March 15, 2007

The U.S. Geological Survey
Toxic Substances Hydrology Program
Five-Year Plan, 2007-2011

U.S. Department of the Interior
U.S. Geological Survey

Toxic Substances Hydrology Program
Five-Year Plan Writing Team

Arthur L. Baehr
Research Scientist
New Jersey Water Science Center

Herbert T. Buxton
Coordinator
Toxic Substances Hydrology Program

Isabelle M. Cozzarelli
Research Scientist
National Research Program

James F. Fairchild
Research Scientist
Columbia Environmental Research Center

John B. French
Research Scientist
Patuxent Wildlife Research Center

Christopher C. Fuller
Research Scientist
National Research Program

Michael J. Focazio
Assistant Coordinator
Toxic Substances Hydrology Program

Sarah Gerould
Coordinator
Contaminant Biology Program

Martin B. Goldhaber
Research Scientist
Mineral Resources Program

Robert P. Koeppen
Office of the Director
Western Region

David P. Krabbenhoft
Research Scientist
Wisconsin Water Science Center

Denis R. Leblanc
Research Scientist
Massachusetts Water Science Center

James M. McNeal
Office of the Director
Eastern Region (Geology Liaison)

Donna N. Myers
Coordinator
NAWQA Program

Brenda S. Pierce
Coordinator
Energy Resources Program

Allen M. Shapiro
Research Scientist
National Research Program

Toxic Substances Hydrology Program
Projects and Project Team Leaders

Subsurface Crude Oil Contamination
Geoffrey N. Delin
MN Water Science Center
Mounds View, MN

William N. Herkelrath,
National Research Program
Menlo Park, CA

Oxygenated Fuel Contamination
Francis H. Chapelle
SC Water Science Center
Columbia, SC

James E. Landmeyer
SC Water Science Center
Columbia, SC

Contamination Associated with Petroleum Production
Yousif K. Kharaka
National Research Program
Menlo Park, CA

Marvin M. Abbott
OK Water Science Center
Oklahoma City, OK

Mixed (Radionuclide and organic) Waste Disposal in Arid Environments
Brian J. Andraski
NV Water Science Center
Carson City, NV

David A. Stonestrom
National Research Program
Menlo Park, CA

Chlorinated Solvents in Fractured Rock Aquifers
Daniel J. Goode
PA Water Science Center
Exton, PA

Claire Tiedeman
National Research Program
Menlo Park, CA

Subsurface Contaminant Plume Research (Treated Wastewater)
Denis R. Leblanc
MA Water Science Center
Northborough, MA

Subsurface Contamination from Landfill Leachate
Isabelle M. Cozzarelli
National Research Program
Reston, VA

Jason R. Masoner
OK Water Science Center
Oklahoma City, OK

Watershed Contamination from Hard-Rock Mining
Briant A. Kimball
UT Water Science Center
West valley City, UT

Christopher C. Fuller
National Research Program
Menlo Park, CA

Chemicals of Emerging Environmental Concern
Dana W. Kolpin
IA Water Science Center
Iowa city, IA

Mercury in Aquatic Ecosystems
David P. Krabbenhoft
WI Water Science Center
Middleton, WI

Mark C. Marvin-DiPasquale
National Research Program
Menlo Park, CA

Pesticide Contamination in Hydrologic Environments
Kathryn M. Kuivila,
CA Water Science Center
Sacramento, CA

San Francisco Bay: Sensitive Aquatic Ecosystem
Cynthia L. Brown
National Research Program
Menlo Park, CA

Amphibian Research
William A. Battaglin
CO Water Science Center
Denver, CO

Foreword

The U.S. Geological Survey (USGS) has 28 programs which support bureau science activities. USGS Five-year Program Plans describe the science goals and priorities of each program. These Plans serve as a guide for USGS managers and scientists as well as external partners regarding the mission, goals and aspirations for the program during the five-year planning period.

The Five-year Plan of the Toxic Substances Hydrology (TOXICS) Program was developed through a planning and information gathering process that combined participation from across the scientific disciplines and organizational entities of USGS, and input from other federal agencies that use the information that we provide. A USGS writing team (identified at the beginning of this report) comprising selected leaders of science programs and regions participated in preparation of this plan. The composition of the writing team was intended to promote opportunities for increased collaboration within USGS and assure that needs of other USGS activities that the TOXICS Program supports are met. The programs represented on the writing team include the: National Water Quality Assessment (NAWQA), Contaminant Biology, Mineral Resources, and Energy Resources Programs. It also included research scientists with a range of expertise that covers the scope of TOXICS Program research activities.

The Five-Year Program Plan was compiled focusing primarily on overall Program priorities and plans. Information was gathered from multiple conference calls for each major research project. Separate calls focused on internal coordination and integrated-science planning and interaction and feedback from external stakeholder agencies. Each project within the Program addresses a specific environmental contamination issue. The projects develop a five-year project plan, which guides the research on that issue, and provides a means to communicate with the specific stakeholder constituency for that issue. The topical conference calls were organized and lead by the Project team leaders (also identified at the beginning of this report) with participation of the writing team and other scientists on the project team. An external review panel comprising representatives of stakeholder agencies participated in the topical conference calls, and reviewed and provided comments on the Program Five-year Plan, which were included in this final document.

Sources of information used in the preparation of this document included the current Program Five-Year Plan (2002-2006), the 2006 Annual Budget Justification, the review conducted by the National Academy of Sciences (1996), the TOXICS Program website, the Program bibliography, and individual project five-year plans.

Contents

I. Executive Summary

The U.S. Geological Survey (USGS) Toxic Substances Hydrology (TOXICS) Program was initiated in 1982. The Program provides reliable and objective scientific information and tools that explain the occurrence, behavior, and effects of toxic substances in the Nation's hydrologic environments. The information and tools are used by resource managers, regulators, industry, and the public to help avoid exposure to toxic substances, to mitigate environmental deterioration from contaminants, to enable cost-effective cleanup, to establish efficient waste-disposal strategies, and to reduce future risk of contamination. The Program is acknowledged for a wide range of contributions to the state of the science of environmental contamination (http://toxics.usgs.gov/highlights/), including developing natural- and enhanced natural-attenuation remediation alternatives, identifying new environmental contaminants, characterizing the processes that affect mercury methylation and bioaccumulation, managing and remediating contaminated fractured rock aquifers, approaches to restore watersheds affected by hard-rock mining, and characterizing pesticide transport and fate in common use settings across the Nation. A searchable bibliography of Program publications (http://toxics.usgs.gov/bib/) includes 1,064 references for the period, 2002-2006.

The Program has 2 major long-term (greater than 5-years) goals. Each goal has a series of objectives that are addressed through issue-based project activities. These goals and the associated objectives/projects for the 2007-2011 planning period are described as follows.

Goal 1 is to develop improved capabilities to characterize, manage and remediate subsurface contamination at local releases, such as chemical spills, leaking storage tanks, industrial discharges and municipal landfills that affect aquifers and local receiving waters. This goal is implemented through a series of field and laboratory projects that address:

1. Hydrocarbons, fuel oxygenates, biofuels, and petroleum-related contamination,
2. Mixed (radionuclide and conventional) waste disposal and contamination in arid environments,
3. Contamination in fractured-rock aquifers, and
4. Contaminant plumes with complex chemical mixtures

Goal 2 is to develop improved knowledge of the factors that control transport, fate and effects of contamination from nonpoint and distributed point sources as they affect watersheds and aquatic ecosystems. This goal is implemented through a series of National, regional, and watershed scale projects that address:

1. Watershed contamination from hard-rock mining,
2. Chemicals of emerging environmental concern (emerging contaminants),
3. Mercury in aquatic ecosystems,
4. Pesticide contamination in hydrologic environments,
5. Human stresses on sensitive aquatic ecosystems, and
6. Hydrologic and contaminant effects on amphibians

Future science directions and research priorities for the TOXICS Program during 2007-11 include: natural attenuation; contamination in fractured-rock aquifers; model development; remediation performance evaluation; science-based approaches to support adaptive management; mercury bioaccumulation; identifying emerging environmental contamination issues; understanding the processes controlling contaminant sources, transport, storage, and

transformation in the environment; developing methods for environmental measurements; and impacts on environmental health.

The most significant opportunities to participate with TOXICS Program research planning during the 2007-11 planning period are in the following research areas.

Subsurface Pont-Source Research - A planning workshop will be undertaken early in the planning period to evaluate future science directions, priority research questions, effective approaches to address these questions, and the field research sites needed to facilitate that research. If appropriate, solicitation will be made for nominations for the field research site(s) best suited to supported new areas of research.

Energy-Environment Research - Energy-environment research being conducted jointly with the Energy Resources Program will be winding down during 2008 and 2009. Priorities for the next focus of TOXICS Program energy-environment research will be discussed during that timeframe.

Pesticides Research - The pesticides research project establishes priorities for developing new analytical methods and conducting environmental assessment in typical pesticide-use settings that provide initial data on the occurrence, transport and fate of new pesticides in the environment. Although a new Five-Year Project Workplan was developed for this project as part of the Program Five-Year Plan development process, input is solicited periodically for priorities for chemicals and pesticide-use settings to be investigated.

Emerging Contaminants Research - Although a new Five-Year Project Workplan was developed for this project as part of the Program Five-Year Plan development process, priorities for research are being revised continually as new contamination issues emerge. Priority areas for research include Concentrated Animal Feeding operations (CAFOs), pathogens, antibiotic resistance, and endocrine disruption.

The TOXICS Program also identifies significant opportunities for development of new program for regional and local stakeholders. The Program invests significant efforts in developing new capabilities and advising Water Science Centers and others on how to implement new areas of research for local and regional stakeholders across the country, especially in pesticides, emerging contaminants, and subsurface point-source contamination research.

II. Introduction

Program Overview

The U.S. Geological Survey (USGS) Toxic Substances Hydrology (TOXICS) Program was initiated in 1982. The Program provides reliable and objective scientific information and tools that explain the occurrence, behavior, and effects of toxic substances in the Nation's hydrologic environments. The information and tools are used by resource managers, regulators, industry, and the public to help avoid exposure to toxic substances, to mitigate environmental deterioration from contaminants, to enable cost-effective cleanup, to establish efficient waste-disposal strategies, and to reduce future risk of contamination. Contamination of surface water, ground water, soil, sediment, and the atmosphere by toxic substances is among the most significant issues facing the Nation. Contaminants such as excessive nutrients, organic chemicals, metals, and pathogens enter the environment, often inadvertently, via industrial, agricultural, mining, or other human activities. The extent of their migration, persistence, and potential impact on human and ecological health are difficult to ascertain. Remediation and restoration strategies are complex and extremely costly. Effective remediation strategies rely on knowledge of the behavior of contaminants in the environment and the ability to measure the relative effectiveness of alternative approaches.

The TOXICS Program's strengths are its (1) long-term field-based approach, (2) interdisciplinary research teams, (3) ability to address contamination problems with a wide range of geographic scales and geologic terrain, and (4) ability to bring to bear fundamental scientific knowledge of the natural environmental response to contamination on the design of natural-attenuation-based clean-up strategies. Maintenance of long-term field research laboratories, data collection on extensive regional and national networks, and use of consistent and reliable methods, make this contribution particularly unique.

Recent Program Accomplishments

The TOXICS Program is acknowledged for a wide range of contributions to the state of the science of environmental contamination. A searchable bibliography of Program publications is maintained on the Internet [http://toxics.usgs.gov/bib/] and has over 4,500 publications, including over 2,900 on-line publications, and over 1,700 papers in peer-reviewed journals (excludes abstracts). The bibliography includes 1,064 references for TOXICS Program reports published during the last planning period, 2002-2006. The following is a list of selected accomplishments during the period 2002-2006. Additional information on these and other accomplishments of the TOXICS Program is available on the Internet at: http://toxics.usgs.gov/highlights/.

- **Using Natural Attenuation as a Cost-Effective Remediation Technology** – The Program is acknowledged for a long-standing record of contributions in this area. Recent contributions have focused on approaches for decision making, design and monitoring of natural and enhanced remediation alternatives, including developing the Natural Attenuation Software, which provides a methodology for designing monitoring strategies and estimating timeframes required for natural attenuation; a simple method for calculating growth rates of petroleum hydrocarbon plumes; and a practical methodology to evaluate the feasibility and long-term

sustainability of natural attenuation at chlorinated solvents sites. Recent contributions have included identifying new biodegradation pathways for well known contaminants and degradation pathways for new contaminants like the disinfection byproduct NDMA (N-nitrosodimethylamine). http://toxics.usgs.gov/topics/attenuation.html

- **Identifying New Environmental Contaminants** – Since 1999, Program results have enabled measurement of a wide range of pharmaceuticals and other emerging wastewater contaminants in the environment. The information has been provided on the environmental transport, persistence and potential health effects with special emphasis on endocrine disruption and antibiotic resistance, thus enabling timely decisions by industry, regulators, and researchers. http://toxics.usgs.gov/regional/emc/index.html

- **Contaminant Remediation** – Knowledge of contaminant behavior in the environment often facilitates discovery of new and innovative treatment technologies. Identification of the environmental conditions under which MTBE degrades naturally in the environment resulted in the demonstration of how conditions in subsurface MTBE plumes can be enhanced to promote and increase biodegradation using oxygen reactive compounds. Two bioreactor treatment systems were patented -- one designed to remove dissolved nitrate from water supplies, and a second to remove gaseous methyl bromide from the exhaust that results from the fumigation of shipping containers. http://toxics.usgs.gov/highlights/mtbe3.html http://toxics.usgs.gov/highlights/bioreactor_patents.html

- **Mercury in Aquatic Ecosystems** – Research on specific ecosystems, including the Everglades and the Experimental Lakes Area in Canada, have documented the factors that affect mercury methylation and why some ecosystems are more susceptible to bioaccumulation. Data collected on mercury in fish have been integrated in a National Model that enables improved analysis of threats from fish consumption by both humans and wildlife. A National dataset on mercury species and potential causal factors have been developed to enable the development of a National Mercury Sensitivity map, which provides a context for the likelihood for mercury contamination levels of concern. http://toxics.usgs.gov/investigations/mercury.html

