

# **Colorado Water Resources Research Institute**

## **Annual Technical Report**

### **FY 2002**

## **Introduction**

Drought Lab Created -- As Colorado's drought worsens, the state's water supplies diminish, and communities are uncertain about how to deal with prolonged dry conditions, Colorado State University researchers responded by establishing DroughtLab. DroughtLab is a joint initiative of Colorado State's CWRRI/Water Center and the Climate Center. The Lab brings together more than 100 researchers from 22 academic departments at Colorado State and scientists at labs and departments at the University of Colorado at Boulder. Disciplines contributing to DroughtLab's efforts include atmospheric science, civil engineering, watershed sciences, soil and crop sciences, rangeland science, forest science, ecology, sociology, political science, and agricultural and resource economics. Outreach education, statewide Cooperative Extension efforts, technology transfer and the communication of drought knowledge to state and local officials and the general public will compliment the lab's research efforts. Research will be conducted on campus and across the state at the university's Agricultural Experiment Station research centers located in communities throughout Colorado.

Co-directors of the DroughtLab are Professor Roger Pielke Sr., Department of Atmospheric Science and director of the Colorado Climate Center at CSU, and Professor Jose Salas, Professor of Civil Engineering at CSU.

Professor Roger Pielke has been at Colorado State University since 1981. His research interests include Mesoscale Meteorology, Meteorological Modeling, Climate Change, and Air Pollution Meteorology. To investigate these topics, he developed the Regional Atmospheric Modeling System (RAMS). This nested grid meteorological model has been used in published studies of a wide variety of atmospheric systems. RAMS has been linked to an ocean model and to an ecosystem dynamics/hydrologic modeling system to evaluate feedbacks between these different geophysical systems. Professor Pielke's investigations include global, regional, and microscale studies.

Professor Salas's research interests include stochastic modeling and simulation of hydrological processes; hydroclimatic variability; flood prediction, forecasting and control; and drought analysis, prediction, and management. From establishing a complex computer model of the Nile River system in Africa to setting up satellite monitoring of the snowpack in the Andes, Jose Salas has traveled the globe for more than 20 years working with foreign nations on hydrologic and water resources projects. He has collaborated with water professionals on projects in Venezuela, Peru, Guatemala, Ecuador, the Philippines, Italy, India, Spain and Portugal. Professor Salas has been developing mathematical models that establish the risk and uncertainty of extreme hydrologic events such as floods and droughts.

DroughtLab researchers are initially focusing on three key areas:

Drought analysis and characterization: Researchers are characterizing the initiation, evolution, termination and recurrence of drought and developing new methods for analyzing various types of drought.

Drought impacts and consequences: Researchers are identifying techniques for impact assessment and evaluation of consequences of extreme drought, including ecological and socio-economic impacts, and consequences to cities, rural communities, agriculture and industry.

Drought response and management: Researchers are developing new technological options for planning and managing the impacts of extreme drought, including analyses of water resources systems, the development of water supply forecasting techniques, developing associated policy, mobilization of institutions and mitigation options that could be useful for local, state and national level decision makers.

New USGS Facility Dedicated -- The new facility of the U.S. Geological Survey Fort Collins Science Center, known as FORT, was dedicated on August 23, 2002. Located on the Colorado State University campus, FORT is part of the Natural Resources Research Center, which is being developed to support and enhance natural resources research conducted by five federal agencies from the Departments of Interior and Agriculture.

#### FY 2002 CWRI RESEARCH PROGRAM

At the annual November 5, 2001 meeting of CWRI's Advisory Committee for Water Research Policy (ACWRP)\* in Denver, faculty in charge of the five FY2001 CWRI projects and graduate students presented updates on the progress of their research. The presenters and topics were:

Tim Gates -- Description and Interpretation of Salinization in the Lower Arkansas River Valley, Colorado; Luis Garcia -- Enhancements to the South Platte Mapping and Analysis Program (SPMAP); Kurt Fausch -- Distribution, Habitat and Life History of Brassy Minnow in Eastern Colorado; Jim Loftis -- Eutrophication of Reservoirs on the Colorado Front Range; John Stednick -- Applicability of Various Trophic Status Indicators for Colorado Front Range and Plains Reservoirs.

The ACWRP reviewed progress on the two multi-year projects and decided to fund them for a third year. They are:

Description and Interpretation of Salinization in the Lower Arkansas River Valley, Colorado -- The Principal Investigators are Timothy K. Gates and John W. Labadie, Department of Civil Engineering, Colorado State University; Co-Investigators are Grant E. Cardon, Department of Soil and Crop Sciences, Colorado State University, and Israel Broner, Department of Chemical Engineering, Colorado State University. (James C. Valliant, Extension Irrigation Specialist, Cooperative Extension, Colorado State University was originally listed as a co-investigator. He retired in April, 2002.) Partial funding for this project was provided by the CSU Agricultural Experiment Station.

Enhancements to the South Platte Mapping and Analysis Program (SPMAP) The Principal Investigator is Luis Garcia, Department of Civil Engineering, Colorado State University. (CWRI funds were supplemented with funds from the Northern Colorado Water Conservancy District, the Lower South Platte River Group, and the Central Colorado Water Conservancy District.)

The ACWRP then reviewed proposals and selected FY2002 CWRI projects within the following priority areas:

Water quality implications of ground/surface water conjunctive use in the Denver Basin; Identifying/evaluating Best Management Practices to control non-point source pollution in Colorado forests and from septic tanks; and Salinity mitigation options for the Lower Arkansas Valley.

The committee voted to devote remaining research funds to the following projects:

Quantifying the Effectiveness of Best Management Practices (BMPs) on Controlling Non-point Source Pollution in a Multiple-Use Forest. The Principal Investigator is Dr. John D. Stednick, Department of Earth Resources, Colorado State University.

Determining the Fate of Non-source Pollution from Septic Tanks in Turkey Creek Basin, Colorado, and Delineating Improved Management Practices. The Principal Investigator is Dr. Eileen Poeter, Department of Environmental Science and Geological Engineering, Colorado School of Mines.

FY2002 USGS National Competitive Grants Program -- Professor Robert Siegrist of the Colorado School of Mines received an award in the FY2002 U.S. Geological Survey National Competitive Grants Program. The award for the project, Occurrence and Fate of Emerging Organic Chemicals in Onsite Wastewater Systems and Implications on Water Quality Management in the Rocky Mountain Region, was made through the Colorado Water Resources Research Institute.

#### CWRRI Activities and Accomplishments

The Water Archive -- The Colorado State University Water Resources Archive is a joint project of the University Libraries, the Colorado Water Resources Research Institute and the Colorado Agricultural Archives. Formally begun in 2001, the Archive consists of collections from individuals and organizations that have been instrumental in the development of water resources in Colorado and the West. The Water Resources Archive has collections of the following individuals and organizations available for research:

Morton W. Bittinger, Whitney M. Borland, Colorado Association of Soil Conservation Districts, Eric Eidsness, Ival V. Goslin, National Water Resources Association, James L. Ogilvie, Rocky Mountain Hydrologic Research Center, Herbert Vandemoer (Colorado Water Conservation Board), David Walker (Colorado Water Conservation Board).

Document types within the collections are numerous, ranging from meeting minutes, reports and correspondence to maps, photographs and audio tapes. These primary materials relate to all aspects of water in Colorado and to contributions made by Coloradoans to water activities. Subject areas include engineering studies, legislative matters, water resources management and more.

What's New: Full text finding aids for the collections are now online. View them through the collection list or perform a keyword search through them all simultaneously. The electronic searching techniques allow the user to find words in documents as long as 100 pages. The University Archives staff provides a world class-service to archive users so this rich history can be tapped in an environment that respects the historical importance of the materials.

Second USDA Grant Received -- A second USDA grant to Colorado State University will provide funding for three additional fellows to conduct research on water management issues critical to Colorado agriculture in the Western United States. The Cooperative State Research, Education, and Extension Service (CSREES) awarded the \$207,000 grant to Jim Loftis, Civil Engineering Department, CSU and

Jessica Davis, Soil and Crop Sciences Department, CSU in February 2002. The doctoral fellowships carry a stipend of \$22,000 per year for three years plus a travel allowance to attend two national technical conferences. The first grant by CSREES was made in early 2000, and fellows selected for the program were Garey Fox, pursuing his Doctorate in Civil Engineering and specializing in modeling the interactions of surface water and ground-water resources; Marci Koski, whose Ph.D project concerns food web relationships, trophic dynamics and how they relate to water quality and other aspects of aquatic ecology in western reservoirs; and Colleen Green, whose research topic will involve runoff and leaching studies with vegetative buffer strips in urban areas versus agricultural areas, where manure has been applied for at least 10 years. The USDA grants are administered through the Colorado Water Resources Research Institute.

Two Scholarships Funded Through CWRRI -- Water users in northeastern Colorado are funding a new \$2500 scholarship at Colorado State University while the Upper Yampa Water Conservancy District (UYWCD) will fund the second year of a scholarship it initiated for the school year 2001/02. Both scholarships are administered by the CSU Water Center/CWRRI. The one-year scholarships provide financial assistance to committed and talented students who are pursuing water-related careers at CSU.

Upper Yampa Water Conservancy District Scholarship -- Jamie Harrington, a junior in Chemical Engineering at CSU, is the recipient of the 2002/2003 Upper Yampa Water Conservancy District Scholarship. Jamie, who is also obtaining a minor in Environmental Engineering, hopes to pursue a career in groundwater treatment upon graduation in May, 2003. Jamie maintains a 3.7 GPA in her Chemical Engineering studies at CSU. She currently serves as Vice President of the CSU Student Chapter of the American Institute for Chemical Engineers and is a member of several honor societies. She is responsible for organizing field trips for the Chemical Engineering students and is arranging a trip to Steamboat Springs in the fall to tour the local water and wastewater plants. This summer, Jamie will participate in a groundwater bioremediation research project at North Carolina State University.

The 2001/02 holder of the UYWCD Scholarship, Josh Duncan, presented his Civil Engineering teams senior design project to the Manager of the UYWCD, John Fetcher, via a conference call on May 16, 2002. Josh's team placed third in the Engineering Days competition with their feasibility analysis of expanding Stagecoach Reservoir by diverting unappropriated water from Morrison Creek. Josh will pursue a Master of Science degree in CSU's hydraulics/hydrology graduate program this fall.

Northeast Colorado Water Users Scholarship -- Skyler Gartin, who recently completed two years of pre-engineering studies at Northeastern Junior College (NJC), is the first recipient of the Northeast Colorado Water Users Scholarship. Skyler, with a 4.0 GPA, plans to major in Civil Engineering at CSU with an emphasis in irrigation systems. Skyler notes he gains a healthy appreciation for water efficient irrigation systems when he watches an aquifer disappear! The Ogallala aquifer is beneath the family farm in Merino, Colorado. Skyler, while maintaining a 4.0 GPA in high school, was All-State in football and All-Conference in baseball. He served as his senior class president and worked on a number of farms in the Merino area while in high school. At NJC, Skyler received a number of honors recognizing his excellent math and science skills, while continuing his active participation in student government.

National Science Foundation Grant -- Now in its 3rd year, an NSF grant awarded to Jorge Ramirez, Department of Civil Engineering, through CWRRI/CSU Water Center, has given a unique opportunity for 15 undergraduate students from four-year colleges and universities to conduct independent research in Water Science and Engineering during an 8-week summer session. Students worked in teams that included faculty, graduate students, and staff to gain hands-on experience in laboratory and field research

methods. Students were under the guidance of faculty from the departments of Civil Engineering, Earth Resources, Soil and Crop Science, Chemical Engineering, Fishery and Wildlife Biology, and Rangeland Ecosystem Science.

Annual Water Resources Seminar -- This one-credit seminar (GS592) is held every Fall semester and is open to all interested faculty, students and off-campus water professionals. The Fall, 2002 seminar focused on the Cross Currents in the Arkansas River: Changing Values, Competing Demands, and Policy Reactions.

#### Additional CWRRI Activities Involving Local, State and Federal Agencies and Other Organizations

The CWRRI/CSU Water Center Director and Water Resources Specialist have contributed to the following activities involving water in Colorado:

During the annual Colorado Water Congress convention in January 2003, CWRRI organized two special sessions serving as technology transfer mechanisms for research results on irrigation science and information technology and protecting and preserving rare and historic Colorado water management papers. Both sessions were held in packed rooms.

