



PROCEEDINGS

for

Irrigation Management in Transforming Western Landscapes

American Water Resources Association Montana Section

24th Annual Meeting

October 11-12, 2007

Yogo Inn - Lewistown, Montana

Contents

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Full Meeting Agenda

About the Keynote Speakers

Concurrent Session and Poster Abstracts*

Session 1. Irrigation Management and Assessment

Session 2. Modeling and Assessment Methodologies

Session 3. Channel Response and Surface Water

Session 4. Water Quality and Groundwater

Poster Session

Meeting Attendees

***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**

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Mike Roberts, Vice President, Montana Department of Natural Resources and Conservation

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- **Montana Water Center, Meeting Coordination**

Steve Guettermann, Rick Holscher, Nancy Hystad, Gretchen Rupp

- **Pre-conference Planners**

Tom Pick, NRCS, Taylor Greenup, DEQ

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Gallatin Local Water Quality District, Montana Department of Environmental Quality-

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And especially, the many dedicated presenters, field trip leaders, moderators, student paper judges, and student volunteers



Tammy Crone



Mike Roberts



Steve Guettermann



May Mace



Tom Pick

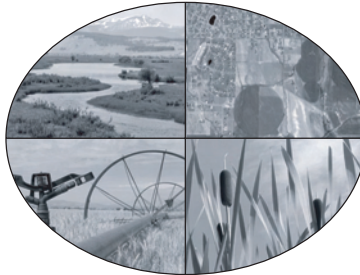


Taylor Greenup

Montana Section

2007 AWRA Pre-Conference Workshop

Understanding Irrigation Effects on Surface Water and Ground Water



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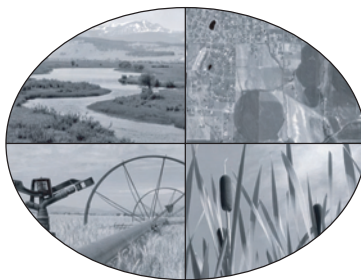
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Montana Section 2007 AWRA Conference

Irrigation Management in Transforming Western Landscapes



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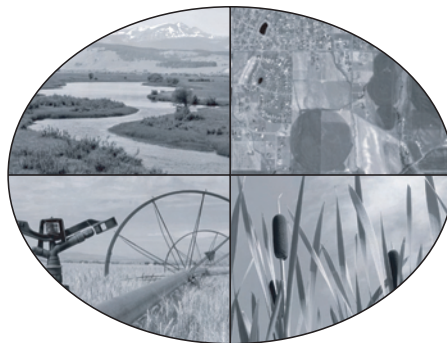


**Montana Section American Water Resources
Association, Bozeman**



**American Water Resources Association Montana Section
24th Annual Meeting
October 11-12, 2007
Yogo Inn - Lewistown, Montana**

AGENDA



Irrigation Management in Transforming Western Landscapes

WEDNESDAY, OCTOBER 10, 2007

- 8:00 am - 10:00 am REGISTRATION, Yogo Inn Lobby - Lewistown
- 9:00 am – 4:00 pm Free **Pre-Conference Workshop** (pre-registration required)
Understanding Irrigation Effects on Surface Water and Ground Water
- 4:00 pm - 6:00 pm REGISTRATION, Yogo Inn Lobby - Lewistown

THURSDAY, OCTOBER 11, 2007

- 7:00 am – 5:00 pm REGISTRATION, Yogo Inn Lobby - Lewistown

FIELD TRIP

- 7:50 am Board buses Buses leave promptly at 8:00 a.m.!
- 8:00 Geology of Lewistown area - **Dick Berg**, Geologist - Montana Bureau of Mines and Geology (MBMG) and **Lee Woodward**, Geologist
- 9:30 Big Spring Creek/Brewery Flats Restoration Project - **Mark Lere**, Montana Fish, Wildlife and Parks (MTFWP); **Steve Paulson**, Lewistown 7th Grade Life Science Teacher; **Duane Ferdinand**, Planner, City of Lewistown
- Noon Buses arrive back at Yogo Inn - **Lunch on your own**

PLENARY SESSION. IRRIGATION MANAGEMENT IN TRANSFORMING WESTERN LANDSCAPES *Sapphire Room A and B*

- 1:00 pm Welcome and Introductions, **Tammy Crone**, AWRA Montana Section President
Water Center Welcome, **Gretchen Rupp**, Director, Montana Water Center
Logistics and Announcements, **Mike Roberts**, AWRA Montana Section Vice President
- 1:15 pm Keynote Speaker, **John Tubbs**, Administrator, Water Resources Division of the Montana Department of Natural Resources and Conservation
- 2:00 pm **Dorothy Bradley**, 18th Judicial District Court Administrator
- 2:30 **Walt Sales**, President, Association of Gallatin Agricultural Irrigators
- 3:00 BREAK
- 3:30 Technical Presentations:
3:30 - **Larry Dolan**, Hydrologist, DNRC. *An Overview of Irrigation in Montana: The Fundamentals*
4:00 - **Chris Gammons**, Hydrogeologist, Montana Tech. *Water Quality & Field Methods*
4:30 - **Scott Irvin**, Regional Manager, DNRC. *Irrigation Management from a Water Policy Perspective*
- 5:00 ADJOURN
- 5:30 pm **Poster Session and Social Hour** (see poster list on last page) *Pool/Center Mark Area*

BANQUET *Sapphire Room A and B*

- 7:00 pm **Banquet**
Special Speaker: **Dick Berg**, Geologist, MBMG. *Yogo sapphires – What Makes Them Special and How Did They Form?*
Photo Contest - Mike Roberts

FRIDAY, OCTOBER 12, 2007

SESSION 1 (Concurrent). *Sapphire Room A*
IRRIGATION MANAGEMENT AND ASSESSMENT

Moderator: **Rich Moy**, Montana Department of Natural Resources and Conservation

8:00 Joel Adams, Hydrosolutions, Inc. *Terrace Aquifers in the Red Lodge Area - Changing Land Use and the Effect on Aquifer Recharge.*

8:20 **Student.** Mark Schaffer (MSU). *Temporal & Spatial Variability of Surface & Groundwater Exchange along West Gallatin River near Four Corners, Montana.*

8:40 Tom Osborne, Hydro Solutions, Inc. *Tongue River Information Program- Overview of Tongue River Hydrology and the Agronomic Monitoring & Protection Program.*

9:00 Brian Story, EIT, USFS. *Canal Seepage Reduction Using Anionic Polyacrylamide.*

9:20 Patrick Crowley, Crowley Consultants LLC. *Drip Irrigation, Growing with Limited Water Resources.*

9:40 Kyle Flynn, Hydrologist, DEQ. *Modeling Streamflow and Water Temperature in the Big Hole River: 2006.*

10:00 am **Break**

SESSION 2 (Concurrent). *Sapphire Room B*
MODELING AND ASSESSMENT METHODOLOGIES

Moderator: **Joanna Thamke**, United States Geological Survey (USGS)

8:00 Katherine Chase, Hydrologist, USGS. *A Watershed Model for the South Fork Flathead River Basin Upstream from Hungry Horse Dam, Montana.*

8:20 John LaFave, Assistant Research Hydrologist, MBMG. *An Assessment of the Impact of Ground water Development on Surface Water Flows in the Bitterroot River, SW Montana.*

8:40 Michael Nicklin, Nicklin Earth & Water. *Gallatin Valley Water Resources Evaluation- Influence of well Development on Ground Water and Stream Flows.*

9:00 John Huddleston, NOAA NWS National Centers for Environmental Prediction. *Preparation of GIS Layers for Spatial Groundwater Modeling of the Gallatin.*

9:20 **Student.** Margie Kinnersley (UofM). *Genomic & Proteomic Approach to Characterizing Natural Variation in E. coli: Toward construction of a Microbial Source Tracking Database to Identify Sources of Fecal Water Contamination in the State of Montana.*

9:40 **Student.** James Swierc (UofM). *Assessment of Geologic Controls to Infiltration through a Coarse Grained Vadose Zone, Missoula Valley, Montana.*

10:00 am **Break**

FRIDAY, OCTOBER 12, 2007 (continued)

SESSION 3 (Concurrent). *Sapphire Room A*
CHANNEL RESPONSE AND SURFACE WATER

Moderator: **Sue Higgins**, Tributary Fund

- 10:30 Clayton Marlow, MSU. *Manipulation of Vegetation Communities to Augment Subsurface Recharge to Small Streams.*
- 10:50 Denine Schmitz, Unfortunately, Denine had to cancel.
- 11:10 **Student.** Dale Engstrom (U of M). *Preferential Flow-paths Developed in Hyporheic Open-framework Gravels of Braided River Sediments.*
- 11:30 **Student.** Dan Durham (MSU). *Restoring Aspen for Improvement of Wildlife Habitat and Riparian Function.*
- 11:50 **Student.** Victoria Balfour (U of M). *Effect of Litter and Duff Consumption and Surface Sealing by Ash on Post-Fire Runoff and Erosion.*
- 12:10 **Student.** Erin Riley (MSU). *Comparison Encroaching Douglas-fir & Resident Aspen: Transpiration Rate, Soil Water Depletion, & Rooting Depth.*
- 12:30 Steven Sando, Hydrologist, USGS. *Methods for Estimating Streamflow Characteristics for Tributary Streams in the Charles M. Russell National Wildlife Refuge, Montana.*

SESSION 4 (Concurrent). *Sapphire Room B*
WATER QUALITY AND GROUND WATER

Moderator: **Kirk Waren**, Montana Bureau of Mines and Geology

- 10:30 am **Student.** Keri Petritz (MTech). *Resources Recovery from Flooded Underground Mine Workings-Butte, Montana.*
- 10:50 **Student.** Richard Labbe (MSU). *Sediment & Heavy Metals Source Determination and Reduction at a Reclaimed Abandoned Mine Site, Alta Mine, Jefferson County, Montana.*
- 11:10 David Nimick, Hydrologist, USGS. *Influence of In-Stream Diel Concentration Cycles of Dissolved Trace Metals on Acute Toxicity to Age-1 Cutthroat Trout.*
- 11:30 Banning Starr, Senior TMDL Planner, DEQ. *Reach Break Stratification & Longitudinal Field Methodologies for Assessment of TMDL Sediment & Habitat Impairments W. Montana Streams.*
- 11:50 James Madison, Geologist. *Hydrogeology of the North Hills, Helena, Montana.*
- 12:10 Tom Patton, Hydrogeologist, MBMG. *Are the Wells Going Dry? The Experiment Continues.*
- 12:30 Gary Icopini, Research Hydrogeologist, MBMG. *Screening for Pharmaceuticals and Endocrine-Disrupting Chemicals in Montana Ground Water.*

CLOSING PLENARY

Sapphire Room A and B

- 1:00 ANNOUNCEMENTS - **OFFICERS, PHOTO CONTEST AWARDS, STUDENT AWARDS**
- 2:00 ADJOURN - HAPPY TRAILS!
- 2:00 MT Ground Water Characterization Committee Meeting

Gypsum Room

AWRA 2007 POSTER PRESENTATIONS

5:30 - 7:00 pm

1. Joanna Thamke, Hydrologist, USGS, *Earth-Science Information for Montana and the Nation.*
2. **Student.** Sarah Summerford, (MSU). *Soil/Vegetation Characterization on Flood-Irrigated Land in Grand Teton National Park.*
3. Holly Sessoms, Water Quality Associate, MSU-Bozeman. *Reducing Irrigation Return Flow Contributions to Rural Drinking Water Supply and Drainage to the Yellowstone River.*
4. **Student.** Able Mashamba, (MSU). *Assessing Watershed Management Practices with a Semi-distributed Environment Model Under Uncertainty.*
5. **Student.** W. Adam Sigler, (MSU). *Evaluation of Buffer Strip Effectiveness at Mitigating Water Quality Impairment from Animal Feeding Operations.*
6. **Student.** Tyler Smith, (MSU). *Predictive Modeling of Snowmelt Dynamics and the Hydrologic Response at the Tenderfoot Creek Experimental Forest, MT.*
7. Amber Kirkpatrick, Research Associate, MSU-Bozeman. *Regional Team Partnering-Working Smarter not Harder to Address Irrigation Concerns about Drought Irrigating with Limited Water Supplies A Practical Guide to Choosing Crops Well-Suited to Limited Irrigation.*
8. Amber Kirkpatrick, Research Associate, MSU-Bozeman. *In the Ditch: Results and Impacts of Collaborative Efforts on Federal Irrigation Projects.*
9. Amber Kirkpatrick, Research Associate, MSU-Bozeman. *Assessing Constructed Wetlands for Beneficial Use of Coal Bed Methane Product Water.*
10. Michael Cannon, USGS. *Estimated Water Use in Montana in 2005.*
11. Kim Hershberger, Water Quality Associate, MSU-Extension. *Mill Coulee and Muddy Creek Water Quality Assessment.*
12. Rick Mulder, Soils/Groundwater Specialist, Montana Department of Agriculture. *Groundwater and Surface Water Monitoring for Pesticides and Nitrate in the Gallatin Valley, MT.*
13. Teresa Warne, Research Associate, MSU-Bozeman. *Montana WELL EDUCATED Program 2007.*
14. **Student.** Beverly Plumb, (MTech). *Nutrient Concentrations and Stable Isotope Chemistry in Silver Bow Creek.*

KEYNOTE SPEAKERS

John Tubbs

Administrator
DNRC - Water Resources Division
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John Tubbs is the Administrator of the Water Resources Division of the Department of Natural Resources and Conservation. He accepted the Administrator's position in November of 2006 leaving a Bureau Chief position in the Conservation and Resource Development Division. The Administrator position manages four Bureaus and eight Regional Offices. John works closely with state associations, conservation districts, counties and municipalities, state agencies, the legislature, tribal governments, federal agencies, and congressional staff to oversee Montana's water resources.

