MINERAL LEASE FUND REPORT

Utah Water Research Laboratory

Fiscal Year 2004

for

Office of the Legislative Fiscal Analyst
Room 425
State Capitol
Salt Lake City, UT 84114

by

Mac McKee, Director

Utah Water Research Laboratory
Utah State University
Logan, UT 84322-8200

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Foreword

The Utah Water Research Laboratory (UWRL) at Utah State University (USU) receives 2-1/4% of all deposits made to the Mineral Lease Account, "to be used for activities carried out by the UWRL having as a purpose the development and exploitation of water resources in the State of Utah."

This report is being submitted to the Legislature by the UWRL in compliance with House Bill 103 which was passed during the 1993 General Session. This legislation requires the UWRL to "provide the Legislature, through the Office of the Legislative Fiscal Analyst, with a complete accounting of the use of that money (MLF) on an annual basis." Following the requirements of the legislation, this report includes the following:

1) Actual expenditures for FY 2004
2) Budgeted expenditures for FY 2005
3) Planned expenditures for FY 2006

The report is divided into an introduction and the summaries of each MLF research project. The introduction describes the role of the UWRL, summarizes the requested MLF expenditure information, describes the history of the UWRL, and discusses how the UWRL maintains the relevancy of its research programs to Utah water problems. Project summary reports are grouped into nine program areas. A table summarizing actual, budgeted, and planned expenditures for FY 2004, FY 2005, and FY 2006, respectively, is presented at the beginning of each program area section.

Each project summary report begins with a project description that includes a statement of the problem addressed and research objectives. Accomplishments for FY 2004 are then described. A synopsis of the FY 2005 and FY 2006 work plans is included for projects that will be ongoing during those fiscal years. A statement of the benefits to the State of Utah is also provided.

This report will be reviewed by the Community and Economic Development Appropriation Subcommittee of the Legislature as part of its normal budgetary process under Title 63, Chapter 38, Budgetary Procedures Act. The UWRL welcomes any comments or questions that result from this review.

Mac McKee
UWRL Director

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Introduction

Role of the Utah Water Research Laboratory

Research programs at the Utah Water Research Laboratory (UWRL) directly address current and future needs of the state, the nation, and the world. State appropriation funds (SAF) and mineral lease funds (MLF) are used to address problems facing the State of Utah. In FY 2004, SAF and MLF accounted for 26% of total UWRL expenditures with the balance coming from federal, private, and other state sources. MLF funds are presently used to match externally funded projects, thereby leveraging significant additional funding for solving important Utah water problems. Total UWRL expenditures for FY 2004 were $8.8 million.

The UWRL is organized into nine major research programs supported by the Environmental Division, the Water Division, and the International Office for Water and Science Education (IOWSE). Brief summaries of these major research programs under these three divisions are presented at the end of this Introduction section.

The UWRL research program related to MLF is very diverse as indicated by the project summaries in this report. The overall research program, funded by both state funds and external contracts and grants, is even broader. We continue to be involved in many field-scale soil and water remediation research projects. At several experimental watersheds, we are investigating hydroclimatological processes. Our hydraulics, erosion control, and environmental-quality laboratories are involved with a range of experimental work and service projects that utilize our unique facilities. Computer models, remote sensing, geographic information systems, digital terrain models, expert systems, and many other modern technologies are developed and applied in our research projects and are used to develop tools for water and environmental managers and professionals in Utah. The UWRL also prepares guidance materials for use by practitioners. Some projects are relatively small in scope while others involve interdisciplinary teams and collaboration with multiple agencies and with the private sector.

In addition to our research role, we continue to be involved in university graduate and undergraduate education through hands-on projects, part-time employment, and research assistantships. We are also involved in public and professional service, technology and information transfer, and public education. Almost all research and applied projects include student involvement, and result in masters or doctoral degrees. Ninety-seven graduate students were supported in FY 2004. Undergraduate student involvement in UWRL projects is significant, as student education and training are integrated with our basic and applied research programs. The UWRL employed approximately 58 undergraduate students in FY 2004 through leveraging of MLF and SAF support to build the larger total UWRL program. As they are hired by Utah employers, our students become effective means of technology transfer from the UWRL to the Utah water and environmental communities to assist with wise water use within drought conditions. Technology and information transfer are focused on public education, and on working with the Utah Department of Natural Resources, Water Resources Division, the Utah Department of Environmental Quality, the twelve Utah local health departments, and several large water users organizations.

History of Utah Water Research Laboratory

The Utah legislature authorized the establishment of the UWRL at Utah State University in 1959 as an important component of the State of Utah's commitment to water resources research. Construction was completed in December 1965, and included one of the best hydraulics laboratories in the United States and a unique erosion testing facility with a large rainfall simulator. Sixteen years later, an extensive remodeling project, including the addition of an environmental quality laboratory, was completed. In addition to the physical facilities, the State of Utah provides state-appropriated funds (SAF) and mineral lease funds (MLF) for research support at the UWRL.

In 1964, Congress approved the Water Resources Research Act that created a water research institute in every state. The Utah institute, known as the Utah Center for Water Resources Research (UCWRR), was established at the UWRL as a part of the national network of water research institutes. Total research funding through the UWRL was almost $8.8 million in FY 04, making it one of the largest institutes in the nation. It is also one of the most productive in terms of research publications and graduate student education.

Introduction

There are 22 faculty and 51 support staff at the UWRL. During FY 2004, 67 master's students and 30 doctoral students received support from UWRL projects. An additional 58 undergraduate students assisted with UWRL research. UWRL faculty collaborate with colleagues from other USU departments, faculty from other institutions, professionals from the private sector, and government agencies in Utah, and elsewhere. Several of our faculty, including the former UWRL Director, have been awarded the Utah Governor's Medal for Science and Technology. In addition, our faculty have received many national honors and recognition, and served on national and international engineering and science panels and committees.

Management of USGS 104 Program for State Benefit

The Water Resources Research Act of 1964 created a national network of Water Resources Research Institutes (WRRIs) in the US and an allotment program for providing funds to the institutes, called the Section 104 Program. The Utah Institute, known as the Utah Center for Water Resources Research (UCWRR), is located at the Utah Water Research Laboratory (UWRL). Currently, the Section 104 Program is funded at an annual level of approximately $90,000 of federal funds. This year, we used the base grant from the U.S. Geological Survey (USGS) in combination with MLF support to directly benefit the State of Utah in areas of: (1) source water protection, (2) on-site wastewater treatment training and certification, (3) management strategies for small dams in Utah for mitigation of fish damage and related issues, as described above, and (4) development of user-friendly decision support systems for management of large watershed areas in Utah. The state thus benefits directly with regard to water-related public health and environmental protection as well as with regard to water sustainability issues in both urban and rural areas of Utah.

We will continue to use the USGS 104 Program support to develop applied research information and to accomplish technology transfer for source water protection strategies, tools development, and programs across the State of Utah.

Mineral Lease Fund Expenditures

The table at the beginning of this Introduction section summarizes the actual, budgeted, and planned expenditures of MLF allocated to the UWRL for FY 2004, FY 2005, and FY 2006 by the nine major research program areas. A breakdown of these expenditures by individual projects is contained in tables presented at the beginning of each research program area section of this report. UWRL administration and technology transfer expenditures accounted for approximately 17% of total MLF, budgeted and planned expenditures in FY 2004.

Relevancy and Benefits of the Mineral Lease Fund

Research Identification

In FY 2004, UWRL faculty kept current on state and national water research needs through professional and service activities and through research on improving efficiency during drought conditions. The Utah Center for Water Resources Research (UCWRR) participated as an active member of the National Institutes for Water Resources (NIWR). In addition, UWRL faculty participated as a member of the Lake Powell Technical Advisory Committee activities to identify research needs and arrange collaborative research efforts. The current Director represented the UWRL to the Universities Council on Water Resources (UCOWR). The UWRL also participated in the U.S. DOE-sponsored Inland Northwest Research Alliance (INRA), and the former Director (now the Interim Associate Director) served as the University Programs Coordinator (UPC) for INRA. The UWRL Director, Associate Director, and many faculty met frequently with state and federal agency managers and personnel from local water organizations to discuss research needs and opportunities for the UWRL to respond to these needs. UWRL faculty were also active in state sections of professional organizations, such as the American Water Resources Association, the American Society of Civil Engineers, the American Water

Works Association, and served on state, local, and national committees. All these activities provided opportunities to identify current and future research needs that will affect our state and the nation.

We continually seek to strengthen the UWRL research identification process to maintain Utah relevancy of our research programs. We are doing this through participation on state committees. The former UWRL Director serves on the DEQ Water Quality Board, UWRL Faculty member Dr. William J. Doucette serves on the Board of the Division of Hazardous Wastes, and Dr. Laurie McNeill serves on the DEQ Drinking Water Board. Dr. Darwin L. Sorensen is a member of the Lake Powell Technical Advisory Committee. The UWRL also encourages faculty participation in meetings attended by the Utah water community, such as the Utah Water User's Association Annual Meeting, the Utah Rural Water User's Association, the Water Environment Association of Utah, the Annual Uinta Basin Water Conference, the Utah Annual Water Summit, the Utah League of Cities and Towns, and the recently formed Utah On-Site Wastewater Treatment Association (UOWA).

Technology Transfer

Besides working on research that is relevant to Utah, we seek to effectively communicate our basic and applied research results to all those who can benefit from them. We are continually assessing ways to make our research findings more accessible at the local, state, and national levels.

Our information transfer activities include our World Wide Web (WWW) site, conferences, workshops, training for State of Utah, U.S., and international professionals, publications' production support and sales, general education, and brochures. The UWRL World Wide Web address for UWRL publications is http://www.engineering.usu.edu/uwrl/www/uw_pub.html. Faculty share their expertise with state water resources and environmental agency personnel through ongoing presentations, meetings, and seminars offered in Salt Lake City and other venues in Utah.

The mission of the UWRL includes outreach activities related to technology transfer for the benefit of State of Utah agencies, Utah citizens, and the nation. Our outreach activities with regard to information dissemination include the following Internet sites: Utah On-Site Wastewater Treatment Training Center [http://www.engineering.usu.edu/uwrl/training], our World Wide Web (WWW) site: [http://www.engineering.usu.edu/uwrl], Utah Water Atlas [http://www.engineering.usu.edu/uwrl/atlas], and Utah Water Journal [http://www.engineering.usu.edu/uwrl/uwj].

Our ongoing interactions with state agencies at the faculty level and state agency staff level on a variety of issues will continue to operate as the core of our approach to focusing UWRL activities so that we can achieve maximum impact from our current budget. In addition, the UWRL Director, Associate Director, and faculty will continue to work with UDEQ, UDNR, the State Engineer's Office, and other state and local water agency administrative and management personnel to provide guidance and priority to state needs and issues.

Examples

Specific state benefits resulting from MLF research projects are listed at the end of each project summary in the following sections of this report. Projects conducted by the UWRL in the past year have produced activities in every county of the state. (Refer to Figure 1 for a tally of UWRL projects by county). A few examples of current, past, and expected future benefits of MLF funding are listed below:

- The UWRL is has worked for the past three years with the UDEQ, Drinking Water Division, to address national regulations and requirements regarding Source Water Protection Plans in Utah. The assistance includes the development of new tools and methods for source water assessment of the risk of contamination of surface water supplies in Utah. This is especially important under drought conditions that have been recently experienced in Utah. A source water protection assessment tool (SWPAT) is under development for the Ogden River Watershed as a technology transfer product of this research.

- On-site wastewater treatment training and technology transfer for State of Utah personnel in the Utah Department of Environmental Quality (UDEQ) and local health departments continued in FY 2004. Current activities are described in this report. Undergraduate and graduate students participate through projects that involve hands-on, real-world activities. Utah health department staff and other Utah On-Site Wastewater Treatment professionals were trained in site characterization, treatment, and monitoring on-site systems and source water protection aspects

of on-site systems. Additional information can be found at the UWRL web site: http://www.engineering.usu.edu/uwrl/training.

- UWRL faculty and staff taught on-site wastewater treatment workshops throughout the State of Utah over the past 12 months to local health department personnel and contractors that included: (1) Soil Evaluation and Percolation Testing, (2) Design, Inspection, and Maintenance, and (3) Design, Inspection, and Maintenance of Alternative Systems.

- The Utah On-Site Wastewater Association (UOWA) provides a major technology transfer service regarding site selection, installation, maintenance, and monitoring for Utah local health departments, UDEQ, and other on-site professionals.

- UWRL faculty are currently assisting UDEQ personnel in the evaluation of state needs regarding Total Maximum Daily Loads (TMDLs) for Utah's lakes, rivers, and streams, and the impacts of proposed land use changes on water quality. Personnel from the UWRL have provided direct technical assistance in 2004 for the preparation of TMDLs in several Utah locations.

- Results of our laboratory investigations continue to provide cost-saving methods for improving the performance and safety of dams and of dam spillways in Utah, and can be expected to play an important role in future dam safety rehabilitation in the state. In addition, UWRL faculty and staff continue to develop procedures that consider risks associated with the performance of dams.

- In FY 2003 through FY 2007, the UWRL has been requested to assist the State of Utah to develop a plan and methods of management to minimize sediment release from dams during drawdown events. The UWRL has received U.S. EPA funding to assist the state in this effort.

- UWRL faculty serve on state and local advisory panels as part of our outreach and service activities, including the Utah Drinking Water Board (Dr. Laurie McNeill), Utah Water Quality Board (Dr. Ronald C. Sims), the Utah Solid and Hazardous Waste Board (Dr. William J. Doucette), Lake Powell Technical Advisory Committee (Dr. Darwin L. Sorensen), Salt Lake County Solid Waste Management Council (Dr. R. Ryan Dupont), and the Utah On-Site Wastewater Association (UOWA) (Dr. Ronald C. Sims, Ms. Judith L. Sims, and Dr. Darwin L. Sorensen).

- A geographic information system (GIS) approach has been developed by UWRL faculty and students to improve statewide water use estimations to forecast future water needs. UWRL faculty are working with personnel in the Department of Natural Resources, Division of Water Rights, to implement this tool. This work was partially supported by funds received from the US Geological Survey.

- Real-time management of irrigation systems in the Sevier River Basin is being implemented using computer models to increase the efficiency of basin-wide water management. This is especially useful when the total quantity of water decreases as in the recent drought conditions in Utah.

- Computer models for managing the quality of streamflows and improving the operational efficiency of Weber Basin water treatment plants continue to be developed and are expected to be transferable to other river systems in Utah.

- UWRL faculty are currently involved in improving drinking water treatment and plant performance in Utah with regard to coagulation and arsenic removal processes. We are also working closely with the Utah Water Quality Alliance through Dr. Laurie McNeill.

- Monitoring of fish populations within the Sevier River drainage is a cooperative project with the State of Utah Division of Wildlife Resources and the Sevier River Bridge Canal Company to guide decisions about long-term water allocation and enhancement of native fish in the Sevier River Basin. Similar assistance is being provided for the Virgin River Basin.

- The UWRL obtained land from USU and worked with Utah health departments and DEQ to establish the Utah On-Site Wastewater Treatment Physical Demonstration Facility in FY 2001, and the site became operational in FY 2002. In 2002, 2003, and 2004, the site was used extensively for training provided to a variety of participants from all around the state. Support was provided by the U.S. EPA and private industry through the submission of proposals.

- The use of vegetation for reclaiming mining areas is being investigated through the development of phytoremediation techniques at the UWRL to assist Utah and other intermountain areas with metal-contaminated soil and ground water.

- UWRL faculty continued to provide technical support to the Virgin River Resource Management and Recovery Program in FY 2004. The program considers actions that will promote protection of species and meet water allocation needs. UWRL faculty have participated in this important program for nearly two decades.

- UWRL personnel provided research support on a more realistic approach to assessing the impacts of altered flow regimes on drifting feeding fish species (i.e., trout). This will provide resource managers with a tool to make better decisions on protecting Utah fisheries resources.

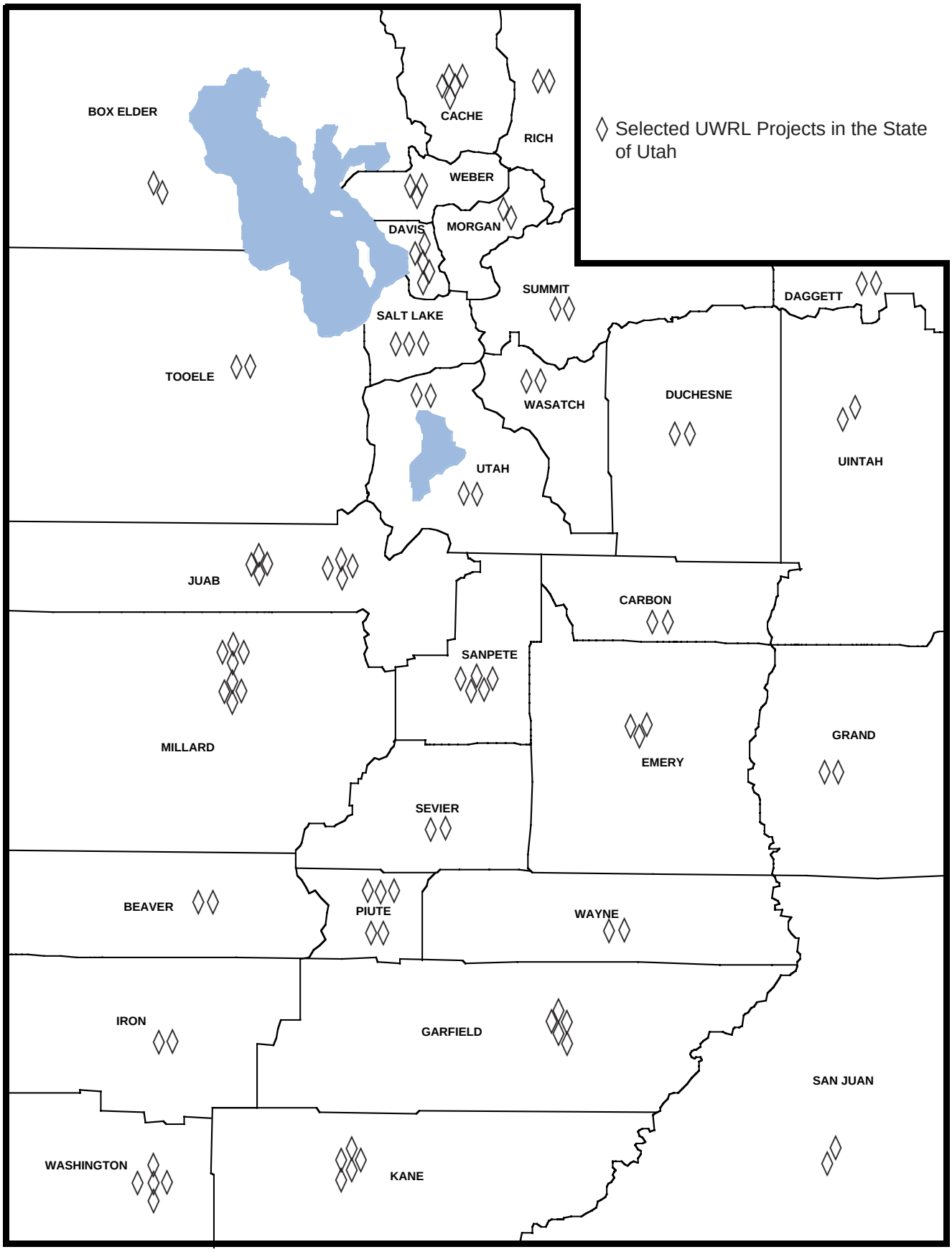

Figure 1. Projects conducted by the UWRL in the State of Utah.

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Summary by Research Projects

Total	FY2004 Actual Expenditures	FY2005 Budgeted Expenditures	FY2006 Planned Expenditures
Administration	$146,233.77	$185,620.78	$194,901.82
Bioprocess Engineering	$26,978.19	$70,200.00	$68,110.00
Hazardous and Toxic Waste Management	$189,243.21	$350,622.62	$337,321.42
Water Quality Engineering	$192,464.71	$266,546.28	$256,431.90
Water Education and Technology Transfer	$47,116.68	$69,837.42	$68,201.88
Fluid Mechanics and Hydraulics	$39,659.09	$114,659.09	$107,892.04
Ground Water	$26,465.79	$46,527.62	$48,854.00
Hydrology	$34,849.71	$65,895.20	$73,689.96
Water Resources Planning and Management	$211,889.64	$420,940.73	$443,796.97
Totals	**$914,900.79**	**$1,590,849.75**	**$1,599,200.00**

Bioprocess Engineering

Bioreactor processing of environmental materials and engineering scale-up of biologically-based environmental reactions are being explored. Areas of specialization include: composting, waste reuse, biosolids processing, management of environmental biotransformations, and engineering optimization of wetlands.

Hazardous and Toxic Waste Management

This program emphasizes an integrated engineering and science approach for characterization and remedial design approaches for contaminated subsurface environments. In addition to laboratory scale work, the program has the largest field scale research dimension of any similar academic program in the nation.

Natural Systems Engineering

Impacts of engineered systems on habitat in aquatic ecosystems are evaluated through the development and application of assessment methods using computer simulation data analysis, and remote sensing. This program addresses threatened and endangered species, habitat enhancement, instream flow assessments, remote sensing of fish habitat, and videography-based prediction of stream sediment and meso-scale hydraulic features.

Water Quality Engineering

The program focuses on the development of engineering approaches for production of drinking water; treatment, reclamation, recycling, and reuse of municipal and industrial wastewater; and modeling of water quality. Areas of specialization include: low technology and advanced treatment processes for potable water treatment, characterization and control of dissolved and particulate natural organic matter (NOM), modeling conventional and toxic contaminants in natural and engineered systems, water reuse engineering, water-quality management, and assessment and control of nonpoint source pollution and storm water.

Water Education and Technology Transfer

Several projects conducted by the Utah Water Research Laboratory, including many that are funded from sources other than Mineral Lease Funds, have substantial education, outreach, and training components. Resources provided by Mineral Lease moneys are sometimes used to enhance the development of training modules or educational materials, sometimes to provide technical support to Utah state agencies on water-related issues (such as the State Attorney General's office in litigation involving liability assessment in hazardous waste problems), and development of curricular materials for use in K-12 education programs in the state.