- **Contaminant Plumes in Fractured Rock Aquifers** – Program scientists have developed field and modeling approaches to characterize contaminant plumes in fractured rock aquifers. These contributions are acknowledged as contributing to improved ability to monitor, manage and remediate plumes that in recent years were often considered unmanageable because of scientific uncertainties. http://toxics.usgs.gov/investigations/fracrock_aquifers.html

- **A Watershed Approach to Contamination from Hard Rock Mining –** USGS, working with Federal land-management agencies has developed a watershed approach to contamination from hard rock mining that enables managers to make informed decisions regarding where to invest limited resources in restoration, what are realistic restoration goals, and how to monitor success of restoration efforts. http://toxics.usgs.gov/investigations/hardrock_mining.html

- **Agricultural Chemical Contamination in Common Pesticide-Use Settings** – The Program has developed methods to measure new pesticides and their environmental degradation byproducts (degradates) in environmental samples and has gathered information on the

occurrence, transport and potential health effects of numerous compounds. These data have been used to evaluate both human and environmental health significance, including the listing of several compounds on the USEPA drinking water Contaminant Candidate List (CCL) and to aid in registration and recertification of common use pesticides. http://toxics.usgs.gov/topics/agchemicals.html

- **Developing Field methods and Technologies** – Program scientists have developed a wide range of field and laboratory methods and technologies ranging from laboratory analytical methods to measure a wide range of chemicals in environmental samples, to field methods for making measurements of environmental properties that control the transport, fate and effects of contaminants. http://toxics.usgs.gov/topics/measurements.html

- **Acknowledgement of Program Research Scientists** – The scientific contributions of the TOXICS Program are made by an outstanding group of research scientists, who are acknowledged internationally for their expertise and accomplishment. During 2004 and 2005, Program scientists received the following awards:

  2005

  - The International Association of Hydrogeologists (IAH), President's Award, in recognition for a distinguished research career and for a decade of service as the executive editor of the journal *Hydrogeology*, was awarded to Clifford I. Voss.
  - The National Ground Water Association, M. King Hubbert Award, presented annually "to a person who has made a major science or engineering contribution to the ground water industry through research, technical papers, teaching, and practical applications", was awarded to Mary C. Hill.
  - Four scientists were elected as Fellows of the Geological Society of America, Barbara A. Bekins, Frank H. Chapelle, Isabelle M. Cozzarelli, and Paul A. Hsieh.
  - The Geological Society of America (GSA), Subaru Outstanding Woman in Science Award, recognizing a woman that has impacted the field of geosciences in a major way based on her Ph.D. research, was awarded to Michelle A. Walvoord.

  2004

  - The National Ground Water Association (NGWA), John Hem Award in recognition of contributions to the understanding of the hydraulics of water table aquifers and their interaction with surface water, was awarded to Allen F. Moench.
  - The Geological Society of America, Birdsall-Dreiss Distinguished Lecturer, recognizing expertise in an area of science related to hydrogeology, including the influence of hydrogeology on 25 years of natural attenuation at a crude oil spill site, was awarded to Barbara A. Bekins.
  - The National Ground Water Association, Henry Darcy Distinguished Lecturer in Ground Water Sciences, was named Allen M. Shapiro.
  - The 2004 Presidential Rank Award for a Meritorious Senior Professional, awarded each year by the President to recognize and celebrate a small group high-performing senior career employees, was awarded to Samuel N. Luoma.

- New Mexico Institute of Mining and Technology, Langmuir Award for excellence in research for an outstanding scientific research paper by any student or graduate of New Mexico Tech, was awareded to Michelle A. Walvoord.
- The National Association of Government Communicators, Gold Screen Award and a First Place 2004 Silver Telly Award was given to USGS for production of a 22-minute television program "Delta Revival --Restoring a California Ecosystem."
- Earth Tech's 2004 President's Award for Technical Excellence—Best Environmental Paper Presented at a Technical Conference (Gold Award) was awarded to Brian Andraski and his colleagues for their paper *Evapotranspiration cover for containment at U.S. Army Fort Carson landfill site*.
- Elected as Fellow of the American Geophysical Union, Ronald S. Oremland.
- The American Geophysical Union's Editors' Citation for Excellence in Refereeing was awarded to Paul A. Hsieh for his services to the Journal *Water Resources Research.*

More information on these and other awards and recognition of Program scientists is available on the Internet at: http://toxics.usgs.gov/topics/faq/awards.html

Future Science Directions

Future science directions and research priorities for the TOXICS Program during 2007-11 are described in the following section.

Natural Attenuation – Improving our knowledge of the natural contaminant attenuation pathways, emphasizing biodegradation and phytoremediation. Develop characterization and monitoring methods that quantify the long-term viability of natural cleanup alternatives and thus reduce uncertainty and build public confidence in the effectiveness of low-cost natural attenuation remediation alternatives as compared to more costly invasive or engineered alternatives.

Contamination in Fractured-Rock Aquifers – Providing understanding of the complexities of contaminant behavior in fractured rock, particularly the chemical and microbiological processes that control contaminant transport and fate, the influence of the presence of dense nonaqueous-phase liquids (DNAPLs) on contaminant transport, and simulation tools for flow and transport in varying types of fractured-rock aquifers.

Process Understanding – Characterize the physical, chemical and biological processes that control contaminant source loading, transport, storage, and transformation in the environment with special emphasis on the natural response of hydrologic systems to contamination.

Simulation and Statistical Modeling Tools – Developing models to explain the persistence, movement, and fate of contaminants within and across compartments in the hydrologic cycle, to design and evaluate management and remediation alternatives, including monitoring networks, best management practices, and new techniques for waste disposal and remediation, and to test the vulnerability of selected ecosystems or hydrologic environments to environmental contamination.

Remediation Performance – Evaluate the performance of engineered remediation alternatives. Knowledge of environmental processes and capabilities to measure contaminant levels and

process rates provide a unique capability to design and implement remediation performance assessment studies. Partnerships with other federal agencies that emphasize development and field testing of remediation technologies is essential.

Science-Based Approaches to Support Adaptive Management – Developing approaches and management tools that enable cost-efficient problem characterization and mitigation, both through management practices and through targeted cleanup activities.

Mercury Bioconcentration/Biomagnification – Develop improved scientific understanding of the processes affecting mercury cycling and bioaccumulation in aquatic ecosystems, the factors leading to high levels of mercury in consumable game fish in certain areas of the US, and implications for National and global source reductions.

Identifying Emerging Environmental Contamination Issues – Identify and assess new or understudied chemicals and microorganisms, and support analytical and sampling methods development, reconnaissance assessments, and investigation of ecological effects, through collaboration with other water quality and biology programs. Potential contaminants include household and industrial chemicals, pesticides, pharmaceuticals and pathogens.

Environmental Measurement – Developing methods for environmental measurement of a wide range of physical, chemical and biological properties that control the rates of transport and transformation processes, and measurement of contaminants and their byproducts in environmental samples from different media at levels low enough to explain their environmental processing.

Environmental Health – Develop improved methods for describing the pathways and effects of contaminants on organisms, and ecosystems, and the potential long-term implications for human and environmental health.

Partnerships

The TOXICS Program works in partnership with other Federal agencies to ensure that Program research plans and priorities will address their priority science needs, including other DOI bureaus, the U.S. Environmental Protection Agency (USEPA), the U.S. Department of Agriculture (USDA), the Departments of Defense and Energy (DOD and DOE), the Nuclear Regulatory Commission, and more recently, public health agencies, such as the Centers for Disease Control and Prevention (CDC), the Food and Drug Administration (FDA), and the National Institute for Environmental Health Sciences (NIEHS). As an objective science agency, USGS program information and methods often provide a basis for consensus in contentious issues and for achieving cost efficiencies by meeting the needs of numerous management and regulatory agencies.

Scientists from universities, other Federal agencies, and industry find significant opportunities for research through collaboration in TOXICS Program activities and at TOXICS Program research sites (see Appendix I and the Program Internet site http://toxics.usgs.gov/topics/faq/). The membership of the research teams of each project are listed on the Internet at: http://toxics.usgs.gov/investigations/. A complete list of TOXICS Program partners, collaborators, and beneficiaries also is available at: http://toxics.usgs.gov/topics/faq/partners.html.

The Program has developed strong collaborative relationships with several USGS Programs, which share goals related to environmental quality. As examples, the Energy Resources, Mineral Resources, Contaminant Biology and TOXICS Programs have developed two formal collaborative relationships in (1) research on environmental effects of mine drainage, and (2) research on the occurrence, methylation, bioconcentration/biomagnification, and effects of mercury. Both formal collaborations have discussion groups and an integrated web page that presents, in a coordinated manner, all USGS activities related to contamination from mine drainage: http://mine-drainage.usgs.gov/, and mercury contamination http://www.usgs.gov/mercury/. Programs, with which major collaborations have been established, are described here. Additional more specific collaborations with other programs, teams, or individual scientists are provided in Appendix I. One example is a collaboration with the Geographic Analysis and Monitoring (GAM) Program to develop a user interface for a National model of mercury in fish [http://emmma.usgs.gov/].

National Water Quality Assessment (NAWQA) Program – The NAWQA Program has an extensive network of hydrologic monitoring stations throughout the Nation. The TOXICS Program often conducts field research collaboratively at these field stations to develop new methods and capabilities and to test new hypotheses. New research methods developed by the TOXICS Program often are implemented in NAWQA activities.

Contaminant Biology Program (CBP) – The CBP [http://www.cerc.usgs.gov/contam/] investigates the effects and exposure of environmental contaminants to the Nation's living resources. As such, the CBP is a natural partner with the TOXICS Program with collaborations on numerous research issues, including contamination from hard-rock mining, endocrine disruption, development of new methods to measure contaminant exposure, and the effects of contamination on ecological health.

Energy Resources Program (ERP) – In providing information on energy resources, including the economic, technical, and environmental factors affecting energy resource occurrence, availability, and recoverability, the ERP [http://energy.usgs.gov/]also addresses issues related to environment and health related to energy production. Specific partnerships with ERP scientists continue successfully in the areas of produced water (water produced as a byproduct of oil and gas production), mercury contamination, and acid mine drainage.

Minerals Resources Program (MRP) – The MRP [http://minerals.usgs.gov/] provides scientific information for objective resource assessments and unbiased research results on mineral potential, production, consumption, and environmental effects. Collaborations with MRP scientists include: (1) extensive research on the adverse environmental effects of hard-rock mining, (2) investigations of mercury contamination from regional and global sources, and (3) development and application of improved non-intrusive geophysical techniques to characterize subsurface geologic features and contamination.

Wildlife: Terrestrial and Endangered Resources Program – The TOXICS Program is a formal participant in supporting the Amphibian Research and Monitoring Initiative lead by the Wildlife Program [http://biology.usgs.gov/wtrp/]. The TOXICS Program supports the hydrologic and environmental quality components of the Initiative. Hydrologists collaborate in each of the 7 regions and at the National level. TOXICS scientists work with biologists and herpetologists to provide information on the climatic, hydrologic and water quality factors that affect amphibian declines and deformities.

National Stream Quality Accounting Network (NASQAN) – TOXICS Program scientists have conducted innovative interpretations of NASQAN [http://water.usgs.gov/nasqan/] datasets, specifically in relation to applications to the role on nutrient delivery from the Mississippi River Basin and its relation to hypoxia in the northern Gulf of Mexico. New methods to measure contaminants in environmental samples have been tested at NASQAN monitoring sites. An example dataset is high frequency data on new herbicides in the Mississippi River Basin

Priority Ecosystems Studies – These activities provide a means for USGS Programs to collaborate to provide scientific information essential for management decision making in priority ecosystems facing critical issues related to encroachment of human development [http://access.usgs.gov/]. The TOXICS Program provides approximately $2.3 million annually to this program and is a major contributor to research being conducted in the Florida Everglades and in San Francisco Bay.

Geology Discipline – Formal scientific collaborations occur with scientists from across the Geology Discipline [http://geology.usgs.gov/]. When these collaborations occur in areas that are outside of the program mission of a specific geology program, the TOXICS Program supports these scientists directly. Approximately $600,000 annually is dedicated to support this research.

Information and Technology Transfer

Information and technology transfer, both within the agency and to other agencies, industry and the public, is an important Program responsibility. The TOXICS Program provides information on emerging environmental issues, new and more efficient methods to make environmental measurements, the science that supports new management approaches, and new remediation techniques. This information is transferred to and used by environment and resource managers, industry, the public, and other USGS programs.

Program results are distributed at briefings for regulatory agencies and industry groups, at workshops, at national scientific meetings, in USGS reports and Fact Sheets, and in scientific journals and books. Outreach to stakeholders includes identification of appropriate technology transfer mechanisms.

The program complements other USGS programs that monitor and assess the quality of the Nation's waters by focusing rapidly on new issues, by identifying issues that warrant future attention, and by developing improved and needed methods. These programs (such as the National Water Quality Assessment (NAWQA) Program and National Stream Quality Accounting Network (NASQAN)) use the information and tools the TOXICS Program provides to improve their performance.

The TOXICS Program also identifies significant opportunities for development of new program for regional and local stakeholders. The Program invests significant efforts in developing new capabilities and advising Water Science Centers and others on how to implement new areas of research for local and regional stakeholders across the country, especially in pesticides, emerging contaminants, and subsurface point-source contamination research.

Performance

The TOXICS Program supports bureau and departmental performance measures through a specific subset of the bureau intermediate and end outcome performance measures related to the DOI serving-communities goal. In response to the Office of Management and Budget, Program Assessment Rating Tool (PART), the TOXICS Program supports a series of performance measures defined for Water Resources Research activities of the USGS. These include information on: the number of formal workshops or training provided to customers; the number of systematic analyses and investigations delivered; and percent of targeted contaminants for which laboratory analytical methods are developed to measure potential environmental occurrence and health significance. Information related to these measures is provided on the Internet:

Technical Transfer: http://toxics.usgs.gov/topics/faq/dissemination.html

Analyses/Investigations: http://toxics.usgs.gov/investigations/

Analytical Methods: http://toxics.usgs.gov/bib/bib-lab.html

III. Program Mission and Long-term Goals

Program Mission - Provide unbiased and reliable scientific information and tools that explain the occurrence, behavior, and effects of toxic substances in the Nation's hydrologic environments.