John has worked for the State of Montana for 22 years, working in both policy and financial programs. As Chief of the Resource Development Bureau, John managed grant and loan programs including the Renewable Resource Grants and Loans, Reclamation and Development Grants, Irrigation Development Grants, and Regional Water System Financing. Before managing financial assistance programs for the department, John was an economist in the Energy and Water Resources Divisions of DNRC. John received a M.A. in Economics and a B.S. in Forestry, both from the University of Montana, Missoula.

John married Stephenie Ambrose Tubbs in 1983. They have two sons, Alex 20 and Riley 17. The Tubbs family enjoys Montana's rivers and landscapes as active hikers, bikers, skiers and sportsmen.

Abstract of his presentation:

Increasingly scarce water in the face of Montana's changing landscape is a formidable and growing concern for water resource professionals and water users in the 21st century. The Montana DNRC is addressing the state's many water resource challenges through various ongoing efforts and understanding the role of irrigation will continue to be critical to effective water management in Montana. Recent appropriations to DNRC fund studies that will assess the status of irrigation infrastructure and the economic benefit of irrigation in Montana and the feasibility of new irrigation projects. Irrigation projects such as the St. Mary's Canal Rehabilitation have evolved into water resources projects that benefit the economic base of small communities through the enhancement of water supplies, fisheries, wetlands, and associated recreation values.

Whether it is through the effects of climate change on irrigation and development and/or the altering of our western valley aquifers through the conversion of historically irrigated land to large developed tracts, hydrologic landscapes are changing. From these changing landscapes arise many issues facing water managers including the protection of existing water rights in closed basins, the impact of exempt wells on water availability, and the potential for water markets and water banking. An interim legislative water policy committee has convened to address these issues and the implementation of HB831. This important legislation addresses the permitting of ground water in closed basins and addresses mitigating potential adverse effects of net depletion to surface water resulting from these actions.

KEYNOTE SPEAKERS

Dorothy Bradley

Administrator
18th Judicial District Court
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Dorothy Bradley grew up in Bozeman, Montana, received her BA from Colorado College in 1969 in Anthropology and her JD from American University in 1983. At age 22, she won a seat in the Montana House of Representatives, where she served as the only woman in 1971. She served a total of eight terms and was known for the difficult issues she championed as well as her consensus-building approach. Dorothy was the Democratic nominee for Governor in 1992. Since that time, she briefly taught at a small school next to the Northern Cheyenne Indian Reservation, was the Director of the Montana University System Water Center, and presently is the District Court Administrator.

Abstract of her presentation:

In 1962, an article was published in *Science Magazine* entitled *Human Water Needs and Water Use in America*. The first sentence read, "A permanent water shortage affecting our standard of living will occur before the year 2000." Now, 45 years later, is this forecast coming true? What challenges have we westerners inherited as a result of earlier water decisions? What are our successes and hopes? What challenges are we handing on to the next generation?

Walt Sales

Director
AGAI, the Association of Gallatin Agricultural Irrigators.
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Walt Sales is the director and a founding member of AGAI, the Association of Gallatin Agricultural Irrigators. AGAI was formed in the spring of 2004 when 37 irrigators met to discuss creating an organization that would represent the interests of irrigators on water issues. Since 2004, AGAI has been an often-heard voice on issues related to the rapid growth in Gallatin County, possible adverse effects to Gallatin River flows and senior surface water rights, and the connection between river flows and groundwater pumping.

Walt is a 4th generation Montana rancher and farmer. He and his family work about 700 acres in the Gallatin Valley, the same homestead that has been in his family for over 100 years. Walt's son and two daughters have an interest in keeping the ranch in the family for, as Walt says, "It does offer something that can't be bought."

KEYNOTE SPEAKERS

Dick Berg

Geologist

Montana Bureau of Mines and Geology

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Dick Berg earned a B.S. in geology at Beloit College in 1959 and a Ph.D. in geology at the University of Montana in 1964. After teaching geology for two years at the State University College at Plattsburgh, N.Y., he joined the Montana Bureau of Mines and Geology in 1966. While at the Montana Bureau of Mines and Geology he has published reports and articles on bentonite, common clays, building and decorative stone, talc, chlorite, barite, zeolites, vermiculite, and sapphires. During a year as a visiting geologist at the Illinois Geological Survey he published a report on tripoli in southern Illinois. In recent years he has authored or coauthored 19 geologic maps covering areas in central and western Montana as well serving as technical editor of a several publications. His current research interests are gravels in the Cut Bank – Choteau area and the alluvial sapphire deposits of southwestern Montana. Dick has carefully avoided administrative obligations in favor of field studies. Currently he is a Senior Research Geologist and Curator of the Mineral Museum.

Abstract of his presentation:

Sapphires are one of the big three (sapphires, rubies, and emeralds) colored gem stones. Montana's famous sapphires were mined in large quantities mainly from alluvial deposits in southwestern Montana. They were used for watch bearings before the development of synthetic sapphires in the 1930s. Yogo sapphires were ideally suited for this market because they are typically flat tablets as compared to the other sapphires that are more nearly equidimensional. Now the gemstone market is the sole market for Montana sapphires. Because of their pale colors, essentially all sapphires from southwestern Montana are heat treated to make them blue or orangish. However the Yogo sapphires are naturally a beautiful blue or purplish blue. Because of the desire for naturally colored gemstones, Yogo sapphires command unusually high prices.

The Yogo deposit in central Montana was discovered by Jake Hoover who was mining Yogo Creek for gold and intrigued by the pretty blue gemstones he recovered. After realizing their true value, mining along Yogo Creek quickly changed from gold to sapphires with the subsequent discovery of the "mother lode" or Yogo dike. Early mining was conducted by an English firm in an open cut along the dike and from underground workings along the dike. In recent years a number of other firms mined Yogo sapphires from the area. The most recent of these was Yogo Creek Mining. It discontinued mining in 2005 when the dike rock encountered was too hard for economic recovery of the sapphires.

At first glance it may appear that the sapphires in the igneous dike crystallized from the magma that formed the dike. However investigation of these sapphires revealed they were foreign to the dike. Some investigators surmised the sapphires were derived from corundum-bearing metamorphic rocks in the basement rocks at considerable depth that were included in the magma during its upward transport. Recent work by Andreas Cade has shown that the sapphires come from a much greater depth, in fact from the mantle. Igneous dikes in central Montana similar to the Yogo dike have not been thoroughly prospect for sapphires and could conceivably yield Yogo-like sapphires.

TECHNICAL PRESENTERS

Larry Dolan

Hydrologist
MT DNRC
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Larry Dolan is a hydrologist with the Montana Department of Natural Resources and Conservation. He has a Bachelor's Degree in Earth Sciences from Frostburg State College in Maryland; and a Master's Degree in Geography and Water Resources from the University of Wyoming. He spent the first four years of his career working at the Wyoming Water Research Center. During the past 18 years Larry has been with the Montana DNRC. Although he's had little academic training with respect to irrigation, he's had to learn about it to do his job at the water management agency for a state where irrigation is such a dominant water use. In the process, he's become quite interested in irrigation and its influences on stream hydrology. His work at DNRC has included hydrologic investigations in the Shields, Ruby, Boulder, Sun, Smith, Tongue and Milk River watersheds.

Abstract of his presentation:

An Overview Of Irrigation In Montana: The Fundamentals And Hydrologic Effects

Irrigation is by far the largest consumptive water use in Montana with over 2 million acres of land irrigated. The water supply for most irrigation is surface water and water is diverted for irrigation from almost all major Montana streams. Given the extent of irrigation and the volume of water that is diverted for it, understanding the hydrology of most of our streams requires an understanding of irrigation. This presentation will overview irrigation in Montana and discuss its hydrologic effects. It will describe how land is irrigated and how water is delivered from the streams to the fields. Ways that irrigation affects the hydrology of streams also will be discussed, including the effects of diversions, depletions, and return flows. The role of the infrastructure that supports irrigation, such as dams and reservoirs, will be described as well. Finally, there will be a discussion on how irrigation in Montana is changing and what implications these changes might have.

Chris Gammons

Professor
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Chris Gammons is a Professor in the Dept. of Geological Engineering in Butte, where he has been a faculty member since 1997. Chris [Dr. Gammons, whichever you prefer] originally hails from Massachusetts. In 1980 he got a BS in Geology at Bates College, Maine, and then a PhD in Geochemistry at Penn State in 1988. In between degrees he worked for a while as an exploration geologist for the Anaconda Minerals Company in Colorado, Nevada and Alaska. After his Ph.D. Chris had post-Docs in Australia (Monash University), Switzerland (ETH-Zurich) and Montreal (McGill University), before finally landing in Butte. Dr. Gammons' main research interests are in the application of geochemistry to the study of natural waters, both polluted and pristine. He is widely published, with over 50 journal articles on topics that run the gamut from the Berkeley Pit and the Big Hole River to acid rivers of Spain, Peru, and Argentina. Despite all this globe-trotting, Chris and his family love Montana and have no plans to leave.

TECHNICAL PRESENTERS

Abstract of his presentation:

Water Quality and Irrigation: Issues and Unanswered Questions

This presentation will address the link between irrigation and water quality in Montana. The extent to which irrigation may degrade the chemistry of nearby groundwater or surface water depends on many factors, including the water quality of the irrigation source water, the method of water application, the local geology and climate, the type of crop grown and/or livestock density, and the extent of fertilizer or herbicide application. There appears to be a trend in Montana away from flood irrigation and towards sprinkler irrigation. Unfortunately very few published data exist with which to compare the water quality of flood- vs. sprinkler-irrigated fields under otherwise identical environmental conditions. Although flood irrigation has beneficial effects, such as increasing groundwater storage which can then augment river flows during the inevitable late summer drought, this irrigation practice increases the risk of leaching of contaminants (such as nutrients, herbicides, bacteria, or pharmaceuticals) from topsoil into shallow groundwater and thence into nearby rivers and streams. In some cases, flood irrigation may also increase erosion rates and delivery of suspended sediment to downstream waters.