Fluid Mechanics and Hydraulics

This program utilizes the UWRL hydraulics laboratory for physical modeling of hydraulic structures, including evaluation of scour below spillways and other structures, testing and evaluation of hydraulic machinery and piping systems, flow meter calibration, and testing of erosion control systems for slopes and channels. Analytical aspects of the program include design of pipe networks for water supply, porous media flow, sediment transport, and open channel flow.

Ground Water

Current research activities cover topics from theoretical developments in the stochastic and numerical analysis of transport in groundwater to practical aspects of the design of clean-up technologies for fuel-contaminated sites and management of Utah aquifer systems.

Hydrology

This diverse program has strengths in both the theoretical and applied aspects of modern hydrology, including climate modeling, rainfall processes, snow hydrology, floods, droughts, terminal lake analyses, soil erosion, and stream water quality modeling.

Water Resources Planning and Management

This program addresses institutional and legal aspects of water rights transfers, distributed water demand and supply modeling using geographical information systems, and cost allocation and determination of user fees for multiple purpose water resources projects. Additional areas include reservoir operating policies, water conservation, river basin planning, user-driven decision support systems for water planning, terminal lake water level management, and dam safety risk assessment.

Bioprocess Engineering

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Bioprocess Engineering

Project Name	FY2004 Actual Expenditures	FY2005 Budgeted Expenditures	FY2006 Planned Expenditures
Identifying and Overcoming Impediments to Expanding the Beneficial Use of Biosolids	$26,978.19	$50,200.00	$52,710.00
Designated Amount for FY05/FY06 Research Projects		$20,000.00	$15,400.00
Undesignated research projects in program area		$0.00	$0.00
Total	**$26,978.19**	**$70,200.00**	**$68,110.00**

Identifying and Overcoming Impediments to Expanding the Beneficial Use of Biosolids

Principal Investigator(s):
Michael J. McFarland
Chen Yan
Dharmin Desai

Project Description:

In general, the State of Utah desires to significantly expand the beneficial use of biosolids (appropriately treated wastewater treatment sludge) rather than having them landfilled or incinerated. Specifically, the State of Utah would like to determine the potential environmental, ecological and economic benefits of land applying lime-stabilized biosolids, aerobically digested biosolids and animal manures to alkaline rangelands located in Skull Valley, Utah (an area located approximately 80 miles southwest of Salt Lake City, Utah).

Accomplishments:

Two proposals, focused on the land application of biosolids within the State of Utah were prepared, submitted, and funded during FY 2004. The first proposal was focused specifically on meeting the biosolids management needs of the City of Tooele, Utah. The City of Tooele Wastewater Treatment Plant is currently employing a hybrid lime stabilization/pasteurization process to achieve Class B pathogen levels required for biosolids land application under the 40 CFR Part 503 rule. The 40 CFR Part 503 rule mandates that bulk biosolids cannot be applied to agricultural land, forest land or a public contact site at a rate greater than the agronomic rate. The principal investigator together with his graduate students obtained and analyzed a preliminary set of biosolids and soil samples (approximately twenty samples of each) to establish reasonable agronomic biosolids land application rate. A draft final report, which was submitted to the City of Tooele in November 2004, has recently been approved. The second proposal was focused on monitoring the changes in natural rangeland vegetation in response to the increased availability of nutrients and organic matter furnished by land applied biosolids and animal manures. This proposal has been funded jointly by the Utah Department of Environmental Quality (UDEQ) as well as the U.S. Environmental Protection Agency (EPA) Region VIII (Denver, CO). A number of potential field plots were evaluated during the initial stages of this effort.

Soil samples were taken and analyzed for the following parameters: 1) soil texture, 2) electrical conductivity, 3) sodium adsorption ratio, 4) nitrogen and phosphorus content, and 5) pH. In addition, biosolids samples from Tooele City, Utah and Park City, Utah, as well as animal manures from Ensign Ranches, Inc. were analyzed for the following parameters: 1) moisture content, 2) total nitrogen, 3) nitrate, 4) ammonia, and 5) phosphorus content. Based on laboratory results, defensible agronomic biosolids land application rates for the two (2) biosolids and animal manures were estimated. Preliminary results were furnished to both UDEQ and the EPA through progress reports and conference calls.

Work Plan FY 05/FY 06:

The immediate focus for FY 2005 and FY 2006 is to complete the two-year biosolids land application project for the UDEQ and the EPA. This will entail, amongst other things, a comprehensive field testing program to ensure that the land application of biosolids is having a beneficial effect on marginal rangelands located in Skull Valley, Utah. Beyond completion of the biosolids land application project, both UDEQ and EPA have insisted that all the scientific information generated from this effort be presented at a nationally recognized conference and/or submitted as a technical article to a reputable environmental journal.

Benefits to the State:

The information generated from these projects will be critical for the State of Utah in identifying potential problems and opportunities associated with the beneficial use of biosolids. The 40 CFR Part 503 Rule was a risk-based regulation that was supposed to ensure reasonable protection of public health and the environment. However, identification of unanticipated adverse effects resulting from the practice of land application of biosolids may require the State of Utah to impose management standards that are more stringent than the ones currently found in the 40 CFR Part 503 Rule. It is anticipated that the results of the research will lead to management practices that will result in minimizing the indirect discharges of nitrogen and phosphorus as well as other pollutants from biosolids land application sites in the State of Utah.

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Hazardous and Toxic Waste Management

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Hazardous & Toxic Waste Management

Project Name	FY2004 Actual Expenditures	FY2005 Budgeted Expenditures	FY2006 Planned Expenditures
Ambient Particulate, Gaseous Ammonia, and Vehicular Emissions Behavior in Cache Valley, Utah	$42,171.65	$68,100.95	$71,506.00
Analysis of Environmental Organic Contaminants	$6,200.14	$16,200.14	$17,010.15
Defining the Bioavailability of Toxic Trace Elements Using Microbial Biosensors	$8,895.50	$9,162.37	$9,620.48
Evaluating the Uptake of Nonylphenol and Nonylphenol Ethoxylates by Crested Wheatgrass	$66,987.49	$51,201.13	$8,092.76
Field Scale Bioremediation	$17,880.76	$38,417.18	$0.00
Iron and Arsenic Release Due to Treatment of TCE-Contaminated Groundwater at Hill Air Force Base	$15,195.86	$25,195.86	$26,455.65
Remediation of TCE-Contaminated Groundwater at Hill AFB	$21,082.27	$31,082.27	$32,636.38
Uptake of ^{14}C-TCE by Apple and Peach Trees: Greenhouse Study	$5,414.77	$5,685.51	$0.00
Uptake of TCE by Apple and Peach Trees and their Fruit Near Hill Air Force Base (HAFB)	$5,414.77	$5,577.21	$0.00
Designated Amount for FY05/FY06 Research Projects		$100,000.00	$137,000.00
Undesignated research projects in program area		$0.00	$35,000.00
Total	**$189,243.21**	**$350,622.62**	**$337,321.42**

Ambient Particulate, Gaseous Ammonia, and Vehicular Emissions Behavior in Cache Valley, Utah

Principal Investigator(s):
Randal S. Martin
Philip Silva
Dongzi (Davis) Zhu

Project Description:

The levels of particulate matter less than 2.5 microns (PM2.5) in Cache Valley's ambient air has exceeded the 24-hour National Ambient Air Quality Standard (65 $\mu g / m^3$) in most of the last few winters. The Logan site consistently records the highest wintertime concentrations in the state, with the Utah record value being recorded February of 2002 (138 $\mu g / m^3$). Federal declaration of non-attainment status has not yet been achieved; however, the three-year averaging protocol of the standard is likely to cause official exceedance in 2005 or 2006.

The determination of the sources / causes of these elevated levels is, therefore, of great interest to local and regional regulators and scientists. The goal of this project, therefore, is to determine the composition and valley-wide behavior of the $PM_{2.5}$ particulate matter and, thereby, estimate the various source strengths. This would, in turn, allow elected officials and regulators to identify and implement the most efficient and effective remediation strategies.

Work conducted during the winters of 2000 / 2001, 2001 / 2002, and 2003 / 2004 by Dr. Martin and colleagues within Utah's Division of Air Quality (DAQ) has found that the chemical composition of the $PM_{2.5}$ can be broken down into five broad classes: light absorbing carbon (3-6%), organic carbon (16-19%), soils / metals (1-2%), sulfates (9-21%), and nitrates (43-59%). The sulfates and nitrates are typically associated with combustion, the latter especially associated with vehicular emissions. Chemically, sulfates and nitrates actually exist in the particulate phase as their ammonium salts. It is equally important to understand the atmospheric ammonia budget of Cache Valley to determine whether the basic component (NH_3) or the acidic components (NO_3 and SO_4) are the formation limiting species. Given the agricultural nature of Cache Valley, there could be an abundance of atmospheric ammonia. Further, with the dominance of nitrate and organic carbon as significant fractions of the particulate burden, understanding of the local prime source (vehicular traffic is essential).

Accomplishments:

Using Mineral Lease funds (MLF) supplied via the Utah Water Research Laboratory (UWRL), several subprojects were initiated. The operation of a PM_{10} and $PM_{2.5}$ sampling station was continued in Smithfield, Utah, approximately 10 miles north of the DAQ Logan City sampling location. This site has shown that the particulate problems are not centered in Logan, but are a homogeneous problem throughout the Valley. This is especially true during the high-concentration periods associated with January and February inversion episodes. Continuing from a smaller PM_{10} study conducted in 2002 / 2003, fifteen portable AirMetric $PM_{2.5}$ samplers on loan from the DAQ were deployed at additional sampling locations throughout Cache Valley, including the Utah State University (USU) campus, USU's Animal Science Farm, USU's Evan's Farm (Nibley), Hyrum, Wellsville, Mendon, the Cache Valley Hunter Education Center, Newton, Cornish, Richmond, Amalga, Franklin (Idaho), and Preston

(Idaho). The data showed that, within a 95% confidence interval, the winter-long $PM_{2.5}$ concentrations were equivalent throughout the valley, although there appeared to be some identifiable sites with typically lower concentration (e.g. Hyrum and Preston, ID). These results were similar to the smaller 2002/2003 PM_{10} study, but more applicable to the entire Cache Valley.

The operation of the atmospheric ammonia sampling system established October 2002 at the DAQ's Logan City sampling site was continued through 2003, until the Spring of 2004. The sampling and analysis have shown the highest ambient NH_3 concentrations on the order of 20 ppb, occurred during the winter, specifically during the periods of elevated $PM_{2.5}$ concentrations. The lowest concentrations occurred during the summer months and were on the order of 5 ppb. It should be noted that even the lower values are equivalent to concentrations reported by other investigators for highly agricultural areas. Kinetic calculations have shown that Cache Valley is indeed NH_3-rich in regards to $PM_{2.5}$ formation, indicating that more effective control strategies should target NO_x (automobile) emissions. An Environmental Engineering M.S. student (Dongzi Zhu), brought into the project in the Fall of 2002, has continually progressed with the research project and his other degree requirements, and draft final thesis delivered to Dr. Martin in December 2004.

Another project initiated in 2003, and continued through 2004, was the analysis of a vertical temperature network for Cache Valley. Frequent inversions within the Valley are significant contributors to the area's wintertime particulate problems. An inversion is physically defined as a positive change in temperature with altitude and it is the vertical location of this temperature shift which determines the height of a particular inversion and thereby the volume in which pollutants can be trapped. The elevation, frequency, and persistency of inversions are keys to understanding the local pollutant concentrations. With the aid of undergraduate researchers, a series of temperature loggers were deployed from the Valley floor up along the vertically steep Dry Canyon/Logan Canyon. Semimonthly collection of the recorded data, initiated in March of 2003 and continued through June 2004, showed clear evidence of the timing and elevation of several inversions.

In early summer 2004, in cooperation with investigators from Utah's Division of Air Quality and Utah County's Department of Health, on-road vehicle emissions were monitored at several locations throughout Cache Valley. The results suggest that implementation of a vehicle inspection and maintenance program could reduce automobile emissions into the local air shed by as much as 25-50%, depending on the specific pollutant.

Work Plan FY 05/FY 06:

Particulate sampling will continue at the Smithfield site on the current 1-in-6 day schedule. As of December 2004, discussions are being held with Utah DAQ to repeat portions of the $PM_{2.5}$ saturation study using Federal Reference Method (FRM) $PM_{2.5}$ monitors for additional validation. Recently, a real-time ammonia monitor was borrowed from the Idaho DAQ and installed at rural locations to compare with the previous ammonia sampler; this will continue throughout the year. Additional, NH_3 saturation studies are planned using passive denuder systems to examine the extent and distribution of Cache Valley ambient NH_3, furthermore, studies are being planned to quantify agricultural emissions for comparing local emission rates with nationally recommended emission algorithms. It is also planned to repeat, the vehicle emission studies under different road and weather conditions.

Benefits to the State:

A more complete understanding of the sources and behaviors of Cache Valley ambient particles will directly benefit the State of Utah by providing detailed information to the relevant authorities in order for them to make the best possible decisions regarding future remediation schemes. Data generated from these studies were instrumental in the passage of recent resolutions in Cache Valley for the future implementation of a vehicle I & M Program. Utah State University would benefit not only through the establishment of a successful research program (especially beneficial if the cooperative proposal is funded), but also through the support of both graduate and undergraduate students. Utah State University has reaped indirect benefits associated with this project via contacts established with Utah's Division of Air Quality and the Idaho Department of Environmental Quality in the form of donated research and teaching equipment, contacts for future employment of students, and presentations of graduate seminars by state personnel. Furthermore, Kori Moore, an undergraduate research student working on the vertical temperature profile studies presented some of the data at the "Poster on The Hill" presentations at the State Capitol in January of 2004 and presented the final results at a International Air & Waste Management Association convention in June of 2004, where he was awarded first place in the undergraduate division.

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Analysis of Environmental Organic Contaminants

Principal Investigator(s):
William J. Doucette
Mike Petersen
Coreen Crouch
Terry Carlsen

Project Description:

The Organic Analysis Section of the Environmental Quality Laboratory of the Utah Water Research Laboratory (UWRL) is involved with the identification and quantification of organic compounds in Utah environmental field samples, or in samples derived from laboratory experiments. Methods for the analysis of environmental organic contaminants in a variety of environmental matrices including soil, water, air, and biota are developed using techniques such as: supercritical fluid extraction, purge and trap extraction/concentration, headspace extraction, solid phase extraction, high performance liquid chromatography (HPLC), gas chromatography (GC), and gas chromatography/mass spectrometry (GC/MS).

Accomplishments:

Analytical methods utilizing HPLC, GC, and GC/MS have been developed for a wide variety of organic compounds and samples in support of laboratory and field scale studies including trichloroethylene (TCE), methyl tertiary butyl ether (MTBE), and pharmaceutical chemicals such as estradiol that affect water quality in Utah.

Work Plan FY 05/FY 06:

Method development will continue with a focus on headspace/GC/MS methods for the determination of metabolites of TCE, PAH, and MTBE in soil and plant tissue samples and solid phase extraction/HPLC methods for pharmaceutical chemicals in drinking water.

Benefits to the State:

The analytical methods developed by the Organic Analysis Section are used for the analysis of samples collected from various sites in Utah, such as Hill Air Force Base, in support of projects involved with soil and ground water monitoring and remediation.

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Defining the Bioavailability of Toxic Trace Elements Using Microbial Biosensors

Principal Investigator(s):
Joan E. McLean
Mindy Wouden

Project Description:

Regulations on the concentration of toxic heavy metals in water and soils are based on total contaminant concentration. This assessment does not provide information on potential bioavailability of the metal. The objective of this project is to develop microbial biosensors for the direct measurement of bioavailability of metals in environmental samples.

Accomplishments:

CURI proposal submitted for expanding this research effort for the analysis of bioavailable selenium, a major pollution problem in eastern Utah and of interest to the Bureau of Land Management and Forest Service. A technical paper has been prepared for publication in *Applied and Environmental Microbiology*.

Work Plan FY 05/FY 06:

To test metal bioavailability, we are developing metal detecting bioluminescent methods using *P. putida*, a root-colonizing bacterium. The bacterium produces light until there is oxidative stress in the cell on exposure to bioavailable metals. Various mutants of this bacteria are being produced that show selectivity for cadmium, lead, copper, and other metals so that an array of sensors can be developed.

Benefits to the State:

These results will be used to develop technical management strategies with regard to risks for soil, sediment, and surface and ground water contamination, and to develop approaches to reduce risk to ground water and surface water posed by metal contaminated soil in Utah. Results will be useful to the Utah Department of Environmental Quality, various municipalities in the State of Utah, the State of Utah Division of Oil, Gas, and Mining, and county agencies for developing effective water quality management programs for heavy metal contaminated sites.

Results will directly impact the counties in Utah with current metal contamination from abandoned hardrock mining and counties planning to expand industries and development in the State of Utah.

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Evaluating the Uptake of Nonylphenol and Nonylphenol Ethoxylates by Crested Wheatgrass

Principal Investigator(s):

William J. Doucette
Ronald C. Sims
Bruce Bugbee
Julie Chard
Mike Petersen
Coreen Crouch
Terry Carlsen
Erik Dettenmaier
Clint Rogers

Project Description:

Nonylphenol ethoxylates (NPEs) are widely used surfactants that are commonly disposed of in wastewater collection systems in Utah. NPEs are subject to biological treatment within wastewater treatment facilities, but measurable amounts of untreated NPE and biodegradation intermediates such as nonylphenol (NP) have been identified in digested sewage biosolids. These biosolids are often applied to agricultural soils for their nutrient value. Further biodegradation of NPE and NP within the soil / biosolids system has been observed, but little is known about the potential of plants to take up these compounds or their metabolites.

Accomplishments:

Microcosm experiments were conducted to evaluate the fate of nonylphenol (NP), nonylphenol tetraethoxylate (NPE_4), and nonylphenol nonylethoxylate (NPE_9), in a soil / biosolids system (99.5 / 0.5% w / w). Planted and unplanted microcosms were compared to determine the impact of plants (crested wheatgrass) on degradation and to evaluate the potential uptake and translocation of these compounds into above ground plant tissue. Poisoned controls were used to quantify abiotic losses. Biosolids collected from a municipal wastewater treatment plant were spiked with NP, NPE_4, and NPE_9 (^{14}C-labeled and unlabeled), allowed to age for 14 days, then mixed with an agricultural soil to yield nominal concentrations of 5, 20, and 40 mg / kg. A single concentration of ^{14}C-phenol (20 mg / kg) was also evaluated as a readily degradable compound for comparison. Mineralization during the course of the study was quantified by collecting the $^{14}CO_2$ produced. Plant shoot tissue was analyzed for ^{14}C at 50 and 83, days and shoot and roots at 150 days by combustion and liquid scintillation counting; parent compound was evaluated at the completion of the study using supercritical fluid extraction and GCMS or HPLC. Mineralization at the end of the study (150 days) for non-poisoned microcosms ranged from 6% (NP) to 53% (phenol). There was no significant difference in mineralization between the planted and unplanted systems. Plant uptake was a function of exposure concentration and amount of water transpired. For NP, NPE_4, and NPE_9, most of the ^{14}C concentration in the plant tissue was associated with the roots $\approx$ 60 %. Concentrations of ^{14}C in the foliar tissue ranged from 1.2 to 61 mg-equivalent per kg (dry weight). However, preliminary HPLC results suggest that most of the ^{14}C was in the form of metabolites or was inextractable.

Work Plan FY 05/FY 06:

The final year of the project will focus on determining the identity of the ^{14}C in the plants using GC and HPLC/MS. Based on the results obtained in FY 2004, it is hypothesized that NP, NPE_4 and NPE_9 are degraded to a common metabolite that is taken up into the plant. Metabolite standards will be obtained from APERC or other sources in order to verify the identify of the common metabolic product.

Benefits to the State:

Quantitative information regarding potential plant uptake and transfer of NP and other surfactant-related compounds into plant foliar tissue is needed by the State of Utah to determine appropriate loading rates for the land application of municipal sewage sludge (biosolids). The Utah Water Research Laboratory is collaborating with the Utah Department of Environmental Quality (UDEQ), Division of Water Quality, to identify land application sites for sampling and analysis. The information developed in this project will be provided to the UDEQ.

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Field Scale Bioremediation

Principal Investigator(s):
Ronald C. Sims
Darwin L. Sorensen
J. Karl Nieman
Yanna Liang
Kevin Hall

Project Description:

This year we completed Phase III, the final phase, of the project to design and develop a gene probe that can be used for soil bioremediation in Utah. The gene probe can be used for: (1) determining the presence of polycyclic aromatic hydrocarbons (PAH) degrading microorganisms at a site, (2) monitoring the rate and extent of bioremediation at a site, and (3) determining the effect of nutrients and other management tools for increasing the presence of PAH-degrading microorganisms at a site.

Accomplishments:

The discovery by the research team of the new microorganisms that have the capability to biologically destroy carcinogenic chemicals in soil and water systems, mycobacteria JLS, KMS, and MCS, were further studied. In order to understand the application of these microorganisms to soils and vegetation for enhancing treatment of contaminated soil, we submitted a proposal to the U.S. Department of Energy Joint Genome Institute for obtaining critical genetic information on the three organisms.

The proposal to the U.S. Department of Energy Joint Genome Institute was funded at a value of $1.7 million for the identification of the genetic composition of the three microorganisms discovered at Utah State University. The information will be developed by the U.S. DOE/JGI and supplied to the USU researchers during the next year. The results will provide critical information on the genetic and biochemical properties of these microorganisms that will enable them to be applied in engineering systems for the cleanup of contaminated soils and groundwater resources in Utah.

Genetic probe was designed, built, and tested.

Refereed Publications:

Hall, K., C. Miller, K. Nieman, J. McLean, A. Anderson, and R. Sims (2004). Development of a catabolically significant genetic probe for polycyclic aromatic hydrocarbon-degrading mycobacteria in soil. *Biodegradation Jour.,* October.

