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WATER SCIENCE & TECHNOLOGY BOARD

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20TH ANNIVERSARY ISSUE

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

WATER SCIENCE AND TECHNOLOGY BOARD

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Edited and designed by
Jeffrey Jacobs and Ellen de Guzman.

The National Academies' New Address

In 1999 the Academies purchased a parcel of land in Northwest Washington D.C. known as 500 5th Street. The property is bordered by 5th, 6th, and E Streets and a district firehouse on F Street. The site is diagonally across from the MCI Center and the National Building Museum and is convenient to three Metro stations (Archives/Navy Memorial, Gallery Place/Chinatown, and Judiciary Square). In June 2002, after a three-year period of construction, the WSTB and other Academies offices took occupancy of a new eleven-story building, pictured below.

Along with staff offices and workstations, the building includes 16 state-of-the-art conference rooms, a 175-person lecture hall with broadcast capabilities, a full service cafeteria, a credit union, a library, a travel office, a fitness center, and exterior terraces.

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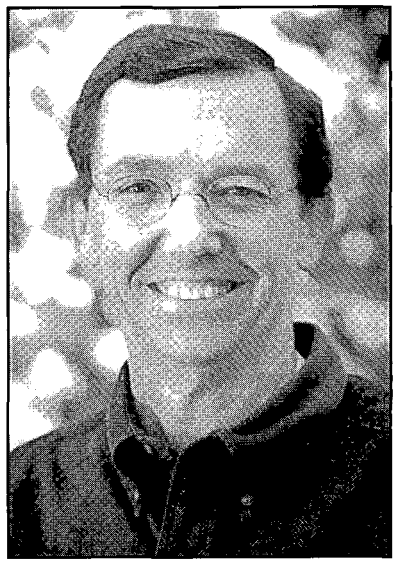
MESSAGE FROM THE CHAIR



Dear Friends:

This Annual Report marks the twentieth anniversary of the Water Science and Technology Board (WSTB) (1982-2002). The WSTB's mission is to "improve the scientific and technological basis for resolving important questions and issues associated with the efficient management and use of water resources." Clearly, this is a vital activity, and a principal task of the WSTB is to ensure that our studies remain focused on this mission. I believe the WSTB's longevity and value result from its philosophy of serving the government and the nation, rather than serving as an advocate for any particular group, and by addressing significant crosscutting issues that encompass the multiple dimensions of water resources including scientific, engineering, economic, and policy components.

The WSTB's success in these endeavors is marked by several factors: an increasing willingness of the U.S. Congress to call upon the WSTB's advice through congressionally-mandated studies; the high visibility in the national media of several WSTB studies; a sustained interest of several federal agencies and other sponsors in supporting WSTB studies; and a continued ability to engage a wide variety of highly-respected scientists, engineers, and scholars to WSTB study committees. The WSTB takes pride in these achievements, and we look forward to a future in which the WSTB continues to provide credible and objective advice for the sound management of the nation's water resources.

The WSTB gives high priority to strategic planning, and we retreat biennially to reflect on present and emerging factors influencing water science, technology, and policy issues within our purview. The result is a suite of several studies we try to develop that complement the studies normally requested by the government. In this way the WSTB aims to remain proactive in identifying new topics that have not yet received the full attention of sponsoring agencies. Our recent studies on bioavailability of contaminants in soils in sediments and privatization of water services are examples of activities that were initiated during our strategic planning sessions.

As with any organization, excellence can only be maintained through a regular process of planning and review. The NRC periodically reviews the activities of its various units, and an external review of the WSTB was completed early in 2002 by its parent Division on Earth and Life Studies. I am pleased to say that the WSTB received a glowing report. In my communications with the review group, I stressed that our important future tasks include the challenges of providing sufficient quantities of high-quality water to a growing population and the concerns for maintaining the security of our water supply systems. In this connection, WSTB vice-chair Joan Rose, myself, and other WSTB members have spoken publicly about these security issues, and I gave congressional testimony in support of an effort to begin an analysis of our vulnerabilities and possible protective measures.

With respect to concerns about the provision of adequate amounts of high-quality water, the WSTB recently spent considerable time preparing an "agenda for water resources research for the twenty-first century." The resultant report, published last year, focuses on the adequacy of future water supplies. The WSTB believes that the implications of dramatic population increases in the United States, largely in urban areas, present the greatest challenges to our nation's ability to provide sufficient quantities of high quality water for potable use. These needs often compete with the demands of agriculture, industry and other economic sectors, and ecosystem protection. These challenges will be heightened by factors such as an unpredictable economic future in a globalizing economy, the introduction of new technologies with unknown potential side effects, security-related

concerns, a desire to preserve and in many cases restore aquatic ecosystems, the need to repair and expand our public works infrastructure, and the impacts related to climate variability and change.

Issues and problems arising from these factors are complex and demand a systems or regional (or "watershed" in our field) management approach, including better data and the collaboration of experts from many disciplines. The relationships between water and agriculture in the West present a good example of the manifestation of many of these factors. Off-stream uses of water for irrigated agriculture account for over 80 percent of water use in the West, a rapidly-growing region that is arid. As farmers continue to use large amounts of federally-supplied and subsidized water, nearby cities apply advanced technologies at high costs to provide potable water for a burgeoning population. Stressed river systems are challenged to meet the needs of traditional users, such as hydropower energy distributors, while also supplying water for growing cities and maintaining instream flows to meet the needs of aquatic ecosystems and endangered species. The issues associated with striking the proper balance between agriculture, urban, and environmental interests in the West are numerous and complex, and exemplify the problems that could be addressed through assessments by the WSTB, and the National Research Council more broadly. In addition to water management's scientific and technological dimensions, there are important issues related to policy shifts and organizational capacities within our nation's water resources institutions. As these latter issues are unfortunately not often carefully evaluated, research focusing on the nation's water management institutional structure should receive much more attention in the twenty-first century than in the past.

The WSTB's success depends upon a highly dedicated staff and the work of many volunteers. I am thankful for such outstanding support and, as always, I welcome your comments on the WSTB's mission and activities.

Richard G. Luthy
CHAIR

OVERVIEW

Organizational Context

The Water Science and Technology Board (WSTB) is a multidisciplinary group of experts available to advise the government and the nation on water resources issues. It is a unit of the National Research Council (NRC), the operating element of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. These organizations, collectively referred to as The National Academies, comprise the most important independent scientific advisory bodies available to the U.S. Government.

The National Academy of Sciences was chartered by Congress in 1863. It was initially composed of 50 of the nation's eminent scientists. In addition to being honored for their achievements, these scientists were required to advise the government on technical matters. The Academy's charter specified that the scientists would not be compensated for their labor, but only for direct costs incurred in carrying out studies. Since its inception, the Academy's financial and organizational independence from the government has enabled it to provide scientific advice unbiased by political influences.

The onset of World War I increased the government's need for scientific advice. In response to President Woodrow Wilson's request to broaden the scientific expertise available to the government, the Academy created the NRC in 1916. Wilson envisioned an institutional mechanism through which large numbers of scientists and engineers—Academy members and nonmembers alike—could provide impartial technical advice. Today, about 10,000 scientists and engineers serve the nation each year by their voluntary participation in NRC activities.

The National Academy of Engineering was created in 1964 to recognize the importance of engineering in technological advancement. The Institute of Medicine was created in 1970 to address matters affecting the status of medicine and the adequacy of national health services. Today, the two academies and the institute serve as honorary societies while the NRC carries out the work of advising the government.

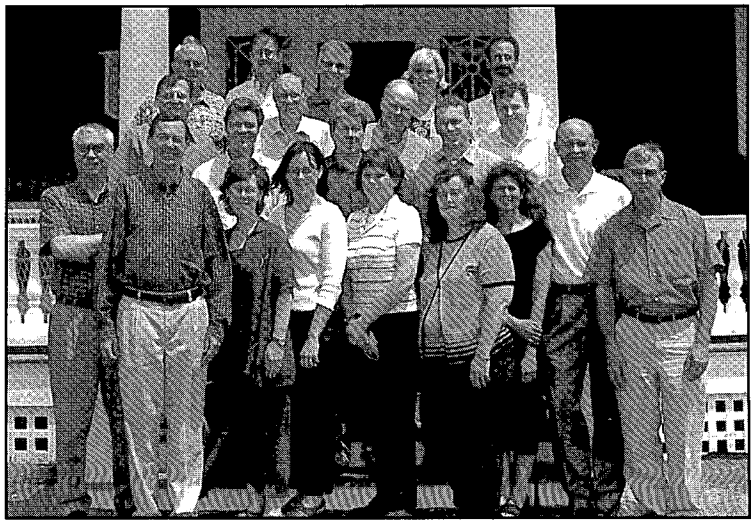
As the NRC grew in response to the increasing need for unbiased scientific information, it was divided into commissions (or, today, divisions), which were subdivided into boards, to guide studies in specific scientific disciplines. Reports issued by various units within the NRC cover a vast array of topics, from the development of dietary standards, to research agendas of a variety of programs, to the assessment of health consequences of various military activities. In the past year, the Academies have assumed an increased role in helping the nation avert and prepare for terrorist activities.

Created in 1982, the WSTB oversees studies of water issues. Volunteers from universities, government, industry, and other organizations currently serve as board members for staggered three-year terms, thus maintaining annual rotation of membership. Several hundred other volunteers serve as study committee members, as report reviewers, and as government agency liaisons to the WSTB.

Studies

Studies carried out by the WSTB are usually initiated in one of two ways. Some studies are undertaken at the direct request of a government agency or the U.S. Congress. Alternatively, the WSTB may identify a topic of pressing concern and seek support for a study from federal agencies and other organizations. The principal products of studies are written reports. These reports cover a wide range of water resources issues of national concern. The following three recently-issued reports illustrate the scope of the WSTB's studies.

- *Envisioning the Agenda for Water Resources Research in the Twenty-First Century* was released in June 2001 after two years of deliberation at WSTB meetings. This self-generated study was born out of WSTB members' concerns about the adequacy of future water supplies for a growing population, the sustainability and restoration of aquatic ecosystems, the adequacy of the physical infrastructure and the institutional water resources framework, and whether the current water resources research establishment can provide sufficient knowledge to address emerging problems. Forty-three research recommendations are made in the areas of water availability, water use, and water institutions. The report stresses the need for a new federal commitment to research, greater coordination among the agencies supporting and conducting research, and additional research funds. Congress subsequently requested a follow-on study to determine the adequacy of the nation's investment in water resources research.
- *The Missouri River Ecosystem: Exploring the Prospects for Recovery* resulted from a study conducted at the request of the Environmental Protection Agency and the Corps of Engineers. The nation's longest river, the Missouri River and its floodplain ecosystem experienced substantial environmental and hydrologic changes during the twentieth



Members and staff of the Water Science and Technology Board at the J. Erik Jonsson Center, Woods Hole, Massachusetts. Front row (from left to right): Richard Luthy, Richelle Allen-King, Laura Ehlers, Diane McKnight, Jeanne Aquilino, Christine Moe, Rhodes Trussell, James Crook; 2nd row: Robert Perciasepe, Jerald Schnoor, Steven Gloss, Jeffrey Jacobs; 3rd row: Gregory Baecher, John Letey, Rutherford Platt, Mark Gibson; 4th row: Stephen Parker, William Logan, Kenneth Bradbury, Joan Rose, Peter Gleick.

century. The contemporary context of Missouri River dam and reservoir system management is marked by strong differences among stakeholders regarding the river's proper operations regime. The management agencies have thus been challenged to determine the appropriate balances among these competing interests. A WSTB committee reviewed the ecological state of the river and floodplain ecosystem, scientific research of the ecosystem, and the prospects for implementing an adaptive management approach, all with a view toward helping move beyond scientific and other differences. The committee issued its report in early 2002, which notes that continued ecological degradation of the ecosystem is certain unless some portion of pre-settlement river flows and processes were restored. The report also includes recommendations to enhance scientific knowledge through carefully planned and monitored river management actions, and a recommendation that the U.S. Congress enact a Missouri River Protection and Recovery Act.

- *Assessing the TMDL Approach to Water Quality Management* recommends a more science-based approach to improve the nation's major program that requires states to clean up over 21,000 of the nation's lakes, rivers, and other bodies of water. The report is the culmination of a fast-track study requested by Congress in early 2001 to assess the scientific basis underlying the Total Maximum Daily Load (TMDL) program. Implementation of the EPA's TMDL final rule was suspended until this study and other related activities could be completed. The report considers the quantity and quality of information required in each major step of the TMDL process, from standard setting and listing of impaired waters to TMDL development and implementation. In particular, the report calls on the EPA to implement a two-step process that puts certain waters on a preliminary list before moving them to the final 303d list of those requiring cleanup. Also, the greater use of statistical approaches for the design of monitoring programs and for the analysis of data to determine if standards have been violated is promoted. So that TMDL plans are not halted because of a lack of scientific information, the report recommends that states adopt an approach called adaptive implementation, whereby plans are periodically assessed and revised using new data and scientific tools.

Symposia and Lectures

In addition to conducting studies and producing reports, the WSTB occasionally hosts symposia for calling attention to and discussing current water issues. A recent example is symposium convened in January 2002 concerning water supplies and security, prompted by the terrorist attacks against the United States on September 11, 2001. This symposium brought together national experts and prompted exchange of ideas concerning a matter of importance and urgency. The WSTB also hosts an annual lecture in honor of Dr. Abel Wolman, a pioneer in the water supply and sanitation fields. In 2001, Dr. Perry

McCarty, Professor Emeritus of Stanford University, Stanford, California lectured on "Water Technology Development in the 21st Century: What Should We Do, Not What We Can Do." In 2002, Dr. Rita Colwell, director of the National Science Foundation, lectured on "A Global Thirst for Safe Water: The Case of Cholera."

Meetings

The WSTB generally meets three times each year. At WSTB meetings, staff and members discuss ongoing projects, do strategic planning, and develop new initiatives. In addition to providing time for WSTB business, the meetings foster communication within the water resources community. Most agencies with water-related responsibilities have liaison representatives who regularly attend the meetings.

Website

The WSTB can be accessed on the world-wide web through http://www.nationalacademies.org/wstb. The website contains WSTB member and staff contact information, newsletter archives, information about current and future projects, and links to published lectures and reports.

Staff

The WSTB is supported by a 12-member staff in Washington, D.C. The staff organizes meetings, helps formulate study topics and select committee members, maintains contact with government agencies, conducts research, provides editorial guidance for reports, facilitates review of reports, and produces a newsletter.

Financial Support

For 2001–2002, financial support for the WSTB's activities totaled over $2.5 million. Support was provided by internal NRC funds and the following numerous and diverse sponsors:

- **Federal government agencies:** Department of Agriculture (Agricultural Research Service; Cooperative State Research, Education, and Extension Service; Natural Resources Conservation Service; and Forest Service); Department of Defense (Corps of Engineers; U.S. Air Force; U.S. Army; U.S. Navy); Department of Energy; Department of Health and Human Services (Agency of Toxic Substances and Disease Registry and National Institute for Environmental Health); Department of the Interior (Bureau of Land Management; Bureau of Reclamation; National Park Service; U.S. Geological Survey); Environmental Protection Agency; National Aeronautics and Space Administration; National Oceanic and Atmospheric Administration (National Weather Service Office of Global Programs); National Science Foundation.
- **State and municipal governments and water utilities:** American Water Works Company, Inc., California Water Service Company, Severn Trent Environmental Services, the State of Washington, and the University of California.
- **Corporations, associations, and foundations:** the Allegheny Conference on Community Development and the Gas Research Institute.

"Most everyone we talked with felt that WSTB does a good job in selecting the best scientific and technical experts both for board and committee memberships. As stated by one Academy member: 'The board and its committees always seem to reflect a diversity of opinion, geographical location, and institutional affiliation. I have always been impressed with the care that the WSTB and staff take to ensure that there is representation from the private sector and from various levels of government as appropriate.' To their credit, the WSTB seems willing to reach beyond the core water science and technology community in recruiting volunteers ..."

Evaluation report by the NRC's Division on Earth and Life Studies

CURRENT STUDIES

The Water Science and Technology Board's key asset in conducting its studies is the participation of the nation's leading experts in water science, engineering, and policy. This network enables the WSTB to address critical water resources problems using contemporary scientific and engineering knowledge.

The WSTB's studies are conducted by committees of experts appointed to work under the board's supervision. When a study begins, the WSTB typically gathers 60 to 100 or more committee member nominations from several sources and then selects the best-qualified experts for committee service. Committee size generally ranges from fewer than 10 to 15 or more members, depending on the nature of the problem and study design.

Study committees typically meet several times a year to gather information and to discuss issues related to the problem or issue under investigation. The committee concludes its study by publishing a report. The following summaries describe the current suite of the WSTB's activities (as of October 2002).

Assessment of the Corps of Engineers Methods of Analysis and Peer Review Procedures for Water Resources Project Planning

In Section 216 of the Water Resources Development Act of 2000 (WRDA 2000), Congress directed the Corps of Engineers to arrange for a National Academies assessment of the agency's peer review procedures and methods of analysis. To carry out this charge, the Water Science and Technology Board, working in collaboration with the Ocean Studies Board, appointed a coordinating committee and four study panels—peer review, methods for project planning, river basin and coastal systems planning, and adaptive management—to evaluate different aspects of the Corps' planning. The coordinating committee and study panels are collectively known as "The 216 Studies" after the authorizing section of WRDA 2000. The panel on peer review procedures completed its report in 2002, and the other three study panels and the coordinating committee will complete their reports in mid-2003.

Coordinating Committee

Members of the coordinating committee include the chairs of the four study panels, plus several other water resources experts. The coordinating committee is charting the progress of the four study panels to ensure consistency in their approaches to their studies, as well as to minimize gaps or overlaps in the topics they are assessing. Members of the coordinating committee are also attending meetings of the study panels to help ensure beneficial exchanges of ideas and preliminary findings.

The coordinating committee's report will synthesize the findings and recommendations of the four study panels and will provide advice on implementing those recommendations. The synthesis report will also identify overarching themes, issues, or recommendations that emerge from the panels' studies, including possible future roles for the Corps in sustainable management of inland and coastal waters.

Funding for the coordinating committee and the study panels is provided by the Corps of Engineers. Jeffrey Jacobs is the coordinating committee's study director and Ellen de Guzman is the project assistant. Members of the coordinating committee are:

Leonard Shabman, *Chair*, Resources for the Future, Washington, D.C.
Gregory B. Baecher, University of Maryland, College Park
Donald F. Boesch, University of Maryland Center for Environmental and Estuarine Studies, Cambridge
Robert W. Howarth, Cornell University, Ithaca, New York (through September 2002)
James K. Mitchell, Virginia Polytechnic Institute and State University, Blacksburg
Geraldine Knatz, Port of Long Beach, Long Beach California
Larry A. Roesner, Colorado State University, Fort Collins
A. Dan Tarlock, Chicago Kent College of Law, Chicago, Illinois
Victoria J. Tschinkel, Landers and Parsons, Tallahassee, Florida
James G. Wenzel, Marine Development Associates, Inc., Saratoga, California
M. Gordon Wolman, Johns Hopkins University, Baltimore, Maryland

Panel on Peer Review

One result of recent criticisms of the Corps of Engineers was a call for the Corps' planning studies to be subjected to a greater degree of independent review, which as noted above, eventually resulted in a request from Congress for the National Academies to recommend ways to improve the review procedures of Corps studies. The panel on Corps peer review procedures began and completed its study earlier than the other study panels. The panel held its first meeting in October 2001, two additional meetings in early

2002, and issued its report in July 2002.

One of the report's recommendations is that the Corps' more complex and costly planning studies be subjected to independent, expert review. The decision regarding whether to submit a planning study to external review should be made by an Administrative Group for Project Review that should be housed either within the office of the Assistant Secretary of the Army for Civil Works or the office of the Chief of Engineers. Less complex and less costly studies should be formally reviewed by internal review panels, which should usually consist of a balance of Corps of Engineers staff and external experts, or be reviewed according to the current procedures. The administrative group should also prepare a summary document for review panels that explains a planning study's key assumptions and methods. The administrative group should receive occasional input and advice from a Review Advisory Board.