Program Mission

The TOXICS Program provides unbiased and reliable scientific information and tools that explain the occurrence, behavior, and effects of toxic substances in the Nation's hydrologic environments. These results support sound decision making by resource managers, regulators, industry, and the public. The program supports the strategic missions of the Department of the Interior (DOI, 2003) and the U.S. Geological Survey (USGS, 2002). The Program supports the USGS mission to serve the Nation by providing reliable scientific information to: describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy and mineral resources; and enhance and protect our quality of life. In turn, the Program supports the DOI Serving Communities strategic goal of advancing knowledge through scientific leadership and informing decisions through the application of science.

The contamination problems investigated by the TOXICS Program are widespread and pose significant risk to human health and the environment. Based on input from many agencies and organizations, the USGS identifies high priority problems for intensive, field-based research. These field studies are conducted at representative sites, watersheds, or areas that focus on subsurface point-source contamination or nonpoint-source contamination.

Long-term Program Goals:

1. *Subsurface, Point-source Contamination, and*
2. *Watershed- and Regional-scale Contamination,*

Program Long-term Goals

The long-term (greater than 5-years) goals of the program are:

Goal 1: Subsurface, Point-source Contamination – Develop improved understanding of, and improved capabilities to characterize, monitor and remediate, contamination at local releases, such as chemical spills, leaking storage tanks, industrial discharges and municipal landfills that affect aquifers and local receiving waters.

Goal 2: Watershed- and Regional-scale Contamination – Develop improved knowledge of the factors that control transport, fate and effects of contamination from nonpoint and distributed point sources as they affect watersheds and aquatic ecosystems at broad regional scales.

Subsurface, Point-source Contamination Research

Subsurface, point-source contamination is investigated through intensive field investigations of common types of subsurface contamination in a variety of hydrogeologic environments. Field research sites are established at representative sites contaminated with common types of environmental contamination and located in commonly occurring geohydrologic and geochemical settings.

An interdisciplinary team of project researchers identify and quantify the physical, chemical, and biological processes that control contaminant transport and fate at the research site. Through extensive characterization and field experimentation, each site provides field-laboratory conditions that enhance research opportunities. Results from the sites are generalized by field and laboratory experiments at other sites that describe the range of field conditions and the range of rates of the controlling processes. Knowledge, methods, and models produced at these representative sites improve the effectiveness and reduce the cost of characterization and remediation at similar sites across the Nation by improving the scientific basis for decision making. Chlorinated solvents, sewage effluent, landfill leachate, radionuclides, and petroleum hydrocarbons, including fuel oxygenates, are being investigated.

A unifying theme of this research is characterization of the natural response of hydrologic systems to contamination. This approach, combined with the long-term nature of the research, enables the TOXICS Program to excel in assessing the potential and limitations of natural-attenuation remediation alternatives and remediation-performance monitoring. The results are used by stakeholders to characterize contamination, to select and design remediation alternatives, and to evaluate performance of remediation and waste-disposal alternatives.

The TOXICS Program conducts the only organized research on subsurface contamination from point sources within the USGS and is regarded by those responsible for contaminated site cleanup as a unique provider of information and methods on issues such as contamination in fractured rock aquifers and long-term performance of monitored natural attenuation.

Watershed- and Regional-scale Contamination

Investigations address watershed-scale and regional-scale contamination problems typical of widespread land uses or human activities that may pose a threat to human and environmental health throughout large areas of the Nation. These investigations involve: determining to what extent widely used chemicals enter the environment (at what levels and in what mixtures); characterizing contaminant sources and source mechanisms; understanding the processes that control transport and fate of contaminants in the hydrologic cycle (including degradation byproducts); investigating the processes that transform contaminants into different and possibly more toxic forms; investigating the mechanisms by which nonpoint-source contamination affects aquatic ecosystems; and developing approaches and modeling tools for aiding management decision making.

Current investigations include contamination from agricultural chemicals, human wastewater, historic hard-rock mining, human activities in estuarine ecosystems, and atmospheric mercury emissions.

The results are useful for characterizing and managing contamination, for development of best management practices, for developing regulatory policies and standards, for registering the use

of new chemicals, for decisions on what chemicals to manufacture, and for development of chemical usage guidelines. The TOXICS Program watershed- and regional-scale investigations focus rapidly on new capabilities, new issues, emerging contaminants, and understanding the processes that affect whether an issue may be of widespread concern. As such, these investigations complement the NAWQA Program, the National Stream Quality Accounting Network and other USGS water-quality activities which monitor and assess the status and trends of the quality of the Nation's water resources and use TOXICS Program results for planning their future activities.

IV. Program Five-year Objectives

The Program objectives are presented and discussed in the following section. They are nested under the Program long-term goals. The projected funding for the Program and for each goal is provided in Table 1. The funding is based on FY 2006 funding and does not consider potential earmarks. Funding through the planning period (2007-11) is expected to remain approximately level.

Table 1. Estimated TOXICS Program funding by Program goal for the planning period (2007-11).

PROGRAM GOAL	FUNDING	PERCENT
Subsurface Point-source Contamination	5,300,000	40%
Watershed- and Regional-scale Contamination	7,900,000	60%
Total Program Funding	$13,200,000	100%

Goal 1: Subsurface, Point-source Contamination

The objectives under the subsurface point-source contamination goal are to develop improved understanding of, and improved capabilities to characterize, monitor and remediate, contamination at the following types of local releases:

1. Hydrocarbons, fuel oxygenates, biofuels, and petroleum-related contamination,
2. Mixed (radionuclide and organic) waste disposal and contamination in arid environments,
3. Contamination in fractured-rock aquifers, and
4. Contaminant plumes from wastes comprised of complex chemical mixtures.

These objectives and the specific activities planned to address them are described in the following sections.

A subsurface point-source contamination workshop will be convened early during the 2007-11 planning period to discuss future science directions, priority research questions, effective approaches to address these questions, and the field research sites needed to facilitate that research. The workshop will bring together researchers involved in current Program subsurface point-source contamination studies, other scientists with related expertise, and stakeholders. The resulting guidance document will guide activities and funding decisions for future research.

Hydrocarbons, Fuel Oxygenates, Biofuels, and Petroleum-Related Contamination

Hydrocarbon contamination occurs in association with petroleum development, transport, storage, and use. The large number of hydrocarbon contamination sites across the Nation requires systematic and science-based decision making related to management and cleanup. The introduction of fuel oxygenates, such as MTBE, to improve air quality have significantly exacerbated subsurface contamination problems from gasoline. Research will focus on addressing contamination associated with petroleum production, the limitations to natural clean-up options, and development and improvement of methods to design, monitor, and evaluate natural attenuation including bioremediation and phytoremediation. Current research on

hydrocarbons and petroleum-related contamination is being conducted at three field research sites: (1) a crude oil spill site near Bemidji Minnesota, (2) an oxy-fuel spill site in Laurel Bay South Carolina, and (3) a produced-water contaminated site near an area of petroleum development (the Osage-Skiatook Petroleum Environmental Research site, OSPER) in Oklahoma. Additional research is conducted at other field sites to generalize and transfer knowledge and in the laboratory. The research priorities at these sites are described in the following paragraphs. Additional information on research related to hydrocarbons and petroleum-related contamination is available on the Internet at: http://toxics.usgs.gov/investigations/petroleum_contamination.html

Crude Oil Contamination Research, Bemidji Minnesota – The research will focus on the Program's long-term research site at Bemidji MN. Remediation at this site from 1998–2004 has provided Bemidji researchers with an important opportunity to evaluate the impact and efficacy of a free-product crude-oil recovery strategy used at this well-characterized site. This free-product recovery strategy, similar to pump and treat, is commonly used throughout the world. Despite large public and private expenditures on development and implementation of aquifer remediation technology, very few well-documented field-scale case studies of remediation performance have been published.

Research will emphasize the role of the unsaturated-zone in the long-term transport and fate of subsurface contamination. Remediation of the unsaturated zone in the source area poses significant challenges. Residual contamination can form a long-term source of contamination that complicates and prolongs cleanup and threatens down gradient expansion of the plume. The research will quantify rates of biodegradation, dissolution, advection, and dispersion of crude oil and its derivatives in the unsaturated zone. A simple method for calculating growth rates of petroleum hydrocarbon plumes, which was developed at the site, will be evaluated by examining the expanding front of the Bemidji plume. In addition, the Bemidji plume will be compared to an oil spill in a nearby aquifer at Cass Lake, MN. The comparison of the two plumes, formed in aquifers of similar chemistry, but with different spill times, will provide information on the generality of the plume growth rate method and its applicability to other sites across the Nation.

Oxy-fuel Contamination Research, Laurel Bay South Carolina – Methyl tertiary-butyl ether (MTBE) is just one of a number of additives used as fuel oxygenates and just one of the hundreds of compounds found in gasoline. The widespread handling and use of gasoline for vehicles and other uses across this Nation have resulted in ubiquitous point sources from spills and leaking storage tanks. MTBE can comprise up to 15% by volume of gasoline and is highly soluble in water and more recalcitrant than the other common gasoline contaminants (benzene, toluene, ethyl-benzene and xylene, BTEX). As such, releases of gasoline containing MTBE to the subsurface are often characterized by contaminant plumes where MTBE has considerably higher concentrations and extends farther down gradient than either benzene or toluene, the most soluble aromatic hydrocarbons in gasoline (each about 1 - 2% of gasoline). As a result of this higher solubility and volume, plumes of MTBE contamination in some ground-water systems can often be over 1,000 feet long.

Past research by the TOXICS Program has included studies of regular (non-oxygenated) gasoline at a field research site at Galloway, New Jersey. Recent research has examined the natural attenuation and fate of MTBE from a leaking underground storage tank in Laurel Bay, SC. The

research has focused on plume scale analysis of the transport and fate of MTBE compared with the most mobile aromatic petroleum hydrocarbon (benzene); the capability of MTBE to degrade naturally in the subsurface; and the design and effectiveness of natural and engineered remediation alternatives. In light of the recent ban of MTBE usage (it will still be manufactured for use overseas) in the United States as part of the Energy Policy Act, ongoing research on MTBE will emphasize (1) evaluation of oxygen supplementation to point-sources of fuel-oxygenate contaminated ground waters via naturally occurring passive processes, (2) the role of plants on uptake of soluble fuel compounds, such as fuel-oxygenates, from the subsurface, including development of a solute-transport code to account for the uptake by plants of soluble fuel compounds from ground water and the vadose zone, and (3) the fate of alternative fuel oxygenates and biofuels (ethanol, butanol, etc) in ground water. Research at this site will be winding down during the planning period, as the MTBE concentrations have significantly decreased due to natural and engineered processes. Evaluation of the priorities and directions for research on MTBE, alternative fuel oxygenates, and biofuels will be addressed in the program planning workshop for subsurface point source contamination.

Environment-Energy Research: Contamination Associated with Petroleum Production, Skiatook Lake, Oklahoma – The 3.5 million oil and gas wells drilled in the U.S for exploration for and production of petroleum have caused local detrimental impacts to soils, surface water, ground water, and ecosystems in the 36 producing states. The impacts arose primarily from improper disposal of large volumes of water produced with oil and gas, from accidental hydrocarbon and produced-water releases, from abandoned oil wells, and ground-surface disturbances in the order of several acres per well. Prior to federal regulations in the 1970s, produced waters, which are highly saline and may contain toxic metals, organic and inorganic components, and naturally occurring radioactive materials, were commonly discharged into streams, creeks, and unlined evaporation ponds, causing salt scars and surface- and ground-water contamination. New environmental laws and improved technology and industry practices have reduced the most detrimental effects of petroleum activities. Some operators have taken steps to reverse damages resulting from prior petroleum operations. The historical releases and the ongoing improper disposal of some produced water have become important national issues that concern petroleum producers, land owners, and state and federal regulators.

The TOXICS Program and Energy Resources Program, along with their partners are conducting a multidisciplinary investigation to determine the fate and effects of produced water on the near-surface environment. Field studies are being conducted at the Osage Skiatook Petroleum Environmental Research (OSPER) sites located in Osage County near Skiatook Lake in the southeastern part of the Osage Indian Nation in northeastern Oklahoma. Results from this research will help provide information to environmental officials, land managers, petroleum companies, and land owners needed to assess human and ecosystem impacts and to develop risk-based corrective actions to clean up contamination from produced water. Additional data collection activities over the next two years will provide geochemical and hydrologic input to complete the study, including robust solute transport modeling for the OSPER A site; research will conclude during the 5-year planning period. Priorities for future research on the environmental effects of produced water will be discussed jointly with ERP scientists and others at the Program subsurface point-source planning workshop.

Mixed (Radionuclide and Organic) Waste Disposal and Contamination in Arid Environments

Mixed radioactive and organic wastes often are disposed by shallow subsurface burial in arid environments. Controlled and uncontrolled releases from disposal facilities have resulted in gas- and liquid-phase contaminant dispersal that has proven difficult to describe with existing theories and models. Such gaps in understanding cause concern regarding management of existing facilities and plans for future facilities. Inadequate knowledge of the behavior of these wastes has deadlocked national decisions about the disposition of low-level radioactive wastes. Delays in resolving long-term disposal options are costly due to the expense of interim storage and the risks of storage sites dispersed through populated regions.

Research will focus on quantifying the processes that affect movement of radionuclides, volatile organic chemicals, and other contaminants in arid environments and on developing broadly applicable methods to monitor and predict contaminant migration in the subsurface. This research is being conducted primarily at the Amargosa Desert Research Site near Beatty Nevada, which adjoins a disposal facility for low-level radioactive waste (1962–92) and hazardous chemical waste (1970–present).

Amargosa Desert Research Site (ADRS), Nevada – USGS began hydrologic studies of the thick (100 m) unsaturated-zone at the ADRS site in 1976 as part of the USGS Low-Level Radioactive Waste Program. After radioactive contaminants (tritium and carbon-14) were confirmed in the unsaturated zone beneath the site in 1995, contaminant research at ADRS was initiated formally as part of the TOXICS Program in 1997.