CWRRI collaborated with the Colorado Water Well Contractors Association and the Colorado Division of Water Resources in sponsoring three one-day workshops on use of ground water for domestic purposes. The workshops were particularly aimed at informing real estate agents about key aspects of ground water supply and septic tank impacts on groundwater quality.

CWRRI assisted the Bureau of Reclamation in hosting a drought workshop in Greeley; Cooperative Extension in hosting a drought meeting in the Lower South Platte River Valley; and the Colorado Department of Agriculture in hosting an examination of the future of agriculture under severe drought conditions.

The CWRRI Director, Robert Ward, serves as NIWR President for 2002-03;

Helped organize the Colorado Watershed Assembly, an umbrella organization for watershed groups across the state;

Is a member of the National Water Quality Monitoring Council, the Colorado Water Quality Monitoring Council (CWRRI played a major role in establishing the Council), the Bureau of Reclamations Research Steering Committee, the GreenCO Water Task Force, the Fort Collins Water Board, and the Larimer-Weld Water Issues Group;

Is Commissioner-designate for the Poudre Heritage Alliance;

Serves as peer reviewer for two NRC council reports (TMDLs and NAWQA design enhancements);

Is working with the Colorado Water Conservation Board to establish a student intern program whereby diverse students are brought into the organization for summer jobs; and

Supports and participates in activities of the Colorado Water Congress, a state-wide organization of water users and managers.

Reagan Waskom, Water Resources Specialist for the Colorado Water Resources Research Institute, is principal or co-principal investigator on the following research/education projects: an investigation of selenium on Colorado's West Slope and an agricultural education project funded by the U.S. Department of Agriculture, a project related to phosphorus runoff funded by the U.S. Department of Agriculture and the Environmental Protection Agency, and a project on ground water education funded by the Colorado Department of Agriculture.

\*ACWRP membership is provided for in CWRRIs by-laws. The ACWRP is comprised of: the Chair of the Colorado Senate Committee on Agriculture, Natural Resources and Energy, the Chair of the Colorado House Committee on Agriculture, Livestock and Natural Resources, the Executive Director of the Colorado Department of Natural Resources, the Executive Director of the Colorado Department of Public Health and Environment, the Commissioner of the Colorado Department of Agriculture; and six members of the general public selected based on their participation in setting Colorado water policy in the legislative process and involvement in obtaining funding for such policy. The ACWRP's mandate is to address two functions: to advise CWRRIs regarding research to be undertaken as part of the federally supported, state-based water research program; and to seek state and local water research funding to provide the state match required. See Attachment A for a list of members of the CWRRIs Advisory Council on Water Research Policy.

## **Research Program**

# Managed Ground Water Recharge for Habitat Restoration: The Development of a Biological Component to the South Platte Mapping and Analysis Program (SPMAP)

## Basic Information

<b>Title:</b>	Managed Ground Water Recharge for Habitat Restoration: The Development of a Biological Component to the South Platte Mapping and Analysis Program (SPMAP)
<b>Project Number:</b>	2002CO1B
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	1/28/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	4th
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	Ecology, Groundwater, Hydrology
<b>Descriptors:</b>	Stream depletion factor, Augmentation, GIS, State-listed aquatic species, Habitat restoration
<b>Principal Investigators:</b>	Luis Garcia

## Publication

1. Shrier, Catherine J., 2002, Habitat Potential Assessment Tool (HPAT): Planning Tools to Support Development of Recharge Ponds and Wetland Habitat in the Lower South Platte of Colorado, in South Platte Forum Proceedings, Information Series No. 94, Colorado Water Resources Research Institute, Colorado State University, Fort Collins, Colorado, p. 32.
2. Shrier, Catherine J., Jay Stafford, and Jon Altenhofen, 2002, Integration of Habitat Enhancement Efforts into Managed Groundwater Recharge Facilities, in AWRA 2002 Summer Specialty Conference Proceedings, Ground Water / Surface Water Interactions, American Water Resources Association, Herndon, VA. 473-477.

## SYNOPSIS

### Problem and Research Objectives:

The South Platte Lower River Group (SPLRG) was organized to address critical water management problems in the lower portion of the South Platte basin. SPLRG'S focus is the creation and enhancement of (1) groundwater well augmentation, (2) in-stream flows for which Colorado receives credit in a Platte Basin Endangered Species Program or ESRP, and (3) wetlands and wetland habitat for aquatic wildlife species of concern, waterfowl and other wildlife species. The increased flows in the Platte River during critical periods are to be developed by re-timing the flows in the South Platte, mainly through the creation of new recharge ponds in the Lower South Platte. In Colorado this activity is referred to as the "Tamarack Plan", after the Tamarack Ranch State Wildlife Area, where several of the recharge facilities are being developed. The entire Tamarack Plan, however, will include recharge facilities on both public and private lands, particularly in the last 30 miles of the South Platte River in Colorado, where return flows are unlikely to be diverted prior to reaching the state line. Under the Tamarack Plan, SPLRG is overseeing the development of a series of managed groundwater recharge projects to re-time river flows in order to assist with in-state water management and to provide Colorado's water contributions to the Platte River ESRP. In pilot recharge projects developed at the Tamarack Ranch State Wildlife Area, SPLRG, the Colorado Division of Wildlife (CDOW), and Ducks Unlimited (DU) have integrated habitat components into recharge facility designs, including the use of multiple recharge ponds to control temperature of return flows, the development of a live stream fed by ponds, and the development of a wetland area fed by recharge return flows (see Figure 1).

There is strong interest among private land owners in the region in developing additional recharge facilities for the Tamarack Plan to meet interstate water obligations, and in designing these recharge facilities both for wildlife habitat and for recharge credits for in-state water use. There is also strong interest from CDOW in continuing to restore wildlife habitat at the new recharge facilities. In 2001, the CDOW received a directive from Colorado Department of Natural Resources Director Greg Walcher to work towards the prevention of further federal threatened and endangered species listings in Colorado, and to attempt to recover currently listed species to the point where they can be de-listed. Several partnership programs with state and federal agencies and private wildlife organizations are available that can provide financial and technical assistance to private landowners who develop habitat on their property. The partnership programs include the U.S. Fish and Wildlife's Partners for Fish and Wildlife and the Natural Resources Conservation Service's Wildlife Habitat Incentive Program (WHIP) and Wetlands Reserve Program (WRP). These partnership programs can fund 75% to 100% of the costs for construction of the recharge facilities, and also provide technical expertise for the design of the facilities to maximize the potential habitat benefits. Joining private landowners with habitat partnership programs also helps the mainly agricultural users to meet the costs of developing recharge facilities for well augmentation and for the Three States Agreement.



COLORADO  
TAMARACK PLAN  
RECHARGE, MINNOW STREAM & WETLAND HABITAT PROJECT  
Tamarack Ranch State Wildlife Area, West Side

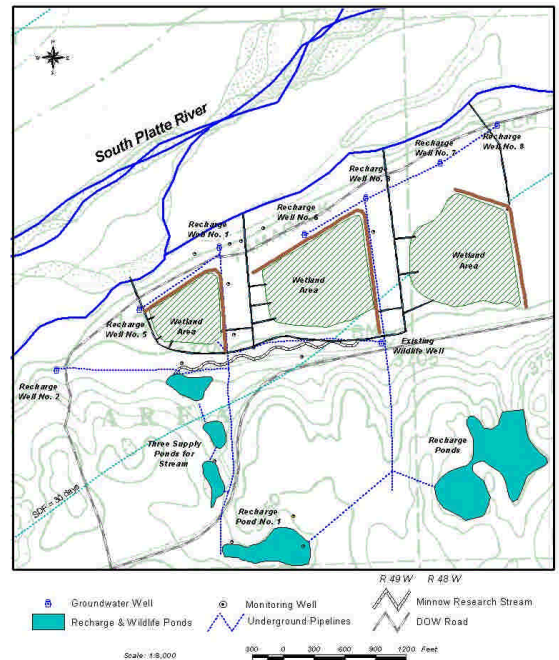


Figure 1. Tamarack Plan Recharge, Minnow Stream  
Wetland Habitat Project

The goal of the research outlined in this synopsis was to increase the amount of wetlands and wetlands habitat for aquatic wildlife species of concern, waterfowl, and other wildlife species in the lower South Platte River by linking recharge facility development with habitat development partnership programs. We accomplished this primarily by:

developing a screening tool to identify locations for recharge facility development; collecting and providing information on existing habitat development activities, species sampling activities, CDOW wildlife management activities at State Wildlife Areas, CDOW data on riparian vegetation, and water user organization information on the location and availability of water storage and delivery facilities to partnership programs that develop habitat; and facilitating a more formal relationship between habitat development partnership programs and the water user organizations, and providing educational materials on habitat development on private lands in the lower South Platte River of Colorado, so that the development of habitat on private lands and distribution of funds to private landowners can occur in a more coordinated manner.

Methodology:

1) Developing a screening tool to identify locations for recharge facility development

The tools developed for this project, collectively called HPAT (Habitat Potential Assessment Tool), were created as modular additions to the South Platte Mapping and Analysis Program (SPMAP). SPMAP is a GIS-based water management decision support system that has been used by most of the major water user groups in the Lower South Platte basin since SPMAP's inception in 1995. SPMAP was created as a "user-directed effort". HPAT adds a biological

component to the SPMAP tools. For HPAT, a multi-criteria decision analysis approach has been developed to analyze and compare individual sites for their potential to be developed as recharge pond sites and as waterfowl habitat sites.

One of the GIS-supported site assessment tools included in HPAT is the Recharge Potential Assessment Tool (RPAT). It has been developed in ArcView GIS, using Avenue programming. RPAT was developed based upon the knowledge acquired from interviews with local experts and literature reviews on what information was needed for assessment of recharge potential.

The Recharge Potential Assessment Tool (RPAT) provides information to support decisions regarding the feasibility of developing a recharge facility at a potential site. Several of the coverages containing maps and data necessary for assessment of recharge potential at a site were already available as a part of SPMAP. New coverages added to SPMAP specifically for RPAT include National Resources Conservation Service soil maps for Morgan and Sedgwick Counties and Digital Raster Graphics (DRGs), which are digital versions of the U.S. Geological Survey topographic maps. The graphical user interface for RPAT automatically opens the appropriate coverages and provides maps and reports showing information related to recharge potential for a user-selected site.

The following information is provided in the RPAT report and map layout:

Site location:

- Site name, owner, and contact information.
- Name of and distance (in meters) to the nearest town.

Proximity to water sources:

- Distance (in meters) to the South Platte River (which is always assumed to be downhill from the site).
- Location, name, and distance (in meters) to the 3 nearest ditches and whether the ditch is uphill or downhill from the site.
- Location, name, and distance (in meters) to the 3 nearest wells, and whether the well is uphill or downhill from the site.

Site characteristics:

- Soil type.
- Stream depletion factor (in days).

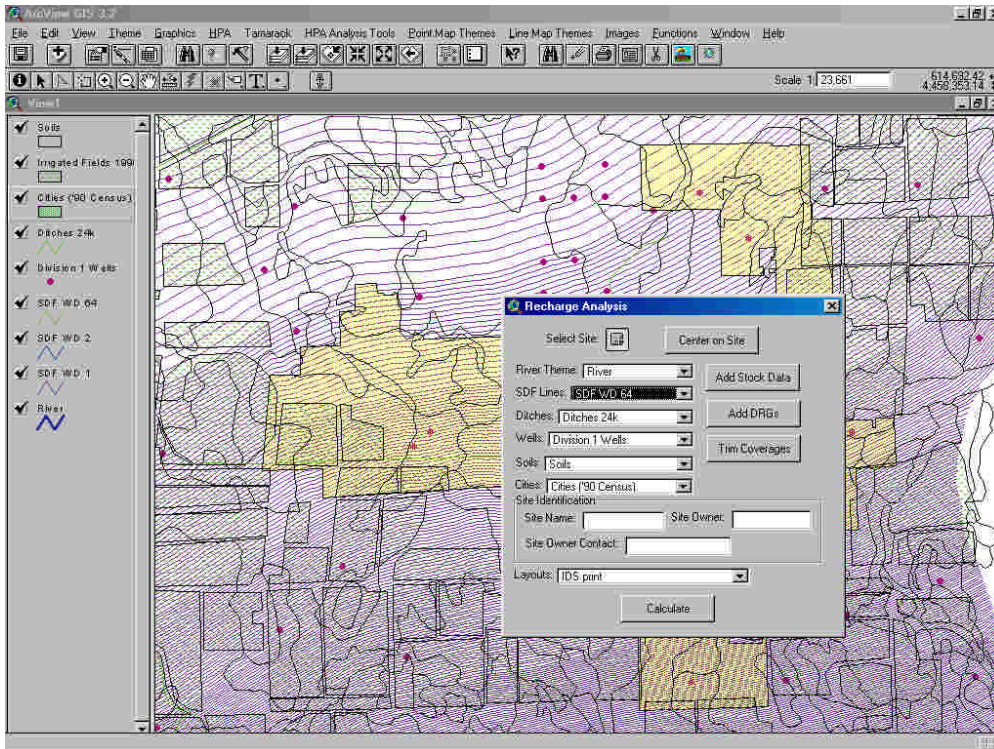


Figure 2. RPAAT Graphical User Interface

2) Collecting and providing information on existing habitat development activities, species sampling activities, CDOW wildlife management activities at State Wildlife Areas, CDOW data on riparian vegetation, and water user organization information on the location and availability of water storage and delivery facilities to partnership programs that develop habitat.