Jeffrey Jacobs was the study director and Jon Sanders was the project assistant. Panel members were:

James K. Mitchell, *Chair*, Virginia Polytechnic Institute and State University, Blacksburg
Melbourne G. Briscoe, Office of Naval Research, Arlington, Virginia
Steven J. Burges, University of Washington, Seattle
Linda A. Capuano, Honeywell Electronics, San Jose, California
Denise Fort, University of New Mexico, Albuquerque
Porter Hoagland, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts
David H. Moreau, University of North Carolina, Chapel Hill
Craig E. Philip, Ingram Barge Company, Memphis, Tennessee
John T. Rhett, consultant, Arlington, Virginia
Richard E. Sparks, University of Illinois, Urbana-Champaign
Bory Steinberg, Steinberg and Associates, McLean, Virginia

Panel on Methods and Techniques of Project Analysis

The Corps of Engineers uses a body of planning procedures known familiarly as "The Principles and Guidelines" (P&G). Formulated in 1983 by the U.S. Water Resources Council, this document guides the planning for individual federal water projects. Other Corps planning documents and policies, such as the Corps 2000 Planning Guidance Notebook, draw upon and are consistent with the 1983 P&G.

This panel is reviewing the Corps' formulation and evaluation techniques and methods for individual water projects that are explained in the P&G. In addition to evaluating the Corps' implementation of the P&G, the panel is also considering Corps planning methods and techniques such as benefit–cost analysis, and development and application of models. The panel is assessing the use of these methods in light of state-of-the-art practices, as well as practices of other federal agencies and the private sector. The panel will make recommendations for improving Corps methods and techniques and may make recommendations regarding areas of the P&G in need of modernization.

Jeffrey Jacobs is the study director and Ellen de Guzman is the project assistant. Its members are:

Gregory B. Baecher, *Chair*, University of Maryland, College Park
John B. Braden, University of Illinois, Urbana-Champaign
David L. Galat, University of Missouri, Columbia
Gerald E. Galloway, International Joint Commission, Washington, D.C.
Robert G. Healy, Duke University, Durham, North Carolina
Edwin E. Herricks, University of Illinois, Urbana-Champaign
Catherine L. Kling, Iowa State University, Ames

"Throughout the years, the Corps has enjoyed a productive and enriching relationship with the NRC and its WSTB. The reports produced by the WSTB have been used to help us re-evaluate our water resources management policies and to improve our processes and procedures. In a time when water resources management and development is one of the nation's most complex endeavors, the recommendations and suggestions of the expert staff of the WSTB and the excellent committees assembled by the WSTB are truly welcome. We look forward to continuing our professional relationships with the WSTB as we strive to provide water resources projects that are economically and environmentally sustainable."

James Johnson
Chief of Planning, Civil Works
U.S. Army Corps of Engineers

Some members of the Panel on Methods and Techniques of Project Analysis of the Corps of Engineers 216 study group at the St. Anthony Falls on the Mississippi River, Minneapolis, Minnesota.

Linda A. Malone, College of William and Mary, Williamsburg, Virginia
Ram K. Mohan, Blasland, Bouck, and Lee, Inc., Annapolis, Maryland
Max J. Pfeffer, Cornell University, Ithaca, New York
Doug Plasencia, Kimley-Horn and Associates, Phoenix, Arizona
Denise J. Reed, University of New Orleans, Louisiana
Jan A. Veltrop, Harza Engineering (retired), Skokie, Illinois

Panel on River Basins and Coastal Systems

In addition to planning individual, site-specific water projects, the Corps of Engineers is also promoting the management of those projects in a systems, or "watershed," context. This panel is reviewing the Corps' efforts in managing systems infrastructure in the nation's river basins and coastal systems, which includes multiple purpose formulation and evaluation methods, trade-off analysis, interagency cooperation, scheduling the use of existing facilities, and the spatial integration of water development plans, including effects of other projects in the region. For existing programs, some of these operational outputs are established in law; however, changing economics, science, and public values suggest that new approaches to managing projects in a systems context may need to be considered.

John Dandelski of the Ocean Studies Board is the study director and Julie Pulley of the Ocean Studies Board is the project assistant. Committee members are:

Larry A. Roesner, *Chair*, Colorado State University, Fort Collins
Gail M. Ashley, Rutgers University, Piscataway, New Jersey
Denise L. Breitburg, The Academy of Natural Sciences, St. Leonard, Maryland
Virginia R. Burkett, U.S. Geological Survey, Lafayette, Louisiana
Joseph J. Cordes, George Washington University, Washington, D.C.
Robert G. Dean, University of Florida, Gainesville
John A. Dracup, University of California, Berkeley
William J. Mitsch, Ohio State University, Columbus
Robert E. Randall, Texas A&M University, College Station
A. Dan Tarlock, Chicago Kent College of Law, Chicago, Illinois
Peter R. Wilcock, Johns Hopkins University, Baltimore, Maryland

Panel on Adaptive Management for Resources Stewardship

In an effort to balance the demands of competing stakeholder groups and to better integrate scientific knowledge into decisionmaking, the Corps of Engineers has been striving to operate some of its systems and projects consistent with the paradigm of adaptive management. The adaptive management paradigm and an emphasis on monitoring and operational changes in some ways represents a novelty for the Corps, an agency historically primarily charged to construct civil works projects. Successful implementation of adaptive management also poses scientific and political challenges. Nonetheless, the concept holds promise for promoting more flexible operations and ecosystem restoration, and the Corps has been employing the concept in systems such as the Greater Everglades Ecosystem and the Missouri River and reservoir storage system.

This panel is reviewing the Corps' efforts in applying adaptive management concepts to project and program

planning and operations, and is identifying adaptive management's potential as well as its limitations. The panel is seeking ways in which the Corps might usefully implement adaptive management, as well as identifying barriers to its implementation.

Jeffrey Jacobs is the study director and Jon Sanders is the project assistant. Committee members are:

Donald F. Boesch, *Chair*, University of Maryland Center for Environmental Sciences, Cambridge
Henry J. Bokuniewicz, State University of New York, Stony Brook
G. Edward Dickey, consultant, Baltimore, Maryland
Holly D. Doremus, University of California, Davis
Carlton H. Hershner, Jr., Virginia Institute of Marine Science, Gloucester Point
Frederick J. Hitzhusen, Ohio State University, Columbus
Charles D. D. Howard, Charles Howard and Associates, Ltd., Victoria, British Columbia, Canada
William R. Lowry, Washington University, St. Louis
Richard de Neufville, Massachusetts Institute of Technology, Cambridge
Barry R. Noon, Colorado State University, Fort Collins
Thayer Scudder, California Institute of Technology, Pasadena
Robert W. Sterner, University of Minnesota, St. Paul

Assessment of Water Resources Research

In early 2002, Congress mandated the Department of the Interior to commission the WSTB to undertake an assessment of water resources research funded by federal agencies and significant non-federal organizations. This new study is effectively a follow-up activity to the 2001 WSTB report, *Envisioning the Agenda for Water Resources Research in the Twenty-First Century* (see page 28), which identifies topics in need of additional study to better address the nation's water problems. The new committee is defining those scientific activities that constitute water resources research and identifying significant federal and non-federal sponsors of such research. Liaisons to the federal agencies will help describe the nature of their water resources research activities and programs, including approximate budget information. Using this information, the committee will assess the adequacy of the nation's investment in water resources research, with an emphasis on identifying areas that may be receiving inadequate attention to address emerging needs.

A second task of the committee will be to address the need to better coordinate the nation's water resources research enterprise. This will be pursued with recognition that some research is of interest to multiple entities and some is not. The goal will be to identify institutional options for improved coordination, prioritization, and implementation of research in water resources. The final report will be published in late 2003.

This study is sponsored by the U.S. Geological Survey. The study director is Laura Ehlers and the project assistant is Anita Hall. Committee members are:

Henry J. Vaux, *Chair*, University of California Division of Agriculture and Natural Resources, Oakland
J. David Allan, University of Michigan, Ann Arbor
James Crook, CH_2M Hill, Boston, Massachusetts
Joan G. Ehrenfeld, Rutgers University, New Brunswick, New Jersey
Konstantine P. Georgakakos, Hydrologic Research Center, San Diego, California
George R. Hallberg, Cadmus Group, Watertown, Massachusetts
Debra S. Knopman, RAND, Arlington, Virginia
Lawrence L. MacDonnell, Porzak, Browning & Bushong, Boulder, Colorado
Thomas K. MacVicar, MacVicar, Federico & Lamb, West Palm Beach, Florida
Rebecca T. Parkin, George Washington University, Washington, D.C.
Franklin W. Schwartz, Ohio State University, Columbus
Amy K. Zander, Clarkson University, Potsdam, New York

"The Water Science and Technology Board provides an excellent opportunity for scientists, academics, and practicioners to engage in meaningful dialogue on current water resources issues and future challenges. The WSTB report, *Envisioning the Water Resources Research Agenda for the Twenty-First Century*, focuses attention on the challenges facing water management and the expanding need for investments and improvements in research necessary for us to meet those challenges. We have used it to guide our actions and to educate others about water resources research issues."

Shannon Cunniff
Director, Research and Natural Resources
U.S. Bureau of Reclamation

WSTB committees typically meet at one of The National Academies facilities located in Irvine, California; Washington, D.C.; or Woods Hole, Massachusetts. Pictured at the right are the members of the Committee on Environmental Remediation at Navy Facilities at the Beckman Center, Irvine, California.

Columbia River Water Resources Management: Instream Flows for Salmon Survival

Water managers, scientists, and politicians in the Columbia River Basin must frame water management policies, within a highly developed hydropower system to balance economic needs of a rapidly-growing regional population and the needs of altered aquatic ecosystems and imperiled fisheries. There are hundreds of pending applications for new water rights, and there are disagreements regarding streamflow levels necessary to support various species of salmon and their habitat.

The State of Washington has provided resources to the WSTB, which is collaborating with its sister Board on Environmental Studies and Toxicology, to review existing scientific data related to instream flows and salmon survival. The committee will host a workshop to gather information from the scientific community; to review and evaluate existing scientific data and analyses related to endangered fish species; to review and evaluate environmental parameters critical to survival and recovery of endangered fish species; to evaluate the implications of salmonid survival under a range of Columbia River system management scenarios and hydrologic conditions; and to identify gaps in the scientific information needed to develop comprehensive strategies for recovering listed species and meeting human needs.

As this report went to press, the committee was being formulated. This committee will issue its report in mid-2004.

Environmental Remediation at Naval Facilities—Phase 2

Since 1997 the WSTB has studied issues associated with remediation of contaminated soil, sediment, and groundwater at Navy facilities. The second phase of this committee's work targets the latter stages of site cleanup. In particular, the committee is developing a decisionmaking framework that is embodied within a "systems engineering approach" to site cleanup. This framework allows for the reconsideration of remedies over time, including the introduction of both new and alternative innovative technologies. This is necessary because chosen remedies may not remain optimal over the long term because of changing site conditions, limited life span of technologies, or the discovery of new contamination. At many Navy sites, continued operation of remedies beyond a certain level may not yield a marked improvement in site conditions. Thus, the committee is considering what criteria should be used to determine when technologies should be "turned off," and what criteria should be used to determine milestones in site cleanup. Finally, the study is reviewing the state of technology development for cleanup of groundwater, sediment, and soils. Special attention is being given to the top technologies that should be considered for the three to four greatest problems encountered by the Navy. This evaluation will update previous NRC reports rather than provide an exhaustive study of all possible innovative technologies. The committee's report is scheduled to be published in late 2002.

The study is sponsored by the U.S. Navy. Laura Ehlers is the study director and Anike Johnson is the project assistant. Committee members are:

Edward J. Bouwer, *Chair*, Johns Hopkins University, Baltimore, Maryland
Gene F. Parkin, *Vice-Chair*, University of Iowa, Iowa City
Sidney B. Garland, Bechtel Jacobs Co., Oak Ridge,

Some participants in the Committee on Hydrologic Science's workshop on Groundwater Fluxes Across Interfaces *at Egg Harbor, Wisconsin.*

Tennessee
Patrick E. Haas, Mitretek, San Antonio, Texas
Robert Johnson, Argonne National Laboratory, Columbus, Ohio
Michelle M. Lorah, U.S. Geological Survey, Baltimore, Maryland
Frederick G. Pohland, University of Pittsburgh, Pennsylvania
Danny D. Reible, Louisiana State University, Baton Rouge
Lenny M. Siegel, Center for Public Environmental Oversight, Mountain View, California
Mitchell J. Small, Carnegie Mellon University, Pittsburgh, Pennsylvania
Ralph G. Stahl, Jr., E. I. duPont de Nemours & Co., Wilmington, Delaware
Alice D. Stark, New York State Department of Health, Albany
Albert J. Valocchi, University of Illinois, Urbana-Champaign
William J. Walsh, Pepper Hamilton LLP, Washington, D.C.
Claire Welty, Drexel University, Philadelphia, Pennsylvania

Hydrologic Science

The Committee on Hydrologic Science (COHS) was formed in 1999 to review and provide advice on scientific activities of U.S. federal agencies and U.S. contributions to international programs in hydrologic science, and to provide guidance for development of the science itself. This standing committee (with rotating membership) was assembled because hydrologic science historically has been distributed among other geoscience disciplines, and because the development of hydrology as a science has often been secondary to engineering applications designed to meet water management needs.

Two of this committee's reports are in preparation, both of which are scheduled to be published in early 2003. The first, *Groundwater Fluxes across Interfaces*, is based on a May 2002 workshop focused on interactions of recharge and discharge with climate and scaling issues. The second report, *Research at the Boundary of Ecology and Hydrology*, is based on an October 2000 workshop on the same topic.

In 2001 the committee published *Report of a Workshop on Predictability and Limits-to-Prediction in Hydrologic Systems*, which is summarized on page 33. The committee also formed a panel to review the U.S. Global Change Research Program's Plan for a New Science Initiative on the Global Water Cycle, in cooperation with the Climate Research Committee (CRC) of the Board on Atmospheric Science and Climatology. This panel was composed of six members of the COHS and three members of the CRC. Its report was completed in early 2002 and is described on page 35.

Funding for the committee's activities is provided by the Bureau of Reclamation, the Environmental Protection Agency, the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, the National Science Foundation, the U.S. Army and the U.S. Geological Survey. William Logan is the study director and Anita Hall is the project assistant. Committee members are:

Eric F. Wood, *Chair,* Princeton University, New Jersey
Dara Entekhabi, (chair through December 2001), Massachusetts Institute of Technology, Cambridge
Mary P. Anderson, University of Wisconsin, Madison

Roni Avissar, Rutgers University, New Brunswick, New Jersey (through December 2001)
Victor R. Baker, University of Arizona, Tucson
Roger C. Bales, University of Arizona, Tucson (through December 2001)
Nancy B. Grimm, Arizona State University, Tempe
George M. Hornberger, University of Virginia, Charlottesville
Dennis P. Lettenmaier, University of Washington, Seattle
William K. Nuttle, Consultant, Ottawa, Canada (through September 2002)
Marc B. Parlange, Johns Hopkins University, Baltimore, Maryland (through December 2001)
Christa Peters-Lidard, Georgia Institute of Technology, Atlanta (through September 2001)
Kenneth W. Potter, University of Wisconsin, Madison
John O. Roads, Scripps Institution of Oceanography, La Jolla, California
John L. Wilson, New Mexico Tech, Socorro

Indicators for Waterborne Pathogens

To help ensure high quality drinking water in the United States, regulators have traditionally used indicator microorganisms to determine the possible presence of microbial contamination from human waste. Enumerating total coliforms in water samples has proved to be a useful method for assessing sewage contamination of water, and along with chlorination to reduce coliform levels has led to a decrease in diseases such as cholera and typhoid fever. However, an increased understanding of the diversity of waterborne pathogens and physiology has resulted in a growing concern that total coliform tests do not indicate the presence of other important classes of pathogens such as parasites, viruses, or bacterial pathogens that do not have their origins in human waste.

"In recent years, there seems to be no important environmental controversy related to water that has not attracted the attention of the WSTB. Its advice on issues ranging from the Missouri River to wetland policy to the Everglades has each time proved insightful, balanced, and influential."

Tim Searchinger
Attorney
Environmental Defense

The Committee on Indicators for Waterborne Pathogens, jointly administered by the Board on Life Sciences and the WSTB, was formed in early 2002 to study candidate indicators and/or indicator approaches (including detection technologies) for microbial pathogens in the nation's recreational waters and source water (including groundwater) for drinking. The committee's report will suggest candidate indicators and/or indicator approaches that are deemed scientifically defensible and practical to monitor, and how such a list of candidates might change with future technological developments. The report will also review and provide perspectives on the importance and public health impacts of waterborne pathogens, both in terms of drinking water and recreational activities. The committee's report is scheduled to be published in early 2003.

The study sponsor is the Environmental Protection Agency. WSTB staff officer Mark Gibson and Board on Life Studies staff officer Jennifer Kuzma are co-study directors and Seth Strongin of the Board on Life Sciences is the project assistant. Committee members are:

Mary Jane Osborn, *Chair*, University of Connecticut, Farmington
R. Rhodes Trussell, *Vice-Chair*, Montgomery Watson Harza, Inc., Pasadena, California
Ricardo De Leon, Metropolitan Water District of Southern California, La Verne
Daniel Y. C. Fung, Kansas State University, Manhattan
Charles N. Haas, Drexel University, Philadelphia, Pennsylvania
Deborah Levy, Centers for Disease Control and Prevention, Atlanta, Georgia
J. Vaun McArthur, Savannah River Ecology Laboratory, Aiken, South Carolina, and University of Georgia, Athens
Joan B. Rose, University of South Florida, St. Petersburg
Mark D. Sobsey, University of North Carolina, Chapel Hill
David R. Walt, Tufts University, Medford, Massachusetts
Stephen B. Weisberg, Southern California Coastal Water Research Project Authority, Westminster
Marylynn V. Yates, University of California, Riverside

Restoration of the Greater Everglades Ecosystem

The Everglades was once a free-flowing "river of grass" extending from the Kissimmee lakes to Florida Bay. However, beginning in the late 1800s and continuing throughout the twentieth century, more than 1,700 miles of canals and levees were dug to reclaim land, reduce flood

The Committee on the Restoration of the Greater Everglades Ecosystem at Royal Palm Visitor Center, Everglades National Park, Florida.

damages, and provide water supply to the rapidly growing population. More than half the Everglades wetlands were lost to development. A collaboration of local, state, federal, and tribal entities has been working to reverse some of the environmental degradation and restore more natural conditions in much of the Everglades. This has resulted in the Comprehensive Everglades Restoration Plan (CERP), which was approved by Congress in the 2000 Water Resources Development Act.

The Committee on Restoration of the Greater Everglades Ecosystem (CROGEE) was formed in September 1999 to provide scientific guidance to agencies charged with restoration and preservation of the Everglades. It provides scientific overview, strategic guidance, and focused advice on technical topics. The committee is presently working in a number of areas, including ecological indicators, marine and estuarine ecosystems, and options for water storage in the restoration program. A report titled *Progress towards Adaptive Monitoring and Assessment for CERP* is in review and scheduled to be published in late 2002. The committee has also formed the Panel to Review the Critical Ecosystems Science Initiative, described below.

The committee has released three reports in the last two years. These include *Aquifer Storage and Recovery in the Comprehensive Everglades Restoration Plan*, *Florida Bay Research Programs and their Relation to the Comprehensive Everglades Restoration Plan*, and *Review of Draft Project Management Plan (PMP) for Aquifer Storage and Recovery (ASR) Regional Study*, which are summarized in the section "Completed Studies."

Funding for the committee's activities is provided by the Corps of Engineers and the Department of the Interior. Advice is provided to the South Florida Ecosystem Restoration Task Force. This activity is overseen in collaboration with the Board on Environmental Studies and Toxicology (BEST). Stephen Parker is the study director, assisted by David Policansky (BEST), William Logan, and Patricia Jones-Kershaw. Committee members are:

Jean M. Bahr, *Chair*, University of Wisconsin, Madison
James M. Davidson, (Chair through April 2001), University of Florida (retired), Gainesville
Scott W. Nixon, *Vice-Chair*, University of Rhode Island, Narragansett
John S. Adams, University of Minnesota, Minneapolis
Linda K. Blum, University of Virginia, Charlottesville
Patrick L. Brezonik, University of Minnesota, St. Paul
Frank W. Davis, University of California, Santa Barbara
Wayne C. Huber, Oregon State University, Corvallis
Stephen R. Humphrey, University of Florida, Gainesville
Daniel P. Loucks, Cornell University, Ithaca, New York
Kenneth W. Potter, University of Wisconsin, Madison
Larry Robinson, Florida Agricultural and Mechanical University, Tallahassee
Steven E. Sanderson, Emory University, Atlanta, Georgia (through January 2002)
Rebecca R. Sharitz, Savannah River Ecology Laboratory, Aiken, South Carolina, and University of Georgia, Athens
Henry J. Vaux, Jr. University of California Division of Agriculture and Natural Resources, Oakland
John Vecchioli, U.S. Geological Survey (retired), Odessa, Florida
Jeffrey R. Walters, Virginia Polytechnic Institute and State University, Blacksburg

Review of the Critical Ecosystem Studies Initiative

While not all parties agree on the details of the Everglades restoration effort, there is near-universal agreement that the best possible science should support planning, implementation, and, ultimately, operation of the restoration projects.