Miller, C.D., K. Hall, Y.N. Liang, K. Nieman, D. Sorensen, B. Issa, A.J. Anderson, and R.C. Sims (2004). Isolation and characterization of polycyclic aromatic hydrocarbon-degrading Mycobacterium isolates from soil. *Microbial Ecology*, 48(2):230-238.

Work Plan FY 05/FY 06:

Project completed.

Benefits to the State:

Provide cost-effective and efficient technology for cleanup of soil contaminated with carcinogenic polycyclic aromatic hydrocarbons (PAH).

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Iron and Arsenic Release Due to Treatment of TCE-Contaminated Groundwater at Hill Air Force Base

Principal Investigator(s):

Joan E. McLean
Darwin L. Sorensen
R. Ryan Dupont
Jeanette M. Norton
Heather Mickelson

Project Description:

This research project examines the use of various carbon sources to degrade TCE in groundwater at Hill Air Force Base. A consequence of such treatments is the extensive reduction of Fe(III) minerals with the release of Fe(II) and arsenic to groundwater. We are studying the mechanisms of Fe release under these imposed reducing conditions and how these reactions may inhibit the reduction of TCE.

Accomplishments:

Laboratory scale treatability studies are being used to evaluate the rate and extent of Fe(II) production and define changes in Fe(III) minerals.

Work Plan FY 05/FY 06:

Technical paper prepared for publication: Iron and arsenic release from aquifer solids during enhanced TCE degradation (McLean, Sorensen, and Dupont).

Proposal submitted to the Utah State University Center for Integrated Biology (CIB): Metagenomic evaluation of microbial community succession, iron reduction, and dehalorespiration in biostimulated aquifers (Cutler, Dupont, McLean, Norton, Sorensen).

White paper submitted to CIB: Genomics-based exploration of the microbial ecology of TCE dehalogenation (Sorensen, Norton, Dupont, McLean) rewarded $50,000.

Presentation at annual meetings of the American Society of Microbiology: Can Fe(III) reduction block or delay the development of a TCE dehalogenating community in biostimulated aquifers? (Sorensen, Dupont, McLean, Norton, Zhou, and Mickelson).

Presentation at annual meetings of the Inland Northwest Research Alliance (INEL): Functional group and 16rRNA clone library of dechlorinating cultures (Zhou, Dupont, Sorensen, Norton, McLean).

Benefits to the State:

Many military and industrial sites have groundwaters contaminated with TCE due to past disposal practices. On-site remediation methods are needed for cleanup of such sites as Hill Air Force Base, Tooele Army Depot, and Dugway Proving Grounds. Results will directly impact the counties in Utah with military bases or industries using chlorinated solvents.

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Remediation of TCE-Contaminated Groundwater at Hill AFB

Principal Investigator(s):
R. Ryan Dupont
Joan E. McLean
Darwin L. Sorensen
Jing Zhu
Han Lai

Project Description:

The objective of this study is to evaluate the effectiveness of biostimulation (carbon donor addition) for the remediation of TCE contamination at several sites at Hill Air Force Base (AFB), versus the need for the addition of a known dechlorinating culture (the Bachman Road culture) to stimulate TCE dechlorination and the removal of TCE contamination at these sites. In addition, engineering design information and appropriate monitoring methods are being developed that will lead to field-scale technology demonstration studies and full-scale site remediation.

Accomplishments:

This Water Lab support is associated with two recently completed projects and two ongoing projects that have involved the construction of laboratory-scale anaerobic microcosms containing soil and groundwater from two sites at Hill AFB, OU5 and OU2. These microcosms were amended with a variety of carbon donors to drive them anaerobic and to attempt to stimulate the degradation of TCE that exists as soil and groundwater contamination from historical waste disposal practices. Microcosms were sampled over time to assess the rate of TCE degradation, if any, in response to this carbon addition. Following the carbon only studies, additional studies have been completed to evaluate the effectiveness of bioaugmentation (the addition of small volumes of a known dechlorinating culture isolated from a contaminated site in Michigan) as a means of stimulating TCE degradation that did not occur in response to carbon addition alone. Again, mixtures of site soil, groundwater, and dechlorinating culture were added together under anaerobic conditions, were incubated and sampled over time to quantify the degradation of TCE and its daughter products that were found to occur with culture addition. Identification of optimal carbon donor and microbial culture combinations from these microcosm studies have lead to the final design of pilot-scale, flow-through column experiments that began in FY 04 and that are ongoing in FY 05.

Work Plan FY 05/FY 06:

Monthly Progress Reports, two Final Engineering Project Reports, Battelle Bioremediation Conference Platform Presentation, Conference Proceedings Paper and Posters, three proposals to various campus and external funding agencies to continue the molecular biology component of this work.

Benefits to the State:

Soil and groundwater samples from Hill AFB, Operable Units 5 and 2 have been used in laboratory microcosm studies to evaluate the effectiveness of carbon donor and microbial inocula addition in stimulating TCE remediation and removal from contaminated soil and groundwater. Soil from OU5 has

been used in large-scale flow-through columns to evaluate TCE degradation rates in preparation for full-scale demonstration at the Hill site. Results have indicated the need for bioaugmenation at OU5, and have demonstrated the need for additional controls at OU2 to prevent undesirable degradation products from being produced and released from the site. These findings have provided site specific remediation design information that has been used to finalize remediation approaches at OU5 and has prevented Hill from making large scale expenditures in field studies that have been shown at the lab-scale to be ineffective.

Field site and soil and groundwater samples collected from a location in Weber County directly adjacent to Hill AFB. The primary benefit is to residents that live adjacent to Hill, but findings and methods for monitoring and process analysis are relevant at TCE-contaminated sites throughout Utah.

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Uptake of ^{14}C-TCE by Apple and Peach Trees: Greenhouse Study

Principal Investigator(s):

William J. Doucette
Bruce Bugbee
Coreen Crouch
Mike Petersen
Julie Chard
Brandon Chard
Rebecca Parisi
Clint Rogers
Demetrio Cabanillas
Tiffany Leo

Project Description:

A greenhouse study was conducted to quantify the uptake of ^{14}C-trichloroethylene (TCE) by apple and peach trees and determine if TCE or ^{14}C was transferred into edible fruit. Triplicate dwarf apple and peach trees were subsurface irrigated with solutions of TCE (^{14}C-labeled and unlabeled) at total concentrations of approximately 5 and 500 µg/L. These concentrations bracketed groundwater levels observed during a field survey conducted in the fall of 2001 where trace levels of TCE were detected in several fruit samples collected from residential areas surrounding Hill Air Force Base (HAFB), Utah. Control trees were grown within the canopy of the dosed trees and in a separate greenhouse. Tissue samples (leaves, stems, fruit, trunk, roots) were analyzed for TCE and ^{14}C using headspace gas chromatography mass spectrometry (HS/GC/MS) and combustion/liquid scintillation counting (LSC).

Accomplishments:

All non-control plant tissue contained measurable levels of ^{14}C and the levels were proportional to the exposure concentration and amount of water transpired. ^{14}C concentrations were greatest in leaves followed by stems and fruits. No TCE was detected in any tissue samples except in the lower portion of the trunk and the roots. This implies that the ^{14}C detected in the leaves and fruit is associated with nonvolatile TCE transformation products and/or TCE strongly bound to the plant tissue. TCE metabolites trichloroacetic acid (TCAA) and dichloroacetic acid (DCAA) were identified only in leaves from a high dose apple tree.

Fruit were regularly sampled throughout the study and ^{14}C concentrations were highest in individual fruit midway through the season. This may indicate that a majority of the ^{14}C (TCE or TCE metabolites) moves into fruit early in the season when the fruit receives a greater percentage of their water from xylem and is diluted as the fruit grows. Fruit/soil bioconcentration factors (BCFs) could not be calculated for TCE since it was not identified in the fruit. However for ^{14}C, fruit/soil BCFs ranged from 0.07 to 0.01 for apples and peaches, respectively which are an order of magnitude less than previously modeled for TCE. The results suggest that the likelihood of TCE contamination of apples and peaches growing over TCE contaminated groundwater plumes is minimal but the identity of the ^{14}C in fruit must be determined before a final risk assessment can be conducted.

Work Plan FY 05/FY 06:

Sampling and analysis of fruit and fruit trees for ^{14}C and TCE continued through the 2004 growing season. The greenhouse project is anticipated to end after the fall 2004 sampling.

Benefits to the State:

The potential uptake and transfer of TCE and other chlorinated solvents into fruits and vegetables is a critical concern for residents living near Hill Air Force Base. Results obtained from this study will benefit the State of Utah by providing baseline information that can be used in screening level-risk assessments.

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Uptake of TCE by Apple and Peach Trees and their Fruit Near Hill Air Force Base (HAFB)

Principal Investigator(s):

William J. Doucette
Bruce Bugbee
Coreen Crouch
Mike Petersen
Julie Chard
Brandon Chard
Rebecca Parisi
Clint Rogers
Demetrio Cabanillas
Tiffany Leo

Project Description:

Trichloroethylene (TCE) contaminated groundwater originating from Hill Air Force Base (HAFB) in northern Utah has migrated into surrounding communities. In the fall of 2001, a preliminary survey of edible fruit and vegetables growing above contaminated groundwater plumes in the communities of Clinton, Layton, Riverdale, Roy, South Weber, and Sunset was conducted. Low levels of TCE were found in several samples ranging from non-detect to 18-µg/kg fresh weight using a headspace gas chromatography electron capture detection method. A follow-up survey conducted in Fall 2002, found no TCE in any edible fruit or vegetables above the method detection limit. However, TCE was identified by GC/MS in several fruit samples below the reporting limit and was consistently found in cores collected from some of the fruit trees. The apparent difference between the Fall 2001 and 2002 results was thought to be the result of more conservative reporting limits, improved data quality (no false positives) and/or changes in the environmental conditions associated with transfer of TCE into fruit.

Accomplishments:

To further evaluate TCE uptake and transfer into fruit and examine the potential variations in concentrations over the growing season, a third more focused study was initiated in June 2003. Five sampling sites were selected for more comprehensive sampling based on several criteria including: previous years participation, depth to groundwater, TCE groundwater concentration, and availability of mature fruit trees. Groundwater samples were also collected biweekly from July through early October in 2003. Over 1,100 plant tissue samples (fruit, stems, cores) were collected and TCE was found in only three fruit samples above the average method detection limit of 0.1 µg/kg fresh weight.

Work Plan FY 05/FY 06:

Sampling and analysis of fruit and fruit trees for TCE at the five sites sampled in 2003 will continue. The field project is anticipated to end after the fall 2004 sampling.

Benefits to the State:

The potential uptake and transfer of TCE and other chlorinated solvents into fruits and vegetables is a critical concern for residents living near Hill Air Force Base. Results obtained from this study will benefit the State of Utah by providing baseline information that can be used in screening level risk assessments.

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Water Quality Engineering

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Water Quality Engineering

Project Name	FY2004 Actual Expenditures	FY2005 Budgeted Expenditures	FY2006 Planned Expenditures
Development of Sediment Management Protocols for Small Diversion Reservoirs in Utah	$12,303.51	$42,303.51	$44,418.69
Echo Reservoir TMDL Study	$6,417.40	$6,609.92	$0.00
Fate of Pharmaceuticals in Drinking Water Treatment Plants: Bench and Pilot Scale Evaluations	$5,414.77	$0.00	$0.00
Process Performance Indicators for Arsenic Removal	$44,024.85	$45,345.60	$0.00
Real Time Streamflow and Water Quality Monitoring Station in the Logan River at the Utah Water Research Laboratory (UWRL)	$6,417.40	$21,417.40	$32,488.27
Source Water Protection Tools Development	$79,196.98	$81,572.89	$85,651.53
Utah On-Site Wastewater Treatment Training Program	$18,450.87	$48,450.87	$50,873.41
Weber/Ogden Basin Water Quality Study	$20,238.93	$20,846.10	$0.00
Designated Amount for FY05/FY06 Research Projects		$0.00	$30,000.00
Undesignated research projects in program area		$0.00	$13,000.00
Total	**$192,464.71**	**$266,546.28**	**$256,431.90**

Development of Sediment Management Protocols for Small Diversion Reservoirs in Utah

Principal Investigator(s):
Mac McKee
Blake Tullis
Ronald C. Sims
Thirumurugan Bose

Project Description:

Uncontrolled sediment releases from small reservoirs have been shown to produce deleterious impacts on downstream fish populations and their habitat. This is a significant non-point source water quality problem in Utah and around the west. The purpose of this project is to develop and disseminate management guidelines for the flushing of sediments from small reservoirs to minimize environmental impacts on water quality and aquatic resources, with emphasis on reservoirs located in regions with arid climates, such as Utah. These guidelines will be based on hydrology and geology of the watershed within which the reservoir is located, and on the hydraulic characteristics of the reservoir itself. The project will use First Dam, a small dam owned by Utah State University on the Logan River at the mouth of Logan Canyon, as a case study.

Accomplishments:

The project began in late FY 2003. It has developed an extensive literature review of reservoir flushing and sluicing approaches and available models for evaluating sediment mobilization needs and methods in reservoirs. A plan for controlled flushing of sediments from First Dam has been developed, including monitoring procedures to ensure protection of downstream fisheries resources during flushing events. A stream gauging station has been installed downstream of First Dam so that real-time flows can be measured during flushing events as well as throughout the rest of the year.

Work Plan FY 05/FY 06:

Work in FY 2005 will focus on the implementation of a water quality and stream flow monitoring program. The plan will be tested through controlled releases of sediment during spring runoff, and the effectiveness of these controls will be evaluated from monitoring data. The experience gained from sediment management experiments on First Dam will be used to develop guidelines for management of sediment in small diversion reservoirs in Utah. Results to date will be presented at the Utah Water Users Conference in March, 2005.

Benefits to the State:

The knowledge gained from experimentation at First Dam will be used to prepare general guidelines appropriate for sediment management on the approximately 200 small reservoirs in Utah. These guidelines will address such factors as:

- Implications of watershed geology for water chemistry and sediment toxicity.
- Implications of watershed hydrology for sediment loading rates.
- Recommendations for most effective and / or least costly sediment control methodologies, based upon reservoir size, geomorphology, and bathymetry.
- Recommendations for flushing procedures, based on active reservoir volume, current morphologic characteristics of sediment deposits, inflow rates and discharge capacities, hydraulic limitations on control of outlet works, potential toxicity of bottom sediments, and downstream water quality regulations that must be met.

Dissemination in electronic and hard copy form of the general guidelines to Utah water resources agencies, river commissioners, water conservation districts, and dam owners and operators.

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Echo Reservoir TMDL Study

Principal Investigator(s):
Eric Duffin, Cirrus Environmental
David K. Stevens
Daniel Ames
Jeff Horsburgh
Eric Wahlstrom
Crystal Yap
Bok Nam Lee

Project Description:

Echo Reservoir, in Summit County, Utah, is the subject of a total maximum daily load (TMDL) project to protect its long-term use as a mixed-use reservoir for irrigation, recreation, and culinary water support. It is protected for primary contact recreation (swimming) and as a cold-water fishery. Excessive phosphorus loadings into the reservoir have resulted in the deterioration of the fish-habitat resource and have resulted in excessive algal growth leading to deterioration of the resource as a culinary water supply. The objectives of this project are to establish existing phosphorus loading conditions to the reservoir, to develop acceptable loadings for restoring the reservoir for these purposes, and to develop an implementation plan for load reduction.

Accomplishments:

Work in this project began in FY 03, in conjunction with a Cache Valley environmental consulting company, Cirrus Environmental. Utah State University's role was to build a flow and water quality database, complete a river basin flow balance and water quality assessment, estimate existing phosphorus loading to Echo Reservoir, and provide reports and technical memos concerning these activities. Some of these goals have been accomplished. Others have been delayed at the request of the State of Utah until FY 04.

Work Plan FY 05/FY 06:

Our role was to provide technical support to Cirrus Environmental in the development of the load allocation and implementation plans for the TMDL. Under this support umbrella, Utah State University has provided data collection and management support, mathematical modeling, loading calculation, and implementation planning.

Benefits to the State:

This project is being carried out in conjunction with the State of Utah and Cirrus Environmental. The results of this work are a data report, and loading report, and a set of computer-based data visualization and analysis tools to aid the State establishing and implementing load reductions to return Echo Reservoir to its designated use.

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Fate of Pharmaceuticals in Drinking Water Treatment Plants: Bench and Pilot Scale Evaluations

Principal Investigator(s):
William J. Doucette
Laurie McNeill
Ronald C. Sims
Coreen Crouch
Mike Petersen
Julie Chard
Clayton TenEyck
Clint Rogers
Demetrio Cabanillas
Tiffany Leo

Project Description:

The potential impact of drinking water treatment processes (coagulation / flocculation, sedimentation, filtration, and ozonation) on the removal of low levels of pharmaceuticals was evaluated for four compounds (caffeine, estradiol, salicylic acid, and trovafloxacin mesylate) using pilot (23-26 L / min) and bench (0.03 L / min) scale systems. The compounds were selected to be representative of a variety of pharmaceuticals in terms of charge (neutral, cationic, anionic and zwitterionic) and expected fate within drinking water treatment facilities. Pilot and bench systems were compared to determine the influence of scale on contaminant fate. The pilot scale system, owned and operated by the Metropolitan Water District of Salt Lake City and Sandy, Utah was used to optimize treatment in a conventional plant and evaluate ozonation processes. The bench scale system was designed and constructed to mimic the operation of a full-scale system.

Accomplishments:

Test compounds were added to the influent of each system to yield concentrations from 100 to 500 µg / L. The concentrations used were based on the analytical detection limits for each compound. Influent and effluent samples were collected from each treatment operation over time and analyzed by HPLC to determine removal. Conventional treatment (coagulation, flocculation, sedimentation, and filtration) removed 100% of the estradiol and trovafloxacin mesylate, 17% of the caffeine and none of the salicylic acid in the pilot plant trials. Ozonation, evaluated as an isolated treatment option, removed 63%, 12%, 99% and 7% of the estradiol, trovafloxacin mesylate, caffeine, and salicylic acid, respectively. Similar results were observed at the laboratory scale with removals of 100%, 100%, 18%, 10% using conventional treatment and 100%, 33%, 31%, and 11% using ozonation for estradiol, trovafloxacin mesylate, caffeine and salicylic acid, respectively. The results suggest that conventional treatment is not effective in removing highly water soluble compounds like caffeine and salicylic acid, but may remove less soluble compounds such as estradiol and trovafloxacin mesylate. Ozonation, used in addition to conventional treatment, may provide additional compound removal. The results also imply that a properly designed laboratory scale system can provide useful information regarding the fate of pharmaceuticals in drinking water treatments plants.

Work Plan FY 05/FY 06:

The project was completed July 2004.

Benefits to the State:

Evaluating the potential removal of pharmaceuticals during drinking water treatment processes is an important issue for regulatory involved in setting drinking water standards. Results obtained from this study will benefit the State of Utah by providing baseline information that can be used in screening level-risk assessments.

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Process Performance Indicators for Arsenic Removal

Principal Investigator(s):
Laurie McNeill
Ryan D. Anderson

Project Description:

Due to increasing concern about the adverse health effects from exposure to low levels of arsenic in drinking water, the United States Environmental Protection Agency (USEPA) has lowered the Maximum Contaminant Level (MCL) for arsenic from 50 ppb down to 10 ppb. Utilities trying to meet the new MCL must be able to accurately measure arsenic concentrations in their raw and treated water. Although there are well-established laboratory methods for quantifying arsenic at concentrations less than 1 ppb, they require instrumentation that is expensive, complicated and not available at the typical utility. In fact, most water treatment utilities, especially the smaller utilities that will be most affected by the new arsenic MCL, must send samples off-site to a contract or state laboratory for arsenic analysis. This is not only expensive, but can also make it difficult for a utility to optimize arsenic removal due to the time lag between collecting a sample and receiving the analytical results. The goal of this project is to develop a fast, safe, easy-to-use and relatively inexpensive field test that can quantify arsenic at the low ppb level. The methods being investigated are based on standard hydride generation followed by arsine detection with a portable gas monitor.

Accomplishments:

Laboratory studies combined with field testing of the method at eleven water utilities (including four in Utah).

Work Plan FY 05/FY 06:

Project report published by AWWARF, paper in progress for journal publication.

Benefits to the State:

The State of Utah will be particularly hard hit by the new arsenic regulation, with an estimated 50 water systems impacted by the new MCL. The estimated cost of compliance with the new rule for the State of Utah is $63 million. The vast majority of the impacted utilities are small groundwater systems that have little or no treatment in place, so meeting the new MCL may be very complicated and expensive. Four Utah water utilities (Metropolitan Water District of Salt Lake and Sandy, Taylorsville-Bennion Improvement District, Eagle Mountain Water System, and City of Delta) were among the eleven utilities who tested the field detection method at their plant. This testing provided method validation for the project and also provided the utilities with free, instantaneous arsenic analysis in their water. Dr. McNeill will work with the Utah Division of Drinking Water, the Utah Rural Water Association, and the Utah Water Quality Alliance to offer this developed field method for Utah water utilities wishing to use it.

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Real Time Streamflow and Water Quality Monitoring Station in the Logan River at the Utah Water Research Laboratory (UWRL)

Principal Investigator(s):
David K. Stevens
Jeff Horsburgh

Project Description:

This proposal is to request funds from the Utah State University (USU) Water Initiative Research Initiation Program for the creation of a real time water quality monitoring station in the Logan River. This real time monitoring station, to be located in the Logan River near the USGS gaging station at the exit from Logan Canyon, Logan, Utah (USGS 10109000), will provide continuous monitoring of water quality and will be coupled with the data stream from the existing real time USGS streamflow gage to provide a high frequency, continuous record of streamflow and water quality, with real-time climate data from the UWRL weather station funded separately. These data will support integrated water-related research and educational activities at USU and the Utah Water Research Laboratory (UWRL). The proposed monitoring station will also serve as a model in terms of logistics, equipment, and partnerships for potential future real time monitoring stations located throughout the Bear River Watershed in support of the Water Initiative's Laboratory Watershed effort.

Accomplishments:

This project began in FY 04. Instrumentation has been purchased and installation is progressing.

Work Plan FY 05/FY 06:

In FY 05 we will complete instrumentation installation and begin water quality and flow monitoring.