A second GIS-supported site assessment tool included in HPAT is the Waterfowl Habitat Assessment Tool (WHAT). Like RPAAT, WHAT has been developed in ArcView GIS, using Avenue programming. WHAT was developed based upon the knowledge acquired from interviews with local experts and literature reviews on what information was needed for assessment of waterfowl habitat potential.

The Waterfowl Habitat Assessment Tool (WHAT) provides information to support decisions regarding the feasibility of developing waterfowl habitat at a potential site. Several of the coverages containing maps and data necessary for assessment of waterfowl habitat potential for a site were not available as part of SPMAP, and were acquired or created based on data from various wildlife agencies and habitat partnership programs. Like RPAAT, the graphical user interface for WHAT automatically opens the appropriate coverages and provides maps and reports showing information related to recharge potential for a user-selected site. The assessment provides some basic information about the site that can be used by a representative from a habitat partnership program prior to a site visit.

The following information is provided in the WHAT report and map layout:

Site location:

- Site name, owner, and contact information.
- Name of and distance (in meters) to the nearest town.

Proximity to water sources:

- Distance (in meters) to the South Platte River (which is always assumed to be downhill from the site).
- Location, name, and distance (in meters) to the 3 nearest ditches and whether the ditch is uphill or downhill from the site.
- Location, name, and distance (in meters) to the 3 nearest wells, and whether the well is uphill or downhill from the site.

Site characteristics:

- Soil type.
- Vegetation type.

Proximity to wetlands and managed habitat areas:

- Location, name and distance (in meters) of all Ducks Unlimited, Partners for Fish and Wildlife, or Natural Resources Conservation Services EQIP/WRP/WHIP sites within a five-mile radius of the selected site.
- Location, name, and distance (in meters) to all State Wildlife Areas within a five-mile radius of the selected site.
- Location and distance (in meters) to all recharge ponds within a five-mile radius.
- Location, species name, and distance (in meters) to all Colorado Natural Heritage Program (CNHP) Element Occurrences with a five-mile radius of the selected site.
- Location, biodiversity significance and rank, and distance (in meters) to all CNHP Potential Conservation Areas within a five mile radius of the selected site.

In addition to the Wildlife Habitat Assessment Tool, HPAT includes a Fish Sampling Coverage, Report Maker, and Site Photo Links. Data records from fish sampling in the Lower South Platte have been put into a coverage and associated tools. The records include fish sampling from the South Platte basin, the Lodgepole Creek tributary, and the Republican River Basin. These records are electronic versions of the data from actual CDOW field reports including sets of photographs for each sampling site taken on the date of sampling.

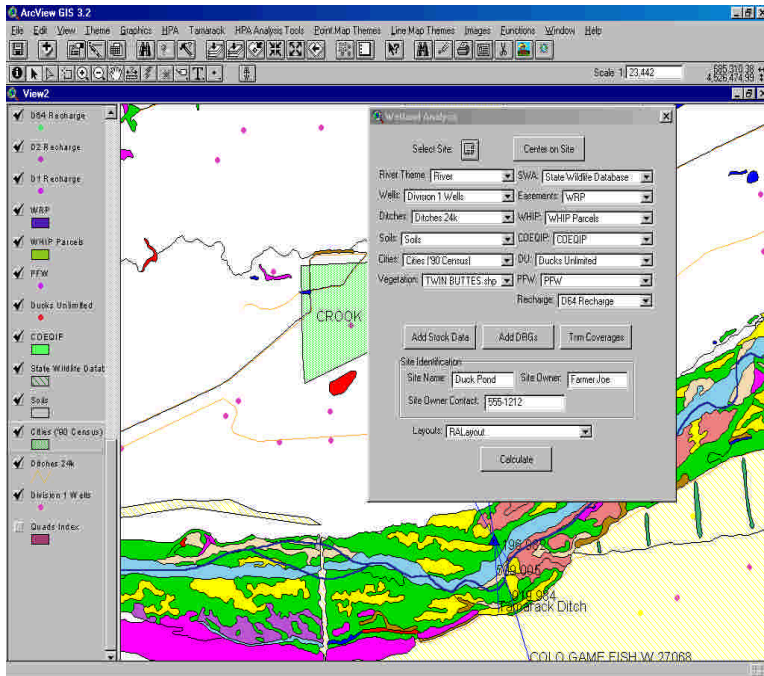


Figure 3: WHAT User Interface

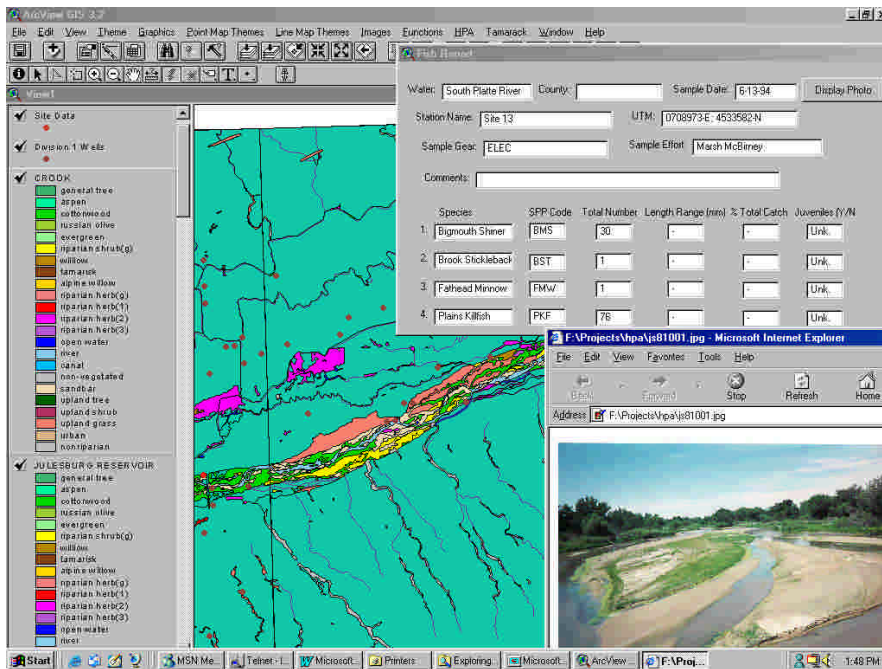


Figure 4. Fish Sampling Tool

Facilitating a more formal relationship between habitat development partnership programs and the water user organizations, and providing educational materials on habitat development on private lands targeted to the lower South Platte River of Colorado, so that the development of



habitat on private lands and distribution of funds to private landowners can occur in a more coordinated manner

The HPAT project provided a biological module to SPMAP, which has been used extensively by water users in the region. This module was developed to be compatible with existing GIS coverages and tools. This provides water users and habitat users with a similar platform of tools with which to work.

By combining data and information from diverse contacts, the HPAT project helped to more firmly establish relationships between habitat development partnership programs and water user organizations. For this project, the programs which have been most interested in supporting waterfowl habitat projects within the South Platte region, for which recharge ponds could provide the greatest benefits, were identified, namely:

Ducks Unlimited, Inc., which administers North American Wetlands Conservation Act (NAWCA) grant money  
Natural Resources Conservation Service Habitat Programs  
Environmental Quality Incentives Program (EQIP)  
Wildlife Habitat Incentives Program (WHIP)  
Wetlands Reserve Program (WRP)  
U.S. Fish and Wildlife Service's Partners for Fish and Wildlife Program (PFW)

The HPAT guidance manual was developed to provide background information on recharge requirement, Colorado water law, and habitat programs in the region. This manual also provides information on eligibility requirements, funding mechanisms, and local program contacts for each of these programs.

#### Principle Findings and Significance:

Knowledge Base Development. Through interviews with local experts in managed groundwater recharge and habitat development programs, the essential site characteristics sought to assess the potential for a site to be developed for recharge or waterfowl habitat were identified. The site characteristics for recharge and for waterfowl habitat in this region had previously been poorly represented in the literature. This effort also represented one of the first attempts to use a knowledge-based approach to the development of site assessment tools in this region, and the first to develop integrated knowledge bases addressing both water management and habitat development concerns.

GIS Coverage Compilation. To support site assessments based upon the site characteristics identified through the knowledge base development, several GIS coverages were acquired, enhanced, or created, and compiled as part of the HPAT biological module, including:

- Soil types
- State Wildlife Areas
- Vegetation Types
- Ducks Unlimited sites

- NRCS habitat program (EQIP/WHIP/WRP) sites
- Partners for Fish and Wildlife sites
- Recharge ponds
- CNHP element occurrences and potential conservation areas

In some cases, map coverages were available with little or no data provided in the attribute tables, which were needed to provide data for the assessment reports. There were also cases in which, site databases were available separate from the map coverages, but the identifiers for the sites for which data was available did not match the identifiers in a map coverage. In these cases, HPAT developers attempted to match sites identified in the databases with those represented in the map coverage. This process revealed the need for better coordination among database managers and GIS coverage developers, to ensure that spatial and tabular data are developed in a compatible and consistent format.

GIS Coverage and Assessment Tool Applications: Waterfowl Habitat Programs. The GIS coverages and assessment tools have proven to be immediately applicable to support water resources and habitat planning and management efforts in the region. The GIS coverages have been used by the South Platte Wetlands Focus Area Committee (SPWFAC) to develop maps for inclusion in the SPWFAC Strategic Plan and to support the South Platte's inclusion in the Intermountain West Joint Venture for the administration of North American bird conservation initiatives. The coverages compiled and criteria identified during the HPAT project are also being used by Ducks Unlimited as a basis for the identification of target areas for restoration in the region.

GIS Coverage and Assessment Tool Applications: Fish Sampling Data. The fish sampling data program has been used as a model for a similar fish data program developed by the Colorado Division of Wildlife (CDOW). The graphical user interfaces for the fish sampling data tool and the other HPAT tools were also reviewed by the CDOW Integrated Management Program South Platte Prototype Workgroup to provide guidance on the development of tools to support agency habitat management programs.

GIS Coverage and Assessment Tool Applications: Water Users. The criteria identified through the recharge potential knowledge base has been used by water managers in educational programs for water users to explain what to consider in selecting recharge sites. Future work has also been discussed by area water managers regarding the potential use of coverages and assessment tools to support regional planning efforts by identifying potential recharge pond sites using GIS.

HPAT Application for Multi-Criteria Decision Analysis Development for Recharge Pond and Waterfowl Habitat Development. The knowledge bases, GIS coverages, and assessment tools developed for the HPAT project provided basic information on user-selected sites to support the users' assessment of that site for recharge and/or habitat potential. The HPAT project has led to additional work to support the site-specific and regional analysis of recharge and habitat potential on the basis of multiple criteria. This new research, which is being conducted as dissertation research by the graduate student who had been supported by the HPAT project, involves the development of a Multi-Criteria Decision Analysis (MCDA) using knowledge bases and GIS coverages developed as part of the HPAT project. The criteria for the MCDA were also

identified through a knowledge base development process, and the GIS coverages and knowledge bases were enhanced and linked to the Excel-based MCDA prototype.