Some members of the panel evaluating the Department of the Interior's Critical Ecosystems Studies Initiative prepare to survey the Everglades National Park by air.

Yet in the past few years, investment in science and research relevant to the restoration has eroded measurably within some agencies. One of these is the Department of the Interior's Critical Ecosystem Studies Initiative (CESI), whose budget has decreased from $12 million/year (in fiscal year 1997) to $4 million/year (in fiscal year 2002).

In response to congressional concerns over this decline in science funding, a panel was formed in 2002 to review the CESI program. The panel is assessing the adequacy (types and funding levels) of the science conducted in the CESI program in light of other restoration science activities and the needs of the overall restoration. The panel will also provide guidance for improving strategic planning, management, and review; coordination and integration with relevant research outside the program; and communication of CESI research findings to assure support for restoration decisionmaking. A report is scheduled to be provided to the Department of the Interior and the Congress in early 2003.

The study is being funded by the Department of the Interior. Stephanie Johnson is the study director and Jon Sanders is the project assistant. Panel members are:

Linda K. Blum, *Chair*, University of Virginia, Charlottesville
Jeb A. Barzen, International Crane Foundation, Baraboo, Wisconsin
Lauren J. Chapman, University of Florida, Gainesville
Peter L. deFur, Virginia Commonwealth University, Richmond
F. Dominic Dottavio, Ohio State University, Marion
William L. Graf, University of South Carolina, Columbia
James P. Heaney, University of Colorado, Boulder
Stephen R. Humphrey, University of Florida, Gainesville
Stephen S. Light, Institute for Agriculture and Trade Policy, Minneapolis, Minnesota
Charles R. O'Melia, Johns Hopkins University, Baltimore, Maryland
Carol M. Wicks, University of Missouri, Columbia
Daniel E. Willard, Indiana University (retired), Bloomington

Services and Values of Aquatic and Related Terrestrial Ecosystems

Aquatic and related terrestrial ecosystems include lakes, rivers, streams, estuaries, wetlands, adjacent riparian systems, and upland areas, together with their associated flora and fauna. They perform environmental functions such as recycling nutrients, attenuating floods, recharging groundwater, and providing wildlife habitat. In addition, aquatic and related terrestrial ecosystems often form the basis of economic livelihoods and are used widely for recreation. But human activities have increasingly led to pollution, adverse modification, and devaluation of these natural systems. While ecosystem functions may be useful markers for studying physical, biological, and chemical processes, they are seldom experienced directly by resource users. In contrast, economists often find it helpful to envision resource "services" as things that create value for human users, which allows for the values of hydrologic, biogeochemical, and biological services to be more readily assessed.

The Committee on Assessing and Valuing the Services of Aquatic and Related Terrestrial Ecosystems was formed in the spring of 2002 to identify and assess existing methods for defining and assigning economic values to the

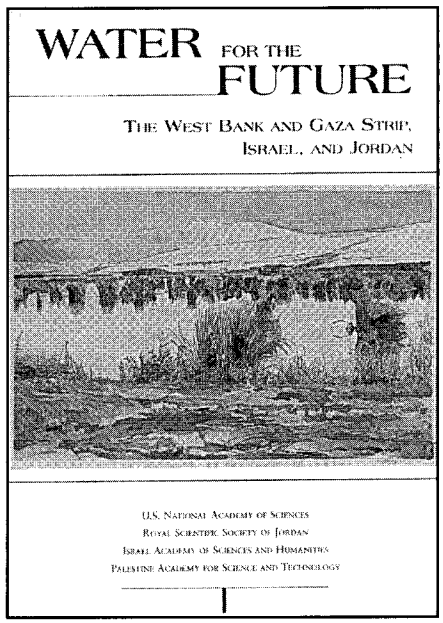
services of such ecosystems. The committee will consider the errors and biases of such methods and whether their increased use will lead to better environmental decisionmaking. The committee's report is expected to be published in late 2003.

The study sponsors are the Corps of Engineers, the Department of Agriculture, and the Environmental Protection Agency. Mark Gibson is the study director and Ellen de Guzman is the research associate. Committee members are:

Geoffrey M. Heal, *Chair*, Columbia University, New York City
Edward B. Barbier, University of Wyoming, Laramie
Kevin J. Boyle, University of Maine, Orono
Alan P. Covich, University of Georgia, Athens
Steven P. Gloss, U.S. Geological Survey, Flagstaff, Arizona
Carlton H. Hershner, Jr., Virginia Institute of Marine Science, Gloucester Point
John P. Hoehn, Michigan State University, East Lansing
Stephen Polasky, University of Minnesota, St. Paul
Catherine M. Pringle, University of Georgia, Athens
Kathleen Segerson, University of Connecticut, Storrs
Kristin Shrader-Frechette, University of Notre Dame, Notre Dame, Indiana

Source Removal of Contaminants in the Subsurface

The U.S. Army has over 100 contaminated facilities (comprising thousands of sites) across the country, including underground storage tanks, landfills, spill areas, and storage areas. The estimated cost to complete these cleanups is estimated at $6 billion. The most significant problems are for those sites contaminated with dense nonaqueous phase liquids (DNAPLs) such as chlorinated organic solvents, polychlorinated biphenyls, tars and creosotes, and organic explosives. Traditional cleanup methods, such as pump and treat, have captured little of the total contaminant mass even under the best of conditions. In addition, in many subsurface environments these compounds are not susceptible to biodegradation, making monitored natural attenuation ineffective. The Army is interested in pursuing aggressive technologies with the potential for removing a substantial portion of the contaminant mass in a short time frame—termed source removal strategies—if they can achieve cleanup goals. There is concern both within the Army and academic circles as to whether source removal actions will help the Army meet water quality goals for groundwater, provide meaningful risk reduction, or reduce life-cycle costs.



The WSTB also occasionally conducts studies on international water issues. This 1999 report assesses opportunities for improved management of water supplies in the Middle East in order to avoid over-exploitation of water resources.

In mid-2002, the WSTB established a committee to undertake an assessment of contaminant source removal in the subsurface. The study will describe the data and analytical methods needed to determine the effectiveness of source removal projects for recalcitrant organic contaminants. In addition to literature reviews and analysis of existing data on source removal activities, the committee will try to determine the effectiveness of source removal activities at Army sites. The goal of the study is to provide meaningful commentary on the future use of source removal as a cleanup strategy. The committee's report is scheduled to be published in mid-2004.

The study is sponsored by the U.S. Army Environmental Center. Laura Ehlers is the study director and Jon Sanders is the project assistant. Committee members are:

John C. Fountain, *Chair*, North Carolina State University, Raleigh
Linda M. Abriola, University of Michigan, Ann Arbor
Lisa M. Alvarez Cohen, University of California, Berkeley
Mary Jo Baedecker, U.S. Geological Survey, Reston, Virginia
David E. Ellis, E. I. duPont de Nemours & Co., Wilmington, Delaware

Thomas C. Harmon, University of California, Los Angeles
Nancy J. Hayden, University of Vermont, Burlington
Peter K. Kitanidis, Stanford University, Stanford, California
Joel A. Mintz, Nova Southeastern University, Ft. Lauderdale, Florida
James M. Phelan, Sandia National Laboratories, Albuquerque, New Mexico
Gary A. Pope, University of Texas, Austin
David A. Sabatini, University of Oklahoma, Norman
Thomas C. Sale, Colorado State University, Fort Collins
Brent E. Sleep, University of Toronto, Ontario
Julie L. Wilson, Landau Associates, Lake Oswego, Oregon
John S. Young, Hebrew University, Jerusalem, Israel
Katherine L. Yuracko, YAHSGS, Richland, Washington

U.S. Geological Survey Water Resources Research

The Committee on U.S. Geological Survey Water Resources Research was formed in 1985 to advise the USGS on its programs in hydrology and water resources. This group is effectively a "standing committee" with a rotating and staggered membership. The committee has studied and published reports on a variety of topics over the years, such as watershed research, hydrologic hazards, the stream gauging network, groundwater research, and water use.

The committee is currently reviewing the National Streamflow Information Program (NSIP). The NSIP was created in response to congressional concerns about the progressive loss of stream gages, especially those with a long period of record. It consists of a core of stream gages funded and operated by either the USGS or other agencies that provide data to meet national needs. The committee is evaluating the appropriateness of the NSIP-selected minimum national streamflow information needs, design characteristics of the network, and the components of the NSIP plan. It will also comment on how the program should contribute to river science (e.g., interaction of hydrology, geomorphology and ecology). This report is scheduled to be published in mid-2003.

The committee's 2002 report, *Estimating Water Use in the United States: A New Paradigm for the National Water-Use Information Program*, is described on page 29. Funding for the committee's work is provided by the U.S. Geological Survey. William Logan is the study director and Anita Hall is the project assistant. Committee members are:

David R. Maidment, *Chair,* University of Texas, Austin
A. Allen Bradley, University of Iowa, Iowa City
Michael E. Campana, University of New Mexico, Albuquerque (through December 2001)
Benedykt Dziegielewski, Southern Illinois University, Carbondale
N. Leroy Poff, Colorado State University, Fort Collins
Karen L. Prestegaard, University of Maryland, College Park
Stuart S. Schwartz, Water Resources Research Institute of the University of North Carolina, Raleigh
Donald I. Siegel, Syracuse University, Syracuse, New York
Vernon L. Snoeyink, University of Illinois at Urbana-Champaign (through December 2001)
Mary W. Stoertz, Ohio University, Athens
Kay D. Thompson, Washington University, St. Louis, Missouri

Water Quality Improvement for the Pittsburgh Region

Thousands of residents of southwestern Pennsylvania, particularly in rural areas, lack access to clean and reliable water supplies, adequate wastewater systems, or both. Moreover, nearly all of the region's residents receive water from surface and groundwater sources that are periodically compromised by inadequate sanitation (i.e., contain unacceptable levels of potentially harmful microbial pathogens). The cost of the infrastructure improvements necessary to correct this regional water quality problem would be very large; however, the cost of letting the water quality problem continue unabated may be greater over time, as it would entail adverse impacts on public health, the environment, and economic growth.

The Committee on Water Quality Improvement for the Pittsburgh Region was formed in the spring of 2002 to undertake a study of the water and wastewater quality problems of the Pittsburgh area, and to recommend how these issues and needs of the region can be best addressed by the multiple jurisdictions on a cooperative basis. The study should help public and private organizations of the Pittsburgh region develop public awareness of the issues and the need for collaborative strategies for water quality improvement and management. This study could also provide lessons for other urban areas seeking cooperative approaches to solving water quality problems. The committee's report is scheduled to be published in early 2004.

The study sponsor is the Allegheny Conference on Community Development. Mark Gibson is the study director and Anike Johnson is the project assistant. Committee members are:

Some members of the Committee on Water Quality Improvement for the Pittsburgh Region at the Alleghany County Sanitation Authority wastewater treatment plant, north of Pittsburgh on the Ohio River.

Jerome B. Gilbert, *Chair*, J. Gilbert, Inc., Orinda, California
Brian J. Hill, Pennsylvania Environmental Council, Meadville
Jeffrey M. Lauria, Malcolm Pirnie, Inc., Columbus, Ohio
Gary S. Logsdon, Black & Veatch, Inc., Cincinnati, Ohio
Perry L. McCarty, Stanford University, Stanford, California
Patricia Miller, West Virginia University, Morgantown
David H. Moreau, University of North Carolina, Chapel Hill
Nelson P. Moyer, University of Iowa, Iowa City
Rutherford H. Platt, University of Massachusetts, Amherst
Stuart S. Schwartz, Water Resources Research Institute of the University of North Carolina, Raleigh
James S. Shortle, Pennsylvania State University, University Park
Joel A. Tarr, Carnegie Mellon University, Pittsburgh, Pennsylvania
Jeanne M. VanBriesen, Carnegie Mellon University, Pittsburgh, Pennsylvania
Paul F. Ziemkiewicz, West Virginia University, Morgantown

COMPLETED STUDIES 2001~2002

In 2001~2002, Water Science and Technology Board committees completed 15 reports, which are summarized below. Studies ranged from comprehensive assessments to broad water resources issues, to more focused reports providing advice on federal agency programs.

Aquifer Storage and Recovery in the Comprehensive Everglades Restoration Plan: A Critique of the Pilot Projects and Related Plans for ASR in the Lake Okeechobee and Western Hillsboro Areas

Aquifer storage and recovery (ASR) is a major component in the Comprehensive Everglades Restoration Plan, which was developed by the Corps of Engineers and the South Florida Water Management District. The plan would use the Upper Floridan aquifer to store large quantities of surface water and shallow groundwater during wet periods for recovery during droughts.

ASR may limit evaporation losses and permit recovery of large volumes of water during multi-year droughts. However, the proposed scale is unprecedented and little subsurface information has been compiled. Key unknowns include impacts on existing aquifer uses, suitability of source waters for recharge, and environmental and/or human health impacts due to water quality changes during subsurface storage.

To address these issues, the Corps of Engineers and the South Florida Water Management District proposed Aquifer Storage Recharge pilot projects in two key areas. The Committee on Restoration of the Everglades Ecosystem's (CROGEE) charge was to examine a draft of their plans from a perspective of adaptive management. The report concludes that regional hydrogeologic assessment should include development of a regional-scale groundwater flow model, extensive well drilling and water quality sampling; and a multi-objective approach to ASR facility siting. It also recommends that water quality studies include laboratory and field bioassays and ecotoxicological studies, studies to characterize organic carbon of the source water and anticipate its effects on subsurface biogeochemical processes, and laboratory studies. Finally, it recommends that pilot projects be part of adaptive assessment.

The Department of the Interior was the study sponsor. William Logan was the study director and Patricia Jones-Kershaw was the project assistant. The committee met once during the six months of its study to focus on the ASR plan. The CROGEE is overseen jointly with the Board on Environmental Studies and Toxicology.

Committee members were:

James Davidson, *Chair* (through May 2001), (retired) University of Florida, Gainesville
Jean M. Bahr, *Chair* (after May 2001), University of Wisconsin, Madison
Scott W. Nixon, *Vice-Chair*, University of Rhode Island, Narragansett
John S. Adams, University of Minnesota, Minneapolis
Linda K. Blum, University of Virginia, Charlottesville
Patrick K. Brezonik, University of Minnesota, St. Paul
Frank W. Davis, University of California, Santa Barbara
Wayne C. Huber, Oregon State University, Corvallis
Stephen R. Humphrey, University of Florida, Gainesville
Daniel P. Loucks, Cornell University, Ithaca, New York
Gordon H. Orians, University of Washington, Seattle (until December 2000)
Kenneth W. Potter, University of Wisconsin, Madison
Larry Robinson, Florida Agricultural and Mechanical University, Tallahassee
Steven E. Sanderson, Emory University, Atlanta, Georgia
Rebecca R. Sharitz, Savannah River Ecology Laboratory, Aiken, South Carolina, and University of Georgia, Atlanta
John Vecchioli, U.S. Geological Survey (retired), Tallahassee, Florida

Aquifer Storage and Recovery in the Comprehensive Everglades Restoration Plan: Review of Draft Project Management Plan for Aquifer Storage and Recovery Regional Study

The fourth draft of a project management plan for the above-cited Aquifer Storage and Recovery Regional Study (ASR) was prepared by Comprehensive Everglades Restoration Plan scientists in May 2002, and the CROGEE was asked to conduct a technical review of this document. Specifically, this review examined the adequacy of the proposed scientific methods to address issues raised in the 2001 NRC report and the ASR Issue Team of the South Florida Ecosystem Restoration Task Force Working Group.

Overall, the Regional ASR project management plan responds well to these issues. It is comprehensive, for the most part, and is integrated well with the pilot ASR studies. The most important overall improvement to the plan would be a greater emphasis on adaptive management, i.e., the concept that each activity be viewed as an experiment accompanied by one or more hypotheses that predict how that step will improve the system.

With respect to specific tasks proposed for the Regional Study, more monitor wells and well nests at the pilot sites are needed to characterize hydraulic and biogeochemical processes, due to heterogeneity of the aquifer system. Likewise, recharge during testing of the wells should continue until some time after the injection water is detected at all monitor wells, and water quality sampling during all pilot tests at all sites should be a priority to provide critical information on the extent of mixing and water quality changes likely to occur during ASR operations. Some of the funds to expand such monitoring and sampling may be found by de-emphasizing continuous coring, which is costly and may yield unreliable and non-representative data.

Results from column studies proposed to assess interactions between microorganisms and the subsurface materials should be treated with caution. Due to the presence of fractures and other features in the Florida Aquifer system, it may be impossible to obtain representative, quantitative information on transport using column studies. Finally, proposed bioassays and mesocosm studies should be integrated with monitoring and assessment of ecological indicators to understand sublethal effects of contaminants on the sampled organisms as well as community-level effects on the larger ecosystem. Such monitoring should be done in coordination with broader the Comprehensive Everglades Restoration Plan adaptive assessment initiatives.

William Logan served as study director and Patricia Jones-Kershaw served as research associate. The committee consisted of the CROGEE supplemented with three special consultants. These were:

Thomas Morris, Las Vegas Valley Water District, Nevada
Marylynn V. Yates, University of California, Riverside
Michael C. Newman, Virginia Institute of Marine Science, Gloucester Point

"EPA values the thoughtful analysis in this (TMDL) report, which provides helpful direction to states, tribes, and the EPA in our efforts to move forward to meet Clean Water Act goals. We are incorporating key concepts into guidance and regulation."

Robert Wayland
Director, Office of Wetlands, Oceans, and Watersheds
Office of Water, U.S. Environmental Protection Agency

Assessing the Total Maximum Daily Load Approach to Water Quality Management

The Clean Water Act's Total Maximum Daily Load (TMDL) program requires states to list and remediate waters that are not meeting water quality standards. These requirements have become the most pressing regulatory water quality challenge for the states, with about 21,000 polluted river segments, lakes, and estuaries requiring more than 40,000 TMDLs.

Produced in response to a request from Congress, *Assessing the Total Maximum Daily Load Approach to Water Quality Management* recommends two major programmatic changes in the TMDL process. First, the Environmental Protection Agency should approve the use of both a *preliminary list* and an *action list* instead of one "303d" list. Many waters now on state 303d lists were placed there without the benefit of adequate water quality standards, data, or waterbody assessment. These potentially erroneous listings contribute to a large backlog of TMDLs and foster the perception of a problem that is larger than it may actually be. States should be allowed to move those waters for which there is a lack of adequate water quality standards or data and analysis from the 303d list back to a preliminary list.

Second, TMDL plans should employ iterative, adaptive implementation and revision—a cyclical process in which TMDL plans are periodically assessed for their achievement of water quality standards including designated uses. Adaptive implementation is needed to ensure that the TMDL program is not halted due to a lack of data and information, but rather makes progress while better data are collected and analyzed with the intent of improving initial TMDL plans. Other recommendations about the use of science in the TMDL program include discussion of water quality standards, statistical sampling, waterbody assessment, models, and uncertainty analysis.

The study was funded by the Environmental Protection Agency. Laura Ehlers was the study director, Jeanne Aquilino was the project assistant, and Leonard Shabman served as visiting WSTB scholar during the tenure of the committee. The committee held three meetings during this six-month study. Committee members were:

Kenneth H. Reckhow, *Chair,* Duke University, Durham, North Carolina
Anthony S. Donigian, Jr., AQUATERRA, Mountain View, California
James R. Karr, University of Washington, Seattle

Jan Mandrup-Poulsen, Florida Department of Environmental Protection, Tallahassee
H. Stephen McDonald, Carollo Engineers, Walnut Creek, California
Vladmir Novotny, Marquette University, Milwaukee, Wisconsin
Richard A. Smith, U.S. Geological Survey, Reston, Virginia
Chris O. Yoder, Ohio Environmental Protection Agency, Columbus

Bioavailability of Contaminants in Soils and Sediments

In May 2000, the WSTB began evaluating a key concept that underlies hazardous waste cleanup—whether contaminants are *bioavailable* to humans, animals, and plants. Contaminants bound to soil or sediment may be less available to cause a toxic effect in organisms than contaminants in the aqueous phase or other forms. These observations have bred interest in amending cleanup goals to reflect only the bioavailable portion of a contaminant source. *Bioavailability of Contaminants in Soils and Sediments* evaluates the state of the science used to make decisions about bioavailability at hazardous waste sites.

