STAR REPORT

U.S. EPA Office of Research and Development's Science To Achieve Results (STAR) Research in Progress

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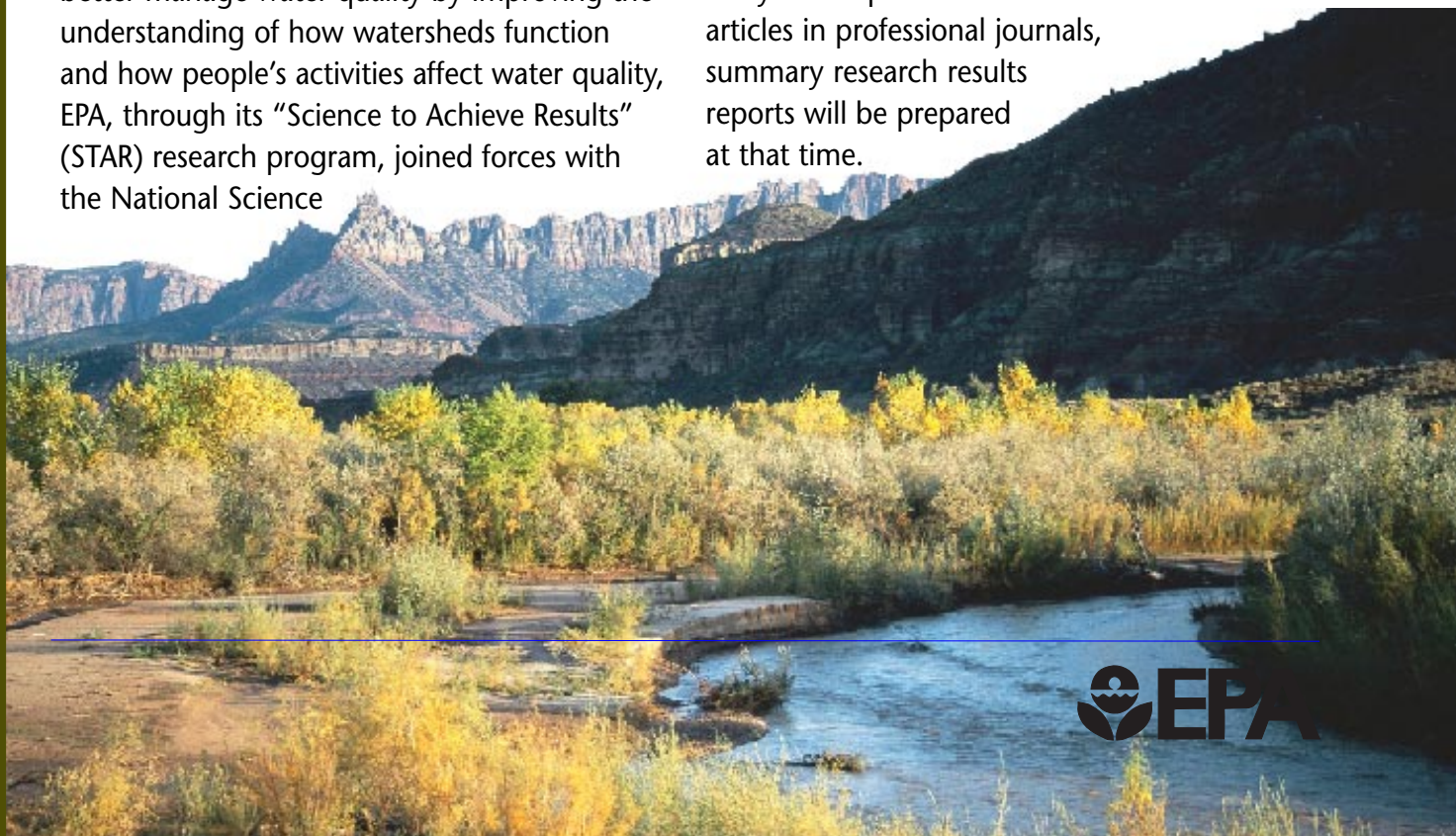
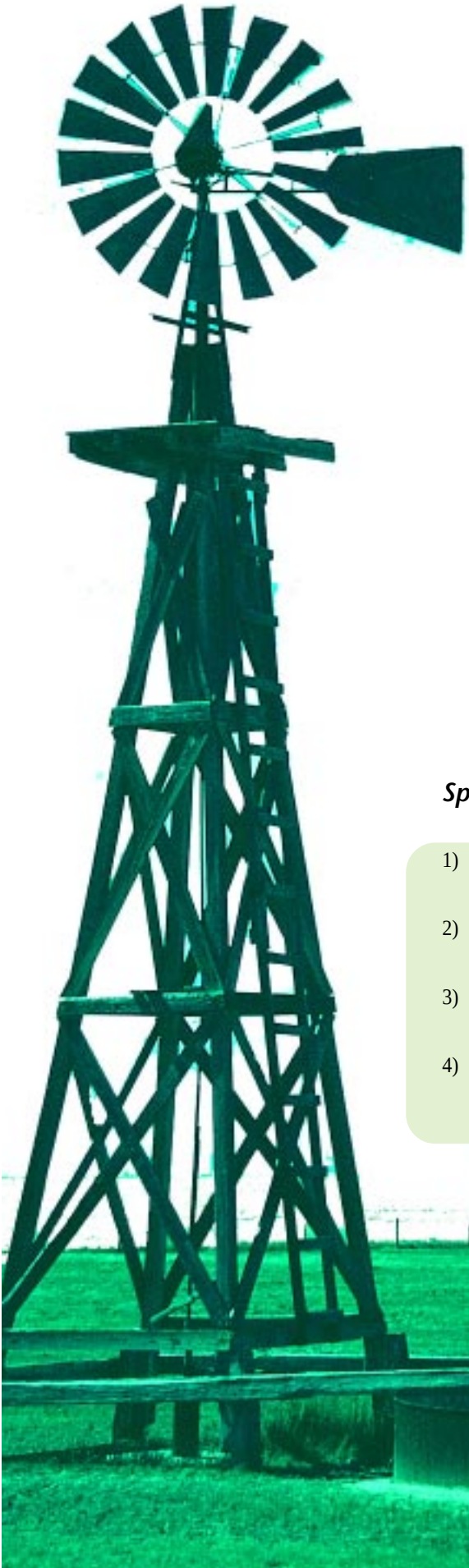
WATER and WATERSHED RESEARCH