# Enhancements to the South Platte Mapping and Analysis Program (SPMAP)

## Basic Information

<b>Title:</b>	Enhancements to the South Platte Mapping and Analysis Program (SPMAP)
<b>Project Number:</b>	2002CO2B
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	4th
<b>Research Category:</b>	Ground-water Flow and Transport
<b>Focus Category:</b>	Agriculture, Groundwater, Water Use
<b>Descriptors:</b>	Agricultural consumptive use, Geographic information system, Augmentation, Conjunctive use of groundwater/surface water
<b>Principal Investigators:</b>	Luis Garcia

## Publication

## SYNOPSIS

### Problem and research objectives

The South Platte River System is operating closer and closer to its absolute capacity due to an exploding urban population, steady agricultural demand and new mandates for instream flows. The severe drought that the region has been experiencing in recent years has only highlighted the magnitude of the problem. However, water scarcity in the region might be mitigated by further development of ground and surface waters and more innovative cooperation and trading between decreed water users. The focus of the SPMAP project is to develop tools for conjunctive management of ground and surface water that will allow for a more flexible supply while maintaining obligations for downstream water users required by law.

SPMAP already provides a set of valuable modular tools for managers in the South Platte basin who provide water primarily to agricultural users. (Agricultural use is the highest water use category in the basin). SPMAP includes accurate spatial data in a program called SPGIS, a way to determine consumptive use from ground water withdrawals (SPCU), and a method in a component called SDF View to estimate stream depletion (or accretion in the case of ground water recharge).

The goal of this project to enhance SPMAP is to identify gaps in the current management tools and implement computer systems and acquire data to fill these gaps. The following objectives were identified for 2002-2003.

1. Work with water users to coordinate any image acquisition and develop a long-term data management system. This will ensure that there is no duplication of effort regarding data acquisition among water users. Also, continue to update and integrate new GIS layers into SPGIS.
2. Expand the capabilities of SPCU to allow users to generate different types of scenarios that will be compatible with the capabilities of SDF View.
3. Expand the capabilities of the SPCU model to include additional daily methods: Penman-Montieth, New ASCE Equation.
4. Include the capability to do water budget computations with the daily SPCU methods.
5. Work with water users in the application of the different models to several case studies. This will allow us to determine any needs for new tools as we calibrate and validate all the modules of the system to several case studies.
6. Document, test and revise the daily SDF model.
7. Continue to work on the development of a protocol and long term plan for module maintenance, upgrades and access through the IDS web site.

### Methodology

Since 1995 the Integrated Decision Support (IDS) Group at the Colorado State University Water Center has adopted a user-centered approach to developing the SPMAP tools. The IDS Group has worked closely with a number of local and regional water management organizations along

the Lower South Platte River to develop the SPMAP decision support tools. In producing enhancements to these tools, the IDS Group continues to pride themselves on their responsiveness to area water managers.

Objective 1: Work with water users to coordinate any image acquisition and develop a long-term data management system. This will ensure that there is no duplication of effort regarding data acquisition among water users. Also, continue to update and integrate new GIS layers into SPGIS.

Contact with water managers and the State Engineer's office is continuous ensuring that data layers are kept accurate. The SPGIS ArcView has been enhanced making it easier for users to select GIS information and transfer it to the SPCU or the SDF Model.

Objective 2: Expand the capabilities of SPCU to allow users to generate different types of scenarios that will be compatible with the capabilities of SDF View.

The SPCU Model has been enhanced to allow users to generate scenarios that are compatible with SDF View. Scenarios that show the impacts of drought have been particularly useful to water managers as Colorado continues to experience extremely dry conditions.

Objective 3: Expand the capabilities of the SPCU Model to include additional daily methods: Penman-Montieth, New ASCE Equation.

The SPCU Model can compute CU by using the Blaney-Criddle, Kimberly-Penman or Penman-Monteith techniques. This year the capability of computing consumptive use with daily methods was also added to the SPCU Model.

Objective 4: Include the capability to do water budget computations with the daily SPCU methods.

Water budget computations can now be made using the daily methods and exported into the daily SDF View model.

Objective 5: Work with water users in the application of the different models to several case studies. This will allow us to determine any needs for new tools as we calibrate and validate all the modules of the system to several case studies.

This past year IDS has worked with Central and GASP to import their well data into SPCU. During this process we added new functions to help users calculate presumed depletion factors by incorporating gross pumping figures from their databases and comparing them to calculated well depletions.

Objective 6: Document, test and revise the daily SDF model.

We have sent out the daily SDF model to a group of users to test the model, and we think that the model is now ready for general release. Documentation and further testing are in the works.

Objective 7: Continue to work on the development of a protocol and long term plan for module maintenance, upgrades and access through the IDS web site.

All the work developed under this new project is documented or in the process of being documented. At each major stage of development the software is provided to the participating organizations via the World Wide Web from the internet site:

- <http://www.ids.colostate.edu/projects/spmap>

#### Principal findings and significance

SPMAP continues to be a valued set of tools for water managers in the South Platte region. Enhancements made to the tools through this project have made SPMAP even more popular with users. The work that the IDS Group has done importing data from the databases provided by the Central Water Conservancy District and the Groundwater Appropriators of the South Platte has allowed users to do larger studies. The SPCU Model has pleased users with its accuracy and ability to model real world scenarios.

# Quantifying the Effectiveness of Best Management Practices (BMPs) in Controlling Non-Point Source Pollution From Forestland Uses

## Basic Information

<b>Title:</b>	Quantifying the Effectiveness of Best Management Practices (BMPs) in Controlling Non-Point Source Pollution From Forestland Uses
<b>Project Number:</b>	2002CO4B
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	4th
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Ecology, Ecology, Water Quality
<b>Descriptors:</b>	Non-point source pollution, Best Management Practices, Sedimentation
<b>Principal Investigators:</b>	John Stednick

## Publication

## SYNOPSIS

### Problem and research objectives:

The most direct way to determine Best Management Practice (BMP) effectiveness is to measure sediment produced in areas of implementation, and directly compare this with locations of similar hydrologic inputs in this case directly adjacent the BMP. The BMPs measured in this study were institutional or structural and have a direct connection to Trout Creek, a sediment impaired waterbody. Non-point sources are diffuse and difficult to identify, but BMPs are visible and measurable.

The objectives for this study were: 1) to determine the effectiveness of BMPs on controlling sediment inputs to Trout Creek by measuring on-site soil erosion and comparing this to background data. 2) to determine effectiveness of BMPs by measuring the sediment size distribution in the creek above and below the land use. 3) to determine effectiveness of BMPs by measuring suspended sediment concentrations in the creek above and below the land use. 4) to compare these methods and determine their applicability in determining BMP effectiveness and accuracy.

### Methodology

The study area is Trout Creek and its tributaries, located in the Pike-San Isabel National Forest near Colorado Springs, Colorado. Land uses include roads, logging, grazing, and recreation, and BMPs have been implemented for each (Carlson, 2001). All forestland uses in this area may contribute to increased sediment inputs (Gowen, 1981). The creek has also been identified as an area with an exceedance of sediment and targeted for a TMDL (Hageman, 2001). The monitoring effort was at various spatial scales; watershed scale, reach scale, and individual BMP.

#### Basin Scale

Analyzing sediment yield at the basin scale is important for determining the cumulative effectiveness of all BMPs implemented in the area. This method has been used most widely in research arenas. However if beneficial uses and standards are not being met, this method does not provide a direct linkage to sources of sediment or individual BMPs. Conducting a paired watershed study to determine effectiveness was considered, however watersheds in this area have all been impacted by humans and the variability in basin characteristics may not address the sensitivity in sediment values.

Effectiveness was determined by comparing collected data to 'natural conditions'. Suspended sediment were collected at each site using a U.S. Geological Survey DH-48 depth integrated sampler, during the discharge measurements, and frequently during storms. The samples were appropriately stored until transferred to the CSU water quality lab for analysis, where they were filtered, and oven dried for total suspended sediment determination. Total sediment load and yield can be calculated, and related to past systematic data as well as 'natural' conditions. A USGS gage station now out of commission can provide systematic data on past flows, which can

be related to sediment discharge. Natural yields were estimated from a variety of techniques including climate, infiltration, vegetation, and historic data.

#### Reach Scale

Often a combination of BMPs are implemented at each land-use site, this complicates the issue of relating individual BMPs to land-use and water quality. The effects of various land-uses that implement BMPs can be determined by an above and below sampling scheme within the creek.

Creek bed particle size distribution at each site were characterized using the zigzag pebble count (Bevenger and King, 1995). This involves zigzagging across the channel moving up-stream, while measuring randomly selected particles' secondary axis. This can better characterize the longitudinal profile of particle distribution. This zigzag scheme may also eliminate some of the spatial bias when only measuring a single cross section.

#### Individual BMP monitoring

Analyzing the effectiveness of individual BMPs is where research has lacked the most. Most studies have focused on determining effectiveness at the watershed scale, and have ignored the individual BMPs, which isn't helpful for individual BMP technique improvement. This proposed research will focus mainly on analyzing individual BMPs using an on-slope technique to measure erosion and sediment to the stream. This technique, sediment traps, is more appropriate than instream water quality sampling for many reasons. Sediment traps more accurately represent erosion rates by integrating inputs over time, they are less expensive and less time consuming, and they are more appropriate for use by managing agencies (Corner, 1996).

Sediment traps were used to determine individual BMP effectiveness. Trap design consists of a small (~ 12 by 7 in., and 1 in. deep) aluminum tray, placed in the soil at locations of likely runoff. The sampling scheme is systematic and includes 1 site, consisting of 3 locations: a BMP area, a nearby location with the same land-use and similar characteristics but without BMPs, and a control site with no apparent land-uses.

The sediment traps were installed in the spring, and removed in early September. The sampling period was shortened by a wildfire that burned through the study area. The traps were checked weekly, and after each rain event. Samples were collected as needed (not removing the traps), oven dried, and weighed. Comparisons of erosion rates from the BMP location, and the control can quantitatively assess effectiveness. BMPs of the same structure can be compared and generalizations can be made as to their effectiveness, when considering site characteristics and land-uses.

#### Principal findings and significance

The Forest Service put up informational signs for off-road vehicle users to avoid using certain trails or roads to reduce erosion and aesthetic effects. Sediment traps were used to collect sediment from 10 storms, and the results suggested a significant increase in soil erosion when the signs were in place. The signs seemed to attract ORV users rather than discourage them.

Cattle allotments were fenced and not fenced to assess the effect of fencing on stream reach stability. Fencing significantly reduced the amount of streambank slumping and erosion.

A series of forest road cross drains were monitored for erosion. Sites were paired with and without drain culverts. There was significantly more soil erosion below the culverts. Much of the erosion appeared to be from improperly placed culverts, the outlet being too high created channel knick points.

At the watershed scale, there were no detectable differences between suspended sediment concentrations measured at various point in the watershed above and below the BMPs. Similarly there was no difference between the Wolman pebble count and the estimated mean particle size at any of these points. Individual BMP effectiveness is measurable on-site. The effectiveness of the BMPs at the stream reach and at the basin level was not measurable. The stream selected for this study has a variety of multiple land use activities, however much of the hydrology is controlled by an upstream storage reservoir, thus basin level streamflow responses were not significant. Furthermore, the study was affected by a large wildfire through much of the study are, a significant drought, and the compounding influence of a burgeoning beaver population and associated beaver dams on Trout Creek. Additional research at the watershed or basin level is needed.



# Determining the Fate of Non-source Pollution from Septic Tanks in Turkey Creek Basin, Colorado, and Delineating Improved Management Practices

## Basic Information

<b>Title:</b>	Determining the Fate of Non-source Pollution from Septic Tanks in Turkey Creek Basin, Colorado, and Delineating Improved Management Practices
<b>Project Number:</b>	2002CO5B
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	6th
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Non Point Pollution, Water Quality, Groundwater
<b>Descriptors:</b>	Non-point source pollution, Septic tanks, Colorado
<b>Principal Investigators:</b>	Eileen Poeter, John E. McCray

## Publication

1. Dano, K., E. Poeter, and G. Thyne, 2002, Geochemical and geophysical determination of the fate of septic tank effluent in a mountain watershed, Colorado, Geol. Soc. Am. Abstracts with Programs, 34(6).
2. Thyne, G.D., C. Guler, and E. Poeter, 2003, submitted to Ground Water, Use of multivariate statistical and spatial analysis combined with geochemical modeling for the characterization of watersheds: Example from a fractured rock aquifer, Turkey Creek Basin, Colorado.
3. Poeter, Eileen, G.D. Thyne, G. VanderBeek, and C. Guler, 2003, Ground Water in Turkey Creek Basin of the Rocky Mountain Front Range in Colorado, in Engineering Geology in Colorado - Contributions, Trends, and Case Histories, Association of Engineering Geologists, Denver, Colorado.
4. VanderBeek, G., E. Poeter, G.D. Thyne, and J.E. McCray, 2003, Ground-water availability in Turkey Creek Basin, Colorado, Geol. Soc. Amer., Abstracts with Programs, 35(5).
5. VanderBeek, G., E. Poeter, G. Thyne, J.E. McCray, 2002, Ground-water Availability in Turkey Creek Basin, Colorado, Geol. Soc. Amer., Abstracts with Programs, 33(4).

