
PROCEEDINGS

for

“RECLAIMING THE HEADWATERS OF THE CLARK FORK”

20th Annual Meeting of the Montana Section of the American Water
Resources Association

Butte, America
October 2nd and 3rd, 2003
Red Lion Inn



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THANKS TO ALL WHO MAKE THIS EVENT POSSIBLE!

- **The 2003 AWRA Officers (pictured right)**
*President, Montana Bureau of Mines and Geology
 President, Beaverhead-Deerlodge National Forest
 Montana Department of Natural Resources and
 May Mace, Montana Section Executive Secretary*

- **Montana Water Center, Meeting Sponsorship and**
*Gretchen Rupp, Susan Higgins, Sue Faber, Molly
 Nehasil*

- **And, many enthusiastic paper and poster presenters,
 moderators, student paper judges, and student volunteers**



*John LaFave,
 David Salo, Vice-
 Chuck Dalby,
 Conservation*

Coordination
Boucher, and MJ

field trip leaders,



**20TH ANNUAL
MONTANA WATER CONFERENCE**
***"RECLAIMING THE HEADWATERS
OF THE CLARK FORK"***
 Red Lion Inn, Butte, Montana
 October 2nd and 3rd, 2003



Thursday, October 2, 2003

8:00 – noon	Field Trip to the New Horseshoe Bend Treatment Plant and Montana Resources Mine! Note: To tour the Horseshoe Bend treatment plant you <u>must</u> provide and wear your own hardhat, safety goggles and steel-toed shoes. Vans will depart from the Red Lion Hotel parking lot and return by noon.
8:00 – 5:00	REGISTRATION AT RED LION INN, Red Lion Foyer
1:00 – 1:20	OPENING REMARKS , John LaFave, AWRA Section President and Conference Chair (<i>Big Sky 4 and 5</i>)
Session 1. Moderator:	PLENARY SESSION: RECLAIMING THE HEADWATERS OF THE CLARK FORK: PART I (<i>Big Sky 4 and 5</i>) Gretchen Rupp, Montana Water Center
1:20 – 1:40	Land reclamation at Clark Fork River Basin Superfund sites: an overview from Butte to the Clark Fork River. Dennis Neuman, MSU Bozeman.
1:40 – 2:00	Butte area surface water and groundwater issues and solutions. Chuck Stilwell and M. Yovich, ARCO, Butte.
2:00 – 2:20	Superfund update: Butte Priority Soils Operable Unit remedial investigation/feasibility study; Butte, Montana. Mark Hills and Angela Frandsen, CDM, Helena.
2:20 – 2:40	Storm Water and Superfund: EPA's approach for achieving water quality standards in Silver Bow Creek at the Butte Priority Soils Operable Unit. Angela Frandsen and Mark Hills, CDM, Helena.
2:40 – 3:00	Butte reclamation evaluation system. Pamela Blicher, MSU, Bozeman.
3:00 – 3:20	BREAK

Thursday, October 2

Concurrent Sessions

Session 2. RECLAIMING THE HEADWATERS OF THE CLARK FORK: Part II (<i>Big Sky 2 and 3</i>) Moderator: Daryl Reed, Montana Department of Environmental Quality	Session 3. GROUNDWATER ISSUES (<i>Big Sky 1</i>) Moderator: Kate Miller, Montana Bureau of Mines and Geology
3:20 – 3:40 Remediation of streamside tailings along Silver Bow Creek near Butte Montana. Bill Bucher, G. Fischer, and L. Cawfield, Maxim Technologies, Inc., Helena.	3:20 – 3:40 Evaluation of nutrient distribution and water quality in selected shallow aquifers in the Flathead Valley, northwestern Montana. Catherine McDonald and John LaFave, Montana Bureau of Mines and Geology, Butte.
3:40 - 4:00 Development of a watershed restoration plan for the Silverbow Creek watershed. Carol Endicott and James Lovell, Confluence Consulting, Bozeman; David Marshall, DTM Consulting, Bozeman; Mary Ellen Wolfe, Civil Dialogue, Bozeman; and Carol Fox and Greg Mullen, Natural Resource Damage Program, Helena.	3:40 - 4:00 S Characterization of dynamic groundwater flow patterns in a highly conductive floodplain, Middle Fork of the Flathead River, MT. Cain Diehl, Brian Boer, Jack Stanford, and William Woessner, University of Montana. Missoula.

4:00 - 4:20	Alternative mine waste repository design to allow for redevelopment and reuse of land in Butte, Montana: from Clark Fork tailings to the Copper Mountain Sports and Recreation Complex. Brad Archibald, Pioneer Technical Services, Butte; F. P. Crowley, DEQ, Helena; and Chuck Stilwell, ARCO, Butte.	4:00 - 4:20	Water-level changes from drought and industrial impacts in the Sand Creek Drainage Basin, southwestern Montana. Willis Weight and Heather Schledewitz, Montana Tech, Butte.
4:20 - 4:40	Changes in water quality of the Butte metro storm drain during an early summer storm event. Christopher Shope, Desert Research Institute, Reno and Chris Gammons, Montana Tech, Butte.	4:20 - 4:40	Hydrogeology and source water protection of the public water supplies in the North Hills of the Helena Valley. James Swierc, University of Montana, Helena.
4:40 - 5:00 S	Sub-aqueous oxidation of pyrite by dissolved ferric iron: a model for the Berkeley Pit. Damon Pellicori and Chris Gammons, Montana Tech, Butte; Simon Poulson, University of Nevada, Reno; and James Madison, Montana Bureau of Mines and Geology, Butte.	4:40 - 5:00	Exploring ground water nitrate-nitrogen and coliform bacteria in the Gallatin Local Water Quality District. Taylor Greenup, Land and Water Consulting, Helena.
5:00 - 5:20 S	Geochemistry of mine waters in the non-flooded, underground workings of the Lexington Tunnel, Butte. Chris Gammons, Montana Tech, Butte.	5:00- 5:20	Hydrostratigraphic interpretation of groundwater conditions in the north Havre residential area. Willis Weight, Montana Tech, Butte; and David Erickson, Water and Environmental Technologies, Butte.
5:30 - 7:00	POSTER SESSION AND HAPPY HOUR - Pop, snacks, and partially-hosted bar. (Poolside) Music by "Lark Ascending"		
7:00	BANQUET - <i>The PIG returns!</i> (Big Sky 4 and 5) Photo contest, too!		

Friday October 3, 2003

Concurrent Sessions

Session 4. SURFACE WATER/GEOCHEMISTRY (Big Sky 2 and 3) Moderator: Clain Jones, Montana State University	Session 5. WATERSHED MANAGEMENT AND MONITORING (Big Sky 4 and 5) Moderator: Mike McLane, Montana DNRC
8:00 - 8:20 S Importance of temperature in the diel cycling of metals in Fisher Creek, Montana. Stephen Parker, Montana Tech, Butte.	8:00 - 8:20 Improving late-summer streamflows when water demands exceed water supplies. Larry Dolan, DNRC, Helena.
8:20 - 8:40 S High Ore Creek reclamation and water-quality monitoring in Jefferson County, Montana. Jodi Belanger-Woods and Butch Gerbrandt, Montana Tech, Butte; and James Madison, Montana Bureau of Mines and Geology, Butte.	8:20 - 8:40 Response of riparian ground-water levels to prescribed fire. Clayton Marlow, MSU Bozeman.
8:40 - 9:00 Seasonality of diel cycles of dissolved trace-element concentrations in a Rocky Mountain stream. David Nimick and Thomas Cleasby, USGS, Helena.	8:40 - 9:00 Clark Fork River response to volunteer nutrient reduction program. Watson, Vicki, University of Montana; and Gary Ingman, John Babcock, Bruce Anderson of Land & Water, Inc.

9:00 – 9:20	Determination of metal loads and sources in watersheds draining mined areas. Joanna Thamke and Thomas Cleasby, USGS, Helena.	9:00 – 9:20	Quantitative assessment of the effectiveness of post-fire erosion control techniques in western Montana. Amy Groen and Scott Woods, University of Montana, Missoula.
9:20 – 9:40	PCB's: They're always in the last place you look . . . Pete Schade and Rebecca Ridenour, Montana Department of Environmental Quality.	9:20 – 9:40	Spatial variability of post-fire soil hydrophobicity in lodgepole pine forests of western Montana. Anna Birkas and Scott Woods, University of Montana, Missoula.
9:40 – 10:00	BREAK	9:40 – 10:00	BREAK