The main research goals during 2007-11 are to:

1. Characterize the factors and processes that control the fate and transport of mixed wastes in the unsaturated zone in arid environments, including accounting for complex stratigraphic layering, the heat and pressure generated by decaying waste residues, coupled transport with volatile-organic compounds, barometric pumping, and the role of desert plants their micro- and macro-symbionts and potential accumulation and attenuation of mixed-waste constituents and breakdown products. Natural and introduced tracers (mercury and sulfur hexafluoride) will be used to test hypotheses and develop models that reproduce actual field conditions. Other gas-phase radionuclides present at the ADRS are candidates for study, including iodine-129, krypton-85, and radon-222.
2. Define the interactions of mixed-waste contamination with the xeric-plant ecosystems that maintain the sensitive hydrologic balance in unsaturated zones beneath deserts. At mixed-waste sites, the risk to plants, which are often used for phytoremediation, is from a combination of radioactive and volatile organic contaminants in addition to drought, nutrient limitation, and other ambient environmental stressors. The behavior of radionuclides in the food chain is an important component of ecological risk modeling. Investigation of soil-root-leaf and soil-atmosphere-leaf pathways will improve understanding of radiocarbon transfers and provide for more accurate assessments of ecosystem risk.
3. Characterize the factors and processes that control the natural accumulation and environmental cycling of perchlorate and other oxyanions. Plant samples collected near the ADRS and at other remote locations show that naturally occurring perchlorate is widely

distributed across all four major deserts of the USA. Vertical profiles beneath xeric vegetation shows that perchlorate concentrations track those of atmospherically derived nitrate, chloride, and sulfate. Process-oriented investigations into the chemical, biological, and climatic controls on perchlorate formation, accumulation, and persistence will take advantage of archived unsaturated-zone samples, bulk-precipitation samples, and plant samples from the Amargosa Desert. The existing ADRS database and infrastructure provides a solid foundation upon which to base further investigations of naturally occurring perchlorate, nitrate, and other oxyanions of interest.

Thick unsaturated zones that separate xeric-shrub ecosystems at land surface from saturated ground water at depth are largely unexplored. Future research at the ADRS will require increased contributions from biologic and climatologic sciences, plus renewed contributions from geology, chemistry, and hydrology—contributions made possible by emerging modeling and measurement technologies. Additional information on research related to mixed (radionuclide and organic) waste disposal and contamination in arid environments is available on the Internet at: http://toxics.usgs.gov/sites/adrs_page.html

Contamination in Fractured-Rock Aquifers

Great uncertainty exists in determining the direction and rate of water and contaminant movement, and the ability of chemical and microbial reactions to mitigate contamination in fractured-rock aquifers. Remediation is delayed or stymied at many such sites by an inability to measure properties that control water and contaminant movement and a lack of knowledge of fundamental contaminant transport processes. Program research on contamination in fractured rock aquifers was initiated in the late 1980's at an uncontaminated site in Mirror Lake New Hampshire (the Hubbard Brook Experimental Forest) with fractured crystalline rock. The research at Mirror Lake here focused on developing methods to characterize the interconnectivity of fracture networks with respect to the way they transmit water. This research has now been extended to a contaminated fractured rock aquifer at the former Naval Air Warfare Center (NAWC) in West Trenton, NJ. Additional research and methods, including geophysical methods are being tested at other sites.

Solvent Contamination in Fractured Sedimentary Rock, NAWC, West Trenton New Jersey - The U.S. Navy tested jet engines at the NAWC site from 1951-1998. Releases of trichloroethylene (TCE) occurred on the 60-acre facility, resulting in contamination of ground water in the underlying dipping sedimentary rocks of the Newark Basin. Concentrations of TCE at the site as high as about 200 milligrams per liter have been detected in some bedrock wells, suggesting the possible presence of free-phase DNAPL. Cis-1, 2-dichloroethylene and vinyl chloride are also present in very high concentrations and likely have been produced by microbial degradation of TCE. Bedding-plane fractures and thin fissile and laminated mudstone units are the primary contaminant transport pathways. The hydrogeologic framework and extent of contamination have been well-characterized using data from about 70 bedrock wells. A ground-water extraction and treatment system operating fully since 1998 contains (hydraulically) the contaminants and prevents off-site migration. However, this has not significantly reduced contaminant concentrations, suggesting that a large amount of contaminant mass lies in the primary porosity of the low-permeability rock matrix.

During 2007-2011, research will address the following objectives: (1) understanding the physical, chemical, and biological processes affecting the transport and transformation of aqueous and non-aqueous phase chlorinated solvents and other contaminants in fractured rock aquifers, (2) evaluating processes of contaminant removal in fractured rocks, principally by natural and enhanced biodegradation and by ground-water extraction, and (3) determining what data are needed to design effective and efficient remediation strategies for fractured rock aquifers.

Contaminant transport issues to be investigated include geologic controls on transport, such as the effect of geologic structure on the degree of channeling within fractures and on the connectivity between permeable fractures; and contaminant migration between fractures and the rock matrix, such as the effects of rock heterogeneity, geochemical conditions, and contaminant concentrations on diffusion of contaminant mass into and out of the rock matrix. Transformation research focuses on microbially mediated processes and degradation rates; and the effect of biogeochemical conditions on microbial degradation. Remediation research will focus on quantifying natural attenuation processes; enhancing natural biodegradation; identifying which site characterization activities are most important for designing effective and efficient remediation strategies; and developing methods for accurately monitoring remediation effectiveness. Finally, synthesis will employ conceptual and numerical models to integrate results of the investigations on transport, transformation, and remediation of contaminants in fractured rock aquifers. The models will be used to understand controls on these processes, to estimate mass removal rates by different remediation strategies, and to translate uncertainty in transport processes and properties to uncertainty in model predictions.

Ground-water flow in Fractured Rock, Mirror Lake, New Hampshire – Although research has largely been discontinued at this uncontaminated site, an extensive monitoring network is still maintained. Intermittently, tracer and other field experiments have been and will be conducted at the site to take advantage of both the existing infrastructure and knowledge of the local aquifer and flow conditions. Additionally, research on the geologic controls on fracture patterns and interconnectivity will be continued.

Additional information on research related to contamination in fractured rock aquifers is available on the Internet at: http://toxics.usgs.gov/investigations/fracrock_aquifers.html

Contaminant Plumes with Complex Chemical Mixtures

Contaminant plumes with complex mixtures of organic and inorganic contaminants, such as landfill leachate and wastewater discharges, are difficult to characterize, manage, and remediate. Reactions among dissolved chemicals, reactions between dissolved chemicals and the aquifer material, and microbial reactions can significantly accelerate or retard contaminant movement and complicate natural and engineered remediation. Research will focus on understanding the geochemical conditions that control contaminant transport and methods to characterize process rates and the corresponding properties that control them. This research currently addresses two contamination types (treated wastewater disposal via infiltration lagoons and landfill leachate), and has two field research sites respectively (Cape Cod Research Site, MA and the Norman Municipal Landfill, OK). The Cape Cod Research Site also serves as a fundamental point-source field research site where controlled field tracer experiments are used to test specific hypotheses

about transport processes and contaminants of global concern that are not necessarily specific to the wastewater plume.

Subsurface Contamination by Treated Wastewater, Cape Cod, Massachusetts – TOXICS Program research on subsurface point source contamination was initiated in the early 1980's with adoption of the Cape Cod Field Research site. The Cape Cod site is near the wastewater-treatment facility at the Massachusetts Military Reservation (MMR). The site is characterized by a plume of treated sewage-derived wastewater that originates from the facility and extends more than 6 kilometers in a sand and gravel aquifer. Wastewater was disposed via infiltration beds from 1936 to 1995. The plume contains a complex mixture of toxic metals, phosphate, nitrate, detergents, organic chemicals, and microbes. Natural biodegradation of organic compounds in the plume has resulted in steep vertical biogeochemical gradients and distinct oxic, suboxic, and anoxic zones in the aquifer.

The research at Cape Cod has served the purposes of investigating (1) the fundamental factors that affect subsurface contaminant transport (such as physical, chemical, and biological heterogeneity), (2) the physical, chemical, and biological processes that control the fate of treated wastewater and similar complex mixtures of contaminants, and (3) field, laboratory, and modeling methods to characterize these factors and processes.

Research on the plume has documented how a complex mixture of phosphate, nitrate, metal ions, detergents, organic chemicals, and microbes is transported in the subsurface, and how reactions with the aquifer material have affected aquifer recovery since wastewater disposal at the site ended in 1995. More than 1,500 wells have been drilled and thousands of samples have been analyzed to characterize this plume and to investigate various processes, such as the movement of bacteria and viruses in the plume and the dispersion that is caused by the geologic structure of the aquifer.

Several well arrays have been constructed specifically for controlled field tracer experiments, in which water with specific chemical or biological tracers are tracked in the subsurface; the largest array has more than 12,000 sampling points. More than 75 experiments have been conducted in these well arrays, in which water containing tracers is injected and tracked as the tracers move in and are altered in the different subsurface geochemical environments. These experiments, which take advantage of the distinct biogeochemical zones in the plume, have examined many contaminants of global concern, such as nitrate, arsenic, pathogens, and estrogenic organic compounds.

Research at the site during 2007-11 will focus on the following five objectives:

1. Improving understanding of the natural restorative processes in contaminated aquifers,
2. Determining how physical, chemical, and microbiological heterogeneity affect the transport and attenuation of subsurface contaminants,
3. Characterizing the processes that affect contaminant plumes as they discharge to surface-water bodies,
4. Developing and testing new methods to monitor water quality and to characterize the heterogeneity of the subsurface, and
5. Generalizing results from the site to a wide range of contaminated sites and contaminants

of global concern across the Nation.

Additional information on sewage-derived wastewater-contaminated ground water and the Cape Cod research site is available on the Internet at: http://toxics.usgs.gov/sites/cape_cod_page.html

Contamination from Landfill Leachate, Norman Municipal Landfill, Oklahoma – The United States produced about 245 million tons of solid waste in 2005, about 54 percent of which is disposed of in landfills. Disposal of municipal solid waste in landfills was largely unregulated prior to the 1970s when most solid waste was deposited in unlined pits. Precipitation and ground water seeping through the waste produces leachate contaminated with the various organic and inorganic substances in the waste. Leachate seeping from landfills often contaminates local ground water forming a plume in the direction of groundwater flow that extends in some cases for many hundreds of meters. Many studies have shown leachate plumes emanating from old unlined landfills. Estimates for the number of closed landfills in the United States are as high as 100,000. Federal and state regulations passed in the 1980s and 1990s require that most landfills use liners and leachate collection systems to minimize the seepage to ground water. Although liners and leachate collection systems minimize leakage, they can fail and may not collect all the leachate that escapes from a landfill. The fate and transport of leachate in the environment, from both old and modern landfills, potentially is a serious environmental problem.

Research on landfill leachate is focused at the Norman Landfill Research Site, a closed municipal solid waste landfill, formerly operated by the city of Norman, Oklahoma. The research team has installed a large network of ground-water sampling devices and instruments to investigate the chemical, biological, and hydrologic processes in ground water and surface water affected by landfill leachate. Natural attenuation of organic contaminants in the leachate plume and the associated biogeochemical processes is a major emphasis of the research.

Three major hypotheses will be addressed over the next five years:

1. The leachate source changes composition over time as the landfill evolves through different redox stages.
2. Biogeochemical zones in the aquifer down gradient from the landfill evolve with implications for natural attenuation of contaminants in the leachate plume.
3. The availability of electron acceptors such as oxygen, nitrate, or sulfate and the associated influence on natural attenuation at mixing interfaces, such as those that exist at the plume boundaries including the interface with the receiving surface waters (slough and wetland), have a significant affect on plume migration and chemical composition.

Additional information on contamination from landfill leachate and the Norman OK research site is available on the Internet at: http://toxics.usgs.gov/sites/norman_page.html

Goal 2: Watershed-scale and Regional-Scale Contamination

The objectives under the watershed- and regional-scale contamination goal are to develop improved knowledge of the factors that control transport, fate and effects from the following types of nonpoint and distributed point-source contamination:

1. Watershed contamination from hard-rock mining,
2. Chemicals of emerging environmental concern (emerging contaminants)

3. Mercury in aquatic ecosystems,
4. Pesticide contamination in hydrologic environments,
5. Human stresses on sensitive aquatic ecosystem, and
6. Hydrologic and water-quality factors affecting amphibians.

These objectives and the specific activities planned to address them are described in the following sections.

Watershed Contamination from Hard-Rock Mining

Thousands of historical hard-rock mines exist across the Western United States. Drainage of metal-enriched acidic water from abandon mines, tailing piles, and flood plains that contain mine wastes often contaminate the surrounding watershed and its ecosystems. Weathering of exposed unmined mineral deposits also results in acid drainage and metal-enriched waters. Watersheds affected by hard-rock mining can have hundreds of abandoned mine sites with little information on their relative significance, making the traditional site-by-site cleanup approach grossly inefficient. Regulatory and land-management agencies charged with the stewardship of these areas require the best scientific information to guide decision making. To date, TOXICS research has consisted largely of investigations of processes occurring on cm to km scales over time scales of hours to days. Although, these studies have significantly advanced knowledge of processes at cm to km scales, these studies also identified the need to investigate processes over broader spatial and temporal scales within catchments and to integrate the knowledge to address the broader decision-making framework typically faced in actual contaminated catchments. Our research will improve information and tools that support decisions related to management, risk assessment, remediation planning, and mitigation of the anthropogenic effects of mine drainage on the surrounding catchments and ecosystems. The research will a) characterize hydrologic and biogeochemical processes that affect dispersal of metals and associated contaminants over a range of spatial and temporal scales and b) describe metal contaminant pathways to organisms through diet and exposure. Conducting research in direct conjunction with site management and restoration activities is essential to making the results relevant to management decision making.

The research will be conducted at three nested spatial scales to investigate processes that control the source, transport, and fate of hard-rock mine contaminants: the catchment or watershed scale, the stream scale nested within the catchment, and the interface scale nested principally within the stream scale, over temporal scales ranging from seconds to months and years. The goals of this research are provided for each spatial scale and for synthesis and application, respectively:
Catchment-Scale Research **–** Catchment-scale research will develop methods: to characterize subsurface pathways from source areas to streams; to identify distant sources of contaminants; and to reconstruct pre-mining conditions, combining new tools such as age dating and isotope methods with proven tools such as tracer-dilution, synoptic sampling, and reactive solute-transport modeling.