## SYNOPSIS

### Problem and research objectives

The rapid growth of population and development in mountain watersheds caused Jefferson County of Colorado to begin collecting data in a pilot study of ground-water resources in the Turkey Creek Watershed. Located approximately 20 miles west of Denver, the local communities are served by a fractured-crystalline rock aquifer, typical of those in the western US that provide water through individual domestic wells and treat wastewater with individual sewage disposal systems. Resource managers in the county commonly assume that 90% of water pumped by a residence is returned to the ground water system via individual septic treatment systems. This is inconsistent with the observation that the surface water quality has declined since 1975, while the ground-water quality has been relatively constant. This discrepancy suggests that high permeability regolith may support strong lateral flow in shallow zones between sewage disposal systems and streams. Such a short-circuiting of domestic sewage return flows is consistent with the fact that ground-water levels have been declining over the last few decades. Although long-term hydrographs from individual wells are not available, static water level data at the time of drilling was contoured for wells drilled in the 1970s and the 1990s. The wells were drilled in different seasons and different years. Thus, the contours provide only a general sense of water level conditions. The data were gridded at the same locations, using a variety of algorithms. The average difference of hydraulic head at grid locations between the 1970s and 1990s indicates an average water level decline on the order of 150 to 200 ft for all of the gridding approaches. Separating the data seasonally revealed an average decline of 140 ft in summer water levels and 190 feet in winter water levels. Precipitation at Stapleton Airport, in nearby Denver, CO was below average during the 1970s and above average during the 1990s, consequently the difference in precipitation over the periods is not responsible for the decline. This hypothesis is also consistent with the observation that the few available hydraulic tests (single well tests) suggest very high storage coefficients (not borehole storage) that are not consistent with the fractured rocks.

This project will evaluate the possibility that septic system return flows are short-circuiting the deep ground water system via lateral flow through regolith on the bedrock surface and rapidly reaching streams.

### Methodology

An existing septic system is examined. An EM31 survey is used to evaluate depth to bedrock, slope of bedrock, locate the water table, and identify the septic wastewater plume. A doser was installed to monitor discharge to the drain field. Thirty piezometers are installed to monitor water levels and acquire water samples for quality analysis and comparisons with water quality from the drain field. An evapotranspiration dome has been readied for the 2003 field season. Time-varying water levels and water quality are mapped. Water budgeting and analytical modeling identify the fate of the plume.

### Principal findings and significance

Work is in progress. The septic plume travels laterally in the regolith, but appears to dissipate into the fractured bedrock before reaching the stream.

Twenty-seven shallow (<10 feet deep) piezometers have been installed downstream of the septic leach field of a single home in the Turkey Creek Basin. Holes were augered in the overlying regolith layer down to the regolith-bedrock interface. The piezometers have been installed in a grid pattern and ranging over one hundred feet downstream from the leach field.

The large mid-March snow (>4 feet) melted over the period between late March and late April. This large volume of water saturated the regolith layer overlying the bedrock and produced a large volume of sheet flow over the piezometer grid. The measured depth-to-water in most of the piezometers was 0 feet.

Weekly sampling since early April has shown a gradual drop in the depth-to-water measurement in each piezometer as the snowmelt moves through the regolith. Specific conductivity (SC) and temperature have also been measured weekly. The variations in SC have revealed the flow path of the septic plume (high SC). Several sets of samples from the piezometers have been collected. The chemical changes of the septic effluent with respect to distance from the leach field are being determined.

A dose counter was professionally installed in the dosing chamber of the septic tank. It digitally registers every dose of septic tank effluent that is flushed out of the tank. This indicates the volume of effluent that enters the leach field. Once the snowmelt is gone from the regolith layer, the dimensions of the zone of effluent saturation will be determined. From these volumes, the rate of effluent infiltration into the bedrock can be determined.

# Evaluating Strategies to Mitigate Waterlogging and Salinization in Colorado's Lower Arkansas River Valley

## Basic Information

<b>Title:</b>	Evaluating Strategies to Mitigate Waterlogging and Salinization in Colorado's Lower Arkansas River Valley
<b>Project Number:</b>	2002CO6B
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	4th
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Water Quality, Groundwater, Agriculture
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	Timothy Gates, Grant E. Cardon, W. Marshall Frasier, John W. Labadie

## Publication

1. Burkhalter, J.P., T.K. Gates and J.W. Labadie, 2002, Strategies for regional-scale recovery of a salinity-threatened irrigated river valley, in Proc. of Conf. on Energy, Climate, Environment and Water \_ Issues and Opportunities for Irrigation and Drainage, USCID and EWRI, San Luis Obispo, California.

## SYNOPSIS

### Problem and research objectives

There is growing evidence that the irrigated lands of the lower Arkansas River Valley in Colorado are suffering from severe waterlogging and salinization. Over the last few years, we have conducted scientific investigations with the objectives of accurately diagnosing these problems. This project builds upon on-going studies to apply and refine sound modeling tools, rooted in and calibrated by extensive field data, and founded upon strong working relationships with numerous agencies and with over 80 valley farmers. The goal of the first phase of this project was to build, through application of an existing calibrated model and through comparative economic analysis, a framework for evaluating strategies to support a productive irrigated agriculture in this salinity-threatened valley.

The results of this study will be a proposed set of the most-promising strategies that would both (a) lower the saline high water table leading to lower soil salinity resulting in increased crop yields, and (b) significantly reduce loading of salts and other pollutants to the river. Strategies to be considered will include: increased irrigation efficiency, reduced seepage from irrigation canals, increased pumping rates from existing pumping wells with excess flows (above legal permit) routed through drains to the river, installation of horizontal subsurface drains, lowering of water surface elevation along the river, conversion to more salt-tolerant crop varieties, and combinations of these strategies.

We proposed to pursue this course through the following objectives and general procedures:

- (1) Refine the solution strategies listed above through interaction with farmers and agencies, via meetings and information-transfer technologies;
- (2) Evaluate the strategies for application in the representative upstream study subregion near La Junta. Data collected by on-going projects in this subregion will be used to refine and support a model for predicting outcomes of implementing the alternative strategies. Cooperation with ongoing projects will allow evaluation of the practical implementation of target strategies, with input from farmers and agencies, at the field scale for selected representative fields in the upstream study subregion;
- (3) Refine target strategies and rank their effectiveness according to predefined economic, environmental, and legal/institutional criteria using multicriteria decision analysis; and
- (4) Work with farmers and agencies to propose development of organizations and schemes for implementing the most promising alternatives.

### Methodology Synopsis

The Groundwater Modeling System (GMS) was applied to simulate impacts of various salinity control strategies in the upstream study subregion. The GMS software package links the MODFLOW groundwater flow model, and the MT3DMS contaminant transport model for solving the flow and transport equations within a spatially-referenced geographic information system (GIS). The original project plan proposed to apply MODFLOW and MT3DMS to conditions of steady flow to explore the comparative order of magnitude of effects to be

expected from scenarios associated with proposed strategies. Instead, it was decided that efforts should be redirected toward calibrating and applying the model in a dynamic framework, using one-week time steps. In addition, an unsaturated zone mass balance model was developed to allow estimation of the impact of considered improvement strategies on root-zone soil salinity. The model was calibrated and validated using historic baseline data for the period April 1999 to October 2001, encompassing three irrigation seasons. The model was used to simulate alternative improvement strategies under the same historic conditions, and predicted results for water table depth, water table salinity, soil salinity, and return flow and salt loading to the river were compared to baseline conditions. Preliminary economic analysis of the alternatives has also been completed.

### Principal findings and significance

Extensive field data have been collected from 1999 to the present. This database was used to define baseline conditions for model simulations over the period April 1999 to October 2001. Data collected in 1999 revealed that the average water table depth was less than 2.5 m below ground surface under 43% of the cultivated area. Data from the drier 2000 and 2001 seasons indicated an average water table depth less than 2.5 m below ground surface under 38% and 32% of the cultivated area, respectively. The average measured salinity (as electrical conductivity, EC) of the water table in the study region was about 3.4 dS/m (3025 mg/l) in 1999, 3.3 dS/m (2930 mg/l) in 2000, and 3.1 dS/m (2770 mg/l) in 2001. Soil salinity measured (as electrical conductivity of saturated extract, EC<sub>e</sub>) in overlying fields varied from benign to extreme, tending to exceed threshold tolerances for crops when the depth to the saline water table was less than about 2 to 2.6 m. The overall average soil salinity was estimated as 3.0 dS/m (2650 mg/l) in 1999, 3.1 dS/m (2735 mg/l) in 2000, and 3.3 dS/m (2910 mg/L) in 2001.

Numerous improvement strategies have been simulated and evaluated to date. These include boosts in irrigation efficiency to reduce average recharge to the water table by 10 to 90% (in increments of 10%); uniform lining of all irrigation canals to reduce seepage rates by 50%, 70%, and 90%; lining of selected reaches of irrigation canals to reduce seepage by 90%; increases of 25%, 50%, 100%, and 200% in pumping volumes from existing wells; installation of subsurface horizontal drains in poorly drained areas at a depth of 2 m and at spacings of 50 m, 75 m, 100 m, and 150 m; and combinations of these strategies. Predicted impacts on water table depth and salinity, soil salinity, return flows and salt loads to the river, and upflux under fallow fields to nonbeneficial consumptive use are being evaluated. Preliminary assessment indicates that the strategy having the most impact on water table depth and soil salinity would be a combined recharge reduction of 50%, a seepage reduction over all canals of 90%, and sub-surface horizontal drains installed at a spacing of 50 m. The model predicted that if this strategy had been implemented over the historic period, it would have resulted in a reduction in average water table depth of about 2.1 m by the 2001 irrigation season, and a reduction of about 985 mg/L (about 33%) in average soil salinity. Results for all combined strategies generally indicated substantial reduction in salt load to the river, with the largest impact [41% average decrease; 907,324,018 kg (1,000,154 tons) total reduction over the 130-week modeled period] being predicted under a combined strategy of 80% recharge reduction, 90% seepage reduction over all canals, and sub-surface drains installed at a spacing of 50 m.

Preliminary economic analysis indicates average crop yield reduction due to waterlogging and salinity in the upstream study area was about 13% over 1999 – 2001. The associated total value of forgone productivity are estimated to range from approximately \$3.1 to \$5.4 million annually, averaging around \$4.3 million/year or approximately \$168/ha. This represents the potential of increasing average annual profits by approximately 39% if the effects of waterlogging and soil salinity were to be removed.

The costs associated with implementing improvement strategies have been identified and the resulting benefits to agricultural productivity within the study area have been estimated. Each strategy evaluated was capable of increasing regional productivity, although the associated costs were typically higher. However, this research indicates that certain strategies appear more promising than others, including improving irrigation efficiency to reduce recharge to the saline shallow water table. Reducing recharge rates by 50% through the universal adoption of gated pipe with surge valve irrigation systems was shown to increase agricultural productivity returns on average by approximately \$42.63/ha/year or \$1,098,019/year. Although the estimated annual cost of \$64.21/acre is higher, this alternative is predicted to reduce salt load to the river by an average quantity of 2,619 tons/week (14.4%) and reduce the quantity of water consumed by non-beneficial upflux under fallow fields by 1234 m<sup>3</sup>/week (106 acre-feet/week, or 22%). With these benefits in addition to the productivity gains that offset approximately 66% of the costs, this alternative appears promising. If the additional benefits of reducing non-beneficial upflux are assumed to be zero, the cost of reducing annual salt load using this alternative is approximately \$4.10/ton. If future research indicates the value of salt load reduction to exceed \$4.10/ton, the total benefits of this alternative would surpass the costs without including the value of reducing non-beneficial upflux. For reference, research by Gardner and Young (1985) estimated the benefits (damages avoided) of salt discharge reduction to be approximately \$26/ton in the lower Colorado River Basin.

Work is continuing to refine predicted effects of alternative improvement strategies and the associated economic impacts at the subregional scale. Efforts are also underway to extend the analysis to a representative subregion downstream of John Martin reservoir and to consider basin-scale impacts using a calibrated basin-scale model.