Session 6. WORLD WIDE WATER: WEB-BASED INFORMATION		Session 7. FLOODPLAIN AND CHANNEL PROCESSES MONITORING	
Moderator: Joe Meek, Montana Department of Environmental Quality		Moderator: Karin Boyd, Applied Geomorphology, Inc., Bozeman	
10:00 – 10:20 MWC	Communicating water science to public audiences: Montana Water and Montana Watershed websites. MJ Nehasil, Molly Boucher, and Susan Higgins. Montana Water Center, Bozeman.	10:00 – 10:20	Musings regarding how we describe channel plan form. Steve Custer, MSU, Bozeman.
10:20 – 10:40	Locating Montana water quality information. Catherine Love, Natural Resource Information System, Helena.	10:20 – 10:40	S
10:40 – 11:00	Montana water rights: WEB access: Part 1. Jane Horton, Mike McLane, and Julie McNichol, DNRC, Helena/Missoula; and TJ Abbenhaus, NRIS, Helena.	10:40 – 11:00	U.S. Highway 93 fish passage project. Darren Baune, Otto Stein, Amanda Hardy, and Joel Cahoon, MSU, Bozeman.
11:00 – 11:20	Montana water rights: WEB access: Part 2. TJ Abbenhaus, NRIS, Helena; and Jane Horton, Mike McLane, and Julie McNichol, DNRC, Helena.	11:00 – 11:20	The state of floodplain management in western Montana: an Association of Montana Floodplain Managers report. Scott Gillilan, Gillilan Associates, Inc., Bozeman.
11:20 – 11:40 MWC	Citizen volunteer monitoring in Montana: can it be exciting, reliable, and accessible? Michelle White, Montana Water Center, Bozeman; and Karen Filipovich, Montana Watercourse, Bozeman.	11:20 – 11:40	Fluvial geomorphology and geomorphic channel classification of the Upper Yellowstone River, Gardiner to Springdale, Montana. Chuck Dalby, Jim Robinson, Jane Horton, Michael Roberts, Larry Dolan, and Paul Azevedo, DNRC, Helena.
11:40 – 12:00	BREAK	11:40 – 12:00	BREAK

12:00 – 12:30	CLOSING PLENARY PRESENTATION (<i>Big Sky 4 and 5</i>) <u>Climate change and Precipitation Map for Montana</u> , Phil Farnes, Snowcap Hydrology, Bozeman. Introduced by John LaFave.
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12:30 – 12:45

- Announcement of student presentation awards, John LaFave
- Election of 2003-2004 AWRA incoming officer, David Salo

12:45 p.m.

ADJOURN

POSTERS (*Poolside, Thursday October 2, 5:30 – 7:00 p.m.*)

Authors will be present for the Poster Session during Thursday's happy hour

S – Student research project

MWC – Research funded through the Montana Water Center

1/ Montana Watersheds Coordination Council's 2003 Symposium: Opportunities for Landscapes and Communities. Karen Filipovich, Montana Watercourse, Bozeman.

2/ Geology of alluvial aquifers along the Clark Fork River from St. Regis to Missoula, Montana. Larry Smith, Montana Tech, Butte.

3/ Copper Mountain Sports Park: Alternative mine waste repository design to allow for redevelopment and reuse of land in Butte, Montana. Brad Archibald, Pioneer Technical Services, Butte and C. Stillwell, ARCO, Butte.

4/ Ground-water modeling at Milltown Reservoir to predict impacts of dam removal. Chris Brick, Clark Fork Coalition, Missoula.

5/ Water-level monitoring in eastern Montana. Clay Schwartz, Montana Bureau of Mines and Geology, Billings.

6/ Watershed characterization of abandoned mined lands in upper Prickly Pear Creek, west-central Montana. Joanna Thamke, USGS, Helena; Terry Klein, USGS, Denver; and David Harper, USGS, Wyoming.

7/ Potentiometric surface map of the basin-fill and fractured-bedrock aquifer system in the Bitterroot Valley, Ravalli County, Montana. John LaFave, Montana Bureau of Mines and Geology, Butte.

8/ Natural stream design for Silver Bow Creek near Butte, Montana. W. H. Bucher, G. Fischer, and L. Cawfield, Maxim Technologies, Inc., Helena.

9/ Characterization of surface-water/ground-water interaction: an investigation along the Spokane River, Idaho and Washington. Rodney Caldwell and Craig Bowers, USGS, Helena.

10/ Characterization of the Judith River aquifer in Treasure and Yellowstone counties, Montana. John Olson, Montana Tech, Billings.

11/ A ground-water classification system for watershed planning and conservation of ecotones in basin fill sediments of the Rocky Mountain West. Scott M. Payne, KirK Environmental LLC, Sheridan, Montana.

12/ Ground-Water characterization of shallow aquifers in the Many Lakes area, Flathead Valley, Montana. Gregory Lorensen, Montana Bureau of Mines and Geology, Butte. (S)

13/ The effects of the Fridley Fire on snow water equivalent, depth and density. Robert Campbell and Kristin Neibling, MSU, Bozeman. (S)

14/ Development of an updated microbial standard for Montana's surface waters. David L. Feldman and Randall Apfelbeck, Montana Department of Environmental Quality, Helena.

15/ Analysis of natural thermal pulses in a floodplain aquifer: interpreting aquifer properties and relative flowpath lengths along the Umatilla River, Oregon. Brian Boer and William Woessner, University of Montana, Missoula; Steven Thomas and Geoffrey Poole, Eco-Metrics Inc., Oregon; Scott O'Daniel, Confederated Tribes of the Umatilla Indian Reservation, Oregon and University of California, Santa Barbara; and Alicia Arrigoni and Leal Mertes, University of California, Santa Barbara. (S)

16/ A continued study of the hydrogeologic characterization of AMD production along Belt Creek near Belt, MT. Shawn Reddish, Bureau of Mines and Geology, Billings. (MWC)

17/DNRC Renewable Resources Grant and Loan Program. Deeda Richard, DNRC, Helena.

SESSION 1

Land Reclamation at Clark Fork River Basin Superfund Sites: an overview from Butte to the Clark Fork River. *Dennis R. Neuman, Director and Research Scientist, Reclamation Research Unit, and Adj. Asst. Professor, Department of Land Resources and Environmental Sciences, Montana State University, Bozeman, MT. 406/994-4821 (voice), dneuman@montana.edu.* Metal mining, milling and smelting in the western United States has had a relatively short history of some 150 years. Ecological damage from this legacy includes soil and water contamination caused by tens of thousands of abandoned mine sites. Many of these sites contain uncontrolled waste materials bearing contaminants of environmental consequence such as arsenic, copper, cadmium, lead, zinc, and mercury. In addition to environmental degradation, exposure to these metals is a threat to human health. In Montana, there are nearly 10,000 abandoned mine sites, and the largest of these have been designated as Superfund sites by the US Environmental Protection Agency. A large landscape in the Clark Fork River Basin has been impacted by over a century of world class metal mining, milling, and smelting. An overall description of several remedial actions and restoration activities, with an emphasis on land reclamation, that are underway or planned for this 10,000 km² watershed will be presented. Mitigation strategies are selected on their efficacy to reduce risks to human and environmental health. Remedial goals for a large portion of the watershed are to establish a self-sustaining assemblage of plants capable of stabilizing the soil from wind and water erosion, utilizing precipitation, providing wildlife habitat, accelerating successional processes, and minimizing transport of contaminants to ground and surface water receptors. Different technologies are being implemented depending on risk management, land use, and landscape position. Almost all remedial action include a land reclamation component including removal/replacement, soil and vegetation covers, other caps, in-situ treatment, subaqueous disposal, channel reconstruction, and waste repositories. Specific land reclamation and restoration examples will be presented from sites in Butte, along Silver Bow Creek, at Anaconda Smelter, and the Clark Fork River.

Butte area surface water and groundwater issues and solutions. *C. Stilwell and M. Yovich.* Mine wastes and impacts to surface water and groundwater in the Butte area have been studied and are being addressed under the Butte Priority Soils Operable Unit (BPSOU) under the Superfund program. Under BPSOU, the water resources of concern are the alluvial groundwater, the surface stream (specifically Silver Bow Creek through west Butte), and the stormwater (or wet weather) flows from the historic mining areas which drain to Silver Bow Creek from the Butte hill. The bedrock aquifer and surface waters east of Butte not draining to Silver Bow Creek are addressed under a separate remedy for the Berkeley Pit. This presentation pertains to the issues and potential solutions for the groundwater and surface water in the BPSOU.

Alluvial groundwater at the base of the Butte hill has been impacted by historic mining activity, resulting in elevated levels of metals and arsenic. The approach being considered to address these impacts is to collect the surficial expression of the groundwater, then to treat that water before being discharged to Silver Bow Creek. An expedited action was performed in the 1990s which removed extensive floodplain tailings deposits from the Silver Bow Creek area, set up a groundwater collection system and reconstructed a new floodplain and creek through west Butte (commonly called Lower Area One). In addition to the previous reclamation, future work will involve installing a groundwater collection system on the east side of Butte (Metro Storm Drain), and completing a full-scale treatment system to treat the collected groundwater before discharging it into Silver Bow Creek.

Also performed in the 1990s through 2003 were actions to reduce impacts to stormwater impacted by mine waste. These measures, called Best Management Practices, are currently being studied through water quality monitoring to determine their effectiveness, and what additional actions could be taken to further reduce metals levels in the stormwater from the Butte hill. Details of these past actions and possible future actions will be presented.

Superfund Update: Butte Priority Soils Operable Unit Remedial Investigation/Feasibility Study; Butte, Montana. *Mark W. Hills (hillsmw@cdm.com) and Angela Frandsen (frandsenak@cdm.com, CDM, 28 North Last Chance Gulch, Helena, Montana 59601, 406-495-1414, Fax: 495-1025.* Superfund work completed to date and planned for the near future at the Butte Priority Soils Operable Unit (BPSOU) has been and will continue to change the face of Butte, Montana. The U.S. Environmental Protection Agency (EPA) has been addressing environmental contamination within and around the community Butte for over 15 years and soon will be issuing a Record of Decision for this operable unit. There has been significant removal work performed to date to address human health and ecological risks from site contaminants in solid media, surface water, and groundwater. The Record of Decision will identify EPA's remedial strategy for the BPSOU and will specify remedial activities that will continue to enhance human and environmental

health throughout the community of Butte. This presentation will provide an update on the removal work performed to date at the BPSOU as well as remedial work that is currently being evaluated for implementation after the Record of Decision.