Benefits to the State:

The results of this work are to be a working real-time water quality monitoring station, supporting software and internet interface, and a data report.

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Source Water Protection Tools Development

Principal Investigator(s):

Darwin L. Sorensen
David G. Tarboton
Mariush W. Kemblowski
David K. Stevens
Nancy Mesner
R. Ryan Dupont
Gilberto E. Urroz
Ronald C. Sims
Donald T. Jensen
Saraubh Gogate
Qiang Shu
Nickhil Monga

Project Description:

Integrate the principles of watershed management and drinking water quality management into the development of a simplified exploratory hydrologic and pollutant transport model that retains indispensable mechanisms to provide managers with an assessment system with low data requirements.

Accomplishments:

The USGS ground water model, MODFLOW, and the companion ground water quality model MT3D were interfaced with the graphical user interface of the computer program. Users will be able to evaluate the potential for contamination of well water used for drinking water. It will also allow them to consider the potential for contaminated ground water to degrade the quality of water in streams and reservoirs that may be diverted for drinking water treatment. The development of a modeling component for the fate and transport of pollutants through reservoirs was in progress. The modeling system was described, with an emphasis on its use of geographic information systems, in a presentation entitled "Terrain Analysis for Water Quality Modeling" at the American Water Resources Geographic Information Systems (GIS) and Water Resources III Specialty Conference in Nashville, Tennessee.

Work Plan FY 05/FY 06:

The tool includes a simplified exploratory hydrologic and pollutant transport model that retains indispensable mechanisms to provide managers with an assessment system with low data requirements. The model output is a first approximation of contaminant concentration at the drinking water treatment source point of diversion (POD). The model results may prompt questions about pollutant transport that can lead to an enhanced understanding of human activities and natural systems that influence unacceptable contamination risks. Major advantages of this modeling approach are that fundamental elements of watershed hydrology are included and arbitrary management boundaries are not used.

The development of Geographic Information Systems (GIS) and Digital Elevation Models (DEMs) has provided an unprecedented opportunity to describe the pathways of water movement in a watershed. Tarboton (1997) developed a procedure for the representation of flow direction and calculation of upslope areas using rectangular grid DEMs. This procedure has been included in the Terrain Analysis using Digital Elevation Models (TauDEM) software (Tarboton 2000; Tarboton 2002) that is used as a basis for the Surface Water Protection Assessment Tool (SWPAT) that is being developed. Overland flow and the transport of contaminants simulated in the assessment tool are routed using the surface flow model.

Visualization of the locations of potential contaminant sources relative to stream locations and topography within a watershed along with the possible route or routes of pollutant transport provides watershed managers with insight that can help in the risk ranking process and in selecting or designing pollution control mechanisms. GISs provide an elegant mechanism for displaying this kind of information as well as facilitating models for routing water and associated pollutants through the watershed to the drinking water treatment plant.

The tool assists the user in inventorying potential pollution sources within the watershed. We have essentially completed the development of the surface water transport portion of the model and have been focusing on groundwater transport processes.

Benefits to the State:

Utah drinking water purveyors are engaged in planning and conducting source water protection programs. The drinking water industry uses a multi-barrier approach to protecting the safety of drinking water that is distributed to the public. Assuring a safe source of untreated water is the first barrier. Protective measures may be expensive and land use restrictions to protect water quality can decrease the potential for development. It is very important that source water assessments correctly identify potential risks and present a scientifically credible evaluation of the magnitude of the risk so that public health can be protected while the monetary and social costs of protective management are minimized. It is vital that sound scientific principles are used to direct the assessment approach and that arbitrariness is avoided.

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Utah On-Site Wastewater Treatment Training Program

Principal Investigator(s):
Judith L. Sims
Ronald C. Sims
Margaret M. Cashell
Richard Jex
Darwin L. Sorensen
J. Karl Nieman
Todd Wright

Project Description:

The Utah On-Site Wastewater Treatment Training Program was established in January, 1998 in cooperation with the Utah Department of Environmental Quality (DEQ) and the twelve Utah local health departments to provide classroom and field (hands-on) training to Utah homeowners, regulators, designers, installers, pumpers, and other stakeholders in on-site wastewater treatment systems.

Adequately protecting environmental health and enhancing user satisfaction are achieved through knowledgeable selection, competent design, correct installation, and proper operation of on-site systems. Applying the right technology in the right place depends on having accurate information and up-to-date training. Landowners, homeowners, developers, lenders, installers, regulators, planners, municipal authorities, and elected authorities are all stakeholders in Utah on-site issues and must have current information and training to address these matters responsibly.

Properly selected, designed, installed, and operated on-site wastewater treatment systems provide high levels of protection of human health and environmental quality. However, some systems do fail, with most of the documented failures of these systems occurring by discharge of effluent into saturated soils, backup into the house, or wastewater ponding on the soil surface. Systems are also considered to be failing if wastewater effluents high in nitrogen, phosphates, or pathogenic microorganisms reach surface or groundwater resources. Training of all those involved in wastewater treatment and disposal, i.e., those who evaluate a site to see if it is suitable for an on-site system, those who design and install the system, regulators who oversee the system, and homeowners who operate the system, will aid in the prevention of such failures.

Utah will continue to grow, and housing developments will continue to expand into current open space. Such development may include areas of groundwater recharge, shallow soils, or shallow groundwater. Current Utah rules allow the use of conventional septic tank systems as well as three alternative treatment systems that may be installed in areas with soils unsuitable for conventional systems. Training of those involved in the use of alternative systems will ensure that these types of systems, which require more management, will operate effectively.

In this project, statewide training addressing state-mandated certification of persons associated with and responsible for wastewater treatment for on-site (septic) systems is conducted and coordinated. Personnel trained included local health department personnel, on-site system site evaluators, designers, and installers, and the general public with an interest in on-site wastewater treatment.

Accomplishments:

A state legislative initiative was introduced and passed as House Bill 14s during the 2001 Legislative Session to develop a certification program for persons involved in siting, designing, operating, and maintaining both conventional and alternative on-site systems. The certification program, administered by the Division of Water Quality in the Utah Department of Environmental Quality, involves training provided by the Utah On-Site Wastewater Treatment Training Program.

The certification program includes three levels, each of which requires workshops provided through the Utah On-site Wastewater Treatment Training Program:

Level I: Soil Evaluation and Percolation Testing

Level II: Design, Inspection, and Maintenance of Conventional Systems

Level III: Design, Operation, and Maintenance of Alternative Systems

Level III Certification expires after two years, so we are also conducting Level III recertification workshops.

In addition, we are providing leadership in the development of an on-site wastewater treatment professional program (Utah On-Site Wastewater Association [UOWA]) to promote, facilitate, and elevate the professional development of individuals in the on-site industry and also to increase public awareness and education concerning on-site wastewater treatment issues.

Work Plan FY 05/FY 06:

Several series of workshops will continue to be provided in support of the certification program for on-site wastewater professionals. We will also continue our work with the UOWA, especially in helping to plan conferences and educational meetings and in facilitating the annual election process for members of the board of trustees.

We will also focus on the development of educational brochures for homeowners, system designers and installers, and other decision-makers involved in on-site wastewater treatment.

During FY 2004, the following workshops in support of the certification program were held:

Level I: Vernal, September, 2003; Tooele, October, 2003; St. George, March, 2004; and Heber City, May, 2004.

Level II: Vernal, September, 2003; Tooele, October, 2002; St. George, March, 2004; and Heber City, May, 2003.

Level III: Logan, November, 2003.

On May 5, 2004, we sponsored an educational meeting at the Utah Water Research Laboratory concerning the use of peat filters for on-site wastewater treatment. Approximately 35 people attended.

In addition, Dr. Ronald Sims, provided assistance to the State of Utah with regard to on-site wastewater treatment issues as a member of the Utah Water Quality Board. Ms. Sims served as the past chairman of the UOWA and also acted as chairman of the annual conference planning committee.

Benefits to the State:

As population growth and associated housing developments continue to threaten the preservation of agricultural lands in Utah, there is an increased need for accurate and thorough information on on-site wastewater treatment technologies. The Utah On-Site Wastewater Treatment Training Program addresses these challenges through such means as workshops, newsletters, and educational brochures.

Many of the soils in Utah are marginal or unacceptable for use for conventional soil absorption systems due to high or fluctuating water tables, slowly permeable or highly permeable soil horizons, and extreme slopes. Experience with and knowledge of alternative systems that can be utilized on such sites with unsuitable conditions is generally low in Utah. The On-Site Training Program also provides the necessary education to utilize alternative systems in an effective manner that will protect both public health and the environment.

The Utah On-Site Wastewater Treatment Training Program is being considered as a model for other states as they develop certification and training programs.

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Weber/Ogden Basin Water Quality Study

Principal Investigator(s):
David K. Stevens
Thomas B. Hardy
Jeff Horsburgh

Project Description:

One of the pressing issues in the Weber Basin in Utah is lake eutrophication from increased phosphorus and nitrogen from point and non-point sources. Population density and resultant sewage disposal is also causing increase in biological contamination in the surface and groundwater associated with numerous reservoirs.

The purpose of this study is to assist the State of Utah, local governments, and water districts in monitoring and understanding water quality in the Weber Basin. Specific water quality problems and their causes will be identified, and specific measures which should be implemented to preserve or enhance water quality will be determined. The study will result in a report documenting specific water quality problems and their causes and the procedures for implementing nonstructural or minimally structural solutions for preserving or improving water quality. Utah State University's (USU) role, in conjunction with the U.S. Bureau of Reclamation (USBR), Weber Basin Water Conservancy District (WBWCD), and the State of Utah Department of Environmental Quality (UDEQ), is to provide expertise in development of computer based decision support tools and models for water quality prediction and improvement in the Weber Basin.

Accomplishments:

In FY 03, a request was made by the USBR to investigate modifications to the model and decision support package to allow for simultaneous partial releases from reservoirs that would more closely track the day-to-day operation of the Weber Basin system. After considerable effort, it was found that fundamental limitations in the water balance model preclude these modifications within the existing scope of work. Additional requests were made by the Weber Basin Water Conservancy District to modify the Decision Support Software (DSS) to allow for direct modification of flows and water quality as model inputs at control points that were previously estimated from the database and upstream model simulations. A prototype of this modification was completed and is in review by USBR and WBWCD. An outline of the final report has also been submitted for USBR review.

In FY 04, estimates were determined for the level of effort required to modify the water balance model for the purpose of simulating partial releases from reservoirs and it was found that the level of effort was excessive for the current contract. Avenues for funding this effort will be pursued in FY 05. The modifications to the DSS for direct modification of flows and water quality at controls points were completed and tested and are now part of the DSS package. The final report outline was reviewed and the final report will be completed in FY 05.

Work Plan FY 05/FY 06:

Work will be carried out by project PI's under a no-cost project extension to complete model modifications and final reporting.

Benefits to the State:

This project is being carried out in conjunction with the State of Utah, Division of Water Quality, Division of Fish and Wildlife, Weber Basin Water Conservancy District, in addition to the U.S. Bureau of Reclamation. The results of this work will be a set of computer-based decision support tools and models to aid the state and the entities in the Weber Basin in managing basin stream flows to help maintain water quality, primarily for improving the operations and efficiency of water treatment plants using Weber Basin water.

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Water Education and Technology Transfer

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Water Education and Technology Transfer

Project Name	FY2004 Actual Expenditures	FY2005 Budgeted Expenditures	FY2006 Planned Expenditures
Development of Environmentally Friendly Selection Methods for Surface Coatings	$12,071.10	$8,740.47	$5,300.09
Development of Training Modules for the Utah On-Site Wastewater Treatment Demonstration Site	$29,358.92	$30,239.69	$31,751.67
Statewide Nonpoint Source Pollution Education Related to On-Site Wastewater Treatment Systems	$5,686.66	$5,857.26	$6,150.12
Designated Amount for FY05/FY06 Research Projects	$0.00	$25,000.00	$25,000.00
Undesignated research projects in program area	$0.00	$0.00	$0.00
Total	**$47,116.68**	**$69,837.42**	**$68,201.88**

Development of Environmentally Friendly Selection Methods for Surface Coatings

Principal Investigator(s):
R. Ryan Dupont
John Gershensen, Michigan Tech
Richard Ratliff
Yu Ming
Revathi Pepalla

Project Description:

In this research project, a method is being developed for quickly comparing different industrial coating choices based on their environmental and societal impacts and their performance in a given application. The method will expedite the selection of industrial coatings during conceptual design by developing a set of expressions that relate coating key performance criteria (abrasion resistance, hardness, corrosion resistance, chemical resistance, *etc.*) to environmental and societal impacts (human health effects, resource depletion, energy utilization, *etc*.). These performance-based relationships provide a common ground for choosing among similarly functioning alternatives and provide insight for minimizing the environmental burdens these coating alternatives represent. Final coating selections can then be made based upon their cost and their ability to minimize the magnitude of their environmental and societal impacts. These impact characteristics are chosen, not only for their importance in determining the environmental burden of the coating selection, but also for their auditability. The impact characteristic must be reliably quantifiable to insure the development of stable and meaningful relationships.

Design and manufacturing engineers need tools to allow them to weigh the environmental and societal impacts along with the cost of their component and process selection decisions early in the design process when information is scarce. While the proposed method is applicable to a wide range of manufacturing processes and products, industrial coatings were selected as the initial application for the development of the methodology due to the size of the coatings industry, the wide range of industries utilizing product and special purpose coatings, the wide range and large quantity of raw materials used in the production of commercial coatings, and the large variety of alternative coating methods that are available for analysis and alternative coating selection.

The selection process provides a rapid, quantitative methodology for identifying the most environmentally benign candidate for a given coating application, which minimizes energy and resource utilization, without conducting exhaustive analyses of the systems. The method is used during conceptual design and it is understood that traditional optimization of specifications should be used during embodiment design.

Accomplishments:

A subset of coating performance variables has been selected for development and demonstration of this tool. These include abrasion resistance, impact resistance, dry heat resistance, and moisture vapor transmission. A coating selection taxonomy has been developed that generates a list of feasible coating alternatives based on requirements of a given performance variable. For example, for a given coating performance variable (abrasion resistance), based on the environmental conditions under which the coating is to function (dry / moist, acid / alkaline, saline / fresh water, etc.), the substrate on which it is to be placed (wood, plastic, metal, composite), and what layer of coating it is to be used for (primer,

intermediate coat, top coat), a list of various coatings within a range of available coating types (acrylic, epoxy, alkyd, etc.) is generated.

An environmental impact taxonomy has also been developed that generates impact indices for each feasible coating based on the components of each coating, and the surface preparation (primer, cleaning, etc.), application (chemical reducer requirements and application equipment efficiency), and removal processes utilized for each coating type. The impact taxonomy generates impact estimates over the life cycle of the coating at the global (global warming potential, ozone depletion potential, fossil fuel depletion), regional (acid rain production, ozone production, water use), and local (toxicity, land use) scales. The impact of each coating is expressed as an impact index that allows the selection of an optimal coating generated from the performance taxonomy based on the minimal life-cycle environmental footprint.

Work Plan FY 05/FY 06:

Project completed.

Benefits to the State:

This project is intended to improve the selection of industrial coatings by design and manufacturing engineers by reducing the overall environmental, energy, and resource-use impact, their decision ultimately have. The product of this research will benefit the numerous users of industrial coatings in the public and private sector in the state, it can benefit manufacturers of coatings (e.g., Huntsman Chemical) by facilitating their evaluation of a coating's environmental impact during coating initial conceptual and final process design, and will benefit citizens within the entire state through improving environmental quality by facilitating the selection and use of coatings that minimize local and regional environmental impacts.

Conducted in Cache County, results benefit all counties as well as all areas nationally that are impacted by waste generation from industrial coating use. Project products improve selection of coating materials with both coating performance and coating environmental impacts incorporated into the decision-making process.

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Development of Training Modules for the Utah On-Site Wastewater Treatment Demonstration Site

Principal Investigator(s):

Judith L. Sims
Margaret M. Cashell
Richard Jex
Todd Wright
Blake Tullis
Darwin L. Sorensen

Project Description:

In this project, in support of the DEQ-sponsored certification program, the Utah On-Site Wastewater Treatment Training Program is developing a physical demonstration and training site at a 2-acre field site located near the Utah Water Research Laboratory (UWRL) on the campus of Utah State University (USU). This site is used for training in the correct design, siting, installation, operation, maintenance, and troubleshooting of on-site wastewater treatment systems. Users of the site include on-site system installers, designers, regulators, students, land developers, and homeowners. Additional audiences may include equipment vendors, real estate agents, municipal authorities, elected officials, landscape architects, and septic tank manufacturers.

Accomplishments:

An initial grant from the Huntsman Environmental Research Center was used to prepare the site and install several educational modules. During this first phase of construction, we installed modules on:

1. Water conservation.

2. Septic tanks.

3. Conventional distribution systems.

4. Trench and bed construction.

5. Pumping and electrical control systems.

Other partners who supported the Phase I effort included Utah septic tank manufacturers and national vendors of on-site equipment, with donations of equipment and materials valued at $15,000.

In this project, we continued to construct Phase II of the physical demonstration and training site. Phase II consisted of developing and installing the following educational modules:

1. Troubleshooting techniques.

2. Demonstration of appropriate construction techniques for Utah systems.

3. Installation of three advanced technology systems:

   Sand filter system
   Subsurface drip system
   Peat filter system

Work Plan FY 05/FY 06:

During this fiscal year, we completed Phase II, including completion of two sand filters: an intermittent sand filter and a recirculating sand filer as well as installation of a peat filter. Project was completed this fiscal year.

Benefits to the State:

As population growth and associated housing developments continue to threaten the preservation of agricultural lands, there is an increased need for accurate and thorough information on on-site wastewater treatment technologies. The Utah On-Site Wastewater Treatment Training Program addresses these challenges through the continued development of the demonstration and training site on the campus of Utah State University, where education will be enhanced by “seeing and doing.”

The Utah On-Site Wastewater Treatment Training Program is being considered as a model for other states as they develop certification and training programs.

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Statewide Nonpoint Source Pollution Education Related to On-Site Wastewater Treatment Systems

Principal Investigator(s):
Darwin L. Sorensen
Judith L. Sims

Project Description:

This project is developing and implementing an information and education program that will provide elected officials, students, and the general public with on-site wastewater management information related to the prevention of non-point source pollution.

Accomplishments:

An approach to developing guidelines for on-site wastewater treatment system density within areas not suitable for conventional septic systems is in development. Nitrate accumulation is being used as the principal criterion for this determination. The use of the U.S. Department of Agriculture's NLEAP model for estimating nitrate leading potential was evaluated. Methods for determining denitrification potential in surface soil and in aquifer environments were developed. Training of local officials and their staff members will include the concepts and approach developed.

Work Plan FY 05/FY 06:

Guidance, training tools, and a training course for planning and implementing on-site wastewater treatment so that nonpoint source pollution can be prevented are being developed. These materials are being developed for local government officials, homeowners, landowners and developers, and elementary school students.

Benefits to the State:

Local government officials, health department officials, and homeowners living in rural areas must respond to many technical and economic issues related to ground water quality protection while providing for domestic wastewater treatment and disposal. It is very important that people in each of these groups are aware of the need to properly locate, install, and operate on-site wastewater treatment systems.

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Fluid Mechanics and Hydraulics

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Fluid Mechanics & Hydraulics

Project Name	FY2004 Actual Expenditures	FY2005 Budgeted Expenditures	FY2006 Planned Expenditures
Hydraulic Design Data for Environmentally Sensitive Culvert Installations	$8,990.90	$13,990.90	$14,690.45
Hydraulic Structures for Flood Control and Flood Bypass	$11,683.13	$21,683.13	$22,767.29
Sediment Transport and Flood Control	$18,985.06	$28,985.06	$30,434.31
Designated Amount for FY05/FY06 Research Projects		$50,000.00	$40,000.00
Undesignated research projects in program area		$0.00	$0.00
Total	**$39,659.09**	**$114,659.09**	**$107,892.04**

Hydraulic Design Data for Environmentally Sensitive Culvert Installations

Principal Investigator(s):
Blake Tullis

Project Description:

Currently, very little design information is available for culvert designs for environmentally sensitive areas. It is becoming more common to design culverts, not based on the smallest diameter required to pass a design flow rate, but rather limit the maximum design velocity to facilitate fish and debris passage. The missing design information includes inlet and outlet loss coefficients for outlet-controlled flow and design flow curves for inlet-control. Commonly, these culverts have buried inverts or are bottomless. With this type of configuration, the determination of a representative Manning's n value (hydraulic roughness) becomes much more complicated as the channel walls and floor are made of different materials.

Accomplishments:

Conducted a thorough literature review to determine standard practices for environmentally-sensitive culvert installations and identify design data currently available. A test facility was constructed and tests were conducted to identify the presence of size scale effects on the inlet loss coefficients for circular culverts; 6-, 12-, and 24- inch culverts were tested. Inlet control flow performance data were also collected.

Work Plan FY 05/FY 06:

We will focus on the following objectives:

- Evaluate inlet loss coefficients and inlet control curves for buried invert culverts (fish passage culverts).
- Evaluate the performance of multi-barrel culverts to determine the appropriateness of superposition design methods.
- Evaluate predictive methods for composite roughness in rectangular channels and in circular culverts with buried inverts, with the goal of identifying a method that can be applied to fish passage culverts.

Benefits to the State:

Although Utah does not have a significant migratory fish population, fish habitat can be significantly reduced by a culvert, which inhibits fish passage. The need to facilitate natural debris passage may also become more important in the State of Utah as the need to maintain natural systems grows. In general, a design manual, which will function as supplement to the Federal Highways Administration's Hydraulic Design Study #5 (HDS-5), will be the final product of this study. It should prove a valuable resource for Utah Department of Transportation projects. Several Master's students are participating in this project.

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Hydraulic Structures for Flood Control and Flood Bypass

Principal Investigator(s):
William J. Rahmeyer
John Newton

Project Description:

Participate with the Utah Floodplain and Storm Water Management Association and the Utah Office of Homeland Security in developing a series of joint workshops on flooding and floodplain problems. Represent the Utah Water Research Laboratory (UWRL) on the board of directors of the Utah Floodplain and Storm Water Management Association. Flood routing, management, and planning. Retro-fit of dams for drought control and storage. Rehabilitation and retro-fit of spillway control structures.