In 1998, our group examined changes in water chemistry at 4 cattle ranches along the Big Hole River that use traditional flood irrigation methods (Phillip, 1999)¹. The salinities of the return waters were 2 to 3 times higher than the source waters, while the ratio of major solutes stayed more or less unchanged. Although concentrations of nutrients (nitrate, ammonia, phosphate) in the return waters were low, nutrient mass loads were probably appreciable due to the large volumes of water passing through the fields. Coming up with a detailed water and solute balance for each individual ranch proved to be exceedingly difficult, due to the complex manner in which water enters and exits each field area, coupled with uncertainty as to how much irrigation water was lost to evapotranspiration. These problems are magnified by changes in weather patterns, making it difficult to extrapolate results obtained in wet years (e.g., 1997-1998) to much drier years (e.g., 1999-2007).

Overall, Montana (at least western Montana) is blessed with abundant high quality groundwater. Irrigation impacts the quality of this water in ways that are difficult to quantify in the field, let alone predict. More detailed field studies of solute and water mass balances in irrigated land are needed, and ideally such work should be carried out over several successive water years.

¹Phillip A. (1999) *A chemical survey of irrigation and return flow waters in the Big Hole River basin of southwest Montana*. M.S. thesis, Montana Tech, Butte, MT.

Scott Irvin

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Scott Irvin is the manager of DNRC's Lewistown Water Resources Regional Office. He has been employed with the department for 19 years. Scott is responsible for implementation of a variety of water-related programs, including water rights. His experience with irrigation and water policy come from assisting ranchers and farmers with the legal aspects of their water use, and participation on numerous policy development committees. He has a B.S. in Soil Science from Montana State University. Scott, his wife Sue, and their daughter Kinsey enjoy the rural setting and outdoor opportunities that come with living in central Montana. They have made Lewistown their home for the last 18 years.

TECHNICAL PRESENTERS

Abstract of his presentation:

Irrigation Management From A Water Policy Perspective

Irrigation has played a vital role in the development of the west, bringing prosperity to areas that otherwise wouldn't flourish. In Montana many communities and counties rely on irrigated agriculture for their livelihoods and to support local government services. In order to compete in an ever-changing world, some producers strive to be more efficient with their water use. Primary goals are to increase crop production and decrease labor costs. Nearly every government agency that supports agriculture offers technical assistance, research, and funding mechanisms with similar goals in mind for the individual producer. However, much of this government assistance is provided with little understanding of water law, or the cumulative hydrologic impacts of the project(s) being addressed. Irrigation began in Montana in the 1800s by flood irrigation, and it remains today a common method of application. Flood systems vary widely in their ability to produce crops, but it is not uncommon for them to be as low as 30% efficient, or less. The conversion to sprinkler irrigation has become popular since the 1960s, and the percentage of land changes from flood to sprinkler irrigation varies in degree, depending upon locale. Modern center pivot sprinkler systems can be 80%+ efficient, sometimes increasing crop production by two or more times over historic flood operations. Sprinkler irrigation often requires reduced diversions, but contrary to popular belief, conversions to modern irrigation systems can greatly increase water usage/consumption. These changes can conflict with water law and have detrimental impacts to water sources and other irrigators. As crop production increases, crop water use increases. Return flows are minimized or eliminated. Mid-late season water use may increase due to the ability of sprinkler systems to capture low flows. Stream flow patterns are changed. Existing water rights, including fishery water rights, which have historically relied on flow conditions associated with lower consumptive flood irrigation, can be adversely impacted by the very mechanism that is so widely held to "save" water. Generally, water law prohibits increased water use/consumption under existing water rights. The Prior Appropriation Doctrine, the Water Use Act, and statutory case law limit water users to historic levels of consumption and the "no adverse effect rule." All water users, juniors and seniors alike, enjoy legal protection from adverse impacts due to changes to stream flows by irrigation modifications. Trends include conversions of highly inefficient flood irrigated land to highly efficient sprinkler irrigation, addition of storage reservoirs to capture water that historically escaped the appropriator's control, and relocation to individual pump sites from multiple-user ditch systems to increase water availability. All of these trends may make sense on an individual basis, but may have dire consequences for other water users. From a practical and legal standpoint, every irrigation water right and potential conversion is unique in historic and future operation, which requires unique analysis from a regulatory perspective.

Terrace Aquifers In The Red Lodge Area : Changing Land Use And The Effect On Aquifer Recharge

Joel Adams, Hydrosolutions Inc, P.O. Box 2446, Red Lodge, MT 59068, (406) 444-2709, joela@hydrosi.com.

Near Red Lodge, Rock Creek is flanked by the East and West Benches as it flows to its confluence with the Clarks Fork of the Yellowstone River in Carbon County, Montana. The benches are Quaternary terraces composed of coarse-grained fluvial and glacial deposits. The unconsolidated sediments range from tens of feet to over 100 feet thick, and overlie consolidated sediments of the Tertiary Fort Union Formation. The base of the gravel terrace deposit generally is above the elevation of Rock Creek. For the past century, water has been diverted from Rock Creek and its tributaries onto the East and West Benches for irrigation. The ditches that convey water to points of use are unlined, leaky, and consist of coarse-grained sand, gravel and cobbles. Water levels in the aquifers appear to be controlled largely by recharge from ditch leakage and irrigation return flows. Numerous springs flow at the basal contact of the terrace deposits, form extensive wetlands in the Rock Creek valley, and provide late-season return flows to Rock Creek. Residential development occurring on the East and West Benches is resulting in a reduction of irrigated acreage. Those same residential developments depend on aquifers recharged partially by irrigation return flow and leakage from irrigation ditches. Although the major irrigation ditches remain largely intact, it is conceivable that land use changes may alter them in the future. This presentation explores long term solutions to the challenges posed by changing land use in the Red Lodge area, and identifies data needs and planning tools that will help communities to understand and balance the effects of changing land use.

Temporal And Spatial Variability Of The Surface And Groundwater Exchange Along The West Gallatin River Near Four Corners Montana

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Along the West Gallatin River Flood Plain, irrigation inefficiencies, such as leaky ditches and excessive irrigation, have created an artificially elevated water table in the fluvial aquifer. The excess water stored along the river is believed to be especially beneficial to irrigators and the riverine ecosystem after the spring high flows recede. Hydrologic data which characterize the surface and groundwater exchange along the West Gallatin River, near Four Corners Montana, were collected during the 2006 water year. This data was collected to develop a conceptual model of the exchange process and provide empirical data for the calibration of future hydrologic models. This data illustrates that the surface and groundwater exchange is dynamic, changing over space and time. Specific electrical conductance measured in the Gallatin River's channel, streambed, and the aquifer along with temperature, discharge and water level measurements indicate that groundwater discharge into the river varied throughout the study area on both the scale of meters and kilometers. In addition, irrigated areas along the river resulted in significant temporary rises in water table elevations which altered the surface and groundwater exchange on a temporal scale. The findings from this study will be discussed in terms of implementing aquifer storage and recovery management schemes which aim to maintain both the delivery of water to irrigators and a healthy riverine ecosystem as development continues to replace irrigated agricultural land.

The Tongue River Information Program-Overview Of Tongue River Hydrology And The Agronomic Monitoring & Protection Program

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Abstract submission for oral presentation at the 24th Annual Montana Section AWRA Conference. Title The Tongue River Information Program- Overview of Tongue River Hydrology and the Agronomic Monitoring & Protection Program Authors Tom Osborne, Neal Fehringer, William Schafer and Kevin Harvey Abstract The Tongue River valley of Wyoming and Montana has over 60,000 acres of irrigated land which has supported cattle ranching and farming for more than 100 years. The Tongue River also runs through the coal-rich Powder

River geologic basin which has experienced growth in coal bed natural gas (CBNG) development since 1999, along with surface coal mining since the 1970's. The Tongue River Information Project (TRIP) was sponsored by the Montana Board of Oil and Gas Conservation (MBOGC) in 2006-2007 in response to concerns by irrigators, industry and policy makers that the discharge of CBNG produced water could be affecting river water quality and, in turn, soil properties and crop production. TRIP includes the Agronomic Monitoring and Protection Program (AMPP), and a hydrologic component. All TRIP reports may be accessed on-line at: <http://www.bogc.dnrc.state.mt.us/CoalBedMeth.asp>. In 2006, approximately 3,000 CBNG wells were active in the basin, 73% of these in Wyoming. Produced water rates within the basin averaged about 3.1 gpm per well in both states, equivalent to a total of 19.4 cfs. More than three-fourths of this total was discharged to off-channel impoundments, beneficially used, treated prior to discharge or injected, with the remainder discharged untreated via authorized permits. Three of the direct discharge permits are in Montana and four are in Wyoming, with a total of 36 outfalls. They are authorized for discharge of from 1,640 to 2,630 gpm (3.6 – 5.9 cfs) of untreated CBNG water, and 4,438 gpm (9.9 cfs) of treated CBNG water. Actual CBNG discharges have ranged from 55% to 90% of permitted rates. Comparisons of Specific Conductance (SC) and Sodium Adsorption Ratio (SAR) data at comparable stream flows for periods before and after the onset of CBNG development do not indicate increasing trends at any main-stem USGS station. Some increases in SC and SAR occur above the State Line, and between Brandenburg and Miles City. CBNG discharges contribute to this in upper reach, but do not exist in the lower reach. The most significant influences on water quality are changes in surface geology and the degree of irrigation. AMPP consists of three tiers of sampling. Tier 1 soil sampling and crop monitoring is provided as a service to participating growers. Tier 2 consists of 10 fields in a systematic basin-wide soil and crop yield monitoring program repeated each fall since 2003. Tier 3 consists of test plots to evaluate irrigation with varying mixtures of CBNG produced water and Tongue River water. Crop yields in 2006 were comparable to average county yields. Variations were not correlated to differences in salinity or sodium levels. Other factors, especially crop and irrigation management, appeared to have a greater affect on yields. Plant tissue samples collected from irrigated crops and forages did not show a trend of increasing sodium levels, which indicates that CBNG activity is not affecting major ion uptake by crops. There were no statistically-significant changes in pH, EC, or SAR through time in the AMPP soils. Similar results have occurred for the non-Tongue River irrigated fields.

Canal Seepage Reduction Using Anionic Polyacrylamide

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This research investigated the effectiveness of anionic polyacrylamide (PAM) application in unlined irrigation canals in reducing water seepage. In the field test, PAM slurry was injected into a flowing canal. Flow data suggest PAM treatment produced a mean 21% increase in water loss over the test reach. Soil physical properties and low in-stream PAM concentrations likely contributed to the increase. In the laboratory, column and flume experiments tested three PAM application methods in uniform sand with and without added suspended solids. Hydraulic conductivity reduction (HCR) and treatment longevity proceeded in the order: granular turbid>granular>slurry surface>>liquid injection turbid>liquid injection. HCR was likely achieved by extensional viscosity, polymer aggregate filtration, or PAM gel formation, depending on the application method and suspended solids concentration. Within 42 hours, hydraulic conductivity returned to control-adjusted background levels in all laboratory tests except granular surface applications with added suspended solids and at high mass loading rates.

Drip Irrigation. Growing With Limited Water Resources

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Drip irrigation systems can provide landowners with the ability to grow trees, bushes, and gardens using low yield wells, while reducing evaporation losses and water waste on unneeded plants. Drip systems apply water at or near the ground surface. Care must be taken in the sizing of individual drip sectors as well as the emitters used in specific areas. Sectors are easily isolated to suit the well yield. Switching can be done either

by hand or electronically. The types of emitters selected are based on the type of plants, the water demands, the maintenance of the area, and the water quality and soil conditions. Basic system design parameters are explained. The various types of emitters and micro sprayers are illustrated along with their specific applications. 15 years of site-specific experience are shown with several examples from the Helena Valley.

Modeling Streamflow And Water Temperature In The Big Hole River: 2006

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The one-dimensional, dynamic stream water quality model Heat Source v7.0 was applied to the Big Hole River in southwestern Montana to evaluate stream temperature improvement scenarios for a 150 kilometer reach extending from Wisdom to the confluence with the Beaverhead River near Twin Bridges. This reach has been identified as a primary concern due to elevated summer temperatures and low late season flows. Specifically, irrigation improvement efficiencies and stream shade scenarios were evaluated such that the mechanistic relationship between water temperature and associated management practices could be established for the summer critical low flow period. An extensive field investigation was completed to support the modeling. This included detailed field measurement of streamflow and water temperature, quantification of irrigation return flows and withdrawals, characterization of river hydraulics, measurement stream shading, and continuous monitoring of climate. At this time, model calibration has been completed and preliminary modeling of associated scenarios is underway. It is hoped that through predictive simulation, feasible options can be identified to mitigate thermal impacts to the system. This work has been completed by the Montana Department of Environmental Quality as part of the Total Maximum Daily Load (TMDL) program.