Since 1987, EPA has been working with the Montana Department of Environmental Quality, Butte-Silver Bow County, and the Potentially Responsible Parties to address potential human health concerns and severe environmental impacts that remain from the long history of mining activity within and around the community of Butte. Time-critical response actions and expedited response actions have been conducted contemporaneously with the remedial investigation at the BPSOU. More than 300 acres of mine-impacted lands have been reclaimed, storm water channels and detention basins have been constructed and are currently operational, 1.2 million cubic yards of the historic Colorado Smelter tailings were removed from the Silver Bow Creek floodplain and arsenic contaminated railroad grades have been removed or otherwise addressed. The remedial investigation, completed in 2002, characterized the extent of heavy metal contamination in solid media (soils and mining-related waste material), surface water, and groundwater. Remedial alternatives are currently being evaluated to address remaining environmental contamination within these media across the site. EPA anticipates that the Record of Decision for the BPSOU will be issued in 2004.

The Record of Decision at the BPSOU will select an appropriate remedy to achieve EPA's remedial objectives and goals for solid media, surface water, and groundwater. The remedy will involve a variety of remedial components that will include additional waste removals, land reclamation, and groundwater and surface water controls and treatment. The remedy at the BPSOU will also identify operation and maintenance programs to monitor the performance of all facets of the remedy and identify appropriate corrective actions when necessary. EPA's overarching remedial goal for the BPSOU is to implement a permanent remedy that will provide for long-term protection of human health and the environment. The remedy will address all contaminated solid media exceeding site-specific, risk-based action levels, prevent contaminated groundwater from entering Silver Bow Creek and/or exiting the site, and, to the extent practicable, achieve applicable Federal and State water quality standards for site contaminants in Silver Bow Creek under both normal and wet-weather flow conditions.

Storm water and Superfund: EPA's approach for achieving water quality standards in Silver Bow Creek at the Butte Priority Soils Operable Unit. *Angela Frandsen (frandsenak@cdm.com) and Mark Hills (hillsmw@cdm.com), CDM, 28 North Last Chance Gulch, Helena, MT 59601, 406-495-1414.*

The Butte Priority Soils Operable Unit (BPSOU) presents a unique environmental storm water challenge. There is little or no precedence in Superfund or in municipal storm water regulations for how to address the contaminated storm water from a Superfund site like Butte, Montana. Once contaminated groundwater inputs (such as the Metro Storm Drain) are removed and the stream channel is restored, storm water impacts from the BPSOU will be the last major challenge to restoring a fishery within the uppermost reaches of Silver Bow Creek. The U.S. Environmental Protection Agency (EPA) is evaluating a performance-based remedial program for storm water that is intended to achieve in-stream regulatory standards through an iterative monitoring/corrective action approach. This presentation describes the remedial program that EPA is currently evaluating for addressing contaminant loading to Silver Bow Creek that occurs as a result of storm water runoff from the Butte Hill.

The Butte Hill is an urban area that was built over a globally renowned mining district. The Butte Hill is steep, with an average grade of six percent between the Alice Dump and Lower Area One. The combination of the steep grade and widespread mine wastes over an urban area results in contaminated storm water rushing down to Silver Bow Creek. Silver Bow Creek is a small mountain stream (base flow around 15 to 20 cubic feet per second) that is quickly overwhelmed by urban runoff. Contaminated storm water runoff from the BPSOU can easily increase discharge in Silver Bow Creek by an order of magnitude or more. Exceedances of acute aquatic life criteria for heavy metals are routinely observed in Silver Bow Creek during storm events.

Some storm water problems have already been addressed in Butte. On the upper northeast portion of the Butte Hill, storm water (up to the 25-year storm event) has been diverted to the Berkeley Pit. In Missoula Gulch on the west side of the Butte Hill, waste dumps have been reclaimed and a series of concrete channels and catch basins have been added to reduce the level of suspended loads entering Silver Bow Creek. However, recent storm water monitoring performed by ARCO still shows significantly elevated concentrations of metals in Silver Bow Creek, especially copper and zinc.

EPA has proposed an aggressive program to address metals impacted storm water from the BPSOU. The program is currently being evaluated as part of the feasibility study. The program entails storm water monitoring at key locations in Silver Bow Creek, as well as at the bottom of the different subdrainages across the Butte Hill. As

storm water data are gathered, a mass-loading approach will be used to determine where the worst storm water problems are located. Monitoring will then proceed upstream in targeted subdrainages to better identify problem areas. Source controls, such as additional reclamation and Best Management Practices (BMPs), will be implemented. The program uses this iterative approach to identify and prioritize problem areas, perform remedial actions, and then monitor the successes or failures of those actions. If source controls and BMPs are not adequate, storm water treatment or pumping all storm water to the Berkeley Pit may be implemented.

Butte reclamation evaluation system. *Pamela S. Blicher, Reclamation Specialist, Reclamation Research Unit, Montana State University, Bozeman, MT.* The Environmental Protection Agency (EPA) designated Montana's Silver Bow Creek a Superfund site in 1983. By 1987 it was recognized that mine waste piles within the city of Butte, Montana posed a significant health risk to local residents and represented a major source of contamination to the Creek. The city of Butte was then added to the Silver Bow Creek Superfund site. Beginning in 1988 and continuing to date, EPA has performed response actions to address waste piles within the Butte Priority Soils Operable Unit (BPSOU). Response actions have focused on addressing mine waste "in-place". These response actions include land reclamation techniques using coversoil caps and revegetation. The Butte Reclamation Evaluation System (BRES) was developed as an evaluation tool designed to ensure that the integrity of all reclaimed land, including soil cover caps or other forms of engineered caps covering mine-waste left-in-place, are maintained at a level that provides for the long-term protection of human health and the environment in an urban-upland setting. EPA will utilize the BRES over the long-term to assess the condition of response action sites, identify problem areas, specify corrective action, and determine long-term monitoring schedules. During the development of the BRES, stakeholder representatives (County, State, EPA, and the Potentially Responsible Party Group) worked together to establish overarching objectives, develop site assessment methodologies, provide guidance, and identify evaluation parameters. Reclamation evaluation parameters include ground cover, erosion, condition of site edges, exposed waste material, bulk soil failure or land slumps, barren areas, and gullies. This presentation describes the BRES field evaluation parameters used to characterize response action sites in terms of meeting human health and environmental risk objectives and the evaluation parameter performance standards that collectively determine the appropriate corrective action.

SESSION 2

Remediation of streamside tailings along Silver Bow Creek near Butte, Montana. *W. H. Bucher, G. Fischer, L. Cawfield, Maxim Technologies, Inc., Helena, Montana.* Mining wastes deposited along Silver Bow Creek downstream of Butte, Montana have posed a threat to human health and the environment for over 100 years due to the presence of heavy metals and arsenic in the wastes. Under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), the State of Montana has undertaken the remediation of more than 2.5 million cubic yards of mine waste deposited along approximately 26 miles of Silver Bow Creek and its floodplain. Maxim Technologies, Inc., is the design contractor for the Montana Department of Environmental Quality on this project. During remediation, mine waste is excavated from the stream and floodplain, selected materials are treated with lime, and the waste is placed in local or regional repositories constructed for the project. The stream and floodplain are rebuilt to restore their natural function and maintain streambank stability during vegetation reestablishment. The long-term remediation objective of this source removal action is to attain groundwater and surface water quality standards in the floodplain and stream.

Development of a watershed restoration plan for the Silver Bow Creek watershed. *Carol Endicott¹, James Lovell¹, David Marshall², Mary Ellen Wolfe³, Carol Fox⁴, and Greg Mullen.⁴* Watershed planning in the Silver Bow Creek watershed presents a number of unique opportunities and challenges. Decades of mining in the basin have resulted in injuries to natural resources and associated recreational opportunities that cover an extensive portion of the basin. These injuries range from mild to severe contamination of water and soil resources and an assortment of physical alterations. Adding to the challenge is the variety in human activities across this landscape. The Silver Bow Creek watershed supports a relatively large, urban population as well as rural lands that are important for agriculture, wildlife, native species, and associated recreational values. The Natural Resource Damage Program (NRDP), which was formed to administer funds for restoration activities, recognized the need to plan and prioritize restoration activities in the Silver Bow Creek watershed. To fill this need, they commissioned the development of a watershed restoration plan. There were several objectives of the restoration plan development including determination of existing

and potential conditions of ecological resources; identification of potential opportunities for restoration; acquisition of public input; and prioritization of restoration activities. We incorporated concerns identified during the public participation process and results of data analysis into a geographic information system (GIS) based spatial model. This model serves as a tool to help develop a map-based inventory of priorities for restoration and identify restoration potential across the watershed. The final product will provide guidance to those seeking grant funds in developing projects consistent with the vision for the Silver Bow Creek watershed and to NRDP in evaluation of potential projects.