Accomplishments:

The fusegates were successfully tested, redesigned, retested, and evaluated for application in Utah and the United States. An international presentation was made last year that focused on flood control practices in Utah and the application of fusegates. Fusegates offer Utah a much more versatile and cost-effective design that allows increased flood control and flood storage with minimal environmental impact.

Detail data and laboratory measurements were made of the side channel lateral weirs used for bypass control. The weirs were analyzed for both flood control and for the effect of sediment diversion. A very unique design was created that allowed flood diversion and negated the effects of sediment deposition at the bypass structure. A student thesis was published based on this concept.

Another study was the effect of bridge or highway columns on flooding in floodplains and flood ways. The study included column geometry, the effect of debris trapped by the columns, and the effect of the columns on sediment transport and deposition. The results of this study have importance to Utah because of the need to add additional bridge columns or piers to existing stream crossings to accommodate the widening of Utah roads and highways.

A curved ogee crest was studied for the Success Dam near Porterville California. Several different designs and crest shapes were evaluated. An important concept that was investigated was the effect of reducing the peak outflow hydrograph of the reservoir by improving the efficiency of the crest at lower flowrates and reservoir levels.

Work Plan FY 05/FY 06:

Several papers will be written and published. Continued participation in the Utah Floodplain and Storm Water Management Association. Co-chair the next annual Floodplain and Storm Water Management meeting in St. George, Utah. Physical modeling and numerical modeling of several reservoirs and dams for the U.S. Army Corps of Engineers and the City of New York.

Benefits to the State:

There are several reasons why flood control has become even more of a critical issue for the State of Utah. One reason is the development along and within our floodplains. Urban growth not only contributes to larger floods, but also reduces the size and ability of our flood ways and channels to convey major flows. Research was conducted on two new and innovative concepts in hydraulic structures that will have a direct impact and benefit for Utah communities. The fusegate control structure was investigated as an alternative design to the more traditional and costly control structures such as radial gates. Fusegates are also a very attractive alternative for restoration of Utah's older and under-designed flood-control structures. The use of fusegates has been limited to applications in Europe and Asia. Only one application of fusegates has been used for flood control in Santa Fe, New Mexico. The year 2004 will see the first major application of a fusegate structure at Terminus Dam in California. Terminus Dam is almost complete and will be dedicated in March 2004. A second study of fusegate design was studied at the Utah Water Research Laboratory (UWRL) in 2003.

Another concept that was researched this year was the concept that utilizes bypass conduits to route excess flows around a section of channel or river. The bypass conduits utilize large control weirs that control the flood hydrographs and manage the sediment transport. There are a number of issues related to the bypass concept that have prohibited the use of bypass structures in Utah. A current study is focusing on the effects of bridge pier columns on flow diversion in flood channels. The construction of the bypass culverts for the Guadalupe River in downtown San Jose, CA are partially finished and should be complete in early 2004.

The retrofit of dams and reservoirs for increased storage is an important issue. Such projects involve a unique design of a spillway and control structure that can both raise the pool elevation of the reservoir and also increase the outflow capacity of the spillway. Many of the dams and spillway structures in the Western United States are located in the diversion channels that were used to construct the reservoirs and dams. It is too expensive to widen and excavate the channels to increase flow capacity so new ideas and designs for the spillway crest control sections are being researched. A unique design of a curved ogee crest utilizing an under-designed crest was modeled in 2003. It was found that the design increased pool elevation and increased flow capacity without the need to widen the diversion channels.

Salt Lake County, Davis County, and almost all of the other counties in Utah will benefit from this project.

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Sediment Transport and Flood Control

Principal Investigator(s):
William J. Rahmeyer
John Newton

Project Description:

Fundamental hydraulics of sedimentation and erosion; equations and methodologies to predict the sediment transport in steep mountain streams and closed conduits; develop sediment transport equations and methods for the Utah Department of Transportation (UDOT); an understanding of the effect of vegetation on the sediment transport in floodplains; study the effect of willows and salt cedars on flow resistance and flood plain management with W.E.S. and Salt Lake County (Brent Birdal), possibility expand to include Sevier River basin and Bear Lake districts. Continue research and publishing journal articles on flood plain resistance and the effect of vegetation on flow resistance; the effect of the sedimentation process on erosion and deposition at culverts and road crossings.

Present papers and discussion on sediment transport at the next symposiums sponsored by the International Erosion Control Association (IECA) and the United States Committee on Large Dams (USCOLD) and the Environmental Water Resources Institute (EWRI); Publish a journal paper of Floodplain Resistance Due to Vegetation with the International Hydraulic Research Association.

Accomplishments:

Research projects with the Waterways Experiment Station of the U.S. Army Corps of Engineers. Publish papers on sediment transport and the effect of vegetation. Several conference presentations.

Work Plan FY 05/FY 06:

Conference presentation in St. George Utah and in Logan, Utah. Paper submitted to the International Association of Hydraulic Research (IAHR).

Benefits to the State:

Since Utah streams and rivers formed under unique geologic and climatic conditions, understanding sedimentation and erosion processes is important. How is sediment produced in our watersheds? How is it transported in the streams and rivers? What is the balance between erosion and deposition in our floodplains? The sedimentation process affects most man-made activities including agriculture, urbanization, reclamation, and mining. Short-term and long-term changes in climate and precipitation interact with the sedimentation process to cause flooding and debris flow problems in Utah. A major interest to the State of Utah and other Western States is the effect of the sedimentation process on the flooding and flood routing in floodplains.

Present knowledge and methodologies were developed for climates and geology different from those in Utah. Our research objectives are: 1) continue developing prediction methods and models of sedimentation and scour, 2) conduct basic and applied research to solve specific sediment problems that affect Utah, and 3) work with local and state agencies to provide education and support in the area of sedimentation.

Direct benefits to the State of Utah will be from the knowledge and methodology gained from this research in sedimentation and erosion. Almost all areas of agriculture, mining, forestry, reclamation, and transportation should benefit directly from this research. The Division of Oil, Gas, and Mining; Division of Water Quality; Division of Water Resources; Utah Department of Transportation; and water conservancy districts will be informed of our results. A better understanding of this research and how it applies to Utah may positively impact federal guidelines and requirements of sedimentation and erosion control for Utah.

Ground Water

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Ground Water

Project Name	FY2004 Actual Expenditures	FY2005 Budgeted Expenditures	FY2006 Planned Expenditures
Bacterial Growth Due to Wave Effects in Coastal Waters	$2,061.01	$2,122.84	$2,228.98
Forecast of the Great Salt Lake	$6,207.14	$11,207.14	$11,767.50
Optimal Management of Nitrogen Pollution of Ground Water in Agricultural Watersheds	$11,637.01	$16,637.01	$17,468.86
Prediction of Irrigation Water Availability for Sevier River Basin	$6,560.63	$16,560.63	$17,388.66
Designated Amount for FY05/FY06 Research Projects		$0.00	$0.00
Undesignated research projects in program area		$0.00	$0.00
Total	**$26,465.79**	**$46,527.62**	**$48,854.00**

Bacterial Growth Due to Wave Effects in Coastal Waters

Principal Investigator(s):
Gilberto E. Urroz

Project Description:

1. Develop lab-scale model of wave action including bacterial growth analysis.

2. Develop measurements in lake or ocean shorelines.

Accomplishments:

Outline of a proposal.

Work Plan FY 05/FY 06:

Proposal to the U.S. Environmental Protection Agency (EPA), National Science Foundation (NSF), or other agencies. The following are specific steps that are proposed for the study:

1. Building of small-scale wave basins at the Utah Water Research Laboratory (UWRL) where wave action and bacterial growth can be analyzed under controlled conditions.

2. Data collection in inland lakes (e.g., Lake Powell) and in the ocean (e.g., San Diego) to compare with controlled-conditions data as described in 1 above.

3. Data analysis aimed at identifying water flow parameters that influence bacterial growth in the shoreline areas.

Benefits to the State:

1. Improve water quality prediction in lake beaches (e.g., Bear Lake, Lake Powell).

2. Provide criteria for public health advisories on water contamination in lake beaches.

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Forecast of the Great Salt Lake

Principal Investigator(s):
Mariush W. Kemblowski

Project Description:

In this study, we focused on the lake volume for the falling and ascending parts of volume time series. Some fifteen years ago, during the time when the Great Salt Lake level was continuously increasing, the problem of forecasting the lake volume, and thus the lake stage, was thought to be very important. Since that time the lake stage has fallen and/or remained approximately constant, and the importance of this issue has significantly diminished in the eyes of the public and state agencies. However, it is rather likely that in the future we will face the rising lake level again, and hence the need for a stage-forecasting tool.

Accomplishments:

In this project we utilized the dynamical (chaotic) system theory and the Support Vector Machine (SVM) approach to predict the lake volume. The SVM was trained using one portion of the available volume time series, and tested using the remaining portion of data. The testing demonstrated that the SVM performed significantly better than any other models used so far.

Work Plan FY 05/FY 06:

This work needs to be now transferred to the relevant state agencies.

Benefits to the State:

Ability to forecast the Great Salt Lake volume and stage, which is particularly important during the period of rising lake stage.

Journals

Asefa, T., M.W. Kemblowski, G. Urroz, M. McKee, and A. Khalil (2004). Support Vectors–Based Groundwater Head Observation Networks Design. *Water Resources Research*, 40.

Asefa T., M. Kemblowski, G. Urroz, and M. McKee (2004). Support Vector Machines for Ground Water Quality Monitoring Network Design. *Ground Water.*

Asefa, T., M.W.. Kemblowski, M. McKee, and A., Khalil (2004). Multi-Time Scale Stream Flow Prediction: The Support Vector Machines Approach. *Journal of Hydrology.*

Asefa T., M. Kemblowski, U. Lall, and G. Urroz (2004). Support Vector Machines for Nonlinear State Space Reconstruction: Application to the Great Salt Lake Time Series. *Water Resources Research*.

Gill, M.K., T. Asefa, M.W. Kemblowski, and M. McKee (In preparation). *Soil Moisture Predictions Using Support Vector Machines.*

Gill, M.K. and M.W. Kemblowski (In preparation). *Assimilation of Soil Moisture Data Using Support Vector Machines & Ensemble Kalman Filter*.

Khalil A., M. McKee, M.W. Kemblowski, and T. Asefa (2004). Basin-Scale Water Management and Forecasting using Multi-Sensor Data and Artificial Neural Networks. *Journal of American Water Resources Association*.

Khalil A., M. McKee, M. Kemblowski and T. Asefa (2004). Sparse Bayesian Learning Machine for Real-Time Management of Reservoir Release. *Water Resources Research.*

Khalil A., M.N. Almasri, M. McKee, M. Kemblowski, and J.J. Kaluarachchi (2004). Applicability of Statistical Learning Algorithms in Ground Water Quality Modeling. *Water Resources Research*.

Khalil A., M. McKee, and M. Kemblowski (2004). Optimal Groundwater Quality Monitoring Network Design. *Water Resources Research*.

Khalil A., K. Gill, M. McKee, and M. Kemblowski (Submitted). Soil Moisture Data Assimilation Using Data-Driven Modeling and Particle Filtering. *Water Resources Research*.

Pande, S., M. McKee, and M. Kemblowski (In preparation). *Inference of Predictor Relevance (A): Probabilistic Wrapper Approach to Predictor Subset Selection.*

Pande, S., M. McKee, and M. Kemblowski (In preparation). *Inference of Predictor Relevance (B): Detecting Non-stationarity in a Conservation of Mass Model.*

Pande, S., M. McKee, M. Kemblowski, W. Walker (In preparation). *Complexity Based Nearest Neighbor Modeling of Hydrologic Time Series.*

Conference presentations:

Asefa, T. and M.W. Kemblowski (2004). *Stream Flow Prediction Using Support Vector Machines.* Spring Runoff Conference, 1st Utah State University Water Initiative Annual Conference. Managing Water Resources, Quantity and Quality. March 25-26.

Gill, M.K., T. Asefa, Q. Shu, M.W. Kemblowski (2003). *Soil Moisture Prediction Using Support Vector Machines*. INRA 2003 Subsurface Science Symposium, Salt Lake City, Utah, October 6-8.

Gill, M.K. and M.W. Kemblowski (2004). *Assimilation of Soil Moisture Using Support Vector Machines (SVM) & Ensemble Kalman Filter (EnKF)*. First Spring Runoff Conference at Utah State University, Logan, Utah, March 25-26.

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Optimal Management of Nitrogen Pollution of Ground Water in Agricultural Watersheds

Principal Investigator(s):

Jagath J. Kaluarachchi
Thomas B. Hardy
David K. Stevens
David G. Tarboton
Mac McKee
Mariush W. Kemblowski
Mohammad Almasri

Project Description:

1. Develop the on-ground nitrogen loading model from different land use activities.

2. Develop the soil nitrogen model to predict the net nitrate recharge to ground water.

3. Develop the fate and transport model of nitrate in ground water to predict the concentration at selected receptors.

4. Develop a multi-objective decision analysis model to assess the costs and benefits of different best management practices.

Accomplishments:

1. Collected necessary data and information.

2. Developed conceptual models and corresponding mathematical models.

3. Simulated the basecase scenario and performed model verification and validation.

4. Simulated the management scenarios and demonstrated the applicability.

Work Plan FY 05/FY 06:

The work described here is innovative and the results obtained from the work have been published through four manuscripts in reputed research journals. In addition four referred conference proceedings have been published in the U.S. and Europe. One student received a Ph.D. through this work. This work has provided national reputation to USU in the form of cutting edge research and also has enhanced graduate education and research at USU.

Manuscripts:

Almasri, M. and J. Kaluarachchi (2004). Assessment and management of long-term nitrate pollution of ground water in agriculture-dominated watershed. *Journal of Hydrology*, 295:225-245.

Almasri, M. and J. Kaluarachchi (2004). Implications of on-ground nitrogen loading and soil transformations on ground water quality management. *Journal American Water Resources Association*, 40(1):165-186.

Almasri, M. and J. Kaluarachchi (2004). Modular neural network to predict the distribution of nitrate in ground water using on-ground nitrogen loading and recharge data. *Environmental Modeling and Software*, April.

Almasri, M. and J. Kaluarachchi (2004). Multi-criteria decision analysis for the optimal management of nitrate contamination of aquifers. *Journal of Environmental Management*, August.

Abedalrazq K., M. N. Almasri, M. McKee, and J J. Kaluarachchi (2004). Applicability of statistical learning algorithms in groundwater quality modeling, in review. *Water Resources Research*, August.

Conference Proceedings:

Almasri, M. and J.J. Kaluarachchi (2002). *Modeling of nitrogen fate and transport at watershed-scale for management decision-making.* Proceedings of the 4th International Conference on Calibration and Reliability in Groundwater Modeling: A few steps closer to reality. Prague, Czech Republic, 17-20, June.

Almasri, M. and J.J. Kaluarachchi (2002). *Predicting stream-aquifer interaction using artificial neural networks: Methodology, application, and reliability*. Proceedings of the 4th International Conference on Calibration and Reliability in Groundwater Modeling: A few steps closer to reality. Prague, Czech Republic, 17-20, June.

Almasri, M. and J.J. Kaluarachchi (2003). *Regional-scale modeling of nitrate contamination of ground water in agriculture-dominated watersheds*. Proceedings of the International Conference on MODFLOW and More 2003: Understanding through Modeling, Golden, CO.

Almasri, M. and J.J. Kaluarachchi (2003). *Regional variability of on-ground nitrogen loading due to multiple land uses in agriculture-dominated watersheds*. Proceedings of the 7th International Conference on Diffuse Pollution and Basin Management, Dublin, Ireland.

Benefits to the State:

This work provided a sound management framework to minimize ground water pollution due to nitrogen introduced through various land use activities especially in agricultural watersheds. Most agricultural watersheds have extensive farming of agricultural crops and dairy farming. The use of fertilizer in these land uses together with fertilizer used in lawns in residential areas, septic systems in rural areas and natural sources such as atmospheric deposition have caused large-scale nitrogen contamination of valuable ground water resources. The obvious answer to reduce such pollution is to reduce the use of nitrogen-rich fertilizer, reduce dairy farming, and reduce the density of septic systems. However, these changes invariably produce negative economic impacts to the community and especially to stakeholders dependent on the economic return from these land uses. In this work, we developed a multi-objective optimal framework that is capable of evaluating the costs and benefits of various best management practices considering hydrology, water chemistry, fate and transport of nitrogen species, and economic costs.

The work and the results of this work can be readily exported to any agricultural watershed in Utah. The decision-support system developed in this work uses GIS tools enhancing wide applicability in Utah and elsewhere.

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Prediction of Irrigation Water Availability for Sevier River Basin

Principal Investigator(s):
Mariush W. Kemblowski

Project Description:

This project is concerned with estimating the volume of water available for the irrigation season several months ahead, based on information such as snow-water equivalent measurements, snow coverage, stream flow time series, North Pacific Ocean temperatures, etc.

Accomplishments:

The Support Vector Machine (SVM) approach was used to map input into seasonal water volume. The predictions agreed very well with the observed quantities.

Work Plan FY 05/FY 06:

Application of the SVM procedure to Utah Basins as needed.

Benefits to the State:

Ability to predict the volume of irrigation water in Sevier River Basin for each irrigation season.

Journals

Asefa, T., M.W. Kemblowski, G. Urroz, M. McKee, and A. Khalil (2004). Support Vectors–Based Groundwater Head Observation Networks Design. *Water Resources Research*, 40.

Asefa T., M. Kemblowski, G. Urroz and M. McKee (2004). Support Vector Machines for Ground Water Quality Monitoring Network Design. *Ground Water.*

Asefa, T., M.W.. Kemblowski, M. McKee, and A. Khalil (2004). Multi-Time Scale Stream Flow Prediction: The Support Vector Machines Approach. *Journal of Hydrology.*

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Gill, M.K., T. Asefa, M.W. Kemblowski, and M. McKee (In preparation). *Soil Moisture Predictions Using Support Vector Machines.*

Gill, M.K. and M.W. Kemblowski (In preparation). *Assimilation of Soil Moisture Data Using Support Vector Machines & Ensemble Kalman Filter*.

Khalil A., M. McKee, M.W. Kemblowski, and T. Asefa (2004). Basin-Scale Water Management and Forecasting using Multi-Sensor Data and Artificial Neural Networks. *Journal of American Water Resources Association*.

Khalil A., M. McKee, M. Kemblowski and T. Asefa (2004). Sparse Bayesian Learning Machine for Real-Time Management of Reservoir Release. *Water Resources Research.*

Khalil A., M.N. Almasri, M. McKee, M. Kemblowski, and J.J. Kaluarachchi (2004). Applicability of Statistical Learning Algorithms in Ground Water Quality Modeling. *Water Resources Research*.

Khalil A., M. McKee, and M. Kemblowski (2004). Optimal Groundwater Quality Monitoring Network Design. *Water Resources Research*.

Khalil A., K. Gill, M. McKee, and M. Kemblowski (Submitted). Soil Moisture Data Assimilation Using Data-Driven Modeling And Particle Filtering. *Water Resources Research*.

Pande, S., M. McKee, and M. Kemblowski (In preparation). *Inference of Predictor Relevance (A): Probabilistic Wrapper Approach to Predictor Subset Selection.*

Pande, S., M. McKee, and M. Kemblowski (In preparation). *Inference of Predictor Relevance (B): Detecting Non-stationarity in a Conservation of Mass Model.*

Pande, S., M. McKee, M. Kemblowski, W. Walker (In preparation). *Complexity Based Nearest Neighbor Modeling of Hydrologic Time Series.*

Conference Presentations

Asefa, T. and M.W. Kemblowski (2004). *Stream Flow Prediction Using Support Vector Machines.* Spring Runoff Conference, 1st Utah State University Water Initiative Annual Conference. Managing Water Resources, Quantity and Quality. March 25-26.

Gill, M.K., T. Asefa, Q. Shu, M.W. Kemblowski (2003). *Soil Moisture Prediction Using Support Vector Machines*. INRA 2003 Subsurface Science Symposium, Salt Lake City, Utah, October 6-8.

Gill, M.K. and M.W. Kemblowski (2004). *Assimilation of Soil Moisture Using Support Vector Machines (SVM) & Ensemble Kalman Filter (EnKF)*. First Spring Runoff Conference at Utah State University, Logan, Utah, March 25-26.

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Hydrology

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Hydrology

Project Name	FY2004 Actual Expenditures	FY2005 Budgeted Expenditures	FY2006 Planned Expenditures
Investigation on the Application of Non-Uniform Grids for Land Surface Modeling Over Semi-Arid Areas and Evaluation Using Similarity Measures	$34,849.71	$55,895.20	$58,689.96
Designated Amount for FY05/FY06 Research Projects		$10,000.00	$15,000.00
Undesignated research projects in program area		$0.00	$0.00
Total	**$34,849.71**	**$65,895.20**	**$73,689.96**

Investigation on the Application of Non-Uniform Grids for Land Surface Modeling Over Semi-Arid Areas and Evaluation Using Similarity Measures

Principal Investigator(s):

Luis A. Bastidas
Shujun Li

Project Description:

The purpose of the present project is to carry out an investigation to establish how much can be gained by using non-uniform grids for land surface modeling over the semi-arid Southwest U.S. The specific topographic characteristics of the terrain (basin and range), the vegetation distribution (riparian areas and desert floor), and the hydrologic processes (mountain recharge fronts, no recharge over desert floors) suggest that an approach with different resolutions will be more appropriate for that type of environments than the traditional mosaic approach currently used.

