PROCEEDINGS

for

Montana's Lakes and Wetlands: Improving Integrated Water Management

23rd Annual Meeting
of the
MONTANA SECTION
of the
American Water Resources Association
Polson, Montana
October 12th and 13th, 2006
KawTuqNuk Inn

Contents

***These abstracts were not edited and appear as submitted by the author, except for some changes in font and format.**

THANKS TO ALL WHO MAKE THIS EVENT POSSIBLE!

- **The AWRA Officers**
  Kate McDonald, President, Ecosystem Research Group
  Tammy Crone, Treasurer, Gallatin Local Water Quality District
  Mike Roberts, Montana Department of Natural Resources and Conservation
  May Mace, Montana Section Executive Secretary

- **Montana Water Center, Meeting Coordination**
  Molly Boucher, Sue Faber, Susan Higgins, MJ Nehasil, Gretchen Rupp

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Meeting planners Sue Higgins, May Mace, Lynda Saul, Tammy Crone, Mike Roberts and Katie McDonald.

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American Water Resources Association
Montana Section's 23rd Annual Meeting
KawTuqNuk Inn, Polson, Montana
October 12 and 13, 2006

AGENDA

MONTANA'S LAKES AND WETLANDS: IMPROVING INTEGRATED WATER MANAGEMENT

WEDNESDAY, OCTOBER 11, 2006

8:00 am – 10:00 am REGISTRATION, KawTuqNuk, Lower Lobby

9:00 am – 4:00 pm Free **Wetlands Identification Workshop** with Pete Husby and Dr. Greg Kudray. Alexander Room. Pre-registration required.

THURSDAY, OCTOBER 12, 2006

7:00 am – 5:00 pm REGISTRATION, KawTuqNuk, Lower Lobby

8:00 am Meet at KawTuqNuk Lobby for optional **Field Trip** to Ninepipes National Wildlife Refuge and other areas near Polson. Hosted by **John LaFave**, **Larry Smith**, **Seth Make Peace**, and **Sue Ball**. Must pre-register, cost $25.

Noon Return from Field Trip; **Lunch on Your Own**

PLENARY SESSION. ***Michelle, Victor, Alexander Rooms***
MONTANA'S LAKES AND WETLANDS: IMPROVING INTEGRATED WATER MANAGEMENT

1:00 pm Welcome and Introductions, **Katie McDonald**, MT AWRA President
Water Center Welcome, **Gretchen Rupp**, Director Montana Water Center
Logistics and Announcements, **Tammy Crone**, MT AWRA Vice President

1:20 pm **Keynote Speaker, Dr. Richard Hauer**, Professor of Limnology, Flathead Lake Biological Station
Montana's River Floodplains: Critical Landscapes of Our Ecological Heritage

2:20 pm **Dr. Michael Suplee**, Water Quality Specialist, Montana DEQ: *The State of Montana's Lakes*

2:40 pm **Lynda Saul**, MDEQ Wetland Manager: *The State of Montana's Wetlands*

3:00 pm Break

3:20 pm **Panel:** *Tools for Integrating Lake and Wetlands Protection into Large-scale Watershed Management*
Moderator: **Gretchen Rupp**, Montana Water Center
Panelists: **Rich Moy**, Montana Department of Natural Resources and Conservation
Sue Ball, Confederated Salish and Kootenai Tribes
Paddy Trussler, Lake County Commissioner
Robin Steinkraus, Flathead Lakers
Ric Hauer, Flathead Lake Biological Station, University of Montana

5:20 pm **Adjourn**

5:30 pm **Poster Session.** ***Charlo Hallway***
Beer, wine, soft drinks and appetizers on the house. See titles last page.

7:00 pm **Pig Roast Banquet** with vegetarian option and no-host bar. ***Michelle/Victor Rooms***
Special Speaker: Dr. Daniel Fagre, Global Change Research Coordinator for the USGS Northern Rocky Mountain Science Center at Glacier National Park, presenting: *Climate Change in the Northern Rockies: What Disappearing Glaciers Tell Us about the Future of Water*

Afterwards: THE PHOTO CONTEST

FRIDAY, OCTOBER 13, 2006

SESSION 1 (Concurrent). *Michelle/Victor Rooms*
WETLANDS AND STREAMS

Moderator: **Lynda Saul**, Montana DEQ

8:00 am — A strategy for integrating wetland inventory, monitoring and assessment into watershed planning. Randy Apfelbeck, Montana DEQ.

8:20 am — Ecological processes as a link between wetland assessment and restoration. Tom Parker, Geum Environmental Consulting, Inc.

8:40 am — Mapping and analysis of isolated wetlands after Rapanos/Carabell. Linda Vance, Montana Natural Heritage Program.

9:00 am — Wetland change in Montana's large river valleys. Greg Kudray, Montana Natural Heritage Program.

9:20 am — Mercury in wetlands in the Lostwood National Wildlife Refuge, North Dakota. Steve Sando, David Krabbenhoft and Christopher Fuller, USGS.

9:40 am — **Student.** Subalpine wetlands: environmental drivers and response to human perturbation and restoration. Sunni Heikes-Knapton and Duncan Patten, MSU.

10:00 am — Spring characterization in Bighorn Canyon NRA. Denine Schmitz, Brian McGlynn and Duncan Patten, MSU.

10:20 am — **Break**

SESSION 2 (Concurrent). *Alexander Room*
MINING AND WATER QUALITY

Moderator: **Larry Smith**, Montana Bureau of Mines and Geology

8:00 am — Hydrogeologic characterization of acid mine drainage (AMD) along Belt Creek near Belt, MT. Jon Reiten, Shawn Reddish and Justin Brown, Montana Tech.

8:20 am — **Student.** Hydrogeologic characterization of a remediated mine site. Richard Labbe, MSU.

8:40 am — **Student.** Investigations of diel changes in the concentration of metals and sediment-water interactions. Kenneth Bates, Douglas Cameron and Steve Parker, Montana Tech.

9:00 am — **Student.** Preliminary investigations of temporal variability in the concentration and composition of DIC and DOC in streams. Garrett Smith, Steve Parker, and Douglas Cameron, Montana Tech.

9:20 am — Diel cycling of iron in hyper-acidic waters of the Rio Tinto and Rio Odiel, Andalucia, Spain. Steve Parker, Chris Gammons, Dean Synder, Montana Tech of The University of Montana; and David Nimick, U.S. Geological Survey, Helena.

9:40 am — Recent and long term variations of surface water quality in a mineralized watershed of the Little Rocky Mountains, Phillips County, Montana. Wayne Jepson and George Furniss, Montana DEQ; and Tom Osborne, Hydro-Solutions, Inc.

10:00 am — Groundwater flow in fractured rock at the Landusky Mine Site, Phillips County, Montana. Tom Osborne and Joel Adams, Hydro-Solutions, Inc.; and Wayne Jepson, Montana DEQ.

10:20 am — **Break**

FRIDAY, OCTOBER 13, 2006 (continued)

SESSION 3 (Concurrent). ***Michelle/Victor Rooms***
GROUND WATER AND SURFACE WATER STUDIES

Moderator: **Alan English**, Gallatin Local Water Quality District

10:40 am — Nitrate in domestic wells: a Montana ground-water assessment perspective. John LaFave, Montana Tech.

11:00 am — Geospatial groundwater modeling of the Gallatin River Basin. John Huddleston, NOAA National Centers for Environmental Prediction, MD.

11:20 am — **Student.** Nutrient loading to Upper Silver Bow Creek. Beverly Plumb and Chris Gammons, Montana Tech.

11:40 am — Role of artificial recharge in streamflow management: past, present, and future (Gallatin Valley Case Study). Eloise Kendy, Kendy Hydrologic Consulting, and John Bredehoeft, The Hydrodynamics Group.

12:00 noon — Nitrates in the Lost Creek fan shallow aquifer near Kalispell, Montana. Laura Alvey, Montana DEQ.

12:20 pm — Basin analysis of groundwater changes in the northern Dillon area. Willis Weight and Dean Snyder, Montana Tech.

12:40 pm — Pharmaceuticals, personal care products, endocrine disruptors (ppcps) and microbial indicators of fecal contamination in ground water in the Helena Valley, Montana, USA. Kate Miller and Joseph Meek, Montana DEQ.

SESSION 4 (Concurrent). ***Alexander Room***
SEDIMENT, CHANNEL PROCESSES, FLOODPLAINS AND RESERVOIR MANAGEMENT

Moderator: **Scott Gillilan**, Gillilan Associates, Inc.

10:40 am — Yellowstone River LIDAR mapping project. Jim Robinson, DNRC; Doug Jacoby and Brien Raber, Merrick & Company; and Gerry Daumiller, Montana State Library.

11:00 am — A watershed model for the South Fork Flathead River Basin upstream from Hungry Horse Dam, Montana. Katherine Chase, USGS.

11:20 am — Use of regression and time-series methods to estimate a sediment budget for Nevada Creek Reservoir, Montana, USA. Chuck Dalby, DNRC.

11:40 am — Effects of sediment pulses on channel morphology and sediment transport in a gravel-bed river. Dan Hoffman, PBS&J and Manny Gabet, University of Montana.

12:00 noon — Voluntary nutrient and sediment reduction efforts to Flathead Lake: Ashley Creek watershed restoration. Steve Buckley, Watershed Consulting.

12:20 pm — Estimating streamflow characteristics—new approaches in Montana. John Kilpatrick and Steve Sando, USGS.

CLOSING PLENARY ***Michelle, Victor, Alexander Rooms***

1:00 pm — AWRA officers announce **next year's officers, student awards, and photo contest standouts**, etc.

1:30 pm — Adjourn – Happy Trails!

POSTER SESSION

Charlo Hallway

1. **Student.** Landscape controls on hillslope-riparian-stream hydrologic interactions in a set of nested catchments, Northern Rocky Mountains. Kelsey Jencso and Brian McGlynn, MSU.

2. **Student.** Preliminary data on ground-water/surface-water interaction Near Four Corners, Gallatin County, Montana. Mark Schaffer and Stephan Custer, MSU.

3. **Student.** Sources of groundwater and subsurface water acquisition and utilization by conifers invading riparian communities in western Montana. Erin Thais Riley and Clayton Marlow, MSU.

4. **Student.** Bail-test analysis of hydraulic properties of alluvial materials near the Gallatin River, Gallatin County, Montana. Jonah Morsette, MSU.

5. **Student.** Vertical gradients in geochemistry of flooded mine shafts in the Butte, Montana, flooded mine complex. Dean Snyder and Chris Gammons, Montana Tech.

6. **Student.** Microbial source tracking of *E. coli* in Montana: A case for development of novel biomarkers for detection and identification of microbial contaminants. Margie Kinnersley and Jim Gannon, University of Montana.

7. Geology of surficial deposits on the Plains 30 X 60-minute Quadrangle, Lake, Missoula, and Sanders Counties, Montana. Larry Smith, Montana Tech.

8. Comparison of channel migration zones in plane bed, pool riffle and anabranching channel segments of the Upper Yellowstone River. Chuck Dalby, DNRC.

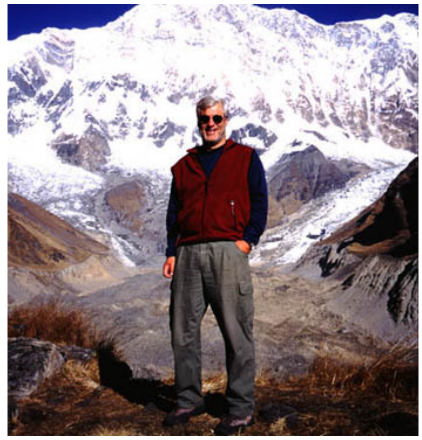
9. How to access and use the new statewide aerial photography and national wetland inventory maps. Greg Kudray, Montana Natural Heritage Program.

10. Critical lands project: A collaborative effort to protect lands critical for maintaining clean water, wildlife habitat and quality of life in the Flathead Lake Watershed in Northwest Montana. Constanza von der Pahlen, Critical Lands Project, Polson.

KEYNOTE SPEAKERS

Dr. F. Richard Hauer

Professor of Limnology
Holds FLBS Endowed Chair in Limnology
Flathead Lake Biological Station
The University of Montana
311 Bio Station Lane
Polson, MT 59860-9659
(406) 982-3301
ric.hauer@umontana.edu



Richard Hauer is a Professor at the University of Montana and holds the Flathead Lake Biological Station Endowed Chair in Limnology. He has taught and conducted his life's teaching and research in Montana since 1976. He has authored over 100 peer-review publications in international journals and is co-author and senior editor of the book "Methods in Stream Ecology", the single most widely used book in the field world wide. His research has centered primarily on the processes that effect stream and river ecosystems. Most recently, his research has been directed toward using aerial remote sensing to more fully understand river ecosystems across muliple spatial and temporal scales.