In recent years, the U.S. Environmental Protection Agency (EPA), other federal agencies and the states have made an integrated "watershed approach" the cornerstone of their water quality protection programs. This year, in response to the Vice Presidential Clean Water Initiative, EPA has developed a Clean Water Action Plan, whose primary goals include placing greater emphasis on watershed management. To help environmental agencies better manage water quality by improving the understanding of how watersheds function and how people's activities affect water quality, EPA, through its "Science to Achieve Results" (STAR) research program, joined forces with the National Science Foundation (NSF) and the Department of Agriculture to support the "Water and Watersheds" research program. This program supports research that cuts across disciplines, to elucidate important principles for assessing, protecting and restoring watersheds. This report summarizes research funded in 1995 through 1997. Findings will be available starting in 1999 as the projects, typically supported for three to four years, complete data analysis and peer review. In addition to articles in professional journals, summary research results reports will be prepared at that time.





INTEGRATED RESEARCH:
EMPHASIZING THE HUMAN DIMENSION

Watersheds are the basic units of land, surface water and groundwater that integrate water flow, ecosystem dynamics and water quality renewal. The ecology of aquatic life is intimately coupled to conditions of a watershed's terrestrial ecosystems. We do not sufficiently understand how stresses from man's activities, such as land development, pollutant releases, deforestation, river channelization and agricultural use, affect these linked watershed processes. Consequently, there is a special focus in this program on research that integrates socioeconomic studies, taking into account the human factors associated with watershed stress along with analyzing data on ecological impacts.

BACKGROUND:
CURRENT U.S. WATER QUALITY IMPACTS

For 25 years, the United States has made a great deal of progress cleaning up waters polluted by "point source" discharges such as sewage plants and industrial facilities. However, states' assessments find serious remaining water quality problems in much of the nation. The most common causes of today's problems are "nonpoint sources" of pollution, such as runoff from agriculture, forestry, land development or historic or current mining locations. While many areas have far better water quality than at any time in the preceding century, other areas are experiencing moderate to severe declines in surface- and ground-water quality. In these places, it is common to find serious impacts on fish and wildlife, including decreased fish and shellfish catches, and in rarer cases there have been documented risks to human health.

Specific Problems:

Current examples of such problems in the U.S. include:

1) bans on fishing, shellfishing or recreational water use because waters violate health standards for chemicals or fecal bacteria introduced from the watershed;

2) declines in numbers, health or reproductive success of fish, waterbirds and other aquatic life in the lakes, rivers and streams of pollution-impaired watersheds;

3) coastal fish kills and human health risks from hazardous algal blooms that scientists believe can be stimulated by excess nutrient loads from watersheds; and

4) declines in coastal fish populations due to oxygen-depleting pollution, such as the "dead zone" off the Gulf Coast in which shrimp and fish landings sometimes decline to zero, thought to be related to nutrients carried by the Mississippi River.

More information on these and other issues is available from EPA's Clean Water Action Plan website, http://www.epa.gov/cleanwater/.

RESEARCH SUPPORTED BY THE WATER AND WATERSHEDS PROGRAM

This program addresses multiple stresses affecting watersheds, and early warning signals of emerging impacts. Included is research on ecology, hydrology and environmental management. An important criterion for project selection is that there is good promise for transferring results from one area to others.

Integrated Watershed Projects Relevant to Multiple Land-Uses.

The **University of Maryland** is developing a complex ecosystem model that takes into account economic factors, including land values under various uses, in predicting aquatic ecosystem conditions in a mid-Atlantic watershed. This will support projections of how policy alternatives would influence land use and ecological quality. A similar multidisciplinary project, to inform state policy decisions about land use planning alternatives for the Illinois River watershed, is being conducted by a team from the **University of Oklahoma** and **Oklahoma State University**. A project on multiple land uses, water quality and ecological conditions at the **University of Georgia** will predict aquatic impacts in Georgia, using a refined set of technical indicators for stream ecosystem health.

Estuarine and marsh ecosystems can be severely impaired by increased nitrogen inputs, diminishing fish survival and otherwise degrading the ecoysystem. The **Marine Biological Laboratory of Woods Hole** is conducting field studies to refine models of impacts on juvenile fish and other aspects of the food web due to increased nitrogen inputs in the watershed. In a second phase, these researchers are working with the **University of Connecticut** and the **Social and Environmental Research Institute** of Leverett, Massachusetts to determine how their coastal ecological modeling can best be made useful to local planners and citizens making coastal zone land use decisions.

