

W S T B

A newsletter from the Water Science and Technology Board

National Research Council

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Thinking About the Demand for Water Services

An Interview with John Boland, 2003 Abel Wolman Lecturer



John Boland is professor at the Department of Geography and Environmental Engineering of the Johns Hopkins University, Baltimore and will deliver the 2003 Abel Wolman Distinguished Lecture. Dr. Boland is an engineer-economist with extensive experience in the water science and engineering fields. He was a founding member of the Water Science and Technology Board in 1982, and served as its second chair from 1985-1988.

We asked Dr. Boland about his thoughts on the topic of the lecture.

Q. You have co-authored two books and many articles on the topic of water demand. Do you see any hopeful trends that indicate that the world is making progress in managing our water resources?

A. One indication of progress would be an understanding that most water uses respond to changes in human behavior. When I

was first employed by a water utility, it was an article of faith in the industry that water use per person was invariant and not related to, for example, the price of water. I remember a widely cited consulting report from the late 1960s that ridiculed the very idea that water use would respond to price, claiming that water is, after all, a necessity. There was similar resistance to discussions of the effects of

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THINKING ABOUT THE DEMAND FOR WATER SERVICES: WHY IS IT SO DIFFICULT TO UNDERSTAND?

2003 Abel Wolman Distinguished Lecture

April 21, 2003 at 4:00 p.m.

Auditorium of the National Academies

2101 Constitution Avenue, NW

Washington, DC

RSVP to Anita Hall at (202) 334-3422 or ahall@nas.edu.

An Increased International Role for the WSTB?

In his 2001 President's address, National Academy of Sciences president Bruce Alberts asked Academy Members to think of ways to rearrange and aggregate Academy reports to make the information more valuable to the international community. Dr. Alberts cited as an example the more than 80 reports on various water issues. Although most of these reports have been written for U.S. policymakers, they also contain important advice that may be adapted by many others, for example, by those working on water issues with women's organizations in Africa, or by water departments of governments around the world.

Our board members have been thinking about just such global questions. Indeed, some are involved in international research projects of their own. Many are active participants in international conferences such as the World Summit on Sustainable Development or serve on boards of international water associations or edit international journals. All are aware, as then-WSTB chair Henry Vaux wrote in 1997, of "the increasing globalization of knowledge about and experience with the management of water resources" (WSTB Annual Report, 1997-1998).

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Interview with Dr. Boland...

household income, conservation practices, etc. It has happened with glacial slowness, it seems to me, and there are still pockets of resistance, but this attitude has changed.

Q. Do you see any negative trends that make you worry?

A. At the opposite end of the ideological spectrum is the view that water is a market good like all market goods and its provision, once turned over to the private sector, ceases to be a concern of government. This is an idea that has gained wide currency in the developing world and is often talked about in the United States. In fact, the various forms of privatization are certainly among the useful operational and financing alternatives available to water managers, but their adoption does not affect the responsibility of government to protect the public interest. My worry is that many think that private sector involvement ends the responsibility of government.

Q. Ecological water use is a theme that has captured more attention in recent years. Is this a topic that is here to stay? If so, how might it affect long-term water management in the United States?

A. Our views on ecological water use will continue to have a major effect on water management. We have long ago accepted the notion that the quantity of water diverted to human uses must be constrained by some allocation to ecosystem needs, and the trend has been to increase those allocations. We also understand that these decisions can feed back on water quality, further impacting human uses. It would be nice to think that this can all be decided by science, but the fact is that we have no ability to weigh objectively the tradeoff between human and ecosystem uses. This has been and will continue to be a matter of judgment. I can only hope that science will help improve the quality of this judgment.

Q. You have asked the question in the past of whether urban water supply is a market commodity, or a public good. Can you at least give us a teaser of an answer to that question?

A. The answer is that urban water supply is both. I will say more about that in the Wolman lecture.

Q. When you first got involved in international work, what most surprised you about the differences or similarities in the challenges faced by water supply systems in developing countries vs. those faced in more developed countries?

A. My greatest surprise was that there are very few, if any, water issues that are unique to the developing world, just as there are very few issues unique to industrial countries. The menu is basically the same; the differences are in the relative importance of particular issues.

Q. You have done some work on energy issues also. In your experience, how is understanding and predicting water demands different from predicting demands for other utilities, such as energy?

A. I spoke earlier about the resistance of the water industry to the idea that water use is a function of human behavior. The energy industry was not hampered by this fixation. So innovations such as energy conservation, load management, econometric demand modeling, etc., took hold much sooner. Furthermore, there was less argument concerning the need to collect data in support of demand management. Today, despite an extraordinarily complex industry (in the U.S., at least), energy demand forecasting is much more advanced and much more useful than water demand forecasting. This despite the fact that water demand forecasting is an inherently easier task.

Q. You were an engineer before becoming an economist. How do you feel having these two distinct backgrounds is important to your work? Would you recommend this approach to others interested in water use?

A. At least three things have been important to my work: (1) my training as an engineer, (2) early management experience in water and sewer utilities, and (3) my training as an economist. This has allowed me to work as an applied economist very close to the interfaces among economics, engineering, management, and policy. I have enjoyed this career greatly, but occupying the fringes of established disciplines is not necessarily to everyone's taste. In any case, my career path was not calculated but followed an evolving interest.

2003 Abel Wolman Distinguished Lecture is free and open to the public. The program will begin at 4:00 p.m. in the Auditorium of the National Academies, 2101 Constitution Avenue, NW, Washington, DC (entrance at C Street). A reception will follow the Lecture in the Great Hall.

NRC MEETINGS

Columbia River Committee

March 20-21, 2003
Vancouver, WA

Aquatic and Related Terrestrial Ecosystems Services and Values

March 20-21, 2003
Washington, DC

Corps Water Resources Project Planning Coordinating Committee

April 3-4, 2003
Palo Alto, CA

Source Removal

April 14-15, 2003
Washington, DC

WSTB Meeting

April 21-22, 2003
Washington, DC

Abel Wolman Lecture

April 21, 2003
Washington, DC

Workshop on Sustainable Underground Storage

April 23, 2003
Washington, DC

Pittsburg Water Quality

April 24-25, 2003
Washington, DC

Assessing Water Resources Research

April 29-30, 2003
Washington, DC

The WSTB has received internal and external funding to host two workshops on topics identified by board members as in critical need of attention and better understanding, and which may represent opportunities for future WSTB studies. These are:

Workshop on Sustainable Underground Storage of Recoverable Water, April 20, 2003, Washington, DC

The United States may be hard pressed to meet needs for fresh water in the future, because of population increases and demographic shifts, reallocation of water resources to protect sensitive aquatic species, and other reasons. One new strategy for water management is temporary detention and storage of surface water during times of excess for release during times of need. This avoids some of the problems of aboveground reservoirs, such as evaporative losses, land consumption, and ecological impacts. However, some of these aquifer storage and recovery, artificial recharge, and conjunctive use projects encounter technical difficulties of their own.

These challenges may arise from unique hydrogeologic conditions, unsubstantiated assumptions, or poorly conceptualized models. Legal and institutional issues may also play a role. Aquifer “boundaries” are often not aligned with institutional boundaries. Distinct laws may govern the same water before, during, and after recharge. Ownership and responsibility when recharged water moves and/or affects surrounding water supplies may be unclear. Regulation of aquifer storage systems in many states is in the early stages of development.

The workshop, which is cosponsored by the **American Water Works Association Research Foundation**, will address topics such as the following:

1. What interactions between recharged water and existing groundwater and aquifer materials may diminish aquifer storage, cause subsidence, or mobilize or increase the bioavailability of naturally occurring contaminants?

When do such interactions actually improve water quality?

2. What impact may recharge projects have on microbiological contaminants in water withdrawn from such projects?

3. How may the physical processes underlying the movement and mixing of recharged water in karstic, stratigraphically heterogeneous, or fractured aquifers, affect the performance of these systems?

4. What types of monitoring are necessary to evaluate the above processes?

5. What are the factors that favor the various storage technologies with regard to preserving pre-recharge water quality?

6. How may ecological impacts due to changes in amplitude, seasonality, or spatial distribution of flow, caused by withdrawing or returning water from streams, constrain such systems?

7. What key legal issues associated with sustainable underground storage need to be identified and addressed?

For information contact Will Logan at 202-334-3422 or wlogan@nas.edu.

**Workshop on Stream Restoration
September 2003
Minneapolis, Minnesota**

The management of water resources for sustained provision of environmental services and amenities is a national priority, particularly for the streams and rivers degraded by human disturbance or modification. Restoration of these waterbodies is critical to maintaining and improving water quality, ensuring the sustainability of fish and wildlife species, protecting wetlands, and reducing the impacts of flood events.

Both the public and private sectors have a strong interest in stream restoration. As an emerging science, stream restoration faces critical challenges that need to be defined, clarified, and resolved before it can effectively contribute to the goals of a national water resources agenda. Among these challenges are as follows:

1. Most research that support restoration practice has been compartmentalized along traditional disciplinary boundaries even if there is a strong public support and political will for multiobjective restoration efforts.

2. The current focus of most restoration practice is on establishing the appropriate form or structure of the system with little emphasis on system processes and their connections.