Abstract of his presentation: Floodplains are among the most dynamic landforms on Earth. In their natural form and function, floodplains are ever-changing landscapes composed of multiple biophysical patches forming habitat mosaics used by a complex array of species. However, rivers, and in particular river – floodplains, are now also among the most threatened and endangered of the earth's prevalent ecosystems. Montana's river floodplains are naturally highly dynamic. The riverscapes of Montana, composed of the river channel, floodplain, riparian vegetation and wetlands, and the subsurface aquifers, are particularly complex forming regional biodiversity hotspots. Many species depend on the occurrence of specific floodplain habitats to fulfill all or part of their life history. Nonetheless, many of Montana's large river systems have been significantly altered by various forms human intervention that directly affect either hydrologic or geomorphic processes through river regulation by dams and flooding or erosion control structures. Understanding the processes of our river systems and how they respond to societal attempts to "tame" them will be critical during the 21st century as we examine past mistakes and strive for sensible restoration.

KEYNOTE SPEAKERS

Dr. Daniel B. Fagre
Ecologist/Global Change Research
Coordinator
USGS-NRMSC
Science Center, c/o Glacier National Park
West Glacier, Montana 59936-0128
Phone: 406-888-7922
Fax: 406-888-7990
dan_fagre@usgs.gov

Daniel Fagre is Research Ecologist and Global Change Research Coordinator for the Northern Rocky Mountain Science Center of the U. S. Geological Survey. He is stationed at Glacier National Park, Montana and is a faculty affiliate at the University of Montana, Montana State University, and several other universities. He's worked for the past 15 years with many staff, partners and collaborators in the Northern Rocky Mountains to understand how global-scale environmental changes will affect our mountain ecosystems. His diverse research programs have addressed glaciers, avalanches, amphibians, alpine plants, paleoclimates, snow chemistry and ecosystem dynamics of bioregions. He received his Ph.D. from the University of California, Davis, and has held positions in universities and several federal agencies. He helped establish the Western Mountain Initiative, a program to tie mountain science across different areas, and is active in several international science networks that address mountain issues. He co-authored a book on national parks and protected areas published in 2005 and has another on a mountain ecosystem in press. He recently received the Director's Award for Natural Resource Research from the National Park Service.

Abstract of his presentation: Changes in alpine glaciers, especially mass balance and size, reflect changes in recent climate. In the western United States, virtually all the small alpine glaciers are shrinking and many will be gone in a few decades if current warming trends continue. These vanishing glaciers are indicative of pervasive changes throughout mountain ecosystems that are not as readily apparent nor as easily measured as are glaciers. Mountain ecosystem dynamics, and "services" to humans, will be affected in concert with changes to glaciers. One change glaciers readily reflect is a change to hydrologic regime and perhaps the most important mountain ecosystem service is the provision of water to a growing population in the American West.

The history and potential future of glaciers in Glacier National Park (GNP) clearly suggest that major mountain ecosystem changes are a reality. Glaciers were present within current park boundaries as early as 7,000 years ago but may have survived an early Holocene warm period, making them much older. Records show that around A.D. 1850 there were an estimated 150 glaciers and large perennial snow/ice fields. Based on 1966 aerial photographs, the first comprehensive map of the regions glaciers was published by the U.S. Geological Survey in 1968. Only 37 glaciers were named out of a total of 84 perennial snow-and-ice bodies. It's likely that some of the remaining 47 snow-and-ice bodies may have qualified as glaciers but they have since

melted. Key et al. estimated that 99 km^2 of ice covered GNP in 1850 but that only 26 km^2 remained by 1968. Aerial photographs were acquired in late September 1998 of all GNP glaciers. The glacier area measurements from these photographs were the first for all glaciers since 1966. The overall glacier coverage for GNP was reduced to 17 km^2. Only 27 glaciers existed of the original 150. Other former glaciers appeared to have shrunk to the point of being miniscule and stagnant ice masses. Red Eagle glacier, for example, was reduced to half its size between 1993-1998 and no longer meets the 0.1 km^2 criterion for being a glacier. A glacier margin survey was completed for Grinnell Glacier in 2001 and showed a loss of 0.17 km^2, or 19%, from 1993-2001. The margin survey of Grinnell was repeated in 2004 and a further loss of 0.4 km^2, or 5.6%, occurred in 3 three years.

As glaciers disappear from mountains because of climatic change, snowpacks obviously will be affected as well. Numerous studies document lower moisture content in late spring snowpacks and earlier melting of these snowpacks by as much as two weeks during the past 50 years. The BIOME-BGC model has been used to more closely examine spatial variability in climate, vegetation production, water budgets, and carbon stocks in the Northern Rocky Mountains and Pacific Northwest (Washington, Idaho and Montana). Climate change scenarios were applied that decreased current summer precipitation and increased annual temperature (the IPCC A2 scenario). Not unexpectedly, this resulted in reduced water supplies (outflows) from mountain areas and across the region. However, the greatest effects were at mid-elevation sites where most of the forests grow and where the increasing human population tends to build new homes. Under this scenario, the amount and predictability of the regional water supply will be of even greater concern than today. The low-lying areas, already relatively dry, show no major changes but the highest elevations, which have miniscule regional spatial representation, actually increased outflow. Thus, the highest mountains may be even more critical in providing ecosystem services to people in the future as the regional "water towers".

SESSION 1 WETLANDS AND STREAMS

A Strategy for Integrating Wetland Inventory, Monitoring and Assessment into Watershed Planning

Randy Apfelbeck, Montana Department of Environmental Quality, 1520 East Sixth Street, Helena, MT 59601, (406) 444-2709, rapfelbeck@mt.gov.

The Environmental Protection Agency has identified the development of a State comprehensive wetland monitoring and assessment program as a top priority to determine the causes, effects and extent of pollution to wetland resources and to improve pollution prevention, reduction and elimination strategies. They have also recommended that States consider developing strategies to identify the cumulative effects of wetland loss, degradation or restoration in order to provide information that can be used to develop watershed restoration plans; and that wetlands should be integrated into a State's broader water monitoring and assessment strategy, which includes streams, rivers and lakes. The Montana Department of Environmental Quality (DEQ) has been leading the development of wetland inventory, assessment and monitoring tools to meet EPA's recommendations using a three-tiered framework. This framework breaks wetland inventory, assessment and monitoring procedures into three levels that vary in intensity and scale, ranging from broad landscape-level assessments and mapping (Level 1); rapid field assessments (Level 2); and intensive assessments (Level 3). The framework provides States, local governments and watershed groups the flexibility to use and integrate various levels of effort and a variety of tools to inventory wetlands, assess their conditions, and monitoring trends. The focus of the presentation will be on the application of the wetland inventory, assessment and monitoring framework and tools that have or currently are being developed by DEQ. In addition, the presenter will discuss the benefits of integrating wetland inventory, monitoring, assessment and management into watershed planning and a broader water monitoring and assessment strategy.

Ecological Processes as a Link between Wetland Assessment and Restoration

Tom Parker, Geum Associates, 307 State Street, Hamilton, MT 59840, (406) 363-2353, tparker@geumconsulting.com.

While significant resources are assigned to both wetland assessment and wetland restoration, these activities are often independent of each other. Restoring ecological processes is often a programmatic goal for long-term habitat restoration efforts in western Montana. Examples of restoration projects where this is true include the Jocko River, Milltown Dam, and stream projects in the Blackfoot River, Tobacco River, Thompson River, and Bitterroot River watersheds driven by local partnerships, consent decrees and mitigation requirements. A comprehensive restoration planning process should incorporate the wetland assessment stage. To achieve this, the planning process should include careful selection of metrics that link assessment methodologies with project goals and effectiveness monitoring methods. When project goals include restoring wetland and floodplain ecological processes, these processes can become a common currency between assessment and restoration.

Mapping and Analysis of Isolated Wetlands after Rapanos/Carabell

Linda Vance, Montana Natural Heritage Program, 1515 E. 6th Ave., Helena, MT 59601, (406) 444-3380, livance@mt.gov.

Under the Supreme Court's 2000 ruling in Solid Waste Agency of Northern Cook County (SWANCC) v. United States Army Corps of Engineers, geographically isolated wetlands such as prairie potholes were removed from the scope of the Clean Water Act's permitting requirements. The June 2006 Supreme Court decisions, Carabell v. United States and United States v. Rapanos, appear to have restricted the Act's applicability even more, with a plurality of the Court finding that the Clean Water Act only protects those wetlands with a continuous surface water connection to relatively permanent standing or flowing water. Because this holding was not joined by a full majority of the Court, there is considerable confusion about the status of ephemeral and intermittent tributaries, wetlands adjacent to seasonal or impermanent streams, and wetlands that lack continuous surface water connections to navigable waters. In Montana's semi-arid environment, where wetlands are often isolated in space and/or time from permanent rivers, streams or lakes, these rulings may have far-reaching consequences. The Montana Natural Heritage Program is currently conducting a mapping and analysis effort to identify

Montana wetlands affected by the SWAANC decision, and those that may be impacted by the recent rulings. This presentation reports on the methodology we used to identify and map isolated wetlands and ephemeral/intermittent streams, and discusses the extent of wetland functions and values that may be at risk under different interpretations of the 2006 rulings.

Wetland Change in Montana's Large River Valleys

Greg Kudray, Montana Natural Heritage Program, 1515 E. 6th Ave., Helena, MT 59620, (406) 444-0915, gkudray@mt.gov.

Wetlands of the arid West are concentrated in large river valleys, as is the most intensive human development. We will present findings from the Yellowstone River riparian corridor and the Bitterroot valley that trace how wetland and riparian areas have changed over time. We used four dates of aerial photos beginning in 1950 along two reaches of the Yellowstone River to map wetlands and riparian areas and evaluate how they have been affected by natural and human events. We also assessed Government Land Office original survey notes for their applicability in evaluating riparian/wetland vegetation change since settlement. Our larger study of Bitterroot Valley wetlands contrasts the National Wetlands Inventory (NWI) mapping from the early 1980s with mapping based on 2005 imagery, spanning an interval of rapid development in the Valley. The NWI classification system used in these studies identifies wetland vegetation types so the analysis includes not only wetland acreage change but also how wetland vegetation habitat has changed.

Mercury in Wetlands in the Lostwood National Wildlife Refuge, North Dakota

Steven Sando, U.S. Geological Survey, 3162 Bozeman Ave., Helena, MT 59601, (406) 457-5928, sksando@usgs.gov. With Christopher Fuller and David Krabbenhoft, U.S. Geological Survey.

In recent years, research on mercury in the environment and effects on human health has received increasing attention and resulted in numerous fish-consumption advisories. Research activities largely have focused on human-health risks, but some valuable ecosystems (including wetlands) that do not play a direct role in human exposure have started to gain more attention. In many areas, mercury occurs as a result of atmospheric mercury emissions (primarily from coal combustors and waste incinerators), medium- and long-range transport, and subsequent deposition. Thus, almost all aquatic ecosystems receive inputs of mercury (primarily in inorganic forms) by atmospheric deposition. Inorganic mercury is not particularly toxic, but under certain conditions it can be converted to methylmercury (an organic form that is a very potent neurotoxin) by bacterially mediated sulfate reduction, assimilated by aquatic organisms, and magnified in the food chain. During 2003-04, a cooperative study was conducted by the North Dakota Department of Health, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and U.S. Geological Survey to investigate the occurrence of inorganic mercury and methylmercury in wetland water and bed sediment, biota, and the atmosphere in the Lostwood National Wildlife Refuge (LNWR), northwestern North Dakota. LNWR is about 75 miles east of the Montana-North Dakota border and lies within glacial terrain similar to much of northern Montana. LNWR has a very high density of depressional wetlands. Because of the complex hydrogeologic setting and differences in inundation patterns among the wetlands, water quality is highly variable among individual wetlands in LNWR. However, atmospheric deposition of inorganic mercury probably is very similar over the relatively small geographic area of LNWR. This presentation primarily focuses on the interaction of water-quality factors that are associated with variability in mercury methylation in LNWR wetlands. During the springs of 2003 and 2004, water and bed-sediment samples were collected from 44 LNWR wetlands distributed among four different hydrologic regimes (temporary, seasonal, semipermanent, and permanent). Samples were analyzed for physical properties and constituents related to mercury chemistry in aquatic systems. During 2003, methylmercury concentrations in water collected from seasonal and semipermanent wetlands were large (range 0.58 to 9.6 ng/L; median 1.2 ng/L), with many samples exceeding 1 nanogram per liter. In both years of the study, methylmercury concentrations in seasonal and semipermanent wetlands were larger than in temporary and permanent wetlands. Methylmercury concentrations were larger for all wetland hydrologic regimes during 2003 than during 2004. Preliminary results indicate that methylmercury concentrations in water samples collected from LNWR wetlands are strongly correlated with pH, organic carbon, and sulfate. Seasonal and semipermanent wetlands that had methylmercury concentrations in water greater than 1 nanogram per liter had pH values less than about 7.5, organic-carbon concentrations greater than about 30 milligrams per liter, and sulfate concentrations between about 10 and 100 milligrams per liter. These preliminary results provide valuable information about water-quality factors associated with the occurrence of methylmercury in the northern United States. The LNWR data illustrate the importance of specific wetland water-quality characteristics associated with variable capacity for methylation of inorganic mercury.

Subalpine Wetland Response to Disturbance, Restoration and Mitigation in Southwest Montana

Student: Sunni Heikes-Knapton, Montana State University, LRES. Home address: P.O. Box 1178, Ennis, MT 59729, (406) 570-4193, Knapton@3rivers.net. With Duncan Patten, Montana State University.