The **University of Oregon** and **Oregon State University** are studying effects of changes in flow, sediment loads and food chain ecology on Columbia River salmon stocks, some of which are endangered. Salmon recovery will depend on the availablity of stream habitat with coldwater patches, needed prey organisms and other factors. This study will help determine how the "carrying capacity" of streams for salmon can best be defined based on physical and biological characteristics. Another study supporting habitat restoration for at risk fish stocks is being conducted by the **University of California at Davis.** They are focusing on striped bass, salmon and smelt in the lower Sacramento River, and will will predict likely outcomes of water quality management alternatives by developing a model that includes hydrology, water quality and biological factors. Potential remedies include restoring streambank habitats, curtailing or rescheduling water diversions and reducing specific pollutant sources.

Sedimentation is being studied by the **University of Minnesota**, using models based on observed impacts of forestry, mining and road building. The **University of North Carolina** is assessing the success of local jurisdictions' regulatory programs to reduce impacts of erosion from housing construction, road building and agriculture on the ecological health of watersheds. They are comparing streams' biological conditions to determine which regulatory approaches are most effective. Stream reforestation research is being conducted in the mid-Atlantic region by the **University of Delaware, Pennsylvania State University** and the **Academy of Natural Sciences of Philadelphia**. They will document ecological benefits of wooded streams compared to those where woods are cleared, together with gathering information about the pros

and cons of reforestation strategies from the perspectives of area landowners.

The **University of Illinois** is conducting research on restoring the ecology and productive human uses of floodplains and floodplain rivers. They are working with state agriculture, water and natural history agencies to assess economic factors such as farm production, recreation values and flood damages along with the natural factors of hydrology and floodplain forest ecology for a portion of the Illinois River. Results are expected to help agencies better balance costs and benefits of floodplain management and restoration options.

Reducing acidification of high elevation lakes and their watersheds is one objective of programs to control air emissions of nitrogen and sulfur, as mandated by the Clean Air Act. Ongoing monitoring is tracking atmospheric deposition and its impacts. To support extrapolations of regional conditions based on data from intensively monitored lakes, the **University of Maine** and the **University of Virginia** are jointly developing analytic and modeling tools. These will support assessments and predictions of water quality and forest productivity for use by EPA, states and regulated industries in impact assessments.

The **University of Washington** is comparing watershed processes in west Pacific basins to improve the ability to predict large-scale runoff of dissolved and particulate materials based on climate, geology, ecology and land use. Model development will be compared and coordinated with related research through an international network of scientists and water resource managers. Another collaborative international project involves **Pennsylvania State University** and the **Bulgarian Academy of Sciences**. Techniques for modeling multireservoir hydrologic systems, developed by an international institute, will be combined with Pennsylvania State's existing geographic information system-based watershed models to better predict locations of water quality improvements based on pollution reductions in upstream locations.

Urbanized Watersheds

The **University of Washington** is developing rehabilitation methods for channelized streams in older and newly urbanizing areas. Factors considered include aesthetic preferences, degrees of aquatic ecological protection and costs for alternate designs. **Marquette University** is refining methods for assessing benefits of flood control and restoration projects in urban and suburban watersheds near Milwaukee, to better balance flood control needs with the ecological benefits of preserving or restoring habitat.

Almost the entire drainage area of the Los Angeles basin is urbanized, with most wetlands eradicated. The **University of California at Los Angeles** is analyzing the many pollution sources that threaten coastal water quality and the ecological integrity of small remaining areas of habitat such as salt marshes. Data include levels and impacts of DDT, trace metals, industrial organic chemicals, nutrients and other pollutants from sewage, industrial disposal, street runoff and airborne sources. Results will be incorporated with runoff and hydrology models to help local managers set remediation priorities.

Several other studies involve simultaneously assessing socioeconomic and ecological aspects of urban impacts. The **University of Georgia and Georgia Institute of Technology** are testing hypotheses that citizens' values and commitments to preserving watershed conditions are influenced by their perceptions of how rapidly impacts are occuring, and of the degree to which they expect that desirable future environmental conditions can be attained or maintained over various time scales, including conditions to be experienced by future generations. **Boston University**, working with the **Marine Biological Laboratory at Woods Hole**, is involving stakeholder groups in a Boston area watershed

to develop management models applicable to land-use decisions at multiple spatial scales. Other urbanization impact assessment methods are being developed by the **Virginia Polytechnic Institute and State University**, for the upper Roanoke River watershed, the **Institute for Ecosystem Studies of Millbrook, New York,** for a Baltimore area subwatershed, and **Cornell University**, which is developing a river and aquifer simulation model intended to be applicable to many Northeastern watersheds. **Yale University** is surveying peoples' attitudes about nature and economic conditions in watersheds with various combinations of urbanization and environmental quality, with an eye to evaluating how restoring degraded watersheds can contribute to improved socioeconomic conditions.

Lake Tahoe, on the border of California and Nevada, is a model for the growing number of lake watersheds on boundaries between urbanizing areas and pristine mountain landscapes. This watershed presents intense needs to reconcile multiple uses. The Lake and undeveloped lands are unique ecological and recreational resources, while developed and partially developed lands are very highly valued for current and potential resort, vacation home, other commercial and urban uses. The **University of California at Davis** is building on a large body of previous ecosystem research to address the specific scientific questions involved in developing an ecologically sound and economically feasible erosion control management plan for the area.