¹ Confluence Consulting, Inc, PO Box 1133, Bozeman, MT 59715, (406) 585-9500, cendicott@confluenceinc.com

² jlovell@confluenceinc.com; ³DTM Consulting, 211 N. Grand Ave, Suite J, Bozeman, MT 59715, (406) 585-5322, david@dtmgis.com; ³Civil Dialogue, 211 North Grand, Suite E, Bozeman, MT 59715, (406) 587-6532, mwolfe@bigsky.net; ⁴Natural Resource Damage Program, 1301 E Lockey, Old Livestock Building, PO Box 201425, (406) 444-0209, cfox@state.mt.us; ⁴ gmullen@state.mt.us, (406) 444-0228

Alternative mine waste repository design to allow for redevelopment and reuse of land in Butte, Montana: from Clark Fork Tailings to the Copper Mountain Sports and Recreation Complex.

B. Archibald, F.P. Crowley, and C. Stilwell. Reclamation of mine waste areas and design of mine waste repositories and covers must take into consideration regulatory, technical, and end-use issues. Presented here is a case study of a site in Butte, Montana, where a unique approach was taken to design and construct a mine waste repository and municipal landfill closure that met all regulatory requirements while allowing the redevelopment of the site into a multi-purpose recreational complex for the community. The project required the involvement and cooperation of multiple stakeholders, including the Atlantic Richfield Company, Butte-Silver Bow local government, state and federal regulatory agencies, and local residents.

The Clark Tailings were a historic tailings impoundment approximately one mile southwest of Butte, Montana. The 25-hectare site contained 800,000 m³ of mine waste and is adjacent to the old Butte municipal landfill. Because of the proximity to the local landfill, EPA allowed the Clark Tailings to be removed from the regional Superfund project area. A combined remedy for the mine waste and municipal landfill was performed under RCRA jurisdiction. To accommodate the development of a park and to speed-up completion of a nearby Superfund project on Silver Bow Creek, 650,000 m³ of mine waste from Lower Area One were consolidated at the site. The waste placement and repository cover designs considered plans for future redevelopment into a recreational complex, which included large irrigated areas for turf-grass ballfields, play areas, park buildings, and parking areas. Though the cap was designed to meet the prescriptive regulatory requirements, many alternative features were incorporated, including using locally available soil to meet strict infiltration barrier requirements. Waste placement and the final cover were designed in 1997 and constructed in 1997 and 1998. Park improvements were completed in 2001, and the community is currently enjoying the Copper Mountain Sports and Recreation Complex.

Changes in water quality of the butte metro storm drain during an early summer storm event.

Christopher L. Shope, Desert Research Institute, Dept. of Hydrologic Sciences, Reno, NV, 89512,

clshope@dri.edu; and Christopher H. Gammons, Dept. of Geological Engineering, Montana Tech, Butte, MT

59701, cgammons@mtech.edu. The Butte Metro Storm Drain (MSD) is a man-made ditch that conveys groundwater and storm water along the base of Butte Hill, from the Civic Center to its confluence with Blacktail Creek at Harrison Avenue. A detailed hydro-geochemical investigation was undertaken of the MSD during the 24-hour period between 6 a.m., June 26 and 6 a.m., June 27, 2002. On the afternoon of June 26, a heavy thunderstorm caused streamflow in the MSD to increase 100-fold, from 0.2 to more than 20 cfs (cubic feet per second). Field and chemical data were continuously collected before, during, and following the storm. These data included streamflow, water temperature, pH, specific conductivity, dissolved oxygen, alkalinity, filtered (0.45 µm) metals, and unfiltered (raw-acidified) metals. This talk is a summary of the major findings, which have recently been published as an MBMG Open-File report (Gammons et al., 2003).

The most significant finding in this study was that concentrations of copper increased during the storm surge, whereas the concentrations of most other elements decreased sharply. The calculated loadings (gram/hour) of both dissolved and particulate copper increased more than 100-fold in the first hour following the storm, and remained elevated over baseline conditions for the remainder of the study. Other metals, such as Zn, Cd, and Mn, showed a decrease in loading from pre-storm to post-storm conditions. The difference in behavior of copper with respect to the other heavy metals suggests the widespread presence of sources of soluble copper in the MSD watershed, or in the Metro Storm Drain itself. It is not possible to determine whether the storm flow became enriched in copper before or after it entered the storm drain. In addition to the large flush of copper, loadings of soluble P (most likely as orthophosphate) increased during the storm, whereas dissolved oxygen dropped to very low levels (< 2 mg/L).

Geochemical modeling indicates that the pre-storm MSD waters were close to saturation with the minerals gypsum (CaSO₄·2H₂O), calcite (CaCO₃), rhodochrosite (MnCO₃), otavite (CdCO₃), and hydrous Zn carbonate

($\text{ZnCO}_3 \cdot \text{H}_2\text{O}$), but were strongly undersaturated with all Cu-bearing minerals. Unlike many polluted streams draining abandoned mine lands in Montana, the MSD waters showed no evidence of diel (24-hour) cycling of heavy metals in the 10-hour period prior to the thunderstorm.

Reference:

Gammons C. H., Shope C., and Duaine T. (2003) Water quality monitoring of the Butte Metro Storm Drain during a storm event: June 26-27, 2002. Montana Bureau of Mines and Geology, Open-File Report 474, 44p.

Sub-aqueous oxidation of pyrite by dissolved ferric iron: a model for the Berkeley Pit. Damon Pellicori¹, Chris Gammons², Simon Poulson³, James Madison⁴. The conditions conducive to acid generation during the weathering of sulfide minerals are fairly well understood. With respect to pyrite, the key reactions can be written as follows:
 $\text{FeS}_2 + 7/2\text{O}_2 + \text{H}_2\text{O} \rightarrow \text{Fe}^{2+} + 2\text{SO}_4^{2-} + 2\text{H}^+$ $\text{FeS}_2 + 14\text{Fe}^{3+} + 8\text{H}_2\text{O} \rightarrow 15\text{Fe}^{2+} + 2\text{SO}_4^{2-} + 16\text{H}^+$

Methods of acid abatement in pyrite-rich waste hinge upon removing the requirements of oxidation. A common belief is that isolating reactive sulfide mine waste by submerging it under water will quell the oxidation process, by removal of O_2 (reaction 1). However, if conditions are such that ferric iron is abundant, pyrite oxidation can proceed via reaction 2 in the absence of oxygen, and at a much faster rate. It is proposed that this process is responsible for the continual decline in Berkeley Pit water quality.

The primary inputs of water to the Berkeley pit-lake are groundwater, sampled from nearby mine shafts and bedrock monitoring wells, and the Horseshoe Bend spring, which presently accounts for ~50% of the input water to the lake. Contributions from direct precipitation and runoff are minor. In all cases, the input waters are higher in pH and lower in metal concentration than the Berkeley pit-lake itself. In addition, analysis of stable isotopes of sulfur and oxygen in sulfate shows that SO_4^{2-} in the Berkeley pit-lake – presumed to be derived through pyrite oxidation – is isotopically distinct from that of the influent waters. This implies that most of the sulfate in the pit-lake was derived in-situ by water-rock interaction on the pit walls, and not by importation from influent waters.

It is theorized that the explanation for the difference in isotopic composition of sulfate from the pit-lake and the surrounding groundwater is due to changes in the mechanism of pyrite oxidation. Reaction 1 is the governing equation for sulfate produced in aerobic environments; reaction 2 applies to sulfate produced in subaqueous environments by ferric iron oxidation. The large difference in isotopic composition of atmospheric oxygen ($\delta^{18}\text{O} \sim +23.5 \text{‰}$) and meteoric water ($\delta^{18}\text{O} \sim -17$ to -18‰ in Butte) allows the determination of oxidation mechanisms. Thus, in aerated environments sulfate will be enriched in ^{18}O from atmospheric O_2 , whereas sulfate produced by subaqueous ferric iron oxidation will be isotopically lighter, more similar to the surrounding water. Preliminary oxygen isotope data from the Berkeley Pit are consistent with oxidation via ferric iron (reaction 2), lending further credence to the theory of subaqueous pyrite oxidation. Additional isotopic analyses are in progress, and will be reported in this talk.

¹Dept. of Geological Eng., Montana Tech, Butte, MT: dapellicori@mtech.edu

²Dept. of Geological Eng., Montana Tech, Butte, MT: cgammons@mtech.edu

³Dept. of Geological Sci., Univ. of Nevada-Reno, Reno, NV: poulson@mines.unr.edu

⁴Montana Bureau of Mines and Geology, Butte, MT, 59701: jmadison@mtech.edu

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Geochemistry of mine waters in the Non-flooded, Underground workings of the Lexington Tunnel, Butte. Chris Gammons, Associate Professor, Dept. of Geological Engineering, Montana Tech of the University of Montana, Butte, MT 59701. The Lexington Tunnel is the last accessible underground mine in the Butte District. Used as recently as 1982, the tunnel and adjacent workings on the 400-foot mine level have been abandoned for over 20 years. Montana Tech is currently re-opening the tunnel for use as an underground miner training facility. Although the Lexington Tunnel is several hundred feet above the regional water table, perched water is present over much of its extent. Mine water near the portal is moderately acidic (pH 4 to 5), with extremely high concentrations of metals, including Cu (up to 1000 mg/L) and Zn (up to 1400 mg/L). In the middle reaches of the tunnel, the quality of the water is relatively benign, with near-neutral pH, high bicarbonate alkalinity, and low concentrations of heavy metals. The low acidity and metal content is attributed to a lack of pyrite and other sulfides in this portion of the mine, as well as the presence of carbonate minerals, such as rhodochrosite (MnCO_3), in exposed veins. Sulfide minerals are more widespread further back in the tunnel (e.g., near the Lexington Shaft), and are now oxidizing rapidly, leading to pockets of severe acid drainage (pH < 3, dissolved Zn up to 5000 mg/L). Many of the mine waters in the tunnel are

lined with secondary mineral precipitates. These include blue Cu-sulfates, oxy-hydroxides of Fe (orange-red) and Al (white), and black Mn-Zn oxides. The latter are the predominant type of crust associated with the pH-neutral waters.