3. Current stream restoration activities are mostly based on classification schemes derived from static characterizations of stream attributes or from functional statistical relations derived from empirical analysis of large datasets. Streams, however, make continuous adjustments in their ecological, geomorphological, hydrological and hydraulic attributes.

4. The practical demand for stream restoration has outpaced development in scientific research and technology. The success of the various “recipe-oriented” approaches to restoration that have been developed is uncertain because few attempts have been made to systematically evaluate the their post-project performance.

5. The traditional river engineering approach involves simplification for command-and-control. In contrast, most restoration projects involve increasing the complexity of a simplified system. There is a need to innovatively integrate restoration science and engineering.

6. Urban/suburban watersheds are the focus of diverse institutional management arrangements. They also address a broad range of management objectives such as water quality, habitat restoration, flood mitigation, recreation, and scenic amenity. Innovative strategies are required for management of such watersheds.

Cosponsored by the **St. Anthony’s Falls Laboratory of the University of Minnesota** this workshop will help prioritize these issues and identify institutions, literature, and experts for a larger NRC study on stream restoration.

For interest and/or questions, contact Will Logan at 202-334-3422 or wlogan@nas.edu.

International Initiatives at WSTB

International activity is not a new concept to the WSTB. *Mexico City Water Supply: Improving the Outlook for Sustainability* and *Water for the Future: The West Bank and Gaza Strip, Israel, and Jordan* are two frequently cited reports with an international focus. WSTB reports such as *Hydrologic Science Priorities for the U.S. Global Change Research Program* explicitly address U.S. efforts in international enterprises. Many others, such as *Privatization of Water Services in the United States*, devote considerable attention to the international experience in their study topic. *Safe Water from Every Tap: Improving Service to Small Communities* (Japanese), *New Directions in Water Resources Planning for the U.S. Army Corps of Engineers* (Chinese), *Opportunities in the Hydrologic Sciences* (Chinese), *Restoration of Aquatic Ecosystems* (Japanese), and *Managing Wastewater in Coastal Urban Areas* (Japanese) have even been translated into other languages.

However, the WSTB, consistent with the direction of The National Academies as a whole, is looking for creative ways to further increase the international profile of the WSTB. During its

October 2002 board meeting the following were suggested:

? Increased involvement in international water conferences such as the Stockholm Water Symposium, World Water Forum, International Water Association, and International Water Resources Association through presentations by WSTB members or staff, or a booth or table with reports displays, brochures, etc.

? Inviting international guests to attend WSTB meetings and discuss opportunities for collaboration. These might include representatives from international organizations or science attachés from developing countries.

? Increased dissemination of WSTB reports to international organizations, and government and non-governmental agencies. In principle much of this could be done through the Internet.

? Continued efforts to promote joint projects with National Academies in other countries, or with the International Water Academy or Stockholm Environmental Institute. Past suggestions by board members have included topics such as *The Potential of Markets and Trading in Promoting Effective International River Management*, *Sustainable Water Resource Management in the U.S.-Mexico Border Area*,

and *Impacts of Free Trade Agreements on Global Water Resources*.

The challenges to such initiatives are many. Core funding for the WSTB is limited, placing constraints on publicity initiatives. Distribution of WSTB reports require close collaboration with the National Academies Press for both financial and copyright issues. Support for international projects generally comes from funding sources with which the board has only limited contacts and experience.

Despite these challenges, the WSTB anticipates further discussions of the role of the WSTB in international water issues. The stakes are too great not to make the effort. As Bruce Alberts said in his 2000 Presidential Address, "The world population is expected to increase from 6 billion to 9 billion in the next 50 years...How can the Earth accommodate even the most basic needs of these people ...without destroying the natural resources on which we all depend?" We hope that the WSTB will be an important part of the Academies' response to the world's water problems, and we welcome your contributions to the ongoing discussion by contacting Steve Parker at 202-334-3422 or sdparker@nas.edu.

WATERMARKS

WSTB Welcomes New Staff

Stephanie Johnson began her WSTB career in the spring of 2002 in a consulting capacity and later transitioned to part-time staff officer. She was the study director of the fast-track study that issued the report *Science and the Greater Everglades Ecosystem Restoration: An Assessment of the Critical Ecosystem Studies Initiative* (see page 7 of this issue) Stephanie is a graduate of Vanderbilt University and subsequently did a stint as a hydrologist with the USGS. Currently, she is wrapping up her PhD in hydrology/environmental sciences at the University of Virginia.

Lauren Alexander came aboard the WSTB in October 2002 as part-time staff officer while she continues a complementary affiliation with the USGS, completes her PhD at Harvard, and publishes some papers. Lauren holds bachelors (systems engineering) and masters (environmental planning) degrees from the University of Virginia and has had experience in the environmental consulting profession, the Department of the Interior policy office, and the USGS national water resources research program. With this broad education and experience, Lauren will claim the discipline of landscape ecology.

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Richelle Allen-King, a member of the WSTB, is the 2002-2003 Henry Darcy Distinguished Lecturer for the National Ground Water Association. Her lecture titles are "A Hydrogeochemist's Perspective on Organic Contaminant Transport in Ground Water" and "Ground and Surface Water Contributions to Chemical Mass Discharge: Considering the Problem at Field and Basin Scales."

Jean Bahr, chair of the Committee on Restoration of the Greater Everglades Ecosystem, has been selected as the 2003 Birdsall-Dreiss Distinguished Lecturer by the Geological Society of America's Hydrogeology Division. She will present lectures on "Groundwater as an Ecosystem Resource," and "Geochemical Heterogeneity of Groundwater in Uncontaminated & Contaminated Aquifers."

Pete Loucks, NAE, Cornell University, member of the Committee on Restoration of the Greater Everglades Ecosystem, was

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Bioavailability of Contaminants in Soils and Sediments

by Laura J. Ehlers

Bioavailability processes are defined as the individual physical, chemical, and biological interactions that determine the exposure of plants and animals to chemicals associated with soils and sediments. Although long employed in toxicology and agricultural sciences, the concept of bioavailability has recently sparked the interest of the hazardous waste industry as an important consideration in deciding how much waste to clean up. This interest stems from observations that some contaminants in soils or sediments appear to be less available to cause harm to humans and ecological receptors than is suggested by their total concentration, such that cleanup levels expressed as bulk concentrations may not correlate with actual risk. After two years of deliberation, a WSTB committee has weighed in on the concept with the report *Bioavailability of Contaminants in Soils and Sediments: Processes, Tools, and Application*.

The report notes that the potential for the consideration of bioavailability to influence decision-making is greatest where:

- ? the contaminant is (and is likely to remain) the risk driver at a site;
- ? the default assumptions made during risk assessment that affect the final cleanup goal are inappropriate;

? significant change to remedial goals is likely, for example, because substantial quantities of contaminated soil or sediment are involved;

? conditions present at the site are unlikely to change substantially over time; and

? regulatory and public acceptance is high.

Defining Bioavailability processes

“Bioavailability processes” are defined as the individual physical, chemical, and biological interactions that determine the exposure of organisms to chemicals associated with soils and sediments. This incorporates all the steps that take a chemical from being bound or isolated in soil or sediment to being absorbed into an organism (A through D in Figure 1). For a given situation, a few select processes are expected to dominate. However, mechanistic understanding of these processes is highly variable, and quantitative descriptive models of bioavailability processes are in most cases lacking.

Bioavailability in Risk Assessment

In both ecological and human health risk assessment, bioavailability is usually reflected in default values or site-specific data that are inserted into exposure equations. Although a multi-

tude of processes can affect bioavailability (see Figure 1), a typical bioavailability assessment generates *one* value that is used to adjust the applied dose. For this reason, many bioavailability processes are hidden within risk assessment, and assumptions made about these processes are not clear.

Studies using animals as surrogates for humans to determine bioavailability for different chemical–solid combinations have been conducted at a small number of sites. To improve the accuracy of risk assessment, the report encourages further work in this area, and it recommends guidance from EPA that addresses what information must be included in a bioavailability assessment, its scientific validity, acceptable tools and models, and other issues. Bioavailability processes are more frequently accounted for in ecological risk assessments, although they have not been labeled as “bioavailability adjustments” per se.

Bioavailability Tools

Many physical, chemical, and biological tools that have been used to measure bioavailability are evaluated. The tools span the range from physicochemical techniques like microscopy to chemical extractions and finally to bioassays. The report concludes that tools that further mechanistic understanding and promote predictive model development are preferred over conventional empirical approaches.

The report ranks the strengths and weaknesses of all tool types, using the following criteria:

- ? the tool’s applicability to field settings;
- ? its applicability to the solid phase;
- ? whether it measures a single process vs. lumped processes;
- ? its relevance to initial biouptake across a membrane;
- ? whether its results can be generalized to other hazardous waste sites;
- ? its relevance to regulation; and
- ? its usefulness as a research tool.