A Watershed Model For The South Fork Flathead River Basin Upstream From Hungry Horse Dam, Montana

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The Bureau of Reclamation (BOR) plans to develop a water-resource management model for the Clark Fork of the Columbia River basin. This model could be used to 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 developing 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 is being 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 is being used to link 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 base flow. The resulting watershed model is being calibrated and tested by simulating daily streamflow and snowpack characteristics and comparing the results with observed data. The calibrated and tested watershed 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, a river-and-reservoir management model developed and used by BOR. These models will be part of the BOR's Decision Support System (DSS) for the South Fork Flathead River system. This DSS will allow the BOR to forecast hydrologic conditions in the South Fork Flathead River basin using the most up-to-date information and will enable water-resource managers to optimize reservoir operations at Hungry Horse Dam to meet downstream flow requirements.

An Assessment Of The Impact Of Ground-Water Development On Surface Water Flows In The Bitterroot River, Southwest Montana

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In the Bitterroot Valley, in southwest Montana, ground water is used almost exclusively for private domestic and municipal supplies. Rapid population growth and population density are reflected in the growth and density of domestic wells. There has been a more than 5-fold increase in the number of private domestic wells installed between 1970 and 2000; well densities exceed 300 per square mile in places, the highest in the state. Ground water is also used for irrigation, although not nearly to the extent as surface water. The increased ground-water use has prompted concern about potential impacts to flows in the Bitterroot River—a river closed to further appropriations. Historic base flows in the Bitterroot River at Darby and Missoula, above and below the main area of ground-water use, were evaluated and compared with well development and long-term precipitation records. An increase of consumptive ground-water use between Darby and Missoula should manifest itself as a decrease in base flows at Missoula. Lower base flows at Missoula should produce a decreasing trend in the base-flow difference between Darby and Missoula. Between 1940 and 2005, there was a slight decreasing trend in the difference in base flows between Darby and Missoula. However, a regression analysis of the number wells against the difference in base flows suggests no significant relationship; limiting the comparison to the period of most rapid ground-water development, 1970 to 2005, reveals an even a weaker correspondence. There was a much better correspondence between long-term annual precipitation data and the difference in base flows; about 36 percent of the variability seen in the base-flow data can be explained by the annual variation in precipitation. Comparing estimated annual consumptive ground-water withdrawals (2.2 billion gallons) in the watershed to: 1) the estimated amount of water stored in the shallow basin-fill aquifer (625 billion gallons) and, 2) the annual base-flow rate (i.e. ground-water contribution to the Bitterroot River), measured at the base of the watershed, (230 billion gallons), reveals that ground-water use represents a minor percentage of water that is stored in, and transmitted through the shallow basin-fill aquifer.

Gallatin Valley Water Resources Evaluation - Influence Of Well Development On Ground Water And Stream Flow

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Nicklin Earth & Water is conducting a watershed evaluation of the Gallatin Valley which is located at the northern end of the Gallatin watershed. The evaluation focus has been to better quantify the significance of ground-water use on ground-water levels and stream flow in the valley. Climatic, stream flow, ground-water data, and other information were evaluated accordingly. It was determined that the stream flow of the Gallatin River in the valley is dominated by each given year's mountain snow pack in the Gallatin Watershed. Snow pack in the last seven years has been far below average. This has led to a recent period of lower than average stream flows in the Gallatin River and other streams entering the valley. The most significant human-induced influence on stream flow in the valley is surface-water diversions for irrigation. Careful scrutiny of the data from the 1930s to 2000s reveals no significant long-term trend for change in stream-flow behavior associated with water-use transitions over this lengthy period of time. Ground-water levels in the Gallatin Valley have not changed significantly since the 1950s. There is no evidence of "cumulative impacts" from wells that can be discerned at a watershed scale. Any short-term changes that have occurred are correlated to temporal variations in precipitation and snow pack (e.g., drought, etc.). One very important variable affecting the outcomes described above is that the total area of irrigated acreage in Gallatin Valley has likely decreased with time, especially in areas where rural subdivisions exist. Unless there is an increase in overall evapotranspiration associated directly with increased irrigated acreage, increased consumptive use will not occur. Therefore, before drawing conclusions about the overall implications of ground-water use on stream flows, it is necessary to define how the land was used before and after ground-water development. In areas of the valley where growth has been most intense and where wells are being used for irrigation purposes that same land had been irrigated before by surface water. Based upon a review of infrared imagery in the valley, it is apparent that there is less irrigation in areas where subdivisions are present. In order to accurately quantify the relative significance of wells on the overall water budget in the valley, it is necessary to add and subtract (conduct water budget analyses) at both the project scale and valley-wide scale. Agencies have all too often only considered the extraction associated with ground-water development but have not meaningfully considered the implications of the accompanying reduction in surface water irrigation or net changes in evapotranspiration. Seasonal variations in stream-flow and ground-water levels are also being evaluated as part of this study. The above information is being incorporated into a valley-wide three-dimensional ground-water model which will be used to assess the significance of land-use transitions, water use, and drought on ground-water levels and stream flow in the valley. Utilization of constraint-based optimization methodology is being tested as a means of evaluating options which may be used to facilitate attainment of goals of various interest groups.

Preparation Of GIS Layers For Spatial Groundwater Modeling Of The Gallatin

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Geospatial groundwater flow and transport modeling on a watershed and basin basis can be performed by preparing spatial layers of precipitation recharge, soils hydraulic conductivity and depths, and geologic parameters. There is a variety of natural resource information available from state and federal agencies. This presentation will discuss the issues involved in preparing geospatial layers for groundwater modeling with ESRI, MODFLOW and ArgusONE software on the Gallatin River Basin in Montana.

A Genomic And Proteomic Approach To Characterizing Natural Variation In E. Coli: Toward Construction Of A Microbial Source Tracking Database To Identify Sources Of Fecal Water Contamination In The State Of Montana

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Microbial Source Tracking (MST) is a unique and promising approach to identifying animal sources of fecal water contamination using molecular or biochemical markers associated with an indicator species such as

Escherichia coli. Most molecular MST studies to date have utilized a “library” approach in which indicator isolate genetic fingerprints are matched to a library of fingerprints from known sources. However, these libraries often require thousands of known fingerprints to function successfully and are therefore expensive and time-consuming to generate. For these reasons, there has been a recent push to develop library-independent MST techniques in which identification of unknown isolates is based on the presence or absence of one or a few molecular markers. The overarching goal of this study was to characterize the genomic, transcriptomic and proteomic variation in naturally occurring *E. coli* populations in Western Montana and to correlate this data with animal host species information to discover biomarkers useful for identifying animal sources of fecal water contamination. Preliminary protein profiles, microarray-based comparative genome hybridizations and transcriptional profiles for human, bear and deer *E. coli* show that there are a number of molecular differences that may be useful for distinguishing human from animal isolates. The utility of these markers for broader source tracking applications is currently under investigation.

Assessment Of Geologic Controls To Infiltration Through A Coarse Grained Vadose Zone, Missoula Valley, Montana

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A storm water infiltration study has been initiated in the Missoula Valley of Western Montana to assess the impact of the use of storm water drainage sumps on water quality in a sole source, unconfined receiving aquifer. The vadose zone in the Missoula Valley is comprised of coarse grained sand, gravel and cobbles, with little clay or organic materials. This system allows for relatively rapid percolation of water through the unsaturated zone. The USEPA classifies storm sumps as Class V Injection Wells, used for disposal of wastewater, with more than 6,000 cataloged wells in the Missoula area. The initial component of the vadose zone assessment comprised reviewing data from environmental sites across the Missoula Valley. Well logs, water surface elevation and chemistry data were collected into a database to review the properties of the vadose zone in mitigating the impacts from released contaminants to the environment. The results indicate, indirectly, that the coarse grained vadose zone material does not appear to provide a significant barrier to mitigate the effects released contaminants into the vadose zone materials. The results of this preliminary effort were used to design a more comprehensive field and laboratory study of the physics of infiltrating waters from point sources through coarse grained vadose zone materials. For the study, several wells have been instrumented to assess the infiltration hydrogeology and geochemistry of percolating storm water. Sump instrumentation comprises shallow sandpoint wells with a string of thermistors, data logging water level sensors, gypsum block sensors at multiple depths, and suction lysimeters. Preliminary data from the gypsum block sensors show the expected drying of the vadose zone with time since the last significant rainfall and the onset of the summer hot and dry period. Planned activities for the late summer of 2007 include rotary sonic drilling to collect complete stratigraphic cores to assess geologic controls to percolation characteristics. In addition, wells will be constructed for geophysical borehole tomography studies of infiltration coupled with infiltration tracer tests. Data will be utilized to support development of infiltration models to understand the hydraulics of storm water infiltration from point sources through coarse-grained vadose zone materials.

Manipulation Of Vegetation Communities To Augment Subsurface Recharge To Small Streams

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Considerable attention has been given to the affects of global climate change on water availability in the middle to higher latitudes of North America, Europe and Asia. Recently a synthesis of several climate change models indicates that elevated temperatures will shift regional precipitation from snow to rain based. Minimal reservoir storage capacity and societal demands for re-establishment of anadromous fisheries migration coupled with earlier and faster runoff from mountain snowpacks will limit water availability for agriculture and urban use. Concurrently, a growing body of information indicates that woody plant encroachment into riparian areas can exacerbate water shortages caused by drought and climate change. Based on this information significant water shortages might be averted through strategic removal of conifers from watershed catchments. This theory is being tested at two Montana locations; Dry Armells Creek near Lewistown and Little Whitetail Creek near Whitehall. Thinning of existing ponderosa pine and Douglas-fir stands was accomplished as part of the Bureau of Land Management hazardous fuels reduction efforts in 2002 and 2005. Fire prescriptions were developed to remove 70% of woody understory species without destroying more than 30% of the mature forest canopy. Information on range and riparian condition, channel morphology (cross-section) and shallow groundwater elevation was collected in each treatment watershed prior to fire application. At each location two watersheds were left unburned to use as comparisons with the burned areas. Ninety percent of the woody understory was removed with prescribed fire with only a 30% loss of the mature forest canopy in the Dry Armells watershed. These levels were not reached during the Whitetail prescribed fires with only 8% of the woody understory removed by fire. Over a 4 year period at Dry Armells shallow groundwater elevation in burned drainages was higher.

Channel Response Assessment To Removal Of Mike Horse Dam

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Helena National Forest (HNF) has committed to fully restoring ecosystem function to the floodplains in the Upper Blackfoot Mining Complex. As the focus now turns to concerns over the fate of Mike Horse Dam and the ensuing restoration, it is more important than ever to fully understand the nature of the stream system. Up and downstream from Mike Horse Dam floodplain ecosystem function is the product of centuries of natural variation in hydrology followed by decades of human changes in flow regime. The goal of this project was to assess the ecological response potential of floodplains associated with Mike Horse Dam. Two questions pertained to the Upper Blackfoot. 1) How can stream ecosystem restoration be maximized? And, 2) how can risk of further contamination be minimized? We used the temporal and spatial contexts of the stream reaches to classify their potential ecological response to changes in flow regime induced by dam construction, breach, and hazard reduction. Historic aerial photographs from 1938 (pre-construction), 1961 (post-construction), 1966 (pre-breach), 1979 (post-breach), 1995 (post-breach), and 2005 (pre-reduction) were used to track channel, floodplain, and riparian vegetation cover. Topographic surveys of flood stage indicators (flood scars and deposits) and valley wide cross sections were used to model (HEC-RAS) past hydrologic events with step backwater and time varying techniques. From the historic ecological response classification we predicted responses to the proposed dam hazard reduction. To test this prediction we collected topographic, hydrologic, and biological data at the same locations before and after action on Mike Horse Dam. An evaluation of floodplain ecological response based on its spatial and temporal context within the watershed was used to distinguish dynamic reaches from stable. Armed with this information decision makers can maximize restoration potential and minimize risk from contaminated sediment.