Geochemical modeling suggests that the near-neutral waters – the most voluminous type encountered in the Lexington Tunnel – are close to equilibrium saturation with rhodochrosite (MnCO_3) and hydrous Zn-carbonate ($\text{ZnCO}_3 \cdot \text{H}_2\text{O}$). The Eh of these waters is most likely controlled by redox reactions involving dissolved Mn^{2+} and secondary Mn-oxides. In contrast, the Eh of the acidic waters appears to be controlled by reactions involving $\text{Fe}^{2+}/\text{Fe}^{3+}$. Most of the acidic waters are saturated with K-jarosite, which forms delicate, straw-like dripstones hanging from the ceiling at several localities.

Timber used to support the underground mine workings is in various stages of decay, with locally heavy growth of white fungus, and a few small mushrooms. Decaying mine timbers could be an important renewable source of organic carbon for heterotrophic microorganisms, such as iron- and sulfate-reducing bacteria, deeper in the mine workings. More work is needed to elucidate the range of geochemical and microbiological processes taking place in the non-flooded underground mine workings of the Lexington Tunnel. (For a preliminary report of this work, contact the author at cgammons@mtech.edu.)

SESSION 3

Evaluation of nutrient distribution and water-quality in selected shallow aquifers in the Flathead Valley, northwestern Montana. *Catherine McDonald and John L. LaFave, Montana Bureau of Mines and Geology, 1300 West Park Street, Butte, Montana 59701, kmcdonald@mtech.edu.* The Montana Bureau of Mines and Geology and the Flathead Lake Biological Station, in cooperation with the Flathead Basin Commission, evaluated nutrients and water quality in selected shallow aquifers in the Flathead Basin. The work was completed to assist with on-going efforts to characterize and manage nutrient loading to Flathead Lake as part of the TMDL water-quality restoration plan. This project focused on evaluating nutrient distribution and general water-quality in shallow ground-water systems that discharge directly into Flathead Lake or the Flathead River. Elevated nutrient concentrations have been documented in some shallow aquifers in the basin, however, sufficient data were not available in other areas to evaluate potential impacts to surface water or to identify which shallow aquifers are of most concern as non-point nutrient sources to Flathead Lake.

From May 2002 through April 2003, 38 wells and 2 springs were monitored in 3 different focus areas; the Flathead Lake perimeter, the Evergreen aquifer, and the Pothole Lakes area. Wells were selected from different landuse types (e.g. residential, agriculture, urban) to evaluate potential difference in water-quality due to landuse. Water samples were collected on a seasonal basis and analyzed for major ions, trace metals, and nutrients.

The results show that water quality is good in all three focus areas, with low TDS (generally < 300mg/L) and no-exceedences of water-quality standards. Nitrate concentrations were low in all study areas with average concentrations less than 1.5 mg/L as nitrogen. Nitrate was detected most frequently in the Evergreen aquifer but at low levels (average concentration of 0.8 mg/L). The lowest number of detections were in the Pothole Lakes area. The highest nitrate concentrations were in wells in the delta area at the north end of Flathead Lake and along the eastern flood plain of the Flathead River. Phosphorus was present in all samples but at very low concentrations (average of 15 $\mu\text{g/L}$ total phosphorus and 7 $\mu\text{g/L}$ orthophosphate). Seasonal variations and differences in nutrient concentrations based on land-use types showed only minor variation.

Characterization of dynamic groundwater flow patterns in a highly conductive floodplain, Middle Fork of the Flathead River, MT. *Cain Diehl¹, University of Montana Geology Department, 32 Campus Drive, Missoula, MT 59812, 406-370-9255, caindiehl@hotmail.com; Brian Boer, University of Montana Geology Department; Jack Stanford, University of Montana Flathead Lake Biological Station; and William Woessner, University of Montana Geology Department.* The exchange of groundwater and surface water is an important component of floodplain aquifers. The purpose of this study is to identify how deep groundwater, shallow groundwater and hyporheic water mix in the floodplain. Wells will be utilized to sample groundwater for stable isotopes, radon, conductivity, dissolved oxygen and major ions and to collect head data. Temperature probe arrays will record vertical temperature fluctuations within the subsurface at depth discrete intervals. The temperature, chemistry and head data will be utilized to create a numerical model of the overall groundwater flow patterns at the floodplain scale.

Preliminary results show that groundwater is entering the subsurface when the Middle Fork enters the floodplain through a canyon. The majority of the water remains in the subsurface until it reemerges as the Middle

Fork leaves the floodplain through another canyon. Therefore, this groundwater has the longest flow path. Any loss or gain in the Middle Fork within the interior of the floodplain is probably shallow groundwater and hyporheic exchange with relatively short flow paths. Several tributaries within the floodplain demonstrate shallow communication with the groundwater, but seem to be less connected with deeper groundwater (> 1 meter deep).

Water-level changes from drought and industrial impacts in the Sand Creek drainage basin, Southwestern Montana.

Willis D. Weight and Heather Schledewitz, Department of Geological Engineering, Montana Tech of the University of Montana. The Sand Creek Drainage Basin is located approximately five miles southwest of Butte, Montana. The area has been zoned as heavy industrial and has undergone three major changes affecting groundwater in the past four years. These changes include influences from: 1) a silicon manufacturing plant (AsiMI), which began discharging approximately 890,000 gallons of water per day in 1998, 2) a phosphorous production plant (Rhodia), which ceased pumping in excess of one million gallons of water per day, from pumpage that began in the early 1950's, and 3) influences from drought conditions over the past three years. The purpose of this undergraduate research project was to examine water-level data affected by these stress changes and compare with data collected by Borduin (1999) between 1997 and 1999. Static water levels from 38 wells were measured and potentiometric surfaces were constructed. The study documented: 1) a decreasing effect from the drought in parts of the study area, 2) the recovery of Rhodia's cone of depression, and 3) the formation of a wetland in Sheep Gulch. The data represent significant baseline information to resolve possible future questions in this dynamically changing industrial setting.

Hydrogeology and source water protection of the public water supplies in the North Hills of the Helena Valley.

James Swierc, University of Montana – Helena, 406-542-0862, swiercj@umh.umt.edu. The hydrogeology of the public water supplies in the North Hills area of the Helena Valley in Montana reflects a shallow alluvial aquifer overlying a fractured bedrock aquifer. The two aquifers locally communicate, with flow in the bedrock interpreted to reflect fracture patterns. Recent dewatering of the upper aquifer has resulted in a temporary closure of the area for the installation of new water wells, except for replacing existing wells. Source Water Protection management areas were delineated for the public water supplies following the criteria established in the Montana program. The inventory zone, the primary management zone, is based on a three-year time of travel distance for the aquifer. The regional water table surface generally follows topography in the area. Public water supply and other wells in the area generally draw water from the alluvial aquifer, when present. However, near the northern limits of the aquifer, the yield is not sufficient resulting in wells installed to greater depths into the bedrock aquifer.

A total of seven community public water supplies are present in the northern part of the Helena Valley, with six non-community systems. The inventory zone for the wells incorporate the area topographically upgradient from each well. The recharge area includes the Silver Creek Watershed, and smaller watersheds into the North Hills which represent the topographic limit to the valley. Surface water buffer zones are delineated around Silver Creek and the Helena Valley Irrigation Canal since both discharge into the shallow aquifer. In general, the primary potential contaminant sources to the aquifer are from agricultural land use and areas with concentrated numbers of septic systems. The primary limit to development in the area appears to reflect the limited potential yield of the combined aquifers.

Exploring ground water nitrate-nitrogen and coliform bacteria in the Gallatin Local Water Quality District.

Taylor Greenup, Land & Water Consulting, 801 N. Last Chance Gulch, P.O. Box 239, Helena, MT 59624, taylor.greenup@landandwater.net. Rapid growth outside of municipal boundaries in Gallatin County, Montana, has raised concerns over ground water quality. Comprehensive ground water quality data is needed in order to effectively manage the sustainability of the resource and to protect public health. Research on water quality in the region has been limited to well monitoring networks of 100 wells or less. This presentation will discuss the compilation and exploration of a spatial ground water quality database, primarily for nitrate-nitrogen and coliform bacteria in the Gallatin Local Water Quality District (GLWQD). Close to 1,000 records for nitrate and over 4,000 records for coliform bacteria were collected and standardized into an electronic database. Well locations were plotted within a Geographic Information System (GIS), and a priori independent variables of septic system limitation ratings, housing density, land application of domestic wastes, farming practices, well depth, and hydrogeology were assigned to wells based on spatial location in the GIS. Statistical tests were then performed to discern the relationship between ground water nitrate-nitrogen and coliform occurrence and the a priori independent variables. As well,

kriging surfaces were modeled for ground water nitrate-nitrogen. Results, conclusions, and future strategies will be discussed.