Development in mountainous landscapes often disturbs natural wetlands requiring restoration and mitigation to achieve approval from state and federal regulatory agencies. Affected wetlands often lose some functions such as habitat for wetland plants and filtration of flow through water. Restoration techniques attempt to restore these functions but monitoring of affected wetlands is designed to address habitat recovery with little concern for functional integrity. Little is known about the paired recovery of wetland habitat and functional integrity, particularly in challenging subalpine growing conditions. Complexity of restoration/mitigation success may be assessed through comparison with natural wetlands in the same or similar landscape settings. The goal of this study is to compare functional parameters of disturbed/restored/created wetlands to those of similar natural wetlands in a mountain landscape in southwest Montana. Functional parameters to be compared include both biological and physical/chemical processes. This study will select a number of disturbed/restored/created wetlands in a relatively large Madison watersheds and natural wetlands in adjacent undeveloped drainages for comparison of functional parameters. It will use vegetation cover and composition as a biological metric, and soil redox potential as a physical/chemical metric. Controlling factors such as geomorphic setting, hydrology (flow through and water depth), and surrounding vegetation communities will be assessed and used in selecting wetlands for comparison. Hypotheses: 1. Wetland vegetation cover and composition will vary among restoration techniques and with time. 2. Redox potential of restored/created wetland soils is dependent on establishment of a vegetation cover and composition equivalent to a natural wetland. 3. Geomorphic setting of restored/created wetlands plays a role in achieving short-term success in comparison of functions with natural, equal setting wetlands. 4. Development of soil functions in restored/created wetlands is related to the quality of restored soils as well as time since restoration. Little is known about how vegetation, soil, and hydrologic characteristics of an affected subalpine wetland can influence functional integrity. Researchers and agencies alike stand to gain by exploring the possible role that features such as cover and composition play in functions such as filtration and nutrient uptake. Restoration companies stand to gain by examining the success levels of affected wetlands in response to restoration techniques and recovery time. Conclutions from this project may encourage the most effective type of restoration/creation technique, and may predict the expected recovery of functional integrity of affected wetlands in the subalpine. Note: This project is ongoing and data collection continues. We anticipate collecting sufficient data by the October conference to give some indication as to hypothesis testing.

Spring Characterization in Bighorn Canyon NRA

Denine Schmitz, Montana State University, LRES, 334 Leon Johnson Hall, Bozeman, MT 59717, (406) 994-6499, dschmitz@montana.edu. With Duncan Patten and Brian McGlynn, Montana State University.

Bighorn Canyon National Recreation Area (BICA) is an arid landscape supported by a nexus of springs along the eastern foot of the Pryor Mountains. In developing a protocol to monitor the ecological condition of spring ecosystems we asked two initial questions about groundwater sources: 1) What is the residence time of groundwater discharging from BICA springs, and 2) What is the recharge area for the groundwater sources of BICA springs? We piloted a water chemistry protocol at four of 33 springs to address these questions and gain insight into the drivers of spring ecosystems. Variations in major anion and cation compositions corresponded with the geology of strata from which springs discharge. Seasonal analyses showed no variation. Deuterium and 18-O analyses indicated that spring water arose from recharged snowpack in the Pryor Mountains. Water ages ranged from 5 to more than 50 years based on tritium levels. These data suggest that impacts to groundwater may not be apparent at springs for more than 50 years. National Park Service managers will use this information to make management decisions at areas surrounding springs and when working with a diverse set of public and private neighbors. The effect of the time lag between recharge and discharge on spring endemics provides an opportunity to understand past environments and their relics. Seasonal chemical analyses suggested that stable groundwater environments support spring ecosystems which include biota that are adapted to fairly constant environments. One endemic plant species is known to exist only in calcareous springs in the Bighorn Basin, a possible indicator of environmental stability allowing development of endemism. However, Bighorn Canyon springs may be remnants from an earlier climate. We now ask the question, “Are Bighorn Canyon springs relics of past environments or products of constant environments?”

SESSION 2 MINING AND WATER QUALITY

Hydrogeologic Characterization of Acid Mine Drainage

Jon Reiten, Montana Bureau of Mines and Geology – Billings, 1300 N.27th, Billings, MT 59191-0108, (406) 657-2630, jreiten@mtech.edu. With Shawn Reddish and Justin Brown, Montana Bureau of Mines and Geology.

Decades of underground coal mining have resulted in acid mine drainage (AMD) that has contaminated ground-water and surface-water resources in Belt, Montana. The AMD has lowered the pH of Belt Creek and increased trace-metals concentrations in the stream. The overall goal of work in the Belt area was to define the hydrogeologic regime in the vicinity of Belt so that recharge to old mine workings, the source of acid mine drainage, could then be delineated with a reasonable level of certainty. Several possible sources of recharge were suggested when this project started; others developed as new information became available. Possible sources include: 1) recharge from regional aquifers such as the Madison aquifer, 2) upward seepage from deep aquifers along fault planes, 3) localized recharge from precipitation in areas directly overlying the mines or up-gradient recharge areas, 4) water loss from Box Elder Creek, and 5) focused recharge through shallow depressions overlying the mines. The most likely source of recharge to the mines is infiltration of precipitation on the land surface overlying the mine workings, including up-gradient areas that recharge the local Kootenai aquifer system. A significant source of water to the Anaconda Mine appears to be from the overlying Kootenai Formation; which is about 260 feet thick in the Belt area. Ground water is interpreted to flow from a divide located about 3.5 miles south of the Anaconda Mine. Only precipitation falling north of this divide has the potential to move towards the mine. Once recharge infiltrates vertically to the saturated zone, ground-water flow is generally to the north, perpendicular to the potentiometric contours illustrated in the predominant recharge area to the mine. Based on the data collected, it appears that recharge to the Anaconda Mine is locally derived. The recharge appears to be relatively constant; as recorded in the discharges from the mine. Fluctuations in precipitation cause significant changes in discharge from the overlying Sunburst aquifer springs. However, the mine discharges remain stable. Apparently the head increase, caused by precipitation-derived recharge, is rapidly dissipated through leakage at contact springs. If this interpretation of a localized flow system is correct, the volume of AMD discharging from the mine could be reduced or possibly eliminated by changing land-use in the recharge area. Other possible remediation options would be diverting flow from overlying aquifers to prevent filling the mine voids or flooding the mine voids to reduce pyrite oxidation. Growing alfalfa or other water-consumptive crops would have the potential to significantly reduce infiltration and possibly decrease the AMD discharges.

Hydrogeologic Characterization of a Remediated Mine Site

Student: Richard Labbe, Montana State University, Land Resources Department, 101 10th St. Belgrade, MT 59714, (406) 490-3168, rjlabbe@mtech.edu.

The Alta Mine Remediation Project was completed in 1999 as an attempt to alleviate human health risk posed by metals-laden mine waste at the Alta Mine west of Jefferson City, MT. The project included the removal of 154,000 yd^3 of waste that contained elevated levels of contaminants such as arsenic, lead, and manganese. Surface water at the Alta site was impaired both by heavy metals and by acid produced from sulfide-bearing rock. In the present hydrogeologic investigation, post-remediation surface water quality will be studied with an emphasis on the contribution of both water quality and quantity from leaking adits and other mine workings. In characterizing the site, the importance of groundwater and surface water interaction will be examined and a comparison made between pre and post-remediation water quality.

Investigations of Diel Changes in the Concentration of Metals and Sediment-water Interactions

Student: Kenneth Bates, Montana Tech, 1300 W. Park CBB302, Butte, MT 59701, KMBates@mtech.edu. With Douglas Cameron and Steve Parker, Montana Tech.

Preliminary results will be presented into the investigations of diel (24-h) processes that control the flux of metals to and from benthic surfaces across the sediment-water interface. Diel concentration changes of metals have been shown to occur in a variety of streams. Photosynthesis and respiration of aquatic plants and microorganisms drive the diel pH cycle in a healthy river. However, temperature and pH dependent sorption to surfaces play a significant role in the concentration cycles of both anions and cations in the river system. Since the transport and fate of chemical species within a river can have a significant impact on the health of the aquatic system and the surrounding environment, a better understanding of the of the mechanisms affecting diel concentration cycles will lead to a better fundamental understanding of river systems and water quality within natural waters. Previous examination of the Clark Fork River has demonstrated diel concentration changes in dissolved and particulate forms of Mn, Zn, Fe, Al, and Cu. These concentrations may be effected by daily biogeochemical processes in the benthic biofilm surfaces. It was additionally observed that the concentration of dissolved Mn and Zn cycles were in phase, suggesting that the cycles are linked by a common dependence to temperature, pH, photoperiod, and possibly hydrological cycles. A model has been proposed that links these diel concentration changes to the dissolution and precipitation in association with biofilm and algal populations through a daily solubility and redox cycle. Initial results of laboratory and in situ experiments will be presented that are intended to further investigate the role that benthic surfaces have in the diel concentration cycles of metals in streams. Field work on several streams will include the use of flux chambers to isolate benthic surfaces from the flowing water column. A comparison of the concentration changes of Mn and Zn within these isolation chambers will be compared to the water column to better identify the sources of the metals and the cause of the cyclic phenomena.

Preliminary Investigations of Temporal Variability in the Concentration and Composition of DIC and DOC in Streams

Student: Garret Smith, Montana Tech, 614 W. Silver St. Butte, MT 59701, (505) 860-4375,gsmith@mtech.edu. With Douglas Cameron and Steve Parker, Montana Tech.

The current work includes preliminary results into the investigations of daily and seasonal processes that control changes in the content of dissolved organic (DOC) and inorganic carbon (DIC) in streams. Diel concentration fluctuations of metals and other chemical species in streams have been well documented in the literature. Daily cycles of temperature, oxidation-reduction, photosynthesis and respiration, force chemical and physical changes in pH, alkalinity, dissolved oxygen, redox speciation, dissolved carbon dioxide, and dissolved and particulate element concentrations. It has been demonstrated that there is a significant and reproducible diel cycle in the carbon stable isotope composition of DIC (_13C-DIC) in both the Clark Fork (CFR) and Big Hole Rivers (BHR) in Montana. These changes are caused by the combined effects of photosynthesis and respiration of aquatic plants and microbes, and it is reasonable to expect diel changes in the isotopic composition of the DOC as it is influenced by changes in the sources of the organic carbon. DOC represents the single largest pool of reduced organic carbon in most aquatic systems; however, the presence of short-term temporal changes of the concentration of DOC has only been recently demonstrated. Both DOC and DIC have important roles in the natural processes that take place in streams. DIC can accumulate in surface waters from air-water gas exchange, community respiration, weathering of minerals or from groundwater contributions. Sources of DOC can include decomposition of organic matter and secretion by aquatic plants and microbes. However, little is known about the connection between these general classes of carbon reservoirs in natural systems. This current investigation is examining the connection on a diel (24-h) basis between DIC and DOC in several Montana rivers. It will also provide insight into the relationship between daily changes in DOC and transport of metals in these rivers. The objectives of this study are: 1) to measure the concentrations and 13C composition of DIC and DOC over a 24-h period, 2) to investigate and quantify the connection between the diel cycles of DIC and DOC, 3) to investigate the diel mobility of trace metals in the system in relationship to temporal changes in DOC concentration.

Diel Iron Behavior in the Hyper-Acidic Waters of the Rio Tinto and Rio Odiel, Andalucia, Spain

Steve Parker, Montana Tech, 1300 W. Park St., Butte, MT 59701, (406) 496-4185, SParker@mtech.edu. With Chris Gammons and Dean Snyder, Montana Tech; and David Nimick, USGS, Helena.

Preliminary results of field work on two highly acidic river systems that drain a mining region in the Iberian Pyrite Belt near the towns of Minas de Riotinto and Nerva in the Spanish province of Andalucía are presented. This investigation focused on diel cycling of iron in the Rio Tinto and Rio Odiel , which are each about 100 km long and flow into tidal estuaries that in turn flow to the Gulf of Cadiz of the Atlantic Ocean. The mining region contains massive sulfide deposits that have been a major source of metals and acid since mining first began there nearly 5,000 years ago. The processes affecting diel behavior in these rivers are compared to those in the acidic reaches of Fisher Creek, Montana and Rio Agrio, Argentina, where diel variations in iron concentrations result from iron photoreduction and associated geochemical reactions. The Rio Tinto and Rio Odiel are hyper-acidic, with pH values typically in the range of 2 to 3. Diel variations in pH were small, with maximum increases of about 0.1 pH unit during the day. Concentrations of dissolved metals are very high (for example, iron as much as 3,500 mg/L; zinc as much as 300 mg/L; copper as much as 150 mg/L). One estimate has put the annual contribution of dissolved zinc to the world oceans from these two rivers at about 8% of the global load (Braungardt and others, 2003). Thriving microbial communities exist in the hyper-acidic waters of the Rio Tinto and Rio Odiel. These communities are dominated by various forms of acid-tolerant iron-oxidizing and iron-reducing bacteria and also include algae and fungi. For comparison purposes, the aqueous geochemistry of the Rio Tinto and Rio Odiel is similar to that of the Berkeley Pit lake in Montana, although the high abundance of acid-tolerant micro-organisms in the rivers differs greatly from the low biological activity in the pit lake. Field and laboratory measurements indicated concentrations of Fe(II) in the Rio Tinto and Rio Odiel increased during the day and decreased during the night. This cycling likely is facilitated by microbes. Reference: Braungardt, C.B., Achterberg, E.P., Elbaz-Poulichet, Francoise, and Morley, N.H., 2003, Metal geochemistry in a mine-polluted estuarine system in Spain: Applied Geochemistry, v. 18, p. 1757-1771.