Preferential Flow-paths Developed In Hyporheic Open-framework Gravels Of Braided River Sediments

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Preserved networks of interconnected, clast-supported, large diameter pore spaces that provide conduits for rapid water transport are found within near-horizontal beds of coarse open-framework sediments naturally deposited and modified by braided rivers. These pore networks provide highly conductive pathways that dominate water flux in fluvial bars and bar complexes and become interconnected at scales of 10's to 100's of meters. They are here hypothesized to provide rapid flow through extensive hyporheic exchange networks in the braided river-flood plain setting. However, these thin open-framework gravel beds have not been tested by other workers to determine their importance in the hyporheic flow scheme. At two field sites in the Nyack floodplain in Montana, coarse, open-framework layers have been geologically located within braided river bar sediments, duplicating what others have found in other braided river settings. To hydrologically detect these coarse-grained layers, a number of small vertical-interval techniques were used to detect ground water velocities and hydraulic conductivities developed in closely-spaced wells along a flow-line. Geophysical techniques, including GPR and electrical resistivity tomography, were used to detect braided bar architecture in comparison with the geologic and hydrologic findings, and to extend the geology of the sediments beyond the wells. The demonstrated comparison of the geologic, geophysical and hydrologic results allows the detection of the link between sedimentological conditions and hyporheic exchange mechanisms in the braided river setting.

Restoring Aspen For Improvement Of Wildlife Habitat And Riparian Function

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Across Montana, and much of the western U.S., quaking aspen (*Populus tremuloides*) stands are being replaced by conifer forest as a result of fire suppression and historic overgrazing. It is also likely that this condition is being exacerbated by recent changes in precipitation coupled with warmer temperatures. As a result, aspen acreage in Montana has declined by over 60% when current numbers are compared to historical forest inventory data. This shift in vegetation, termed conifer encroachment, appears to have important long term implications for both water users and wildlife. Various studies show that water yield will vary depending on the surface vegetation type, with aspen typically yielding more than coniferous forest. We are therefore investigating the effectiveness of prescribed fire as a tool for restoring aspen, increasing water availability and improving overall vegetative condition in the Whitetail watershed. In this drainage, north of Whitehall Montana, Douglas fir (*Pseudotsuga menziesii*) and rocky mountain juniper (*Juniperus scopulorum*) have replaced aspen in meadow complexes and riparian areas. Prescribed fires were conducted in 2005 and 2006 to reduce hazardous fuel loads, conifer density and stimulate aspen and herbaceous understory growth. We are now studying five sites across the Hay Canyon and Little Whitetail drainages to compare grass and forb recovery, total aspen sucker production, utilization of aspen suckers by cattle and big game and aspen growth rates following these burns. Of particular concern for successful aspen regeneration is the intense use of young trees for forage. Therefore, we are using a series of aspen enclosures to monitor elk and livestock utilization to quantify these impacts. Concurrently, we are monitoring the changes in depth to ground water and soil water content in the burned areas and comparing this data to adjacent control drainages to identify any possible increase in shallow groundwater and surface flow resulting from the conifer removal.

The Effect of Litter And Duff Consumption And Surface Sealing by Ash On Post-fire Runoff And Erosion

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Increases in runoff and erosion after forest fires have been attributed to: 1) the development of water repellent soils; 2) consumption of the litter and duff layers; and, 3) sealing of the soil surface by ash. While there has been considerable work on the influence of water repellent soils on post-fire runoff, less is known about the hydrologic significance of litter and duff consumption and surface sealing by ash. In an effort to better

understand the effect of these two processes on post-fire runoff we conducted three controlled pile burns in each of two forest habitat types in western Montana – a wetter site dominated by Lodgepole pine (*Pinus contorta*) with scattered Douglas fir (*Pseudotsuga menziesii*), sandy loam soils and a mean of 71% ground cover, and a drier site dominated by Ponderosa pine (*Pinus Ponderosa*) with silt loam soils and a mean vegetative cover of just 13% – and used a rainfall simulator to measure pre- and post-burn infiltration and runoff in replicated 0.5 m² plots within each burned area. We also conducted rainfall simulations on adjacent unburned plots before and after mechanical removal of the litter and duff layers. The controlled burns, which were conducted with a fuel load of 90 Mg ha⁻¹, heated the uppermost 1 cm of the soil in the plots to a mean of just 70 deg C, and there was no detectable increase in water repellency. All of the surface litter and the uppermost duff layer in the plots were consumed, leaving a < 1 cm layer of ash and char on the surface. Burning reduced the infiltration capacity of the *P. contorta* sites by 61%, from a pre-fire mean of 77 mm hr⁻¹ to a post-fire mean of 30 mm hr⁻¹. In contrast, the pre- and post-burn mean infiltration capacities on the *P. ponderosa* sites (25 mm.hr⁻¹ and 22 mm.hr⁻¹ respectively) were not significantly different. Mechanical removal of the litter and duff layers reduced the infiltration capacity in both the *P. contorta* and *P. Ponderosa* sites by a similar amount to that caused by burning. We attribute the larger reduction in infiltration on the *P. contorta* sites to the greater loss of ground cover, and clogging of the larger pores in the sandy loam soils by ash.

A Comparison Of Encroaching Douglas-fir And Resident Aspen: Transpiration Rate, Soil Water Depletion, And Rooting Depth

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This project will provide insight into a soil-plant-atmosphere interaction that may be fundamental to the understanding of landscape scale effects of global climate change coupled with grazing and disrupted fire cycles on stream flow in semi-arid regions. We hypothesize that with the encroachment of Douglas-fir into catchments historically dominated by aspen, annual transpiration is higher, soil water draw down is greater, and shallow groundwater recharge is slower causing streamflow decline (Ewers B.E. et al. 2002, Pataki D.E. 2000., Kaufmann M.R. 1985, Jaynes, R.A. 1978). However, the ecophysiological processes that drive aspen stand dewatering by conifer invasion are poorly understood. Rapid declines in groundwater may result from either higher transpiration rates by conifers or greater overall forest community transpiration as tree density increases. Three environmental variables will be monitored because of this shift in ecological condition, transpiration rates, soil water depletion, and rooting zone.

Methods For Estimating Streamflow Characteristics For Tributary Streams In The Charles M. Russell National Wildlife Refuge, Montana

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The Charles M. Russell National Wildlife Refuge (CMR) encompasses about 1.1 million acres in northeastern Montana and is managed by the U.S. Fish and Wildlife Service (FWS). The CMR primarily consists of rugged land bordering the Missouri River (generally termed the Missouri River Breaks) and provides important habitat for numerous animals and plants. To ensure that sufficient streamflow remains in the tributary streams to maintain natural conditions, FWS is negotiating water-rights issues with the Reserved Water Rights Compact Commission of Montana. These negotiations require accurate information about long-term streamflow characteristics for tributary streams crossing the CMR. However, very little long-term streamflow-gaging data exist for these smaller tributaries. Thus, the U.S. Geological Survey, in cooperation with FWS, conducted a study to provide information about long-term streamflow characteristics for the CMR. The long-term streamflow characteristics of primary interest included the monthly and annual 90-, 80-, 50-, and 20-percent exceedance streamflows and means, and the 2-year annual-peak discharge. To address the need for this information, three approaches were used: 1) continuous records of daily mean streamflow were collected for a 5-year period (2000-04) for five streams crossing the CMR; 2) long-term streamflow characteristics were

estimated for the five CMR gaging stations using a record-extension method based on relations between study-period and long-term streamflow characteristics for nearby long-term gaging stations; and 3) regional regression equations were developed to relate streamflow characteristics to basin characteristics. During the 5-year data-collection period, the CMR was characterized by unusually dry climatic conditions and generally low streamflows. Thus, typical record-extension procedures that rely on correlation between concurrent streamflow measurements at a short-term gaging station and individual nearby long-term gaging stations were unsuitable due to the generally small variability in streamflows. The regional adjustment relationship (RAR) provided an alternative to using concurrent-correlation methods. The RAR is based on the concept that the relation between a given streamflow characteristic for a short-term period in comparison to a long-term period is consistent over a somewhat broad and climatically homogeneous region. Ordinary least-squares regressions are performed that relate a streamflow characteristic for the short-term period to long-term streamflow characteristics for several long-term index gaging stations within the defined region. The RAR was used to estimate long-term streamflow characteristics for the five CMR streams gaged during the study period.

Resource Recovery From Flooded Underground Mine Workings- Butte, MT

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Extensive mining in Butte, Montana has created a system of flooded underground mine workings. The groundwater in the Butte Historic Mining District has excessive concentrations of heavy metals and metalloids due to this past mining activity and the high sulfide mineral content of the area. The US EPA determined that it is technically impracticable to remediate this bedrock aquifer. However, there is still potential for utilizing this water in a beneficial way. The Belmont Mine is one of several dozen vertical shafts that were constructed to access the underground mine workings. It is located near the Berkeley Pit Lake viewing stand. A past attempt was made at pumping water from the Belmont shaft for irrigation of a nearby park and a football field. However, after several weeks of continuous pumping, the concentrations of arsenic, manganese, iron, and zinc surpassed the proposed irrigation standards, and the system was abandoned. The idea of using Belmont Mine water for irrigation is now being re-visited by MSE Technology Applications through the Mine Waste Technology Program. The project has three facets: 1) A new pumping test of the Belmont Mine will begin in July of 2007 for a maximum duration of 45 days. The pumping rate and length of the test will be set to simulate the water needs of a full irrigation season. Major cations and anions, total recoverable metals, dissolved metals, alkalinity, iron and arsenic speciation, pH, specific conductivity, temperature, dissolved oxygen, oxidation-reduction potential, and stable isotopes of water, dissolved sulfate, and dissolved inorganic carbon will be monitored for the duration of the pumping test; 2) Bench and field scale experiments will be performed to test different low-cost technologies for treating the Belmont water to meet irrigation standards. From prior pumping data, it is expected that water treatment will need to focus on arsenic, iron, zinc, and manganese; and 3) MSE will examine the potential for using the Belmont pumping station for heating and/or air conditioning of nearby buildings. In summary, this project has the potential to turn an aquifer that was deemed technically impracticable into a valuable resource, and offers an opportunity to learn more about the flooded underground mine workings of Butte, especially with regards to chemistry, hydrology, and the interconnectivity of the mine workings in the southern portion of the district. If successful, using this water in a beneficial way will positively impact the municipal water supply, will possibly provide a heat source for nearby buildings, and reduce the stress on the Big Hole River. The presentation prepared for AWRA will report findings of the July 2007 pumping test, as well as the results and feasibility of water treatment experiments. Work for this project is being conducted under Interagency Agreement DW89-92197401-0 between the U.S. Environmental Protection Agency and the U.S. Department of Energy Environmental Management Consolidated Business Center at the Western Environmental Technology Office (DOE Contract DE-AC09-96EW96405).