Hydrostratigraphic interpretation of groundwater conditions in the North Havre residential area.

Willis D. Weight, Montana Tech; and David J. Erickson, Water and Environmental Technologies, Butte. A technical analysis was performed during litigation involving contamination from a fueling facility in Havre Montana. Diesel and chlorinated solvents migrated into the residential area of north Havre resulting in a law suit. Field investigations, monitoring, and sampling resulted in characterization of the site that was incorporated into a numerical model.

A detailed stratigraphic analysis was performed from data from wells on the fueling facility property, core drilling, residential well logs, electrical conductivity logs, and cone penetrometer testing (CPT) logs. A correlation of stratigraphy led to the interpretation of paleochannels and flood-plain deposits distributed within the north Havre residential area. Paleochannels from previous positions of the Milk River provide conduits for contaminant movement within the north Havre neighborhood to the northeast. The interpreted hydrostratigraphy was incorporated into a transient six-layer numerical groundwater-flow and contaminant-transport model. This was done to incorporate the available subsurface information into one system to evaluate the distribution of contamination. The depth of the model is constrained to depths of approximately 50 to 60 feet from the surface, although some layers extend deeper in parts of the model.

Parameters used in the numerical model are constrained by field parameters and professional judgement. The numerical models can reasonably explain calibration of hydraulic heads and contaminant distributions. The west-to-east influence of surface-water recharge from the Milk River as it makes a bend to the north during spring stage levels, are evident from field work and are captured by the model. Visualizations of the science behind the hydrogeologic interpretations will be presented.

SESSION 4

Importance of temperature on the diel cycling of metals in Fisher Creek, Montana. *Stephen R. Parker¹, Christopher H. Gammons², David A. Nimick.³* Recent research (Brick and Moore, 1996; Nimick et al., in press) has documented the phenomenon of diel (24-hour) cycling of metals in many streams in Montana. This study investigated diel metal cycling in Fisher Creek, a stream affected by acid rock drainage in the New World Mining District near Cooke City, Montana. A unique aspect of Fisher Creek is that the pH changes from strongly acidic to near-neutral over a relatively short distance due to mixing of headwater acid drainage with influent groundwater and tributary streams. The principal source of acid drainage during low flow is the Glengarry adit. Samples were collected at three sites: F1: Upstream site, 0.7 km below Glengarry adit, pH range ~ 3.4 – 3.5; F2: Midstream site, 2.1 km below Glengarry adit, pH range ~ 5.4 – 5.7; F3: Downstream site, 3.5 km below Glengarry adit, pH range ~ 6.7 – 6.9. At each site, 24 hourly samples were collected on August 13-14, 2002, for analysis of filtered and non-filtered cations and trace metals, anions, alkalinity, and $\text{Fe}^{2+}/\text{Fe}^{3+}$ speciation. Stream pH, temperature, dissolved oxygen, and flows were monitored continuously at each site.

Iron was the only metal that showed significant diel cycling under the acidic conditions at F1 and F2. Both total dissolved iron concentration and the $\text{Fe}^{2+}/\text{Fe}^{3+}$ ratio tended to increase during the day at these sites. At the neutral, downstream station (F3), concentrations of dissolved Cu, Zn, Mn, Cd, and Fe increased at night and decreased during the day. Concentrations of dissolved copper (the contaminant of main concern in Fisher Creek) underwent a 2.4-fold increase between the daytime minimum (63 ug/L at 1700 hours) and the early morning maximum (151 ug/L at 0500 hours). These concentration changes were inversely correlated to changes in stream temperature. Temperature changed 11.7 °C at F3 while measured pH changed only 0.07 units. In comparison to most streams, this 24-hr temperature range is substantial and the pH range is very small. Previous experimental studies have shown that sorption of metal cations onto hydrous metal oxides is endothermic, and therefore is favored by an increase in temperature. Temperature congruent diel metal cycling can be expected even in the absence of a pH cycle to drive the sorption process.

The surface complexation simulation in Phreeqc was used to model the dissolved zinc and copper concentrations observed at F3. Due to the lack of biological activity in Fisher Creek and the high concentrations of iron, the only significant sorbent surface was assumed to be hydrous ferric oxide (Hfo). The modeling started with the initial solution composition, which was then equilibrated successively with the hourly temperature and pH values. The Phreeqc database was supplemented with enthalpies for Cu and Zn adsorption to Hfo surfaces (Machesky 1990; Rhodda, Johnson & Wells, 1996). The agreement between observed and calculated Cu and Zn concentrations was

good. These modeling results are consistent with the concept that temperature-dependent sorption reactions are an important component of diel cycling of metals in streams with near-neutral pH. Knowledge of diel cycles and how they can vary over different portions of a stream should be carefully considered when designing and carrying out monitoring programs in mining-impacted watersheds.

References:

- Brick, C.M., and Moore, J. N., 1996. Diel Variation of Trace Metals in the Upper Clark Fork River, Montana., *Environmental Science and Technology*, 30, 1953-1960.
- Machesky, M., 1990, Influence of Temperature on Ion Adsorption by Hydrous Metal Oxides. Chemical modeling of aqueous systems I: American Chemical Symposium Series 416, edited by R. L. Bassett and D. C. Malchoir, 282-292
- Nimick, D.A., Gammons, C. H., Cleasby, T. E., Madison, J. M., Skaar D., and Brick C. M., 2003. Diel variations in dissolved metal concentrations in streams: occurrence and possible causes. *Water Resources Research* (in press).
- Rhodda, D. P., Johnson B. B., and Wells, J. D., 1996. Modeling of the Effect of Temperature on Adsorption of Lead(II) and Zinc(II) onto Goethite at Constant pH. *Journal of Colloid and Interface Science*, 184, 365-377.
- 1: Dept. of Chemistry & Geochemistry, Montana Tech, Butte, MT. sparker@mtech.edu
- 2: Dept. of Geological Engineering, Montana Tech, Butte, MT. cgammons@mtech.edu
- 3: U.S. Geological Survey, 3162 Bozeman Ave., Helena, MT. dnimick@usgs.gov

High Ore Creek reclamation and water-quality monitoring, Jefferson County, Montana. Jodi D. Belanger-Woods¹, Dr. Butch Gerbrandt, P.E.², and James P. Madison³. Reclamation activities as well as post-reclamation monitoring have occurred in the High Ore Creek watershed for over a decade. These activities have predominantly been managed by the U.S. Department of Interior – Bureau of Land Management (BLM) and the Montana Department of Environmental Quality – Mine Waste Cleanup Bureau (MWCB) for the primary purpose of reducing impacts to the environment in the High Ore Creek watershed and ultimately the Boulder River (Upper Missouri River Drainage Basin). In association with the BLM and MWCB, Montana Tech of The University of Montana (Montana Tech), the Montana Bureau of Mines and Geology (MBMG), the U.S. Geological Survey (USGS), the U.S. Environmental Protection Agency (EPA), and the Montana Department of Fish, Wildlife, and Parks (MDFWP) have conducted numerous pre- and post-reclamation studies in the High Ore Creek watershed. These studies have produced data that can be used to assess a Total Maximum Daily Load (TMDL) for High Ore Creek per Section 303(d) of the Federal Clean Water Act.

High Ore Creek, a perennial tributary to the Boulder River, is located nearly 4 miles east of the town of Basin, Montana, in Jefferson County. High Ore Creek originates at approximately 7,400 feet (ft) above mean sea level (amsl), is nearly 7 lineal miles in length, and confluences with the Boulder River at approximately 5,200 ft amsl. The average annual precipitation is 14 inches and the local climate is characterized as semi-arid (typical of southwest Montana).

Hardrock mining activities have occurred in the High Ore Creek watershed since as early as the 1860s and ceased during the 1950s. Mining methods (seeking ore bearing gold, silver, lead, copper, and zinc) included placer mining, underground lode mining, open-pit mining, as well as milling. Abandoned or inactive mine sites within the High Ore Creek watershed include: the Comet Mine and Mill Site, Gray Eagle Mine, Golconda/Reliance Mine, and the King Cole Mine. The Comet Mine and Mill Site, the largest site in the watershed (and also located along High Ore Creek), was identified as the primary source of metals contamination to High Ore Creek due to its waste rock and tailings. In 1993, the Comet Mine and Mill Site was ranked 10 out of 276 on the Abandoned Hardrock Mine Priority Sites List by the MWCB. Since the fall of 2001, all of these mines (excluding the Gray Eagle) have been reclaimed as well as the High Ore Creek floodplain to its confluence with the Boulder River.