Recent and Long Term Variations of Surface Water Quality in a Mineralized Watershed of the Little Rocky Mountains; Phillips County, Montana

Wayne Jepson, Montana Department of Environmental Quality, P.O. Box 200901, 1520 East Sixth Avenue, Helena, MT 59620, (406) 444-0529, wjepson@mt.gov. With Tom Osborne, Hydro-Solutions, Inc. and George Furniss, Montana Department of Environmental Quality.

Placer gold was discovered in the streams of the Little Rocky Mountains in north-central Montana in 1884. The southern boundary of the Fort Belknap Indian Reservation was established along the mountain range's watershed divide in 1888. Lode gold deposits were discovered north of this divide in the early 1890s, resulting in a portion of the Reservation being returned to Federal management to allow for patenting. Intensive underground mining, along with milling and cyanide leaching occurred between approximately 1900 and 1940, and continued sporadically through the 1960s. Open pit mining and associated cyanide heap leaching occurred in the mining district between 1977 and 1998. As a result of bankruptcy, the sites have been managed by the State of Montana and the US Bureau of Land Management since 1999. Acid rock drainage (ARD) can be induced by either natural geologic and climatic variations, effects of mining or other human activities, or a combination of both. As a result, it is often difficult to determine the natural background water quality at older mine sites where limited baseline water quality data were collected. At Swift Gulch, water quality monitoring began concurrently with modern mining at the adjacent Landusky mine over twenty years ago and documents the development of ARD at about the same time the operator declared bankruptcy. Carbon dating of a charcoal fragment from an ancient ferricrete sedimentary deposit adjacent to the stream has documented a previous episode of acid drainage approximately 10,000 years ago. Outcrops along Swift Gulch containing multiple horizons of ferricrete indicate that ARD in this watershed has been episodic over geologic time. The dominant metals in seepage entering Swift Gulch are ferrous iron, manganese, nickel, zinc and arsenic. The iron becomes oxidized in the stream, flocculates, and settles to the stream bed along with adsorbed arsenic and other metals. One of the remedial strategies currently under consideration is to construct in-stream settling ponds to collect the iron hydroxide. These ponds would require periodic dewatering and sediment removal. Wetlands may be designed and constructed downstream of these ponds to further improve water quality by precipitating residual dissolved metals such as zinc. This presentation will discuss the evidence for prehistoric natural acid drainage in Swift Gulch, the mining history of the area, water quality trends in Swift Gulch since 1985, conceptual plans for remediation of the stream, and the need for further research.

Groundwater Flow in Fractured Rock at the Landusky Mine Site, Phillips County, Montana

Tom Osborne, Hydro-Solutions, Inc., Red Lodge, MT, (406) 655-9555, TomO@hydrosi.com. With Joel Adams, Hydro-Solutions, Inc. and Wayne Jepson, Montana Department of Environmental Quality.

The Landusky mine site in the Little Rocky Mountains in north-central Montana was the subject of placer, underground, and open pit mining for most of the last century. The site has been managed by the State of Montana and the US Bureau of Land Management since 1999 as a result of bankruptcy. The hydrogeology of the Landusky mine was characterized as part of the closure and reclamation work at the site. Groundwater flow patterns are controlled largely by a shear zone that trends northeastward through the mine site, extending to Swift Gulch north of the mine. A large-scale aquifer test was initiated in October 1999, during which a flowing artesian well was allowed to flow at rates from 265 to 311 gpm for a period of 12 months. This test resulted in the draining of the Landusky pit lake and affected potentiometric heads over 6,000-ft north of the producing well. Hydraulic responses that were observed during the aquifer test indicated that the shear zone is a preferential groundwater flow path at the site. Swift Gulch, a drainage to the north of the Landusky mine, is a current focus of research in the area. Acid Rock Drainage (ARD) occurs within Swift Gulch in an area within and down-stream of the shear zone. A tracer test was conducted by introducing fluorescein dye into a well that is completed within the Landusky shear zone and is located between the open pit and Swift Gulch. Tracer concentration in surface water and springs in Swift Gulch were monitored for approximately 2 years. Test results indicate a degree of hydraulic connectivity between the north edge of the mine area and Swift Gulch. The results of aquifer and tracer testing at the Landusky mine site will be presented in the context of reclamation activities at the mine site.

Nitrate in Domestic Wells: a Montana Ground-Water Assessment Perspective

John LaFave, Montana Tech, 1300 W. Park St., Butte, MT 59701, (406) 496-4306, jlafave@mtech.edu.
Most rural residences in Montana rely on wells for drinking water. There are records of about 127,000 domestic wells in the Montana Ground-Water Information Center—more than half of those wells (64,800) have been installed since 1985. Private water supplies are not required to be tested under the Safe Drinking Water Act. However, since 1993, 1,286 domestic wells have been sampled as part of the Montana Ground-Water Assessment Program; the nitrate-sample results are being evaluated with respect to aquifer, well depth, and the co-occurrence of other constituents. The samples were collected from wells completed in: 1) alluvial aquifers across the state (basin-fill, terrace, and stream valley alluvial aquifers—716 samples), 2) sedimentary-bedrock aquifers from the eastern two-thirds of the state (Tertiary to Mississippian age—369 samples), and 3) fractured-bedrock aquifers in the mountainous western part of the state (Tertiary and Cretaceous intrusives, and Proterozoic metasediments—201 samples). A preliminary evaluation shows that 42 percent of the domestic-well samples (535) had detectable nitrate (concentrations greater than 0.5 mg/L-N). The "background" concentration of 2.0 mg/L-N was exceeded in 19 percent (243), and the USEPA MCL for nitrate (10 mg/L-N) was exceeded in 4 percent (48) of the samples. Nitrate was detected most frequently in alluvial aquifers; 47 percent of the samples had detectable nitrate. Forty-four percent of the samples from fractured-bedrock and 31 percent of the samples from sedimentary-bedrock aquifers contained detectable nitrate. The occurrence of nitrate above the "background" concentration was comparable: 20 percent of the alluvial and fractured-bedrock aquifer samples, and 17 percent of the sedimentary-bedrock samples contained nitrate greater than 2.0 mg/L-N. The median depth water enters (DWE) for wells with nitrate above background was 75 feet; alluvial wells were generally shallowest with a median DWE of 57 ft, fractured bedrock wells were generally the deepest with a median DWE of 107 ft, and the sedimentary-bedrock wells had a median DWE of 80 ft. In samples where nitrate exceeded the MCL, exceedance of the secondary MCL for TDS was common (76 percent), followed by sulfate (56 percent), and sodium (24 percent). The co-occurrence of elevated nitrate and dissolved solids was more common in the eastern part of the state.

Geospatial Groundwater Modeling of the Gallatin River Basin

John Huddleston, NOAA National Centers for Environmental Prediction, 5200 Auth Road, Camp Springs, MD 20746-4325, (301) 763-8000, John.M.Huddleston@noaa.gov.
Spatial geomechanics and data from the U. S. Geological Survey (USGS) and National Weather Service (NWS) made it possible to create a groundwater model within MONTANA. The Gallatin River Basin was modeled as a three layer aquifer system encompassing 470,800 (1817 sq. mi.) hectares. The spatial geomechanical intersection of hypsography (contours) and hydrography (river) data layers produced prescribed heads. The ArgusONE spatial interface to the USGS MODFLOW model made it possible to use MONTANA hypsography data for both the surface elevation and the bedrock elevation. A mass rate analysis of NWS precipitation data determined the recharge to the groundwater aquifer. This paper will describe the spatial geomechanics used to create the Gallatin groundwater model and explore ways how it can be used to create a groundwater forecasting model.

Nutrient Loading to Upper Silver Bow Creek

Student: Beverly Plumb, Montana Tech, 1300 West Park St, Butte, MT 59701, (406) 496-4182, BAPlumb@mtech.edu. With Chris Gammons, Montana Tech.
In May of 2006 we began systematic sampling of upper Silver Bow Creek (above Rocker, MT) and tributaries for nutrient concentrations and loads. Nutrients analyzed include nitrate, nitrite, ammonia, soluble reactive phosphate, total N, and total P. Additional measurements include pH, temperature, specific conductance, alkalinity, dissolved oxygen, turbidity, streamflow, and total chlorine. The sampling plan is to collect data at 12 stations monthly through the summer, and bimonthly during the winter. Diurnal sampling will also be conducted at several key stations. Results to date show that the effluent from the Butte wastewater treatment plant (WWTP) is the largest single contributor of nutrients to Silver Bow Creek. Total N levels exceed 100 mg/L, mainly as suspended organic particles. Dissolved N is

chiefly present in reduced form as ammonium (NH4+), and concentrations of this solute remain highly elevated for several miles below the point of discharge. Concentrations and loads of nitrite (NO2-) are minimal above the WWTP, but increase with distance downstream below the WWTP. Nitrite may be forming as a byproduct of oxidation of ammonia. The WWTP is also a large source of soluble phosphate and nitrate, increasing the loads of these nutrients in Silver Bow Creek by a factor of 5-10 and ~ 2, respectively. Because the volume of water discharged from the WWTP varies on a diel (24-h) basis, the instantaneous concentration and load of nutrients at downstream sites along Silver Bow Creek also varies, depending on the time of day that a sample is collected. Other significant point sources of nutrients to upper Silver Bow Creek include the effluent from the Lower Area One lime treatment plant and the effluent from the Montana Pole groundwater treatment plant. Both of these facilities add nitrate (but very little P) to the system, with higher concentrations coming from the Montana Pole site. Further upstream, significant increases in the load of both nitrate and phosphate occur along tributary streams as they make their way through the greater Butte area. These inputs are likely due to non-point sources, such as fertilizer runoff, septic tanks, and animal waste. Although preliminary, the results of this study clearly show that upper Silver Bow Creek is negatively impacted by nutrient loads, and that concentrations of some contaminants of concern (in particular, ammonium and nitrite) are above regulatory standards for protection of fish and other forms of aquatic life.

Role of Artificial Recharge in Streamflow Management: Past, Present, and Future (Gallatin Valley Case Study)

Eloise Kendy, Kendy Hydrologic Consulting, 656 N. Ewing St., Helena, MT 59601, (406) 495-9910, ek65@cornell.edu. With John Bredehoeft, The Hydrodynamics Group.

In surface-water irrigated western valleys, ground-water discharge from excess irrigation sustains winter streamflow at levels that exceed natural flows. This unnatural condition has persisted for so long that hydrologists, water managers, and water users consider it to be normal. Changing land uses and irrigation practices complicate efforts to manage ground-water discharge, and, in turn, to protect instream flows. We examined the impacts on streamflow of (1) seasonal ground-water pumping at various distances from the Gallatin River and (2) improving irrigation efficiency in the Gallatin Valley, Montana, USA. We show that the greater the distance from a seasonally pumping well to a stream, the less the stream depletion fluctuates seasonally and the greater the proportion of annual depletion occurs during the non-irrigation season. Furthermore, we show that changing irrigation efficiency has implications beyond simply reducing diversions. Improving irrigation efficiency reduces fall and winter flows to a lower, but more natural condition than the artificially high conditions to which we have become accustomed. However, existing water users and aquatic ecosystems may rely upon return flows from inefficient irrigation systems. By strategically timing and locating artificial recharge within a basin, ground water and surface water may be managed conjunctively to help maintain desirable streamflow conditions as land uses and irrigation practices change.

Nitrates in the Lost Creek Fan Shallow Aquifer near Kalispell, Montana

Laura Alvey, Montana Department of Environmental Quality, 1100 N. Last Chance Gultch, Helena, MT 59620, (406) 841-5062, lalvey@mt.gov.