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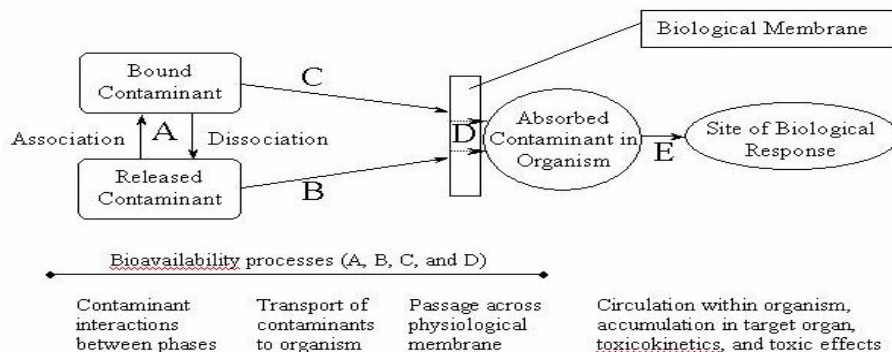


FIGURE 1 Bioavailability processes in soil or sediment, including release of a solid-bound contaminant (A) and subsequent transport (B), direct contact of a bound contaminant (C), uptake by passage through a membrane (D), and incorporation into a living system (E). E processes are not considered bioavailability processes per se because soil and sediment are no longer a factor.

Bioavailability...

No one method achieves the highest rating in all categories, and none fail all criteria, illustrating that every tool has tradeoffs.

The development of tools relevant to bioavailability is a rapidly growing field, such that there can be confusion regarding which tools and how many to choose. Thus, the report advocates a weight-of-evidence approach to bioavailability tool selection to make near-term progress at sites. This involves initially relying on operational tools (e.g., extractions, normalizations, and simple models) along with an intensive effort to develop mechanistic tools and conceptual models based on mechanisms.

Bioavailability and Site Management

Limitations in our understanding of bioavailability processes have important ramifications for site management. In particular, there are treatment remedies that rely on increasing or decreasing bioavailability, and without a

better understanding of bioavailability processes it is difficult to know if such treatments are effective. In addition, treatment technologies may unintentionally alter contaminant bioavailability, especially sediment dredging and new technologies that have yet to be fully tested.

To achieve more widespread consideration of bioavailability processes and promote the use of site-specific measurements of bioavailability, the report proposes an adaptive management approach. This would involve pilot studies to experiment with different tools and models, and then using the results to develop a common systematic approach for how and when to incorporate bioavailability concepts into regulations in a consistent manner. Examples of how this might be done are presented in the report.

The report concludes by noting that most information on bioavailability of contaminants comes from industry-funded studies at specific sites, particularly for human health risk assessments. These studies are usually not conducted in a way that advances mecha-

nistic understanding of bioavailability processes. Unless a greater commitment is made to fund bioavailability studies from a research—rather than an industry-driven perspective, progress in explicitly incorporating bioavailability into human health and ecological risk assessments will be slow.

The study was sponsored by the Environmental Protection Agency, Department of Defense's Strategic Environmental Research and Development Program, the National Institute of Environmental Health Sciences, the Army, the Air Force, the Agency for Toxic Substances and Disease Registry, the DoD Office of Environmental Management, the Department of Energy, and the Gas Research Institute. It was chaired by Richard Luthy of Stanford University. Copies of the report are available from the WSTB office at 202-334-3422 or lehlrs@nas.edu.

Laura Ehlers is a Senior Staff Officer with the Water Science and Technology Board.

NEW REPORT

Biosolids Applied to Land: Advancing Standards and Practices

By Mark Gibson

Since the early 1970s, the U.S. Environmental Protection Agency (EPA) and the wastewater treatment industry have promoted the recycling of treated sewage sludge (often referred to as *biosolids*) to agricultural or other lands in order to improve the properties of the soil. This "beneficial reuse" practice offers an alternative to disposal options such as land filling or incineration and its use has increased since disposal of sewage sludge in oceans was prohibited in 1992. Depending on the level of treatment, biosolids can be applied to sites where there is little exposure of the general public such as forests and reclamation sites, or on public-contact sites such as golf courses, lawns, and home gardens. Regardless, biosolids are complex mixtures that can contain pollutants from household, commercial and industrial wastewaters with organic contaminants (e.g., phar-

maceuticals), inorganic contaminants (e.g., metals and trace elements) and pathogens (e.g., bacteria, viruses, and parasites). Today, roughly 60 percent of the 5.6 million dry tons of sewage sludge disposed of annually is used for land application in the United States.

In 1993, EPA established a regulation governing land application of sewage sludge under the Clean Water Act with the express intent to protect public health and the environment from reasonably anticipated adverse effects. Among other requirements, this regulation (Code of Federal Regulations Title 40, Part 503) sets chemical pollutant limits, operational standards designed to reduce pathogens and the attraction of disease vectors (such as rodents), and management practices for the land application of sewage sludge.

Public health concerns regarding the past and continued use of biosolids

are growing and getting increasing coverage in the media, especially from those who live near application sites. In late 2000, the EPA asked the National Academies to convene a committee—under the auspices of the Board on Environmental Studies and Toxicology with staff support from the WSTB—to conduct an independent evaluation of the technical methods and approaches used to establish the chemical and pathogen standards for biosolids, focusing specifically on human health protection. Notably, the committee was not asked to determine whether EPA should continue to promote land application of biosolids or judge the adequacy of the individual standards in protecting human health, but rather to reassess the scientific basis of the Part 503 rule as a whole. Lastly, the committee was asked to review a previous (1996) WSTB report, *Use of Reclaimed Water and Sludge in Food Crop Production*, and determine whether its recommendations

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Science and the Greater Everglades Ecosystem Restoration: An Assessment of the Critical Ecosystem Studies Initiative

by Stephanie Johnson

The Everglades represents a unique ecological treasure, and a remarkable collaboration of agencies is currently working to reverse the effects of nearly a century of wetland drainage and impoundment. Although not all parties agree on the details of the effort, there seems to be universal agreement that the best possible science should serve as the basis of planning and, ultimately, operating the restoration projects.

In the past few years, however, the investment in science relevant to the restoration has eroded measurably within some agencies, including one major Department of the Interior (DOI) science program, the Critical Ecosystem Studies Initiative (CESI). Funding for the CESI program has decreased from \$12 million per year (1998) to its current level of \$4 million per year. In response to concerns over the declining science funding and the adequacy of science support for restoration decision making, the Congress instructed DOI to commission a study by the National Academies to review the science component of the CESI program. A panel organized by the WSTB and the Board on Environmental Studies and Toxicology held three meetings in early 2002 and released its report in December 2002. The report's conclusions and recommendations for the CESI program are in four main areas: program emphasis, management, funding, and science synthesis and integration.

CESI Program Emphasis. The panel found that the CESI program has produced useful science in support of DOI's resource stewardship interests and restoration responsibilities in South Florida and that the CESI program offers an effective strategy for addressing South Florida's restoration science needs. The CESI program's "gap-filling" approach allows the program to meet complex and changing science needs in the midst of a large number of agencies with science programs. Nevertheless, critical scientific information gaps re-

main. The CESI program has not adequately supported priority research needs in the areas of social science, water-quality modeling, and contaminants. The report recommends that the CESI program identify priority research topics in these under-funded areas. CESI managers should then develop budget estimates and seek additional funding to support these programs.

The report recommends that the fundamental objectives of the CESI's research program remain largely intact, with continued commitment to ecosystem research in addition to model development and environmental assessments. The report recommends that the CESI program continue its research emphasis on the linkages between ecological and hydrologic attributes, since these linkages are critical inputs to restoration planning.

CESI Management. The panel noted that several improvements in CESI management are necessary to improve the effectiveness of the program. The CESI program must move quickly to address emerging science needs and to meet restoration decision-making deadlines, but sometimes this fast action occurs at the expense of appropriate proposal development and review. The report recommends that CESI managers broaden the distribution of requests for proposals, raise proposal review standards, and improve the review of research products before they are released to users. Expert advisors appointed to CESI program advisory committees should be integrally involved with the proposal review process. These expert advisory committees can also serve to promote closer coordination with related research and monitoring activities and assist in the establishment of research priorities.

Changes in the CESI management structure are expected to be implemented soon in accordance with an

interagency memorandum of understanding among DOI's South Florida science programs. The reorganization is designed to facilitate improved science coordination, but the report cautions that the proposed management plan needs to include sufficient scientific expertise and agency representation to ensure appropriate prioritization of the research funds. The report also recommended the appointment of a senior scientist to coordinate the program.

CESI Funding. The report asserts that funding for CESI science has been inconsistent and is now far less than is needed to support DOI's interests in and responsibilities for the restoration. The report recommends that Congress increase CESI research funding, contingent upon key management improvements, to adequately address DOI's current restoration science needs. These needs include continued support for essential areas such as ecological process studies and model refinement, support for additional research in priority science gaps, and significant improvements in review, dissemination, coordination, and synthesis.

Science Synthesis and Integration. The complexity and expanse of South Florida's ecosystems necessitate a synthetic approach to convert data into knowledge that spans multiple spatial and temporal scales. That synthesis is lacking in the CESI program and in other South Florida science programs. The report recommends the development of a single overarching entity to facilitate comprehensive restoration science synthesis and to coordinate scientific efforts beyond the boundaries of the Comprehensive Everglades Restoration Plan or the CESI program. Such an entity would provide scientific vision, promote collaboration, and improve the usefulness of new and existing scientific information.

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Science and the Everglades...

