which water resources are used and managed. Research in water science is essential to such improvement. To be most effective, the water science community must evaluate the current modes of translating science into practice, and make improvements where needed.

The biomedical science community recently concluded that human health has not optimally benefitted from the traditional practice of biomedical science. In response, the National Institutes for Health is supporting a national consortium of research institutions designed to transform how biomedical research is conducted. The goals of this program are “to speed the translation of laboratory discoveries into treatments for patients, to engage communities in clinical research efforts, and to train a new generation of clinical and translational researchers” (http://www.ncrr.nih.gov/).

Clearly the water science community needs to better understand the needs and opportunities for translational science relating to water use and management. To these ends CUAHSI will:

1. Conduct a scientific national survey of water managers, regulators, practitioners, and scientists to determine the needs and opportunities for translational research in the water sciences.

2. Conduct a series of national and regional workshops to explore activities that CUAHSI could undertake to advance translational science in hydrology.
The action items described above are ambitious and far beyond what can be accomplished with existing resources. New activities that are prioritized by the community will require additional funding sources, and CUAHSI will work with public agencies and private foundations to identify required resources. Specific core actions, such as Operational Data Services, CHyMP, Synthesis, and Observatory Networks can be sequenced to build on one another, thereby demonstrating early success, and will contribute to case statements and strategies for additional resources to fulfill the full set of community goals. Instrumentation, Outreach and Education and Translational Science are on-going activities and will continue and grow as additional services come on-line.

The foundation for CUAHSI is an engaged and growing community of scientists. CUAHSI has successfully opened new lines of dialog among a portion of the water science community, primarily the segment of the community interested in physical hydrology and biogeochemistry. In the coming years, a high priority is to expand that community to engage ecologists, other earth scientists, and engineers and social scientists focused on water.

Operational data services will enable the community to publish data from multiple field sites to support larger scale modeling exercises and other synthesis activities. Instrumentation Nodes provide access to advanced instrumentation. One potential outcome from these activities is a more specific design for a network of observatories. One or multiple models can be used to sharpen the core network data requirements to resolve critical community science questions, and define the instrumentation required for collection of comparable data sets across the network. Instrumentation nodes will continue to be developed in parallel with this sequence to improve the capability of individual scientists performing independent research.
CRITICAL SUCCESS FACTORS AND METRICS

CRITICAL SUCCESS FACTORS ARE KEY areas in which CUAHSI must perform well on a consistent basis in order to achieve its mission and vision within fiscal constraints. Metrics gauge progress on the Critical Success Factors and are linked to the strategies noted in parentheses below. These metrics will be linked to specific actions in the implementation plan.

SCIENTIFIC IMPACT
(Service Development, Service Delivery, Translational Science)
Number and impact (e.g., citation number) of papers acknowledging CUAHSI support
CUAHSI instrumentation services
CUAHSI Data Services

SOCIETAL IMPACT
(Community and Governance, Service Delivery, Outreach and Education, Translational Science)
Number, impact and diversity of briefings held for federal and state officials
Number and impact of presentations to non-academic audiences
Number of data sets collected by non-academic entities published using HIS
Participation in advisory bodies
Number of citations of CUAHSI activities in popular press

EDUCATION IMPACT
(Service Delivery, Outreach and Education)
Number of downloads of education material
Number of universities adopting interdisciplinary water curricula referencing CUAHSI reports
Number of short courses, cyberseminars and other professional development activities offered, and number of participants attending.

INTERNATIONAL IMPACT
(Number of international scientists engaged in CUAHSI activities)
Use of CUAHSI products and services by international agencies
Solicitation of input from CUAHSI into international water research, education, and management initiatives

COMMUNITY RECOGNITION AND ENGAGEMENT
(Community and Governance, Service Development)
Attendance at CUAHSI-sponsored science meetings, workshops
Attendance at CUAHSI Town Hall meetings
Extent of distribution of CUAHSI emails and newsletters
Number of website hits and downloads
Participation in CUAHSI standing committees and related technical panels

COMMUNITY EMPOWERMENT
*(Community and Governance, Translational Science)*
Number and diversity of academic scientists participating in CUAHSI-led outreach activities
Number of regional outreach activities, and number of attendees at these events
Number of articles in popular press (e.g., op-ed pieces) written by scientists who participated in CUAHSI outreach workshops

AGENCY RECOGNITION AND ENGAGEMENT
*(Community and Governance, Service Development, Outreach and Education, Translational Science)*
Number and scope of memoranda of understanding and cooperative research and development agreements
Agency participation in CUAHSI events
Agency use of CUAHSI products and services
Number of agencies financially supporting CUAHSI activities

MATURATION OF SERVICES
*(Service Development)*
Number of services progressing from pilot to operational status
Number of potential services identified for piloting

USE OF SERVICES
*(Service Development and Service Delivery)*
Number and diversity of scientists served
Number of papers citing CUAHSI services
Number of proposals generated through use of CUAHSI services

A WELL-FUNCTIONING CONSORTIUM
*(Community and Governance)*
Number and diversity of attendees at annual meeting
Member representative participation in annual meetings, nominations, and elections
Composition of the Board of Directors, standing, and ad hoc committees to reflect diversity of discipline, career status, and demographics of community
Standing committee attendance and regular reporting to the Board of Directors
Board of Directors’ training and assessment; management performance review
Sponsor, community, and employee satisfaction
Audit outcomes and findings; federal compliance
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Colorado School of Mines
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Cornell University
Dartmouth College
Drexel University
Duke University
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Plymouth State University
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Smith College
Smithsonian Environmental Research Center

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CIMA Research Foundation (Italy)
Commonwealth Scientific and Industrial Research Organisation (Australia)
Queensland University of Technology (Australia)
Swedish Hydrological Council
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Inside Front Cover: Unknown stream, Alaska, U.S., courtesy of Aaron Packman
Page 2-3: Lake in Pirin National Park, Bulgaria
Page 8: Chicago River, Chicago, Illinois, U.S.
Page 11: Glacial ice melt, unknown location
Page 12: Clepsydra Geyser, Yellowstone National Park, Montana, U.S., courtesy of Aaron Packman
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Page 28: First row - Left: Courtesy of Wayne Wurtsbaugh and ASLO
Right: Courtesy of Robert Rice
Second row - Left: Courtesy of Jennifer Jacobs
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Third row - Left: Headwaters of the Rio Mapocho, courtesy of Jennifer Packman
Right: Courtesy of Robert Rice
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