The Lost Creek Fan (LCF) is an alluvial outwash fan located northwest of Kalispell, MT. The fan covers about 20 sq km and consists of a thick layer (approximately 30 m thick) of glacial outwash composed mostly of cobbles, boulders, gravels, and some glacial till. The LCF is home to a shallow (15-30 m deep) unconfined aquifer that is underlain by the deep generally-confined regional Kalispell Valley aquifer. The shallow and deep aquifers are important sources of domestic water; there are records of more than 200 wells in the vicinity of the LCF. The hydraulic connectivity between the shallow and deep aquifers is not well understood. Nitrate concentrations in several LCF shallow domestic wells are well above the 10.0 mg/L-N MCL. In 1996-1997, the Montana Bureau of Mines and Geology (MBMG) Ground Water Assessment Program first noted the sensitive hydrogeologic setting of this area and elevated nitrate levels at the fan. Samples from six shallow wells had nitrate concentrations between 2.0 and 8.2 mg/L-N. The wells were re-sampled in 2002 after a sample from a shallow domestic well containing nitrate at approximately 40 mg/L-N was reported to DEQ. The 2002 sampling event showed that nitrate concentrations had increased in 4 of the 6 wells, with samples from 2 of the wells having concentrations

(16.9 and 32.9 mg/L-N) above the MCL of 10 mg/L-N. In July 2005, the DEQ's Groundwater Remediation Program (GRP) conducted a ground-water sampling event to obtain current data for nitrate concentrations, delineate the extent of nitrate impacted ground water, and attempt to identify sources. The 2005 study was conducted with monies provided by the Montana Department of Agriculture (MDA). Thirty-four wells completed in the shallow (21 samples) and deep (13 samples) aquifers within an area of about 20 sq km were sampled. Samples from the deep aquifer samples reported relatively low concentrations of nitrate, ranging from 0.03 to 4.53 mg/L-N. Nitrate concentrations from the shallow aquifer samples ranged from 0.21 to 40.6 mg/L-N, with five of the samples (about 25 percent) reporting concentrations between 4 – 10 mg/L, and eight of the samples (about 40 percent) reporting nitrate concentrations above 10 mg/L-N. Several potential nitrate sources exist on the fan, which, until approximately 5 years ago, predominantly supported agricultural activities. DEQ's 2005 study identified potential sources from nitrogen-based fertilizers, manure from feedlots and dairies, and DEQ-permitted spreading of septic and dairy wastes. Also, the number of private homes with individual septic systems in this area has increased in recent years, representing another potential significant contribution of nitrate. DEQ's GRP, in conjunction with MDA, MBMG, and Flathead County, is working to better understand the factors contributing to the elevated nitrates in the LCF shallow aquifer. However, given the multitude of N sources and the complicated hydrogeology, no clear answers have yet emerged. Understanding the factors contributing to groundwater contamination at the LCF may lead to mechanisms that will protect the LCF groundwater from additional contamination, and may help regulators prevent nitrate contamination in other parts of the state.

Basin Analysis of Groundwater Changes in the Northern Dillon Area
Willis Weight, Montana Tech, 1300 W. Park St., Butte, MT 59701, (406) 496-4329, wweight@mtech.edu. With Dean Snyder, Montana Tech.
An analysis of groundwater levels and surface-water quality data in the northern Dillon area over a period of drought and normal precipitation shows the nature of connection of the local irrigation system with groundwater. The study area encompasses the region from Dillon to Beaverhead Rock, about 30 miles northeast of town and tributaries in between. Water budget efforts from previous studies failed to account for the large increase in flow in the Beaverhead River near Beaverhead Rock, which is a result of irrigation return flows and precipitation recharge at a major groundwater discharge area. Field data were collected over the 2005 and the 2006 water years. Comparisons of water levels in wells during a low-flow year (2004 and 2005), where surface flows in the East Bench and West Canal were below normal are compared with a normal precipitation year (2006), where full allotment of surface water in both canals took place. Comparisons of field data indicate the influence of the irrigation system on groundwater levels. Field water-quality parameters taken during the 2006 irrigation season provide additional insights into the distribution of surface and ground waters in the study area. Wells in the monitoring network were selected up gradient of the canals to assess the role of precipitation recharge. Field data are crucial to understanding the groundwater –surface water interactions in an area taxed with irrigation wells without water use permits. Results of field data will be presented using existing and new observation wells. Discussion of the data is designed to contribute to the understanding of over appropriated watersheds.

Pharmaceuticals, Personal Care Products, Endocrine Disruptors (Ppcps) and Microbial Indicators of Fecal Contamination in Ground Water in the Helena Valley, Montana, USA
Kate Miller, Montana Department of Environmental Quality, 227 Parsley Road, Helena, MT 59602, (406) 444-6972, Kmiller2@mt.gov. With Joseph Meek, Montana Department of Environmental Quality.
The City of Helena, Montana and its surrounding valley (fig.1) are experiencing marked population growth, with attendant proliferation of onsite wastewater disposal (septic tanks and drainfields) systems. Thirty eight public and private domestic water supplies deriving ground water from the Quaternary/Tertiary valley fill aquifer and various bedrock units were sampled in the summer and fall of 2005 for pharmaceutically active compounds, personal care products and endocrine disrupting compounds (PPCP as used here). The two most frequently detected PPCPs are sulfamethoxazole (SMX) and the herbicide atrazine, with detection frequencies of 80% and 40%, respectively. Atrazine demonstrates a strong correlation with chloride and total dissolved solids (TDS). Since chloride and

TDS are commonly used inorganic indicators of water-quality degradation from domestic wastewater discharge, this suggests that atrazine could be occurring in domestic wastewater. This hypothesis should be verified in subsequent investigations. The wells were also sampled for microbial indicators of fecal contamination and for inorganic constituents. There is a poor correlation between the microbial indicators of fecal contamination and PPCP occurrence, with zero detections of either *E.coli* or the somatic or male specific coliphage. Total coliform, though detected at only 8 sites, was superior to coliphage as an indicator organism in ground water.

SESSION 4 SEDIMENT, CHANNEL PROCESSES, FLOODPLAINS AND RESERVOIR MANAGEMENT

Yellowstone River LIDAR Mapping Project

Jim Robinson, Montana Department of Natural Resources and Conservation, P.O. Box 201601, Helena, MT 59620-1601, (406) 444-4247, jrobinson@mt.gov. With Doug Jacoby and Brien Raber, Merrick & Company; and Gerry Daumiller, Montana State Library.

Since the floods of 1996 and 1997 significant amounts of scientific data have been generated for the Yellowstone River floodplain. Developed to support a wide variety of technical studies sponsored by the Upper Yellowstone River Task Force and the Yellowstone River Conservation District Council (YRCDC), the data is available through a variety of Internet portals, the chief being the Yellowstone River data home page at http://nris.mt.gov/yellowstone. Developed and maintained by the Natural Resource Information System at the Montana State Library, this web page provides a single point of access to a variety of data and publication resources compiled for the Yellowstone River corridor. The data were created as part of an interdisciplinary planning study and are intended to support hydraulic, geomorphic, biologic and socioeconomic analyses of the stream corridor ecosystem. Of current interest are the results of 2004 precision topographic mapping project conducted by Merrick & Company under contract to the YRCDC. Completed in April 2005, this project employed a combination of LIDAR (light detection and ranging) and bathymetric survey techniques to produce a continuous digital elevation model of in channel and over bank ground surfaces. Suitable for hydraulic floodplain analysis (0.5-meter horizontal and 0.2-meter vertical accuracy), the project mapped over 295 square miles of floodplain and 130 river miles of active channel in Stillwater, Yellowstone and Dawson Counties and included production of high resolution (30cm pixel), true color digital orthophotography, as well as a wide variety of planimetric feature datasets (roads, buildings, hydrography, etc.). Total contract amount for the work was approximately $400,000.

A Watershed Model for the South Fork Flathead River Basin Upstream from Hungry Horse Dam, Montana

Katherine Chase, U.S. Geological Survey, 3162 Bozeman Ave., Helena, MT 59601, (406) 457-5957, kchase@usgs.gov.

The Bureau of Reclamation (BOR) plans to develop a water-resource management model for the Clark Fork of the Columbia River basin to help optimize reservoir operations to meet increasing Montana water needs while still fulfilling downstream requirements for power generation and instream flow. As a first phase for this work, the U.S. Geological Survey (USGS) is assisting the BOR with development of a watershed model for the South Fork Flathead River, upstream from Hungry Horse Dam. The BOR plans to use this model to estimate daily values of unregulated streamflow at selected locations in the South Fork Flathead River basin. The watershed model will be constructed using the USGS Modular Modeling System (MMS), an integrated system of computer software that provides a framework for the development and application of models to simulate different water, energy, and biogeochemical processes. For this study, MMS will link process modules from the USGS Precipitation-Runoff Modeling System (PRMS) to construct the watershed model. PRMS is a distributed watershed model that simulates precipitation- and snowmelt-driven movement of water through a basin via overland flow, interflow, and baseflow. The basin hydrologic response can be simulated at a daily or more frequent time step. Development of the PRMS model involves dividing the basin of interest into hydrologically homogeneous subunits. Digital-data layers for land use, soils, geology, and topography for each of these subunits are combined in a geographic information system (GIS); data from these layers are extracted for the PRMS model using a USGS GIS interface. In addition to the digital geospatial data, inputs to the PRMS model include daily precipitation, air temperature, solar radiation, and various channel hydraulic characteristics. The PRMS model will be calibrated and then tested by simulating daily streamflow and snowpack characteristics and comparing the results with observed data. After calibration, the PRMS model can be used to simulate the hydrologic response of the basin for various climatic scenarios. MMS will be linked with a hydrologic database which in turn will connect with Riverware, the river-and-reservoir management model to be constructed and used by the BOR. These models will be part of the BOR's Decision Support System (DSS) for the South Fork Flathead River basin. This DSS will allow the

BOR to estimate hydrologic conditions and runoff volumes in the South Fork Flathead River basin using the most up-to-date information, and will help BOR to efficiently operate the Hungry Horse Dam outlet works to meet flow requirements throughout the basin.

Use of Regression and Time-Series Methods to Estimate a Sediment Budget for Nevada Creek Reservoir, Montana, USA

Chuck Dalby, Montana Department of Natural Resources and Conservation, 1424 9th Ave., P.O. Box 201601, Helena, MT 59620, (406) 444-6644, cdalby@mt.gov.

The effect of Nevada Creek Reservoir on downstream fine-sediment concentration, loads and turbidity was evaluated through measurement and modeling of inflowing and outflowing fine-sediment loads and turbidity monitoring. Located in the upper Blackfoot drainage of western Montana, Nevada Creek Reservoir is a storage project developed and operated for irrigation-water supply by Montana Department of Natural Resources and Conservation (DNRC) and Nevada Creek Water Users Association (NCWUA). Total suspended-solids concentration (TSS) was measured daily to twice daily (April-October runoff of 1999 and 2000), above and below the reservoir, using automatic pumping samplers with depth-proportional intake booms designed to minimize bias of point intake samples. The TSS dataset and suspended-sediment concentration (SSC) data, collected by the U.S. Geological Survey at the same sites, were analyzed using time-harmonic regression methods to calibrate statistically significant models relating log-transformed mean daily TSS or SSC to mean daily stream discharge and decimal time of sample. Lag-1 serial correlation of daily values of discharge and TSS was large (ρ=0.7), but an attempt to fit time-series models (e.g. transfer-function models) to the daily TSS dataset was unsuccessful. Calibration sample size was reduced to minimize ρ, and best-fit regression models were developed and used to estimate daily TSS and SSC loads at the stations. Monthly, seasonal and annual reservoir sediment budgets, for the period 1995-2004, were calculated as the difference between loads above and below the reservoir. The pattern of monthly variation in mass balance was consistent from year-to-year; November through June the reservoir mass balance was positive, with inflowing sediment stored, while in July through October (during reservoir drawdown when inflowing sediment loads are small) the mass balance was negative, with more sediment transported from the reservoir than enters. Over the 10-year period, average annual mass balance was positive, with about 60% to 90% of the inflowing load stored in average and above average water years; in low water years (e.g. 2000) annual mass balance was negative, with more sediment lost from storage than gained from spring runoff. During 1999-2000 peak spring runoff, turbidity and TSS were greater above the reservoir than below; at low flow turbidity and TSS and were slightly larger below the reservoir. Variable trap efficiency of the reservoir increases its useful life, but creates potential for excessive sediment flushing at low flow and in low-water years. Recognizing this potential, DNRC and NCWUA have established minimum reservoir pool elevation and capacity guidelines to prevent excessive reservoir sediment entrainment and resulting downstream spikes in concentrations and loads during low flow. KEY TERMS: Reservoir; sediment budget; turbidity; regression; serial correlation; time-series.

Effects of Sediment Pulses on Channel Morphology and Sediment Transport in a Gravel-Bed River

Dan Hoffman, PBS&J, 724 Defoe Street, Missoula, MT 59802, (406) 543-1899, dfhoffman@pbsj.com. With Manny Gabet, University of Montana.

Sediment delivery to stream channels in mountainous basins is strongly episodic with large inputs of sediment typically delivered by infrequent landslides and debris flows. Identifying the role of large but rare sediment delivery events in the evolution of channel morphology and fluvial sediment transport is crucial to an understanding of the development of mountain basins. In July of 2001, intense rainfall triggered numerous debris flows in a severely burnt watershed in the Sapphire Mountains of Montana. Ten large debris flow fans were deposited on the valley floor and investigations focused on the channel response to these inputs of sediment. The channel has aggraded immediately upstream of each fan and braided in reaches immediately downstream. Channel incision through the fans has created sets of coarse-grained terraces. The deposition upstream of the pulses consists almost exclusively of fine material resulting in a median bed material size (D50) 1-2 orders of magnitude lower than the ambient channel material. The volume of sand being transported is so great that these aggrading reaches can

extend hundreds of meters upstream of the fans with 1-2 meters of sand deposited across the entire valley floor. Along a 10-kilometer study reach, cross section surveys, longitudinal profiles, and pebble counts chronicle channel response to a punctuated increase in sediment supply and provide insight on the processes of sediment wave dispersal.