# Occurrence and Fate of Emerging Organic Chemicals in Onsite Wastewater Systems and Implications on Water Quality Management in the Rocky Mountain Region

## Basic Information

<b>Title:</b>	Occurrence and Fate of Emerging Organic Chemicals in Onsite Wastewater Systems and Implications on Water Quality Management in the Rocky Mountain Region
<b>Project Number:</b>	2002CO46G
<b>Start Date:</b>	9/1/2002
<b>End Date:</b>	8/30/2004
<b>Funding Source:</b>	104G
<b>Congressional District:</b>	6th
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Treatment, Water Quality, Toxic Substances
<b>Descriptors:</b>	Contamination transport, Health effects, Septic tanks, Organics, Wastewater treatment, Water quality monitoring
<b>Principal Investigators:</b>	Dr. Robert L. Siegrist, Kathryn S. Lowe, John E. McCray

## Publication

1. DeJong, Kathy, Robert L. Siegrist, Abigail Wren, and Larry B. Barber, 2004, Occurrence of Emerging Organic Chemicals in Wastewater Effluents from Onsite Systems, accepted for platform presentation at the Tenth National Symposium on Individual and Small Community Sewage Systems, March 21-24, 2004, Sacramento, California, Am. Soc. of Agric. Engrs.
2. Siegrist, Robert, 2002, Water Quality Protection Provided by Onsite Wastewater Systems, in Proceedings of the 13th Annual South Platte Forum, Colorado Water Resources Research Institute, Colorado State University, Fort Collins, Colorado, Information Series No. 94, p. 16-17.



## SYNOPSIS

### Problem and research objectives

Emerging organic chemicals (EOCs) such as pharmaceuticals and personal care products (PPCP) have received increasing attention in the last decade due to their possible adverse effects on ecosystems and human health. Several studies have indicated wastewater as a primary contributing source of EOCs to the water environment, but few have quantified their occurrence, especially in onsite wastewater treatment systems and associated receiving environments. To enhance the current understanding, this research project was initiated at the Colorado School of Mines in collaboration with the U.S. Geological Survey to determine the occurrence of EOCs in the effluents produced from varying sources and by different types of onsite wastewater systems (OWS), to assess the fate and transport of EOCs in soil absorption systems prior to groundwater and surface water recharge, and to assess the potential for EOCs to impact receiving waters.

In Colorado and elsewhere in the U.S., interest in improved understanding of if and how EOCs are being released to the environment from OWS is needed since a substantial portion of the wastewater generated in the U.S. is processed by OWS before discharge to the environment. For example, in Colorado there are over 600,000 OWS in operation serving about 25% of the State's population and 7,000 to 10,000 new systems are being installed each year. As a result, over 30 billion gallons of wastewater are being processed by OWS and then discharged to the environment each year.

### Methodology

The initial efforts in this project were focused on student recruiting and subsequent training regarding appropriate laboratory methods and field sampling techniques to be followed over the duration of the project. Protocols for sampling surface water, groundwater, and wastewater effluents from OWS were reviewed and refined as needed to be compatible with the characterization of trace-level EOCs. In collaboration with existing staff and students at CSM and USGS, standard protocols for water and wastewater quality monitoring were followed during initial reconnaissance sampling and analysis of surface water, ground water, and wastewater effluents. These protocols were compared to the standard field protocol required by the collaborating USGS laboratory and, by making adaptations specific to the nature of this EOC project, a new and complete field sampling protocol was developed, including proper collection methods and vessels, transportation of samples, and health and safety issues.

In the laboratory, methods specific for the analysis of emerging organic chemicals were studied and practiced by Ms. Kathleen DeJong, Ph.D. Graduate Fellow. Samples are analyzed for six human indicator compounds in a four-day process involving evaporation and derivitization. Once prepared, these samples are analyzed using gas chromatography/mass spectrometry (GC/MS) to identify the presence and concentrations of the six compounds: ethylene diamine tetraacetic acid (EDTA), nitrilotriacetic acid (NTA), and four nonylphenol ethoxy carboxylates (NP1-4EC). Samples are also analyzed by gas chromatography/mass spectrometry for a suite of more than 50 EOCs including endocrine disrupting compounds. The compounds include wastewater-derived compounds such as bisphenol A and caffeine, hormones such as 17- $\beta$ -

estradiol and testosterone, and human health pharmaceuticals such as ibuprofen and codeine. These samples are isolated using either the traditional separatory funnel method or using continuous liquid-liquid extraction (CLLE) with methylene chloride as the solvent. The conditioning and calibration of the GC/MS instrument and the comprehension of the associated quantitation program are ongoing processes.

To begin collecting data from surface water, ground water and wastewater effluent sources, a specific sampling and analysis schedule was produced. The first watershed of interest was the Dillon Reservoir watershed located in Summit County, Colorado since CSM had a major ongoing water quality study related to environmental effects of OWS in the Blue River Basin of that watershed. Information on individual domestic OWS and private wells was collected from the Summit County Department of Environmental Health. Homeowners were contacted and information regarding recent problems and general usage of their onsite water and wastewater systems was recorded. During each of two initial field monitoring trips during spring 2003, 18 unique locations were visited and samples were collected for a variety of analyses. Of the 18 sites, four were surface waters, six were ground waters, and eight were septic tank effluents from OWS. The four surface water sites are located near USGS gauging stations and water quality data from the previous year is available. Of the six ground waters, four samples are from individual drinking water wells and two samples are from ground water monitoring wells. These sites also have corresponding data on the presence of a variety of ions. The eight OWS were conventional systems (i.e., septic tank - soil absorption systems) consisting of from one to three septic tanks in series and characterized by a varied history of repairs and upgrades. At all locations, general field measurements were taken, including air and water temperature, pH, dissolved oxygen, and specific conductance. In addition, at every site samples were collected for the analysis of the EOCs and the 6 human indicator compounds mentioned above, as well as for dissolved organic carbon, total organic carbon, and ultraviolet light absorption.

Following the quantitation of the first set of data, field sampling will continue in Summit County, focusing on wastewater effluents from commercial and institutional OWS, followed by corresponding laboratory preparation, analysis, and quantitation. The field sampling will expand to at least one additional county in the Rocky Mountain region. Methods to analyze for new EOCs will be developed.

In Fall 2003, controlled experimentation at the laboratory- and field-scale (CSM and USGS labs and the Mines Park Test Site on the CSM Campus) will be initiated. The purpose of this work is to elucidate the transport/fate of key EOCs in soil and ground water systems, which are the receiving environments to which OWS discharge their effluents.

#### Principle findings and significance

In a reconnaissance survey, samples of domestic septic tank effluent (STE) were collected from two separate multifamily residential sites and analyzed for 48 different EOCs. Eighteen EOCs were identified, including caffeine (~69,000 ng/L), estrone (~355 ng/L), 17 $\beta$ -estradiol (~800 ng/L), 17 $\beta$ -ethinylestradiol (~35 ng/L), 4-nonylphenol (~760 ng/L), and bisphenol A (~9000 ng/L). The results of samples collected from a broader suite of OWS in the same region are

presently being analyzed and will aid defining the area in terms potential risks to ecosystem or human health due to EOCs discharged in OWS effluents.

# Use of Low-Cost Data to Simulate Fractured-Aquifer Watersheds for Management of Water Quality and Quantity

## Basic Information

<b>Title:</b>	Use of Low-Cost Data to Simulate Fractured-Aquifer Watersheds for Management of Water Quality and Quantity
<b>Project Number:</b>	2001CO261G
<b>Start Date:</b>	9/1/2001
<b>End Date:</b>	1/31/2004
<b>Funding Source:</b>	104G
<b>Congressional District:</b>	6th District
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Water Quality, Geochemical Processes, Non Point Pollution
<b>Descriptors:</b>	Water quality, Water quantity, Fractured-aquifer watersheds
<b>Principal Investigators:</b>	Eileen Poeter

## Publication

1. Poeter, E., G. Thyne, J. McCray, J. Lee and G. VanderBeek, 2002, Low-Cost Data for Characterization and Management of Fractured-Crystalline Aquifers, Proceedings of Fractured Rock Aquifers 2002, National Ground Water Association.
2. Day, S., G. Thyne and E. Poeter, 2003, Using statistical analyses to characterize effects of population growth on water quality, Geol. Soc. Amer., Abstracts with Programs, 35(5), p. 30.
3. Day, S., G. Thyne, E. Poeter, and J.E. McCray, 2002, Effects of population growth on water quality in a mountain watershed, Geol. Soc. Amer. Abstracts with Programs, 34(6).
4. Day, Sharon, Geoff Thyne, John McCray, and Eileen Poeter, 2002, Evaluation of the effects of population growth on water quality in a mountainous watershed, Geol. Soc. Amer. Abstracts with Programs, 33(4).
5. Guler, C., and G. Thyne, 2002, Hydrochemical evolution model and characterization of flow in a fractured crystalline rock aquifer, Turkey Creek, Colorado, Geol. Soc. Amer. Abstracts with Programs, 34(6).
6. Thyne, G., S. Day, J.E. McCray, and E. Poeter, 2002, Evaluation of the effects of population growth in mountain watershed water quality, EPA Fractured Rock Aquifers 2002 Focus Conference, Denver, Colorado.

## SYNOPSIS

### Problem and research objectives

Mountain watersheds are primary water resources in the western United States, but we lack a scientific basis for making credible decisions regarding mountain land use. The rapid growth of population and development in mountain watersheds caused Jefferson County of Colorado to begin collecting data in a pilot study of ground-water resources in the Turkey Creek Watershed, a fractured-crystalline rock aquifer, typical of those that support individual domestic wells and sewage disposal systems for residents of the county and similar areas throughout Rocky Mountains, United States, and the world. A number of agencies funded data collection in the watershed, but the data are in different forms at many locations and have not been integrated into a model for a management tool. Although a ground-water model of the watershed is not expected to predict conditions in a particular well, it can provide information about future conditions in specific areas of the watershed. The proposed research utilizes a rare database from the watershed to complement and extend the work of the USGS by integrating data from many sources and developing models to: 1) better understand the flow system, 2) determine which low-cost data are instrumental in describing the system and which data reduce uncertainty, and 3) simulate the impacts of alternative development scenarios on ground-water levels, quality, and its to the total maximum daily load in streams. The value of the low-cost data value will be confirmed using the more unusual data. The methods developed in this research will be useful for assessing the effects of population growth and development in other fractured-aquifer watersheds. The most difficult portion of this task is evaluating the fracture character of the aquifer. At this time, society cannot afford to characterize every detail of the subsurface water-bearing fractures to manage ground water. This project will use an elaborate database to determine the value of low-cost, holistic measures for evaluating the character of three-dimensional fracture flow and the scale at which equivalent porous media models can be used to predict impacts of management scenarios. Before collecting additional field data, modeling studies can glean information from existing data and determine which data will decrease uncertainty.

### Methodology

Task 1) compile and organize available data in a manner that will facilitate its dissemination;  
Task 2) evaluate the data by viewing their distribution from a variety of perspectives;  
Task 3) utilize the data to develop representative synthetic equivalent-porous-media and fracture flow models, with characteristics similar to that of Turkey Creek Watershed, to evaluate attributes generally believed to differentiate porous media and fracture flow systems and compare the character of hydraulic head and water quality observed in Turkey Creek Watershed to synthetic model behavior to estimate the scale at which Turkey Creek Watershed can be represented as equivalent porous media;  
Task 4) use results of task 3 to generate models of Turkey Creek Watershed applicable to the management scale, calibrate the models using multiple regression techniques, and identify the data that are instrumental in describing the flow system, as well as, the type

and location of new data that will improve the calibration or confirm the value of the low-cost data

Task 5) collect data identified in task 4 and incorporate the data into the model calibration to modify and improve the representative models;

Task 6) use the representative models to predict the impact, and associated uncertainty, of increased development on the quantity and quality of water resources;

Task 7) identify the data that are instrumental in making accurate predictions and evaluate the type and location of new data that would reduce prediction uncertainty or confirm the value of the low cost data;

Task 8) prepare a report and provide project findings to the public; and

Task 9) train future geological engineers while accomplishing the previous objectives.