Agricultural Watersheds

In the agricultural midwest, perhaps the single greatest impact on water quality is from stream channelization, which increases erosion, destroys vegetation and eliminates or reduces abundance of many fish. The **University of Illinois** is surveying drainage district commissioners and farmers to assess current practices in channelization and associated watershed usage and maintenance factors. Researchers will compare this information with data from state-wide fisheries collections. Results will be of immediate use in discussions among drainage district managers, state fish and wildlife managers and farmers on the most effective practices to meet farmers' needs while preserving or improving stream fishery conditions.

Also in the "cornbelt plains" ecoregion, **Ohio State University** is correlating remote sensing data with biological data to assess risks to streams affected by channelization, streambank defoliation and changing land use. The "index of biotic integrity" applied in this study incorporates data on aquatic food chains and streambank habitat condition. Iowa **State University**, the **University of Michigan**, the **University of Minnesota** and **Oregon State University** are attempting to develop an "alternative landscape design" to support watershed planning for the western corn belt. They are incorporating data on terrestrial vegetation, birds, stream condition and aquatic life with hydrology and agrichemical tranport modeling. They will project potential crop and land use scenarios for 25 years to predict impacts on water resources, ecosystem function and socioeconomic conditions.

Runoff from crops, livestock and poultry production and sewage can produce nutrient levels that exceed natural uptake, depleting oxygen and killing aquatic life. The **University of Louisville**, the **University of Michigan** and **Transylvania University** are using stream data from EPA's Environmental Monitoring and Assessment Program to assess relationships between nutrient enrichment and ecological impacts across "ecoregions" (areas with distinct geologic and ecological characteristics). A team at the **University of Minnesota** is assessing streams in a number of agricultural ecoregions, comparing ecological conditions with each watershed's farm, forest, habitat management and sewage treatment practices. Results are expected to be of use in local restoration decisions. Research on reducing nutrient enrichment impacts is also being conducted by the **University of Wisconsin** and the **Ohio State University.** They are developing water quality and socioeconomic analyses for upper Mississippi River watersheds. Agricultural runoff degrades this region's streams and rivers, and a significant portion of the nutrients that cause Gulf of Mexico oxygen depletion are also believed to originate there. Approaches under development are intended to provide farmers and resource managers with useful information on specific soil and water conservation systems most likely to

reduce excess nutrient release.

In Oregon's Tillamook Bay watershed, **Oregon State University** is assessing water quality from forested subwatersheds to the north to dairy farming areas and partially urbanized subwatersheds to the south. They are studying local perceptions of aquatic environmental health, which often differ from scientific assessments, to help support more effective planning to protect water quality in the rivers and the Bay.

Coliform bacteria tests used in routine surface water monitoring do not distinguish cells from sources likely to pose health risks, such as human sewage or livestock wastes, from those from natural sources unlikely to also carry human disease organisms. The **University of North Carolina at Chapel Hill** is using new genetic typing methods to determine whether it is possible to better distinguish coliform sources that may indicate health threats from those that may not.

Pesticides can be carried long distances through watersheds in their original forms, or as breakdown products that still pose health and ecological risks. The **University of Virginia** is studying the transport and breakdown of atrazine, one of the most widely used herbicides. Factors considered will include rapid transport through rock or soil flowpaths, and enhancement by colloid particles, which are more prevalent in some geologic and agricultural settings than in others.

Water quality in the tropics is particularly impaired by agriculture that fragments forests and reduces soil and water retention. The **University of Hawaii** and the **East-West Center** are studying data on bamboo and other farming practices in Vietnam to predict impacts of various land use alternatives.

Statistical Design for Watershed Research.

At **Pennsylvania State University**, a team of modelers, statisticians and natural resource scientists is refining statistical approaches to watershed sampling design. The objective is to take into account the natural variability of biological and physical data sets, so that sampling can be targeted most cost-effectively. The work has implications for hydrological, ecological and landscape characterization data.

Groundwater Quality

Murray Sate University in Kentucky is studying the interaction of the relatively poorly understood "hyporheic" zone where streams and groundwater connect. Studies of bacteria, algae and invertebrates will gather basic data about how conditions in these zones can have important influences on streams' ecological condition.

The **Baylor College of Medicine at the University of Texas** and the **University of California at Irvine** are investigating chemical and physical processes underlying natural disinfection of groundwater contaminated by human gastrointestinal viruses. Viral sources can include septic tanks and groundwater recharge basins.
The **New York State Department of Health** is studying rates at which groundwater bacteria break down sewage. Findings may help develop ways to enhance natural bioremediation of wastes. The **University of Illinois at Urbana-Champaign** is also investigating processes that could affect bioremediation of industrial wastes and sewage. They are modeling how groundwater travelling waves affect transport of soluble organic pollutants. Successful modeling would provide simpler ways to compute dispersion and breakdown rates.

Stanford University is developing a hydrologic model of how heterogeneity of soils and rocks affects transport rates of dissolved substances. This will support more accurate modeling of pollutant transport at some contaminated sites.

Toxicology of Widespread Aquatic Pollutants

A grant to **Princeton University** supports fundamental research on processes affecting the aquatic toxicity of mercury. Mercury contamination from a variety of industrial sources is an especially widespread problem, affecting aquatic food chains throughout the United States and leading to many public health advisories against fish consumption. Methods to mitigate mercury pollution are a top priority for EPA and the states. The Princeton research will test whether polysulfides increase the rate at which bacteria methylate mercury in the absence of oxygen. Investigators are also determining the rates at which mercury will be released to the atmosphere. If confirmed, this polysulfide hypothesis could be a breakthrough in understanding the factors that affect how toxic mercury will be in natural food webs.