Voluntary Nutrient and Sediment Reduction Efforts to Flathead Lake: Ashley Creek Watershed Restoration

Steve Buckley, Watershed Consulting, 635 Denver Street, Whitefish, MT 59937, (406) 862-3565, steve@watershedconsulting.com.

Ashley Creek is a major source of nutrients and sediment to Flathead Lake. Recognizing this as a basin-wide problem, the Flathead Basin Commission has developed a voluntary nutrient and sediment reduction strategy, or VNRS. The overall aim is to reduce sediment and nutrient delivery to streams in the watershed by working cooperatively with private landowners. Over the past six years, with the help of these landowners, sources of sediment and nutrients in the Ashley Creek watershed have been identified and prioritized. Problem sites include straightened stream reaches, wetland ditching, riparian vegetation removal, over-grazing and erosion of road cuts into adjacent stream corridors. Thus far, stream restoration and fish habitat improvement projects have been conducted at seven sites, along with several thousand feet of riparian fencing, riparian re-vegetation projects and a large-scale road/sediment reclamation project. This paper will detail the various restoration techniques that were used in the projects, and the results of the initial monitoring of the sites.

Estimating Streamflow Characteristics—New Approaches in Montana

John Kilpatrick, U.S. Geological Survey, 3162 Bozeman Ave., Helena, MT 59602, (406)-457-5902, jmkilpat@usgs.gov. With Steve Sando, U.S. Geological Survey.

Since the 1940s, the U.S. Geological Survey (USGS) has been documenting selected basin characteristics associated with streamflow-gaging stations. These basin characteristics serve as explanatory variables for developing regression equations to estimate streamflow characteristics at ungaged stream sites. In the past, the basin characteristics were manually derived from variously scaled USGS topographic quadrangles or other maps with relevant environmental data such as soil-infiltration rate and mean annual precipitation. This process was time-consuming and regression analyses sometimes were limited by the availability of accurate and up-to-date maps and environmental data. Further, even when up-to-date data were available, the magnitude of the effort to manually assemble those data for several hundred gaging stations limited the number of explanatory variables analyzed.

In the 1980s, the development of geographic-information-system (GIS) software presented opportunities for substantial advances in compilation and analysis of topographic and environmental information for drainage basins. More recent software developments in topographic analysis and an increase in availability of geospatial datasets (including detailed soils, geology, climate, and land-cover/use data) have further automated the compilation and analysis of topographic and environmental characteristics of drainage basins.

Nationally, USGS has been pursuing many of the opportunities presented by GIS advances to improve estimation of streamflow characteristics at ungaged stream sites. In addition to more convenient derivation of traditional basin characteristics, new geospatial datasets and analytical techniques make it possible to more readily explore the hydrologic importance of other basin characteristics (such as surficial geology and several GIS-derived topographic characteristics) and to use more-detailed and accurate information related to some traditional basin characteristics (such as soil permeability and land-cover data). Also, USGS has developed software to provide estimates of streamflow characteristics at ungaged stream sites. One software program (StreamStats), developed by the USGS Office of Surface Water, is simple to use, requiring only that the user click on the stream site of interest to determine basin and streamflow characteristics. Prototype versions of StreamStats are available for several States (including Idaho, Pennsylvania, Vermont, and Washington).

In Montana, USGS is assembling and analyzing geospatial datasets to derive updated basin characteristics for streamflow-gaging stations. A preliminary comparison of GIS- and manually derived basin characteristics has shown good agreement, but a comprehensive comparison is needed. When this comparison is completed and required datasets have been prepared, USGS plans to implement StreamStats for Montana using existing geospatial datasets and USGS-developed regression equations. In conjunction with the planned implementation of StreamStats for Montana, USGS is in the process of developing new regression equations to estimate low-flow characteristics at ungaged stream sites using GIS-derived basin characteristics. These steps bring us closer to providing convenient Web-based access to basin and streamflow characteristics at ungaged sites in Montana.

POSTER SESSION

1. Landscape Controls on Hillslope-Riparian-Stream Hydrologic Interactions in a set of Nested Catchments, Northern Rocky Mountains

Student: Kelsey Jencso, Montana State University, 334 Leon Johnson Hall, Bozeman, MT 59717, (406) 994-5705, jfriar@montana.edu. With Brian McGlynn, Montana State University.

Understanding how local hillslope-riparian connections and source water dynamics translate to catchment scale hydrologic and solute response remains a challenge. We examined hydrologic connections between hillslope, riparian, and stream zones across catchments ranging in size from 3 to 30 km^2, within the Tenderfoot Creek Experimental Forest (U.S. Forest Service) in the northern Rocky Mountains of Montana, USA. We quantified hillslope and riparian lateral contributing area and estimated the volume of riparian reservoirs through landscape analysis of Airborne Laser Swath Mapping (ALSM) derived digital elevation models. Based on this landscape analysis, 12 transects of topographic end-members were selected with a range of hillslope and riparian extents. Wells and nested piezometers were installed across the stream, riparian, and hillslope zone along each transect, and were monitored for solutes, specific conductance, and water table dynamics. Patterns in water-level fluctuations and solute/conductivity measurements through the year and during runoff events suggest hydrologic connections and dynamics unique to each landscape. Our approach provides a framework for quantification of the spatial distribution of runoff source areas and first steps toward spatially explicit links between localized hillslope/riparian controls on runoff source areas and whole catchment hydrologic and solute response.

2. Preliminary Data on Ground-Water/Surface-Water Interaction near Four Corners, Gallatin County, Montana

Student: Mark Schaffer, Montana State University, 200 Traphagen Hall, Bozeman, MT 59717-3480, (406) 580- 8008, aguamontana@yahoo.com. With Stephan Custer, Montana State University.

Ground-water-surface-water interaction is important in a river basin closed to new appropriations. To understand the interaction, data is needed both on the ground water and on the surface water. The Four Corners area in Gallatin County is rapidly growing. This area is in the upper Missouri Drainage Basin which is a closed basin and was the subject of the 2005 Montana AWRA Field trip in Bozeman. Since that meeting, data has been collected from over 40 wells, 20 of which are deep/shallow piezometer pairs many of which are near the river. Bail tests provide information on hydraulic conductivity. In addition data were collected from seepage runs, as well as stream bed temperatures and hydraulic gradients at many points in the stream bed. Preliminary results indicate that the river and aquifer are hydrologically connected but that the connections are spatially and temporally variable.

3. Sources of Groundwater and Subsurface Water Acquisition and Utilization by Conifers Invading Riparian Communities in Western Montana

Student: Erin Thais Riley, Montana State University, Animal and Range Sciences - Linfield #16, Bozeman, MT 59717, eriley@montana.edu. With Clayton Marlow, Montana State University.

Woody plant encroachment into grassland ecosystems has been reported on a global scale (Huxman, T.E., Wilcox, B.P. 2005). Often encroachment is most pronounced in adjoining riparian areas where high levels of wildlife and livestock use leave ecosystems vulnerable to invasion by woody species like Douglas fir (*Pseudotsuga menziesii*) and Rocky Mountain juniper (*Juniperous scopulorum*) (Auken, Van, O.W. 2000). Comparing past vegetative community structure with current vegetative community status makes it apparent that we must reassess current management strategies. Future ecological studies must take into account the health of the entire ecosystem due to changes in climate, grazing pressures, and hydrologic conditions. An example of this redirection in thinking is an investigation of Quaking aspen (*Populus tremuloides*) decline throughout the Western U.S.. Historically, aspen was found in large expanses throughout the Rocky Mountain and Great Basin landscape. Stands were kept free of encroaching conifers by fires occurring on a regular 3 to 15 year cycle. Fire suppression programs have been aggressively implemented and are no longer a component of riparian vegetative communities and shade tolerant conifers are invading former aspen stands. Aspen replacement by conifers could lead to negative changes in hydrologic activity within adjacent riparian areas (Ansley, J.R 2000). To aid in riparian

conservation efforts I will: 1) distinguish between water use by depth for large and small trees; 2) test the response of riparian groundwater levels to the eradication of small trees in sub-watersheds through prescribed burns; and 3) compare water use between coniferous and deciduous tree species within and among sub watersheds.

4. Bail-Test Analysis of Hydraulic Properties of Alluvial Materials near the Gallatin River, Gallatin County, Montana

Student: Jonah Morsette, Montana State University, 200 Traphagen Hall, Bozeman, MT 59717-3480, (406) 697-0385, jammin_j_m@hotmail.com.

Upper Missouri Basin is fully appropriated and therefore closed to new surface-water withdrawals. For this reason, water development has moved to ground water sources. Recent court decisions in Montana have held that where ground water and surface water are directly and immediately connected, ground-water withdrawal is also not allowed. Direction and rate of ground water flow are critical to the assessment of the connection. To assess connection, hydraulic conductivity data is needed. This data allows calculation of flux of water if hydraulic gradients are known. Hydraulic gradient and hydraulic conductivity were measured in several well pairs. One well was deep and one well was shallow. Water levels were measured in the wells. Gradient was computed by taking the difference of water elevations and dividing that value by the distance between the two wells. Hydraulic conductivity was then assessed with bail tests, which is the method of measurement used to investigate aquifer characteristics. A bail test is conducted by adding a piston to a well and measuring the subsequent rate of rise of the water level in the well. A pressure sensor inside the well records water levels repeatedly at any time increment desired (in most cases it was set to half seconds). The data is then downloaded from the sensor to a PC for analysis. Spreadsheet modeling is then utilized for convenience of performing mathematical calculations of hydraulic conductivity. The bail test hydraulic conductivity will be used with hydraulic gradient data along with Darcy's law to assess ground water flow into, out of, or along the bed of the Gallatin River in the Four Corners area. The primary method applied is the Bowen-Rice Method although the Van Der Kamp method was applied for comparison.

5. Vertical Gradients in Geochemistry of Flooded Mine Shafts in the Butte, Montana, Flooded Mine Complex

Student: Dean Snyder, Montana Tech, 1300 West Park Street, Butte, MT 59701, (406) 546-6135, DMSnyder@mtech.edu. With Chris Gammons, Montana Tech.

The main objective of this study is to characterize gradients with depth in the geochemistry and stable isotopic composition of groundwater in the Butte flooded underground mine complex. The flooded underground mines of Butte include over 15,000 km of interconnected vertical shafts, horizontal drifts and stopes. The data collected in this study will be used to: 1) investigate the dominant solubility controls on the concentration of dissolved metals, including Al, As, Cu, Fe, Mn, Ni, U, and Zn; 2) examine in more detail the lateral and vertical changes in groundwater temperature in the flooded mine complex, which could provide clues to groundwater flow paths; and 3) to determine if sulfate-reducing bacteria have established themselves in the deeper levels of the East Camp shafts. Work to date on this project has examined vertical changes in water chemistry to a depth of 1000 ft. BSWL in the Anselmo, Steward, and Kelley mine shafts. The Kelley shaft contains groundwater that is unusually warm (over 34°C), and it is also the only mine shaft in the Butte District that is strongly acidic ($pH < 4.5$). With depth, the water becomes warmer and more acidic ($T = 38°C$ and $pH = 3.8$ at 1000 ft. BSWL). With the exception of copper, dissolved metal concentrations also increase with depth. Despite the fact that the Kelley was mined primarily for copper, dissolved copper concentrations are very low (< 50 µg/L) in the shaft waters. It is possible that copper is being scavenged from solution as elemental copper or chalcocite (Cu_2S) in a manner that is typical of natural supergene enrichment of porphyry copper ore deposits. Laboratory experiments are in progress to test this hypothesis. Unlike the Kelley mine, the Anselmo and Steward shafts have a near-neutral pH, and show very minor changes in temperature or water chemistry with depth. The absence of any gradients with depth suggests that these two mine shafts undergo vertical circulation of groundwater, although the mechanism driving this circulation is not known. Future work will expand our database for the Steward and Kelley mine shafts to greater depths (up to 3000 ft. below SWL). We will also examine other mine shafts, including the Granite Mountain, Pilot Butte, Travona, and Orphan Boy shafts. The latter two are particularly interesting because they are known to contain hydrogen sulfide formed by bacterial sulfate reduction. This study is being funded by the U.S. Environmental Protection Agency through its Office of Research and Development under IAG DW89938870-01-0 and through the U.S. Department of Energy (DOE) National Environmental Technology Laboratory under Contract DE-AC22-96EW96405.

6. Microbial Source Tracking of *E. Coli* in Montana: A Case for Development of Novel Biomarkers for Detection and Identification of Microbial Contaminants
Student: Margie Kinnersley, University of Montana., P.O. Box 1353, Florence, MT 59833, (406) 360-7930, mkinners@yahoo.com. With Jim Gannon, University of Montana.
Demands on public waterways as a result of urbanization and agricultural land usage have led to an increase in the number of Montana rivers and streams for which recreational contact is threatened due to the presence of elevated levels of fecal bacteria. While non-human fecal contamination is of minor concern, human contamination provides an opportunity for the spread of waterborne communicable diseases such as gastroenteritis, dysentery or cholera. Microbial Source Tracking (MST) is a relatively inexpensive and simple technique for determining the animal origin of intestinal microbes recovered from a contaminated water sample. In this study, three different DNA based rep-PCR fingerprint MST techniques were used to build and test a database of animal and human E. coli DNA fingerprints from the Many Glacier area of Glacier National Park. A novel fingerprinting technique in which restriction enzymes were used to modify rep-PCR generated patterns was the most reliable for determining the animal origin of *E. coli*. However, none of the three techniques employed were able to correctly identify human *E. coli* more than 80% of the time suggesting that more research is needed to uncover novel biological markers that can be used to unequivocally distinguish between human and non-human fecal bacteria.