Sediment and Heavy Metals Source Determination and Reduction at a Reclaimed Abandoned Mine Site, Alta Mine, Jefferson County, Montana

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The Alta Mine is an abandoned silver and lead mine in the Lake Helena Watershed. Specifically, the Alta tributary discharges into Corbin Creek, which is on the 303(d) list for water quality impairments. A remediation project was completed by the Montana Department of Environmental Quality in 1999 in an attempt to alleviate health risk posed by waste rock piles containing heavy metals and arsenic. The Alta Mine was divided into 2 sites (upper and lower) in the 1999 reclamation effort. However, only the lower Alta was reclaimed; and both sites may persist as sources of heavy metals and sediment to the stream. The problem addressed by the current research was the lack of baseline information necessary to successfully re-vegetate the reclaimed area and to determine the amount of sediment and heavy metals produced by both reclaimed and un-reclaimed portions of the Alta Mine. Lastly, the efficacy of lime and compost amendments at increasing soil productivity and supporting vegetative cover at the lower Alta was tested on 20'x 30' plots during the summer of 2007. A survey of site conditions conducted in the previous summer revealed that approximately

½ of the reclaimed site had less than 20% vegetative cover. Low vegetative success corresponded to poor soil quality. Low soil organic matter and fertility were discovered by sampling 30 soil pits. Soil pH, acid base potential (ABP), and metals and arsenic concentrations were heterogeneously distributed across the site. Concentrations of Lead (Pb) and Arsenic (As) as high as 1,800 mg/kg and 2,100 mg/kg, respectively, were uncovered in the top 24" of soil. ABP as low as -57 T CaCO₃/1K T soil were found; thus, the potential exists for acid drainage to carry metals to the Alta tributary. Water samples collected since the 1999 reclamation project revealed Zinc (Zn) loads in the Alta tributary to be as high as 40 lb/day; while, recently established Total Maximum Daily Load (TMDL) allocations for Corbin Creek (Alta's receiving waters) were set at 2.35 lb/day. Extensive sampling for Pb, As, Zn, cadmium (Cd), copper (Cu), and total suspended solids (TSS) performed during summer 2007 further quantify Alta's contribution to downstream water quality impairments. A particularly deleterious source, known as the #8 shaft, was found to perennially discharge acid mine drainage to the Alta tributary at rates as high as 30 gpm. Early observations indicate that vegetation plots treated with both lime and compost may produce vegetative cover greater than untreated areas. Treatments with greater vegetative cover are expected to erode less and contribute less sediment to the tributary. This hypothesis was tested in the summer of 2007 with the construction of upland sediment catches below each treatment type. Research at the Alta Mine revealed that land reclamation practices, such as those applied in 1999 and in summer 2007, were limited by harsh conditions and the poor soil resource on site. Further, land reclamation and re-vegetation attempts have done little to improve water quality that is impaired by acid generation in deep underground mine workings.

Influence Of In-Stream Diel Concentration Cycles Of Dissolved Trace Metals On Acute Toxicity To Age-1 Cutthroat Trout (*Oncorhynchus Clarki Lewisii*)

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Extrapolating results of laboratory bioassays to streams is difficult because conditions such as temperature and dissolved metal concentrations can change substantially on diel time scales. Field bioassays conducted for 96 hours in High Ore Creek and Dry Fork Belt Creek, two mining-affected streams, compared survival of hatchery-raised metal-naïve westslope cutthroat trout exposed to dissolved (0.1-µm filtration) metal concentrations that either exhibited the diel variation observed in streams or were controlled at a constant value. Cadmium and Zn concentrations in these streams increased each night as much as 61 percent and 125 percent, respectively, and decreased a corresponding amount the next day. In High Ore Creek, survival (33 percent) after exposure to natural diel-fluctuating Zn concentrations (214-634 µg/L; mean = 428 µg/L) was significantly ($p = 0.008$) higher than survival (14 percent) after exposure to a controlled constant Zn concentration (422 µg/L). Similarly, in Dry Fork Belt Creek, survival (75 percent) after exposure to diel-fluctuating Zn concentrations (266-522 µg/L; mean = 399 µg/L) was significantly ($p = 0.022$) higher than survival (50 percent) in the constant-concentration treatment (392 µg/L). Survival likely was greater in these diel treatments because the periods of lower metal concentrations provided some relief for the fish and because toxicity during periods of higher metal concentrations was lessened by the simultaneous occurrence each night of lower water temperatures, which reduce the rate of metal uptake. Based on this study, current water-quality criteria appear to be protective for streams with diel concentration cycles of Zn (and perhaps Cd) for the hydrologic conditions tested.

Reach Break Stratification And Longitudinal Field Methodologies For The Assessment Of TMDL Sediment And Habitat Impairments In Western Montana Streams: Lolo Creek And Miller Creek Watershed Pilot Study And The Bitterroot Mainstem TMDL Planning Area

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A water body stratification approach and associated field methodologies tailored to address sediment and habitat impairments to aquatic life and fisheries beneficial uses has been developed by the Montana Department of Environmental Quality (MT DEQ) for use in the TMDL process. The main goal of this approach is to improve the overall understanding of the impairment status of 303(d) sediment and/or habitat listed water bodies using a consistent approach for selecting sample locations and a consistent set of

sampling procedures at the selected locations. This allows for a higher level of certainty for sediment TMDL development, or for demonstrating that sediment or habitat impairment conditions do not exist. With this foundational goal in mind, the primary sample design objective of this approach is to better characterize water body segments within the context of their individual landscape settings by describing the constituent stream reaches in terms of reach-scale reference conditions. A second objective is to establish a general framework for the achievement of data quality objectives (representativeness, comparability, and completeness) within sampling designs during TMDL related sediment and habitat investigations in western Montana. The approach stratifies individual water body segments into discrete assessment reaches that are delineated by distinct variability in landscape controls such as ecoregion, Strahler stream order, valley slope, and valley confinement. These characteristics were chosen because they are generally beyond anthropogenic control, and because they serve as a logical context for analyzing sediment and habitat data from stream reaches that display different morphology. Additionally, inherent differences in landscape controls between stream reaches often prevents a direct comparison from being made between the geomorphic attributes of one stream reach to another. By initially stratifying water body segments into stream reaches having similar geomorphic landscape controls, it is feasible to make comparisons between similar reaches in regards to observed versus expected channel morphology. Likewise, when land use is used as an additional stratification (e.g. grazed vs. non-grazed sub-reaches), sediment and habitat parameters in sub-reaches with localized land uses can be compared to reaches that meet the same geomorphic stratification criteria but are lacking localized land uses to provide an additional evaluation of localized versus watershed scale impacts. Within the Bitterroot Mainstem TMDL Planning Area Lolo Creek and Miller Creek, located just south of Missoula Montana, were chosen as a pilot study watersheds for the implementation of the reach break stratification approach. The objectives of the study were (1) implement the reach break stratification approach within the Lolo and Miller Creeks watersheds; (2) identify and sample applicable reaches; (3) compare data to reference or expected conditions (4) update and/or refine impairment determination and (5) provide additional analysis of the stratification approach and field methodologies prior to larger scale efforts in the Bitterroot Watershed and elsewhere in Montana.

Hydrogeology Of The North Hills, Helena, Montana

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The North Hills area is about 8 miles north of Helena, Montana. The study area is 52 square miles and contains more than 1,600 residences. A Controlled Groundwater Area was established in 2002 to address why wells in the area have gone dry or the water in the well has dropped to a level that cannot be pumped. Average annual precipitation at the Helena WSO weather station, about 8 miles to the south of the study area, is 11.90 inches. A nearby weather station located about 2 miles south of the North Hills and three project stations, indicate that average annual precipitation falling on the North Hills may be up to 25 percent less than at the Helena WSO weather station. Silver Creek flows through the southwest corner of the study area and most times loses all of its stream flow by infiltration into the valley-fill sediments. The North Hills area is comprised of mostly flat, gentle southerly sloping pediment surfaces and alluvial plain surrounded on the west, north and east by slightly rugged mountainous terrain composed mostly of lower middle Proterozoic rocks of the Belt Supergroup. Tertiary sediments outcrop in the southeast part of the North Hills and consist of interbedded clay and silt with lenses of sand and gravel. The Tertiary sediments underlie and are concealed in most places by pediment surfaces and alluvial plain. Quaternary alluvium covers most of the study area where bedrock is not exposed. Three aquifers were delineated within the North Hills. Groundwater flow in the North Hills' aquifers is generally from the north to the south, and all three aquifers appear to function as single hydrostratigraphic unit. Recharge to the North Hills aquifers is through infiltration of Silver Creek streamflow, irrigation water, and precipitation. Ground water discharges from the North Hills' aquifers to drains, wells, and as underflow through the south boundary of the study area. Discharge of water through wells is 550 acre feet/year, which is about 4 percent of the total amount discharged from the aquifer. In 2000, the streamflow in Silver Creek was about 10% of normal. The aquifer in the southwest part of the study area received less recharge because of this, and water level in wells fell during the summer of 2001. Since then streamflow has increased and the

water levels in the wells have returned to normal. In other parts of the North Hills where the ground-water system is recharged only by rain and snow melt, water levels in some wells have declined. Although the decline in some wells is near the most developed part of the North Hills, the decline has also been measured in wells where development is minimal. The decline, therefore, is probably related more to climatic anomalies and to a lesser extent over drafting by well withdrawals.

Are The Wells Going Dry? The Experiment Continues

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Water-level hydrographs often include multiple signals of varying magnitudes and frequencies that represent stresses on aquifers near monitored wells. For example, a monitoring well near pumping may produce a hydrograph that has a daily pumping cycle overprinted on an annual cycle that is related to precipitation and/or snow melt. The combined daily and annual signals may themselves be part of a multi-year signal related to climate or development. The multi-year signals often may be the highest amplitude signal in the hydrograph. When water levels in statewide monitoring network wells are compared to precipitation departures, it appears that multi-year signals in hydrographs generally move downward or upward as 30-month departures from average precipitation become more or less negative. Correspondingly, whether or not water levels in a monitored well are above or below their quarterly average largely depends on the upward or downward movement of any multi-year signal. The statewide 30-month departure from average precipitation became negative in 2000 and increasingly negative until early 2002 when it was about two standard deviations below average. After 2002, 30-month precipitation departures became less negative but remained about 1 standard deviation below average until 2005. In 2006 precipitation accumulations were near their 30-month averages. Between 2000 and 2002 the percentage of wells below their quarterly averages increased from about 50 to more than 80 percent. Since 2002 the percentage of wells with below-average water levels has slowly decreased to about 70 percent. Most of the period of comparison so far has been during a drought. If precipitation amounts continue to improve and the 30-month departure from average should become positive or strongly positive, it will be interesting to see if observed relationships between precipitation and water levels in network wells continue.

Screening For Pharmaceuticals And Endocrine-Disrupting Chemicals In Montana Ground Water

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Pharmaceuticals and other endocrine-disrupting chemicals have recently been reported in a number of streams throughout the U.S.A. The source for these chemicals to the environment is usually human or animal sewage waste. These biologically active chemicals are generally present at very low concentrations (generally ppt to ppb). Even at these low concentrations, they have been shown to have adverse impacts on aquatic life (e.g. feminization of fish). Wastewater treatment plants operated by urban municipalities can be effective at removing many of these chemicals. However, biologically active chemicals coming from minimally treated or untreated waste sources, such as septic tanks (Godfrey and Woessner, 2004) and confined-animal feeding operations, are less likely to be degraded or removed from the waste stream prior to being released into the environment. Since these contaminants are derived from human and/or animal waste, near-surface aquifers, as well as streams, may be at risk. A recent assessment of ground water in the Helena Valley, Montana revealed that human and/or animal-waste pharmaceuticals were present in approximately 80 percent of the wells sampled (Miller and Meek, 2006). The majority of the chemicals in the analyte list were human pharmaceuticals and most of the occurrences were attributable to human waste emanating from septic systems. However, there were also a number of occurrences that appear to be attributable to agricultural activities. These results demonstrate that pharmaceutical and endocrine-disrupting contaminants are likely present in Montana's near-surface aquifers. This initial state-wide survey of near-surface aquifers in Montana for the presence of the pharmaceutical and endocrine disrupting chemicals in has the primary goal of assessing aquifer contamination from agricultural practices, and in particular livestock operations. A secondary goal of this survey is to assess aquifer contamination from human sources in predominately agricultural areas. The selection of wells for

this survey reflected these goals. Approximately 50 to 60 percent of the selected wells are from agricultural areas that have a potential to be impacted by livestock waste. Approximately 30 to 40 percent of the selected wells are from areas in or near unsewered subdivisions in former agricultural areas. Approximately 10 to 20 percent of the selected wells are from agricultural areas that are unlikely to be impacted by livestock waste. Results from this project will indicate whether agricultural practices in Montana are contaminating near-surface aquifers with pharmaceutical or endocrine-disrupting chemicals and also provide an indication of the extent to which suburban septic systems may be contaminating aquifers traditionally used for agriculture.