Post-reclamation monitoring, in cooperation with the BLM, has been on-going since the summer of 1999. Improvement in water quality is one of several criteria that are used to assess the success of the High Ore Creek watershed reclamation efforts. As part of the assessment process, base flow, snowmelt, and storm event sampling are conducted annually along High Ore Creek by Montana Tech and the MBMG. The sample results are compared with pre-reclamation water quality data collected by the MBMG, BLM, and the MWCB. In addition to assessing the success of the High Ore Creek watershed reclamation, Montana Tech is studying the causes of large, reproducible 24-hour diel variations in the concentration of zinc and other metals and the interaction(s) between surface water and groundwater. Throughout the remaining months of 2003, additional monitoring will continue.

The volumes of pre- and post-reclamation environmental data require compilation and review in order to generate a TMDL for High Ore Creek. In turn, this will enable governing agencies to identify an approach to improve water quality to a level where the beneficial uses are restored and protected if necessary.

¹Civil Engineering Masters Student, Montana Tech of the University of Montana, 6095 Albany Avenue, Butte, Montana, 59701, 406-494-6591, jodi_woods@msn.com or JDWoods@mtech.edu.

²Professor and Department Head, General Engineering Department, Montana Tech of the University of Montana, 1300 West Park, Butte, Montana, 59701, 406-496-4109, bgerbrandt@mtech.edu.

³Hydrogeologist, Montana Bureau of Mines and Geology, 1300 West park Street, Main Hall, Butte, Montana, 59701, 406-496-4619, JMadison@mtech.edu.

Seasonality of diel cycles of dissolved trace-element concentrations in a Rocky Mountain stream.

Thomas E. Cleasby and David A. Nimick, U.S. Geological Survey, 3162 Bozeman Avenue, Helena, Montana 59601, tcleasby@usgs.gov or dnimick@usgs.gov. Substantial diel (24-hour) cycles in dissolved (0.1- μ m filtration) trace-element concentrations were observed during summer and winter low flow and spring snowmelt runoff in Prickly Pear Creek in western Montana. During six diel-sampling episodes lasting 34-61 hours, concentrations of Mn and Zn varied in a consistent daily pattern from minimum values in the afternoon to maximum values shortly after sunrise. Arsenic concentrations exhibited the inverse temporal pattern. Mn and Zn diel concentration increases ranged from 24-152 percent and 70-500 percent (respectively) and correlated strongly with the timing of diel cycles in pH and water temperature. This concurrent timing suggests that instream geochemical processes control diel trace-element cycles during all seasons. Diel changes in As concentration (33-55 percent) were less variable among the seasonal sampling episodes and did not significantly correlate with diel increases in pH and temperature. Diel streamflow cycles also were examined as a possible explanation, but the timing of minimum and maximum streamflows was inconsistent among sampling episodes owing to differences in seasonal hydrology and was not synchronous with concentration. Because diel streamflow cycles had little relation to the timing of diel trace-element concentration cycles, hydrologic processes are not considered a primary control. Diel concentration cycles appear to occur year-round in streams having neutral to alkaline pH. Thus, sampling plans to characterize temporal variations in trace-element concentrations in streams need to consider potential impacts of diel concentration cycles on interpretations of trends, remediation effectiveness, or exceedances of water-quality standards.

Determination of metal loads and sources in watersheds draining mined areas. *Joanna N. Thamke and Thomas E. Cleasby, U.S. Geological Survey, 3162 Bozeman Avenue, Helena, Montana 59601.*

jothamke@usgs.gov or tcleasby@usgs.gov. Metals in drainage from mined areas and undisturbed areas of mineralized rock have affected the quality of water, aquatic habitat, and stream biota in watersheds in many parts of the western United States. The effects of metals in drainage on water quality can range from negligible to severe. In severe cases, typical aquatic life is absent. The degree to which drainage from mined or mineralized areas influences water quality depends on the metal load discharged into a receiving stream, downstream changes in streamflow, and geochemical reactions. To determine metal loads, water-quality and streamflow data commonly are collected at numerous locations within a watershed over a short period of time. This synoptic-sampling method allows quantification and comparison of metal loads over broad areas of a watershed under uniform hydrologic conditions in order to identify the most important source areas.

Accurate streamflow measurements are necessary for quantifying loads. In many streams, traditional current-meter methods are adequate for determination of streamflow. However, in high-gradient mountain streams, the accuracy of traditional current-meter measurements can be hampered by irregular cross sections, turbulent flow, and the coarse substrate of the streambed. The tracer-injection method is an alternative means to determine streamflow and uses conservation-of-mass theory applied to downstream dilution of an injected tracer, such as chloride. In addition to accounting for the underflow through coarse substrate, an advantage of the tracer-injection method is that streamflow data can be obtained at many sites more quickly than with current-meter measurements. This efficiency allows a long study reach to be characterized during a relatively short period of time, thus minimizing the potential effect of temporal changes in streamflow and water quality that could complicate between-site load comparison.

Metal loads and sources have been determined within a number of watersheds affected by drainage from abandoned mines in Montana: Cataract Creek, Bullion Mine tributary, and Uncle Sam Gulch near Basin; Tenmile Creek near Rimini; Daisy, Fisher, Miller, and Soda Butte Creeks near Cooke City; Bear Creek near Gardiner; and Middle Fork Warm Springs Creek near Helena. Tracer-injection methods to quantify metal loads are continually being improved to enhance their application to various environmental settings.

References:

- Boughton, G.K., 2001. Metal loading in Soda Butte Creek upstream of Yellowstone National Park, Montana and Wyoming—A retrospective analysis of previous research; and quantification of metal loading, August 1999: U.S. Geological Survey Water-Resources Investigations Report 01-4170.
- Cleasby, T.E., and Nimick, D.A. 2002a. Streamflow, water quality, and quantification of metal loading in the upper Tenmile Creek watershed, Lewis and Clark County, west-central Montana, September 1998: U.S. Geological Survey Water-Resources Investigations Report 02-4072, 64 p.
- Cleasby, T.E., and Nimick, D.A. 2002b. Metal concentrations and sources in the Miller Creek watershed, Park County, Montana: U.S. Geological Survey Water-Resources Investigations Report 02-4148, 32 p.
- Cleasby, T.E., Nimick, D.A., Kimball, B.A. 2000. Quantification of metal loads by tracer-injection and synoptic-sampling methods in Cataract Creek, Jefferson County, Montana, August 1997: U.S. Geological Survey Water-Resources Investigations Report 00-4237, 39 p.
- Kimball, B.A. 1997. Use of tracer injections and synoptic sampling to measure metal loading from acid mine drainage: U.S. Geological Survey Fact Sheet FS-245-96, 8 p.
- Kimball, B.A., Nimick, D.A., Gerner, L.J., and Runkel, R.L. 1999. Quantification of metal loading in Fisher Creek by tracer injection and synoptic sampling, Park County, Montana, August 1997: U.S. Geological Survey Water-Resources Investigations Report 99-4119, 40 p.
- Nimick, D.A., and Cleasby, T.E. 2001. Quantification of metal loads by tracer injection and synoptic sampling in Daisy Creek and the Stillwater River, Park County, Montana, August 1999: U.S. Geological Survey Water-Resources Investigations Report 00-4261, 51 p.
- Thamke, J.N., Wotan, T.R., Cleasby, T.E., and Nimick, D.A. 2002. Arsenic loads and source areas in and along Bear Creek, Park County, Montana, September 2000: U.S. Geological Survey Water-Resources Investigations Report 02-4074, 25 p.

PCBs: They're always in the last place you look... *Pete Schade and Rebecca Ridenour, Montana DEQ.* Located in Central Montana, Big Spring Creek has the distinction of being a blue ribbon trout stream. However, PCBs in fish tissue and stream sediments, originally detected in 1981, have resulted in fish consumption advisories and numerous investigations to locate the source of PCBs. Brewery Flats, an old rail and industrial area upstream of Lewistown, was thought to be the source for the PCB pollution, prompting several intensive sampling investigations of adjacent deposits. Most recent investigations, however, have traced the source of PCBs upstream to the Big Springs Trout Hatchery.

At present, Montana Department of Fish, Wildlife and Parks, is attempting to pinpoint the source of PCBs through further targeted sampling. Potential sources that are being investigated include marine paint use to line raceways and fish feed pellets. This investigation is in-progress and final results are pending, yet one cannot deny the possible implications this study may have for fish hatcheries throughout the state.

SESSION 5

Improving late-summer streamflows when water demands exceed water supplies. *Larry Dolan, Hydrologist, Montana Department of Natural Resources and Conservation, 1424 9th Ave, Helena, MT 59620, ldolan@state.mt.us, Phone: 406-444-6627.* Because late-summer streamflows in many Montana streams are not high enough to supply all the demands for irrigation and fisheries, increasing these flows has been a goal of watershed groups in the state. And because most diversionary water uses in Montana are for irrigation, the apparent obvious solution would be to improve irrigation water-use efficiencies, such as by converting flood irrigation systems to sprinklers or by lining irrigation canals. But will improving irrigation efficiencies always result in more water in the stream? In this presentation, a study of the water supply and irrigation efficiencies in the upper Shields River watershed will be described. Streamflow and irrigation data have been collected to develop a water budget for this watershed and to determine the potential for increasing late-season flows by improving irrigation efficiencies. Preliminary findings are that irrigation system improvements need to be carefully planned or they could be counterproductive to the goal of increasing streamflows.