7. Geology of Surficial Deposits on the Plains 30 X 60-Minute Quadrangle, Lake, Missoula, and Sanders Counties, Montana
Larry Smith, Montana Tech, 1300 W. Park Street, Butte, MT 59701, (406) 496-4379, lsmith@mtech.edu.
As part of an effort to map the geology of Montana at a scale of 1:100,000, the Montana Bureau of Mines and Geology will publish a new geologic map of the Plains 30 x 60-minute quadrangle in 2007. Preliminary work on the unconsolidated to partially consolidated surficial deposits shows that most of the valleys are covered by sediments deposited in glacial Lake Missoula; some deposits resulted from catastrophic draining of the lake. The major valleys in the quadrangle, the Mission, Jocko, Ninemile, Camas Prairie, and Little Bitterroot, contain partially consolidated sandy siltstone and gravel overlying Belt Supergroup bedrock near valley perimeters. These sedimentary rocks are typically gray to yellowish brown, contain swelling clays and volcanic clasts. A radiometric date on volcanic ash in these deposits suggests that the valleys had formed by mid-Tertiary time and had begun to accumulate fine-grained sediments. The Tertiary sedimentary rocks produce little to no ground water to wells. Glacial Lake Missoula sediments of laminated silt, clay, and minor fine sand are common in the Mission, Jocko, Clark Fork River, Ninemile, Plains, and Camas Prairie Valleys. Interbedded silty gravel and laminated silt in the Mission Valley represent high-energy subaqueous debris fan sedimentation; the coarse-grained beds in the Mission Valley are important aquifers. Gravelly alluvium underlies the glacial-lake silts in the Jocko, Clark Fork River, and Plains Valleys and along the Flathead River downstream from Dixon. This mostly clast-supported cobble-sized gravel is tens to hundreds of feet thick in canyon areas, makes up >200 ft-tall giant dunes and eddy deposits in the Clark Fork River Valley, and is an important aquifer in the Clark Fork and Flathead River canyons. These deposits were deposited during one or more catastrophic drainings of glacial Lake Missoula. These events are older than the lake in which the laminated silts were deposited. Gravel-capped terraces are inset into the glacial Lake Missoula deposits along all of the major drainages. The most extensive terraces are along the Flathead River. The incorporation of the Glacier Peak volcanic ash (dated 13,200 yr before present) into terrace deposits near the Flathead River, shows that most of the rivers downcut through the glacial lake sediments rapidly after draining of the last lake. Partially abandoned valleys are common on top of the glacial-lake deposits; they developed during the retreat of the last lake. Partially stabilized eolian dune fields occur in the Mission Valley on "The Oxbow" flat near the Flathead River and south of Lower Crow Reservoir. These dune fields likely

developed shortly after drainage of glacial Lake Missoula, during time of low vegetation cover. The current dune forms show shapes indicative of local devegetation and dominant west-to-east winds.

8. Comparison of Channel Migration Zones in Plane Bed, Pool Riffle and Anabranching Channel Segments of the Upper Yellowstone River

Chuck Dalby, Montana Department of Natural Resources and Conservation, 1424 9th Ave., Helena, MT 59620, (406) 444-6644, cdalby@mt.gov.

Fixed-bed hydraulic model (e.g. HEC-RAS) studies of flood plain inundation are typically used to assess risk of flooding; such studies provide the basis for FEMA's Flood Insurance Rate Maps (FIRM's) that are used to manage flood risk for an extended period of time. These "fixed-bed maps" may lead to planning decisions that ignore the dynamic aspect of alluvial river channels and their tendency to migrate laterally through bank erosion and avulsion--geomorphic processes that may alter the lateral extent of areas prone to flood risk, as well as directly damage or threaten civil structures over the long-term. A Channel Migration Zone (CMZ or area where the river flood plain is susceptible to erosion and lateral migration for a designated length of time--in this case, 100 years) was defined for the Upper Yellowstone River using historic channel migration data and geomorphic analysis. Using methods similar to those developed by the state of Washington, a composite 100-Year CMZ was mapped in a GIS and consists of the following zones: historic migration, avulsion hazard, and an erosion hazard area (projected future lateral erosion and mass wasting over 100-year period)--all adjusted for the disconnected migration area where manmade structures (e.g. riprap, levees, barbs, roads) physically moderate or eliminate channel migration. The resulting CMZ boundary was compared with three other boundaries: 1) the geologic floodplain (lateral extent of recent and Holocene/Pleistocene fluvio-glacial alluvium) which represents the maximum possible extent of erodible material in the valley; 2) recent alluvium that has been reworked over the past ~1,500 years; and 3) boundaries of the 100 to 500-year floodplain (based on HEC-RAS) -- map features that are nearly equivalent, due to the valley/ floodplain configuration and the relatively flat slope of the flood frequency curve. Surprisingly in many areas the 100-Year CMZ was roughly equivalent to the hydraulic 100 or 500-year floodplain. Agreement between the CMZ and hydraulic floodplain is due to the valley/floodplain architecture in different geomorphic channel types. Plane bed and pool riffle channels are single thread and laterally confined by large Holocene/Pleistocene terraces; anabranching channels have one or more main channels and a complex of side-channels that dissect the entire valley floor and widely distribute floodwater. The CMZ occupies about 54% of the geologic floodplain, and 89% of the recent (~1500 year) floodplain; approximately 43% of the CMZ consists of disconnected areas caused by bank protection and other flood plain development. The CMZ was also compared with the geomorphic channel classification (Montgomery-Buffington) and found to increase in width in direct proportion to declining channel stability (e.g. plane-bed, pool-riffle, and anabranching). Delineation of a CMZ provides supplemental information allowing flood plain managers to more completely assess susceptibility of flood plain developments to erosion and flood risks; it also provides information for evaluating long-term effects of channel and floodplain modification on geomorphic processes and channel stability.

9. How to Access and Use the New Statewide Aerial Photography and National Wetland Inventory Maps

Greg Kudray, Montana Natural Heritage Program, 1515 East Sixth Avenue, P.O. Box 201800, Helena, MT 59620, (406) 444-0915, gkudray@mt.gov.

Montana now has statewide natural color and color infrared aerial photography that was flown during the summer of 2005. The photography is easily available and high quality with a one-meter resolution. The Montana Natural Heritage Program has established a Wetland and Riparian Mapping Center to use the color infrared aerial photography to create new National Wetlands Inventory and riparian maps for Montana. The classification systems used in the mapping are USFWS national wetland and riparian standards that describe types based on vegetation, hydrology and other characteristics. These systems have additional interpretative material available at the Montana Natural Heritage Program website, www.mtnhp.org. We will discuss how to access and use the imagery, maps, and classification systems.

10. Critical Lands Project: A Collaborative Effort to Protect Lands Critical for Maintaining Clean Water, Wildlife Habitat and Quality of Life in the Flathead Lake Watershed in Northwest Montana

Constanza von der Pahlen, Critical Lands Project, PO BOX 70, Polson, MT 59864, (406) 883-1341, criticallands@flatheadlakers.org.

The Critical Lands Project is a collaborative effort of local stakeholders to protect lands critical for maintaining clean water, wildlife habitat and quality of life in the Flathead Lake Watershed in Northwest Montana. The Flathead Lakers initiated the Critical Lands Project in 1999 to address concerns that adverse land use practices associated with acute growth and development and other threats may damage lands and waters critical to maintaining the quality of Flathead Lake. Goals of the Critical Lands Project are: 1) identify and promote protection and restoration of lands and waters critical to the quality of Flathead Lake and its tributaries and associated habitat, recreation and aesthetic values, 2) gain grassroots support for protecting and restoring critical areas by informing the public about the importance of critical lands 3) build cooperation among various agencies and organizations committed to protecting critical lands. Resource professionals from tribal, state, federal, and county resource management agencies, research scientists, and conservationists have worked together to develop criteria for defining critical lands, to identify initial priority areas, and to develop strategies for critical lands protection and restoration. The project has a core group of partners that meets regularly to plan and implement projects. The North Flathead Valley above Flathead Lake is the initial focus area. It contributes the highest nutrient loads to the lake and is facing acute growth pressures. Priorities for protection include wetlands, riparian areas, flood plains and the shallow alluvial aquifer. These areas are among the most important areas for maintaining water quality in Flathead Lake and also provide productive and diverse wildlife habitat and recreation opportunities Critical Lands Project past efforts included compiling and evaluating information about ecologically significant areas in the Flathead Valley (Critical Lands Status Reports and G.I.S. maps), protecting nearly 2,000 acres of sloughs, wetlands, riparian areas, and surrounding farmland, completing two stream restoration projects, commenting on growth and development plans and policies in Flathead and Lake counties that could affect critical lands and water quality, and conducting education and outreach activities to promote protection of critical lands, including presentations, tours, workshops, and maps.

MEETING REGISTANTS AS OF OCTOBER 6, 2006

Ginette Abdo, University of Montana-Montana Tech, Butte, (406) 496-152, gabdo@mtech.edu
Evette Allison, Montana State University, (406) 528-5178, eallison@montana.edu
Laura Alvey, Montana Department of Environmental Quality, Helena, (406) 841-5062, lalvey@mt.gov
Randy Apfelbeck, Montana Department of Environmental Quality, Helena, (406) 444-2709, rapfelbeck@mt.gov
Stephen Armiger, Bureau of Land Management, Dillon, (406) 683-8017, sarmiger@blm.gov
Corey Baker, Gradient Environmental Inc., Helena, (406) 461-5593, gradient.consulting@gmail.com
Susan Ball, Confederated Salish and Kootenai Tribes, Pablo, (406) 883-2888 x7203, sueb@cskt.org
Amy Bamber, Montana Department of Agriculture, Helena, (406) 444-3676, abamber@mt.gov
Kenneth Bates, University of Montana-Montana Tech, Butte, KMBates@mtech.edu
Rebecca Bodnar, Salish Kootenai College, Pablo, (406) 275-4725, rebecca_bodnar@skc.edu
Jodie Bones, Montana State University, Bozeman
Craig Borrenpohl, Montana State University, Bozeman
Charles Brasen, State of Montana, Helena, (406) 444-6625, cbrasen@state.mt.ud
Steve Buckley, Watershed Consulting, LLC, Whitefish, (406) 862-3565, steve@watershedconsulting.com
Joel Cahoon, Montana State University, Bozeman, (406) 994-5961, joelc@ce.montana.edu
Michael Cannon, U.S. Geological Survey, Helena, mcannon@usgs.gov
Camela Carstarphen, Montana Bureau of Mines and Geology, Butte, (406) 496-4633, ccarstarphen@mtech.edu
Amy Chadwick, Watershed Consulting, LLC, Whitefish, (406) 862-3565, amy@watershedconsulting.com
Eric Chase, Montana Department of Natural Resources and Conservation, Helena, (406) 444-0578, echase@mt.gov
Katherine Chase, U.S. Geological Survey, Helena, (406) 457-5957, kchase@usgs.gov
Juliann Clum, Hydrometrics, Helena, (406) 457-0543, clum@mt.net
Autumn Coleman, Montana Department of Environmental Quality, Helena, (406) 841-5029, acoleman@mt.gov
Steve Cook, Montana State University, Bozeman, (406) 585-0906, cooksa@cu.imt.net
Tammy Crone, Gallatin Local Water Quality District, Bozeman, (406) 582-3145, tammy.crone@gallatin.mt.gov
Stephan G. Custer, Montana State University, Bozeman, (406) 994-6906, scuster@montana.edu
Chuck Dalby, Montana Department of Natural Resources and Conservation, Helena, (406) 444-6644, cdalby@mt.gov
Robert Delk, Dover Habitat Restoration, Billings, (406) 252-5500, delk@mkfirm.com
Larry Dolan, Montana Department of Natural Resources and Conservation, Helena, (406) 444-6627, ldolan@mt.gov
James Domino, Montana Department of Natural Resources and Conservation, Helena, (406) 444-6622, jdomino@mt.gov
Jeff Dunn, PBS&J, Bozeman, (406) 587-7275, jdunn@pbsj.com
Alan English, Gallatin Local Water Quality District, Bozeman, (406) 582-3148, alan.english@gallatin.mt.gov
Jenny Erickson, Maxim Technologies, Billings, (406)248-9161, jenny.erickson@tetratech.com
Kirth Erickson, Montana Department of Environmental Quality, Helena, (406) 841-5000, kierkickson@mt.gov
Sue Faber, Montana Water Center, Bozeman, (406) 994-1773, sfaber@montana.edu
Dan Fagre, U.S. Geological Survey, West Glacier, (406) 888-7922, dan_fagre@usgs.gov
Phil Farnes, Snowcap Hydrology, Bozeman, (406) 587-8393, farnes@montana.net
Courtney Frost, Helena, (406) 444-2407, CFrost@mt.gov
George Furniss, Montana Department of Environmental Quality, Helena, (406) 444-4949, gfurniss@mt.gov
Chris Gammons, University of Montana-Montana Tech, Butte, (406) 496-4763, cgammons@mtech.edu
Scott Gillilan, Gillilan Associates, Bozeman, (406) 582-0660, scott@gairesources.com
Sibyl Govan, Montana State Library, Helena, (406) 444-5356, sgovan@mt.gov
Kevin Grabinski, Montana State University, Bozeman
Taylor Greenup, Montana Department of Environmental Quality, Helena, (406) 444-3527, tgreenup@mt.gov
Mitch Guenthner, Montana State University, Bozeman
Kurt Hafferman, Montana Department of Natural Resources and Conservation, Kalispell, (406) 752-2288, khafferman@mt.gov
Phyllis Hargrave, Montana Bureau of Mines and Geology, Butte, (406) 496-4606, phargrave@mtech.edu
Rick Hauer, ric.hauer@umontana.edu
Jeri Healey, Big Sky Resource Analysts, Kalispell, (406) 755-4218, healey@montanasky.net
Philip Healey, Kalispell, phealey@montanasky.net
Sunni Heikes-Knapton, Montana State University, Ennis, (406) 570-4193, Knapton@3rivers.net
Laura Hendrix, Ravalli County, Hamilton, lhendrix@ravallicounty.mt.gov
Gregg Hester, Montana State University-Northern, Havre, (406) 265-4125, ghester@msun.edu