References Godfrey, E., and Woessner, W.W., 2004, Screening level study of pharmaceuticals in septic tank effluent and a wastewater treatment plant waste stream. Proceedings of the 4th International Conference on Pharmaceuticals and Endocrine Disrupting Chemicals in Water, held October 13-15, 2004, in Minneapolis, Minnesota, National Ground Water Association, pp. 296-308. Miller, K.J. and Meek, J., 2006, Helena Valley ground water: Pharmaceuticals, personal care products, endocrine disruptors (PPCPs), and microbial indicators of fecal contamination, Montana Bureau of Mines and Geology: Open File Report 532, 20 p.

1. Earth-science Information For Montana And The Nation

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The U.S. Geological Survey (USGS) places high value on the dissemination of reliable and relevant earth-science and natural-resource information. The USGS annually publishes hundreds of scientific reports that cover a wide variety of topics to meet a variety of needs. More than 70,000 USGS reports are available electronically at the USGS Publications Warehouse (<http://infotrek.er.usgs.gov/pubs/>). Reports in the USGS Circular series provide syntheses of understanding about various earth processes, geographic areas, national issues, and USGS programs. These reports are aimed at enhancing knowledge and understanding among the general public, policy makers, resource managers, university students, and scientists in related fields. During the past decade, USGS Circulars have covered topics such as: nutrients and pesticides in water, volatile organic compounds in ground water, managing and sustainability of ground-water resources, ground water and surface water as a single resource, estimated water use, water quality of streams and aquifers, water availability for the western United States, urban growth in American cities, disease emergence from wildlife, geothermal energy, floods, mining reclamation, coal, uranium, and asbestos. USGS Circulars offer an opportunity to apply a national perspective to issues and processes that apply to and affect Montana's natural resources.

2. Soil/Vegetation Characterization On Flood-Irrigated Land In Grand Teton National Park

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Flood irrigation contributes to the creation of wetlands especially in areas that have existing wetlands from springs or a high water table. The Grand Teton National Park (GTNP) has been flood irrigating the Elk Ranch for nearly 100 years, which has created areas that are now classified as wetlands. GTNP has recently considered closing the irrigation on the Elk Ranch, which has prompted Park Service ecologists to seek information on irrigation-created wetland extent on the Elk Ranch and how cessation of irrigation will change the hydrologic and vegetative characteristic of the historically irrigated hay-meadows. The research objectives will be to characterize plant communities, soils, and shallow groundwater in flood-irrigated hay-meadows in the Elk Ranch, test for relationships between vegetation communities, soils, and groundwater, and determine if those relationships can be used to differentiate between natural and irrigation created wetlands.

3. Reducing Irrigation Return Flow Contributions To Rural Drinking Water Supply And Drainage To The Yellowstone River

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Buffalo Rapids Irrigation District has been identified by the NRCS as a unique, identifiable watershed. The agriculture of the watershed is dependent on irrigation water derived from the Yellowstone River and the domestic water supply is dependent on shallow, alluvial groundwater which is recharged from irrigation-related sources. In 1998, an environmental assessment of the district-based watershed identified sediment, nutrient, and bacterial impaired water quality in the Yellowstone River and surface and groundwater in the watershed, less than optimum irrigation management, and excessive irrigation induced erosion to the irrigated cropland as problems in the watershed. Since the EA, significant efforts and funds have been devoted to implementation of Best Engineering Practices (BEPs) and Best Management Practices (BMPs) in the district. These efforts on the part of the NRCS, Buffalo Rapids Irrigation District, and landowners, have created an opportunity for research and quantification of water quality and water conservation improvements resulting from BMP implementation. In 2006, MSU was awarded an USDA Integrated Research, Extension, Education grant to work with Buffalo Rapids District. MSU Extension Water Quality Program (MSUEWQ) and MSU Watershed Analysis Laboratory have partnered to quantify water quantity and quality responses to BMP implementation in the district, and to develop a watershed scale predictive model. Quantifiable documentation of BEP and BMP implementation at the watershed scale and calibration of the SWAT model will enable science based decision making regarding

future BMP implementation, both within Buffalo Rapids Irrigation District and throughout the western U.S. To further community awareness of water quality issues, MSUEWQ will partner with Montana Water Course to implement a volunteer monitoring program with area high schools. Additionally, study results will be delivered to irrigators within the district and to the public through extension workshops, demonstration sites, and formal education opportunities. The ultimate goal of the project is to advance practices which lead to improved water quality and water conservation in the Yellowstone River.

4. Assessing Watershed Management Practices With A Semi-distributed Environment Model Under Uncertainty

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The Buffalo Rapids watershed is an agricultural tributary to the Yellowstone River in eastern Montana. The watershed includes 155 full-time agricultural crop and/or livestock producers with an average of 164 acres per full time farm. Issues of assessment of drinking water and human health, pollution assessment and prevention, watershed management, and agricultural water management and conservation are integral to the future agricultural sustainability and economics of the watershed. Potential causes of water-resource degradation in the watershed include; i) Irrigation-related nutrient, sediment, and salinity loading; ii) Agriculturally-related nitrate-nitrogen loading to shallow alluvial groundwater, a primary domestic water supply in the watershed; and iii) Inefficient use of water pumped from the Yellowstone River, thereby critically reducing in-stream flows during low-flow periods of the year. Preliminary multi-disciplinary research is currently underway to study the effects of implementing improved watershed management and engineering practices aimed at reducing or eliminating water degradation. The proposed research approach will involve using a well researched complex hydrologic model (the Soil and Water Assessment Tool, SWAT) to model, simulate and statistically analyze the effects of implementing proposed management improvement scenarios on water quality, quantity and use. Results and insights obtained from the research are expected to inform the interests of farmers, local and federal authorities, financiers, researchers and other stakeholders. The main objectives of the modeling and simulation research focus will be; i. To develop an uncertainty framework for the proposed model, using existing data for the Buffalo Rapids watershed. ii. To assess and quantify the data for constraining the predictive uncertainty associated with the model enabling future prioritization of data collection. iii. To assess the potential of the model for assessing management practices on watershed health and developing scenarios for future BEP and BMP implementation. The proposed approach provides several logistical and technical challenges in data management, uncertainty algorithm implementation and watershed assessment. Preliminary modeling results and proposed future directions will be presented and discussed.

5. Evaluation Of Buffer Strip Effectiveness At Mitigating Water Quality Impairment From Animal Feeding Operations

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Animal feeding operations (AFOs) have often traditionally been situated on surface water for ease of livestock watering. Water quality impacts from these operations and the mitigation benefits from relocating these operations have been well documented. However, moving fencing and infrastructure can be expensive and disruptive to livestock management. For this reason, it is important to understand which best management practices (BMPs) and which elements of those BMPs are most important for mitigating water quality impacts. The current study is evaluating the effectiveness of BMP implementation on 4 AFOs in Montana at mitigating E. coli, total suspended solids, and nutrient impacts on surface water. Preliminary observations indicate buffer strips have effectively reduced contamination to surface water originating from AFO runoff. In addition, preliminary results indicate notable decreases in E. coli loading to surface water adjacent to AFOs during baseflow conditions in the absence of runoff.

6. Predictive Modeling Of Snowmelt Dynamics And The Hydrologic Response At The Tenderfoot Creek Experimental Forest, Montana

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In Montana and much of the Rocky Mountain West, the single most important parameter in forecasting the controls on regional water resources is snowpack [Williams et al., 1999]. In the mountainous areas of Montana, in particular, the runoff of snowmelt is the key driving force in downstream supplies of water; water is deposited at much higher volumes in the form of snow in these mountainous areas, which results in greater accumulation and storage and diminished evaporation [Hauer et al., 2007]. The Tenderfoot Creek Experimental Forest (TCEF), located at the headwaters of Tenderfoot Creek in the Little Belt Mountains of the Lewis and Clark National Forest in Meagher County, Montana, is approximately 71 miles southeast of Great Falls, Montana. TCEF, the only United States Department of Agriculture (USDA) experimental forest formally dedicated to research on subalpine forests on the east slope of the northern Rocky Mountains, was established in 1961 and is representative of the vast expanses of lodgepole pine (*Pinus contorta*) found east of the continental divide, encompassing an area of 9,125 acres. The TCEF consists of seven distinct watersheds, with different vegetation and topographic characteristics. Primary data will be assembled from the two Natural Resources Conservation Service's (NRCS) SNOTEL (SNOWpack TELemetry) sites located within TCEF and the ten United States Geologic Survey's (USGS) stream gauges located within TCEF. Auxiliary data will be used from existing field observations performed within in TCEF's watersheds, including stream tracer tests, groundwater levels, etc. In an effort to bridge the gap between theoretical understanding and functional modeling of snow-driven watersheds, a flexible hydrologic modeling framework is being developed; this framework will operate as a tool to investigate the link between hydrologic model predictive performance, model complexity, and observable hydrologic processes. Fundamentally ingrained in this toolkit is its usability across a variety of watersheds, making use of readily available data (NRCS & USGS) which offers water managers the ability to enact near real-time, small-scale forecasts. Such forecasts are directly relevant to local watersheds and provide light to the shadows intrinsic to regional forecasts. In developing the modeling framework, a suite of conceptual model structures are being analyzed and compared; the correlation in predictive modeling between model complexity and predictive uncertainty are well established, with complex models often being more uncertain. By varying the complexity of the structure from simple to complex, comparisons can be made to suggest the appropriate tradeoff between uncertainty and intricacy. The definition of this balance is crucial to developing and implementing a useful predictive modeling toolkit. Model calibration will be performed in two popular (and competing) uncertainty frameworks, namely, Bayesian inference (BI) and Generalized Likelihood Uncertainty Estimation (GLUE). Although there has been much debate over the best framework to use, there has been no widely-held consensus suggesting one method over the other. The two most employed methods are based on the same statistical principles, though the different assumptions made in their implementation culminate in two diverse techniques. Both methods will be implemented and compared for each of the model structures developed.

7. Regional Team Partnering – Working Smarter Not Harder To Address Irrigation Concerns About Drought Irrigating With Limited Water Supplies A Practical Guide To Choosing Crops Well Suited To Limited Irrigation

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Irrigation management involves commitment of substantial time, capital, labor, equipment, and water. Lack of any of these resources can mean the difference between profit and loss. In the past decade, drought throughout much of Montana and the Northern Plains and Mountains region has caused water supplies to become increasingly inadequate to satisfy crop moisture needs during the entire irrigation season. Thus, the purpose of this project is to provide irrigators with a user friendly publication containing practical, low cost strategies to help achieve highest possible economic returns with limited water. Such strategies include fine tuning irrigation scheduling to optimize water use efficiency, capturing and storing precipitation, and growing crops well suited to limited irrigation. While the first two strategies are important in stretching water supplies, primary emphasis

of this publication is placed on analyzing commonly irrigated determinate, indeterminate, and forage crops in terms of water use characteristics and effective management to maximize their production. Determinate crops, including wheat and sunflower, have fixed growth periods and are relatively insensitive to moisture stress during early vegetative stages and highly sensitive during seed formation. Indeterminate crops, such as potatoes and sugarbeets, have season-long, cumulative yield production and, therefore, can endure 4-5 day periods of moisture stress throughout the growing season. Because of their long growing season, determinate crops require more water than indeterminate crops. Perennial forage crops generally have deep, well-established root systems. Thus, they capitalize on early season moisture and withstand moisture stress better than determinate and indeterminate crops. Considering these water use characteristics, irrigators faced with limited water supplies are encouraged to substitute low water requirement crops for high requirement crops, choose crop varieties short in stature, and split fields between low and high water requirement crops or early and late season crops. While drought poses many challenges to irrigators, these strategies can help ease the burden of limited water supplies.