An effective adaptive management process will be critical to incorporate new scientific knowledge and guide restoration project design, but many barriers still hinder communication between researchers, restoration planners, and decision makers. Improvements in existing science institutions could greatly improve research communication, prioritization, and coordination for the restoration effort. The report recommends that sufficient numbers of scientists representing a broad representation of agencies participate in science advisory teams for the restoration. The report also recommends that restoration decision makers reevaluate the current project schedules in cases when critical science questions remain that could impact project design decisions beyond

their inherent operational flexibility and increase up-front investments in critical research that is likely to minimize total restoration costs.

The study committee was chaired by Linda Blum of the University of Virginia. To order the report, contact National Academies Press at (800) 624-6242, <http://www.nap.edu>.

Stephanie Johnson is a Staff Officer with the Water Science and Technology Board.

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Watermarks

the first recipient of the Maass-White Visiting Scholar Fellowship, which partners academic researchers with staff of the Army Corps of Engineers' Institute of Water Resources.

Joan Rose, vice-chair of the WSTB, is now Homer Nowlin Chair in Agriculture and Natural Resource Systems at the Department of Fisheries and Wildlife at Michigan State University. Many happy trails.

Congratulations to WSTB staff associate **Patricia Jones Kershaw** for receiving her Masters of Urban and Environmental Planning from the University of Virginia on January 3, 2003. Further congratulations to Tricia for a new baby boy, **John Michael Kershaw** ("Jack") born December 2, 2002. Congratulations also to WSTB staff officer **William Logan** on the birth of his son, **William S. Logan V** ("Quint") on January 30, 2003.

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Biosolids

related to sewage sludge practices had been appropriately addressed by EPA since its release.

Overarching Findings and Recommendations

There remains considerable uncertainty regarding the potential for adverse human health effects resulting from exposure to biosolids. To help assure the public and to protect public health as mandated, there is a need to update the scientific basis of the Part 503 rule. The report identifies several broad data gaps and issues in biosolid management practices and research that should be addressed, including:

? *A lack of health information on exposed populations.* The report recommends implementing human health studies, including short-term investigations of unusual episodes of release, exposure, or disease, and large-scale preplanned studies of exposures and their association, if any, with disease.

? *Reliance on outdated risk-assessment methods.* Since 1993 when the rule was established, risk assessment methods have advanced significantly. The report recommends that new risk assessments be used to update the scientific basis of the chemical limits and the regulatory criteria for pathogens.

? *Reliance on outdated characterization of sewage sludges.* Changes in treatment processes and chemical uses over the last decade have changed the composition of sewage sludges. The committee recommends a new national survey of chemicals and pathogens in sewage sludges—the former was also recommended in the 1996 WSTB report—and a review of management practices to ensure that risk assessment principles are put into practice.

? *Inadequate programs to ensure compliance with biosolids regulation.* EPA should expand its oversight activities to include procedures to (1) assess the reliability of biosolids treatment processes and effectiveness of management practices, (2) monitor compliance with chemical and pathogen standards, (3) conduct environmental hazard sur-

veillance, and (4) study human exposures and health.

? *Lack of resources devoted to EPA's biosolids program.* Additional funding and staff resources are needed to implement the recommendations in this report. The report also recommends that EPA delegate authority to more states to administer the federal biosolids regulation.

The report also includes findings and recommendations specific to health effects associated with biosolids exposure and chemical and pathogen standards development and implementation.

The committee chair was Thomas Burke of Johns Hopkins University. Funding was provided by the EPA. To order the report, contact National Academies Press at (800) 624-6242, or (202) 334-3313, <http://www.nap.edu>.

Mark Gibson is a Staff Officer with the Water Science and Technology Board and provided staff support for the study.

Environmental Remediation at Navy Facilities: Adaptive Site Management

by Laura J. Ehlers

As part of its ongoing efforts to help the Navy with its environmental cleanup program, the WSTB recently released *Environmental Remediation at Navy Facilities: Adaptive Site Management*. This report focuses on the latter stages of site cleanup. It is particularly appropriate for those sites with recalcitrant contamination where progress has stalled prior to meeting cleanup goals, thus preventing site closeout. Like other responsible parties with a large liability in hazardous waste sites, the Navy has hundreds of sites where conventional remediation technologies have been shown to be inadequate in meeting drinking-water-level cleanup standards. In many cases it is not clear how to replace or terminate remedies that have proved ineffective or how to change cleanup goals.

In response to this widespread dilemma, the report proposes a comprehensive and flexible approach, referred to as “adaptive site management,” or ASM, for dealing with difficult-to-remediate hazardous waste sites. ASM borrows from the concept of adaptive management—an approach to resource management in which policies are implemented with the recognition that while the response of the system is uncertain, that this response will be monitored, interpreted, and used to adjust programs in an iterative manner, leading to ongoing improvements in knowledge and performance. Not only is ASM consistent with the current cleanup paradigm used at federal facilities (as principally defined by Superfund), it has additional features that stress knowledge generation and transmittal and that complement more traditional cleanup objectives. The approach can accommodate different cleanup objectives, provide guidance at key decision-making points, and deal with the uncertainty inherent in many remedial strategies.

Adaptive Site Management Described

The predominant paradigm for site restoration in the United States has until recently involved a unidirectional march from site investigation to remedial action and eventually to site closure. However, as sites have advanced through the restoration process, there has been a growing recognition that a more iterative approach is needed. The flexible nature of ASM is apparent in Figure 1, which is a schematic of the latter stages of ASM. The management decision periods (MDP) in the figure are designed to take advantage of the feedback loops embedded in ASM, such that uncertainties in site restoration can be addressed. These MDPs are also formal opportunities for the project managers, regulators, and interested stakeholders to evaluate data to determine if the remedial technology is meeting its objectives and, if not, to reach agreement on what additional management steps.

The purpose of MDP1 is to ensure that the remedy selected is practicable and implementable under site-specific conditions and that an appropriate, well-designed monitoring plan is developed. Subsequent to MDP1 and once the remedy is implemented, several actions can potentially occur as part of ASM. Along with operation of the remedy, there are ongoing monitoring activities—lumped under MDP2—that characterize this phase of cleanup. Denoted alongside remedy implementation in Figure 1 is evaluation and experimentation—an activity unique to ASM and one of

the hallmarks of adaptive management in general. It refers to the conducting of experiments and other research activities in parallel with implementation of the chosen remedy. The evaluation and experimentation track is an opportunity to test innovative, less certain, sometimes riskier remedies that were not well enough established to be chosen as the initial remedy in the Record of Decision.

Later management decision periods give remedial project managers an opportunity to use information gained during evaluation, experimentation and routine monitoring to optimize the existing remedy, change the goal, or even change the remedial goal. Depending on the action chosen, MDP3 may lead back to the initial steps of site management, remedy selection, or remedy redesign. MDP3 is a critical

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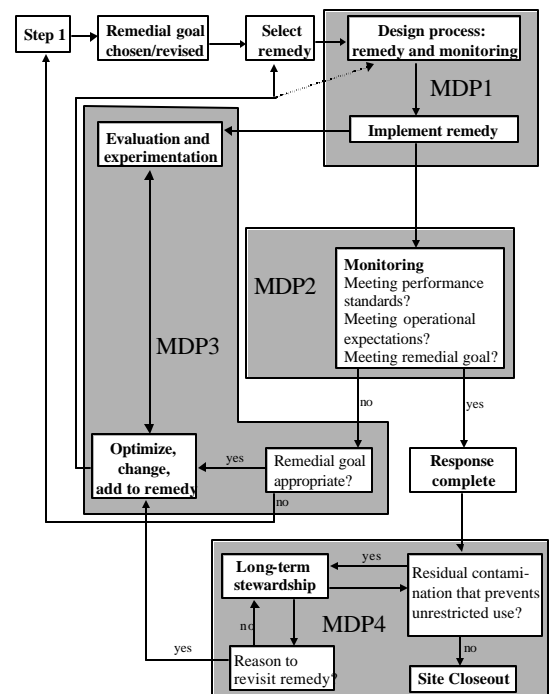


FIGURE 1 Latter stages of adaptive site management: post-remedy selection. The shaded area shows the activities related to the management decision periods described in the text

Assessment of Water Resources Research

Early in 2002, Congress mandated that the NRC conduct a study to determine the federal investment in water resources research. This activity is partly a follow up activity to the WSTB's report *Envisioning the Agenda for Water Resources Research in the Twenty-First Century*. In addition, it will determine the adequacy of the nation's investment in water resources research, given budget information that is being supplied by over 30 federal agency liaisons. The first meeting was held September 19–20 in Washington, DC, at which time the committee heard from its sponsor, USGS, as well as many of the federal liaisons and invited guests. The committee's second meeting held January 9–10, in Tucson, AZ, featured a panel of state representatives who discussed their state's water resources research needs for the next 10 years. Presentations on budget and program information from each of the federal liaisons will be the

focus of the third meeting, scheduled for April 29–May 1 in Washington, DC.

Henry Vaux of the University of California is serving as committee chair. Other committee members include David Allan, University of Michigan; James Crook, consultant; Joan Ehrenfeld, Rutgers University; Konstantine Georgakakos, Hydrologic Research Center; George Hallberg, Cadmus Group; Debra Knopman, RAND; Lawrence MacDonnell, Porzak, Browning & Bushong; Thomas MacVicar, MacVicar, Federico & Lamb; Rebecca Parkin, The George Washington University; Roger Patterson, Nebraska Department of Natural Resources; Frank Schwartz, Ohio State University; and Amy Zander, Clarkson University. For more information, contact Laura Ehlers at 202-334-3422 or lehlers@nas.edu.