### Principal findings and significance

Evaluation of front-range aquifers is only beginning and this project will continue to refine conceptual models and limit the possible range of interpretation through data mining, data collection, and analysis. Current analysis of the available data reveals:

- Water bearing fracture frequency is fairly uniform among rock types (~0.01 water-bearing fractures per foot) but fault zones and coarse granitic rocks have higher yields per fracture, thus are likely to have larger apertures and/or better connectivity.
- Fracture frequency (and yield) is uniform between 100 and 700 feet below ground surface.
- Well yields are higher in the fault zones and coarse granite, which occupy limited area in the upper portion of the basin.
- Depth to water averages less than 100 feet (30m).
- Water levels in wells mimic the topography, with coincident surface and ground-water divides.
- Water levels are responsive to spring recharge and generally exhibit a recession each water year.
- Precipitation is on the order of 20 in/yr (508 mm/yr) while evapotranspiration is on the order of 18 in/yr (457 mm/yr). Both are variable and known from a short period of limited spatial distribution, and thus introduce much uncertainty in the water budget.
- Water levels are declining.
- Storage in the basin is poorly characterized.
- Volume of annual recharge is uncertain but is currently estimated on the order of an inch per year, with 75% pumped, but only 7% consumed because of ISDS recharge.
- Estimates of recharge are uncertain due to the short period of record and limited spatial distribution, consequently the estimate may be somewhat more or substantially less.
- The uncertainty associated with the water budget renders assessment of the sustainable population difficult.
- Surface water chemistry appears to have been adversely impacted by population growth during and after the 1970s.
- Ground-water chemistry has been impacted by anthropogenic effects that include high nitrate and chloride and lower pH, primarily in areas of high population density.

- Limited duration and spatial distribution of data prevents determination of whether the system has reached equilibrium concentrations.
- Ongoing studies will reduce current uncertainties.
- Hydrochemical data, water levels, and response of wells to recharge suggest an equivalent porous medium can represent the watershed for large-scale evaluations.
- Equivalent porous media models can be used to integrate the data, design further data collection and provide predictions of the hydrologic response to further development with ever decreasing uncertainty as additional data are accumulated.

Uncertainty associated with the Turkey Creek Basin water budget is large, making it difficult to determine the population that can be reasonably supported in the basin. Short-term records can be misleading, and must be used with caution. Water quality has been impacted by development, but the limited period of record prevents us from knowing whether concentrations have reached a steady condition or are reflecting only the beginning of a long-term increase. Continued collection of hydrologic records and assessment modeling is necessary to reduce uncertainty.

# Microbe Transport in Saturated Filter Sand and Karst Media

## Basic Information

<b>Title:</b>	Microbe Transport in Saturated Filter Sand and Karst Media
<b>Project Number:</b>	2002CO300
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	3/1/2003
<b>Funding Source:</b>	Other
<b>Congressional District:</b>	4th
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	, Groundwater, Water Supply
<b>Descriptors:</b>	Water quality, Aquifer recharge, Ground water, Wastewater, Karst aquifers
<b>Principal Investigators:</b>	Joseph N. Ryan, Joseph Nolte Ryan

## Publication



## SYNOPSIS

### Problem and research objectives

South Florida is using groundwater from the underlying limestone karst aquifers more rapidly than the groundwater is being replenished by recharge. In addition, water withdrawal is adversely affecting the level of surface waters in the Everglades and limestone mining is reducing groundwater levels. To mitigate this problem, water resource managers are considering artificial recharge of the aquifers using treated municipal wastewater. Treated wastewater may contain pathogenic microbes (viruses, bacteria, protozoa). If these microbes are not removed by passage through the karst aquifer or by filtration during drinking water treatment, public health may be at risk.

The Miami-Dade County Department of Environmental Resource Management (DERM) has enlisted the aid of the U.S. Geological Survey in assessing the effectiveness of microbe removal during transport through the karst aquifers and by filtration during water treatment. The U.S. Geological Survey has, in turn, recruited the assistance of the University of Colorado in carrying out experiments to measure microbe transport in karst and filtration sand media. This proposal describes the role of the University of Colorado personnel in assisting the U.S. Geological Survey in this effort.

The research described in this proposal will measure the effectiveness of karst and filtration sand media in removing microbes suspended in water as a function of flow rate, water chemistry, and microbe type. These results will be presented in terms of parameters describing the attachment, release, and inactivation of microbes during transport in the two media.

With these results, the Miami-Dade DERM will be able to better evaluate the risk of occurrence of pathogenic microbes in drinking water originating from wastewater recharge. Better estimates of this risk will aid in the design of systems (e.g., disinfection) used to treat the wastewater prior to recharge and systems used to treat the water withdrawn from these aquifers.

### Methodology

Microbe transport will be measured in flow-through columns containing the karst and filtration sand media. Transport characteristics will be determined by inverse solution of appropriate microbe transport models. The flow-through column apparatus will consist of a influent solution reservoirs, syringe pumps, a glass column, and a fraction collector. Media (limestone karst aquifer material and filtration sand used in water treatment plants) will be supplied by Miami-Dade DERM. The media will be packed in the column under saturated conditions. The karst material will be placed in the column both as intact cores (with an expanding polyurethane foam used to seal the space between the column and core) and as granular media, reflecting concern that flow through the karst may be dominated by either fractured or porous media (Miami-Dade DERM, 2000). Packed columns will be conditioned for experiments by pumping through water of appropriate solution chemistry until important solution chemistry parameters (pH, specific conductance) are the same in the influent and effluent.

The transport of three types of microbes will be examined in these experiments: (1) a virus, bacteriophage PRD1; (2) a bacterium, a strain of *Pseudomonas*; and (3) a protozoan cyst, of *Giardia lamblia*. These microbes are each roughly spherical and span a size range of 62 nm to about 10  $\mu\text{m}$ . Microbe suspensions will be pulse-injected into the columns. PRD1 will be enumerated by plaque assay. The bacterium and cyst will be enumerated by DAPI staining and epifluorescence microscopy.

In the experiments, flow rate, solution chemistry, and microbe type will be varied in each of the media. In terms of velocity, flow rate will be varied from about 0.1 to 100  $\text{m d}^{-1}$  to approximate the range of possible groundwater flow velocities in porous and fractured media. After establishing a baseline for solution chemistry (focusing on pH, ionic strength, and bivalent cation concentration) that represents ambient conditions in the karst and filtration sand, variations in solution chemistry will be made for pH, ionic strength, and bivalent cation concentration to understand the effects of solution chemistry on microbe transport. Microbe type will be varied as described above – the virus, bacterium, and protozoan cyst spanning the wide size range.

Microbe transport will be quantified by inverse solution of microbe transport models to fit breakthrough data. Key parameters include attachment and release rate coefficients and solution and surface inactivation rate coefficients. The effects of flow rate and solution chemistry on these parameters will be used to develop a capability for predicting microbe transport in the karst and filtration sand media.

The flow-through column experiments will be carried out in the U.S. Geological Survey laboratory of Dr. Ronald W. Harvey in Boulder, Colorado. Dr. Harvey's laboratory is equipped with all of the materials, supplies, and instrumentation to complete this research (e.g., flow-through column apparatus, pumps, fraction collectors, incubators, centrifuges, epifluorescence microscopy and image analysis system).

### Principal findings and significance

1. Attachment isotherm (effect of loading on fractional recovery): Addition versus recovery of microspheres in karst fragments (10 g, 0.5-2.8 mm) in static columns. Linear attachment isotherms were measured for microsphere loadings between  $10^2$  to  $10^7$  microspheres per gram of karst for 0.5, 1.1, and 2.9  $\mu\text{m}$  carboxylated microspheres.
2. Attachment kinetics (effect of time on fractional recovery): Assessment of change in fractional attachment versus time for each microsphere size class. Equilibrium was attained by 500 minutes for all three sizes.
3. Agreement among replicate systems (precision): Comparison of fractional attachment among replicate static columns. Reasonable agreement among replicate columns. Further studies needed to optimize.
4. Changes in porewater chemistry occurring during experimental timeframe: Assessment of the effect of contact time on changes in porewater composition that could affect

attachment behavior of microspheres and *Cryptosporidium* oocysts. Karst fragments imparted modest alkalinity and total dissolved solids to pore water over periods of hours.

5. Optimization/standardization of microsphere recovery procedure: Determination of the number of static column rinses required for best recovery of microspheres. Six rinses is optimal and will be incorporated into future experimental design.
6. Groundwater chemistry measurements: Determination of chemical variability to be used for interpretation and to bracket conditions in lab tests. Compiled regional chemistry data for surface & groundwater. Chemical analyses performed for well NW6B, canal, and nearby surface water. Zeta potential measured for microspheres (pH 8.3, 739  $\mu\text{S cm}^{-1}$ ): -2.5 mV (0.5  $\mu\text{m}$  diameter), -4.99 mV (1.0  $\mu\text{m}$  diameter); -11.0 mV (2.9  $\mu\text{m}$  diameter). Zeta potential measured for powdered (1  $\mu\text{m}$ ) karst (at pH 8.3 & 739  $\mu\text{S/cm}$ ): -8.0 mV.

# **Information Transfer Program**

# Technology Transfer/Information Dissemination

## Basic Information

<b>Title:</b>	Technology Transfer/Information Dissemination
<b>Project Number:</b>	2002CO8B
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	4th
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	Education, None, None
<b>Descriptors:</b>	Technology transfer, Information dissemination
<b>Principal Investigators:</b>	Robert C. Ward

## Publication

1. Brown, Jennifer, Ed., 2002, Who's Running This Ecosystem?, Proceedings of the 13th Annual South Platte Forum, Oct. 23-24, 2002, Information Series No. 194, Colorado Water Resources Research Institute, Colorado State University, Fort Collins, Colorado, 40 pp.
2. Keammerer, Warren R. and Edward F. Redente, Eds., 2002, Proceedings of the High Altitude Revegetation Workshop No. 15, March 6-8, 2002, Information Series No. 195, Colorado Water Resources Research Institute, Colorado State University, Fort Collins, Colorado, 239 pp.

## INFORMATION TRANSFER ACTIVITIES

CWRRI provides Colorado water users with the latest water information and research results through its information and technology transfer program including the CWRRI newsletter, COLORADO WATER, the CWRRI websites, water conferences, seminars, and its publications series.

## WEB SITES

The CWRRI Homepage at <http://cwrri.colostate.edu>



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W&O



Creating and Transmitting New Water Knowledge



The Water Center web site at: <http://watercenter.colostate.edu>



The Water Center brings together a rich history in water related education and research with diverse talent from 25 different departments at Colorado State University students can find the following information at the web site:

<p>Computer Modeling – MODSIM-DSS          Professional Development  <a href="#">Jobs in Water Resources</a>   <a href="#">Meetings/Seminars</a></p>	<p>Study Water at CSU – Undergraduate  <a href="#">Undergraduate Water Minor</a>  <a href="#">Research Experiences for Undergraduates in Water</a></p>
<p>Educational Opportunities  <a href="#">Water Related Courses at Colorado Universities</a>  <a href="#">Fellowships</a>   <a href="#">Short Courses</a>   <a href="#">Scholarships</a></p>	<p>Study Water at CSU – Graduate  <a href="#">Water Information for New CSU Graduate Students</a>          Graduate School at Colorado State University          List of Departments</p>



The Colorado Water Knowledge web site <http://waterknowledge.colostate.edu>

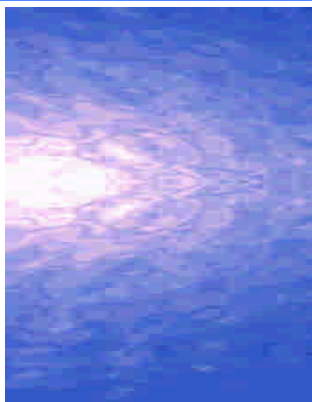
• Colorado Water -

- A huge list of water facts!
- A description of stream processes and an overview of Colorado's geology, water history, and climate. Links to water related definitions are also provided.
- A description of Colorado's major river basins and aquifers, how the water from these sources is used and managed, and methods for conserving Colorado's water.
- A description of the fish and aquatic insects present in Colorado's waters, wetlands, water quality, and links to environmental laws.
- A description of transmountain diversions, interstate compacts, Colorado water rights law, and federal, state, and local administrative agencies.
- A list of frequently asked questions and answers about Colorado water.