8. In The Ditch: Results And Impacts Of Collaborative Efforts On Federal Irrigation Projects

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Research and education at the university level produces valuable data, statistics, facts and figures but sometimes that information doesn't get to the people who could benefit from it most. Multi-agency partnering can lead to positive extension outcomes and help bridge the gap between "scientists" and "non-scientists". Montana State University Extension Water Quality Program (MSUEWQ) and the Bureau of Reclamation – Great Plains Office (Reclamation) have joined forces and are working with four federal irrigation districts to positively influence behavior and promote changes in project wide irrigation practices. Over the years, cooperative work between MSUEWQ, Reclamation, irrigation districts and water user groups has resulted in changes in management practices leading to water conservation, improved water quality and enhanced agriculture. In these partnerships, MSUEWQ plays the role of technical service provider – conducting research, collecting data, and providing technical information for several on-going debates/discussions related to the management of water resources. Data compiled by MSUEWQ is used to identify the best course of action, prioritize the actions and find resources to get the project off the ground. Often, the perception of issues changes and pre-conceived notions are altered when technical information is provided. Ultimately, data generated by MSUEWQ is used by Reclamation and irrigation districts to craft community-based solutions to issues and concerns.

9. Assessing Constructed Wetlands For Beneficial Use Of Coal Bed Methane Product Water

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Changes in agricultural practices, and irrigation strategies combined with natural processes, have led to increased salinization of soil and water resources worldwide. Coal bed methane (CBM) development in the Powder River Basin of Montana and Wyoming results in the co-production of large volumes of sodic and moderately saline discharge water, and represents a potential source of salinization of soil and water resources. Study objective was evaluation of constructed wetlands as a tool for CBM product water management. This was accomplished by assessing seasonal water use, biomass production and water use efficiencies (WUE) of three plant communities. Native species establish hydrologically distinct communities in former ephemeral channels now running with CBM product water, and nine species of those cataloged were selected and segregated into three communities. Closed-system wetland cells were constructed and each community was assigned to four of these cells, i.e., lysimeters. Chemistry of the supply water was sodic and moderately saline, typical of northern portions of the Powder River Basin where low to moderate electrical conductivities and high sodium adsorption ratios are common. Plant community dynamics have been the most interesting aspect of this study. Establishment was very good for seven of the nine species, but over the course of the study we have seen a marked change in community composition. American bulrush and Common cattail had very sparse growth in year one but have not come back at all in subsequent years. Although Inland saltgrass was conspicuously absent during the first three years of the study, in year four it has exhibited surprisingly vigorous

growth – perhaps salinity levels have become sufficiently elevated. Canada Wildrye, Streambank wheatgrass and Creeping spikerush had robust growth in the first two years but growth was hampered in year three and no growth has been observed in year four. Again, this may be a function of elevated salinity and/or sodicity. Prairie cordgrass established quickly and has exhibited vigorous growth each year of the study. Maritime bulrush had a hard time getting established but by year three was doing quite well and is one of the only plants to come back in year four. Results indicate that constructed wetlands planted with native, salt tolerant species have potential to utilize substantial volumes of CBM product water while remaining robust and viable. However, care must be taken in species selection as some are good colonizers, some make better long-term residents and others will remain dormant until salinity and/or sodicity levels become elevated. Observed increases in soil SAR could be the result of preferential plant uptake of Ca and Mg ions and/or little to no water infiltrating into the soil profile, while increases in soil EC could be due to evapoconcentration of salts (especially sodium) on soil surface. i.e. more water evaporating than infiltrating through. Evapoconcentration of salts could lead to adverse soil salinity and sodicity conditions with respect to long-term impoundment, viability and reclamation with high clay content soils being more susceptible than non-clay soils to degradation of physical properties when seasonally irrigated with saline-sodic water.

10. Estimated Water Use In Montana In 2005

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The U.S. Geological Survey has compiled estimates of water use in the United States at 5-year intervals since 1950. Estimated use of water in Montana for 2005 was compiled for seven categories of use—irrigation, public supply, self-supplied domestic, livestock, thermoelectric power, self-supplied industrial, and aquaculture. In 2005, the citizens of Montana withdrew about 10,060 million gallons of water per day (Mgal/d) from Montana's streams and aquifers for these seven categories of use. Withdrawals from surface water totaled about 9,780 Mgal/d (about 97 percent of total) and withdrawals from ground water totaled about 279 Mgal/d (about 3 percent of total). In 2005, about 2.3 million acres in Montana were irrigated. Irrigation accounted for about 9,670 Mgal/d or about 96 percent of total withdrawals for all uses. Surface water was the source of about 98 percent of irrigation withdrawals and ground water provided slightly less than 2 percent. The 2005 average rate of withdrawal for irrigation was 4.7 acre-feet per acre. Not all water withdrawn for irrigation was consumed by plants; much of the water withdrawn eventually discharged back to streams as irrigation return flow. Withdrawals for public supply in 2005 were about 142 Mgal/d, self-supplied domestic withdrawals were about 23 Mgal/d, withdrawals for livestock were about 39 Mgal/d, withdrawals for thermoelectric power generation were about 90 Mgal/d, self-supplied industrial withdrawals were about 67 Mgal/d, and withdrawals for aquaculture were about 29 Mgal/d. Ground water was the primary source for self-supplied domestic and self-supplied industrial water uses.

11. Mill Coulee And Muddy Creek Water Quality Assessment

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Evaluation of effectiveness of natural resource conservation practices, which involve voluntary implementation of Best Management Practices (BMPs), has gained substantial attention in the last several years. An assessment was completed to determine whether natural resource management programs and BMPs implemented to enhance water quality and quantity within the Mill Coulee and Muddy Creek watersheds, located in north-central Montana, achieved their desired goals. Water quality parameters assessed included: specific conductance (electrical conductivity), nitrate + nitrite - N, phosphorus, suspended sediment concentration, pH, and selenium. Available water quality and quantity data was gathered and grouped into pre-EQIP and post-EQIP implementation periods. The grouped data sets were then compared statistically to determine significance of differences between the pre- and post-EQIP data sets. Efforts were undertaken to correlate significant differences between pre- and post-EQIP data to EQIP-related BMP implementation within each watershed. While lack of sufficient pre-EQIP water quantity and quality data precluded any valid statistical analysis for Mill Coulee, analyses conducted for Muddy Creek showed that there have been significant changes, deemed to be improvements, in water quality in Muddy Creek between the period prior to EQIP initiation and since EQIP initiation within the watershed. While it is difficult to say that a particular EQIP-sponsored or related practice

implemented resulted in a specific change in any particular water quality parameter, decreases in water quantity between pre-EQIP and post-EQIP periods were not evident. Thus it would be valid to conclude that the improvements which are reflected as reductions in specific conductance, trends towards reductions in nitrate + nitrite – N concentrations, reductions in suspended sediment, and trends towards reductions in selenium concentration from the pre-EQIP to the post-EQIP period of study are a result of the practices implemented as a whole.

12. Groundwater And Surface Water Monitoring For Pesticides And Nitrate In The Gallatin Valley, Montana

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During the summer of 2006, the Montana Department of Agriculture (MDA) conducted a monitoring project in the Gallatin Valley to determine potential impacts to groundwater and surface water from the use of pesticides. The MDA collected 51 groundwater samples from 26 wells and six surface water samples from three streams and analyzed them for 102 pesticide compounds as well as nitrate and nitrite. Sampling sites were located in areas with different land uses including agricultural, urban, residential, and suburban areas. Pesticides were detected in 29 of the 51 groundwater samples. There were a total of 80 detections of 12 different pesticide compounds and three pesticide degradates in the 29 samples with detections. All of the pesticide concentrations were low and none exceeded or approached human health drinking water standards, where such standards exist. Of the 80 detections, 48 were below the analytical method reporting limits and were not quantified. Nitrate was detected in 39 of the 51 groundwater samples. None of the nitrate concentrations exceeded the human health drinking water standard. The most commonly detected pesticide in groundwater was atrazine and one of its degradates, deethyl atrazine, which accounted for 27 of the 80 detections. The next most commonly detected pesticide was imazamethabenz methyl ester and one of its degradates which accounted for 19 of the 80 detections. Other pesticides that were detected include prometon (12 detections), 2,4-D (5 detections), imazapyr (4 detections), imidacloprid (3 detections), clopyralid (2 detections), MCPP (2 detections), a metolachlor degradate - metolachlor ESA (2 detections), hexazinone (1 detection), MCPA (1 detection), picloram (1 detection), and tebuthiuron (1 detection). Five of the six surface water samples had detections of pesticides. There were a total of 14 detections of seven different pesticides in the five samples with detections. All of the pesticide concentrations were low and none exceeded or approached human health drinking water standards, where such standards exist. Nitrate was not detected in any of the surface water samples. The most commonly detected pesticide in surface water samples was 2,4-D, accounting for five of the 14 detections. Other pesticides detected include MCPA (3 detections), MCPP (2 detections), bromacil (1 detection), diuron (1 detection), imazamethabenz methyl ester (1 detection), and prometon (1 detection).

13. Montana WELL EDUCATED Program 2007

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Annual drinking water testing is an important practice to screen for water quality exceedances that may be detrimental to human health. The WELL EDUCATED Program provides a mechanism to test private well water primarily used for drinking. Drinking water parameters significantly targeted, but are not limited to, coliform presence and nitrate + nitrite as N. Multiple test packages are also available for a variety of constituents, including irrigation and livestock suitability. WELL EDUCATED water testing kits, along with instructional materials, are made publicly available through collaboration with county offices. Water test results and interpretive materials are mailed to each program participant. Interpretive materials create private well owner awareness on well maintenance and upkeep while providing easy to understand information on test results and handling exceedances. To assess program effectiveness, a basic survey is included with the WELL EDUCATED Program registration sheet. Upon program completion, a follow up survey is distributed to randomly selected participants assessing outcomes and impacts of program participation on private well water awareness and maintenance. Long term impacts of the project include a record of private well water results throughout

Montana, well owner education on parameter results and well maintenance, reduced risk of health related problems related to compromised water quality, and a database of private well water quality throughout Montana. During the 2007 program year, roughly 300 well owners or users participated in the program from 15 different counties around the state. Water quality parameters and potential trends can be tracked and identified through the database, which may be especially significant for parameters exceeding drinking water standards.

14. Nutrient Concentrations And Stable Isotope Chemistry In Silver Bow Creek

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Since May of 2006 our group has been collecting data on nutrients in Silver Bow Creek and tributaries in the Butte area. In this poster we summarize information on: 1) monthly synoptic sampling along Silver Bow Creek and tributaries; 2) diurnal variations in dissolved oxygen and other parameters; and 3) stable isotope composition of dissolved nitrate and ammonia. The results of monthly synoptic sampling show significant loading of nitrate and phosphate from non-point sources as Blacktail Creek makes its way through the Butte Summit Valley. However, total-N loads increase dramatically below the confluence of the discharge from the Butte wastewater treatment plant (WWTP). Most of the nitrogen exiting the WWTP is in the form of ammonia. Ammonia concentrations and loads decrease with distance below the WWTP because of microbial oxidation combined with uptake by plants. During baseflow conditions, as much as 2/3rd's of the total nitrate load at the mouth of Silver Bow Creek near Opportunity can be accounted for by oxidation of ammonia from the WWTP. During warm summer months, an extensive "dead zone" exists in the first 2-3 miles of Silver Bow Creek below the WWTP discharge. The dead zone is defined as portions of the creek that exhibit nightly drops in dissolved oxygen (DO) below 4 mg/L, which is lethal to trout. The dead zone is most dramatic just upstream of Rocker, where DO concentrations can drop to near-zero for many hours during the night. The unusual DO consumption rates are most likely due to microbial oxidation of ammonia and organic carbon, the majority of which comes from the WWTP. Preliminary stable isotope data show that the N and O isotopic compositions of dissolved nitrate in Silver Bow Creek are similar to the isotopic composition of nitrate in shallow groundwater in the Butte Summit Valley. Also, the $\delta^{15}\text{N}$ of ammonia from the WWTP is similar to that of nitrate from upstream sources. This makes it difficult to use stable isotopes to distinguish different sources of N contamination. Furthermore, the isotopic compositions of nitrate and ammonia appear to change downstream of the WWTP. As ammonia is gradually converted to nitrate, the $\delta^{15}\text{N}$ of ammonia shifts to heavier values, whereas the $\delta^{15}\text{N}$ of nitrate becomes lighter. Additional stable isotope samples have been collected to test this hypothesis, and results will be reported at the AVRA meeting.

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