Assessing and Valuing the Services 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 study will focus on identifying and assessing existing methods for defining and assigning economic values to the services of aquatic and related terrestrial ecosystems. The committee will consider the errors and biases of

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juncture at which many current sites are stalled because of lack of information about alternatives and the absence of any regulatory incentive to change course.

The final major decision of adaptive site management is MDP4, during which sites with residual contamination levels above cleanup goals are periodically assessed. Like MDP3, this decision can lead to a change in remedy if it is found that alternative technologies exist that can help achieve cleanup goals. This presents a departure from the current cleanup paradigm because the five-year review process that characterizes long-term stewardship does not support changing remedies unless the existing remedy is not protective of human health and the environment. When site managers, regulators, and the affected public have agreed that

there are no unacceptable levels of contaminants left in place (i.e., the use is unrestricted), site closeout can proceed—the last step of ASM.

The report concludes by noting that there is strong support for adaptive approaches already present in recent federal guidance on monitoring and remediation. Indeed, recent Navy guidance calls for developing an alternative strategy at sites where plots of cumulative mass removed versus time exhibit "an asymptotic condition" prior to attaining the cleanup goal. ASM goes further to suggest how to interpret the monitoring data, when to consider using new technologies, and how to reach site closure for all types of sites. ASM affords a way to manage uncertainty while moving forward with the cleanup process because conventional remedies can be implemented first while additional information is gained on innovative but more risky technologies.

ASM is particularly appropriate for high-risk sites with multiple or recalcitrant contaminants, multiple stressors, and heterogeneous hydrogeology where progress has stalled prior to reaching cleanup goals and where projected large costs are at stake. Prior to widespread adoption, the Navy should consider pilot testing ASM at a limited number of sites to allow Navy managers to better understand any transactional costs and delays that may accompany ASM implementation.

The study was sponsored by the Naval Facilities Engineering Service Center. It was chaired by Edward Bouwer of Johns Hopkins University. Copies of the report are available from the WSTB office at 202-334-3422 or lehlers@nas.edu.

Laura Ehlers is a Senior Staff Officer with the Water Science and Technology Board.

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such methods and whether their increased use will lead to better environmental decisionmaking. The committee will hold its final meeting on March 20-21 in Washington, D.C. The committee's report is expected to be published in late 2003.

This study is sponsored by the EPA, the Corps of Engineers, and the Department of Agriculture. Geoffrey Heal of Columbia University chairs the committee. For more information, contact study director Mark Gibson at 202-334-3422 or mgibson@nas.edu.

Assessment of U.S. Army Corps of Engineers' Economics and Environmental Analysis and Peer Review for Water Resources Project Planning

Section 216 of the Water Resources Development Act of 2000 (WRDA 2000) mandated two National Academies studies of Corps of Engineers planning and decision making procedures within its feasibility studies: a) a review of the Corps' state-of-the-art planning and analytical methods, and b) a review of the Corps' independent peer review procedures. The WSTB, working in cooperation with the NRC's Ocean Studies Board has appointed a coordinating committee and four study panels to carry out this request. The study panel topics are peer review, adaptive management for resources stewardship, methods for project planning, and river basins and coastal systems. The work of the coordinating committee and the four study panels is collectively known as "The 216 Studies," named after the WRDA 2000 section mandating them. The peer review panel issued its report in July 2002. The three other study panels and the coordinating committee will issue their reports in fall 2003.

The *Coordinating Committee* is tracking progress of the study panels, ensuring consistency between them, and will produce a synthesis report based on the findings of the four study panels and its own conclusions. Members of the coordinating committee include chairs of the four study panels,

plus several other water resources management experts. Leonard Shabman of Resources for the Future chairs the coordinating committee. This committee held its fifth meeting in Washington, D.C. on January 27-28 and will hold its sixth and final meeting in San Francisco on April 3-4.

The *Peer Review Panel* operated on a shorter time frame than the other three study panels and issued its final report in July 2002. James Mitchell of Virginia Tech chaired this committee. To obtain a copy of the panel's report, *Review Procedures for Water Resources Project Planning*, contact study director Jeffrey Jacobs at 202-334-3422.

The *Project Planning Panel* held its fourth and final meeting on February 26-27 in Washington. This panel is reviewing the Corps' methods for project planning, which are embodied primarily in the federal "Principles and Guidelines" and the Corps' own Planning Guidance Notebook. Gregory Baecher of the University of Maryland chairs the panel. For more information on this panel, contact study director Jeffrey Jacobs at 202-334-3422.

The *River Basins and Coastal Systems Panel* held its final meeting in November 2002. This panel is reviewing the Corps' methods and approaches for planning and coordinating water projects across watershed and river basin systems. Larry Roesner of Colorado State University chairs the panel. For more information on this panel, contact John Dandelski at the Ocean Studies Board at 202-334-1978.

The *Adaptive Management for Resources Stewardship Panel* held its final meeting on February 20-21 in Washington. This panel is reviewing the Corps' efforts and future prospects in implementing the adaptive management paradigm in managing its water resources projects. Donald Boesch of the University of Maryland Center for Environmental and Estuarine Studies chairs the panel. For more information on this panel, contact study director Jeffrey Jacobs at 202-334-3422.

Review of the Desalination and Water Purification Technology Roadmap

Access to freshwater is an increasingly critical national and international issue. In order to maintain economic development and improve standards of living and health, sustainable supplies of high-quality freshwater are needed. This will require the development of innovative and cost-effective methods to improve water management, use, and reuse as well as novel technologies that can "create" freshwater from nontraditional sources. As noted in the NRC/WSTB 2001 report *Envisioning the Agenda for Water Resources Research in the Twenty-First Century*, one area that merits increased consideration is the development and implementation of increasingly cost-competitive desalination technologies. Because saline and brackish waters constitute over 97 percent of the world's water, desalination has the potential to significantly augment the limited freshwater resources in the United States and many parts of the world. Though desalination costs and performance have been significantly improved in recent decades, overall desalination system costs must be further reduced in order to make desalination more competitive with other water supply options and to provide communities with a broader array of choices to meet their growing water needs in a long-term and sustainable manner.

In early 2002, the U.S. Bureau of Reclamation and Sandia National Laboratories initiated a road-mapping activity (now called the Desalination and Water Purification Technology Roadmap) to identify the major research/technology needs and priorities for the nation for the next 20 years. The Roadmap will be used as a planning tool to facilitate science and technology investment decisions and as a management tool to help structure the selection of desalination research, development, and demonstration projects. Proponents hope that the Roadmap also will be used by other institutions that are conducting desalination research so that research is coordinated and

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complementary. The Bureau of Reclamation contacted the WSTB in late 2002 to undertake a review of the Roadmap document. Funding to initiate the study was obtained in January 2003. A brief interim report will follow the first meeting, which will likely occur in spring 2003. The first meeting will also feature a stakeholder workshop to brief the committee on the origin, development, and status of the Roadmap, help frame the issues, and inform the committee of other desalination-related activities of federal, state, and local entities and other stakeholders engaged in desalination research and development.

David H. Marks, Massachusetts Institute of Technology, chairs the committee. Other committee members include Miriam Balaban, Mario Negri Sud Institute for Biomedical and Pharmacological Research; B. Anatole Falagan, Metropolitan Water District of Southern California; Joseph G. Jacangelo, Montgomery Watson Harza; Kimberly L. Jones, Howard University; William J. Koros, Georgia Institute of Technology; John Letey, Jr., University of California, Riverside; Thomas M. Pankratz, CH2M Hill; Richard H. Sakaji, California State Department of Health Services; Charles D. Turner, University of Texas, El Paso, and; Mark Wilf, Hydranautics. For more information, contact Mark Gibson (mgibson@nas.edu) or Stephanie Johnson (sjohnson@nas.edu), both at 202-334-3422.

Indicators for Waterborne Pathogens

The Committee on Indicators for Waterborne Pathogens is slated to report on candidate indicators and/or indicator approaches for microbial pathogen contamination in U.S. recreational waters and source water. This Board on Life Sciences/WSTB study will review and provide perspective on the importance and public health impacts of waterborne pathogens as discussed in previous National Academies reports and other seminal reports and develop candidate lists or sets of appropriate and scientifically defensible indicators

and/or indicator approaches. The study committee has met a total of four times over a 15-month study period. In its September 2002 meeting, a public workshop was held. Topics for the workshop included various issues related to the committee's charge, including: Multiple Uses of Ambient Waters (Chris Crockett, Philadelphia Water Department); Recreational Water—Epidemiologic Evidence (Jack Colford, University of California at Berkeley, School of Public Health); Water Quality: Modeling and Land Use (Geoffrey Scott, National Oceanic and Atmospheric Administration); Parasite Monitoring (Peter Marsden, Drinking Water Inspectorate, UK); World Health Organization—Drinking Water Standards (Mark Sobsey, University of North Carolina, Chapel Hill, and committee member); Innovative Detection Technologies I, (Raymond Mariella, Lawrence Livermore National Laboratory); and Innovative Detection Technologies II, (J. Michael Ramsey, Oak Ridge National Laboratory). The committee's report should enter review in spring 2003 and be released in prepublication by June 2003.