Susan Higgins, Montana State University, Bozeman, (406) 994-1772, shiggins@montana.edu
Tom Hinz, Montana, (406) 994-7889, thinz@mt.gov
Dan Hoffman, PBS&J, Missoula, (406) 543-1899, dfhoffman@pbsj.com
Jane Horton, Helena, (406) 443-6353, hollhort@ixi.net
John Huddleston, NOAA National Centers for Environmental Prediction, Camp Springs, (301) 763-8000, John.M.Huddleston@noaa.gov
Gary Icopini, Montana Bureau of Mines and Geology, Butte, (406) 496-4841, gicopini@mtech.edu
Jennifer Jencso, Montana State University, jfriar@montana.edu
Kelsey Jencso, Montana State University, Bozeman, (406) 599-0441, kjensco@montana.edu
Patricia Jenkins, Montana State University, Bozeman, (302) 383-1364, pjenkins.montana@gmail.com
Wayne Jepson, Montana Department of Environmental Quality, Helena, (406) 444-0529, wjepson@mt.gov
Aaron Johnson, Montana State University, Bozeman
Clain Jones, Montana State University, Bozeman, (406) 994-6076, clainj@montana.edu
Martha Kauffman, Oxbow, Inc., Bozeman, (406) 580-9343, oxbow@littleappletech.com
Eloise Kendy, Kendy Hydrologic Consulting, LLC, Helena, (406) 495-9910, ek65@cornell.edu
John Kilpatrick, U.S. Geological Survey, Helena, (406) 457-5902, jmkilpat@usgs.gov
Margie Kinnersley, University of Montana, Florence, (406) 360-7930, mkinners@yahoo.com
Cat Kirkland, Montana State University, Bozeman
Mike Koopal, Whitefish Lake Institute, Whitefish, (406) 862-4327, mike@whitefishlake, org
Greg Kudray, Montana Natural Heritage Program, Helena, (406) 444-0915, gkudray@mt.gov
Richard Labbe, Bozeman, (406) 994-3727, richard.labbe@myportal.montana.edu
John LaFave, University of Montana-Montana Tech, Butte, (406) 496-4306, jlafave@mtech.edu
John Lavey, Ravalli County, Hamilton, jlavey@ravallicounty.mt.gov
Carol Lee-Roark, Hyalite Environ. LCP, Gallatin Gateway, (406) 763-4228, roark@imt.net
Lance Lehigh, Montana State University, Bozeman
Russell Levens, Montana Department of Natural Resources and Conservation, Helena, (406) 444-6679, rlevens@mt.gov
Dennis Lichtenberg, U.S. Geological Survey, National Wetlands Research Center IAPWS, Ronan, (406) 676-2420, mountaindogd@yahoo.com
Janene Lichtenberg, Confederated Salish and Kootenai Tribes, Pablo, (406) 883-2888 x 7291, janenel@cskt.org
Heather Luinstra, Montana Department of Environmental Quality, Helena, (406) 841-5005, hluinstra@mt.gov
May Mace, Bozeman, EEoffice1@ece.montana.edu
Steve MacNeill, KirK Engineering & Natural Resources, Inc., Helena, (406) 442-9976, kirkenv1@msn.com
Ian Magruder, KirK Engineering & Natural Resources, Inc., Helena, (406) 442-9976, ian_magruder@kirkenr.com
Chris Mahony, Mountain West Reclamation, Livingston, (406) 220-3092, dirtsmoga@hotmail.com
Seth Make Peace, Confederated Salish Kootenai Tribes, Pablo, (406) 675-2700, sethm@cskt.org
Clayton Marlow, Montana State University, Bozeman, cmarlow@montana.edu
Lucy Marshall, Montana State University, Bozeman, (406) 994-4796, lmarshall@montana.edu
Jennifer McBroom, Lewis & Clark County, Helena, (406) 457-8584, jmcbroom@co.lewis-clark.mt.us
Katie McDonald, Ecosystem Research Group, Butte, (406) 782-9421, kmcdonald@ecosystemrg.com
Ryan McLane, Water Rights Solutions Inc., Helena, (406) 461-0440, rmclane@mt.net
Joe Meek, Montana Department of Environmental Quality, Helena, (406) 444-4806, jmeek@mt.gov
Kate Miller, Montana Department of Environmental Quality, Helena, (406) 444-6972, Kmiller2@mt.gov
Kathy Moore, Lewis and Clark County, Helena, (406) 457-8926, moore@co.lewis-clark.mt.us
Jonah Morsette, Montana State University, Bozeman, (406) 697-0385, jammin_j_m@hotmail.com
Robert Morton, Robert Peccia & Assoc., Helena, (406) 447-5000, bobm@rpa-hln.com
Rich Moy, Montana Department of Natural Resources and Conservation, Helena, (406) 444-6633, rmoy@mt.gov
Rick Mulder, Montana Department of Agriculture, Helena, (406) 444-5422, rmulder@mt.gov
Rich Nehl, RLK Hydro, Inc., Kalispell, (800) 406-1669, rich@rlkhydro.com
John Nerud, Cascade County, Great Falls, (406) 454-6905, jnerud@co.cascade.mt.us
Patrick Newby, Montana Department of Agriculture, Helena, (406) 444-3271, pnewby@mt.gov
Tom Osborne, Hydro-Solutions, Inc., Red Lodge, TomO@hydrosi.com
Tom Parker, Geum Environmental Consulting, Inc., Hamilton, (406) 363-2353, tparker@geumconsulting.com
Steve Parker, University of Montana-Montana Tech, Butte, (406) 496-4185, sparker@mtech.edu
Duncan Patten, Montana State University, Bozeman, (406) 582-0594, dtpatten@mcn.net
Tom Patton, Montana Bureau of Mines and Geology, Butte, (406) 496-4153, tpatton@mtech.edu
Bryce Pewonka, Timberline Resources Inc., Billings, (406) 294-9496, bpewonka@timberlineresources.biz
Beverly Plumb, University of Montana-Montana Tech, Butte, (406) 496-4182, BAPlumb@mtech.edu
Mary Louise Polzin, Interior Reforestation Co. Ltd., Cranbrook, (250) 426-5300 x 219, river_rat@msla.net

Eric Regensburger, Montana Department of Environmental Quality, Helena, (406) 444-0916, eregensburger@mt.gov
Jon Reiten, Montana Bureau of Mines and Geology, Billings, (406) 657-2630, jreiten@mtech.edu
Mike Roberts, Montana Department of Natural Resources and Conservation, Helena, (406) 444-6641, miroberts@mt.gov
Eli Robinson, Montana State University, Bozeman
Jim Robinson, Montana Department of Natural Resources and Conservation, Helena, (406) 444-4247, jrobinson@mt.gov
Gretchen Rupp, Montana State University, Bozeman, (406) 994-6690, grupp@montana.edu
Tera Ryan, Montana Salinity Control Association, Conrad, (406) 278-3071, tera6@hotmail.com
Steven Sando, U.S. Geological Survey, Helena, (406) 457-5928, sksando@usgs.gov
Lynda Saul, Montana Department of Environmental Quality, Helena, (406) 444-6652, lsaul@mt.gov
Cami Sawtelle, Watershed Consulting, Whitefish, (406) 862-3565, cami@watershedconsulting.com
Pete Schade, Montana Department of Environmental Quality, Helena, (406) 444-6771, pschade@mt.gov
Mark Schaffer, Montana State University, Bozeman, (406)580- 8008, aguamontana@yahoo.com
Tom Schemm, Montana Natural Heritage Program, Helena, (406) 444-4728, tschemm@mt.gov
Denine Schmitz, Montana State University, Bozeman, (406) 994-6499, dschmitz@montana.edu
Ted Sedell, Montana Watercourse, Bozeman, (406) 994-6317, edwin.sedell@montana.edu
Stephanie Sever, Montana State University, Bozeman, (406) 994-3272, ssever@montana.edu
Ronald Shields, Water Legend Hydrology, Helena, (406) 457-5900, rshields@crom.net
Marcile Sigler, Montana Department of Environmental Quality, Kalispell, (406) 755-8985, msigler@mt.gov
Garrett Smith, Butte, (505) 860-4375, mgsmith@mtech.edu
Larry Smith, University of Montana-Montana Tech, Butte, (406) 496-4379, lsmith@mtech.edu
T.O. Smith, Montana Fish, Wildlife and Parks, Helena, (406) 444-3889, tosmith@mt.gov
Tyler Smith, Montana State University, Bozeman
Dean Snyder, University of Montana-Montana Tech, Butte, (406) 546-6135, DMSnyder@mtech.edu
Marc Spratt, RLK Hydro, Inc., Kalispell, (406) 752-2025, marc@rlkhydro.com
David Stagliano, Montana Natural Heritage Program, Helena, (406) 444-7329, dstagliano@mt.gov
Otto R. Stein, Montana State University, Bozeman, (406) 994-6121, ottos@ce.montana.edu
Robin Steinkraus, Flathead Lakers, Polson, (406) 883-1341, criticallands2@flatheadlakers.org
Ann Storrar, Montana Dept of Environmental Quality, Helena, (406) 444-6697, nafleury@mt.gov
Brian Sugden, Plum Creek Timber Company, Columbia Falls, (406) 892-6368, Brian.Sugden@plumcreek.com
Michael Suplee, Montana Department of Environmental Quality, Helena, (406) 444-0831, msuplee@mt.gov
James Swierc, University of Montana, Missoula, (406) 240-8333, james.swierc@umontana.edu
Cheryl Taylor, U.S. Forest Service, Bozeman, (406) 587-6715, cltaylor@fs.fed.us
Todd Teegarden, Montana Department of Environmental Quality, Helena, (406) 444-5324, tteegarden@mt.gov
Erin Thais Riley, Montana State University, Bozeman, eriley@montana.edu
Joanna Thamke, U.S. Geological Survey, Helena, (406) 457-5923, jothamke@usgs.gov
Chris Thelen, Hyalite Environment, Gallatin Gateway, (406) 582-9702, cthelen@aircom.net
Kyle Thompson, Montana State University, Bozeman
Stacy Thornbrugh, Natural Resources Conservation Service/student, Ronan, (406) 676-2841, sthornbrugh@msn.com
Shelley Thurmond, Timberline Resources Inc., Billings, (406) 294-9496, sthurmond@timberlineresources.biz
Paddy Trussler, Lake County Commission, commissioners@lakemt.gov
Nick Tucci, Montana Bureau of Mines and Geology, Butte, (406) 490-5041, NTucci@mtech.edu
Ronald Tucker, Bozeman, (406) 994-3727, scrambler307@yahoo.com
Bill Uthman, Montana Department of Natural Resources and Conservation, Helena, (406) 444-6720, buthman@mt.gov
Renee Van Hoven, Ravalli County, Hamilton, rvanhoven@ravallicounty.mt.gov
Linda Vance, Montana Natural Heritage Program, Helena, (406) 444-3380, livance@mt.gov
Constanza von der Pahlen, Flathead Lakers, Polson, (406) 883-1341, criticallands@flatheadlakers.org
Willis Weight, University of Montana-Montana Tech, Butte, (406) 496-4329, wweight@mtech.edu
Gary Wiens, Department of Environmental Quality, Helena, (406) 444-7838, gwiens@mt.gov
Jim Wilbur, Lewis & Clark County, Helena, (406) 457-8927, jwilbur@co.lewis-clark.mt.us
Bill Woessner, University of Montana, Missoula, (406) 243-5698, william.woessner@umontana.edu
Debra Zarnt, Montana Watercourse, Bozeman, dzarnt@montana.edu