The Hydrology Days web site at: <http://HydrologyDays.colostate.edu>

Hydrology Days 2002



22nd Annual  
 American Geophysical Union  
**HYDROLOGY DAYS**  
 April 1-4, 2002

Cherokee Park Room  
 Lory Student Center  
 Colorado State University  
 Fort Collins, Colorado, USA

Sponsored by  
 Hydrology Section of the  
 American Geophysical Union

The Research Experiences for Undergraduates Program at:  
<http://waterreu.colostate.edu/>



With funding provided by The National Science Foundation, the Water Center at Colorado State University provided a unique opportunity for undergraduate students from four-year colleges and universities to conduct independent research in Water Science and Engineering during 8 weeks in the summer, under the guidance of faculty in the departments of Civil Engineering, Earth Resources, Soil and Crop Science, Chemical Engineering, Fishery and Wildlife Biology and Rangeland Ecosystem Science. Students work in teams including faculty, graduate students, and staff to conduct research and gain hands-on experience in laboratory and field research methods.

A new addition in 2002 was the website for the Colorado Water Quality Monitoring Council, located at <http://cwqmc.colostate.edu/>.



## PUBLICATIONS

CWRRI publishes and distributes water research information via the following publications:

- **WATER IN THE BALANCE**, a user-friendly new publication series that provides a condensed version of research completion reports that gives water users a 16-24 page review and analysis of the results of research conducted under the auspices of the State Water Institute Program.

Water in the Balance No. 9, "A History of Drought in Colorado: Lessons Learned and What Lies Ahead," was published and printed in February, 2000 in collaboration with Colorado State's Department of Atmospheric Science. With the drought of 2002 a critical factor in Colorado, demand for this publication increased dramatically and resulted in approximately 4000 copies being reprinted and distributed.

- **COMPLETION REPORTS**—These reports contain information about completed research and include details of procedure, analysis of data and conclusions reached.
- **TECHNICAL REPORTS**—CWRRI provides technical information of interest to water resource professionals through this series.
- **INFORMATION SERIES**—This series of reports provides information of general public interest on water-related subjects including conferences and symposia.
- **OPEN-FILE REPORTS**—CWRRI provides complete reports of research at cost upon request. These reports consist primarily of theses and dissertations from CWRRI-funded research projects.

CWRRI is in the process of making all its publications available on the World Wide Web.





## MEETINGS AND CONFERENCES

### 21<sup>st</sup> Annual Hydrology Days Colorado State University -- April 1-4, 2002

The 21st Annual Hydrology Days was held April 1-4, 2002 on the Colorado State University campus. The meeting was dedicated to Professor Ignacio Rodriguez-Iturbi, who obtained a Ph.D in Hydrology in the Civil Engineering Department at Colorado State University. Professor Rodriguez-Iturbe was named the 2002 Stockholm Water Prize Laureate for his significant scientific contributions to the understanding of the interaction among climate, soil and vegetation structures, surface water, floods and droughts. He is the first South American to receive the prize. Professor Rodriguez-Iturbi is a citizen of both Venezuela and the United States.

Hydrology Days provides the opportunity for students to present papers in a friendly, yet professional, atmosphere and also to meet leading hydrologists and hydrology-related professionals. The four-day program includes contributed papers, student papers and a poster session. More than 200 persons, representing 13 countries, attended the meeting, which CWRRI cosponsors.

### Arkansas River Basin Water Forum Peaks to Prairies: Sharing a Watershed Leadville, Colorado – June 6-8, 2002

CWRRI cosponsors this annual meeting that gathers together water interests in Colorado's Arkansas River valley. The 2002 annual meeting focused on areas of successful cooperation, collaboration and unusual solutions among the river basin's stakeholders. Following the close of the forum, attendees participated in the grand opening of the Hayden Meadow Recreation Site, an outstanding example of multi-party collaboration.

### 27<sup>th</sup> Annual Colorado Water Workshop Reclamation at the Century Mark: The Legacy and the Challenge Western State College, Gunnison, Colorado July 31-August 2, 2002

More than 200 people gathered on the campus of Western State College in Gunnison, Colorado to review the achievements, problems, and remaining challenges facing the U.S. Bureau of Reclamation as it celebrated its centennial observation. The 27<sup>th</sup> Annual Colorado Water Workshop attendees included state legislators; county commissioners from both the West Slope and Front Range; and representatives of local, regional, state and federal agencies and the private-sector. University students attending the meeting had an excellent opportunity to meet key water leaders and learn first hand about the latest issues facing Colorado water managers and the history of water development in the West. CWRRI cosponsors the workshop.

### **Who's Running this Ecosystem?** 13<sup>th</sup> Annual South Platte Forum – Longmont, Colorado October 23-24, 2002

Protecting the future of the South Platte River Basin – integrating habitat protection with agricultural production, understanding Colorado climate changes, keeping watch on water quality in Colorado, and redefining beneficial use – these were the issues presented and examined in moderated sessions at the 13<sup>th</sup> Annual South Platte Forum October 23-24, 2002. Highlighting the forum was the special recognition of Chuck GrandPre, the founding chair of the South Platte Forum Planning Committee. Chuck recently

retired from the U.S. Fish and Wildlife Service. CWRRI cosponsors the annual forum with the Colorado Division of Wildlife, CSU Cooperative Extension, Denver Water, the Northern Colorado Water Conservancy District, the U.S. Bureau of Reclamation, the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service and the U.S. Geological Survey.

Colorado Drought Conference  
Colorado State University – Fort Collins, Colorado  
December 4, 2002

Over 250 scientists, public officials, water managers, and media representatives gathered on the campus of Colorado State University on December 4<sup>th</sup> to share lessons learned in managing the driest year on record (2002) and examine options for addressing the uncertainty of water availability in 2003. The Colorado Drought Conference was organized under the auspices of the new CSU DroughtLab, a joint initiative of the CWRRI/CSU Water Center and the Colorado Climate Center to proactively engage higher-education expertise in addressing the knowledge needs associated with not only the current drought, but future drought preparation. The conference was cosponsored by the Colorado Water Conservation Board, the Colorado Water Congress, the Division of Water Resources (State Engineer's Office), and the Colorado District of the U.S. Geological Survey.

The conference examined data from 2002, beginning with the available water supply and the context of the current drought within the historic record. While a three-year drought is not unusual for the semi-arid Colorado climate, the extremely low flow of 2002 is a rare event. While the low flows of 2002 created stresses on Colorado's water management system, the system appeared, in general, to work well. Water managers were able to make the adjustments needed to minimize the impacts. However, several sectors of Colorado's economy, it was noted, such as agriculture and recreation and tourism, experienced major losses.

Lower South Platte Water Symposium  
Northeastern Junior College - Sterling, Colorado  
February 13, 2003

Topics and speakers included in this symposium, which is held every other year, were: Water Law and Issues That Impact The River, Hal Simpson, State Engineer; How The System Works: Where The Water Comes From and Where It Goes, Luis Garcia, Colorado State University; Climatology of the South Platte Basin, Nolan Doesken, Colorado State University; Water Year 2002 In-Review, Jim Hall, Office of the State Engineer, Legal/Practical Issues with Managed Groundwater Recharge, Steve Sims, Assistant Attorney General; History of Water Development In The South Platte, Justice Gregory Hobbs.

STUDENT INTERN PROGRAM

The Institute continued its Student Intern Program in FY2002, a program designed to increase student interest in water issues. Student interns worked on the following projects.

**Children's Water Festivals**--Children's Water Festivals are fun for both students and presenters. These festivals are an excellent way to educate Colorado's children about one of our most precious resources, WATER. CWRRI interns taught children about Careers in Water. The students dressed in attire for their profession and taught other members of their class about their Career in Water.

Student interns also helped maintain, improve and update the CWRRI World Wide Web Homepages;

monitored press reports and prepared newsletter summaries of water issues in Colorado; helped develop and arrange the Colorado Drought Conference and the annual South Platte Forum, and researched background material for unfolding water issues and developed in-depth articles for the CWRRI newsletter, Colorado Water, and/or publications.

**USGS Summer Intern Program**

## Student Support

Student Support					
Category	Section 104 Base Grant	Section 104 RCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	13	0	0	0	13
Masters	2	3	0	0	5
Ph.D.	1	3	0	0	4
Post-Doc.	0	0	0	0	0
<b>Total</b>	16	6	0	0	22

## Notable Awards and Achievements

The rapid onset of a very severe drought dominated CWRRRI activities during 2002. CWRRRI responded by assembling and synthesizing past drought-related research and making it widely available on CWRRRI web sites, as well as reprinting key CWRRRI publications related to drought. Approximately 4,000 copies of Water-in-the-Balance No. 9, a CWRRRI report titled A History of Drought in Colorado, Lessons Learned and What Lies Ahead, and published in 2000, were reprinted over the year to meet the huge demand. In addition, the director of CWRRRI was interviewed numerous times by Colorado TV and radio station personnel as well as newspaper reporters.

CWRRRI also assisted in organizing faculty presentations to Colorado legislative committees holding testimony on the drought. CWRRRI took the lead in organizing a special Colorado Drought Conference, in close collaboration with the Colorado Water Conservation Board, Colorado Water Congress, Colorado Division of Water Resources, U.S. Geological Survey Colorado District, and CSUs DroughtLab. Almost 300 attendees, on December 4, 2002, described a very dire situation laden with uncertainty. Papers from the meeting are being published in a proceedings to capture the high level of uncertainty and concern expressed at what may be the height of the drought (given the wet spring in Colorado).

The Colorado Drought Conference attracted a great deal of interest from the media, with coverage in December located at the following websites. A few of the sites still have active connections.

Denver Channel 9 News: <http://stream.liquidcompass.net/9news/newmedia/> (not active) 9News web site story: <http://www.9news.com/storyfull-co.asp?id=9103> (active) and Denver Channel 7 News: <http://www.thedenverchannel.com/news/1820973/detail.html> (not active) Loveland Reporter Herald: <http://www.lovelandfyi.com/region.htm> (not active) Coloradoan: <http://www.coloradoan.com/news/stories/20021205/news/511560.html> (active) Rocky Mountain News: [http://www.insidedenver.com/drmn/local/article/0,1299,DRMN\\_15\\_1588532,00.html](http://www.insidedenver.com/drmn/local/article/0,1299,DRMN_15_1588532,00.html) (active) Denver Post: <http://www.denverpost.com/Stories/0,1413,36%257E23447%257E1030610%257E,00.html> (not active) Longmont Times Call: <http://www.longmontfyi.com/regionstate.htm#story2> (not active)

Pat ODriscoll, USA Today reporter who now lives in Denver and covers the national weather beat, also attended the conference.

The 2003 session of the Colorado legislature had to address a critical ramification of the drought the inability of 4,000 well pumpers along the lower South Platte River to augment their pumping impacts on senior surface water rights. The products of a CWRRRI research project, the South Platte Mapping and Analysis (SPMAP) software tool, played a key role in the discussions surrounding the bill (Senate Bill 73) as well as in current discussions about its implementation. SPMAP, under the direction of Professor Luis Garcia, is currently being used by a number of water managers along the river to compute, in a scientifically sound and transparent manner, augmentation flow requirements. The projects research results assist in reducing conflict over the computations during a time of high stress, such as the 2002 drought. SPMAP is also being evaluated as a key element of a new \$11 million South Platte Decision Support System being prepared by the Water Resources Division of the Colorado Department of Natural Resources.

The Water Resources Archive in the CSU Morgan Library placed its 10 finding guides on the internet and new collections are being donated to the Archives regularly. The CWRRRI papers were organized and catalogued into the archives during the winter of 2003.

Hydrology Days, an annual celebration of the science of hydrology held on the campus of CSU, received an endowment from the Whitney Borland Donation to CSU. The annual Borland Lecture, presented by nationally and internationally known and respected hydrologists, is funded by the new monies.

## **Publications from Prior Projects**

1. 2001CO861B ("Eutrophication of Reservoirs on the Colorado Front Range") - Water Resources Research Institute Reports - Gelder, Brian, Jim Loftis, Marci Koski, Brett Johnson, and Laurel Saito, 2003, Eutrophication of Reservoirs on the Colorado Front Range, Colorado Water Resources Research Institute, Colorado State University, Fort Collins, Colorado, Completion Report No. 194, 107 pp.
2. 2000CO18B ("Distribution, Habitat, and Life History of Brassy Minnow (*Hybognathus hankinsoni*) in Eastern Colorado Streams") - Articles in Refereed Scientific Journals - Scheurer, Julie A., Kevin R. Bestgen, and Kurt D. Fausch, 2003, 2003, Resolving Taxonomy and Historic Distribution for Conservation of Rare Great Plains Fishes: *Hybognathus* (Teleostei: Cyprinidae) in Eastern Colorado Basins, *Copeia*, Vol. 1, No. 1, pp. 1-12.