This EPA-sponsored study is chaired by Mary Jane Osborn (NAS), University of Connecticut, and vice-chaired by R. Rhodes Trussell (NAE), Montgomery Watson Harza, Inc. For further information, contact Mark Gibson at 202-334-3422 or mgibson@nas.edu.

Platte River Endangered and Threatened Species

The Board on Environmental Studies and Toxicology, in cooperation with the WSTB, is studying habitat needs for several endangered species along the Platte River. A study committee will assess the Central Platte River habitat needs for the whooping crane, piping plover, and interior least tern, and will assess Lower Platte River habitat needs of the pallid sturgeon. The committee will review federal assessments of how current Platte River operations affect the likelihood of survival of and/or limit the recovery of these species. It will also consider whether other Platte River habitats provide similar values that are

essential to the survival and/or recovery of these species. The committee will consider the scientific foundations for the current federal designation of Central Platte habitat as "critical habitat" for the whooping crane and Northern Great Plains breeding population of the piping plover.

This activity is being conducted in response to a request from the U.S. Department of the Interior. Appointment of the committee is pending. There are three meetings with a final report due in early 2004. For more information on this study, contact Lauren Alexander of the WSTB at 202-334-3422 or lealexander@nas.edu.

Restoration of the Greater Everglades Ecosystem

A remarkable collaboration of local, state, federal, and tribal entities has been working to reverse some of the environmental degradation and restore more natural conditions to much of the Everglades. This has resulted in the Comprehensive Everglades Restoration Plan, or CERP, which was approved by Congress in the 2000 Water Resources Development Act.

The Everglades was once a free-flowing "river of grass" extending from the Kissimmee lakes to Florida Bay. However, more than half the Everglades wetlands have been lost to development. The Committee on Restoration of the Greater Everglades Ecosystem (CROGEE) was formed in 1999 to provide scientific guidance to agencies charged with restoration and preservation of the Everglades.

The committee is presently working in a number of areas, including ecological indicators, the role of flow in the system, and options for water storage in the restoration program. A report titled *Progress towards Adaptive Monitoring and Assessment for CERP* should be released in March 2003. A report on Flows and Levels in the Ridge and Slough Region of the Everglades is in preparation.

Funding for the committee's work is provided by the Department of the Interior and the Army Corps of Engineers. Jean Bahr of the University of

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Wisconsin, Madison chairs the committee. Stephen Parker is the study director, assisted by David Policansky (Associate Director, Board on Environmental Studies and Toxicology), Will Logan, and Patricia Jones-Kershaw. For more information, contact Will Logan at 202-334-3422 or wlogan@nas.edu.

Source Removal of Contaminants in the Subsurface

In August, the WSTB commenced a study on the effectiveness of source removal as a strategy for cleaning up contaminated groundwater and soil at hazardous waste sites. Aggressive source removal is increasingly popular as a way to achieve partial or complete reduction of contaminant mass at sites across the country. Little is known about the overall impact of such efforts on groundwater quality and other parameters. The study is considering such source removal technologies as in situ chemical oxidation, thermal treatment, and surfactant flushing, and it will focus on recalcitrant organic compounds, including explosives. At its first meeting, the committee heard presentations from its sponsor, the Army Environmental Center, and from project managers at four Army facilities. The second meeting, held January 29–31 in San Antonio, TX, featured a field trip to Kelly Air Force Base. The third meeting will be held April 14–15 in Washington, DC.

John Fountain of North Carolina State University is serving as chair. Other committee members are Linda Abriola, University of Michigan; Lisa Alvarez-Cohen, University of California, Berkeley; Mary Jo Baedecker, U.S. Geological Survey; David Ellis, DuPont Engineering; Thomas Harmon, University of California, Los Angeles; Nancy Hayden, University of Vermont; Peter Kitaniadis, Stanford University; Joel Mintz, Nova Southeastern University Shepard Broad Law Center; James Phelan, Sandia National Laboratories; Gary Pope, University of Texas, Austin; David Sabatini, University of Oklahoma; Thomas Sale, Colorado State

University; Brent Sleep, University of Toronto; Julie Wilson, Landau Associates; John Young, Hebrew University of Jerusalem; and Katherine Yuracko, YAHSGS. For more information, contact Laura Ehlers at 202-334-3422 or lehlers@nas.edu.

Studies in Hydrologic Science

The Committee on Hydrologic Science 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. Such a committee is needed 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 the needs of water management.

The committee has two reports are in preparation. The first is on *Groundwater Fluxes across Interfaces*, based on a May 2002 workshop focused on interactions of recharge and discharge with climate, scaling issues, and diffuse vs. focused fluxes. The second concerns *Research at the Boundary of Ecology and Hydrology*. The COHS also contributed ideas to the Academies' review of the U.S. Climate Change Science Program's draft strategic plan for climate change and global change studies. The committee will be meeting on May 19–20 to discuss whether to hold additional workshops on topics in hydrologic science or to change its meeting format to roundtable discussions with scientists from governmental and non-governmental entities.

Eric Wood of Princeton University chairs the committee. For more information, contact study director Will Logan at 202-334-3422 or wlogan@nas.edu

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 the Water Resources Division. Previous reports of the committee

included topics such as watershed research, hydrologic hazards, the streamgaging network, groundwater research, and water use.

The committee is currently reviewing the National Streamflow Information Program (NSIP). NSIP was created due to congressional concerns about the progressive loss of streamgages, especially those with a long period of record. It consists of a core of streamgages funded and operated by either the USGS or other agencies that provide data that meet national needs. The committee is evaluating the appropriateness of the NSIP-selected minimum national streamflow information needs and design characteristics of the network, and the components of the NSIP plan. It will also comment on how NSIP should support the development of river science (e.g., interaction of hydrology, geomorphology and ecology). The Committee will meet on May 12–13 to finalize the NSIP report and to consider future activities related to the USGS's current and planned initiatives in river science.

David Maidment of the University of Texas, Austin chairs the committee. For more information contact study director Will Logan at 202-334-3422 or wlogan@nas.edu.

Water Quality Improvement for the Pittsburgh Region

This study will assess the wastewater and water quality problems of the Pittsburgh, Pennsylvania area and make recommendations on how these issues and needs can be best addressed by the multiple jurisdictions on a cooperative basis. The study can also provide an instructive model for the EPA and other urban areas where a regional cooperative approach to water quality management may be considered. The study committee is slated to meet a total of six times over a two year study period and has already met three times in 2002, all in or near Pittsburgh, PA: July 7–8; September 23–24; and December 9–10. The first meeting included a large public stakeholder workshop hosted by Carnegie Mellon

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University while the latter meetings included an urban and rural “water quality field trip,” respectively. The committee’s fourth meeting is planned for April 24-25, 2003 in Washington, D.C., and the fifth meeting for July 17-18, 2003 in Woods Hole, MA. After a final meeting in early fall 2003, the committee’s report should be released in late 2003 or early 2004.

The committee is chaired by Jerome Gilbert (NAE), J. Gilbert, Inc. of Orinda, CA. Jeffrey Lauria, Malcolm Pirnie, Inc.; Gary Logsdon, Black & Veatch, Inc.; Perry McCarty (NAE), Stanford University; Patricia Miller, West Virginia University Safety & Health Extension Service; David Moreau, University of North Carolina; Nelson Moreau, the CADMUS Group; Rutherford Platt, University of Massachusetts of Amherst; Stuart Schwartz, Water Resources Research Institute of the University of North Carolina; James Shortle, Pennsylvania State University; Joel Tarr, Carnegie Mellon University; Jeanne VanBriesen, Carnegie Mellon University; and Paul Ziemkiewicz, West Virginia University.

The study is sponsored by the Allegheny Conference on Community Development. For more information, contact study director Mark Gibson at 202-334-3422 or mgibson@nas.edu.

Water Resources Management, Instream Flows, and Salmon Survival in the Columbia River Basin, Washington

The WSTB, in cooperation with the Board on Environmental Studies and Toxicology, has assembled a committee that is reviewing the relations between instream flows, withdrawals, and impact on salmon in the Columbia River. The study was initiated in response to a request from the Washington State Department of Ecology. The Department of Ecology is responsible for issuing state water withdrawal permits and water rights on the Columbia River (and other rivers) within the State of Washington. Decisions by the Department of Ecology regarding dozens of

permit applications from the Columbia mainstem are currently pending. The agency faces the challenge of not only ensuring that permitting decisions are based on sound scientific knowledge, but also making these decisions in a context of competing scientific studies and interest groups with different perspectives on the impacts of withdrawals. To assist the Department of Ecology with these decisions related to withdrawals and their potential impacts on salmon, this committee is reviewing scientific data and environmental conditions relating to endangered salmon and other species. The committee is also evaluating the potential cumulative effects of a range of water withdrawal and management scenarios.

The committee held its first meeting in Richland, WA on February 3-4. Its second meeting will be held in Vancouver, WA on March 20-21. A third meeting is scheduled for July 28-29 in Olympia, WA. A fourth and final meeting will be held in October at the Beckman Center in Irvine, CA. The committee’s report is scheduled for completion in March 2004.