Stream-Scale Research – Stream-scale research will characterize ground-water/surface-water interactions and associated biogeochemical processes that control metal loading to streams, including contaminant sources, within the river corridor and near-stream ground water flow paths. It will develop better understanding of processes controlling colloid and precipitate

formation, improved characterization of the colloidal composition, molecular structure, and sorption properties. It will characterize processes controlling temporal variability in concentrations and loads of metal contaminants that respond to seasonal flow variations, transient runoff events, cycles of ground-water recharge and discharge from contaminated floodplains, and diel cycles of pH and temperature.

Interface-Scale Research – Interface-scale research will characterize the biogeochemical reactions occurring on molecular to cm-scales that affect transport and attenuation of metal contaminants to provide information for evaluating the long term fate of attenuated contaminants, the temporal variability of dissolved metal concentrations, and contaminant pathways to organisms and for refinement of reactive solute transport models. It will characterize biological pathways and ecosystem effects by advancing understanding of bioavailability, bioaccumulation, and toxicity of metal contaminants by utilizing results of biochemical process studies. It will improve definition of the routes of exposure to organisms and the effects of metal bioaccumulation.

Synthesis and Application to Management – Coordination of interdisciplinary process research and its application to actual management activities is essential to development of approaches and methods that effectively mitigate the impacts of hard rock mining contamination in the field. An important component of synthesis is addressing the specific questions faced by managers, including what were pre-mining conditions, what are the consequences of hydrologic modifications, and, are there other complicating factors that may limit biological recovery.

More information is available on research on contamination from hard rock mining on the Internet at: http://toxics.usgs.gov/investigations/hardrock_mining.html

Chemicals of Emerging Environmental Concern (Emerging Contaminants)

This research is documenting with increasing frequency that many chemical and microbial constituents that historically have not been considered potential environmental contaminants are present in the environment on a global scale. These emerging contaminants (ECs) include both chemicals and microbes of emerging environmental concern. They are commonly derived from municipal, agricultural, and industrial wastewater sources. The objectives of this rapidly evolving research are to: 1) develop the analytical tools required for detecting these chemicals, microorganisms and their traces in the environment, 2) document their occurrence, concentration, and chemical and biological composition in the environment across the United States, 3) characterize the signature of contaminant sources and their relative importance as pathways to the environment, 4) determine important processes and factors that affect their transport and fate, and 5) understand the interactions between chemical and microbiological components in mixtures and the potential deleterious effects of complex mixtures to aquatic and terrestrial ecosystems. The information provided by this project is important to policy and resource management decisions related to a wide range of ecological and human health issues and will be essential for keeping abreast of potential new environmental health threats before they cause harm.

The research issues to be addressed during 2007-11 are defined as a series of research questions with the hypotheses associated with each.

1. What ECs are being transported into the environment?
2. What are the primary sources of ECs to the environment and are there specific contaminant signatures associated with each (including Concentrated Animal Feeding Operations and industrial and residential wastewater sources)?
3. What are the important processes and factors affecting the transport and fate of ECs (including pathogens, antibiotic-resistant bacteria, or their genes)?
4. What is the relative effectiveness of various drinking water and wastewater treatment technologies in their ability to reduce concentrations of complex mixtures of ECs .
5. Are ECs having deleterious effects on human and ecosystem health?

More information on research on chemicals of emerging environmental concern is available on the Internet at: http://toxics.usgs.gov/regional/emc/index.html

Mercury in Aquatic Ecosystems

Mercury is one of the most scientifically challenging contamination threats to our Nation's aquatic resources and is a potential threat to humans and wildlife. Societal concern about mercury contamination of the environment has stemmed largely from the potential adverse health effects of consuming methylmercury contaminated fish, because human exposure to methylmercury is almost wholly due to fish consumption. Presently, 46 US states have issued fish consumption advisories. As a nation, these advisories account for 35% of the Nations total lake acres (or approximately 101,818 lakes); 24% of the Nation's total river miles (or approximately 846,310 river miles); 71% of the Nation's contiguous coastal waters including 92% of the Atlantic coast and 100% of the Gulf coast; and, 100% of the Great Lakes and their connecting waters. Nearly all (95-99%) of the mercury present in fish is methylmercury, a highly toxic form of mercury. Methylmercury readily crosses biological membranes, can accumulate to harmful concentrations in exposed organisms, and biomagnifies to high concentrations in aquatic food webs, posing a threat to humans and wildlife that eat affected fish. Methylmercury is the by product of natural microbial processes in the presence of man-related mercury accumulations. Were it not for the methylation process, concerns over potentially unsafe exposure levels from consuming contaminated fish would be exceedingly rare. However, because mercury methylation occurs to varying degrees in all aquatic ecosystems, and mercury is a globally dispersed contaminant, the potentially unsafe exposure levels can occur almost anywhere.

Much research is focused on those factors that control methylmercury production, including: mercury emissions and loading to ecosystems; factors leading to increased microbial methylation; land management and disturbances that can exacerbate methylation; and, natural ecological factors that make certain ecological settings more susceptible to methylmercury production. The US and other countries across the globe are considering or are presently enacting mercury emission regulations; however it is uncertain how effective these regulatory actions may be in the presence of ubiquitously contaminated soils and sediments.

The objectives of this research during 2007-11 are directed at helping to resolve these uncertainties. Specific research objectives include: (1) to provide an improved understanding of the relation between atmospheric mercury loading rate, or changes to loading rates, and bioaccumulation in aquatic biota; (2) to examine factors (biological, ecological and man-related)

controlling mercury methylation in aquatic ecosystems; (3) to provide scientific information relating spatial setting (proximity to emission sources, air chemistry, effects from other emitted contaminants) and mercury deposition; and, (4) to provide national scale assessments of relative mercury sensitivity (likelihood to yield methylmercury) among aquatic ecosystems across the US.

The relation between mercury loading rate and its effect on methylmercury in food webs has long been debated. In an effort to resolve this issue, controlled mercury-loading studies are underway in two locations, the Everglades and the Experimental Lakes Area (ELA) in northwestern Ontario. The goal of these two in situ loading studies is to provide quantitative assessments of the dose-response relation between a change in mercury load and observed changes in fish. The studies in the Everglades also include alterations to critical water chemistry parameters (most notably sulfate and dissolved organic carbon), which can both have profound influences on methylmercury production and are of concern currently because the Everglades Restoration program may have significant influence on these key methylation factors. While the mercury loading studies in the Everglades are restricted to emplaced environmental enclosures (mesocosms), the loading study at the ELA is a whole watershed loading experiment. This project, called the METAALICUS (Mercury Experiment to Assess Atmospheric Loadings in Canada and the US), is being conducted by an international team of experts, and is unique because it will provide a quantitative response to a change in mercury load (about a 5x increase over ambient) at meaningful scale. Currently, the study team is in its sixth year of loading, and is considering ceasing the loading component of the study. Once ceased, the METAALICUS project will become a mercury reduction project and is expected to run at least five years and yield important quantitative and temporal information on ecosystem responses to load reductions.

Mercury methylation is the convergence of an extremely complex set of processes, and after nearly two decades of study, researchers are still making fundamental discoveries that are constantly changing and improving our scientific understanding. Studies underway by this project focus largely on two major areas of investigation: (1) factors that affect microbial processes leading to methylmercury production; and (2) factors that affect the availability of inorganic mercury to microbes (also called bioavailability) and conversion to methylmercury. Studies are conducted in a wide array of ecosystem conditions (from marine to coastal estuaries to high-elevation lakes) to provide a national context for our scientific findings and support the national sensitivity map development (see below).

Because instrumentation that can reliable measure atmospheric mercury concentrations and speciation only have become available over the past 5 years, atmospheric mercury research remains in the development stages. Atmospheric mercury research conducted by this project seeks to identify the linkages between local, regional and global mercury emission sources, and observed loading (deposition) rates. To support this research, the project team has constructed a Mobile Atmospheric Mercury lab to facilitate rapid and easy deployment of the necessary instrumentation to support atmospheric source apportionment studies. To date, studies have been conducted in a wide array of settings, including: near suspected large natural sources (geothermal in Yellowstone National Park); both near and far from known emission sources; and coastal settings where significant effects from marine aerosols and oxidants can have profound impacts on atmospheric mercury speciation and deposition.

Providing a national context for the relative severity of mercury contamination of native food webs at the regional-to-national scale is a difficult, but important, goal of this project. At the present time, there are tens of thousands of active or pending mercury total maximum daily load (TMDL) analyses, which are extremely difficult to address at the state or federal level. In addition, many important decisions regarding the permitting and construction of present and future coal-fired utilities may hinge on the relative potential impacts of mercury emissions. Presently, decision makers are without a tool that can assist them and possibly minimize environmental impact of mercury emissions by considering the relative mercury sensitivity of nearby aquatic ecosystems. This project is developing such a tool, and will be publishing the first version of a national mercury sensitivity map early in the 2007-2011 planning period. Future efforts will seek to refine the map by including calibration and verification efforts, link it to other national data bases such as the USEPA national fish data base, and expand the utility of the map by collaborations with atmospheric and watershed model developers. More information on research on mercury in aquatic ecosystems is available in the Internet at: http://toxics.usgs.gov/investigations/mercury.html

Pesticide Contamination in Hydrologic Environments

New pesticides are continually being registered for use in a wide range of agricultural and other land-use settings. Understanding the long-term environmental persistence and effects of these new compounds is essential to responsible product registration and use. Environmentally safe use of effective pesticides is important to agriculture, public facilities (parks, roadways, and golf courses), and home maintenance (for protection of lawns, gardens, and structures). The overall goal of this research is to provide knowledge of the occurrence, fate, and effects of new and understudied pesticides, their degradates, and the inert ingredients and adjuvants used to prepare pesticide formulations for application. The knowledge gained from studying these compounds are used to support decisions related to pesticide registration, regulation, and use in agricultural and non-agricultural settings.

The objectives of this research are: (1) to provide information useful for evaluating the potential health and ecosystem effects of new and understudied pesticide applications, (2) to identify the geochemical and hydrogeologic processes that influence the concentrations of the target pesticides and related contaminants in the Nation's water resources, and (3) to prioritize new and understudied pesticides, potential degradates, and related chemicals that warrant investigation.

The research approach builds on a considerable understanding of the occurrence and fate of pesticides and degradates in the environment gained through two decades of research by the TOXICS Program. The planned research addresses multiple studies addressing a range of environmental pesticides contamination issues. Three factors are considered during the identification and design of studies undertaken by the project. These are (1) compound(s) of interest (because they are new or understudied), (2) the pesticide-use setting for the compound, and (3) the sensitive environments that may be affected by the use patterns of the compound(s). Individual studies then address the input, transport, degradation, and bioavailability of targeted compounds in specific pesticide-use settings.

Important components of these studies include:

- Responding rapidly to emerging pesticide contamination issues,

- Developing new analytical methods to measure specific chemicals of concern in environmental samples,
- Investigating occurrence and transport of pesticides and related chemicals in major compartments of the hydrologic cycle,
- Investigating the suite of pesticides and related chemicals applied in common pesticide-use settings (including both new and traditional chemicals),
- Determining sources, transport mechanisms and degradation pathways,
- Incorporating a multi-scale assessment from field-level to regional area,
- Placing special emphasis on sensitive and/or susceptible ecosystems, and
- Assessing the implications for ecotoxicity and human health concerns.

Results of these studies in representative areas are intended to be transferable to areas with similar land use, crop types, and/or farming practices and information about specific compounds may be applied to general environmental evaluations of that compound in the context of the other compounds with which it is used and detected. An example of an ongoing pesticide use study is in the corn and soybean belt of the Midwest, where the environmental effects of increasing use of the herbicide glyphosate is being investigated. Glyphosate use is increasing dramatically with the increasing use of glyphosate resistant crops, and where increasing use of new and traditional fungicides is anticipated in response to the threat of soybean rust. More information on research on pesticides in hydrologic environments and the pesticides and pesticide-use settings under investigation is available on the Internet at: http://toxics.usgs.gov/investigations/pesticide_contamination.html

Human Stresses on Sensitive Aquatic Ecosystems

The increasing complexity of human stresses on natural ecosystems requires a sound interdisciplinary scientific basis for decisions to preserve and restore unique and valued ecosystems. Restoration schemes must be developed that do not exacerbate contamination issues in these systems. Effective restoration will depend on a practical understanding of the processes that affect contamination and other human influences on aquatic ecosystems. Interdisciplinary approaches capable of addressing the broad range of controlling factors are employed in ecosystems that are identified to have high National priority by the Department of Interior and other national stakeholders. The primary objective of these ecosystem studies is to provide scientific information needed to address current ecosystem management decisions related to encroachment of development and other human influences on the ecosystem. The TOXICS Program contributions to this research continue to focus on the Florida Everglades and San Francisco Bay. The TOXICS program supports these activities directly and through contributions to Priority Ecosystems Studies [http://access.usgs.gov/].

San Francisco Bay – Toxic substances enter San Francisco Bay from a variety of natural and human sources. The major goal of this research is the evaluation of the complex effects of contamination on the San Francisco Bay ecosystem with transfer value to other estuarine ecosystems. Studies here focus on characterizing the interrelated sources and processes that affect contaminant dispersal, retention and effects within estuarine and delta ecosystems. Results of these studies provide an understanding of the effects of contamination on species throughout

the food web, and of the effectiveness of resource-management strategies. This research is coordinated closely with the needs of other regional and state programs (e.g., Water Resources Control Board, CALFED Bay-Delta Authority (CBDA), and USEPA).

Five major interrelated research thrusts contribute to the understanding of the fate and effects of contaminants in the San Francisco Bay-Delta.