Bioavailability is described as a number of physical, chemical, and biological interactions termed "bioavailability processes" that are quantifiable through the use of multiple tools, many of which are evaluated in the report. Bioavailability processes fall entirely within existing human health and ecological risk frameworks. However, today "bioavailability" is commonly thought of in relation to one process only—absorption efficiency—such that a single bioavailability adjustment factor is used.

Consideration of bioavailability processes is most likely to impact decisionmaking when the default assumptions made for a particular site are inappropriate; when significant change to remedial goals is likely; when conditions at the site are unlikely to change substantially over time; and where regulatory and public acceptance is high. Finally, moving bioavailability concepts further into the hazardous waste arena will require further research on critical bioavailability processes and large-scale, coordinated testing of bioavailability tools at pilot sites.

The study was sponsored by the Department of Defense's Strategic Environmental Restoration Defense Program, Office of Environmental Management, Army, and Air Force; the Department of Energy; the Department of Health and Human Services' Agency of Toxic Substances and Disease Registry and its National Institute for Environmental Health Sciences; the Environmental Protection Agency; and the Gas Research Institute. Laura Ehlers was the study director and Anike Johnson was the project assistant. The committee met six times during this two-year study. Committee members were:

Richard G. Luthy, *Chair*, Stanford University, Stanford, California
Richelle M. Allen-King, Washington State University, Pullman
Sally L. Brown, University of Washington, Seattle
David A. Dzombak, Carnegie Mellon University, Pittsburgh, Pennsylvania
Scott E. Fendorf, Stanford University, Stanford, California
John P. Giesy, Michigan State University, East Lansing
Joseph B. Hughes, Rice University, Houston, Texas
Samuel N. Luoma, U.S. Geological Survey, Menlo Park, California
Linda A. Malone, College of William and Mary, Williamsburg, Virginia
Charles A. Menzie, Menzie-Cura and Associates, Inc., Boston, Massachusetts
Stephen M. Roberts, University of Florida, Gainesville
Michael V. Ruby, Exponent, Boulder, Colorado
Terry W. Schultz, University of Tennessee, Knoxville
Barth F. Smets, University of Connecticut, Storrs

Classifying Drinking Water Contaminants for Regulatory Consideration

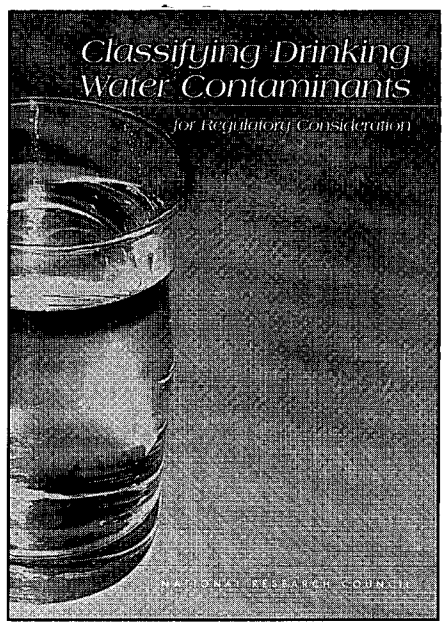
The provision of safe drinking water has been an important factor in improving public health in U.S. communities since the turn of the twentieth century. Despite advances in water treatment, source water protection efforts, and the presence of several layers of overlapping regulatory protection, sources of raw and finished public drinking water in the United States periodically contain chemical, microbiological, and other types of contaminants at sometimes harmful levels. To help address this ongoing public health concern, one new requirement of the Safe Drinking Water Act Amendments of 1996 is that every five years the Environmental Protection Agency is must publish a list of unregulated chemical and microbial contaminants that may pose risks in drinking water. The first such list, called the Drinking Water Contaminant Candidate List (CCL), was published in March 1998, while the mandated release date for the second (2003) CCL is imminent. The CCL will provide the primary basis for deciding whether to

regulate at least five new contaminants from each list every five years and help prioritize related research and monitoring activities.

This third and final report of the Committee on Drinking Water Contaminants significantly expands the conceptual approach for the creation of future CCLs and other related conclusions and recommendations documented in the committee's second (1999) report, *Identifying Future Drinking Water Contaminants.* It also assesses the feasibility of developing and using virulence-factor activity relationships—defined as the known or presumed linkage between the biological characteristics of a microorganism and its real or potential ability to cause harm—for identifying emerging waterborne pathogens for subsequent research and regulatory activities.

Support for this study, carried out with assistance from the Board on Environmental Studies and Toxicology, was provided by the Environmental Protection Agency. Mark Gibson was the study director and Ellen de Guzman was the project assistant. Committee members were:

Deborah L. Swackhamer, *Chair*, University of Minnesota, Minneapolis
R. Rhodes Trussell, *Vice-Chair*, Montgomery Watson Harza, Inc., Pasadena, California
Frank J. Bove, Agency for Toxic Substances and Disease Registry, Atlanta, Georgia
Lawrence J. Fischer, Michigan State University, East Lansing
Walter Giger, Swiss Federal Institute of Environmental Science and Technology, Zurich, Switzerland
Jeffrey K. Griffiths, Tufts University, Boston, Massachusetts
Charles N. Haas, Drexel University, Philadelphia, Pennsylvania
Nancy K. Kim, New York State Department of Health, Troy, New York
Rebecca T. Parkin, George Washington University, Washington, D.C.
David M. Ozonoff, Boston University, Boston, Massachusetts
Catherine A. Peters, Princeton University, Princeton, New Jersey
Joan B. Rose, University of South Florida, St. Petersburg
Philip C. Singer, University of North Carolina, Chapel Hill
Paul G. Tratnyek, Oregon Graduate Institute of Science and Technology, Beaverton



This 2001 report on drinking water contaminants builds on two previous WSTB reports, Identifying Future Drinking Water Contaminants *and* Identifying Drinking Water Contaminants.

Compensating for Wetland Losses Under the Clean Water Act

Despite progress in the last 20 years, the goal of "no net loss" for wetland function is not being met. However, neither the magnitude of the loss of wetland function nor the net loss of acreage is precisely known because not enough data are kept on the ecological status of wetlands that are lost, restored, or created.

To better understand the effectiveness of the mitigation program, this report calls for the Corps of Engineers to create a national database to track the wetland area and functions gained and lost and to encourage the establishment of organizations to monitor mitigated sites. Whenever possible, preservation of a natural wetland is preferable to creating a new one. Wetland restoration or creation will be most successful when the effort is integrated into the larger watershed. Current federal guidelines express a preference for putting new wetlands as close as possible to degraded ones; however, this study showed that this is not always the best choice. Rather, creating new wetlands in areas with proper water levels and flow rates is the key to achieving a self-sustaining wetland. Adaptive management practices will encourage changes to be made to the wetland based on results of early monitoring.

A government program that allows developers to fill in

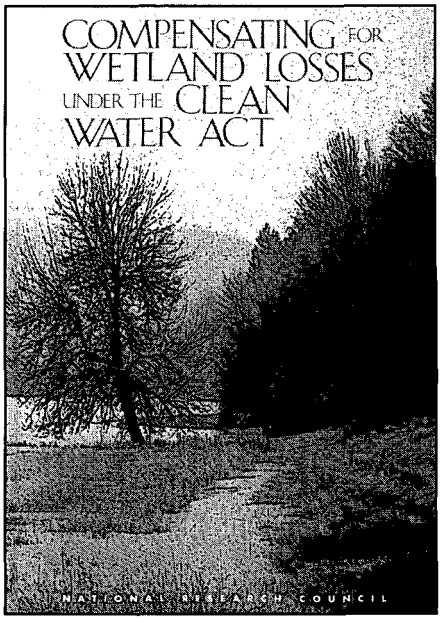
wetlands in exchange for restoring or creating others nearby needs to be improved to meet the goal of "no net loss" in size and function of wetlands. Before granting permits to fill natural wetlands, regulators should give greater consideration to how restored or newly created wetlands can replicate the ecological functions of naturally occurring wetlands and become a sustainable part of the larger watershed.

The study was sponsored by the Corps of Engineers, the Environmental Protection Agency, the National Marine Fisheries Service, and the U.S. Fish and Wildlife Service. Oversight of the study was provided by the Board on Environmental Studies (BEST), with support from the WSTB. Suzanne van Drunick (BEST) was the director of this study. Committee members were:

Joy Zedler, *Chair,* University of Wisconsin, Madison
Leonard Shabman, *Vice-Chair,* Virginia Polytechnic Institute and State University, Blacksburg
Victoria Alvarez, California Department of Transportation, Sacramento
Robert O. Evans, North Carolina State University, Raleigh
Royal C. Gardner, Stetson University College of Law, St. Petersburg, Florida
J. Whitfield Gibbons, Savannah River Ecology Laboratory, Aiken, South Carolina
James W. Gilliam, North Carolina State University, Raleigh
Carol A. Johnston, University of Minnesota, Duluth
William J. Mitsch, Ohio State University, Columbus
Karen L. Prestegaard, University of Maryland, College Park
Ann M. Redmon, Wilson Miller, Inc., Tallahassee, Florida
Charles Simenstad, University of Washington, Seattle
R. Eugene Turner, Louisiana State University, Baton Rouge

Envisioning the Agenda for Water Resources Research in the Twenty-first Century

Increases in population and the need to preserve and enhance aquatic ecosystems will combine to create more intense pressures on U.S. water resources in the twenty-first century than in the previous century. Even as these pressures mount, important transitions are occurring in water management as the efficacy of dams is challenged, as questions are raised about potential changes in the hydrologic cycle and increased hydrologic uncertainty, and as new technology that permits innovative water management becomes available. These factors stimulated a series of discussions by WSTB members about the future of the nation's water resources and the research needed to support sustainable management of those resources. The WSTB deliberated these issues over a two-year period at its meetings and in June 2001 produced a national water resources research vision for the twenty-first century.



This 2002 report evaluates existing wetland mitigation practices to gauge their effectiveness at restoring and maintaining the quality of the nation's waters.

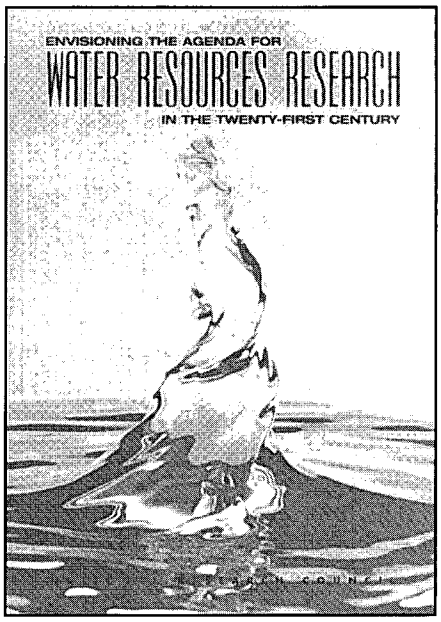
The report's recommendations cover three categories: water availability, focusing on matters that affect water supply including water quality; water use, dealing with factors that affect wants and demands for water; and water institutions, discussed separately to emphasize the need for additional research in this area and to recognize that answers to institutional questions frequently depend upon research from the social sciences.

The report notes that investments in water resources research and existing organizational arrangements for guiding such investment are inadequate to meet the needs of the twenty-first century. It urges the creation of a national water research board, with representation from state and federal governments, research institutions, users and purveyors, nonprofit organizations and public interest groups. Effective implementation and administration of a strategic and proactive research agenda to be developed by the research board should provide the justification and accountability for augmented levels of investment in water resources research.

The study was funded by core supporters of the

WSTB. Laura Ehlers was the study director. This report represents the effort of those who served on the WSTB from 1998 to 2001, as listed below:

Henry J. Vaux, Jr., *Chair*, University of California Division of Agriculture and Natural Resources, Oakland
Richelle M. Allen-King, Washington State University, Pullman
Gregory B. Baecher, University of Maryland, College Park
John S. Boyer, University of Delaware, Lewes
John Briscoe, The World Bank, Washington, D.C.
Denise D. Fort, University of New Mexico, Albuquerque
Efi Foufoula-Georgiou, University of Minnesota, Minneapolis
Steven P. Gloss, University of Wyoming, Laramie
Carol A. Johnston, University of Minnesota, Duluth
William A. Jury, University of California, Riverside
Gary S. Logsdon, Black and Veatch, Cincinnati, Ohio
Richard G. Luthy, Stanford University, Stanford, California
Diane M. McKnight, University of Colorado, Boulder
John W. Morris, J.W. Morris Ltd., Arlington, Virginia
Philip A. Palmer, (retired) E.I. duPont De Nemours & Co., Wilmington, Delaware
Rebecca T. Parkin, George Washington University, Washington, D.C.
Rutherford H. Platt, University of Massachusetts, Amherst
Joan B. Rose, University of South Florida, St. Petersburg
Jerald L. Schnoor, University of Iowa, Iowa City
R. Rhodes Trussell, Montgomery Watson, Pasadena, California
Eric F. Wood, Princeton University, Princeton, New Jersey



The WSTB study on Assessment of Water Resources Research builds on this 2001 report, which presents the WSTB's national water resource research vision for the twenty-first century.

Estimating Water Use in the United States: A New Paradigm for the National Water-Use Information Program

The objectives of the USGS National Water-Use Information Program (NWUIP) are to quantify the nation's use of water and to disseminate this information at local and national levels. The principal product of the NWUIP is a synthesis of county-level data in a national summary of water use every five years.

The committee made five recommendations for the NWUIP, which were as follows: (1) The NWUIP should be elevated to a water-use *science* program, emphasizing applied research and techniques development. The program is presently viewed by some as data collection and database management program. (2) It should synthesize the many available state and national water-use datasets and couple them to GIS technology. Detailed site-specific databases exist for over 20 states, and national databases also exist for some, though not all, water-use categories. (3) Water-use estimation techniques should be further developed. The accuracy and confidence limits of water-use estimates, which must vary greatly from state to state, are presently not quantified. (4) The NWUIP should assist in the development of integrative water-use science. Examples include integrating water use with water flow and quality to develop a total picture of water moving through the landscape, and integrating ecological uses of water within streams and aquifers as a component of water use. (5) Finally, NWUIP should seek funding from Congress for a national component of the NWUIP. At present, the program is primarily funded through a cooperative program, which depends on local cost sharing. The recommendations made in this report will be difficult to carry out without dedicated funding at a national level.

The U.S. Geological Survey sponsored the study. William Logan was the study director and Anita Hall was the project assistant. This committee met five times over this 18-month study. In addition to members of the Committee on U.S. Geological Survey Water Resources Research (listed in the "Current Studies" section), other

committee members (all of whom were members of the Committee on Water Resources Research through December 2000) were:

Ana P. Barros, Harvard University, Cambridge, Massachusetts
Victor B. Baker, University of Arizona, Tucson
Kenneth R. Bradbury, Wisconsin Geological and Natural History Survey, Madison

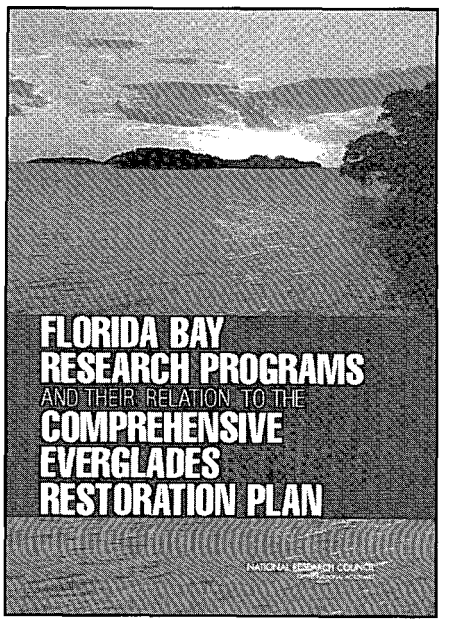
Florida Bay Research Programs and Their Relation to the Comprehensive Everglades Restoration Plan

This report of the Committee on Restoration of the Greater Everglades Ecosystem (CROGEE) evaluated Florida Bay studies and restoration activities that potentially affect the success of the Comprehensive Everglades Restoration Plan (CERP). Florida Bay is a large, shallow marine system immediately south of the Everglades, bounded by the Florida Keys and the Gulf of Mexico. Some of the water draining from the Everglades flows directly into northeast Florida Bay. Other freshwater drainage reaches the Bay indirectly from the northwest.

For several decades until the late 1980s, clear water and dense seagrass meadows characterized most of Florida Bay. However, beginning around 1987, the seagrass beds began dying in the western and central Bay. It is often assumed that increased flows to restore freshwater Everglades habitats will also help restoration of Florida Bay. However, the CERP may actually result in higher salinities in central Florida Bay than exist presently, and thus exacerbate the ecological problems. Further, some percentage of the proposed increase in fresh surface water flow discharging northwest of the Bay will eventually reach the central Bay, where its dissolved organic nitrogen may lead to algal blooms. Complicating the analysis of such issues is the lack of an operational Bay circulation model.

The report notes the importance of additional research in the following areas: estimates of groundwater discharge to the Bay; full characterization and quantification of surface runoff in major basins; transport and total loads of nitrogen and phosphorous from freshwater sources, especially in their organic forms; effects on nutrient fluxes of decreasing freshwater flows into the northeastern Bay, and of increasing flows northwest of the Bay; and the development of an operational Florida Bay circulation model to support a Bay water quality model and facilitate analysis of CERP effects on the Bay.

The Department of the Interior was the study sponsor.



This 2002 report is from the NRC committee advising the South Florida Ecosystem Restoration Task Force on the science and technological aspects of restoration plans and activities in the Florida Bay.

As noted elsewhere, the CROGEE is overseen jointly by WSTB and the Board on Environmental Studies and Toxicology. William Logan was the study director and Patricia Jones-Kershaw was the project assistant. The committee held four meetings during this 15-month study. Committee members included:

Jean M. Bahr, *Chair*, University of Wisconsin, Madison
Scott W. Nixon, *Vice-Chair*, University of Rhode Island, Narragansett
John S. Adams, University of Minnesota, Minneapolis
Linda K. Blum, University of Virginia, Charlottesville
Patrick L. Brezonik, University of Minnesota, St. Paul
Frank W. Davis, University of California, Santa Barbara
Wayne C. Huber, Oregon State University, Corvallis
Stephen R. Humphrey, University of Florida, Gainesville
Daniel P. Loucks, Cornell University, Ithaca, New York
Kenneth W. Potter, University of Wisconsin, Madison
Larry Robinson, Florida Agricultural and Mechanical University, Tallahassee
Rebecca R. Sharitz, Savannah River Ecology Laboratory, Aiken, South Carolina, and University of Georgia, Athens
Henry J. Vaux, Jr., University of California Division of

Agriculture and Natural Resources, Oakland
John Vecchioli, U.S. Geological Survey (retired), Odessa, Florida
Jeffrey R. Walters, Virginia Polytechnic Institute and State University, Blacksburg

Inland Navigation System Planning: The Upper Mississippi River–Illinois Waterway

The 29 locks and dams constructed on the Upper Mississippi River–Illinois Waterway (UMR–IWW) system by the Corps of Engineers are an important component of the nation's inland navigation system. But congestion at some locks presents occasional problems to towboat operators. Much of the UMR–IWW lock and dam system was constructed in the 1930s and is showing signs of age. In the late 1980s, the Corps began a feasibility study to gauge the economic viability of extending several locks on the UMR–IWW system.

The Corps developed a theoretical spatial equilibrium model for this study to help forecast future levels of barge traffic across the waterway system. The Corps also developed the ESSENCE model, which calculates equilibrium values for barge traffic and waterway congestion and calculates changes in barge shipping costs. But because of flawed assumptions and data, the report concludes that the results of the spatial equilibrium model and ESSENCE model should not be used in the feasibility study. The key problem was not the theoretical motivation behind the models, but rather how they were implemented and the data used as input.

"The Water Science and Technology Board's review of the Upper Mississippi River–Illinois Waterway System Navigation Study provides an unbiased assessment of the study's content. The review provides a foundation to move forward into a restructured study that all the collaborative partners can support. Today's planning process is moving forward thanks to the review of the Water Science and Technology Board."

Gretchen Benjamin
Mississippi River Planner
Wisconsin Department of Natural Resources

The report notes that locks and dams on the UMR–IWW system are presently not being used efficiently. It thus recommends that a comprehensive review and assessment of the benefits and costs of nonstructural options for improving waterway traffic management be conducted. It also recommends that Congress direct the Corps to evaluate nonstructural options for improving waterway traffic management.

The Corps conducted many environmental investigations as part of its study. However, it was not clear how these environmental studies affected the decision regarding possible lock extensions. The report thus recommends that the nature of the relations between environmental studies and the decisionmaking process regarding proposed lock extensions be clarified.