Gold mining, particularly using cyanide extraction, can release toxic chemicals to water bodies. Impacts vary depending on interactions of extraction techniques with local hydrology and rock, soil and water characteristics. Arsenic is a common contaminant. The **University of Nevada**, the **Desert Research Institute of Reno** and the **University of California at Davis** are studying arsenic contaminated gold mining pit lakes in the Humboldt River Basin. Impacts include genetic damage in a food chain species, indicating likely long-lasting toxic impacts. The study includes assessing options for dealing with the contamination problem using focus groups that include representatives of the mining industry, the conservation community, farmers and other area residents.

Cadmium is a highly toxic metal associated with historic industrial impacts and some on-going releases. To analyze natural processes that may diminish toxic impacts, the **University of Kansas** and **Wichita State University** will study how humic and fulvic acids released by soils and plants bind cadmium and reduce toxicity under various conditions. The **University of Southern Mississippi** is conducting laboratory studies and field work in the Misssissippi River to test the hypothesis that bacterial effects on manganese, which is a model for toxic metals such as lead, zinc, and others, are strongly influenced by seasonal temperature changes.

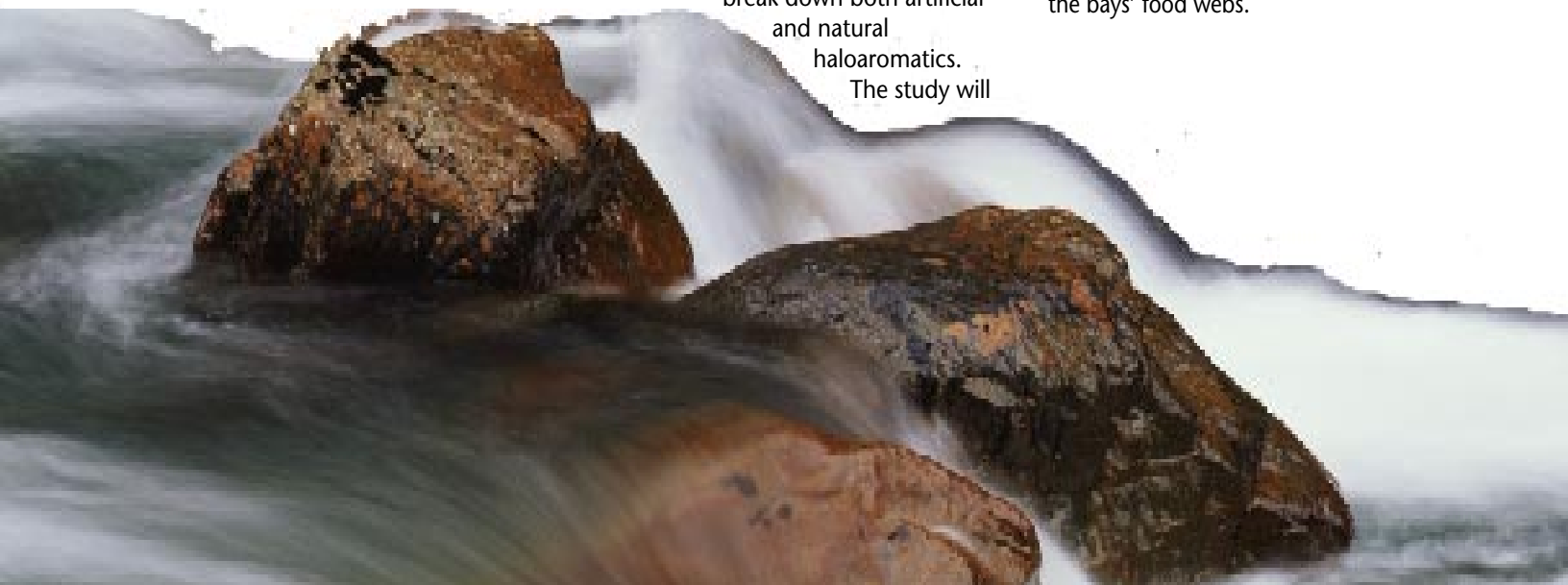
Another high risk group of pollutants are chemicals containing halogens, the chemical group that includes chlorine. The most toxic forms are haloaromatics. Artificial haloaromatics include PCBs, DDT and other industrial chemicals and pesticides. The **University of South Carolina** is investigating how some organisms thrive in coastal sediments heavily polluted by haloaromatics. These include worms, bacteria and other bottom-dwelling animals that break down both artificial and natural haloaromatics. The study will attempt to identify the mechanisms by which they detoxify the chemicals, looking at enzymes, gene characteristics and antibody activity.

Aquatic Ecology

Cornell University is focusing on a potentially critical component of lake ecosystems' recovery from pollution: the dormant (diapaused) eggs of planktonic animals. Eggs can remain in bottom sediments for many years and emerge in response to natural or human-induced changes in water quality. Some eggs remain alive after more than two decades in sediments polluted with mercury and other contaminants. Comparisons of sediment dating, showing when eggs were deposited, to chemical data on the history of lake pollution, will answer questions about how diapaused eggs may lead to faster recovery of lake food webs following long periods of pollution.

The **University of Wisconsin** and the **Institute of Ecosystem Studies of Millbrook**, New York are studying how wetlands and other sources of humic acids mitigate the effects of excess phosphorus, the principle nutrient that causes eutrophication and oxygen depletion in lakes.