1. Plankton Dynamics in Tidal Estuaries
2. Benthic Fluxes of Metals and Nutrients
3. Environmental Influences on Estuarine Benthic Community Dynamics
4. Availability of Trace Elements to Aquatic Organisms, and
5. Geochemistry and Hydroclimatology of Riverine and Estuarine Waters

The 2007-2011 plan for these major research thrusts consists of the continuation of long- term studies which include a three decade long water quality program of research and observation in the San Francisco Bay/Delta, understanding importance of benthic sources, fate, bioavailability and ecological effects of metals, and characterizing variations in regional regimens of streams, snow packs and glaciers and their relations to atmospheric circulation. New studies will begin that will address recent changes in the San Francisco Bay/Delta ecosystem such as large changes in phytoplankton biomass and primary production, and pelagic organism decline. Finally, ecological forecasting will be conducted to develop scenarios for California's hydrologic change in the 21st century as a response to climate change, sea-level rise, and population growth. One specific objective will include assessments of how these changes will alter the movement of toxic contaminants into aquatic food webs. More information on research on San Francisco Bay is available on the Internet at: http://toxics.usgs.gov/sites/sfbay_page.html

Florida Everglades – The Florida Everglades is a complex ecosystem of diverse, interconnected subtropical habitats. Once comprised of over 4 million acres, today the historic Everglades have been reduced by half. Exponential population growth, urbanization, and agricultural practices in the past 50 years have significantly altered the South Florida ecosystem. Hydrologic change have resulted in severe ecosystem degradation, evidenced by a 90% decline in wading bird populations, declines in commercial and recreational fisheries, significant decreases in the number of Everglades tree islands, and widespread invasions of exotic plants and animals. USGS supports ongoing South Florida restoration efforts by providing scientific information to support management decisions. This research is addressing three overarching restoration questions:

1. *What actions will improve the quantity, timing, and distribution of clean fresh water needed to restore the South Florida ecosystem?*
2. *What actions will restore, protect, and maintain natural resources on DOI lands in South Florida?*
3. *What actions will recover South Florida's threatened and endangered species?*

TOXICS Program activities focus on the quantity and quality of water resources that support the health of the aquatic ecosystem. More information on research on the Florida Everglades is available on the Internet at: http://sofia.usgs.gov/

Hydrologic and Water-quality Factors Affecting Amphibians

There is concern worldwide about amphibian declines. Many causes for these declines have been proposed including degradation or loss of habitat, disease and malformations, ultraviolet radiation, climate change, competition from non-indigenous species, xenobiotic chemicals such as endocrine disruptors, and synergistic effects of multiple stressors. In response to mounting evidence for the decline of amphibians and a call for national monitoring efforts using standardized methods, the U.S. Congress appropriated funding for the Amphibian Research and Monitoring Initiative (ARMI) in 2000. ARMI is an innovative, multidisciplinary program with participation of USGS biologists, hydrologists, and geographers. The result has been an effective program with diverse, yet complementary, expertise.

The ARMI approach to research and monitoring is multi-scale. Detailed investigations focus on a few species at selected local sites throughout the country, monitoring addresses a larger number of species over broader areas (typically National Parks and National Wildlife Refuges), and inventories to document species occurrence, are conducted more extensively across the landscape. Monitoring is conducted to draw statistically defensible conclusions about the status of amphibians. At research sites, ARMI focuses on studying species-environment interactions, determining causes of observed declines, and developing new techniques to sample populations and analyze data. Results from activities at all scales are provided to scientists, land managers, and policy-makers, as appropriate.

Over the last five years, the ARMI program and the scientists involved have had an impact on the issue of amphibian declines at local, regional, national, and international levels. Within parks and refuges, findings help land managers make decisions applicable to amphibian conservation. ARMI research and monitoring efforts have addressed at least six of the 21 Threatened and Endangered Species listed by the U.S. Fish and Wildlife Service (California red-legged frog, Chiricahua leopard frog, Dusky gopher frog, Mountain yellow-legged frog, Flatwoods salamander, and the Golden coqui), and nine additional species of concern recognized by the International Union for Conservation of Nature (IUCN). ARMI investigations have addressed time-sensitive research, such as effects on amphibians brought about by natural disasters like wildfire, floods, and debris flows, as well as the effects from more gradual, but constant, environmental change, like urban expansion and road development. Several ARMI investigators have brought international exposure to the program through venues such as the World Congress of Herpetology in South Africa in 2005, and the Global Amphibian Summit, sponsored by the IUCN and Wildlife Conservation International, in Washington, D.C. 2005.

ARMI has partnered with an extensive list of government, academic, and private entities. Accomplishments from these endeavors include more than 40 publications on amphibian status and trends, nearly 100 publications on amphibian ecology and causes of declines, and more than 30 methodological publications (Muths et al., 2006).

During the next 5 years, ARMI will continue to be a leader of amphibian monitoring and research activities across the nation. ARMI will also direct efforts at addressing specific issues or tasks that have been identified from the programs first 5 years. These issues or tasks include: increasing ARMI visibility and partnerships, increasing the use of biotechnology and cross-disciplinary tools (for example a water test that screens for the presence of *Batrachochytrium dendrobatidis*) for examining causes of amphibian declines, developing monitoring frameworks and protocols for rare or elusive species, conducting a tier I assessment of potential amphibian

stressors, developing improved data reporting and management tools, and increasing health screening and amphibian disease research. More information is available on the Internet on:

ARMI: http://armi.usgs.gov/

TOXICS Program contributions to ARMI: http://co.water.usgs.gov/armi/

V. Program Review

Review and planning activities used to guide TOXICS Program research plans occur at 4 levels: bureau, discipline, program and project. Although they all influence Program activities, the input gets increasingly more specific from the bureau to the project level.

Another factor which has a major influence on the program planning and review process described below is the Program's funding distribution, which is largely based on a predetermined allocation. TOXICS Program annual funding (excluding earmarks) is distributed as follows: 5 percent to Geology programs scientists, 17 percent to Priority Ecosystems Studies, 36 percent to National Research Program scientists, and 39 percent to scientists in Water Science Centers, the National Water Quality Laboratory and the Water Resources Discipline Branch of Geophysics. The remaining 3 percent supports costs associated with program management. This funding distribution facilitates developing broad interdisciplinary research teams from across USGS. It is anticipated to remain approximately constant through the planning period.

Bureau Level Review

A unified, bureau-wide, strategic science planning effort has been initiated by the Director. It is intended to provide the USGS with a renewed and shared science vision. The resulting science strategy will build upon the wide range of planning activities that have been conducted in the bureau and unite our diverse scientific talents and capabilities. It will take advantage of USGS strengths, unique position, and potential roles, while keeping focus on serving important societal needs. It will identify challenging goals that are socially relevant and clearly described and advance the role of the USGS as a valuable scientific institution worthy of public support.

USGS scientists and managers will use the new science strategy to set science priorities for the next decade, to guide the design of scientific investigations, and to help make important decisions concerning the investment of resources, such as budget initiatives and workforce development and deployment. The science strategy will influence the activities of all bureau programs.

Periodically, bureau-wide topical reviews are conducted by the National Academy of Sciences, which include the scientific goals and scope of the TOXICS Program. The last such review was conducted a decade ago (NRC, 1996). Such reviews provide a valuable means to evaluate the roles and relationships of USGS programs with complementary goals and expertise.

Discipline Level Review

During 2004 and 2005, TOXICS Program activities were reviewed by the Office of Management and Budget through the Program Assessment Rating Tool review process. Program goals, performance, and activities were reviewed as part of a comprehensive review of USGS water resources research activities. Program planning activities were reviewed and performance measures were established.

The USGS, Water Resources Discipline (WRD) has initiated a review of USGS Water Programs by the National Research Council, Water Science and Technology Board. This review will assist the USGS in evaluating the programmatic direction of WRD activities and the coordination of WRD programs to address the USGS mission related to the Nation's water resources. It will

cover all of the major topical areas of WRD activities, including ground water and surface water, water quality and quantity issues, hydrologic hazards, water availability, water use, and aquatic ecology. It will examine key aspects of WRD science and operation, including data collection and dissemination, interpretive studies, methods development, and basic research. The review will be completed in September 2008. Results of this evaluation are expected in the summer of 2008 and will be used to improve TOXICS Program activities. The following seven questions will be addressed by the review:

1. Where has the USGS shown leadership in water science and technology in recent years and has it successfully met its goals, as they are described in the WRD- and individual program five-year plans?
2. Are USGS water programs relevant to societal needs, and are they addressing emerging hydrologic issues? What are some of these emerging issues that are being addressed well and which issues are receiving too little attention?
3. How should WRD identify priority water issues? Are there important water issues that are not adequately addressed by the current suite of WRD programs?
4. Given anticipated resource levels, is the current content of the USGS water science portfolio appropriate? If not, what changes should be made? What areas of science should receive higher or lower priority? What is the best balance among: a) collection of long-term data, interpretive studies, methods development, information dissemination and research; and b) ground water and surface water; water quality and quantity?
5. Are USGS water programs well managed and conducted in a cost-effective manner? In what areas/topics is improvement possible?
6. Are the USGS water programs engaging important stakeholder groups? Are there stakeholder groups that could be better engaged? If so, who are they and how could they be better engaged?
7. Are USGS Water programs coordinated well among other USGS programs, among federal agencies? Are there areas in which interactions and coordination could be improved?

Program Level Review

Review at the Program level occurs through update of the Program five-year plans. This document is the result of such a process and it is described in the forward of this document (see p. 5). The process focuses on ensuring that the Program is addressing the appropriate set of water quality research issues as defined by both internal and external stakeholders. Decisions regarding addressing new contamination issues and new program directions are guided by workshops and committees that address broad range of contamination issues addressed by the Program and identify new priorities. Stakeholders, such as USEPA, DOI, etc. are consulted for research needs, and opportunities for collaboration. The subsurface point source contamination workshop planned for early in the 2007-11 planning period is an example of such an activity. When a decision is made to implement a new activity, solicitations for the associated project field sites or study areas are submitted to USGS Science Centers through the Office of the Regional Directors, which in turn submit proposals for candidate sites or study areas. An independent committee evaluates the proposals and makes recommendations to the program leadership. Funds are

committed for a period during which a full research team (involving scientists from districts, regions, NRP, other Divisions, and academia) is formed and a work plan is developed for a specific term, usually 5 years.

Project Level Review

The broad spectrum of research issues and the correspondingly broad range of stakeholders that TOXICS Program projects address are best served by planning and review at the project level. Project level planning is implemented through a work plan development process. Planning workshops provide a means of gathering USGS research scientists and stakeholders to develop essential information on current knowledge, research needs, and requirements for new expertise. Research teams are comprised of scientists from NRP, Water Science Centers, and other USGS programs, supplemented by specialists from universities, other government agencies, and industry. The teams develop the project work plan, which is finalized after a formal review conducted by a committee of USGS and non-USGS experts. This approach facilitates bringing research scientists together in a collaborative, synergistic and noncompetitive research environment.

VI. Expertise and Capabilities

The following describes the Program requirements for new expertise, capabilities, major laboratory and field equipment, and capital investments.

Analytical Chemistry Laboratory Capabilities – Increasing demands to maintain state-of-the-art laboratory methods for measurement of new and "emerging" contaminants at trace levels in multimedia environmental samples will require new laboratory facilities and analytical equipment. Issues of primary concern related to the extremely low detection levels required to quantitate potential endocrine disruptors/modulators.

Microbial Pathogens – The need to identify the presence of microbial contaminants (pathogens), their species, and other associated attributes (such as antibiotic resistance, or genetic signatures) will require an assessment of the limitations of existing facilities and equipment. Our current studies of human and animal wastewater contaminants, including antibiotics, are missing an extremely important part of the associated environmental issue, that is, co-occurrence of pathogens, environmental occurrence and transfer of antibiotic resistance genes, and the potential emergence of antibiotic resistant pathogens.

Nanomaterial – The need to measure the potential effects of environmental contamination by nanomaterial will require assessment of the USGS role in this area considering the relation to traditional contaminants and synergies with ongoing Program activities. It likely will require new analytical equipment and expertise not traditionally found in USGS.

Genomics and Proteomics – Recent advances in genomics and proteomics provide a great opportunity to improve on the way we assess adverse effects of environmental contamination, determine the mode of action of contaminants, and even conduct fundamental monitoring activities. An evaluation of the role of this technology in USGS Program activities is warranted along with the role of the TOXICS Program (as a research and methods development program) to develop this technology to a degree where it can be implemented by USGS monitoring and assessment programs.

In situ Sensor Technology – The need is increasing dramatically for economical means to collect time-series or time integrated data in specific locations in the environment, such as at locations representative or organism exposure or at interfaces (the streambed, water table, lake surfaces, or plant interface). Exploration and/or develop of new sensor technologies will provide a more cost-effective way to meet the increasing demands for information required to characterize complex processes. Collaborations with the USGS BRD to improve and field test integrative sampler technology is a priority.

Mobile Field Laboratories – Two field laboratories have been developed recently and have been particularly successful. The first is a mobile field laboratory designed to monitor atmospheric mercury concentration and speciation. The second is a mobile field laboratory developed to evaluate effects that stream waters enriched in wastewaters have on indigenous fish. Both laboratories have been deployed to different locations and are extremely effective at improving environmental observations and experiments. Multiple versions of each of these will provide the ability to conduct experiments at additional locations concurrently. There also will be an increasing need to develop additional field laboratories and to improve upon our ability to conduct controlled *in situ* exposure experiments.

Modeling Capabilities – A major means of generalizing the methods and knowledge gained from representative field investigations, either at point-source or nonpoint-source watershed scales, is development of statistical and process simulation models that facilitate explanation of similar problems elsewhere across the Nation. Modeling capabilities are needed that integrate analysis of contaminants that cross hydrologic compartments within the hydrologic cycle. Some examples include: statistical models that integrate data at local scales to address the large scale regional and watershed issues faced by resource managers, models that simulate processes across the subsurface unsaturated and saturated zones, models simulate contaminant movement between ground-water and surface-water systems, models that simulate contaminant movement through the hydrologic cycle or a watershed. These needs will require new approaches for coordinating development of hydrologic modeling methods and capabilities that enable advancement in interdisciplinary and multi-scale approaches. For example, modeling capabilities need to incorporate ongoing advances in molecular scale characterizing of biogeochemical and microbial processes that affect contaminant mobility, degradation and transformation.

VII. Facilities

There are no facilities needs associated with TOXICS program activities. There may be facilities needs at various cost centers related to TOXICS Program research activities. However, these needs are usually related to individual scientists and are addressed at the cost-center level.

VIII. References

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Appendix I – Internal and External Partnerships

TOXICS Program activities involve numerous partnerships with scientists from other USGS Programs, from universities, from industry and from other government agencies. These partnerships involve active collaborations with these scientists and their formal participation as research team members. About 150 student dissertations have been published associated with research conducted by the Program.Specific partnerships are enumerated below. The membership of the research teams of each project are listed on the Internet at: http://toxics.usgs.gov/investigations/. A complete list of TOXICS Program partners, collaborators, and beneficiaries also is available on the Internet at: http://toxics.usgs.gov/topics/faq/partners.html.