The Department of Defense was the study sponsor. The NRC's Transportation Research Board assisted with this study. Jeffrey Jacobs was the study director and Anita Hall was the project assistant. The committee met three times during this one-year study. Committee members were:

Lester B. Lave, *Chair*, Carnegie Mellon University, Pittsburgh, Pennsylvania
Phillip Baumel, Iowa State University, Ames
Kenneth D. Boyer, Michigan State University, East Lansing
Michael S. Bronzini, George Mason University, Fairfax, Virginia
Kenneth L. Casavant, Washington State University, Pullman
Bonnie G. Colby, University of Arizona, Tucson
Jonathan P. Deason, George Washington University, Washington, D.C.
José A. Gómez-Ibánez, Harvard University, Cambridge, Massachusetts
Delon Hampton, Delon Hampton and Associates, Chartered, Washington, D.C.
Edwin E. Herricks, University of Illinois, Urbana-Champaign
David H. Moreau, University of North Carolina, Chapel Hill

Missouri River Ecosystem: Exploring the Prospects for Recovery

The Missouri River ecosystem has undergone a variety of human-induced changes since the mid-nineteenth century, many of them as part of efforts to modify the river for society's needs. This WSTB report describes the current status of the Missouri River and floodplain ecosystem, and

Some members of the Committee on Missouri River Ecosystem Science enjoying a lunch break on a Missouri River canoe trip near Fort Benton, Montana.

discusses how scientific information might be used to help implement an adaptive management approach for the river and floodplain ecosystem.

The report lists several specific, quantified environmental changes in the Missouri River ecosystem, and states that unless some portion of the hydrologic and geomorphic processes that sustained the pre-regulation Missouri River ecosystem are restored—including flows that emulate the natural hydrograph, and cut-and-fill alluviation processes—ecological degradation will continue.

The rich and extensive body of scientific research on the Missouri River ecosystem is also discussed. The report notes, however, that this research has not been well synthesized, and that there are few studies that consider the ecosystem as a single unit or explore cross-disciplinary linkages. The most significant scientific unknowns in the Missouri River ecosystem are how the ecosystem will respond to management actions designed to improve ecological conditions.

The report recommends that a moratorium be enacted on further revisions to the Corps of Engineers' document for operating the reservoir system—the "Master Manual"—until such revisions reflect a collaborative, science-based approach, based upon adaptive management, to improve the state of the Missouri River ecosystem. The report recommends the establishment of a stakeholder group to help provide input for river management decisions. Finally, in order to ensure support of the adaptive management effort and to keep management actions focused on some degree of ecological improvements, it is recommended that Congress enact a Missouri River Protection and Recovery Act.

The study was sponsored by the Corps of Engineers and the Environmental Protection Agency. Jeffrey Jacobs was the study director and Anike Johnson was the project assistant. The committee met six times during this two-year study. Committee members were:

Steven P. Gloss, *Chair,* U.S. Geological Survey, Flagstaff, Arizona
Robert K. Davis, University of Colorado, Boulder
David T. Ford, David Ford Consulting Engineers, Sacramento, California
Gerald E. Galloway, Jr., International Joint Commission, Washington, D.C.
Larry W. Hesse, River Ecosystems, Inc., Crofton, Nebraska
W. Carter Johnson, South Dakota State University, Brookings
Peggy A. Johnson, Pennsylvania State University, University Park
Kent D. Keenlyne, Biological Services, Inc., Pierre, South Dakota
Stephen S. Light, Institute for Agriculture and Trade Policy, Minneapolis, Minnesota
Ernest T. Smerdon, University of Arizona, Tucson
A. Dan Tarlock, Chicago-Kent College of Law, Chicago
Robert G. Wetzel, University of North Carolina, Chapel Hill

Opportunities to Improve the USGS National Water Quality Assessment Program

The U.S. Geological Survey established the National Water Quality Assessment (NAWQA) Program in 1985 to assess water quality conditions and trends in representative river

basins and aquifers across the United States. The WSTB has provided periodic advice as the program has evolved over the years. Following completion of its first decade of nationwide monitoring (1991 to 2001; called Cycle I), in 1999 U.S. Geological Survey scientists requested the input of the WSTB to help shape NAWQA activities during the program's second decade of monitoring, called Cycle II. This report presents the WSTB's fifth effort to advise the U.S. Geological Survey on the NAWQA program.

The report includes an assessment of NAWQA and its representative accomplishments to date. It finds NAWQA to be a mature and respected national program, with hundreds of publications and with many significant science and policy achievements for the program to build upon in the coming decade. The majority of the report is a detailed assessment with subsequent recommendations of preliminary U.S. Geological Survey plans for Cycle II monitoring and water quality studies that are organized in accordance with NAWQA's three major and continuing goals: status, trends, and understanding of water quality.

The study was sponsored by the U.S. Geologic Survey. Mark Gibson served as the study director. Ellen de Guzman was the project assistant. This committee held five meetings during the course of this two-year study. Committee members were:

"Reviews of the National Water Quality Assessment (NAWQA) Program by the National Research Council (NRC) have been very valuable to the U.S. Geological Survey. We have had the NRC review NAWQA five times over 17 years. Each review has resulted in useful recommendations that we have implemented to improve NAWQA. We have been willing to implement their recommendations because the independent insight of the NRC committees reviewing our program has been focused on the nation's scientific needs that NAWQA can meet, and because NRC committees are composed of specialists well-suited to review large, complex programs like NAWQA."

Timothy Miller
Chief of the NAWQA Program
U.S. Geological Survey

George R. Hallberg, *Chair*, CADMUS Group, Inc., Boston, Massachusetts
Michael E. Campana, University of New Mexico, Albuquerque
Daniel B. Carr, George Mason University, Fairfax, Virginia
Lorraine L. Janus, New York City Department of Environmental Protection, Valhalla
Judith L. Meyer, University of Georgia, Athens
Kenneth H. Reckhow, Duke University, Durham, North Carolina
Marc O. Ribaudo, U.S. Department of Agriculture, Washington, D.C.
Kenneth K. Tanji, University of California, Davis
Richard M. Vogel, Tufts University, Medford, Massachusetts
Marylynn V. Yates, University of California, Riverside

Predictability and Limits-to-Prediction in Hydrologic Systems

The Committee on Hydrologic Science (COHS) is studying priorities and future strategies for hydrologic science. As part of this initiative, a workshop on "Predictability and Limits-to-Prediction in Hydrologic Systems" was held in Boulder, Colorado, September 21–22, 2000.

Numerous topics in hydrologic science involve some form of predictability. Understanding the limits of prediction affects the activities and goals of federal, state, and local agencies, research in the academic community, engineering practices in industry, and public awareness of hydrologic systems.

The workshop resulted in the definition of five research challenges. First, USGCRP agencies should look beyond forecasting and prediction to investigate the limits to predictability of the wider range of hydrologic variables (e.g., groundwater contaminant transport and ecosystem dynamics). Second, there is a need for furthering the understanding between predictability and sub-grid-scale processes. Third, data assimilation, where observations are merged with models, is well developed in the meteorology community but needs to be applied to other areas of hydrologic and environmental sciences. Fourth, multi-agency joint projects need to be devised to maximize the return for the resource investment and to engage a larger cross-section of the research and user communities. Further, there is a need to reverse the degradation of existing monitoring systems where the collection of consistent measurements and observations can lead to improved predictions. Finally, the key to success in research

programs on predictability in hydrologic systems and in operational prediction programs is to develop strong linkages between research institutions and operational activities.

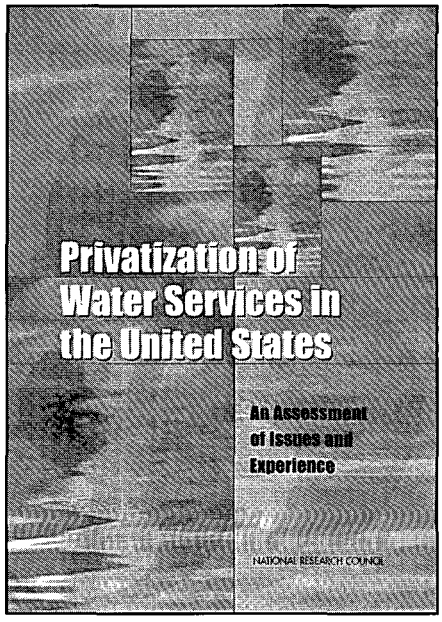
Sponsors and committee members of the COHS are listed on page 16, along with description of the committee's current program. Vaughan Turekian of the Board on Atmospheric Sciences and Climate was the study director and Anita Hall was the project assistant.

Privatization of Water Services in the United States: An Assessment of Issues and Experience

Interests in the prospects for private sector participation in water utility ownership and operations grew markedly during the 1990s, both in the United States and abroad. This report identifies and explains the factors that are driving municipal officials to consider privatization as an option for delivering water services. Privatized water services have a long history in the United States, and the initial water systems in large U.S. cities were private ventures. As the nation's cities expanded, however, the resources required to adequately maintain and extend the water infrastructure generally grew beyond the means of the private sector. Today, investor-owned water utilities account for about 14 percent of total U.S. water revenues, a market share that has held remarkably steady since World War II. The report notes that this share of investor-owned utilities was not likely to change appreciably in the near future.

Competition from large national and global water companies has motivated improved performance on the part of public water utilities in the United States, and practices like "benchmarking" and "re-engineering" are helping improve performance standards in the public sector. Small- to medium-sized water utilities face the greatest challenges, as they have limited resources and access to contemporary facilities and training opportunities, and therefore are prime candidates for taking advantage of services from other sources, which could be public or private. And while the report notes that not all water privatization efforts in the United States have been successful, it also points out that well run and poorly run organizations exist in both the public and private water sectors.

The study was sponsored by American Water Works Company, California Water Service Company, the Environmental Protection Agency, Severn Trent Environmental Services, and the University of California. Jeffrey Jacobs was the study director and Ellen de Guzman was the project assistant. The committee met five times during this two-year study. Committee members were:



This 2002 report evaluates the fiscal and policy implications of privatizing water and wastewater services in the United States, and identifies conditions where privatization would represent a viable option.

Charles W. Howe, *Chair*, University of Colorado, Boulder
Jean E. Auer, American States Water Company, Hillsborough, California
Janice A. Beecher, Beecher Policy Research, Inc., Indianapolis, Indiana
Charles A. Beuscher, Jr., Washington University, St. Louis, Missouri
Larry Chertoff, Water Industry Council, Brooklyn Heights, New York
Jerome B. Gilbert, J. Gilbert, Inc., Orinda, California
Richard Howitt, University of California, Davis
Daniel A. Okun, The University of North Carolina (Emeritus), Chapel Hill
David E. Rager, Cincinnati Water Works, Cincinnati, Ohio
William G. Reinhardt, Public Works Financing, Westfield, New Jersey
William N. Stasiuk, New York City Department of Environmental Protection, Kingston, New York

Review of the Florida Keys Carrying Capacity Study

The Florida Keys have long been recognized as an ecologically rich, but sensitive, area. The Keys have experienced a steady growth in population, and its ecosystem has been steadily degraded by the attendant environmental impacts. The State of Florida has designated the Florida Keys as an Area of Critical State Concern. As a result, Monroe County (which includes the Keys) must meet strict planning standards, which included a 1996 ruling to complete a five-year work program. One component of the program was the Florida Keys Carrying Capacity Study and a companion Carrying Capacity Analysis Model (CCAM). The WSTB and the Ocean Studies Board were requested to assemble a committee to review and evaluate the CCAM.

The report finds that the CCAM, which incorporates data on land use, socio-economics, transportation, water management, and aquatic and terrestrial ecology, represents a potentially useful effort in helping manage the Keys' fragile ecosystems. The report points out, however, that significant improvements are required in several areas if the model is to live up to its expectations, and that the development of a model to determine carrying capacity may transcend current levels of scientific understanding. Nonetheless, the CCAM may be a useful guide to professional judgment by experts if its assumptions and limitations are clearly understood.

The study was sponsored by the Corps of Engineers and the Florida Department of Community Affairs. Joanne Bintz of the Ocean Studies Board was the study director and Mark Gibson and Jeffrey Jacobs provided research support and liaison. Nancy Caputo of the Ocean Studies Board was the project assistant. This committee met twice over the course of one year and produced two reports, an interim report and a final report. Committee members were:

Scott W. Nixon, *Chair,* University of Rhode Island, Narragansett
George H. Dalrymple, Everglades Research Group, Inc., Homestead, Florida
Robert E. Deyle, Florida State University, Tallahassee
Wayne C. Huber, Oregon State University, Corvallis
Mark S. Peterson, University of Southern Mississippi, Ocean Springs
Stephen Polasky, University of Minnesota, Minneapolis
Norbert P. Psuty, Rutgers University, New Brunswick, New Jersey
Malcolm D. Rivkin, University of Maryland, College Park
Daniel P. Sheer, Water Resources Management Inc., Columbia, Maryland

Review of the USGCRP Plan for a Science Initiative on the Global Water Cycle

The global water cycle is central to Earth's climate and reflects the physical, biological, and chemical processes and interactions of the coupled climate system. In addition, water exerts a profound influence on human activities and natural environmental processes. Anthropogenic global changes affect climate, land use, and water use. They also increase the uncertainty in forecasts of the water cycle, especially as these forecasts relate to the water management natural hazards mitigation. Improved knowledge of land surface/atmosphere interactions—including more precise quantification of precipitation, soil moisture, evapotranspiration, river flow, groundwater storage and flow, and the movement of carbon and nutrients—has been recognized as critical to our ability to understand variability and changes in the Earth's climate system.

This WSTB report was produced in response to a request by the Interagency Working Group on Global Water Cycles of the U.S. Global Change Research Program (USGCRP). The report concludes that the foremost priority of the USGCRP must be to ensure a sound foundation of observations, a thorough understanding of hydrologic processes on a large river basin and global scale, and accurate representation of the water cycle in climate models. Priorities should be given to three main areas: clear definition of quantitative observational data requirements for regional and global water cycle elements; validation of

"The NRC review of the U.S. Global Change Research Program Plan for a new Global Water Cycle Initiative provided very fruitful insights that will enrich federal water cycle research programs and their relevance to climate change science."

Rick Lawford
Program manager, Office of Global Programs
National Oceanic and Atmospheric Administration

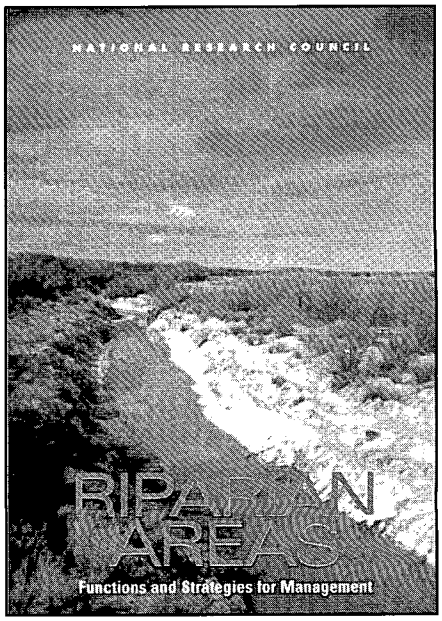
the water cycle components of climate models; and improvements in the understanding of hydrologic processes that link climate variability to outcomes relevant to water resources management.

Funding for activity was provided by the Bureau of Reclamation, the Environmental Protection Agency, the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, the National Science Foundation, the U.S. Army, and the U.S. Geological Survey. The study was conducted by the Panel on Review of "A Plan for New Science Initiative on the Global Water Cycle," composed of six members of the Committee on Hydrologic Science and three members of the Climate Research Committee. Stephen Parker was the study director and Anita Hall was project assistant. Committee members were:

Eric F. Wood, *Chair*, Princeton University, Princeton, New Jersey
Mary P. Anderson, University of Wisconsin, Madison
Antonio J. Busalacchi, Jr., University of Maryland, College Park
William K. Nuttle, Consultant, Ottawa, Ontario, Canada
Marc B. Parlange, Johns Hopkins University, Baltimore, Maryland
Kenneth W. Potter, University of Wisconsin, Madison
Eugene M. Rasmusson, University of Maryland, College Park
Dian J. Seidel, National Oceanic and Atmospheric Administration, Silver Spring, Maryland
John L. Wilson, New Mexico Institute of Mining and Technology, Socorro

Riparian Areas: Functions and Strategies for Management

The Clean Water Act requires that wetlands be protected from degradation because of their important ecological roles, which include maintenance of water quality and provision of fish and wildlife habitat. For the last 15 years, this protection has slowed the precipitous decline in wetland acreage observed in the U.S. since European settlement. However, protection of wetlands generally does not encompass riparian areas—lands bordering rivers, lakes, and estuaries—even though they often provide many of the same functions as wetlands. Growing recognition of the similarities in functioning of wetlands and riparian areas and the differences in their protection led the NRC in 1999 to undertake a comprehensive study of riparian areas.



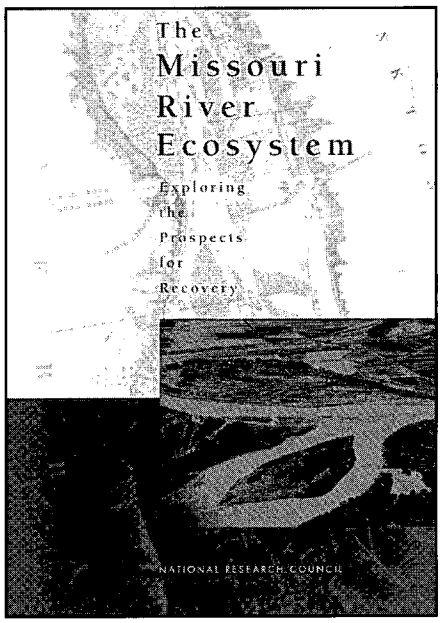
The WSTB conducted a comprehensive study of riparian areas, their functions, ecological importance, and strategies on how to sustainably manage them.

This report provides several overarching conclusions and recommendations intended to heighten awareness of riparian areas commensurate with their ecological and societal values. First, restoration of riparian functions along America's waterbodies should be a national goal. Because riparian areas perform a disproportionate number of biological and physical functions on a unit area basis, their restoration can have a major influence on achieving the goals of the Clean Water Act, the Endangered Species Act, and flood damage control programs. Second, protection should be the goal for riparian areas in the best ecological condition, while restoration is needed for degraded riparian areas. Where degradation has occurred, there are vast opportunities for restoring functioning to these areas. Third, patience and persistence in riparian management is needed. The current degraded status of many riparian areas represents the cumulative, long-term effects of numerous and often incremental impacts from a wide variety of land uses. Years to decades will be required for restoring the functions of many degraded riparian areas. Finally, many riparian areas are not immune to the effects of poor management in adjacent uplands.

The study was sponsored by the Bureau of Land Management, the Bureau of Reclamation, the Environmen-

tal Protection Agency, the Natural Resource Conservation Service, the National Science Foundation, the U.S. Forest Service, and the U.S. Geological Survey. The Board on Environmental Studies and Toxicology assisted with this study. Laura Ehlers was the study director and Anita Hall was the project assistant. The committee held five meetings during this two-year study. Committee members were:

Mark M. Brinson, *Chair,* East Carolina University, Greenville, North Carolina
Lawrence J. MacDonnell, *Vice-Chair,* Porzak, Browning & Bushong, Boulder, Colorado
Douglas J. Austen, Illinois Department of Natural Resources, Springfield
Robert L. Beschta, Oregon State University, Corvallis
Theo A. Dillaha, Virginia Polytechnic Institute and State University, Blacksburg
Debra L. Donahue, University of Wyoming College of Law, Laramie
Stanley V. Gregory, Oregon State University, Corvallis
Judson W. Harvey, U.S. Geological Survey, Reston, Virginia
Manuel C. Molles, Jr., University of New Mexico, Albuquerque
Elizabeth I. Rogers, White Water Associates, Inc., Amasa, Michigan
Jack A. Stanford, University of Montana, Polson



The 2002 report on the Missouri River discusses the opportunities, strategies, and organizational arrangements needed to restore more natural flows and enhance river system ecology.

WOLMAN LECTURES

The Water Science and Technology Board sponsors an annual lecture on a water resource topic of broad interest. Named in honor of the late Abel Wolman, a preeminent water resources engineer and scholar, these lectures have historically covered water resources issues ranging from federal water policy to contemporary scientific advances. The Wolman Lectures in 2002 and 2001 were no exception, as Dr. Rita Colwell and Dr. Perry McCarty covered an impressive array of scientific and engineering, as well as social and policy, considerations in their respective remarks.