Coastal Carolina University and the **Baruch Marine Laboratory**, both of South Carolina, are testing the hypothesis that oyster reefs significantly affect the chemistry and biology of shallow estuaries, helping to sustain the bays' food webs.



Public Policy and Institutional Arrangements

Three awards support institutional and policy studies for watersheds and regional water-use areas. The **University of Arizona** and **Indiana University** are comparing water resource management practices in Arizona, California and Colorado. They will assess results of policies and institutional arrangments for allocating and storing surface water and groundwater. One important factor may be the degree to which coordinated ("conjunctive") management of surface and groundwater is central to a state's institutional approach.

A study of the Rio Grande/Rio Bravo Basin is being conducted by the **Houston Advanced Resarch Center** and the **Instituto Tecnologico y de Estudios Superiores in Monterrey, Mexico.** The project brings together scientists from the two nations to complete analyses of surface and groundwater availability and conditions. They will analyze potential outcomes of alternate binational water management scenarios, based on future projections of socio-economic and ecological factors.

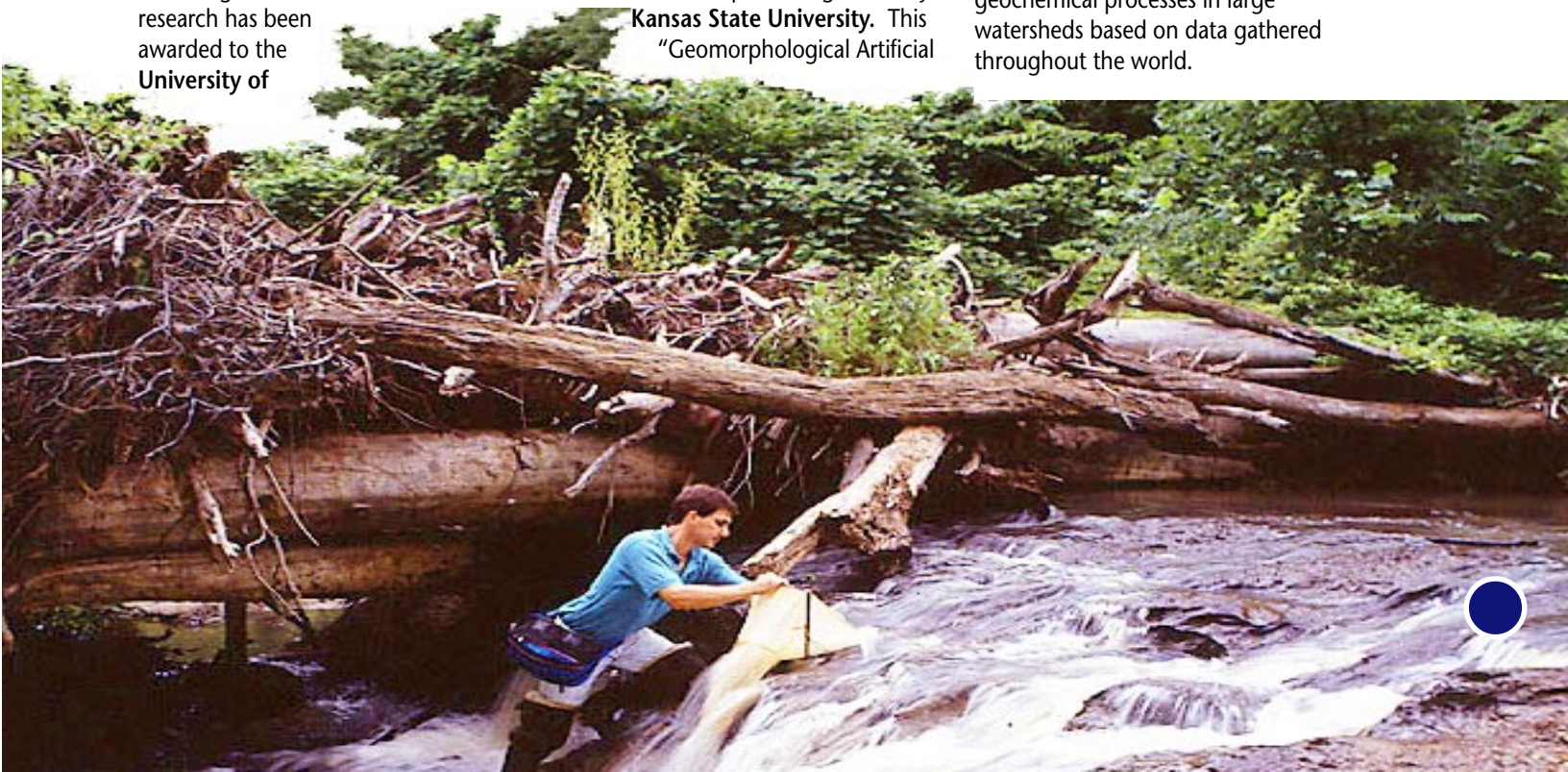
A grant for market economics research has been awarded to the **University of Arizona**. Economists and water users in California's central valley will test a computerized "smart market" for allocating and exchanging water use rights. The smart market integrates more information, such as user needs and willingness to pay, than do simpler tools such as bulletin boards. About 50 water users have volunteered to participate. Results will provide water use managers with information on whether prices to users, and efficiency of water marketing, can be improved with smart market tools.

Weather, Watershed Hydrology and Climate Change Modeling

Five grants have been awarded for studies of watershed impacts of precipitation, long-term climatic shifts and other weather phenomena. Utah State University is developing a hydrologic model applicable to the semi-arid areas that compose much of the western U.S. It is hoped that the model will better predict streamflow in mountainous western areas, where water availability is often the most critical factor in natural resource management.