Land surface processes coupled to atmospheric models (AM) have been described as simple leaky bucket parameterizations in the late 1960s to more complex surface vegetation atmosphere transfer schemes in the mid 1980s, to detailed land surface ecosystem-hydrology models. The evolution of coupled Atmospheric Model-Land Surface Model (AM-LSM) have taken into account more detailed physical processes (e.g., biogeochemistry, streamflow), but so far has always been oriented towards a single column (over a grid cell) conceptual representation of the processes. Data availability has become a limiting factor, especially as the model resolution increased to account for detailed fine-scale watershed processes (50-200m). These models, which are computationally intensive, may lack sufficient input forcing for realistic solutions. Medium-scale (1-12 km) models, on the other hand, may avoid this limitation at a loss of information. Based on some work carried out by Miller (1993, 1995) and as a bridge between these two approaches, we propose a non-uniform grid system that provides fine-scale structure at regions of high land surface sensitivity and medium-scale for regions of low sensitivity or problem-defined homogeneity. Such an approach will reduce computational demand and provide a framework for evaluating medium- and fine-scale models, as well as testing process sensitivities at a range of spatial scales.

Vegetation, topographic, and hydrologic characteristics of the semi-arid Southwest U.S. suggest that, for those environments, it will be more meaningful to link the inherent heterogeneity and scale of the terrain properties and hydrological processes with the grid cell size of the numerical representation in land surface models, rather than pursue the traditional mosaic-type or effective aggregation approach currently used by the state-of-the-art models.

Specific objectives are:

- Design and apply non-uniform LSM grids over the San Pedro Basin and test the sensitivity of the hydrologic response as forced by dynamical (nested atmospheric mesoscale modeling) and statistical-dynamical (self-organized feature maps and/or support vector machines) downscaling procedures.

- Compare the 1-4 km spatially aggregated non-uniform grid and fine-scale grid simulations to the medium-scale 1-4 km simulations. Compare fine-scale and non-uniform solutions and determine the non-uniform scales that result in solutions of similar accuracy as the fine-scale.

Accomplishments:

The project is ongoing and has been partially supported also by a grant for Utah State University (USU) new faculty. A manual procedure for multiple grid representation has been developed over the San Pedro catchment. Currently the automation of such procedure is taking place. We have made presentations at the American Geophysical Union (AGU) Fall meeting and at the National Science Foundation (NSF) Science and Technology Center (STC) Sustainability of Semi Arid Hydrology and Riparian Areas (SAHRA) Annual Meeting. A paper regarding the use of similarity measures is almost ready and will be submitted early in January 2005.

As part of this project, we have used data obtained for the State of Utah to evaluate the actual ETP (Latent Heat Flux) for the entire state at a 1 km resolution. A presentation was made to the State Engineer Office on November 17, 2004.

Work Plan FY 05/FY 06:

We plan to complete the automation of the procedure as well as the full testing of the similarity measures for model parameter estimation in a distributed fashion. Shujun Li is expected to finish his Ph.D. degree during the year.

Benefits to the State:

Semiarid environments are a significant part of the western United States and in particular of the State of Utah. The development of a parameterization specifically tailored for semiarid regions is of obvious importance to the state. Also an evaluation of the actual evaporation within the state has been obtained.

References

Bastidas, L.A. and S. Li (Submitted). On the use of similarity measures for distributed model performance evaluation. *Water Resources Research.*

Li, S. and L.A. Bastidas (2004). *A Quantitative and objective procedure for evaluation of distributed hydrologic and hydrometeorological models.* AGU Fall Meeting, San Francisco, California, USA, December 13-17.

Li, S. and L.A. Bastidas (2004). Distributed land surface modeling over the San Pedro Basin using a multiple resolution grid. SAHRA Annual Meeting, Albuquerque, NM, October 13-15.

Miller, N.L. (1993). *The hierarchical systems flux scheme: The homogeneity test*. Hydroclimatology Conference, American Meteorological, Society, Boston, MA, pp. 36-40.

Miller, N.L. (1995). Sensitivity of surface heat and moisture fluxes due to topographic slope and azimuth. *Journal of Geophysical Research,* 100(D9):18,669-18,685.

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Water Resources Planning and Management

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Water Resources Planning & Management

Project Name	FY2004 Actual Expenditures	FY2005 Budgeted Expenditures	FY2006 Planned Expenditures
Annual Population Monitoring in the Sevier River Drainage	$24,095.79	$59,095.79	$62,050.58
Comparative Analysis of Orographic Effects for Estimating Peak Flows	$24,857.82	$29,857.82	$31,350.71
Culvert Hydraulic Analysis and Design for Rural Roads	$23,873.08	$28,873.08	$30,316.73
Dam Breach Modeling and Extreme Flood Estimation	$19,674.13	$24,674.13	$25,907.84
Dam Failure Life Loss Estimation	$14,104.96	$19,104.96	$20,060.21
Dam Safety Risk Management	$14,104.96	$19,104.96	$20,060.21
Optimal Water Allocation Model for Salt Lake Valley, Utah	$18,522.30	$48,522.30	$50,948.42
Quantification and Management of Uncertainty in Salt Loading from the San Rafael Irrigation System	$46,261.20	$96,261.20	$103,883.46
Real-Time Management of Irrigation Systems in the Sevier River Basin	$17,156.05	$41,207.14	$43,267.50
Technical Support for the Virgin River Resource Management and Recovery Program	$9,239.35	$34,239.35	$35,951.32
Designated Amount for FY05/FY06 Research Projects		$20,000.00	$20,000.00
Undesignated research projects in program area		$0.00	$0.00
Total	**$211,889.64**	**$420,940.73**	**$443,796.97**

Annual Population Monitoring in the Sevier River Drainage

Principal Investigator(s):
Thomas B. Hardy
Matt Combes

Project Description:

This project entails annual monitoring fish populations at standardized locations within the Sevier River Drainage. These efforts are intended to establish trends in fish abundance and community composition in light of inter-annual variations. The results of these studies will guide water resource allocation decisions and provide critical data in the protection of native species in the system.

Accomplishments:

Standardized monitoring of the fish populations were undertaken and the annual population monitoring reports were prepared for the Sevier River Bridge Canal Company and the Utah Division of Wildlife Resources.

Work Plan FY 05/FY 06:

Utah State University will continue to provide technical support through this period.

Benefits to the State:

This project is being carried out in conjunction with the State of Utah Division of Wildlife Resources and the Sevier River Bridge Canal Company. The results of this work will guide long-term water allocation strategies and ultimately the successful protection and enhancement of native species of fish within the Sevier River Basin.

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Comparative Analysis of Orographic Effects for Estimating Peak Flows

Principal Investigator(s):
William J. Grenney
Karthik Kumarasamy
Ramya Cuduvalli Nataraj

Project Description:

Information gained during last year's research on the statewide roadway culvert survey indicated that there may be significant differences in the data used for estimating design flows for drainage structures based on orographic effects.

Because of the great land area in Utah and the scarcity of data monitoring sites, there is seldom sufficient river flow data or precipitation data available to directly estimate peak flows for the design of drainage structures. It is almost always necessary for a design agency to extrapolate data from one watershed to another using conventional engineering techniques. The techniques being used do not account for the effects of predominate wind direction over mountain ridges. However, as a result of doing site specific analyses, engineers have noticed what they believe to be significant effects.

The purpose of this research is to identify precipitation stations in four strategic geographical regions in Utah, and to statistically analyze for orographic effects.

Accomplishments:

Data were obtained from eight precipitation sites in four strategic geographical regions in Utah. The data were analyzed using statistical techniques implemented by means of a computer program developed by the students.

The results contained a great deal of randomness. However, significant differences were found at the 90% and 95% confidence level for certain classes of precipitation. The greatest differences occurred in North Eastern Utah. A typical example of the results is shown in Figure 1.

Work Plan FY 05/FY 06:

Focus will be concentrated on the regions and classes of precipitation where the greatest statistical differences occur. Analytical techniques will be developed to help an engineer take orographic effects into account when estimating peak flows.

Benefits to the State:

There are major economic and liability reasons for applying the best available technology to estimate peak flows so that drainage structures can be properly designed. This research will provide improved methods for estimating peak flows which are essential for the safe and economical design of drainage structures.

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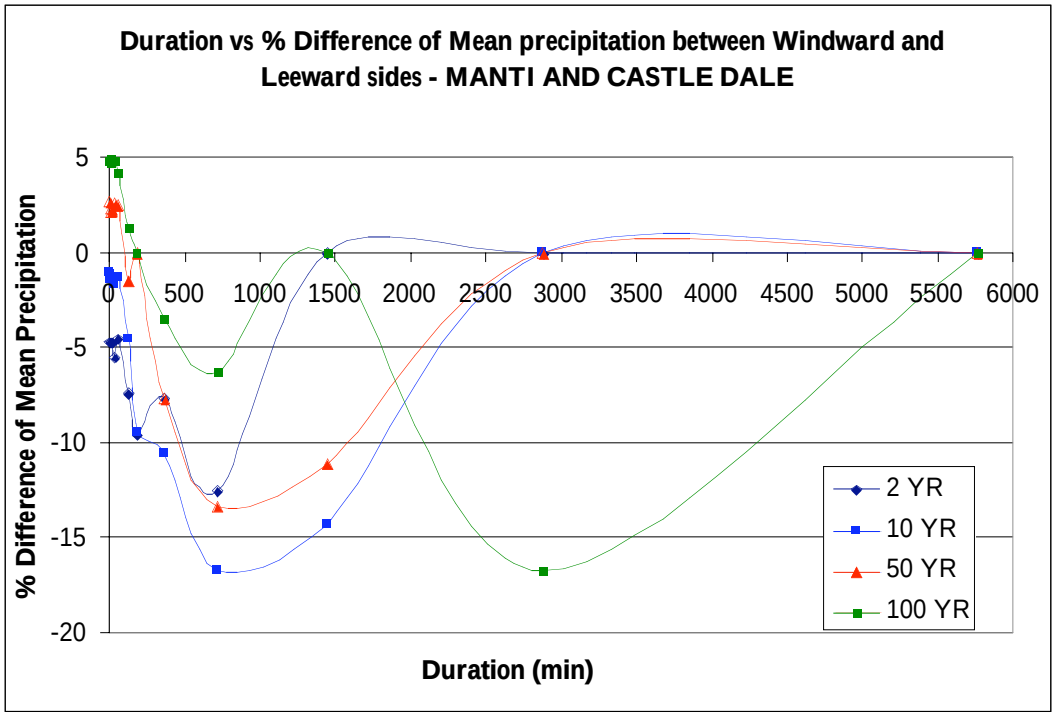
Duration vs % Difference of Mean precipitation between Windward and Leeward sides - MANTI AND CASTLE DALE
% Difference of Mean Precipitation
5
0
-5
-10
-15
-20
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
Duration (min)
2 YR
10 YR
50 YR
100 YR

Figure 1.

Culvert Hydraulic Analysis and Design for Rural Roads

Principal Investigator(s):
William J. Grenney
Ramya Cuduvalli Nataraj
Anisha Arora

Project Description:

Effective transportation within and among communities in Utah is essential for sustaining economic development and maintaining quality of life. Over 80% of Utah roads and highways are low volume rural roads. Because of the great distances between communities and the dispersed population, budgets for construction and maintenance are severely stressed. Often drainage and environmental considerations are important transportation issues having direct impact on communities. There is a continuing need for training, education, and research to implement modern methods in order to obtain the greatest effectiveness from limited dollars. Although much effort has gone into the development of systems for large departments of transportation, this research focuses on the needs of small and medium sized communities.

Accomplishments:

Last year's research focused on the computation of reliable estimates of 25-, 50-, and 100-year peak discharge values for unregulated Utah watersheds in order to provide the necessary input to the culvert design process.

During that study it was learned that two systems were being used to estimate the Intensity-Duration-Frequency curves (IDF curves) which form the basis for estimating point rainfall events. The rainfall events are used in turn to estimate peak flows which are a principal parameter for the design of roadway culverts.

Intensity-Duration-Frequency curves were obtained from two sources for four strategic regions in Utah. One source was the Utah Climate Center (UCC) computer model. The UCC model has been used in association with the design of hundreds of culverts in Utah. The second source was the national data provided by the National Oceanic and Atmospheric Administration (NOAA).

Two hundred and eighty IDF curves were acquired. The data were analyzed using statistical techniques implemented by means of a computer program developed by the students. Results indicated that there are significant differences at the 90% and 95% levels for certain classifications of precipitation. An example of results is shown in Figures 1 and 2.

Work Plan FY 05/FY 06:

The continuing requirements to examine the effects of existing culverts on aquatic habitat has generated a need to analyze the hydraulics of culverts that are partially buried in the streambed. This condition produces a nonstandard irregular cross section, and current design tools for this condition are complex and awkward to use. This research will provide a simpler tool for the analysis of such conditions.

Benefits to the State:

This research will result in a methodology and a computer tool for small and medium sized rural communities to more effectively plan, design, and maintain culverts for unique situations as well as for most standard installations.

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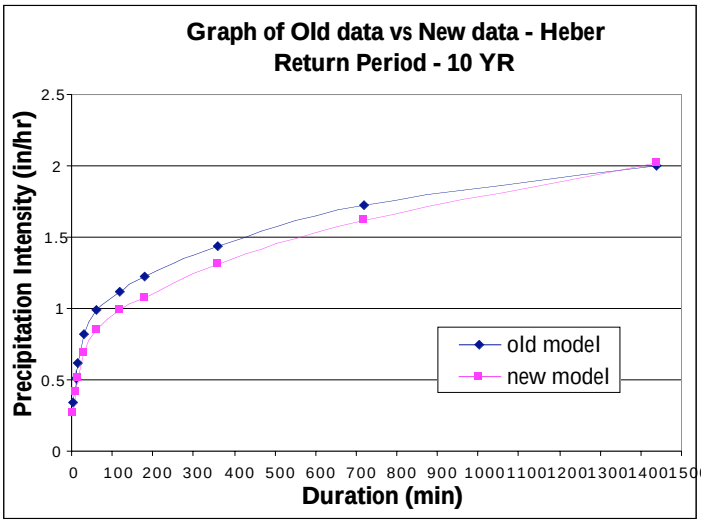

Figure 1.

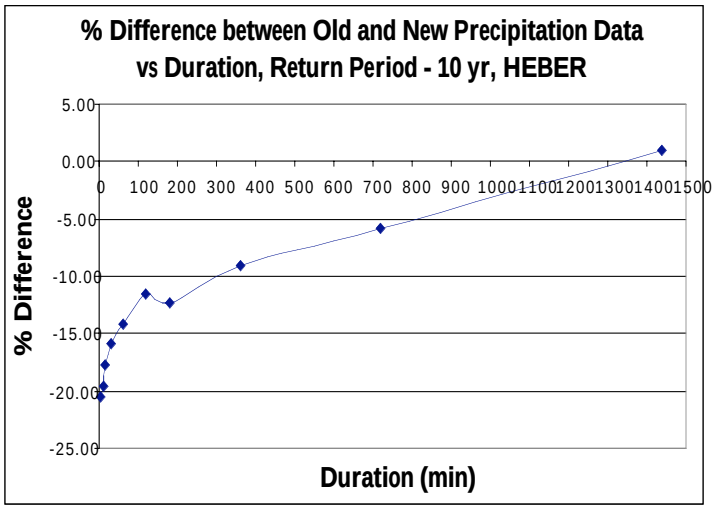

Figure 2.

Dam Breach Modeling and Extreme Flood Estimation

Principal Investigator(s):
David S. Bowles
Loren R. Anderson
Sanjay S. Chauhan
Wang Zhengang

Project Description:

1. To develop a three-dimensional simulation approach to accurately predict the breach hydrograph resulting from the unique characteristics of a particular dam and reservoir as it fails under a particular combination of loading conditions and failure mechanisms.

2. To experimentally comparison of one- and two-dimensional dam breach flood routing in terms of estimating flood severity for use in life-loss estimation.

3. To summarize available approaches to assigning annual exceedance probabilities to the probable maximum flood.

Accomplishments:

1. Dam Breach Modeling.

   The earthen dam breach problem has been studied in the laboratory and through field experiments and examining actual dam failures for many years. Many mathematical models and theoretical studies of the earthen dam breach process and breach outflow rates have been carried out. Commonly, these models, such as NWS DAMBRK, evolve a breach shape using breach dimensions and a breach development time prescribed by the model user. Other models calculate the dam breach outflow using a simplified representation of the complex interaction between soil and water that determines breach hydrographs in actual dam breaks. For example, NWS BREACH uses quasi-steady uniform flow to calculate the flow depth and flow velocity, and the broad-crested weir relationship to calculate the outflow flow rate. However, both of these simplified approaches are not capable of accurately predicting the breach hydrograph resulting from the unique characteristics of a particular dam and reservoir as it fails under a particular combination of loading conditions and failure mechanisms.

   In our staged approach to developing a simulation model for an overtopping breach, we first focused on developing an accurate representation of the hydraulic characteristics of flow through a fixed breach channel in an embankment dam. This is critical for calculation of erosion and for slope stability calculations. In the first phase of our research, we developed a model to calculate the flow characteristics in the typical breach channel with a fixed geometry. The aim of this phase was to provide a method for accurately calculating the hydraulic characteristics (water depth, flow velocity) of breach flow through a homogeneous trapezoidal earthen dam section with fixed breach geometry under a constant reservoir head for the overtopping failure case.

However, the complete earthen dam breach process is a complicated interaction between water and soil. The breach channel changes shape as the flow erodes the soil. Undercutting takes place at the sides of the breach channel due to erosion at the interface between the eroded embankment and the breach flow, which leads to sudden collapses of embankment material into the breach channel as the overlying soil body loses its vertical force equilibrium. Slope instability may also occur resulting in soil sliding into the breach channel. The processes of erosion, sudden collapses, and slope instability work together to determine changes in the channel shape. The flow characteristics then adapt to the new geometry. The flow characteristics are critical to our research for three reasons: 1) the flow profile determines the interface at which erosion takes place; 2) the velocity of flow affects the rate of erosion; and 3) the flow profile provides some lateral support that affects slope stability.

During the past year our work has focused on the second and third phases. In the second phase we have extended our model to the variable breach geometry case through modeling the erosional and instability processes that control breach development for a single breach channel. The two-dimensional Shallow Water Equations have been used to represent rapidly varied flow but not the gradually varied flow that happens at the beginning of the breach development process. In the third phase we have added the capability to represent simultaneous multiple breach development, where each breach is initiated at the center of an overtopped section of dam crest considering both wave setup and uneven or variable crest elevations.

2. Comparison of one- and two-dimensional dam breach flood routing.

Another aspect of our work was completed in the past year and was reported in a Master's Thesis (Zhu, 2004) and by Zhu and Bowles (2003). It was a comparison of one- (DAMBRK) and two-dimensional (MIKE21) hydrodynamic models for estimating flood severity for use in life-loss estimation.

3. Assigning AEPs to the PMF for Dam Safety Risk Assessments.

A summary of available approaches to assigning annual exceedance probabilities to the probable maximum flood was prepared in an IDSRM Technical Note (Bowles, 2004).

Work Plan FY 05/FY 06:

1. Dam breach Modeling.

The three-dimensional dam breach simulation approach, which we have developed, will be tested against several data sets to assess its accuracy in predicting dam breach hydrographs. A Ph.D. dissertation will be completed (Wang, 2005) and a series of papers will be prepared to describe the following aspects of this project so far:

- General Theory
- Calculation of Breach Outflow
- Verifications and Applications
- Effects of Breach Locations on the Breach Outflow under Wind and Wave Actions

2. Empirical dam breach parameter estimation.

Our review of empirical procedures for estimating dam breach parameters (geometry and time to failure) has revealed a significant overestimation of breach hydrographs in comparison to

historical dam failures as represented by empirical procedures for estimating peak breach flows directly. This is mainly due to the use of final fully-developed breach geometry rather than the partially-developed breach geometry associated with the peak breach flow. Through simulating a wide range of cases for an embankment dam, we will propose an approach to adapting empirical estimates of dam breach parameters with the goal of obtaining more realistic estimates of dam failure hydrographs. We plan to publish this approach in a paper (Chauhan et al, 2004).

3. Applying GIS to dam breach flooding characterization.

We are developing and testing procedures for obtaining inputs to dam breach flood routing from GIS sources including digital elevation models and soils information. Procedures for displaying results in forms suitable for flood plain delineation and emergency action planning are also being developed and tested. An additional aspect of this project is to adapt results for dam failure flood life loss and economic consequences estimation using GIS. Our work is focusing on using the HEC GeoRAS model, although it should be readily generalized to other one- and two-dimensional flood routing models. Our work will be summarized in a Master's Report (Nanadoum, 2005) and possibly a paper.

4. PMF determination and Extreme Flood Probability Estimation.

The probable maximum flood (PMF) is the design flood for reservoir safety under traditional approaches in some parts of the world including the USA, Australia, and the UK. Other parts of the world use a rare flood such as the 1 in 10,000 annual exceedance probability (AEP) flood. Dr. Bowles has considerable experience in advancing the state-of-the art in PMF estimation as well as applied experience in estimating PMFs for reservoirs throughout the US and overseas, including the entire Snowy Mountains Scheme in Australia. He has been invited to present a state-of-the practice paper on PMF determination for the NATO Advanced Research Workshop (ARW) "Extreme Hydrological Events: New Concepts for Security" to be held in Novosibirsk, Russia in July 2005 (Bowles, 2005). He plans to address the important relationship between PMF and extreme floods over a wide range of exceedance probabilities that are needed for characterizing flood loading as an input to dam safety risk assessment. As risk assessment approaches assume a more prominent role in determining adequate dam safety levels, it is expected that the PMF concept will be "retired" and replaced by the relationship between annual exceedance probability and flood magnitude.

Benefits to the State:

The approaches to dam breach modeling, flood routing, and extreme flood estimation, which are being improved under this project, will be applicable to dams in Utah. It is expected their application in traditional and risk-based approaches to dam safety in Utah will increase as a direct result of National Dam Safety Program initiatives in both risk ranking and potential failure modes analysis. Potential benefits include improved dam break flood delineation, improved estimation of dam failure consequences for dam safety risk assessment, and improved flood estimation for traditional and risk-based approaches to dam safety. Any county with a dam or potentially impacted by dam failure is a potential beneficiary of this project.

Water Resources Planning and Management

Publications:

Bowles, D.S. (2004). *Assigning AEPs to the PMF for Dam Safety Risk Assessments*. IDSRM Technical Note Utah State University, Logan, Utah, February.