2002

A Global Thirst for Safe Water: The Case of Cholera

Rita Colwell, director of the National Science Foundation, delivered the 11th Abel Wolman Lecture on January 25, 2002. Dr. Colwell opened her lecture by explaining how global population growth is increasing pressure on the world's water supplies. This situation is likely to worsen, as global population is expected to increase by roughly 40 percent in the next two decades. Dr. Colwell pointed out that because the issue of access to safe water supplies has global dimensions and involves complex systems, it is critical to integrate scientific and technological advances with knowledge from different disciplines

Dr. Colwell used perspectives and approaches from a variety of disciplines to help address the problem of continued spread of cholera in Bangladesh. By using approaches from remote sensing, biosciences, genomics, and social sciences, Dr. Colwell and her research team traced several events taking place across various temporal and spatial scales to integrate the multiple facets of cholera. For example, she and her team found a correlation between changes in sea surface temperature and cholera outbreaks. Increases in sea surface temperature, especially off tropical and subtropical coasts, result in phytoplankton growth (phytoplankton is food to zooplanktons such as copepods). By tracking phytoplankton blooms, they were able to identify potential cholera outbreaks.

Despite the simple measures available to provide clean, uncontaminated water for drinking and bathing, continued spread of the disease has puzzled many scientists. Insights from social sciences have shed light on such situations. In the case of cholera in Bangladesh, community behavior is an important factor in the spread of the disease.

Dr. Rita Colwell, director of the National Science Foundation delivered the 2002 Wolman Lecture on the challenges of assuring safe water supply.

Dr. Colwell also discussed the importance of integrative approaches at a time when serious diseases are emerging and reemerging from unexpected sources, and at a time when the question of water security has raised awareness of U.S. public health programs and the security of the nation's water treatment infrastructure.

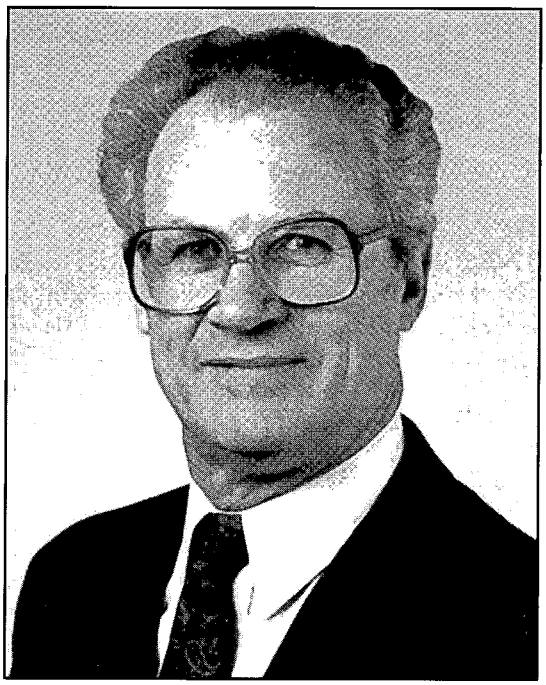
2001

Water Technology Development in the 21st Century: What Should We Do, Not What We Can Do

Dr. Perry McCarty, professor emeritus of Stanford University, delivered the 10th Abel Wolman Lecture on January 22, 2001. Dr. McCarty began his lecture by reviewing some of the twentieth century's key technical water treatment advances. He noted that these advances have been outstripped by the rate at which we have created new environmental problems. He pointed out that this situation calls for greater scientific investigation and understanding, as it is often difficult to convince the public that scientific understanding is adequate for protecting public water supplies.

Dr. McCarty pointed to several reasons to be optimistic about the prospects for future scientific inquiry, such as the revolutionary developments in molecular biology in the second half of the twentieth century. The creation of genetically modified bacteria for degrading contaminants shows great potential, despite slow acceptance by regulators and the public. Dr. McCarty noted that molecular biology's greatest promise may be in its application for monitoring and analysis, and he discussed how the ability to selectively amplify DNA now allows for the presence of a few microorganisms in a drop of water to be detected.

Dr. McCarty also discussed changing technical approaches to water quality management. Among these changes are a reduced dependence on end-of-the-pipe treatment processes, greater efficiency of resource utilization, recycling for multiple uses, and the modification of products to effect greater environmental compatibility. Dr. McCarty closed his lecture with some thoughts on how society's technical advances, or what we *can* do, do not always suggest how those advances should be applied, or what we *should* do.

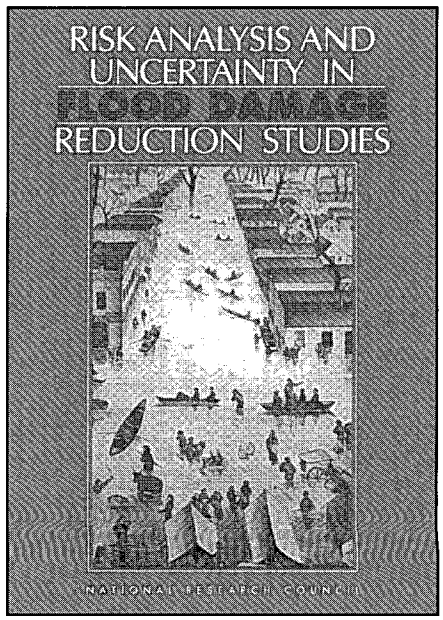


Dr. Perry McCarty, Professor Emeritus of Stanford University, delivered the 2001 Wolman Lecture on the frontiers of environmental science and technology.

FUTURE PLANS

In its efforts to identify emerging water resources problems and issues, the WSTB occasionally devotes the majority of one of its meetings to discussing contemporary and emerging water issues that are candidates for a WSTB study. Examples of studies and initiatives that have resulted from these sessions include a 2001 workshop on Upper Mississippi watershed and water quality management, the 2002 study on U.S. water services privatization, and a 2002 symposium on maintaining the safety of the nation's water supplies. The current suite of emerging WSTB initiatives, some of which are self-generated and some of which are being developed in response to agency and other sponsor requests, are described in this section.

A topic of special interest to the WSTB and its staff is international water management. The WSTB has a modest, but successful, record of investigating international water issues. The WSTB's most recent report that addressed international water issues is the 1999 *Water for the Future* report, in which a committee of Israelis, Jordanians, Palestinians, along with one Canadian and five U.S. citizens, evaluated scientific and technical means for sustainably managing water resources in the Middle East. Despite limited opportunities for becoming more active on this front, the WSTB and its staff remain eager to investigate scientific and technical dimensions of international water issues, including comparative assessments between nations or continents. We note also that WSTB products have been widely disseminated for application in other parts of the world. At least four WSTB reports have been translated and published in other languages (Russian, Japanese, and Spanish).



This 2000 report assesses the Corps of Engineers risk analysis techniques in flood damage reduction studies.

Assessing the Adequacy of Current National Water Quality Monitoring and Assessment Efforts

The EPA Office of Water is requesting an evaluation of the effectiveness of the current effort by state and federal governments to assess and report the health of the nation's aquatic resources. There is considerable variability in the quantity and quality of data and information used by the states to determine attainment of water quality standards. In order to fulfill the promise of the Total Maximum Daily Load (TMDL) program and other water quality efforts, state monitoring programs will need to be improved in several areas. A proposed WSTB study would evaluate (1) the comprehensiveness of water body segmentation; (2) the existing criterion for determining WQS attainment (3) the mix of physical, chemical, biological measures being used to make defensible attainment decisions, (4) appropriate monitoring approaches for obtaining these data, and (5) statistical approaches for making attainment determinations. This would elaborate on the "full assessment" step introduced in the 2001 WSTB report on the TMDL program. It is expected that this step would exhibit less state-to-state variability than earlier steps of the TMDL process, like use designation, water quality standard setting, and preliminary listing decisions. WSTB staff is currently working with EPA to develop a formal proposal.

Assessment and Control of Nonpoint Source Pollution

With the advent of treatment technologies for reducing point source pollution, nonpoint source pollution has become the major threat to water quality in the nation's waterbodies, both coastal and inland. Nonpoint source pollution is associated with a variety of human activities that involve changes in vegetative cover, disturbance of soil, or alteration of hydrology. Consequences of nonpoint source pollution range from minor to severe, depending on the intensity of activity, the vulnerability of the natural systems where the activity occurs, and the technologies that are used to mitigate the adverse effects on water quality and aquatic ecosystems.

This proposed study would investigate (1) the sufficiency of knowledge about sources of nonpoint source

pollution, including land use change and other factors, (2) the state of modeling to predict pollutant loads from these sources, and (3) the effectiveness of regulatory and management approaches in controlling nonpoint source pollution. The study would complement the 2000 NRC report, *Clean Coastal Waters*, by focusing more on inland nonpoint sources of pollution and considering a broader range of pollutant types.

CALFED Bay-Delta Program

California's Bay-Delta is a troubled aquatic ecosystem of enormous importance to California's water supplies and environment. Recently the CALFED consortium of state and federal agencies completed a five-year phase of planning for water supply, water quality, ecosystem restoration, and levee stability projects throughout California. As the effort is moving from a planning phase into implementation, the leaders of the program's science team have initiated discussions with the WSTB and the Board on Environmental Studies and Toxicology concerning an advisory relationship. As of the publication of this report, an appropriate collaborative relationship was being negotiated.

Disinfection Issues and Alternatives

Disinfection of water has been a cornerstone of public health protection for over 100 years. It is accomplished by the use of chemicals (most commonly chlorine) or by ultraviolet radiation, and it is important in industry, healthcare, home hygiene, drinking water, and wastewater applications. There are mounting concerns regarding the use of disinfectants because of the potential for the creation of harmful disinfection byproducts and other environmental impacts. Thus, there is a growing, widespread need for an evaluation of the efficacy, benefits, and environmental costs of disinfectants and for an exploration of alternative disinfectants. This need is equally vital for both industry and government.

The WSTB proposes a study to assess current scientific understanding of water and wastewater disinfection processes and their alternatives. For a suite of chemical and physical disinfectants—including chlorine, ozone, and UV irradiation—the committee will summarize the current state of knowledge regarding primary disinfection, including emerging pathogens and disinfectants, the mechanisms of microbial inactivation via disinfection, and microbial resistance to disinfectants vs. microbial tolerance. It will evaluate methods used to quantify disinfection efficacy and outcome, and it will draw parallels with methods of efficacy testing used in other fields. Finally, the committee will summarize the gaps in the science and practice of disinfection that limit understanding of this process.

Maintaining Safety of Our Nation's Water Supplies

The events of September 11, 2001 have led many to question the vulnerability of our water systems to deliberate attack or sabotage. Although recognized in the past, the vulnerability of our water systems to deliberate acts has usually not received a great deal of attention, partly because developing and maintaining existing water systems received primary attention. Many components of our water systems are aging and need repairs, replacements, or upgrades. This infrastructure improvement has assumed a heightened importance since September 11, as there may be opportunities to protect our water system infrastructure from intentional acts. Although driven by a sense of urgency because of recent events, it is critical to carefully consider new approaches that may ensure water system security.

Several issues need to be better understood to protect our water supply systems from intentional acts, all of which will require engineering analysis, scientific advances, and evaluation of institutional arrangements and water policies. First, water supply, water treatment, and water distribution

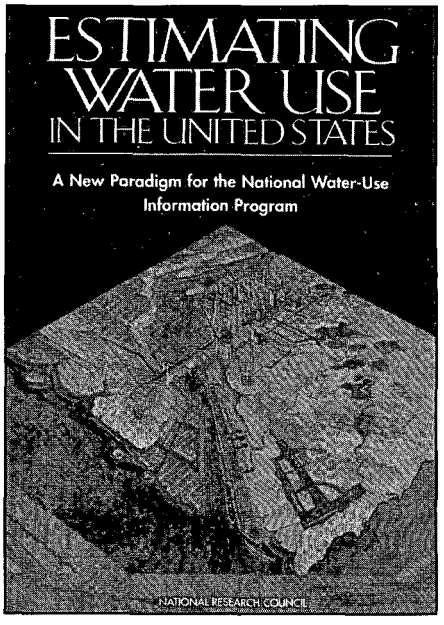
"WSTB reports have given the Army Secretary and the Corps of Engineers leaders invaluable assistance in understanding complex planning and engineering issues within the Army's Civil Works program. Agency policy and practice have moved ahead in important areas with the confidence that the scientific community has provided its best advice. For example, formulation of contemporary flood damage reduction projects now benefits from the WSTB report, *Risk Analysis and Uncertainty in Flood Damage Reduction Studies*. Modern water projects differ from those of even a decade ago, and the work of the WSTB has helped shape that change."

G. Edward Dickey
Private consultant and former Chief of Planning, Corps of Engineers

systems may be the target of physical attacks. Dams, and aqueducts and pumping stations that capture and convey water over long distances are especially vulnerable.

Second, there is potential for harmful chemical or biological agents to be added to water systems, at the source, at the treatment plants, or within the distribution system. Harmful agents could also be introduced into a water source when wastewater treatment facilities malfunction. Technological improvements could improve monitoring of water supplies for a broad spectrum of compounds, both known and unknown.

The WSTB plans to undertake assessments of various aspects of the safety of the nation's water supply systems. An initial activity, focused on the Environmental Protection Agency's Homeland Security efforts, is being organized as of the publication of this report. The goal of WTSB studies in this area will be to help set priorities for current operations, evaluate the state of knowledge and status of new technologies, and identify promising research opportunities.



WSTB studies also involve programmatic reviews such as this 2002 report on the USGS National Water-Use Information Program.

Los Angeles Basin Water Quality Management

Over the last two decades, there has been growing awareness of the significant water quality problems experienced in the greater Los Angeles basin, including nonpoint source pollution in the form of urban runoff and stormwater and wastewater discharges from regulated point sources. These problems have combined to cause water quality violations in the streams and rivers of the region that ultimately empty into the sea. These problems are made more acute by the basin's growing urban population, as well as the highly engineered hydrologic system that moves water from recharge areas to the sea.

The WSTB has been approached in regard to assembling a committee to study water quality management issues in the Los Angles basin. The WSTB is thus convening a workshop to help identify and prioritize the components of a future NRC study. The workshop will assemble a broad range of participants, from scientific experts to local community representatives, including those involved in developing a Sustainable Water Quality Initiative for the region. Technical issues likely to be addressed include how stormwater should be managed as a permitted point source, how to manage nonpoint pollution sources that predominate in the region (e.g., irrigation of residential and other landscaping, car washing, hosing off sidewalks and driveways, and discharges from businesses and industry), and how pollutant discharges within the basin translate into human and environmental health risks in the coastal receiving waters.

Opportunities for Sustainable Underground Storage of Recoverable Water

Future demands may press against the limits of fresh water supplies for a number of reasons, including population growth, increasing recognition of the value of ecological uses of water, groundwater overdraft, and climate change. There are relatively few options for increasing freshwater supply. In addition to increasing water use efficiency through demand side measures, the only strategy other than importation is temporary detention and storage of surface water during periods of high precipitation and flows for release during dryer periods. Because of problems associated with above-ground reservoirs (e.g., evaporative losses, land consumption, and ecological impacts), there is increased demand to store recoverable water underground. Such systems already exist in many U.S. states.

Many of these systems are successful, while some of them fail to meet expectations. There remain many questions about the hydrogeologic, geochemical, ecological, institutional, and legal conditions under which success is likely. The WSTB has discussed the prospects for conducting a comprehensive study of this topic. Such a study would address several issues: it would provide an integrated

assessment of the interrelated technical and institutional issues that arise with the adoption of this method, identify gaps in the science and practice that limit our understanding, provide a prospective examination of how these gaps might be closed, and provide guidance to prevent development of systems founded on unsubstantiated assumptions or poorly conceptualized models.

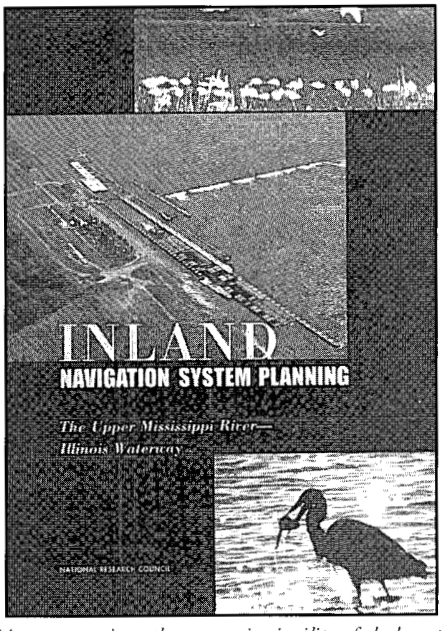
Real-time, Near-continuous Remote Sensing and River Basin Assessment

Advances in sensor systems and information technology over the past decade hold the potential for real-time, near-continuous monitoring, analysis, and forecasting of river basin hydrology, hydraulics, ecosystem functions, and elemental fluxes. This technology applies both to water quantity and quality, and promises to enhance the technological foundation for future river management. The expanded availability of Internet technology means that these data, analytical results, and images can be made available to researchers and cognizant agencies worldwide, nearly in real time. New disciplines, such as hydroinformatics, are being created to access and employ such electronically encapsulated information.

Opportunities for research and operational developments exist in at least three areas: (1) sensor systems for natural processes, (2) web-based environmental information systems, and (3) river basin simulation and prediction. These areas are interconnected. For example, advances in real-time sensing of atmospheric processes drive a demand for more accurate and timely prediction of extreme weather and floods. This research could serve needs of management agencies with respect to endangered species and ecosystems management, risk analysis for flood damage reduction, real-time control of river basin systems, and interbasin and international compacts and treaties. It could also help the private sector, including agricultural entities, water-intensive industrial facilities, and municipal water management authorities, to make better informed planning decisions. The WSTB is discussing a potential study of these topics, which would summarize the state of knowledge in these areas and identify themes for future research and application.

Stream Restoration

Managing our nation's water resources for sustained provision of environmental services and amenities is a national priority. Paramount to this agenda are management strategies that improve the environmental qualities of



This 2001 report reviews the economic viavility of lock extensions along the Upper Mississippi River-Illinois Waterway.

streams and rivers degraded by human disturbance or modification. The WSTB is convening a workshop to plan a study on stream restoration. The term "stream restoration" can mean various types of environmentally oriented stream management activities such as creation, reclamation, rehabilitation, replacement, mitigation, enhancement, and naturalization.

As an emerging science, stream restoration faces critical challenges that need to be defined, clarified, and resolved before it can contribute to the environmental goals of a national water resources agenda. First, improving a cross-disciplinary framework will contribute to multiobjective approaches to restoration efforts, which has strong public and political support. Second, because the current state of the science focuses on structure and form, little is known about system processes and connections, which are fundamental to system sustainability. By studying processes (ecological, geomorphological, hydrological, and hydraulic), restoration models need to consider dynamic interactions between system components. Third, current stream restoration practice derives heavily from trial-and-error approaches, which rely heavily on expert judgment. Because restoration practice and science are relatively new endeavors, the experience and knowledge bases for expert judgments are embryonic. There is a need to systematically evaluate post-project performance of restored stream

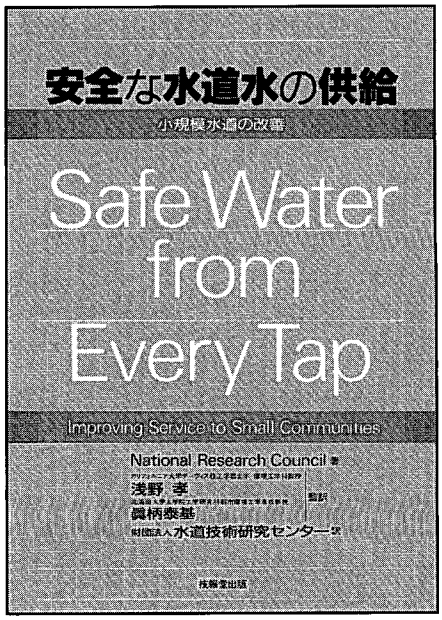
systems. Lastly, there is a need to develop process-based approaches to restoration that allow for incorporation of local context, as existing schemes are relatively inflexible in accommodating geographic variability in system attributes.

Watershed and Water Quality Management for the Upper Mississippi River Basin

The WSTB has been developing an initiative for a study of nonpoint source water pollution issues, problems, and management strategies in the Upper Mississippi River basin. The Upper Mississippi River Basin is an important site for tourism, agriculture, and navigation. Unfortunately, high sediment and nutrient levels threaten the health of the river system and the various activities it supports. For example, sediment fills the navigation channel of the Upper Mississippi and Illinois Rivers, costing over $100 million each year to dredge, and nutrient inputs degrade water quality in the Upper Mississippi River system and have impacts far downstream in the Gulf of Mexico. Strategies for better management of such problems in the Upper Mississippi are hampered by spotty data regarding the main sediment and nutrient sources, as well as the lack of a coordinated system for monitoring and evaluating these issues.