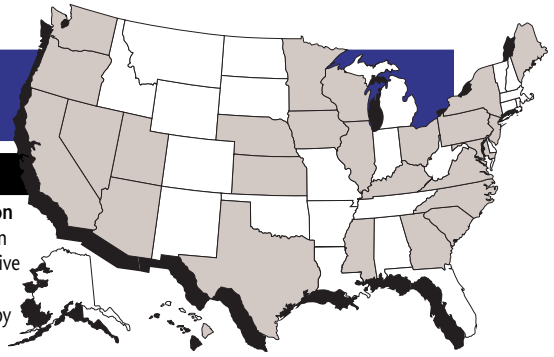
A new way to model rainfall-runoff relationships is being tested by **Kansas State University.** This "Geomorphological Artificial Neural Network" approach may improve abilities to predict watershed runoff with less site-specific physical data than is usually needed. The **University of Nebraska** is refining a model to predict climate-related changes in flows, floods, sediment transport and other hydrologic characteristics over geologic time frames. The **University of California at Davis** is developing a rainfall model based on very detailed time series data of storm events. The approach used, "fractal-multifractal" modeling, is expected to increase accuracy in predicting rain patterns.

The **Marine Biological Laboratory at Woods Hole** and the **University of New Hampshire** are undertaking a complete description of water and nutrient inputs from land-based sources into the Arctic Ocean, based on 15 years of data on precipitation, flow and material fluxes. Another study of the delivery of materials from major watersheds to the ocean is being done by the **University of Washington.** In this "test of concept" grant, a model based on the Amazon watershed is being tested with data on flow and carbon delivery in East and Southeast Asia. This may allow scientists to better predict biogeochemical processes in large watersheds based on data gathered throughout the world.



APPLICATIONS OF RESULTS AND FUTURE DIRECTIONS FOR RESEARCH

The analyses of ecological and socioeconomic factors that are the cornerstone of the integrated watershed studies supported by this program are producing planning and decision support tools based on scenarios of demographic and economic changes expected in various watersheds. These results will be of use to regional and local environmental agencies charged with planning for future environmental protection needs, and are particularly relevant to watershed management programs to be sponsored under the new Vice Presidential Clean Water Initiative. It is already being found that in many cases such assessment tools developed in particular watersheds are transferrable to other watersheds with similar ecological and physical characteristics. In 1998, the water and watersheds program is continuing emphasis on the multidisciplinary approach, based on the theme that the best watershed science is accomplished when researchers take into account the human dimensions of environmental problems and solutions.



STAR Research Projects Described in this Report

1995 EPA Funding

University of Maryland
Integrated Ecological Economic Modeling and Valuation of Watersheds

Marine Biological Lab (MA)
Tracing the Fate of Nitrogen Inputs from Watersheds to Estuaries

Stanford University (CA)
Diffusion Rate Limitations in Heterogeneous Porous Media:Model Structure, Scale and Ecologic Characterization

Ohio State University
Integrated Planning, Forecasting, and Watershed Level Ecological Risk Assessment Techniques: A Test in the Eastern Cornbelt Plains Ecoregion of Ohio

U. California-Irvine
Baylor College of Medicine (TX)
Norwalk Virus-like Particles (VLPs) for Studying Natural Groundwater Disinfection

Cornell University (NY)
The Role of Long-lived Zooplankton Diapausing Eggs: Response and Recovery of Impacted Lakes

University of Virginia
The Role of Colloidal Particles in the Transport of Chemicals Through an Agricultural Watershed

Oregon State University
University of Oregon
Geomorphic, Hydrologic and Ecological Connectively in Columbia River Watersheds: Implications for Endangered Salmonids

University of South Carolina
Resistance of Communities to Chronic Haloaromatic Contamination by Biogenic and Anthropogenic Sources

University of Georgia
Influences of Watershed Land Use on Stream Ecosystem Structure and Function

Princeton University (NJ)
The Role of HG(II) Reduction and Chemical Speciation in Controlling the Concentration of Mercury and its Methylation in Natural Waters

University of Minnesota
Formation and Propagation of Large-Scale Sediment Waves in Periodically Disturbed ountain Watersheds

U. California-Davis
Modeling Temporal Rainfall Via a Fractal Geometric Approach

University of Arizona
A Comparative Institutional Analysis of Conjunctive Management Practices Among Three Southwestern States

U. North Carolina-Chapel Hill
Detecting Fecal Contamination and its Sources in Water and Watersheds

University of Louisville (KY)
An Ecoregion-Specific Comparison of Stream Community Responses to Nutrient Gradients Using Both Survey

Utah State University
Scaling Up Spatially Distributed Hydrologic Models of Arid Watershed

U. Illinois-Urbana
Traveling Wave Behavior During SubsurfaceTransport of Biologically Reactive Contaminants: Implications for in situ Bioremediation

Murray State University (KY)
A Comparison of Agriculture vs. Forested Basins: Carbon and Nutrient Cycling within the Hyporheic Ecotone of Streams

SUNY-Albany (NY)
In situ Assessment of the Transport and Microbial Consumption of Oxygen in Groundwater

Houston Advanced Research Center (TX) Water and Sustainable Development in the Binational Lower Rio Grande/Bravo Basin

1995 NSF Funding

U. Wisconsin-Madison
Insstitute of Ecosystem Studies (NY) Alternative States of Lake Ecosystems: Control by Phosphorus, Humics, and the Food Web