The committee is chaired by Ernest Smerdon, University of Arizona (emeritus). Other members are Richard Adams, Oregon State University; Donald Chapman, BioAnalysts, Inc.; Darrell Fontane, Colorado State University; Albert Giorgi, BioAnalysts, Inc.; Helen Ingram, University of California, Irvine; Carter Johnson, South Dakota State University; John Magnuson, University of Wisconsin; Stuart McKenzie, U.S. Geological Survey (retired); Diane McKnight, University of Colorado; Tammy Newcomb, Michigan Department of Natural Resources; Kenneth Tanji, University of California, Davis; John Thorson, consultant. For additional information on this committee, contact study director Jeffrey Jacobs at 202-334-3422 or jjacobs@nas.edu.

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CALFED Bay-Delta Program

The WSTB with the Board on Environmental Studies and Toxicology is making arrangements to enter into an advisory relationship with the CALFED Bay-Delta Program. The NRC’s objective will be to help assure the quality of the scientific basis of this important effort to restore the San Francisco Bay-Delta ecosystem, enhance the quality and reliability of California’s water supply, and improve the integrity of its levee system. The CALFED Bay-Delta Program is a collaborative program involving 18 federal and California state agencies with agricultural, urban, environmental, fishery, business, native American, and rural interests.

California’s Bay-Delta estuary is a biologically diverse aquatic ecosystem that plays a central role in the distribution of California’s water from the state’s northern regions to its southern, arid, and populous cities and agricultural areas. The Bay-Delta region receives water from the Sacramento and San Joaquin Rivers, which in turn receive flows from tributary streams that drain the westward slopes of the Sierra Nevada Mountains. Outflows from the Bay-Delta, through the San Francisco Bay and into the Pacific Ocean, are balanced by tidal inflows, resulting in a brackish water ecosystem in many reaches of the Bay-Delta, which is the Pacific Coast’s largest estuarine system. In addition to its ecological functions and benefits, there are large withdrawals of fresh water from the southern section of the Bay-Delta, where pumping stations divert large amounts of water into the federal Central Valley Project (primarily for agriculture) and the State Water Project (primarily for Southern California cities). This sophisticated engineering and hydrologic system has met the diverse water-related needs of Californians for decades; however, water quality and water quantity problems in recent decades, along with the challenge of meeting the demands of a rapidly-growing population, have resulted in tensions and strong differences of opinion on the system’s

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proper management.

Initial NRC efforts will focus on the CALFED Science Program itself, with attention to science planning, management, and use in support of the Program. For more information contact Stephen Parker at 202-334-3422 or sdparker@nas.edu.

Great Lakes/St. Lawrence Seaway Studies

The WSTB, in collaboration with Board on Agriculture and Natural Resources and Transportation Research Board, is planning to initiate a set of activities to improve the health of the Great Lakes ecosystem and economy of the Great Lakes region. The planned study will identify, evaluate, and present a suite of new policy options for the Great Lakes region and the St. Lawrence Seaway that will (1) keep open the Great Lakes region to economic activity and world commerce and (2) close the Great Lakes region to the intentional and unintentional transport of biological pathogens.

The Great Lakes ecosystem includes the five Great Lakes, four major connecting channels including Niagara Falls, and an international border between Canada and the United States. The Lakes are the largest freshwater system on Earth and account for about 20 percent of the world's fresh surface water. The Great Lakes drain billions of gallons each day from Lake Superior through Lake Ontario, then to the Atlantic Ocean through the St. Lawrence Seaway system on the St. Lawrence River. The St. Lawrence Seaway's lock and dam system, opened in 1959, is a critical valve in the flow system, controlling access to and exchange of industrial good and services, water, materials, and biologic organisms in and out of the Great Lakes basin. The 60+ year-old structures are showing signs of age, and repairs are necessary and upgrades to the Seaway may be required if the Seaway is to play a larger role in the economy of the Great Lakes region in coming decades.

Updating and rehabilitating the St. Lawrence Seaway is a major undertaking that calls into question what may be the best policy options for the St. Lawrence Seaway and the Great Lakes Region. The options are not clear-cut due to competing interests. For example, updating and rehabilitating the St. Lawrence Seaway could invigorate sluggish industrial production in the basin by increasing capacity for global trade. However, bigger ships are charged with bringing unwanted exotic species in their hulls and ballasts. Two notorious exotic species, the zebra mussel and the sea lamprey, were introduced to the Great Lakes ecosystem via the hulls of ocean-going vessels, and have subsequently leveled severe and deleterious impacts on the Great Lakes ecosystem.

A set of plausible, credible, and viable policy options are needed to help government and regional decision-makers propose and implement the best policies for the Great Lakes region. The NRC study will present a suite of new policies that consider measures and impacts of the introduction and proliferation of exotic (non-native) aquatic species; changes in fish populations; water quality; lake and tributary water levels; and climate change and variability. Likewise, economic data and analysis, including trends in regional-national-global trade for the Great Lakes sectors that export and import goods, shipping line economics (particularly affecting ship dimensions and utilization) that could be or have been transported on the Seaway, waterway traffic levels, and destinations/origins of exported/imported products, will be included in process of developing the policy options for the Great Lakes. The WSTB has an early history of advising on Great Lakes issues but has not addressed the Great Lakes ecosystem explicitly since 1989. Earlier publications include: *The Great Lakes Water Quality Agreement: An Evolving Instrument for Ecosystem Management* (1985) and *Great Lake Water Levels: Shoreline Dilemmas* (1989). For information, contact Lauren Alexander at 202-334-3422 or lealexander@nas.edu.

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 long-term 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 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

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Environmental Cleanup at Navy Facilities: Adaptive Site Management
2003

This report looks at developing a decisionmaking framework to site clean up that is embodied within a “system engineering approach,” which would allow for reconsideration of remedies over time. It is a followup to 1999 NRC report *Environmental Cleanup at Navy Facilities: Risk-Based Methods*. Available at \$37.00 prepublication (*see order form*).

Review Procedures for Water Resources Planning
2002

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. Available for \$12.00 (*see order form*).

Aquifer Storage and Recovery in the Comprehensive Everglades Restoration Plan: A Review of the ASR Regional Study Project Management Plan of the Comprehensive Everglades Restoration Plan
2002

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. Available for \$18.00 (*see order form*).

Florida Bay Research Programs and Their Relation to the Comprehensive Everglades Restoration Plan
2002

This report evaluates Florida Bay studies and restoration activities that affect the success of the Comprehensive Everglades Restoration Plan. Available for \$18.00 (*see order form*).

Review of the Florida Keys Carrying Capacity Study
2002

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.” Available for \$38.25 (*see order form*).

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Future Projects

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. For more information on funding opportunities contact Stephanie Johnson at 202-334-3422 or sjohnson@nas.edu.

Review of the U.S. Army Corps of Engineers Restructured Draft Feasibility Study for the Upper Mississippi River-Illinois Waterway System: Phase II

In early 2001, the WSTB, in cooperation with the Transportation Research Board, issued a report, *Inland navigation System Planning: The Upper Mississippi River-Illinois Waterway*, that reviewed the Corps of Engineers’ draft feasibility study of the Upper Mississippi River-Illinois Waterway (UMR-IWW). Since then, the Corps, working in cooperation with several other federal agencies, has been restructuring this feasibility study in line with the report’s recommendations. The WSTB has now been requested by the Corps to review the restructured feasibility study. Like the 2001 study (Phase

I), this study (Phase II) will evaluate economics models used by the Corps for forecasting future commodity prices, demands, and levels of waterway traffic. The Phase II activity, however, will likely pursue broader topics, including the restructured study’s environmental analyses and its efforts at integrating economic, environmental, and management considerations.

As this newsletter went to press, logistical details of this study were being negotiated. An initial, tentative study timeline calls for a committee to be appointed about May 2003 and numerous events and reports through 2004. For more information on this activity, contact Jeffrey Jacobs at 202-334-3422 or jjacobs@nas.edu.

State Water Quality Monitoring Program in Support of Water Quality Management

During the summer of 2002, the WSTB was approached by EPA’s Office of Wetlands, Oceans, and Watersheds to undertake a study that will assess the adequacy of current state water quality monitoring efforts. Since that time, WSTB staff have created a proposal and submitted it to EPA. The proposed study will evaluate the effec-

tiveness of current state programs for monitoring the health of the nation’s waters and make suggestions for improvement, with an emphasis on better linking the water quality standard setting process and monitoring network design. Several issues will be considered, including water body segmentation, innovative or alternative means for setting water quality standards, appropriate monitoring approaches and monitoring network design, statistical approaches for making attainment determinations, and the relationship between state water quality monitoring efforts and other potentially complementary activities. The resulting report should help improve and advance the water quality monitoring efforts of EPA, states, and other entities. Once a contract with EPA has been established, WSTB will be forming a committee of approximately 13 with expertise in the areas of aquatic chemistry, watershed and water resources management, aquatic and estuarine ecology, hydrology, statistics, and water quality monitoring (including emerging technologies). For further information, or to nominate committee members, contact Laura Ehlers at 202-334-3422 or lehlers@nas.edu.