The WSTB convened a panel discussion in early 2001, co-chaired by Wisconsin Congressman Ron Kind and WSTB member Jerry Schnoor, in which these issues were discussed, along with ways in which a WSTB study might help improve the scientific basis for river system management. In early 2001 Congressman Kind introduced H.R. 3480, "The Upper Mississippi River Basin Protection Act" in the U.S. House of Representatives, where it was unanimously approved and sent to the U.S. Senate for consideration. A provision in that bill appropriate funding to the National Academies for a study the basin's water resources. As this report went to press, the bill was being considered by the Senate.

The WSTB envisions a study that would address several scientific issues related to Upper Mississippi River Basin nonpoint source pollution. Questions the committee might address include: What is the extent of water quality monitoring efforts in the basin? What is the state of scientific knowledge and what are the key research needs surrounding the transport and fate of nutrients, sediment, and pollutants? What is the state of knowledge of riparian ecosystems? Are current management practices helping manage and sustain these ecosystems?



The WSTB report, Safe Water from Every Tap *was translated into Japanese and was published by the Hokkaido University in Japan.*

"During the past year, we have drawn heavily on the analyses and conclusions of the Water Science and Technology Board's studies on wetlands mitigation and Corps of Engineers review procedures. The scientific expertise and credibility of the National Research Council has been invaluable to our efforts."

Melissa Samet
Senior Director, Water Resources
American Rivers

PUBLISHED REPORTS 1983~2002

The Water Science and Technology Board produces reports covering a wide range of water science, technology, and policy matters. This section provides information about reports dating back to 1982, the year the WSTB was formed. These reports are produced in three general formats:

- **Committee reports** are the products of intensive deliberations about critical topics by a committee of experts in the field. Most are published in book format.
- **Colloquium proceedings** contain papers presented at colloquia and an overview prepared by an expert committee. These are published in book format.
- **Wolman Lectures** are transcripts from the Water Science and Technology Board's annual lecture in honor of Dr. Abel Wolman, pioneer in the water supply and sanitation field. Written transcripts and videotapes of the lectures are available.

Reports are available from one of the following three sources:

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COMMITTEE REPORTS

Aquifer Storage and Recovery in the Comprehensive Everglades Restoration Plan: Review of Draft Project Management Plan for Aquifer Storage and Recovery Regional Study

This report reviews the project management plan for the aquifer storage and recovery regional study on adequacy of the proposed scientific methods to address key issues raised by the Committee on Restoration of the Everglades Ecosystem and the ASR Issue Team of the South Florida Ecosystem Restoration Task Force Working Group. *Committee Chair:* Jean M. Barr, University of Wisconsin, Madison.
2002
Prepublication as of October 2002
Published version will be available from The National Academies Press

Review Procedures for Water Resources Planning
This report is the first of a series from a larger study assessing the U.S. Army Corps of Engineers' methods of analysis and review procedures for its water resources project planning. It recommends ways to improve review procedures for Corps planning studies. *Panel Chair:* James K. Mitchell, Virginia Polytechnic Institute and State University, Blacksburg.
2002
Prepublication as of October 2002
Order from The National Academies Press
$12.00

Florida Bay Research Programs and Their Relation to the Comprehensive Everglades Restoration Plan
This report evaluates Florida Bay studies and restoration activities that affect the success of the Comprehensive Everglades Restoration Plan. *Committee chair:* Jean M. Bahr, University of Wisconsin, Madison.
2002
Prepublication as of October 2002
Order from The National Academies Press
$18.00

Review of the Florida Keys Carrying Capacity Study
This report assesses and makes recommendations on scientific methods, principles, and data that form the independent and critical reviews of the "Florida Keys

Carrying Capacity Study: Test Carrying Capacity Analysis Model. First Draft." *Committee Chair:* Scott W. Nixon, University of Rhode Island, Narragansett.
2002
6x9, 180 pages, paperbound
Order from The National Academies Press
$38.25

Compensating for Wetland Losses Under the Clean Water Act
This report evaluates mitigation practice as a way to restore and maintain quality of the nation's waters, particularly under the Clean Water Act. *Committee Chair:* Joy B. Zedler, University of Wisconsin, Madison.
2002
6x9, 322 pages, hard cover
Order from The National Academies Press
$49.95

Bioavailability of Contaminants in Soils and Sediments
This report assesses the current scientific understanding of processes that affect whether chemical contaminants present in soils and sediments at contaminated sites are bioavailable to humans, animals, and plants. *Committee Chair:* Richard G. Luthy, Stanford University, Stanford, California.
2002
Prepublication as of October 2002
Published version will be available from The National Academies Press

Privatization of Water Services in the United States: An Assessment of Issues and Experiences
This report identifies and explains the different issues and factors that drive municipalities to consider privatization as an option for providing and managing water services. *Committee Chair:* Charles W. Howe, University of Colorado, Boulder.
2002
6x9, 138 pages, hard cover
Order from The National Academies Press
$39.95

Opportunities to Improve the U.S. Geological Survey National Water Quality Assessment Program
This report assesses the U.S. Geological Survey National Water Quality Assessment Program and makes recommendations as the program enters into its second decade of nationwide monitoring. *Committee Chair:* George R. Hallberg, The Cadmus Group, Boston, Massachusetts.
2002
6x9, 252 pages, paperbound
Order from The National Academies Press
$34.00

A Report of A Workshop on Predictability and Limits-to-Prediction in Hydrologic Systems
This report discusses research milestones in the fields of predictability and limits-to-prediction in hydrologic systems. *Committee Chair:* Dara Entekhabi, Massachusetts Institute of Technology, Cambridge.
2002
6x9, 138 pages, paperbound
Order from The National Academies Press
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Estimating Water Use in the United States: A New Paradigm for the National Water-Use Information Program
This report reviews the USGS National Water-Use Information Program and makes recommendations and identifies opportunities. *Committee Chair:* David R. Maidment, University of Texas, Austin.
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Review of the USGCRP Plan for a New Scientific Initiative on Global Water Cycle
This report reviews and provides comments on the USGCRP report *A Plan for a New Scientific Initiative on the Global Water Cycle. Committee Chair:* Eric F. Wood, Princeton University, Princeton, New Jersey.
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Missouri River Ecosystem: Exploring the Prospects for Recovery
This report reviews the Missouri River ecosystem's status and trends, science programs and status of scientific knowledge, and organizational arrangements for supporting ecosystem monitoring programs and for implementing

adaptive management. *Committee Chair.* Steven P. Gloss, U.S. Geological Survey, Flagstaff, Arizona.
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This report discusses the characteristics, functioning, and services of riparian areas and makes recommendations for protecting and managing them. *Committee Chair.* Mark M. Brinson, East Carolina University, Greenville, North Carolina.
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Assessing the TMDL Approach to Water Quality Management
This report reviews the scientific basis underlying the development and implementation of the Total Maximum Daily Load program for water pollution reduction. *Committee Chair.* Kenneth H. Reckhow, Duke University, Durham, North Carolina.
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Classifying Drinking Water Contaminants for Regulatory Consideration
This report presents and demonstrates an innovative approach to the generation of future Candidate Contaminant Candidate Lists and explores the feasibility of developing and using virulance-related mechanisms for identifying emerging microbial pathogens for research and regulatory activities. *Committee Chair.* Deborah L. Swackhamer, University of Minnesota, Minneapolis.
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Envisioning the Agenda for Water Resources Research in the Twenty-first Century
This report discusses the future of U.S. water resources and appropriate research needed to address the nation's emerging water problems. *Committee Chair.* Henry J. Vaux, Jr., University of California, Oakland.
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Inland Navigation System Planning: The Upper Mississippi River-Illinois Waterway
This report reviews the Corps of Engineers' draft feasibility study that gauges the economic viability of extending several locks on the Upper Mississippi River-Illinois Waterway. *Committee Chair.* Lester B. Lave, Carnegie Mellon University, Pittsburgh, Pennsylvania.
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Aquifer Storage and Recovery in the Comprehensive Everglades Restoration Plan: A Critique of the Pilot Projects and Related Plans for ASR in the Lake Okeechobee and Western Hillsboro Areas
This report evaluates pilot projects for aquifer storage and recovery in the Everglades. It makes recommendations for studies of regional impacts, water quality, and system performance. *Committee Chair.* James M. Davidson, University of Florida (retired), Gainesville.
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Investigating Groundwater Systems on Regional and National Scales
This report makes recommendation concerning the USGS Ground Water Resources Program, which is designed to do regional groundwater assessment and science. *Committee Chair.* Kenneth R. Bradbury, Wisconsin Geological and Natural History Survey, Madison.
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Risk Analysis and Uncertainty in Flood Damage Reduction Studies
This report reviews and assesses the Corps of Engineers' risk analysis techniques in its flood damage reduction studies. *Committee chair:* Gregory B. Baecher, University of Maryland, College Park.
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Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution
This report assesses how coastal and watershed processes affect nutrient overenrichment of coastal ecosystems and recommends ways to improve research, monitoring, and management at the federal, state, and local levels. *Committee chair:* Robert W. Howarth, Cornell University, Ithaca, New York.
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Natural Attenuation for Groundwater Remediation
This report examines important issues about natural attenuation such as its scientific bases, the criteria for evaluating its potential for success or failure, and public concerns. *Committee chair:* Bruce E. Rittmann, Northwestern University, Evanston, Illinois.
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Watershed Management for Potable Water Supply: Assessing the New York City Strategy
This report evaluates the New York City Watershed Memorandum of Agreement, a comprehensive watershed management plan that allows the City to avoid filtration of its large upstate surface water supply. A range of conclusions and recommendations are made, many of which are applicable to surface water supplies across the country. *Committee chair:* Charles R. O'Melia, Johns Hopkins University, Baltimore, Maryland.
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Ecological Indicators for the Nation
The report provides a framework for selecting ecological indicators, and also provides recommendations on several specific indicators for gauging the integrity of the nation's ecosystems. *Committee chair:* Gordon A. Orians, University of Washington, Seattle.
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Seeing into the Earth: Noninvasive Characterization of the Shallow Subsurface for Environmental and Engineering Application
This report examines why noninvasive characterization is important and how improved methods can be developed and disseminated. *Committee chair:* Phillip R. Romig, Colorado School of Mines, Golden.
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Hydrologic Science Priorities for the U.S. Global Change Research Program: An Initial Assessment
This report makes recommendations regarding important hydrologic processes for the U.S. Global Change Research Program. Two broad areas—predictability and variability of regional and global water cycles and coupling of hydrologic systems and ecosystems through biogeochemical cycles—are identified that could augment the current hydrologic sciences content of the USGCRP. *Committee chair:* Dara Entekhabi, Massachusetts Institute of Technology, Cambridge.
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Downstream: Adaptive Management of Glen Canyon Dam and the Colorado River Ecosystem
This report evaluates the Grand Canyon Monitoring and Research Center's Long-Term Monitoring and Research Plan. *Committee chair:* James L. Wescoat, University of Colorado, Boulder.
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Water for the Future: The West Bank and Gaza Strip, Israel, and Jordan
This report recommends that Israel, Jordan, and the Palestinian Authority cooperate to ensure that an adequate supply of fresh, high-quality water is available for future generations, and offers several findings and observations on water resource management options for this area. *Committee chair:* Gilbert F. White, University of Colorado, Boulder.
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Hydrologic Hazards Science at the U.S. Geological Survey
This report provides advice to the U.S. Geological Survey with respect to its research, interpretive studies, and data collection efforts in the area of hydrologic hazards, which includes droughts, flooding, and related phenomena. *Committee chair:* Kenneth R. Bradbury, Wisconsin Geological and Natural Historic Survey, Madison.
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Identifying Future Drinking Water Contaminants
This report provides a conceptual approach for the development of future Drinking Water Contaminant Candidate Lists. It also includes a dozen papers presented at a workshop on emerging drinking water contaminants. *Committee chair:* Warren R. Muir, Hampshire Research Institute, Alexandria, Virginia.
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Improving American River Flood Frequency Analyses
This report evaluates the usefulness of various kinds of data, including historical and paleoflood data; recommends flood flow frequency distribution for the American River; and reviews recent scientific literature on climate variability and flood frequency. *Committee chair:* Kenneth W. Potter, University of Wisconsin, Madison.
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New Directions in Water Resources Planning for the U.S. Army Corps of Engineers
This report identifies ways in which the Corps of Engineers might reduce the time required in water project planning, and also recommends that the federal Principles and Guidelines for Water and Land Resources Implementation Studies be reviewed and modernized. *Committee chair:* David H. Moreau, University of North Carolina, Chapel Hill.
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New Strategies for America's Watersheds
This report recommends ways to steer the nation toward improved watershed management. It defines important terms, identifies fundamental issues, and discusses the timeliness of bringing watersheds to the forefront of ecosystem management. *Committee chair:* William L. Graf, Arizona State University, Tempe.
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Environmental Cleanup at Navy Facilities: Risk-Based Methods
This report reviews and critiques risk-based cleanup methods and identifies eleven criteria that must be part of any risk-based methodology adopted by the Navy, a responsible party with a large number of complex and

heavily contaminated waste sites. *Committee chair:* Edward J. Bouwer, Johns Hopkins University, Baltimore, Maryland.
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Setting Priorities for Drinking Water Contaminants
This report provides a phased decision process for determining which contaminants on the Drinking Water Contaminant Candidate List are appropriate for regulatory decisions and which will require additional research or monitoring. *Committee chair:* Warren R. Muir, Hampshire Research Institute, Alexandria, Virginia.
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Issues in Potable Reuse: The Viability of Augmenting Drinking Water Supplies With Reclaimed Water
This report recommends strategies for assessment of the safety of projects designed to supplement drinking water supplies with highly treated, reclaimed municipal wastewater. *Committee chairs:* James Crook, Black & Veatch, Boston, Massachusetts, and Richard Engelbrecht, University of Illinois, Urbana-Champaign.
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Innovations in Ground Water and Soil Cleanup: From Concept to Commercialization
This report assesses economic and political factors that have slowed the development of new technologies for ground water and soil cleanup and recommends solutions. It also provides a thorough review of state-of-the-art technologies for ground water and soil cleanup and recommends testing strategies. *Committee chair:* Suresh Rao, University of Florida, Gainesville.
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Valuing Ground Water
This report examines approaches for assessing the economic value of ground water and the costs of contaminating or depleting this resource. It suggests a framework for evaluating tradeoffs when there are competing uses for ground water. *Committee chair:* Larry W. Canter, University of Oklahoma, Norman.
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Building a Foundation for Sound Environmental Decisions
This report outlines a new framework for organizing the research program at the Environmental Protection Agency's Office of Research and Development. *Committee chair:* Raymond C. Loehr, University of Texas, Austin.
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Watershed Research in the U.S. Geological Survey
This report provides advice to the U.S. Geological Survey for improving its strategy for watershed research. It identifies opportunities for further scientific research and emphasizes the importance of collaboration with others in enhancing the agency's research efforts. *Committee chair:* George M. Hornberger, University of Virginia, Charlottesville.
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Alluvial Fan Flooding
This report recommends an updated regulatory definition of alluvial fan flooding, presents criteria for assessing whether an area is subject to such flooding, and provides examples of applying the definition and criteria to real situations. *Committee chair:* Stanley A. Schumm, Colorado State University, Fort Collins.
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This report reviews the status of inland waters and the history of limnology, describes the key future problems that may face water resource managers, and recommends changes in limnology education and research funding to meet water resources management needs. *Committee chair:* Patrick L. Brezonik, University of Minnesota, St. Paul.
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This report explores the impacts of changing supply and demand conditions, assesses current and potential technologies that might help water users adapt to changing conditions, and considers how to mitigate short- and long-term problems associated with irrigation. *Committee chair:* Wilford R. Gardner, University of California, Berkeley (emeritus).
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Meeting the Challenges of Megacities in the Developing World: A Collection of Working Papers
This collection of working papers addresses four significant challenges facing megacities in the developing world: creation of employment opportunities, affordable housing, water and sanitation services, and affordable, less-polluting transportation. Committee Chair: George Bugliarello, Polytechnic University, Brooklyn, New York.
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Hazardous Materials in the Hydrologic Environment: The Role of the U.S. Geological Survey
This report attempts to help shape the overall framework of the U.S. Geological Survey's research in hazardous materials science and technology and identifies general areas of scientific opportunity. *Committee chair:* George M. Hornberger, University of Virginia, Charlottesville.
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Safe Water from Every Tap: Improving Water Service to Small Communities
This report assesses the quality of drinking water in small communities and recommends a three-part strategy for improving it. *Committee chair:* Vernon L. Snoeyink, University of Illinois, Urbana-Champaign.
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Review of the Department of the Interior's National Irrigation Water Quality Program: Planning and Remediation
This report reviews the planning and remediation activities of the Department of the Interior's National Irrigation Water Quality Program at four sites where irrigation-induced water contamination problems exist. *Committee chair:* Rolf Hartung, University of Michigan, Ann Arbor.
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River Resource Management in the Grand Canyon
This report assesses the achievements and shortcomings of the Bureau of Reclamation's Glen Canyon Environmental Studies and reviews research conducted under the program. *Committee chair:* William M. Lewis, Jr., University of Colorado, Boulder.
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Use of Reclaimed Water and Sludge in Food Crop Production
This report reviews the current state-of-the-practice, public health concerns, existing guidelines and regulations, and implementation issues of using municipal wastewater and