Bowles, D.S. (2005). *Probable Maximum Flood Approach to the Estimation of Design Flood.* Invited Key Lecture at the NATO Advanced Research Workshop "Extreme Hydrological Events: New Concepts for Security", Novosibirsk, Russia, July.

Chauhan, S.S., D.S. Bowles, and L.R. Anderson (2004). *Do Current Breach Parameter Estimation Techniques Provide Reasonable Estimates for use in Breach Modeling?* Proceedings of Dam Safety 2004, ASDSO 2004 Annual Conference, Phoenix, AZ, September.

Kinagoto, N. (2005). *Flood Plain Delineation Using GIS*. MS Plan B Report, Utah State University, Logan, UT.

Wang, Z. (2005). *Three-Dimensional Noncohesive Earthen Dam Breach Model and the Effect of Breach Locations on Breach Outflow with Wind and Wave Actions*. Ph.D. Dissertation, Utah State University, Logan, UT.

Wang, Z. and D.S. Bowles (In preparation). Effects of Breach Locations on the Breach Outflow under Wind and Wave Actions. *Journal of Advances in Water Resources*.

Wang, Z. and D.S. Bowles (In preparation). Three-Dimensional Non-Cohesive Earthen Dam Breach Model — Part 1, General Theory. *Journal of Advances in Water Resources*.

Wang, Z. and D.S. Bowles (In preparation). Three-Dimensional Non-Cohesive Earthen Dam Breach Model — Part 2, Calculation of Breach Outflow. *Journal of Advances in Water Resources*.

Wang, Z. and D.S. Bowles (In preparation). Three-Dimensional Non-cohesive Earthen Dam Breach Model — Part 3, Verifications and Applications. *Journal of Advances in Water Resources*.

Zhu, Y. (2004). *Comparison of One- and Two-Dimensional Hydrodynamic Flood Severity Modeling for Life Loss Estimation*. Master of Science Thesis, Utah State University, Logan, Utah.

Zhu, Y. and D.S. Bowles (2003). *Experiment Comparison of MIKE21 and DAMBRK*. Presented at the Second North American Danish Hydraulics Institute (DHI) Software Conference. San Francisco, California, November.

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Dam Failure Life Loss Estimation

Principal Investigator(s):
David S. Bowles
Loren R. Anderson
Terry F. Glover
Sanjay S. Chauhan
Maged Aboelata

Project Description:

The overall objective of this project is to develop a practical approach to life-loss estimation and evacuation planning for natural and dam-failure floods, which overcomes the limitations of the purely empirical approaches, while depending on only readily available data sources and requiring only a reasonable level of effort to implement.

Accomplishments:

The overall Life-Loss Estimation Project consists of the following phases:

1. Case history characterizations and analyses.

2. Development, testing, and demonstration of a Deterministic Mode of the modeling system, LIFESim.

3. Development, testing, and demonstration of an Uncertainty Mode of LIFESim including the Simplified Mode.

4. Development, testing, and demonstration of software for LIFESim including the Simplified Mode.

Most of the work on this project has been funded by the US Army Corps of Engineers, the Australian National Committee on Large Dams (ANCOLD) and eight member organizations, and the US Bureau of Reclamation. Phase 1 has been completed. Phases 2 and 3 are nearing completion. Remaining efforts will focus on developing the Simplified Mode. Phase 4 will be undertaken if funding is made available. UWRL funding has made possible the development, testing and incorporation of a dynamic transportation model.

LIFESim is a spatially-distributed dynamic simulation modeling system for estimating potential life loss. It has been formulated to overcome the limitations of the purely empirical life-loss estimation approaches, which are detailed by McClelland and Bowles (2002) and summarized by Aboelata et al. (2004a). LIFESim can be used to provide inputs for dam safety risk assessment or to explore options for improving the effectiveness of a dam owner's emergency plans or a local authority's response plans.

The LIFESim development philosophy has emphasized including the important processes that can affect life loss, while depending on only readily available data sources and requiring only a reasonable level of implementation effort. It comprises the following internal modules: 1) Loss of Shelter, including prediction of building performance; 2) Warning and Evacuation; and 3) Loss of Life, based on empirical relationships (McClelland and Bowles, 2000). Estimated flooding conditions are obtained from an external dam break flood routing model. LIFESim can be run in Deterministic or Uncertainty Modes.

The Uncertainty Mode propagates input uncertainties through the LIFESim to provide estimates of uncertainties in life-loss estimates, presented as probability distributions. Uncertainties in the following model inputs are considered:

- Warning initiation time relative to time of dam failure, T (hours)
- Warning diffusion curve
- Mobilization time curve
- Modal split between pedestrians and vehicles
- Modal split between cars and SUVs
- Vehicle occupancy rate (people/vehicle)
- Free flow speed (km/hr)
- Jam density (vehicles/km-lane)
- Human and vehicle stability criteria
- Structural damage criteria
- Height of first level in buildings above local ground level (m)
- Life-loss probability distributions for three flood zones

Aboelata et al. (2003) demonstrated a preliminary Deterministic Mode version of LIFESim for flood-induced and sunny day dam failures. The two cases differed in warning and evacuation characteristics with a two-stage evacuation of areas affected by spillway discharges and dam failure being considered for the flood case. Aboelata et al. (2004a) demonstrated a more advanced Deterministic Mode version for sudden and delayed earthquake dam failures for an existing warning and evacuation system and for an improved system. In addition, results from a preliminary Uncertainty Mode version were illustrated and comparisons were made with the empirical Graham (1999) Method of estimating life loss.

Over the past year the number of inputs that are considered in the Uncertainty Mode has been doubled. Additional improvements include the following:

- A dynamic transportation model
- Other PAR types such as hospital, schools, high rises, etc.
- Vertical evacuation
- Enhanced pre- and postprocessors using GIS layers
- Input guidance including default relationships

The transportation model represents the effects of traffic density on vehicle speed and also contraflow, which is sometimes used in evacuations, without requiring the details of road geometry and traffic signal operations.

A paper (Aboelata et al., 2004b) has been prepared for presentation at the 2004 ANCOLD Annual Conference with an emphasis on the role of the new transportation model. In addition to describing and demonstrating the latest Deterministic and Uncertainty Modes of LIFESim, it includes sensitivity studies on warning initiation time, four emergency shelter location cases, and a fivefold increase in population with no change in the capacity of the road network. Comparisons between Graham (1999)

and LIFESim life-loss estimates illustrate the difficulties associated with selection of representative Warning Time and Flood Severity categories in the spatially lumped Graham Method. They also illustrated the benefits of the LIFESim simulation approach.

Work Plan FY 05/FY 06:

A final project report and Ph.D. dissertation are in preparation and will contain a description of the entire modeling system, example applications, and guidance on parameterization. Work is being finalized to integrate the FEMA HAZUS-MH data base of structure types. A Simplified Mode of LIFESim is to be developed using synthetic samples from the Uncertainty Mode for a range of Failure Event - Population Exposure settings. These synthetic samples will be used to develop an "empirical" technique for life-loss estimation, referred to as the Simplified Mode. For settings that are adequately represented, the Simplified Mode is expected to provide life-loss estimates for preliminary risk assessments at a lower level of effort, although with greater uncertainties than the full modeling system.

The present version of LIFESim is a prototype version. To make it readily available for wider application, a user-friendly version of the software needs to be developed. This Phase 4 work has not yet been funded. In the meantime, LIFESim can be applied by its developers to obtain life estimates or to evaluate the effectiveness of evacuation plans.

Benefits to the State:

The approach to dam failure life loss estimation, which is being improved under this project, will be applicable to dams in Utah. It is expected that the use of dam safety risk assessment for dams in Utah will increase as a direct result of National Dam Safety Program initiatives in both risk ranking and potential failure modes analysis. Life loss estimates are needed as inputs for understanding, prioritizing, and justifying dam safety risk reduction measures. The effectiveness of major flood and dam failure evacuation planning can also be improved by using the LIFESim modeling system being developed under this project. Any county with a dam or potentially impacted by dam failure is a potential beneficiary of this project.

Publications:

Aboelata M. and D.S. Bowles (2003). *Evacuation and Life Loss Estimation Model for Natural and Dam-Break Floods*. Poster presentation at the New Engineering Building Dedication, Utah State University, Logan, Utah, October.

Aboelata, M., D.S. Bowles, and A. Chen (2004b). *Transportation Model for Evacuation in Estimating Dam Failure Life Loss*. Proceedings of the 2004 Australian Committee on Large Dams Conference, Melbourne, Victoria, Australia, November.

Aboelata, M., D.S. Bowles, and D.M. McClelland (2004a). A Model for Estimating Dam Failure Life Loss. *ANCOLD Bulletin*, 127:43-62.

Aboelata, M., D.S. Bowles, and D.M. McClelland (2003). *GIS Model for Estimating Dam Failure Life Loss.* Invited paper. Risk-Based Decision Making in Water Resources. In: Y.Y. Haimes and D.A. Moser, (eds.), American Society of Civil Engineers and presented at the Tenth Engineering Foundation Conference on Risk-Based Decision-Making in Water Resources: Protection of the Homeland's Water Resources Systems, Santa Barbara, California.

Graham, W.J. (1999). *A Procedure for Estimating Loss of Life Caused by Dam Failure*. Report No. DSO-99-06, Dam Safety Office, US Bureau of Reclamation, Denver, CO.

McClelland, D.M. and D.S. Bowles (2000). *Estimating Life Loss for Dam Safety and Risk Assessment: Lessons from Case Histories*. Proceedings of the 2000 Annual USCOLD Conference, US Society on Dams (formerly US Committee on Large Dams), Denver, CO.

Perera, S. and D.S. Bowles (2003). Life Loss Estimation Project – Progress Report. Annual Report of ANCOLD, October.

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Dam Safety Risk Management

Principal Investigator(s):
David S. Bowles
Loren R. Anderson
Terry F. Glover
Sanjay S. Chauhan

Project Description:

Dam safety management is intrinsically risk management. A team of Utah State University (USU) researchers has been developing and applying approaches to dam safety risk management for about two decades. We are now recognized internationally as leaders in this field. We have assisted the Utah State Engineer in evaluating dam safety risks at dams throughout Utah. We have also assisted the U.S. Bureau of Reclamation to develop and implement risk assessment in their dam safety program. We are currently assisting the U.S. Army Corps of Engineers implement approaches for individual and portfolio risk assessment. The USU team is also involved in several other countries and with various international efforts to develop guidelines for this powerful emerging field.

The overall objective of this ongoing research is:

To improve the availability and capability of practical risk-enhanced approaches to dam safety risk management.

Accomplishments:

- Continued advances in portfolio risk assessment, including development of procedures for large portfolios in which screening is incorporated and for owners, which have limited resources, such as those regulated by the states and for prioritizing investigations. Improved approaches for integration of individual and portfolio risk assessment outcomes into all aspects of dam safety programs (e.g., monitoring and surveillance programs and emergency management) and various business processes.

- Further development of practical approaches to using information from tolerable risk evaluation for making dam safety decisions on individual dams and portfolio of dams.

- Continued work developing the Life Loss Estimation Model and improving the Deterministic and Uncertainty Modes of the model. The Uncertainty Mode will be used to generate a synthetic database for a range of Failure Event – Population Exposure settings. This database will be used to develop an "empirical" technique for life-loss estimation, referred to as the Simplified Mode. For settings that are adequately represented, the Simplified Mode will provide life-loss estimates for a lower level of effort, although with greater uncertainties, than the full modeling system. However, provided that GIS data are readily available, the level of effort needed for implementing the full modeling system is considered to be reasonable. In addition to model development and testing, the model has been demonstrated for two Corps dams. A dynamic transportation modeling approach has been included in the evacuation component of the Life Loss Estimation model.

- An uncertainty analysis was completed for a risk assessment of a US Army Corps of Engineers dam (Chauhan and Bowles, 2004). This work provided a demonstration of a framework for uncertainty analysis in dam safety risk assessment, including an approach to incorporating input uncertainties into the risk analysis model. It proposed some useful formats for representing uncertainties in risk analysis results, such as expressing risk evaluation outcomes in terms of the confidence associated with meeting tolerable risk guidelines. This is very important additional information for decision makers compared with deterministic analyses, using only best estimate inputs, or sensitivity analyses. Best estimate inputs, even though they represent the best judgment of experienced dam engineering professionals, provide just a single point on the spectrum of estimated risks and will not in general correspond to the best estimate of the output variables. Sensitivity analysis takes a further step by providing the range around the best estimate results, but it has a severe limitation in that it does not provide an estimate of the confidence in results obtained from best estimate inputs.

- Improvement in the bases for estimating system response probabilities for dam safety risk analyses.

- Development of guidelines for dam safety risk analysis and risk assessment. Dr. Bowles served as an author for an ICOLD Bulletin on Risk Assessment and a reviewer for the ASCE, FERC, and UK guidelines.

- Further development and presentation of briefings, seminars, and workshops to professional groups in the United States and overseas.

- Dr. Bowles served as Member of the US Society on Dams Committee on Dam Safety and the USSD Board of Directors, and represented the US at the ICOLD Congress in Montreal, Canada, and Seoul, South Korea.

Work Plan FY 05/FY 06:

This research project is advancing the state-of-the-art and the state-of-the-practice in dam safety risk management in several areas, which are summarized below. At least one proposed work product applies to every area.

1. Portfolio Risk Assessment.

   Continued advances in portfolio risk assessment, including development of procedures for large portfolios in which screening will be incorporated and for owners, which have limited resources, such as those regulated by the states, the use of risk indexes, and for prioritizing investigations. Improved approaches for integration of individual and portfolio risk assessment outcomes into all aspects of dam safety programs (e.g., monitoring and surveillance programs and emergency management) and various business processes.

2. Tolerable Risk Evaluation.

   Further development of practical approaches to using information from tolerable risk evaluation for making dam safety decisions on individual dams and portfolio of dams. This work will include some further investigation of the use of F-N curves for societal tolerable risk, and setting guidelines for medium-term risk in a progressive risk reduction strategy, and short-term risk for design and construction of risk reduction measures.

3. Uncertainty Analysis.

Dams exist in an environment of risk and uncertainty. As with traditional approaches to dam safety evaluation, the risk enhanced approach must address the existence of uncertainties. The overall objectives of this project are as follows:

a) To characterize uncertainties associated with the inputs to dam safety risk assessment (e.g., extreme flood frequencies, earthquake hazard relationships, system response relationships, and consequences relationships).

b) To develop and evaluate alternative approaches to the propagation of input uncertainties in a dam safety risk analysis model to estimate the resulting uncertainties associated with output variables.

c) To evaluate the significance of uncertainties on output variables and the implications for dam safety decision-making.

d) To develop guidance for decision makers for the interpretation of the uncertainties associated with risk assessment outcomes.

Improved uncertainty modeling of dam safety risk assessment calculations to include common cause failure model considerations. We are planning to explore the contributions of uncertainty in different inputs to the uncertainty in various types of outputs using multiple regression analysis and correlation procedures. There is a need for additional research to provide guidance on the appropriate application of uncertainty analysis before it can be widely used. In addition, the consideration of model or epistemic uncertainty is a challenge for which practical approaches are needed.

4. System Response Probability Estimation.

Improvement in the bases for estimating system response probabilities for dam safety risk analyses.

5. Guidance on Dam Safety Risk Management.

Technical Notes are being prepared and updated on a series of topics and made available through the Institute for Dam Safety Risk Management at USU. Dr. Bowles is serving as a reviewer, advisor or author for guidelines for dam safety risk analysis and risk assessment that are under development by various organizations including the ASCE, FERC, ICOLD and NSW DSC, Australia.

6. Briefings, Seminars and Workshops.

Further development and presentation of briefings, seminars, and workshops to professional groups in the United States and overseas. Workshop and seminars are planned for the FERC and US Army Corps of Engineers in the USA and in Spain, Thailand and the UK. In addition, Dr. Bowles has been asked to provide a Plenary Session presentation for the 2005 US Society on Dams Annual Meeting in June 2005.

Results will be presented at professional meetings.

Benefits to the State:

The approaches to dam safety risk management being developed under this project are applicable to dams in Utah. It is expected their use for dams in Utah will increase as a direct result of National Dam Safety Program initiatives in both risk ranking and potential failure modes analysis. Benefits are expected to include improved understanding, prioritization, and justification of dam safety risk reduction measures. Any county with a dam or potentially impacted by dam failure is a potential beneficiary of this project.

Publications:

Aboelata, M. and D.S. Bowles (2003). *Progress Report on Life Loss Modeling Project*. Submitted to Institute for Water Resources, US Army Corps of Engineers, Alexandria, Virginia, September.

Bowles, D.S. (2004). ALARP Evaluation: Using Cost Effectiveness and Disproportionally to Justify Risk Reduction. *ANCOLD Bulletin*, 127:89-106, August.

Bowles, D.S. (2004). *Dam Safety Risk Assessment and the Corps of Engineers: Experience and Opportunities.* Invited presentation to Headquarters, U.S. Army Corps of Engineers, Washington, D.C., May.

Bowles, D.S. (2003c). *Dam Safety Risk Assessment for Individual Dams and Portfolios of Dams*. Invited Seminar presented to Fuji Research Institute Corporation, Tokyo, Japan, October.

Bowles, D.S. (2003f). *Independent Appraisal of the Romanian Risk Assessment Approach for Mine Tailings Dams*. End-of-Mission Report submitted to The World Bank, Washington, D.C. November, 22p.

Bowles, D.S. (2003a). *Report on One-Week National Workshop on Isotope Techniques in Dam Safety and Monitoring Landslide Activity with Emphasis on Risk Assessment, Chisinau, Republic of Moldova*. Submitted to the International Atomic Energy Agency (IAEA), Vienna, Austria. October.

Bowles, D.S. (2003d). *Risk Assessment in Dam Safety Management for Individual Dams and Portfolios of Dams*. Invited Seminar presented to the Japan National Committee on Large Dams (JNCOLD), Tokyo, Japan, October.

Bowles, D.S. (2003e). *Risk Assessment and Risk Management*. Invited presentation at the Regional Workshop on the Management and Safety of Mine Tailings Dams, Sinaia, Romania. Sponsored by The Government of Romania, The World Bank, and The Global Environment Facility, October.

Bowles, D.S. and L.R. Anderson (2003). *Risk-Informed Dam Safety Decision-Making*. ANCOLD Bulletin 123:91-103, April.

Bowles, D.S., L.R. Anderson, and R. Fell (2004). *Failure Modes Analysis: The Australian Experience*. An invited presentation at the U.S. Society on Dams Workshop on: Lessons Learned and Benefits Gained from the Potential Failure Modes Analysis Process. St. Louis, Missouri, March.

Bowles, D.S. and S.S. Chauhan (2003). *Review of Estimated Probabilities of Flood Failure Using Proposed UK Risk Analysis Procedure*. Submitted to Halliburton, Contractor for UK Government DFRA Research Project, December.

Bowles, D.S., W.D. Rowe, and S.G. Vick (2003). *Risk Assessment Template, Future Operations Strategy Review and Control System Requirements Project*. Review Report the Panel of Experts to the Department of Water Resources, State of California, and Washington Group International, Inc., Sacramento, California, August.

Bowles, D.S. and W. Wallin (2003). *One-Week National Workshop on Isotope Techniques in Dam Safety and Monitoring Landslide Activity with Emphasis on Risk Assessment, Chisinau, Republic of Moldova*. Sponsored by the International Atomic Energy Agency (IAEA), Vienna, Austria, October.

Chauhan, S.S. and D.S. Bowles (2004). Dam Safety Risk Assessment with Uncertainty Analysis. *ANCOLD Bulletin*, 127:73-88, August.

Hill, P.I., D.S. Bowles, P. Jordan, and R.J. Nathan (2004). Estimating Overall Risk of Dam Failure: Practical Considerations in Combining Failure Probabilities. *ANCOLD Bulletin*, 127:63-72.

McDonald, L.A., D.N.D. Hartford, D.S. Bowles, J.K. Vrijling, and J. Van Der Meer (2004). *Risk Assessment in Dam Safety Management: A Reconnaissance of Benefits, Methods and Current Applications*. International Commission on Large Dams (ICOLD) Bulletin on Risk Assessment.

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Optimal Water Allocation Model for Salt Lake Valley, Utah

Principal Investigator(s):
Jagath J. Kaluarachchi
Mac McKee
Wafa Hassan

Project Description:

1. Develop a water balance model for Salt Lake Valley considering various sources of water.

2. Evaluate the future needs in water considering different stakeholder groups.

3. Develop a methodology to optimal allocation of existing water resources in the future based on proposed land use changes while considering water quality impacts and economic productivity.

4. Demonstrate the applicability of the methodology and provide guidelines and suggestions to improve the existing water allocation policy.

Accomplishments:

1. Gathered existing information related to water resources, economic growth, environmental concerns, and pollution in the Salt Lake Valley.

2. Analyzed the data and information to assess the current situation of water in the Salt Lake Valley.

3. Developed an optimization model for water allocation. Simulate future water allocation scenarios and provide benefit cost assessment of these scenarios.

Work Plan FY 05/FY 06:

The work described here is innovative and the results obtained from the work will be published in reputed research journals. In addition a number of scientific presentations will be made in refereed conference proceedings. One student will use the work as a part of her Ph.D. dissertation over the next two years. This work provides national reputation to Utah State University in the form of cutting edge research and also enhanced graduate education and research at Utah State University.

Benefits to the State:

This work is directly based on the water resource planning for the rapidly growing Salt Lake Valley of Utah. The work proposed here will develop an optimal water allocation model for the valley considering surface and ground water and other sources of imported water. The work will also address limitation of water use due to poor water quality, economic implications due to change of water allocation policies and decisions, and changes needed in future land use practices to accommodate revised water policy changes.

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Quantification and Management of Uncertainty in Salt Loading from the San Rafael Irrigation System

Principal Investigator(s):

Mac McKee
Lizette Oman
Abedalrazq Khalil
Saket Pande

Project Description:

Irrigation in the valleys of the San Rafael River Basin in Emery County contributes substantial amounts of salt each year to the waters of the Green River. However, there is considerable uncertainty in how much salt flows out of these valleys, how much of the salt load is due to anthropogenic sources, including irrigation, and how salt management projects will affect total salt loads from the basin. This project will employ modern methods of data analysis to provide better estimates of salt loading from the basin and describe the amount of uncertainty those estimates contain. The project will also seek to identify data collection methods to reduce the uncertainty in estimates of salt loading.