WSTB Reports

Compensating for Wetland Losses Under the Clean Water Act

2002

This report evaluates mitigation practice as a way to restore and maintain quality of the nation's waters, particularly under the Clean Water Act. Available for \$49.95 (*see order form*).

Bioavailability of Contaminants in Soils and Sediments

2002

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. Available for \$68.50 (*see order form*).

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

2002

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. Available for \$39.95 (*see order form*).

Opportunities to Improve the U.S. Geological Survey National Water Quality Assessment Program

2002

This report reviews the U.S. Geological Survey's National Water Quality Assessment Program and makes recommendations as the program enters into its second decade. Available for \$34.00 (*see order form*).

Predictability and Limits-to-Prediction in Hydrologic Systems

2002

This is a report of a workshop on Predictability and Limit-to-Prediction in Hydrologic Systems. The report discusses research milestones in this field. Available from the WSTB at 202-334-3422.

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

2002

This report reviews the USGS National Water-Use Information Program (NWUIP) and makes recommendations and identifies opportunities. Available from the WSTB at 202-334-3422.

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

2002

The report reviews and provides comments on the USGCRP report *A Plan for a New Scientific Initiative on the Global Water Cycle*. Available from the WSTB at 202-334-3422.

Missouri River Ecosystem: Exploring the Prospects for Recovery

2002

The report reviews the Missouri River ecosystem's status and trends, science programs and status of scientific knowledge, and organizational choices for supporting ecosystem monitoring programs and for implementing adaptive management. Prepublication copies of the report is available from the WSTB at 202-334-3422.

Riparian Areas: Functions and Strategies for Management

2002

The report discusses the characteristics, functioning, and services of riparian areas and makes recommendations on protecting and managing them. Available for \$52.00 (*see order form*).

Assessing the TMDL Approach to Water Quality Management

2001

This report reviews the scientific bases underlying the development and implementation of the Total Maximum Daily Load program for water pollution reduction. Available for \$28.25 (*see order form*).

Classifying Drinking Water Contaminants for Regulatory Consideration

2001

This report presents new conceptual approach to the generation of future Candidate Contaminant Lists and explores the feasibility of developing and using mechanisms for identifying emerging microbial pathogens for research and regulatory activities. Available for \$42.00 (*see order form*).

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

2001

This report discusses the future of the nation's water resources and appropriate research needed to promote sustainable management of those resources. Available from the WSTB at 202-334-3422.

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

2001

This report reviews the Corps' draft feasibility study that gauges the economic viability of extending several locks on the Upper Mississippi River-Illinois Waterway. Available for \$29.75 (*see order form*).

Aquifer Storage and Recovery in the Comprehensive Everglades Restoration Plan

2001

This report evaluates pilot projects for ASR in the Everglades. It makes recommendations for studies of regional impacts, water quality, and system performance. Available from the WSTB at 202-334-3422.

Investigating Groundwater Systems on Regional and National Scales

2000

This report makes recommendations concerning the USGS Ground-Water Resources Program, which is designed to do regional groundwater assessment and science. Available for \$29.00 (*see order form*).

WSTB Reports

Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution

2000

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. Available for \$54.95 (*see order form*).

Risk Analysis and Uncertainty for Flood Damage Reduction Studies

2000

This report reviews and assesses the U.S. Army Corps of Engineers risk analysis techniques in its flood damage reduction studies. Available for \$40.00 (*see order form*).

Seeing Into the Earth: Noninvasive Characterization of the Shallow Subsurface of Environmental and Engineering Application

2000

This report examines new and improved noninvasive methods for characterization of the shallow subsurface of the earth. Available for \$35.00 (*see order form*).

Natural Attenuation for Groundwater Remediation

2000

This report examines natural attenuation issues about such as public concerns, scientific bases, and the criteria for evaluating its potential for success or failure. Available for \$47.95 (*see order form*).

Watershed Management for Potable Water Supply: Assessing the New York City Strategy

2000

This report evaluates the New York City watershed management plan that is allowing the City to avoid filtration of its large upstate surface water supply. A broad range of conclusions and recommendations are made, many of which are applicable to surface water supplies across the country. Available

for \$56.00 (*see order form*).

Ecological Indicators for the Nation

2000

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. Available for \$39.95 (*see order form*).

Hydrologic Science Priorities for the U.S. Global Change Research Program: An Initial Assessment

1999

This report makes recommendations for the U.S. Global Change Research Program. Two broad science 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. Available from the WSTB at 202-334-3422.

Downstream: Adaptive Management of Glen Canyon Dam and the Colorado River Ecosystem

1999

This report evaluates the strengths and weaknesses of the Long-Term Monitoring and Research Plan of the Grand Canyon Monitoring and Research Center. Available for \$41.50 (*see order form*).

Identifying Future Drinking Water Contaminants

1999

This report summarizes a workshop based on prioritizing potential drinking water contaminants for inclusion on future Drinking Water Contaminant Candidate Lists. Available for \$45.00 (*see order form*).

Water for the Future: The West Bank and Gaza Strip, Israel, and Jordan

1999

This report recommends that Israel, Jordan, and the Palestinian Authority work together to preserve aquatic ecosystems in the Middle East to ensure that an adequate supply of fresh, high-quality water is available for future generations. The report offers a range of findings and

observations on water resource management options for this area. Available for \$35.00 (*see order form*).

New Directions in Water Resources Planning for the U.S. Army Corps of Engineers

1999

This report identifies several ways in which the Corps might reduce the time required in water project planning. The report also recommends that the federal Principles and Guidelines for Water and Land Resources Implementation Studies be thoroughly reviewed and modernized. Available for \$39.00 (*see order form*).

Hydrologic Hazards Science at the U.S. Geological Survey

1999

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. Available from the WSTB at 202-334-3422.

Improving American River Flood Frequency Analyses

1999

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. Available from the WSTB at 202-334-3422.

New Strategies for America's Watersheds

1999

This report provides a timely and comprehensive look at the rise of "watershed thinking" among scientists and policymakers and recommends ways to steer the nation toward improved watershed management. Available for \$49.00 (*see order form*).

Setting Priorities for Drinking Water Contaminants

1999

This report provides a phased decision

WSTB Reports

process for determining which contaminants on the Contaminant Candidate List are appropriate for regulatory decisions and which will require research or monitoring. Available for \$35.00 (*see order form*).

Environmental Cleanup at Navy Facilities: Risk-Based Methods 1999

This report reviews and critiques risk-based cleanup methods, including those developed by the EPA and the American Society of Testing and Materials, and identifies eleven criteria that must be part of any risk-based methodology adopted by the Navy. Available for \$34.25 (*see order form*).

Issues in Potable Reuse: The Viability of Augmenting Drinking Water Supplies With Reclaimed Water 1998

This report looks at the issues involving the use of reclaimed water to supplement drinking water supplies. It discusses issues of water treatment technology, monitoring, and testing of reclaimed water to ensure public safety. Available for \$44.95 (*see order form*).

Hydrologic Sciences: Taking Stock and Looking Ahead 1998

The WSTB used the opportunity of its 1997 Abel Wolman Distinguished Lec-

ture to assess the vitality of the hydrologic sciences by the hydrologic community. This report is a compilation of the Wolman Lecture and four invited papers, preceded by a summarizing overview. Available for \$35.00 (*see order form*).

Innovations in Ground Water and Soil Cleanup 1997

This report provides a comprehensive review of the status of innovative technologies for subsurface cleanup. It also recommends strategies for increasing market demand for innovative remediation technologies, standardizing the collection of pilot and field test data on these technologies, and evaluating cost data. Available for \$44.95 (*see order form*).

Valuing Ground Water 1997

This report examines approaches for assessing the economic value of groundwater and the costs of contaminating or depleting this resource. It suggests a framework for policymakers and managers to use in evaluating tradeoffs when there are competing uses for groundwater. Available for \$39.95 (*see order form*).

Building a Foundation for Environmental Research 1997

This report outlines a new framework for organizing the research program at

EPA's Office of Research and Development. The report calls for the establishment of two kinds of research: *problem-driven* research and *core* research. Available from the WSTB at 202-334-3422.

Watershed Research in the U.S. Geological Survey 1997

This report is intended to assist the USGS in improving its overall strategy for watershed research. Available from the WSTB at 202-334-3422.

Safe Water from Every Tap: Improving Water Service to Small Communities 1997

This report assesses the quality of drinking water in small communities and recommends a three-part strategy for improving it. Available for \$44.95 (*see order form*).

Alluvial Fan Flooding 1996

This report provides an updated regulatory definition of alluvial fan flooding, presents criteria for assessing whether an area is or is not subject to such flooding, and provides examples of applying the definition and criteria to real situations. Available from the WSTB at 202-334-3422.

Freshwater Ecosystems: Revitalizing Educational Programs in Limnology 1996

This report provides an overview of the status of inland waters, the history of limnology, and key future problems that may face water resource managers. It recommends changes in limnology education and research to meet the needs of water resource management. Available for \$54.95 (*see order form*).

Water Science and Technology Board

The Water Science and Technology Board (WSTB) is a unit of the National Research Council, which serves as an independent advisor to the federal government on scientific and technical questions of national importance. The National Research Council, jointly administered by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine, brings the resources of the scientific and technical community to bear on national problems through its volunteer advisory committees.

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For a complete listing of
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