sludge in food crop production. *Committee chair:* Albert L. Page, University of California, Riverside.
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Wetlands: Characteristics and Boundaries
This report establishes a reference definition of wetlands, providing a standard by which regulatory definitions and actions can be assessed, and recommends changes in current regulatory practices to strengthen objectivity and scientific validity. *Committee chair:* William M. Lewis, Jr., University of Colorado, Boulder.
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Review of EPA's Environmental Monitoring and Assessment Program: An Overall Evaluation
This report evaluates the EPA's Environmental Monitoring and Assessment Program, which was established to provide a comprehensive report on the condition of the nation's ecological resources and to detect trends in the condition of those resources. *Committee chair:* Richard F. Fisher, Texas A&M University, College Station.
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Mexico City Water Supply: Improving the Outlook for Sustainability
This bilingual report addresses the technical, health, regulatory, and social aspects of ground water withdrawals, water use, and water quality in the Mexico City metropolitan area and recommends how to improve the balance of water supply, demand, and conservation. *Committee co-chairs:* Charles T. DuMars, University of New Mexico, Albuquerque, and Ismael Herrera-Revilla, Universidad Nacional Autónoma de México, Mexico City.
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Flood Risk Management and the American River Basin: An Evaluation
This report evaluates the Corps of Engineers' efforts to identify and select appropriate flood damage reduction measures and comments on national flood management policies as they affect Sacramento, California. *Committee co-chairs:* Rutherford H. Platt, University of Massachusetts, Amherst, and Kenneth W. Potter, University of Wisconsin, Madison.
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Ground Water Recharge: Using Waters of Impaired Quality
This report examines the uncertainties and possible health risks involved in using impaired waters to augment natural recharge and looks at seven recharge projects currently using reclaimed water. *Committee chair:* Julian B. Andelman, University of Pittsburgh, Pittsburgh, Pennsylvania.
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Alternatives for Ground Water Cleanup
This report provides guidance on how the nation can balance public health and technological realities when addressing ground water contamination, and includes a list of approximately 80 contaminated sites that the committee reviewed and detailed case studies for several of the sites. *Committee chair:* Michael C. Kavanaugh, Malcolm Pirnie, Inc., Emeryville, California.
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National Water Quality Assessment Program: The Challenge of National Synthesis
This report examines the U.S. Geological Survey's national synthesis approach to water quality assessment and provides recommendations for improvement. *Committee chair:* George M. Hornberger, University of Virginia, Charlottesville.
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In Situ Bioremediation: When Does It Work?
This report provides direction for decisionmakers and offers detailed explanations of the processes involved in *in situ* bioremediation, circumstances in which it is best used, and methods for evaluating the results of bioremediation projects. *Committee chair:* Bruce E. Rittmann, Northwestern University, Evanston, Illinois.
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Ground Water Vulnerability Assessment: Predicting Relative Contamination Potential Under Conditions of Uncertainty
This report reviews the classes of current ground water vulnerability assessment methods. It examines the uncertainties associated with various approaches, provides guidance in selecting an approach, summarizes relevant databases available in the United States, and identifies areas of research important for development of future assessment techniques. *Committee chair:* Armando J. Carbonell, Cape Cod Commission, Barnstable, Massachusetts.
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Managing Wastewater in Coastal Urban Areas
This report examines the problems of wastewater and stormwater management in coastal urban settings, where water quality issues are often complex. It recommends a system of integrated coastal management for wastewater and stormwater and provides technical information on implementing such an approach. *Committee chair:* John K. Boland, Johns Hopkins University, Baltimore, Maryland.
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Water Transfers in the West: Efficiency, Equity, and the Environment
This report evaluates the impacts on the environment, rural communities, and other third parties that result when water is transferred from agricultural to other uses. *Committee chair:* A. Dan Tarlock, Chicago-Kent College of Law, Chicago, Illinois.
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Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy
This report outlines a national strategy for restoring the nation's rivers, streams, wetlands, and lakes. *Committee chair:* John Cairns, Jr., Virginia Polytechnic Institute, Blacksburg.
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A Review of Ground Water Modeling Needs for the U.S. Army
This report evaluates the state of the art in mathematical models of ground water flow and contaminant transport and advises the Corps of Engineers on how it might best use such models in its ground water remediation efforts at Army facilities. *Workshop chair:* David L. Freyberg, Stanford University, Stanford, California.
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Regional Hydrology and the USGS Stream Gaging Network
This report evaluates the portion of U.S. Geological Survey's stream gaging network used for estimating streamflow characteristics at sites on ungaged and unregulated rivers and for defining long-term trends. *Committee chair:* George M. Hornberger, University of Virginia, Charlottesville.
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Opportunities in the Hydrologic Sciences
This report presents a comprehensive assessment of scientific hydrology, including research frontiers, data needs, education in the hydrologic sciences, and resources for future work. *Committee chair:* Peter S. Eagleson, Massachusetts Institute of Technology, Cambridge.
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Preparing for the Twenty-First Century: A Report to the USGS Water Resources Division
This report outlines a plan for improved management of the U.S. Geological Survey's Water Resources Division, including the agency's organization, research priorities, data collection systems, and external outreach. *Committee chair:* Walter R. Lynn, Cornell University, Ithaca, New York.
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Toward Sustainability: Soil and Water Research Priorities for Developing Countries
This report highlights soil and water research critical to fostering sustainable agricultural practices for developing countries. *Committee chair:* Leonard Berry, Florida Atlantic University, North Palm Beach Gardens, Florida.
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This report provides advice on the use of ground water models in the regulatory process. *Committee chair:* Franklin W. Schwartz, Ohio State University, Columbus.
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Managing Coastal Erosion
This report discusses natural coastal erosion processes and how they are affected by human activity. It also advises the Federal Emergency Management Agency on how to administer erosion management strategies through the National Flood Insurance Program. *Committee chair:* William L. Wood, Purdue University, West Lafayette, Indiana.
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A Review of the USGS National Water Quality Assessment Pilot Program
This report reviews the U.S. Geological Survey's program to evaluate surface and ground water quality, the National Water Quality Assessment Program. *Committee chair:* Richard Engelbrecht, University of Illinois, Urbana-Champaign.
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Surface Coal Mining Effects on Ground Water Recharge
This report assesses techniques for quantifying ground water recharge in surface-mined areas. *Committee chair:* Herman Bouwer, U.S. Department of Agriculture Water Conservation Laboratory, Phoenix, Arizona.
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Irrigation-Induced Water Quality Problems
This report addresses trace element contamination caused by irrigation. It provides advice about how to mitigate existing irrigation-induced water quality problems and prevent future problems. *Committee chair:* Jan van Schilfgaarde, U.S. Department of Agriculture, Agricultural Research Service, Riverside, California.
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Estimating Probabilities of Extreme Floods: Methods and Recommended Research
This report evaluates techniques for characterizing rare floods. *Committee chair:* Jared L. Cohon, Johns Hopkins University, Baltimore, Maryland.
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River and Dam Management: A Review of the Bureau of Reclamation's Glen Canyon Environmental Studies
This report reviews the Bureau of Reclamation's planning and management of the Glen Canyon Environmental Studies (GCES), the integration of the GCES results into a decisionmaking report, and the utility of the GCES results for managing Glen Canyon Dam. *Committee chair:* G. Richard Marzolf, U.S. Geological Survey, Boulder, Colorado.
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Ground Water Quality Protection: State and Local Strategies
This report reviews ground water protection strategies in ten states and three local areas of the United States. It provides a model for those looking to establish or improve groundwater quality protection programs. *Committee chair:* Jerome B. Gilbert, East Bay Municipal Utility District, Oakland, California.
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A Review of the U.S. Army Construction Engineering Research Laboratory Program for Recycling and Reuse of Laundry and Shower Wastewater
This report evaluates the U.S. Army's Construction Engineering Research Laboratory program for reusing field laundry and shower wastewater. *Committee chair:* Richard Engelbrecht, University of Illinois, Urbana-Champaign.
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The Great Lakes Water Quality Agreement: An Evolving Instrument for Ecosystem Management
This report reviews the 1978 Great Lakes Water Quality Agreement between the United States and Canada. It addresses nutrient enrichment, toxic contamination, and institutional arrangements and sustainable development for preserving water quality. *Committee co-chairs:* Orie L. Loucks, Holcomb Research Institute, Indianapolis, Indiana, and Henry Regier, University of Toronto.
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Safety of Dams: Flood and Earthquake Criteria
This report assesses design levels for withstanding extreme floods and earthquakes at new and existing dams. *Committee chair:* George W. Housner, California Institute of Technology, Pasadena.
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The Lake Erie–Niagara River Ice Boom: Operations and Impacts
This report responds to a request from the International Joint Commission of the United States and Canada to help resolve issues associated with the ice boom at the entrance to the Niagara River. *Committee chair:* Harry Hamilton, Jr., State University of New York, Albany.
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Potomac Estuary Experimental Water Treatment Plant
This report is the culmination of an eight-year review of the Corps of Engineers study to determine the feasibility of using Potomac estuary waters as a water supply source for metropolitan Washington, D.C. *Committee chair:* Perry L. McCarty, Stanford University, Stanford, California.

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Water for the Future of the Nation's Capital Area
This report reviews the Corps of Engineers' determination of future water resources needs for metropolitan Washington, D.C. *Committee co-chairs:* Daniel A. Okun, University of North Carolina, Chapel Hill, and Walter Lynn, Cornell University, Ithaca, New York.
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Safety of Existing Dams: Evaluation and Improvement
This report addresses technical dam safety issues and provides guidance for achieving improvements in safety of existing dams. *Committee chair:* Robert B. Jansen, consulting engineer, Bellingham, Washington.
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Safety of Nonfederal Dams: A Review of the Federal Role
This report evaluates state and federal roles in enhancing dam safety programs. *Committee chair:* Robert B. Jansen, consulting engineer, Bellingham, Washington.
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A Levee Policy for the National Flood Insurance Program
This report provides recommendations for integrating structural and nonstructural flood mitigation in the National Flood Insurance Program. *Committee chair:* L. Douglas James, Utah State University, Logan.
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Hydrologic Sciences: Taking Stock and Looking Ahead
These proceedings are a compilation of the Abel Wolman Lecture presented by Thomas Dunne, at a colloquium on hydrologic sciences. The volume stresses a number of needs for furtherance of hydrologic science. *Wolman lecturer:* Thomas Dunne, University of California, Santa Barbara.
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Sustaining Our Water Resources
These proceedings summarizes a symposium held on the 10th anniversary of the WSTB. The event brought together sponsors, committee and board members, and the public, and examined the evolution of U.S. water resources management. *Symposium chair:* A. Dan Tarlock, Chicago-Kent College of Law, Chicago, Illinois.
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Colorado River Ecology and Dam Management
These proceedings review existing information about the Colorado River ecosystem and how it has been affected by operations of the Glen Canyon Dam. *Steering committee chair:* G. Richard Marzolf, U.S. Geological Survey, Boulder, Colorado.
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Managing Water Resources in the West Under Conditions of Climate Uncertainty
These proceedings examine the scientific basis for and management options available for helping water resources managers in responding to climate change. *Steering committee chair:* Stephen J. Burges, University of Washington, Seattle.
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Ground Water and Soil Contamination Remediation: Toward Compatible Science, Policy, and Public Perception
These proceedings focus on how science influences policy and public perceptions related to cleanup of groundwater and soil contamination, and describe the scientific constraints that should influence soil and ground water cleanup policy. *Steering committee chair:* Richard A. Conway, Union Carbide Corporation, Charleston, West Virginia.
1990
6x9, 261 pages, paperbound
Order from The National Academies Press
$19.00

Great Lakes Water Levels: Shoreline Dilemmas
These proceedings address hydrometeorologic, engineering, land-management, and policy issues related to fluctuations in Great Lakes water levels. *Steering committee chair:* John J. Boland, Johns Hopkins University, Baltimore, Maryland.
1989
6x9, 167 pages, paperbound
Out of print

Hazardous Waste Site Management: Water Quality Issues
These proceedings cover ground and surface water cleanup levels at hazardous waste sites. *Steering committee chair:* Michael C. Kavanaugh, Malcolm Pirnie, Inc., Emeryville, California.
1988
6x9, 224 pages, paperbound
Order from The National Academies Press
$27.95

National Water Quality Monitoring and Assessment
These proceedings discuss the need for a national water quality monitoring and assessment program. *Steering committee chair:* Richard Engelbrecht, University of Illinois, Urbana-Champaign.
1987
6x9, 108 pages, paperbound
Order from National Technical Information Service
Accession number: PB 87-157467
$31.50

Drought Management and Its Impact on Public Water Systems
These proceedings address drought management and its impact on public water systems. *Steering committee chair:* Robert Smith, University of Kansas, Lawrence.
1986
6x9, 127 pages, paperbound
Print-on-demand
Order from The National Academies Press
$30.75

Review of the Great Lakes Water Quality Agreement: Working Papers and Discussion
These proceedings convey the results of a conference to review the Great Lakes Water Quality Agreement. *Steering committee chair:* Orie L. Loucks, Holcomb Research Institute, Indianapolis, Indiana.
1984
8½x11, 174 pages, paperbound
Order from National Technical Information Service
Accession number: PB 85-110807
$44.00

Cooperation in Urban Water Management: Conference Proceedings
These proceedings assess the barriers to efficient management of urban water supplies. *Conference chair:* David H. Marks, Massachusetts Institute of Technology, Cambridge.
1983
8½x11, 187 pages, paperbound
Order from National Technical Information Service
Accession number: PB 83-217992
$44.00

WOLMAN LECTURES

A Global Thirst for Safe Water: The Case of Cholera
In this 2002 lecture, Dr. Rita R. Colwell, director of the National Science Foundation, discusses the issue of assuring safe water supplies in the face of growing world population and how interdisciplinary approaches can be useful in addressing these challenges.
2002
8½x11, 21 pages, photocopied

Order from the Water Science and Technology Board
No charge

Water Technology Development in the 21st Century: What Should We Do, Not What We Can Do
In this 2001 lecture, Dr. Perry L. McCarty, professor emeritus of Stanford University and a member of the National Academy of Engineering, discusses the challenges of new environmental problems that are outpacing advances in sciences and engineering.
2001
8½x11, 21 pages, photocopied
Order from the Water Science and Technology Board
No charge

Water Science and Technology: Some Lessons from the Twentieth Century
In this 1999 lecture, Dr. Gilbert F. White, distinguished professor emeritus of geography at the University of Colorado, Boulder and a member of the National Academy of Sciences, discusses the integration of environmental policy with water management policy.
1999
8½x11, 21 pages, photocopied
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Water, Life, and Justice: A Late Twentieth–Century Reflection From the South
In this 1998 lecture, Kader Asmal, Minister of Water Affairs and Forestry for the Republic of South Africa, discusses his nation's effort to plan and implement one of the world's innovative water management regimes.
1998
8½x11, 21 pages, photocopied
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Fear and Reason in Environmental Policy
In this 1996 lecture, Dr. M. Gordon Wolman, professor in the Department of Geography and Environmental Engineering at the Johns Hopkins University, and a member of the National Academy of Engineering and the National Academy of Sciences discusses the impacts of public fear on recent decades of environmental legislation and regulation related to water resources. Dr. Wolman emphasizes that to successfully address today's environmental problems, fear must be coupled with reason and scientific bases.
1996
8½x11, 32 pages, photocopied
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No charge

Eco-Societal Restoration: Re-Examining Human Society's Relationship with Natural Systems
In this 1994 lecture, Dr. John Cairns, Jr., director of the Center for Environmental and Hazardous Materials Studies, Virginia Polytechnic Institute and State University, and a member of the National Academy of Sciences emphasizes the importance of re-examining society's relationship with the environment to better understand our dependence on natural systems. He asserts that society's ethos must change in order for restoration of natural resources to be successful.
1994
8½x11, 17 pages, photocopied
Order from the Water Science and Technology Board
No charge

Transnational Water Resources Management: Learning from the U.S.–Mexico Example
In this 1993 lecture, Dr. Helen Ingram, director of the Udall Center for Studies in Public Policy at the University of Arizona, discusses the complexities that national borders create in water resources management, as illustrated along the U.S.–Mexico border. She suggests new cooperative approaches for finding solutions to water management problems in border regions.
1993
8½x11, 15 pages, photocopied
Order from the Water Science and Technology Board
No charge

TERMS OF REFERENCE

The Water Science and Technology Board's terms of reference establish the board's operating policies: how study topics are selected, how committee members are nominated, and how WSTB studies are managed. The terms of reference were adopted on November 29, 1982, and modified on December 13, 1990 and September 13, 2002.

Introduction and Purposes

The Water Science and Technology Board was established in 1982 by the National Research Council to provide a focal point for studies related to water resources accomplished under the aegis of the National Academy of Sciences and the National Academy of Engineering. The WSTB's objective is to improve the scientific and technological basis for resolving important questions and issues associated with efficient management and use of water resources.

In carrying out its responsibilities and to serve the national interest, the WSTB responds to requests for evaluations and advice concerning specific and generic issues in water resources, influences action by initiating studies of issues that merit consideration by public agencies and others, identifies issues and topics of research related to water resources, and cooperates with other units of the National Research Council and groups with mutual interests outside the National Research Council.

The WSTB's scope covers all dimensions of water resources, including science, engineering, economics, policy, educational issues, and social aspects.

Areas of Interest

To pursue its objectives, the WSTB is concerned with:

- basic hydrologic and related sciences and their applications in water resource systems, including analyses of the hydrologic cycle, measurement of water quantity and quality, data analysis, and forecasting;
- planning, analysis, and operation of water systems, including resource management, water quality and quantity for all uses, public health and environmental protection, aquifer and watershed protection and management, economic analysis, design standards, modeling methods, risk assessment, system analysis techniques, and management systems;
- nonstructural water resources issues, such as floodplain management, supply demand relationships, water reallocation and reuse, effects of human activities on water resources, legal institutional issues, ecosystem effects, and cultural and aesthetic values;
- structural and traditional engineering aspects of water projects, such as dams and other water control structures, renovation retrofit technologies, and treatment processes; and
- health and vitality of the nation's water-related science and engineering establishment, including educational aspects.

General Activities

The WSTB strives to accomplish its purposes through the following means:

- responding to specific requests for advice from government agencies and others;
- initiating investigations of issues considered to be appropriate by the WSTB, its parent division, and the Governing Board of the National Research Council;
- reviewing research and the state-of-the-art in science, technology, and social sciences related to the development and management of water and related resources, especially in relation to national objectives and priorities;
- projecting future needs for and capabilities of multidisciplinary research and education in the water sciences and technologies;
- disseminating the results of its studies, serving as a repository of scientific and engineering knowledge, and providing a forum for the exchange of information on water science and technology;
- fostering communication among members of the professional community in the United States on national and international water resources issues; and
- evaluating and articulating relevant educational issues, including undergraduate, postgraduate, continuing education, and public education programs and the related needs for equipment and facilities.

Criteria for Activities

Proposed projects or other activities are individually evaluated by the WSTB according to the following criteria (although there may be cases where for good reason not all of the criteria are met):

- generic applicability of the issues to the nation relative to its water needs and quality;
- important scientific and/or technological questions to be addressed;
- involvement of significant institutional and public policy issues, such as resource allocation, risk management, conflicting regulations, and intermedia tradeoffs;
- relevance of the work to the WSTB's areas of interest and competence and its long-range objectives;

- availability of expert volunteers from relevant disciplines who can ensure that the WSTB's contribution will be appropriate, effective, and timely;
- involvement of key policymakers and other interested parties to ensure that the WSTB's response will have a significant audience; and
- uniqueness of the WSTB to conduct the study because of its breadth and independence as a National Research Council board.

Governance and Relationship with Parent Bodies

The WSTB, although responsible for its own immediate governance, is accountable to and supported in the National Research Council by the Division on Earth and Life Studies (DELS), which is primarily concerned with the sciences, technologies, and policies relevant to resource identification and development and environmental management.

The WSTB may undertake activities related to its mission, such as colloquia and seminars. It may collaborate with professional associations and other groups as may be necessary to fulfill its goals.

The WSTB may recommend to the chair of the National Research Council and to DELS such changes in the WSTB's purposes, responsibilities, size, and functions as the WSTB believes desirable.

Board Membership

In order to comprehensively address the full breadth of water resources issues, the WSTB usually consists of about 15 to 18 members. Members are chosen for their expertise and experience as well as for their familiarity with appropriate scientific, technological, and policy issues. While serving on the WSTB, each member, insofar as possible, participates in at least one study conducted under the auspices of the WSTB. Additionally, members normally participate in a variety of project development and oversight efforts.

Terms of appointment are normally for three years. Members are not eligible for more than two consecutive three-year terms. The WSTB chair and a vice-chair are appointed by the chair of the National Research Council for a period not to exceed three years. The WSTB nominates individuals for its own continuing membership.

When appropriate, the WSTB may invite federal agencies and organizations to nominate individuals to serve as nonvoting liaison representatives to the board and any of its work groups.

Study Group Activities

The principal operating units of the WSTB are its separately appointed and individually mandated study groups. The WSTB , assisted by its staff, manages the activities of these units. The scope of the WSTB's activities will vary commensurate with the topic and need. Types of activities range from lectures, seminars, workshops, and colloquia to extended multiyear, carefully deliberated studies. In some cases, study groups will interact very closely with those receiving advice; in other cases, a more independent approach will be more effective.

The WSTB exercises its oversight responsibility for ongoing studies by receiving reports from the chairpersons or staff and meeting with them as it deems appropriate.

The WSTB originates or reviews and approves nominations for membership on the study committees and transmits its recommendations to DELS.

The WSTB chair, with the approval of the chair of DELS and the chair of the National Research Council, appoints members of committees of the WSTB.

In recommending nominations for committees, the WSTB seeks advice from within and outside the National Research Council. Normally, members of committees or panels serve for the duration of a given study.

Reports

The WSTB's principal products are its reports. These range from "letter" reports, generally focused on particular agency programs and read by a limited, but important, audience of government managers, to major reference-type publications that address more general areas of water science, technology, and policy and are distributed by the thousands by the National Academies Press.

The WSTB reviews all reports that develop from its program in accordance with procedures established by DELS and by the Report Review Committee of the National Research Council. All members of the WSTB are routinely invited to participate in report reviews.

Additionally, the WSTB's staff produces an annual report and triannual newsletter, which communicate information about the WSTB's interests, plans, accomplishments, and other activities relevant to the program.

Board Meetings
The WSTB normally meets three times each year. Additional meetings are held as the WSTB deems necessary to carry out its responsibilities for planning, oversight, and review including, but not limited to, assessment of current activities; consideration and approval of new projects, proposals, and proposed memberships; technical and programmatic briefings; and discussions with government decisionmaking and policy personnel.

Program Planning
Periodically, the WSTB develops and reviews a strategic program plan, indicating general objectives and desired study initiatives for the subsequent three- to five-year period. The board then requests funds in support of activities deemed to be logical, appropriate extensions of its program plan, subject to approval by DELS and the National Research Council's Governing Board.

The WSTB reviews all proposals for new activities that require outside funding. Proposals must be approved by the WSTB before a request for authorization to receive funds is submitted to DELS and the Governing Board.

Staff
The WSTB director is responsible to the chair for the general management of the WSTB's program and to the executive director of DELS. The director has the authority to hire additional staff members and consultants necessary to assist in overall management of the WSTB's program, subject to National Research Council administrative policies and financial constraints.

Expenses
Expenses of the WSTB (core support) and its study groups (project funding), including support of its staff and meetings, are ordinarily financed by contracts, grants, or cooperative agreements from federal or state agencies, private foundations, or industries.