Accomplishments:

Work in FY 2004 focused on statistical analysis of data available from historic stream flow and salt concentration measurements, including the real-time data provided in the on-line database operated by the Emery Water Conservancy District (EWCD) (see http://www.ewcd.org/). Work has focused thus far on analysis of salt loading from the San Rafael into the Green River. This will be extended further upstream as data and resources allow. In particular, statistical relationships between stage and discharge, and between conductivity and salt concentration have been developed. This has been done so as to provide the basis for a Bayesian Belief Network (BBN) model that will be used to quantify the uncertainty in the estimate of salt loading from the basin. Additional probabilistic relationships between conductivity and salt concentration have been developed from the fundamental principals of saline chemistry.

Work Plan FY 05/FY 06:

In FY 2005, available data, the estimates of stage-flow and conductivity-concentration relationships, and the probabilistic salt chemistry conductivity-concentration relationships will be used to populate the Bayesian Network, and the resulting model will be made available to the EWCD for generating salt loading estimates and for inclusion on their web site.

Benefits to the State:

Control and management of salt in the tributaries of the Colorado River is a difficult problem that is fraught with uncertainty. Application of methods that are specifically tailored to quantify and manage uncertainty and that can exploit the wealth of data that is becoming available from basin-wide real-time monitoring systems, such as the one operated by the EWCD, can potentially provide efficient and cost-effective ways of quantifying these salt loads and evaluating alternatives for reducing them. This is what will be demonstrated by the use of BBNs in this project.

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Real-Time Management of Irrigation Systems in the Sevier River Basin

Principal Investigator(s):
Mac McKee
Mariush W. Kemblowski
Abedalrazq Khalil
Tirusew Asefa
Saket Pande
Rajaa Hassan

Project Description:

As water demands increase in the western states and as concerns for endangered species and water quality begin to affect the allocation of water resources, greater emphasis will have to be placed on efficient water management if existing water rights are to continue to be met. Improvements in efficiency of water management require a low-cost mechanism for obtaining and distributing information about the state of the water supply system. The object of this project is to develop significant data analysis functionality to the existing Sevier River Water Users (SRWU) web site to support real-time and long-term water management information needs.

Accomplishments:

In FY 2002 and FY 2003, real-time operations models were developed using methods from statistical learning theory. These include artificial neural network (ANN) models, support vector machine (SVM) models, and "lazy learner" (LL) models. These models have been constructed to help provide real-time management information for determining releases from Piute Reservoir and diversions into the Sevier Valley / Piute Canal. The models have been made operational on the SRWU web site for use by reservoir and canal operators. Comparisons of model predictions versus actual canal operations are given in Figure 1.

Short-term predictive models were also built using artificial neural network approaches to forecast diurnal flows from Clear Creek into the Sevier River. An example of these forecasts, made hourly for a period 24 hours in advance, is given in Figure 2.

Long-term predictive models were constructed in FY 2003 to forecast stream flows at the Hatch gage in the Upper Sevier River Basin. These predictions come from an artificial neural network model that uses historical stream flow data, Snotel data, and sea surface temperature anomaly data from the Pacific and Atlantic Oceans. A comparison of the forecasts obtained from the ANN model versus historically measured flows is shown in Figure 3.

In FY 2004, work focused on development and statistical verification of an hourly operational model for predicting required releases from Piute Reservoir. The modeling process utilizes a combination of support vector machines and relevance vector machines (RVMs) to screen incoming data to recognize outliers and / or "drift" in the underlying probability distribution of the input data, develop a revised predictor model if drift in the underlying distribution is detected, and then make a prediction for required reservoir releases for the next hour. Adoption of the RVM approach for developing the predictor model has provided the capability of estimating confidence intervals on the

prediction made by the model. This capability, which has not been previously possible, gives the reservoir operator valuable information about the uncertainty in the prediction made by the model. The suite of models is designed to run in real time and to provide the reservoir operator with an hour-by-hour recommendation for releases needed from the reservoir in order to meet downstream demands for nine irrigation canals. It does this in order to meet water orders that arrive 24 to 48 hours in advance of deliveries, even though travel times from the reservoir to the end of the furthest canal is on the order of five or six days. The suite of models was developed using data from the 2001 and 2002 irrigation seasons, and then tested against the 2003 irrigation season. Figure 4 provides a comparison of actual reservoir releases and model-generated recommendations for release quantities, as well as confidence intervals, for the 2003 season.

Work Plan FY 05/FY 06:

The hourly operational model for Piute reservoir will be tested against data from the 2004 irrigation season. If these tests show satisfactory statistical performance, the suite of models will be programmed on the SRWU computers, and the models will be used to run the gate controllers of Piute Reservoir for the 2005 irrigation season.

Benefits to the State:

Application of this and related technologies in the Sevier River Basin in the past four years have already shown a dramatic increase in the efficiency of basin-wide water management. Similar results could be achieved in virtually every river basin in Utah, especially those with substantial irrigated agriculture. These forecasting techniques could potentially provide valuable information for better long-term decisions by farmers and ranchers for investments in crops and livestock, especially in years where drought might be likely. Similarly, the short-term forecasting methods could supply system managers with information necessary to more precisely control the operation of large irrigation systems, thereby saving water and increasing the overall productivity of the system.

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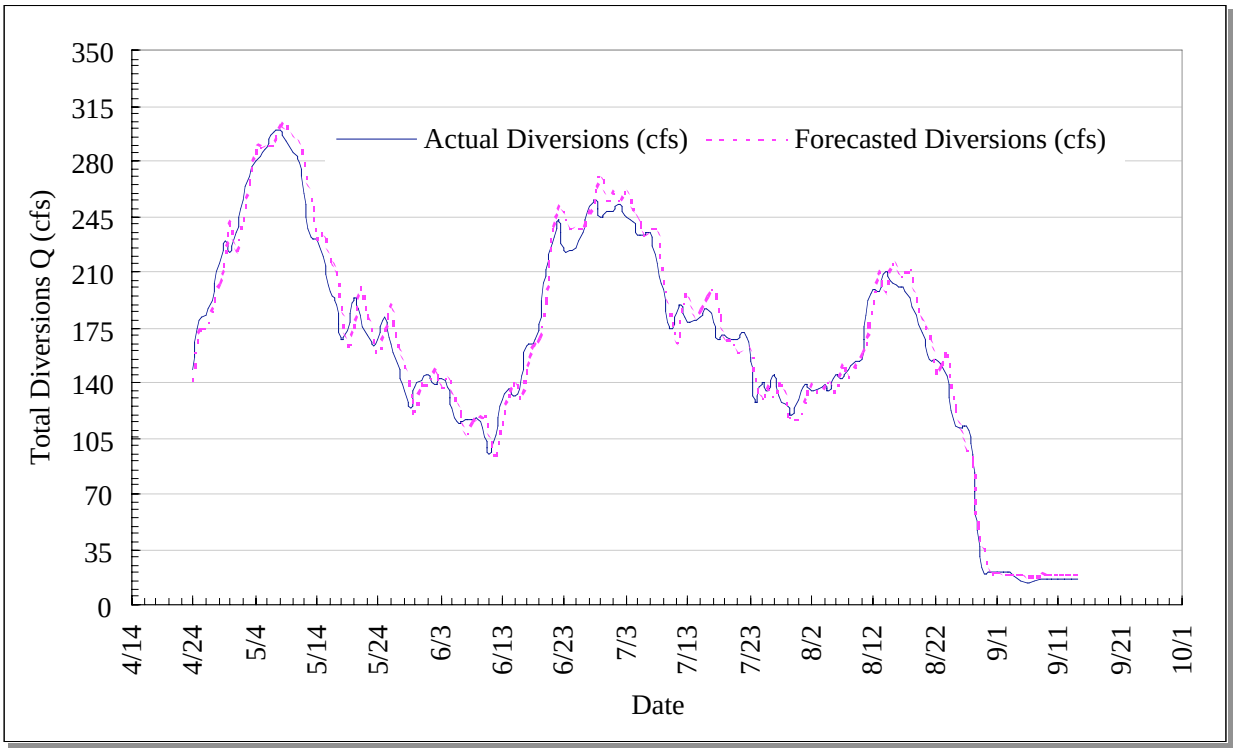

Figure 1. Comparison of Actual Sevier Valley / Piute Canal Diversions in 2002 with ANN Model Forecasted Diversions

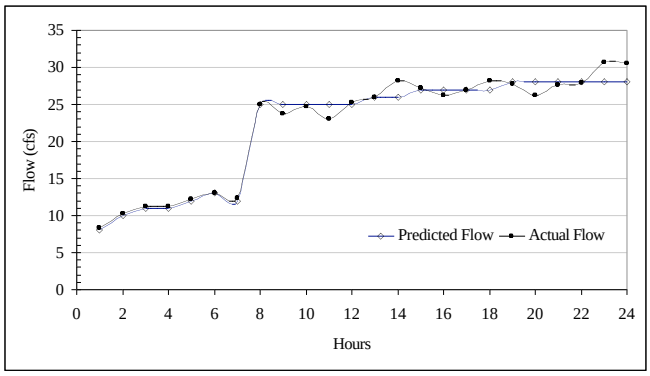

Figure 2. Predicted Versus Actual Diurnal Fluctuation of Flows in Clear Creek on 4/4/2001

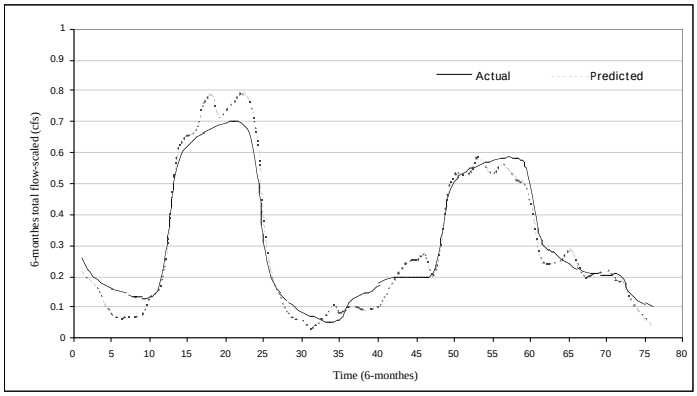

Figure 3. Time-Series Performance of the ANN Model in Predicting Seasonal Flows at Hatch

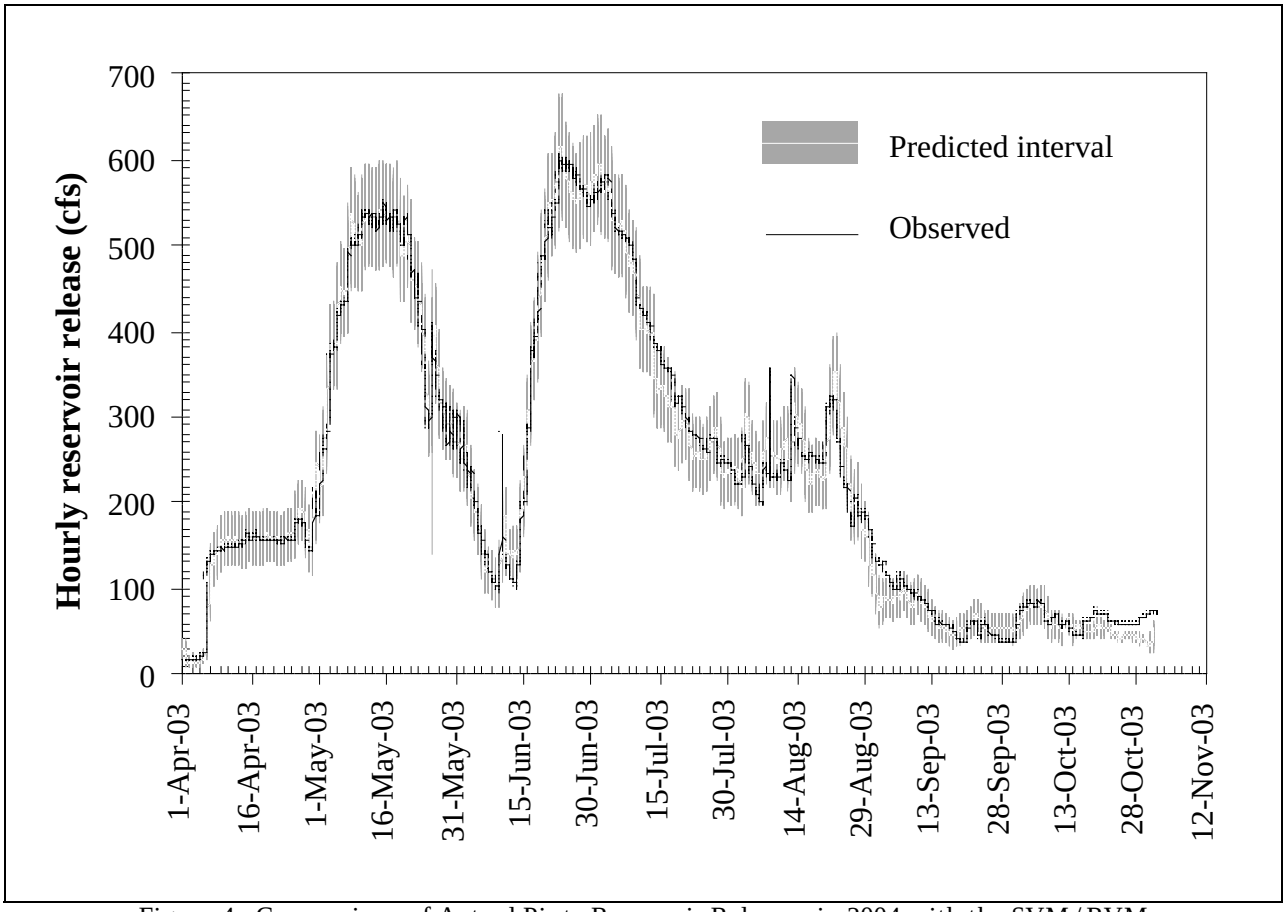

Figure 4. Comparison of Actual Piute Reservoir Releases in 2004 with the SVM / RVM Model Forecast Releases

Technical Support for the Virgin River Resource Management and Recovery Program

Principal Investigator(s):
Thomas B. Hardy
R. Craig Addley

Project Description:

The Virgin River Resource Management and Recovery Program represents a collaborative effort by local, county, state, and federal resource agencies to manage future water development in the Virgin River Basin while meeting recovery goals for listed species. The program involves stakeholders and managers within the Virgin Basin through Technical Teams that identify research and management actions that will promote the protection and recovery of species while providing a framework to meet water allocation needs within the basin.

The purpose of this work is to provide technical support to the program through participation on the Technical Committee. Utah State University (USU) has worked on the endangered fish species and related water resource problems in the Virgin Basin intensively since 1982. This institutional knowledge base and extensive research experience is invaluable to the program as complex water allocation strategies and recovery actions are being considered.

Accomplishments:

USU personnel have actively participated in monthly Technical Team meetings, conducted specific analyses for proposed water resource actions and proposed recovery actions for the Program. This work also included development and review of technical scopes of work and review of study results by participating investigators.

Work Plan FY 05/FY 06:

USU will continue to provide technical support through this period.

Benefits to the State:

This project is being carried out in conjunction with the State of Utah Division of Wildlife Resources, U.S. Fish and Wildlife Service, National Park Service, Bureau of Land Management, and the Washington County Water Conservancy District. The results of this work will guide long-term water allocation strategies and ultimately the successful recovery of the endangered species of fish within the Virgin River Basin.

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Research Faculty, Professional, and Support Staff

Research Faculty, Professional and Support Staff

Utah Water Research Laboratory and Utah Center for Water Resources Research

Mac McKee, Director
Thomas B. Hardy, Associate Director
Jan S. Urroz, Administrative Supervisor
R. Ryan Dupont, Head of Environmental Division
R. Ivonne Harris, Information Dissemination Coordinator
Jagath J. Kaluarachchi, Head of Water Division

Utah State University Water Resources Research Council

H. Scott Hinton, Dean, College of Engineering (Chair)
Mac McKee, Director, Utah Water Research Laboratory / Utah Center for Water Resources Research
Noelle E. Cockett, Dean, College of Agriculture
F.E. Busby, Dean, College of Natural Resources
Martyn Caldwell, Director, Ecology Center
Donald W. Fiesinger, Dean, College of Science
Gary Kiger, Dean, College of Humanities, Arts, and Social Sciences
Brent C. Miller, Vice President for Research
H. Paul Rasmussen, Director, Agricultural Experiment Station

Utah Water Research Laboratory Faculty

Mac McKee, PhD, Director UWRL / UCWRR, Professor, CEE / UWRL
Loren R. Anderson, PhD, Department Head of Civil and Environmental Engineering, Professor, CEE / UWRL
Luis Bastidas, PhD, Assistant Professor, CEE / UWRL
A. Bruce Bishop, PhD, Professor, CEE / UWRL
David S. Bowles, PhD, Professor, CEE / UWRL
Sanjay S. Chauhan, PhD, Research Assistant Professor, CEE / UWRL
William J. Doucette, PhD, Professor, CEE / UWRL
R. Ryan Dupont, PhD, Professor, Head of Environmental Division, CEE / UWRL
William J. Grenney, PhD, Professor, CEE / UWRL
Thomas B. Hardy, PhD, Associate Director, UWRL; Professor, CEE / UWRL
Daniel H. Hoggan, PhD, Professor, CEE / UWRL
Michael C. Johnson, PhD, Research Assistant Professor, CEE / UWRL
Jagath J. Kaluarachchi, PhD, Professor, Head of Water Division, CEE / UWRL
Mariush W. Kemblowski, PhD, Professor, CEE / UWRL
Randal S. Martin, PhD, Associate Professor, CEE / UWRL
Michael J. McFarland, PhD, Associate Professor, CEE / UWRL
Joan E. McLean, MS, Research Associate Professor, CEE / UWRL
Laurie S. McNeill, PhD, Assistant Professor, CEE / UWRL
William J. Rahmeyer, PhD, Professor, CEE / UWRL
Judith L. Sims, MS, Research Associate Professor, CEE / UWRL
Ronald C. Sims, PhD, Professor, CEE / UWRL
Darwin L. Sorensen, PhD, Research Professor, CEE / UWRL
David K. Stevens, PhD, Professor, CEE / UWRL
David G. Tarboton, PhD, Professor, CEE / UWRL
Blake Tullis, PhD, Assistant Professor, CEE / UWRL
Gilberto E. Urroz, PhD, Associate Professor, CEE / UWRL

Research Faculty, Professional and Support Staff

Utah Water Research Laboratory Staff

R. Craig Addley, MS, Director of INSE, Senior Research Engineer
Ben Ames, Office Assistant, STI
Steven L. Barfuss, MS, Research Engineer
Leon Basdekas, BS, Research Engineer
William Bradford, BS, Research Associate
Marianne Brown, Staff Assistant I
Carmell Burns, Staff Assistant III
Terry Carlsen, BS, Research Technician
Peg Cashell, MS, Soil Scientist
Shannon Clemens, BS, Research Engineer
Matt Combes, BS, Research Engineer
Coreen Crouch, BS, Research Technician IV
Jennifer Downs, Staff Assistant, CORE
Debora Escalante, Education Specialist, STI
Andrae Ferguson, BS, Publications Specialist, STI
Ian Gowing, BS, Research Scientist
Barbara Haines, BS, Development Coordinator, STI
Betty J. Hansen, Staff Assistant II
R. Ivonne Harris, BA, Information Dissemination Coordinator
Cindy Henderson, Runner
Jeffery S. Horsburgh, MS, Research Engineer
Danielle Jorgensen, Library Assistant
Tami Kadis, Receptionist
Max Longhurst, MEd, CORE Academy Director, Education Specialist
Debra Lundgreen, BS, Development Coordinator, STI
Sharon Melton, Accounting Technician
Bethany Neilson, MS, Research Engineer
Michael Petersen, PhD, Research Scientist
Tamara Peterson, BS, Business Manager
Carri Richards, Business Assistant
Megan Richards, Coordinator, CORE
Weylia Richards, Office Assistant, CORE
Christopher Schofield, Chief Distribution Engineer
James Shoemaker, MS, Research Engineer
Geoffrey G. Smith, MS & MBA, Director IOWSE
Blaine L. Sorenson, MS, District Education Specialist, STI
Alan Taylor, Shop Foreman
ValaRee R. Tennant, Staff Assistant, STI
Chris Thomas, BS, Accountant III
Zachary Tippetts, MS, Webmaster / On-Line Training Specialist, STI
Jan Urroz, BS, Supervisor of Administrative Services and Infrastructure
Diane D. Weston, Staff Assistant, STI
Meagen Williams, Staff Assistant, CORE
Mark Winkelaar, BS, Research Engineer
Craig Wright, Distribution Engineer, STI

Adjunct Appointments and Emeriti Faculty

Lloyd Austin, MS, Adjunct Professor, CEE / UWRL / Utah Department of Natural Resources
Jay M. Bagley, PhD, Professor Emeritus, CEE / UWRL
Duane G. Chadwick, MS, Professor Emeritus, EE / UWRL
Calvin G. Clyde, PhD, Professor Emeritus, CEE / UWRL
Frank W. Haws, MS, Senior Research Engineer Emeritus, UWRL
Trevor C. Hughes, PhD, Professor Emeritus, CEE / UWRL
C. Earl Israelsen, PhD, Professor Emeritus, CEE / UWRL
Eugene K. Israelsen, MS, Senior Research Engineer Emeritus, UWRL
Roland W. Jeppson, PhD, Professor, CEE / UWRL
Upmanu Lall, PhD, Adjunct Professor, UWRL / CEE / Columbia University
Eva C. Nieminski, PhD, Adjunct Associate Professor, CEE / UWRL / Utah Department of Environmental Quality
J. Paul Riley, PhD, Professor Emeritus, CEE / UWRL
Norman E. Stauffer, PhD, Adjunct Professor, CEE / Utah Department of Natural Resources
J. Paul Tullis, PhD, Professor Emeritus, USU Foundation, CEE / UWRL