The TOXICS Program works in partnership with other Federal agencies to ensure that plans and priorities to meet science needs are coordinated, including other DOI bureaus, the U.S. Environmental Protection Agency (USEPA), the U.S. Department of Agriculture (USDA), the Departments of Defense and Energy (DOD and DOE), the Nuclear Regulatory Commission, and more recently, public health agencies, such as the Centers for Disease Control and Prevention (CDC), the Food and Drug Administration (FDA), and the National Institute for Environmental Health Sciences (NIEHS). As an objective science agency, USGS program information and methods often provide a basis for consensus in contentious issues and for achieving cost efficiencies by meeting the needs of numerous management and regulatory agencies.

The information provided in this appendix summarizes active or recent, internal and external research partnerships. Internal partnerships include activities where different program, discipline or organizational entities within USGS collaborate to address issues of common interest and to address common goals. External partnerships include collaborations with other federal and state government agencies, universities and industry. The partnerships are listed here.

Hydrocarbons and Petroleum-Related Contamination – Petroleum Production-Related Contamination

Internal

- Geology Discipline (GD), ERP; James Otton, Robert Zielinski and others: Partners in the Osage-Skiatook, produced-water research team: Investigating the geology, mineralogy, inorganic solid geochemistry and biogeochemistry of sites contaminated with produced water.
- GD, Crustal Imaging and Characterization Team; Bruce Smith and others: Applying surface and downhole geophysics to contaminant plume sites.
- Biological Resources Discipline (BRD), National Wetland Research Center; Bobby Keeland: Oak-tree ecology and tree-ring chronology applied to contaminated sites.
- BRD, Leetown Science Center; Robin Schrock: Developing an antibody-based method to trace MTBE contamination near a lake.

External

- Oklahoma State University: Field validation of toxicity tests to evaluate the potential for beneficial use of produced water.
- Oklahoma State University: Lacustrine invertebrate ecology and toxicology.

- Oklahoma State University: Field validation of toxicity tests to evaluate the potential for beneficial use of produced water.
- University of Tulsa: Remediation at OSPER A site.
- Oak Ridge National Lab: Hyperspectral mapping of scarred areas, Osage County, OK.
- USEPA, National Risk Management Research Laboratory, Ada, OK: Site characterization and reclamation and geoprobe applications.
- U.S. Army Corps of Engineers, Skiatook Lake: Skiatook and OSPER sites remediation.
- DOI, Bureau of Indian Affairs, Environmental and Natural Resources Department, Osage Nation: Salt discharges to Skiatook Lake and site remediation.
- DOE, National Energy Technology Laboratory, Tulsa OK: Site drilling, characterization and remediation.

Hydrocarbons and Petroleum-Related Contamination – Crude Oil Contamination

Internal

- GD, Crustal Imaging and Characterization Team; Jeffrey Lucius: Developing non-invasive geophysical methods for imaging subsurface strata that control contaminant transport at the Bemidji field research site.

External

- Bemidji State University, the Enbridge Pipe Line Company, University of Minnesota, and the Minnesota Pollution Control Agency: Partnering to: (1) develop or test tools for evaluating natural attenuation of petroleum hydrocarbon contamination, (2) develop and apply new technologies for enhanced remediation, and (3) develop technology transfer and educational opportunities.
- University of British Columbia: Investigating and quantifying the occurrence of gas ebullition at the Bemidji site. Ebullition is the process by which methane and other gases rapidly move from the crude oil to the gas phase in the unsaturated zone and ultimately to the atmosphere.
- University of Texas: Investigating *in-situ* hydrocarbon biodegradation rates in the unsaturated zone.
- University of Kansas: Characterizing the microbial community structure of groundwater in three distinctive biogeochemical environments in the Bemidji aquifer and characterizing the colonizing microbial community structure of aquifer sediment.
- University of Massachusetts: Evaluating the potential for the mRNA-based evaluation of *in situ* metabolism in contaminated aquifers.

Hydrocarbons and Petroleum-Related Contamination – Oxy-fuel Contamination

External

- Virginia Polytechnic Institute: Developing numerical model of plant uptake of fuel oxygenates to evaluate natural attenuation.
- American Petroleum Institute: Investigating the role of the hyporheic zone in decreased surface-water impacts from ground-water plumes of fuel oxygenates.
- U.S. Army Corps of Engineers, Skiatook Lake: Skiatook and OSPER sites remediation.

Mixed (Radionuclide and Organic) Waste Contamination in Arid Environments

Internal

- GD, Crustal Imaging and Characterization Team; Jeffrey Lucius, Jared Abraham, Michael Powers, and Bethany Burton: Developing non-invasive geophysical methods for imaging subsurface strata that control contaminant transport.
- GD, National Cooperative Geologic Mapping Program; Dennis O'Leary and Emily Taylor: Characterizing and modeling the geologic framework of the Amargosa Desert Research Site.

External

- Desert Research Institute: Studying transport and fate of tritium.
- Oregon Health and Science University: Studying transport and fate of volatile organic compounds.
- Pacific Northwest National Laboratory: Developing methods for direct measurement of drainage-water fluxes under waste-site conditions.
- Texas Tech University: Studying the formation, accumulation, and persistence of natural perchlorate and other oxyanions in the environment.
- United States Air Force: Studying the occurrence and distribution of natural perchlorate.
- University of Nevada, Las Vegas: Studying present-day soil moisture variations and paleohydrologic processes.
- University of Nevada, Reno: Studying transport and fate of tritium.
- University of Texas at Austin: Studying coupled flow of heat, fluids, and solutes in thick unsaturated zones.

Contamination in Fractured Rock Aquifers

Internal

- GD, Crustal Imaging and Characterization Team; Karl Ellefsen: Imaging shallow subsurface geologic heterogeneity using seismic tomography.
- GD, Earth Surface Processes Team; William Burton: Characterizing the effect of a major thrust fault on ground-water transport.
- GD, Central Region; Gary Landis, Andrew Manning, and Andrew Hunt: Use of helium isotopes to assess diffusion into the primary porosity of a rock matrix.

External

- GeoSyntec Consultants: Studying field-scale *in situ* enhanced anaerobic biodegradation of chlorinated solvents produced by biostimulation and bioaugmentation.
- University of South Carolina: Studying sources, composition, and bioavailability of organic carbon in fractured-rock aquifers.
- Kansas Geological Survey: Investigating use of surface-wave seismic surveys to image thrust faults.
- Rutgers University: Studying mobilization of arsenic by bacteria in fractured sedimentary rock.
- Temple University: Investigating packer testing methods in fractured rock.
- NJ Geological Survey: Studying Newark Basin geology and borehole geophysics.

- NJ Department of Environmental Protection: Studying transfer value of lessons learned during investigation of the NAWC site to other contaminated sites in the Newark Basin.
- ECOR Solutions Inc.: Studying concentrations of contaminants, major ions, and trace metals; investigating remediation by pump and treat.
- USEPA, Office of Solid Waste and Emergency Response, Technology Innovation and Field Services Division: Technology transfer and information dissemination, including co-sponsoring technical workshops.

Contaminant Plumes with Complex Chemical Mixtures – Landfill Leachate

Internal

- GD, Mineral Resources Program; George Breit and Michele Tuttle: Characterization of redox-sensitive solids and exchangeable ions in clays and precipitation of carbonate minerals.
- GD, Crustal Imaging and Characterization Team; Jeffrey Lucius: Performing electromagnetic induction analyses around the landfill and toward the Canadian River to create 2-D and 3-D models of conductive landfill leachate.

External

- Michigan State University: Hydrological Characterization and numerical modeling to assess the multiple processes that contribute to observed reaction rates using *in- situ* push pull tests
- Texas A&M University: Quantifying the solute transport, geochemical, kinetic, and microbiological controls on terminal electron accepting processes (TEAPs) at mixing interfaces in a contaminated aquifer-wetland system.
- Texas A&M University: Studying plant decomposition rates and processes in wetland environments.
- University of Oklahoma: Investigating abiotic reductive dechlorination of tetrachloroethylene and trichloroethylene in anaerobic environments.
- University of Oklahoma: Studying interactions between leachate pollutants and natural organic matter.

Contaminant Plumes with Complex Chemical Mixtures – Contamination by Treated Wastewater

Internal

- BRD, Leetown Science Center; Paul Baumann: Studying the prevalence of tumors on brown bullhead in ponds with inflowing contaminant plumes (co-funded by USEPA).
- GD, Eastern Earth Surface Processes Team, Byron Stone, and Woods Hole Science Center, S. Jeffress Williams: Developing stratigraphic models of glacial aquifer for analysis effects of large-scale heterogeneity on solute transport.

External

- University of Virginia: Studying potential role of bacterial chemotaxis on natural and enhanced biodegradation of contaminants.
- Worcester Polytechnic Institute: Studying rate of natural restoration of oxygen in anoxic and suboxic ground-water plumes.

- Pennsylvania State University: Studying the use of borehole geophysical methods to monitor redox-process-based enhanced remediation of ground-water plumes.
- Massachusetts Institute of Technology (MIT): Investigating ground-water ages as indication of ground-water-flow and recharge rates.
- Nuclear Regulatory Commission: Studying fate and transport of metals and other inorganics in different geochemical environments.
- Air Force Center for Environmental Excellence: Developing and field-testing methods to remediate phosphate in ground water discharging to ecologically sensitive surface waters.
- Air Force Center for Environmental Excellence: Investigating passive-sampling methods to monitor ground water for volatile organic compounds
- Army Environmental Center: Studying processes affecting the fate and transport of toxic metals, such as lead, in ground water.

Watershed Contamination from Hard Rock Mining

Internal

- GD, Mineral Resources Program; Stanley E. Church and others: Abandoned Mine Lands Initiative.
- GD, Mineral Resources Program; Richard B. Wanty, Philip Verplanck, and others: Collaboration with a Mendenhall Post Doc project on using stable metal isotope ratios to identify and characterize metal sources on a catchment scale.
- GD, Mineral Resources Program; Thomas Chapin and Richard B. Wanty: Developing capability for in situ analysis of constituent concentrations in streams.
- GD, Mineral Resources Program, Central Region Crustal Process Team; Kathleen S. Smith: Characterizing chemical and mineral composition and solubility of streambed floc from upper Mineral Creek.
- BRD, CERC; Aida M. Farag: Studying eco-toxicity of metals in streams affected by mine drainage.
- BRD, CERC, Jackson Field Station; Aida M. Farag and David Harper: Studying the influence of diel metal cycles on acute toxicity to trout.

External

- U.S. Bureau of Land Management: Studying sources of metals to streams affected by mine drainage in Utah and Colorado.
- USEPA Office of Research & Development: Development of a workshop on modeling metals in aquatic systems.
- U.S. Forest Service: Studying sources of metals to streams affected by mine drainage
- U.S. Forest Service: Methods to estimate pre-mining stream water quality from ancient ferricrete deposits.
- Montana Department of Fish, Wildlife and Parks: Studying influence of diel metal cycles on acute toxicity to trout.
- Montana Department of Environmental Quality: Estimating pre-mining stream water quality from ancient ferricrete deposits.
- Utah DEQ: Studying mining impacts on Little Cottonwood Creek and Silver Creek, Utah.
- San Juan Resource Conservation and Development: A pilot study for remediation alternatives, Mineral Creek, Colorado.

- Ouray County, Colorado: Characterizing metal sources in the Red Mountain Creek watershed.
- Lake County Conservation District, State of Colorado Water Quality Control Division: Processes controlling water quality changes following in-situ remediation of fluvial tailings deposits.
- Utah DEQ and Salt Lake County: Studying impacts of septic systems on Emigration Creek, Utah.
- Clemson University: Molecular scale characterization of metals in sediment coatings, biofilms, and benthic invertebrates using spectroscopic techniques.
- Colorado School of Mines: Constructing a ground-water model for the Dinero Mine Drainage Tunnel to help simulate potential hydrologic responses of bulkhead emplacement.
- Colorado School of Mines: Studying water and solute exchange between streams and their catchments.
- University of California, Merced: Characterization of biogeochemical processes affecting metal attenuation.
- University of Colorado: Modeling solute transport in Rocky Mountain and Antarctic Streams.
- Montana Tech of the University of Montana: Studying diel biogeochemical processes in acidic and neutral streams.
- Montana State University: Study stream transport process in the context of the landscape of Tenderfoot Experiment Forest, Montana.
- University of Utah: Studying water residence time in catchments
- University of Texas at El Paso: Using stable isotopes of copper and zinc to characterize biogeochemical processes in streams.
- University of Wyoming: Studying role of biofilm in diel cycling of metals in streams
- Stanford Synchrotron Radiation Laboratory: Application of X-ray spectroscopy to characterize metal speciation in stream sediments and biofilms.
- Animas River Stakeholders Group: Science support on metal source and process studies
- Lake Fork Watershed Working Group (stakeholder's group), Colorado Division of Reclamation, Mining, and Safety, and Bureau of Land Management: Baseline water quality assessment of the Sugarloaf Mining District (in preparation for bulkhead installation in the Dinero Mine Drainage Tunnel)
- Centro de Astrobiologia (Madrid, Spain): Studying diel biogeochemical reactions involving iron in acidic streams
- Regione Toscana (Florence, Italy): Studying mining impacts on the Merse River.

Chemicals of Emerging Environmental Concern (Emerging contaminants)

Internal

- BRD, Leetown Science Center and Fort Collins Science Center (FORT); Vicki Blazer and Patrick Anderson: Fish health (intersex) and fish community structure in relation to exposure to environmental wastewater contaminants.
- BRD, Columbia Environmental Research Center; David Alvarez: Environmental occurrence of emerging contaminants in water via innovative passive sampler technology (POCIS and SPMD).

- National Water Quality Assessment (NAWQA) Program, Agricultural Chemicals Studies field research site, South Fork Iowa River, Iowa: Transport and fate of veterinary medicines.
- NAWQA Program, Source Water Assessment; Greg Delzer: The occurrence and distribution of endocrine disrupting chemicals in drinking water sources.