Coastal Carolina University (SC)
Baruch Marine Laboratory (SC)
Oyster Reefs as Structural and Functional Components of Tidal Creeks: an Ongoing Ecosystem Experiment

Kansas State University
Development of Geomorphological Artificial Neural Networks (GANNs) for Modeling Watershed Runoff

University of Kansas
Wichita State University Metal Binding and Aggregation of Fulvic Acids

Marine Biological Laboratory (MA)
University of New Hampshire Contemporary Water and Constituent Balances for the Pan-Arctic Drainage Sysstem: Continent to Coastal Ocean Fluxes

University of Washington
Towards a Model of the Biogeochemistry of Large-Scale River Basins: An Application to the Pacific Rim

University of Southern Mississippi
Variability of Dissolved Trace Elements in Rivers and Streams: Seasonal Redox Effects

University of Arizona
Water Market Design

U. Nebraska-Lincoln
Late Pleistocene to Modern Landscape Evolution and Climatic Change, Loire and Arroux Rivers, Burgundy Region of France

1996 EPA Funding

University of California, Davis
An Integrated Approach to Assessing Water Management Options in a Major Watershed: Extending a Hydrodynamic-Water Quality Model to Include Biological and Politico-Economic Components

University of North Carolina
University of Maryland Development and Application of Spectroscopic Probes for Measurement of Microbial Activity in Aquatic Ecosystems

Pennsylvania State University
Large Scale Disturbances and Small Scale Responses

University of Michigan
Carbon Exchange Dynamics in a Temperate Forested Watershed (Northern Michigan): A Laboratory and Field Multidisciplinary Study

University of Minnesota
Integrating Modeling and Management of Agriculturally-Impacted Watersheds, Issues of Spatial and Temporal Scale

University of Washington
Urban Stream Rehabilitation in the Pacific Northwest: Physical, Biological, and Social Considerations

University of Nevada-Reno
Desert Research Institute
Geochemical, Biological and Economic Effects of Arsenic and Other Oxyanions on a Mining Impacted Watershed

EPA

University of North Carolina
Effectiveness of Regulatory Incentives for Sediment Pollution Prevention: Evaluation Through Policy Analysis and Biomonitoring

University of Illinois
Watershed Protection in Agricultural Environments: Integrated Social, Geomorphological, and Ecological Research toSupport Ecosystem-based Stream Management

Oregon State University
Iowa State University
University of Minnesota Modeling Effects of Alternative Landscape Design and Management on Water Quality and Biodiversity in Midwest Agricultural Watersheds

University of California-Los Angeles Integrated Urban Watershed Analysis: The Los Angeles Basin and Coastal Environment

1996 NSF Funding

Illinois State Water Survey
Strategic Renewal of Large Floodplain Rivers

Academy of Natural Sciences, Philadelphia (PA)
Streamside Reforestration: an Analysis of Ecological Benefits and Societal Perceptions

University of Hawaii
East West Center (HI)
Influence of Forest Fragmentation on Watershed Functions in Northern Vietnam

1997 EPA Funding

University of Georgia
Community Values and the Long-Term Ecological Integrity of Rapidly Urbanizing Watersheds

Virginia Polytechnic Institute and State University (VA) Landscapes and Waterscapes: An Integrating Framework for Urbanizing Watersheds

U. California - Davis
An Integrated Watershed Approach to Evaluate and Model Ecosystem Effects of Erosion and Pollutant Transport in Urbanized Subalpine Landscapes

University of Wisconsin
An Integrated Ecological and Socio-Economic Approach to Evaluating and Reducing Agricultural Impacts on Upper Mississippi River Watersheds

University of Maine
Linking Watershed-Scale Indicators of Changes in Atmospheric Deposition to Regional Response Patterns

Oregon State University
A Study of Effects of Natural and Anthropogenic Processes on Tillamook Bay and its Watershed: An Integrated Process Study and Land-Use Perspective

University of Oklahoma
Ecological Risks, Stakeholder Values and River Basins: Testing Management Alternatives for the Illinois River

Marquette University (WI)
Risk Based Urban Watershed Management - Integration of Water Quality and Flood Control Objectives

Institute of Ecosystem Studies (NY)
Impact of Social Systems on Ecology and Hydrology in Urban-Rural Watersheds: Integration for Restoration

1997 NSF Funding

Yale University (CT)
Connecting Ecological and Social Systems: Watershed Research Relating Ecosystem Structure and Function to Human Values and Socioeconomic Behaviors

Marine Biological Laboratory (MA)
Social and Ecological Transferability of Integrated Ecological Assessment Models

Marine Biological Laboratory (MA)
Integrated, Ecological-Economic Modeling of Watersheds and Estuaries at Multiple Scales

Pennsylvania State University
Comprehensive Watershed Management: A Spatial Water Quality Assessment System (SWQAS)

Cornell University (NY)
Development and Implementation of Decision Support Systems for Predicting Economic and Ecological Impacts of Alternative Land and Water Management Policies in Urbanizing Regions

Further information is available from the following Internet Websites:

EPA/NCERQA: http://www.epa.gov/ncerqa
NSF, Environmental Research Opportunities: http://www.nsf.gov/geo/egch/envresop.htm
NSF, 1995 Water and Watersheds awards: http://www.nsf.gov/geo/egch/wws95awd.htm
NSF, 1996 Water and Watersheds awards: http://www.nsf.gov/geo/egch/wws96awd.htm

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