External

- CDC: Studying antibiotic resistance in orchards.
- National Oceanic and Atmospheric Administration (NOAA): Studying the movement of environmental wastewater contaminants following irrigation of effluent to a golf course.
- U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS): Studying environmental wastewater contaminants associated with CAFOs in the South Fork Iowa River.
- USEPA: Studying the use of environmental wastewater contaminants and other chemical indicators of human fecal indicators,
- USEPA: Studying the effects of drinking water treatment on EC concentrations.
- Baylor University: Investigating the uptake of selected wastewater contaminants in tissue.
- Colorado School of Mines: Studying wastewater contaminants associated with onsite septic systems.
- Eastern Washington University: Studying the uptake of wastewater contaminants in biosolids and in worms.
- Michigan State University: Studying the movement of pathogens and wastewater contaminants following application of dairy manure.
- St. Cloud State: Evaluating the effects of fish exposure to various wastewater contaminants.
- University of Arizona: Studying the effects of wastewater treatment on wastewater contaminants and the effects on native fish.
- University of Colorado: Conducting field experiments on potential endocrine disruption in fish using the Fish Exposure Mobile Laboratory in Boulder Creek, CO.
- University of Missouri, Rolla: Conducting soil column experiments using select antibiotics.
- University of North Carolina: Developing methods to measure x-ray contrast media in environmental samples.
- University of Wisconsin: Studying antibiotics in wastewater treatment plan effluent.
- Metcalf & Eddy Inc.: Investigating the effects of wastewater treatment on various wastewater contaminants.
- Iowa Department of Natural Resources, Iowa Geological Survey: Investigating the transport and fate of wastewater contaminants.
- HortResearch (New Zealand): Studying the occurrence of wastewater contaminants in biosolids.
- The University of Queensland (Australia): Investigating antibiotics in the environment.

Mercury in Aquatic Ecosystems

Internal

- GD, Energy Resources Program; William Orem: Biogeochemical Processes in the Everglades: Nutrients and Sulfur Contamination.
- BRD, Leetown Science Center; Paul McCormick: Mercury studies in the Everglades and other south Florida ecosystems.

- GD, ERP; Allan Kolker and Mark Engle: Atmospheric Mercury Speciation and Partitioning in coastal settings.
- BRD, Western Ecological Research Center; Steven Schwarzbach: Mercury Bioaccumulation in the Petaluma Marsh, San Francisco Bay, California.
- BRD, University of Maine coop unit: Mercury accumulation in seals of the Gulf of Maine.
- Geography Discipline; Geographic Analysis and Modeling (GAM); Paul Hearn: Development of a web-based information resource on USGS mercury science, the Environmental Mercury, Mapping, Modeling, and Analysis (EMMMA) tool.
- BRD, Upper Midwest Environmental Science Center; Tom Custer: Mercury studies at the Lostwood National Wildlife Refuge.
- BRD, Florida Integrated Science Center; Ken Rice: Mercury studies in the Everglades and other south Florida ecosystems.
- BRD, National Wetlands Research Center; Tom Doyle: Investigating mercury coastal cycling, Gulf of Mexico.
- BRD, Dixon Field Station, California; Mike Saiki: Investigating mercury contamination in Camp Far West and Guadalupe Reservoir, California.

External

- USEPA, Office of Air and Radiation: Atmospheric mercury sources and transport near a point source.
- University of Wisconsin-Madison: Co-Host, 8th International Conference on Mercury as a Global Pollutant.
- USEPA, Office of Research and Development: Factors affecting aquatic ecosystem sensitivity to mercury deposition.
- USEPA, Region 9: Mercury sources, cycling and bioaccumulation at the Lostwood National Wildlife Refuge.
- National Park Service, Everglades National Park: Mercury and sulfate contamination of Everglades National Park.
- Fish and Wildlife Service, Loxahatchee National Wildlife Refuge: Mercury cycling and bioaccumulation in the Loxahatchee Wildlife Refuge, Florida
- Florida Department of Environmental Protection: Mercury and sulfate sources and cycling in the south Florida environment.
- South Florida Water Management District: Mercury cycling and bioaccumulation in the Water Conservation Areas of the Everglades.
- US Army Corps of Engineers: Potential impacts of developing an ASR system on mercury cycling in the south Florida environment.
- NOAA, Weeks Bay (Alabama) National Estuarine Reserve: Atmospheric mercury speciation and deposition in near coastal settings.
- Fish and Wildlife Service, Cape Romaine National Wildlife Refuge (South Carolina): Atmospheric mercury speciation and deposition in near coastal settings.
- University of Nevada Reno: Mercury accumulation and volatilization from desert soils.
- University of Maine (Orono): Mercury accumulation, cycling and transport in snow pack of Acadia National Park.
- National Park Service, Acadia National Park: Mercury accumulation, cycling and transport in snow pack of Acadia National Park

- Montana State University: Mercury speciation and transport processes in geothermal systems from Yellowstone National Park.
- National Park Service, Yellowstone National Park: Mercury speciation and transport processes in geothermal systems from Yellowstone National Park.
- Michigan Department of Environmental Quality: Mercury contamination of Deer Lake, Michigan.
- Minnesota Pollution Control Agency: Mercury contamination of Voyageurs National Park.
- San Francisco Estuary Institute: Mercury cycling and bioaccumulation in the Petaluma Marsh, San Francisco Bay, California.
- Department of Fisheries and Oceans, Winnipeg, Manitoba, Canada: The Mercury Experiment to Assess Atmospheric Loadings in Canada and the US (METAALICUS).
- University of Toronto: (METAALICUS).
- Trent University, Ontario, Canada: The Mercury Experiment to Assess Atmospheric Loadings in Canada and the US (METAALICUS).
- University of Alberta, Canada: The Mercury Experiment to Assess Atmospheric Loadings in Canada and the US (METAALICUS).
- University of Maryland: The Mercury Experiment to Assess Atmospheric Loadings in Canada and the US (METAALICUS).
- Smithsonian Estuarine Research Center: Aquatic Cycling of Mercury in the Everglades (ACME) project.

Pesticides in Hydrologic Environments

Internal

- Biological Resources Discipline (BRD), Columbia Environmental Research Center (CERC); Carl Orazio and Robert Gale: Development of analytical methods for current-use pesticides in biological tissues.
- BRD, CERC; David Alvarez: Studying concentrations of pesticides in water via innovative passive sampler technology (POCIS and SPMD)
- GD, Eastern Region Minerals Resources Team: Rob Robinson: Arsenic contamination in orchards, Great Valley, Virginia and West Virginia.
- GD, Energy Resources Program (ERP); Neil Fishman: Characterizing the mineralogic controls on nutrient and pesticide sorption in the unsaturated zone.
- National Water Quality Assessment Program (NAWQA) Agricultural Chemicals Studies field research site, South Fork Iowa River, Iowa: Studying the transport and fate of glyphosate and other common use pesticides.

External

- Centers for Disease Control and Prevention (CDC): Sharing information on pesticide metabolites for significance to occurrence in humans.
- National Oceanic and Atmospheric Administration (NOAA): Studying off-site movement of pesticides following application on a golf course;
- NOAA: Studying the bioavailability and effects of pesticides on salmon in Pacific Northwest.
- National Park Service: Studying use of herbicides to control invasive plants.

- USDA ARS: Studying the effects of glyphosate use on crops in the South Fork River in Iowa.
- USEPA: Occurrence and fate of fungicides used to control soybean rust, ethylene thiourea in groundwater, occurrence of new pesticides in the environment.
- Purdue University: Investigating toxicity of fungicides applied to control soybean rust.
- Skidaway Institute of Oceanography: Studying the toxicity of the fungicide chlorothalonil and its degradation byproducts to aquatic organisms.
- University of California, Berkeley: Studying the effects of atrazine on amphibians.
- University of California, Davis: Studying the toxicity of pesticides in water and sediments to aquatic organisms.
- University of Missouri, Rolla: Studying the fate of pesticides during drinking water treatment.
- Rutgers University: Soils Testing Laboratory – for studying the partitioning of major ions and nutrients between sorbed and aqueous phases

Human Stresses on Sensitive Aquatic Ecosystems – San Francisco Bay

Internal

- GD, Coastal and Marine Geology Team, Pacific Science Center; Bruce Jaffe: Use and development of ship deployed bottom profiler in determining benthic community structure.
- GD, Coastal and Marine Geology Team, Pacific Science Center; Bruce Jaffe: Geomorphic trends in San Francisco Bay and the ecological effects of described trends.
- GD, Coastal and Marine Geology Team, Pacific Science Center; Rene Takesue: Trace elements in shell microstructure to determine environmental history of in situ bivalves.
- Western Ecological Research Center (WERC), Vallejo; John Takekawa: Salt Pond water quality sampling, analysis, and data compilation.

External

- Stanford University, Stanford CA: Hydrodynamics and grazing in shallow water habitats.
- San Francisco State University, Romberg Tiburon Center for Environmental Sciences: Food web support for the threatened Delta Smelt and other estuarine fishes in Suisun Bay and the Western Sacramento-San Joaquin Delta.
- University of Connecticut: Food web research support for the threatened Delta Smelt and other estuarine fishes in Suisun Bay and the Western Sacramento-San Joaquin Delta.
- University of California, Davis: Forecasting the effects of climate change and infrastructure change on the San Francisco Bay and Delta.
- California Department of Water Resources: Establishing an historical time series of biomass of benthic species for the San Francisco Bay and Delta.
- University of California, Davis: Examining the reasons for the baseline shift in phytoplankton biomass in San Francisco Bay.
- California Department of Fish and Game: Examining the reasons for the baseline shift in phytoplankton biomass in San Francisco Bay.
- USFWS/USEPA, Region 9, Eugenia McNaughton: Development of a site-specific selenium standard for San Francisco Bay.
- USEPA Office of Water: Negotiations for use of Luoma/Presser model to evaluate national standards for selenium.

- Regional Water Board, Southern California: Using Luoma/Presser model to evaluate site-specific selenium objective for San Diego Creek/Newport Bay.
- USEPA, Clean Air Scientific Advisory Committee: Review of atmospheric lead standard (Luoma is panel member).
- City of Palo Alto: Continued partnership in assessing trends in metal contamination in South San Francisco Bay.
- CALFED Bay-Delta Program: Fate and food web effects of mercury in Bay-Delta.
- Bureau of Reclamation: Studying benthic fluxes of nutrients into Upper Klamath Lake, OR, a hyper-eutrophic lake with periodic fish kills.
- Santa Clara Valley Water District: Determining the location of mercury within organisms at a molecular level by X-ray absorption near-edge structure (XANES) analysis (Stanford Synchrotron Radiation Lab).
- University of California, Merced: Collaborating in monitoring and defining mountain stream conductivity field, mostly in Yosemite National Park.
- Santa Clara University: Collaborating in mountain hydroclimatology research, Sierra Nevada and Western U.S.
- California Snow Survey, Yosemite National Park: Installation of a seabird (CTP) at Tuolumne Meadows including a weather monitor and wireless data transmission.
- California Western Science Center and San Francisco Water and Power: Monitoring inflow, conductivity and water temperatures above the Hetch Hetchy reservoir including wireless data transmission and weather data (New gage site Tuolumne River at Grand Canyon of Tuolumne above Hetch Hetchy site ID 11274790).
- NFS (Connie Miller): Installation of seabird in upper San Joaquin River at Devil's Postpile for conductivity and water studies as a framework for other, largely biological, research.
- San Francisco State University, Romberg Tiburon Center for Environmental Sciences: Dissolved inorganic nutrient research and analysis in San Francisco Bay and Delta.
- South Bay Salt Pond Restoration Project (Coastal Conservancy, USFW, Cal DFG).
- NOAA: Representation on the Research, Development, Demonstration, and Technology Transfer (RDDTT) Steering Committee (National Scientific RDDTT Plan on Reducing Impacts from Harmful Algal Blooms): Creation of a symposium as dictated by the Harmful Algal Bloom and Hypoxia Research and Control Act.
- UC Berkeley: Collaboration with WRD scientists and use of the R/V Polaris and her crew for research needs.
- San Francisco State University/Romberg Tiburon Center: Collaboration using the R/V Polaris and her crew for research needs.

Human Stresses on Sensitive Aquatic Ecosystems – Gulf of Mexico Hypoxia

- National Stream Quality Accounting Network (NASQAN), Brent Aulenbach: Development of streamflow and nutrient load information in support of Gulf of Mexico Hypoxia Task Force.

Hydrologic and Water-quality Factors Affecting Amphibians – Amphibian Research and Monitoring Initiative (ARMI)

Internal

- Geography Discipline, EROS Data Center; Alisa Gallant, Robert Klaver, and Paul Bartel: Coordination of research, mapping, and GIS activities with regional and national WRD counterparts.
- BRD, Columbia Environmental Research Center; Carl Korschgan, Kimberly Horton, Edward Little: GIS tools development and evaluation of the effects of amphibian stressors.
- BRD, National Wildlife Health Center; David E. Green; amphibian disease screening.

External

- National Park Service: Research, inventory, and long-term monitoring studies in more than 20 National Park Units Nation-wide including Yellowstone NP, Rocky Mountain NP, Yosemite NP, Voyageurs NP, and Rock Creek NP.
- US Fish and Wildlife Service: Research, inventory, and long-term monitoring studies in more than 20 USFWS Park Units Nationwide including: Atchafalaya NWR, Patuxent Wildlife Research Refuge, Great Swamp NWR, and San Bernadino NWR.
- US Bureau of Land Management: Research, inventory, and long-term monitoring studies in more than 5 BLM Units including: Kingbury Gulch, and Poachie Mountains.
- US Forest Service: Inventory and monitoring studies in more than 5 Forest Service Units.
- Department of Defense: Monitoring in California.
- ARMI researchers have recent or on-going collaboration with researchers from the following universities: University of California, University of Alaska, University of Montana, Idaho State University, Colorado State University, University of Arizona, University of Minnesota, Iowa State University, Texas A&M, University of Florida, University of Kansas, University of Puerto Rico, University of Maine, University of Wisconsin, University of Southern Illinois, and University of Richmond.
- ARMI researchers have recent or on-going collaborations with scientists from the following non-profit or other groups; Nature Conservancy, Montana Heritage Program, California Department of Parks and Recreation, California Department of Fish and Game, and Marine Corps Camp Pendleton.