Response of riparian groundwater levels to prescribed fire. *Clayton B. Marlow, Animal and Range Sciences Department, Montana State University, Bozeman, MT, (406) 994-2486, cmarlow@montana.edu.* Riparian literature is replete with statements on the linkage between ecological processes in upland systems and those occurring in riparian

areas. However, most riparian rehabilitation efforts target streamside alterations without regard to conditions in the watershed that drive the processes that shape and sustain riparian areas. For example, long term fire suppression has probably led to the depletion of shallow groundwater levels because of increased conifer (Ponderosa pine, Douglas fir and Rocky Mountain Juniper) densities. Reduced groundwater levels, in turn, would minimize the results of stream rehabilitation projects because of marginalized soil moisture levels. A cooperative project involving the Lewistown Office, Bureau of Land Management and the Montana Agricultural Experiment Station is tracking the response of shallow riparian groundwater to the thinning of Ponderosa pine and Rocky Mountain Juniper in the Missouri River Breaks. Since June 2002 higher groundwater levels have been recorded in drainages where conifer density had been reduced through prescribed fire than in neighboring drainages that were unburned. If the pattern persists over the next 24 months, it will indicate that riparian rehabilitation efforts will have to address watershed conditions as well as those in the streamside zone.

Clark Fork River response to volunteer nutrient reduction program. Vicki Watson, University of Montana, and Gary Ingman, John Babcock and Bruce Anderson of Land and Water, Inc. In 1998, a public-private partnership signed a volunteer nutrient reduction program for the Clark Fork River to address nuisance algae growths in the river. In the intervening years, nutrient loads and concentrations have been reduced at most sites for some nutrients. Changes in algae levels are more difficult to detect because of the great variability in algae levels which are influenced by many factors in addition to nutrients. Algae monitoring data from 1998 to 2002 will be presented along with recommendations for improving methods of detecting change in this parameter.

Quantitative assessment of the effectiveness of post-fire erosion control techniques in western Montana. Amy H. Groen¹ and Scott W. Woods², School of Forestry, University of Montana Missoula MT 59812; ¹ 406-243-6422, amy_groen@hotmail.com; ²406-243-5257, swoods@forestry.umt.edu. Soil erosion rates in undisturbed forested watersheds are typically very low. However, substantial increases in erosion rates have been observed after forest fires due to the loss of the protective vegetation and litter layers, and changes in the physical characteristics of the soil that increase surface runoff rates. The potential problems associated with post-fire erosion include reduced soil productivity, risks to human health and safety, property damage, and deleterious effects to water quality and habitat in downstream water bodies. The United States Forest Service (USFS) Burned Area Emergency Rehabilitation (BAER) program therefore prescribes various erosion control treatments intended to stabilize hillslopes after a fire. However there is relatively little quantitative information on the effectiveness of individual treatments.

The purpose of our study is to evaluate and compare the effectiveness of three commonly used hillslope erosion control treatments - aerial seeding, straw mulching and straw wattles - for reducing post fire erosion rates. Study sites are within the 2001 Moose Fire and the 2002 Fox Creek Fire in northwestern Montana. Hillslope-scale plots within the Moose Fire complex were treated with mulch and straw wattles in August 2002. Erosion rates from these plots and untreated control plots in response to natural rainfall are being measured using silt fences. Aerial grass seeding was conducted in parts of the area affected by the Fox Creek Fire in the spring of 2003. We are measuring hillslope-scale erosion rates in the seeded areas using silt fences. We are also using a rainfall simulator to compare erosion rates from small (0.5 m²) plots treated with either the aerial seeding or straw mulching to untreated control plots. The results of our study will help to improve the effectiveness of post-fire erosion control projects.

Spatial variability of post-fire soil hydrophobicity in lodgepole pine forests of western Montana.

Anna Birkas¹ and Scott W. Woods², School of Forestry, University of Montana, Missoula MT 59812; ¹406-243-6422, acb6@humboldt.edu; ²406-243-5257, swoods@forestry.umt.edu. Soil hydrophobicity often occurs after forest fires in response to intense soil heating. The degree of hydrophobicity is a function of the fire severity, soil moisture content, vegetation type, and soil texture. Since these factors vary spatially, so does the degree of hydrophobicity. The spatial variability of soil hydrophobicity largely determines its effect on runoff and erosion rates. However, a lack of information on the spatial characteristics of soil hydrophobicity has limited attempts to predict, model and manage the effects of post-fire soil hydrophobicity on runoff and erosion rates.

The purpose of our research is to assess the spatial variability of post-fire soil hydrophobicity, and the cause of that spatial variability, in burned areas of Lodgepole pine forest in western Montana. In 2002 we measured the hydrophobicity along 20-meter transects within a range of fire severity conditions in the Moose Fire complex to

determine an appropriate grid spacings for subsequent more detailed measurements. Semivariogram analyses indicated that hydrophobicity values were correlated at distances of between 0.5 and 4.0 meters. We are now conducting grid-based measurements of soil hydrophobicity across a range of fire severities at the Moose Fire site and at several other locations. Hydrophobicity is being measured every meter on 16 by 16 meter grids, and every 0.25 meters within randomly selected grid squares, using the Critical Surface Tension (CST) method. Soil moisture, duff thickness, fire severity, microtopography and soil texture are also being measured at every point. The results of our work are expected to help explain how and why post-fire soil hydrophobicity varies spatially across the landscape.

SESSION 6

Communicating water science to public audiences: the MONTANA WATER website. *MJ Nehasil, Molly Boucher, and Susan Higgins, Montana Water Center, Montana State University, Bozeman, MT 406.994.6690; nehasil@montana.edu; <http://water.montana.edu>.* MONTANA WATER, a website developed by the Montana Water Center, provided a practical and comprehensive resource for professionals, university faculty, and the many Montanans with an interest in water issues. By making a wide range of water-related information easily accessible, MONTANA WATER fosters the an easy access to statewide water-resource information. MONTANA WATER (<http://water.montana.edu/>) features sections titled Resources, Topics, Education, and Watersheds. Each section includes links to useful and current information about water resources both in Montana and beyond.

Locating Montana water quality information. *Catherine Love, Natural Resource Information System, Montana State Library, PO Box 201800, Helena MT 59620, (406) 444-3345, clove@state.mt.us.*

Locating water quality data can be a challenge with the variety of government agencies and private groups working in the state. Through a grant from the EPA, the Montana Natural Resource Information System (NRIS) has simplified the search for water quality data in Montana with the creation of the Montana Water Quality Tracker (WQT).

The WQT is an Internet tool that allows users to search for information on water quality samples using both spatial and tabular queries. Query results can be displayed in both report and map formats and can also be downloaded for use in an Excel spreadsheet. The reports contain contact information to obtain data or in some cases a link to the data if it is available on-line. Users do not need any special software installed on their computers to access this data.

The water quality information in the WQT comes from public and private data providers. Our data partners provide metadata about their water quality data in a standardized data exchange format but do not share their actual water quality sample results. This allows data providers to retain control of how their data is maintained and distributed.

The Montana Water Quality Tracker is one of many on-line tools available from the Montana Natural Resource Information System (NRIS). NRIS was created in 1985 by the Montana State Legislature to simplify the task of identifying and acquiring natural resource information in Montana. To use the Montana Water Quality Tracker and other on-line map and data tools at NRIS go to: <http://nr.is.state.mt.us/interactive.html>

Montana water rights: Web access (Presented in two sections). *Jane Horton¹ (section I presenter), TJ Abbenhaus² (section II presenter), Mike McLane³ and Julie McNichol.⁴* Computer software installed on servers at the Department of Natural Resources and Conservation (DNRC) and Natural Resources Information System, Montana State Library (NRIS) provide Internet users current water right information as maps and tables. Individual water rights are quickly located from data spanning more than 100 years and displayed as a detailed abstract or location on a map.

There is always a need for public access to water rights records. Using current technologies, especially World Wide Web (WWW) applications, we now provide data access to a larger number of people. The DNRC teamed with NRIS personnel to develop these applications. There is extensive information within the DNRC database; the opportunity to have this resource available through the Internet has been achieved.

Water rights can now be located in the database query system using two distinct methods of search. The web based DNRC query tool provides detailed information to users with a choice of sort order, graph or map. The web based NRIS thematic mapper allows users to search by geographic criteria providing detailed maps to users with a choice of sort order for the attribute data. Location information is displayed according to place of diversion or place of use, while acreage of use is thematically displayed with scaled symbols.

Weekly updates approaching complete automation provide users current detailed water right information including new map locations. Users do not need any special tools installed on their machines to access water right data as either a map or table. The water right data is downloadable for use offline on the users computer as both geographic information system files (shapefiles) and tab delimited text files.

1/ GIS Program Manager, DNRC, PO Box 201601, Helena, Montana 59620-1601, (406) 444-5926, jhorton@state.mt.us.

2/ GIS Programmer/Analyst, NRIS, Montana State Library, PO Box 201800, Helena MT 59620, (406) 444-0539, tjabbenhaus@state.mt.us.

3/ Senior Planner, Water Management Bureau WRD-DNRC, 1424 9th Ave., Helena Montana 59620-1601

4/Water Rights Database Migration Coordinator, Water Rights Bureau R. O. WRD-DNRC, 1610 S. Third St. West, Suite 103, Missoula Montana 59806-5004.

Citizen volunteer monitoring in Montana: can it be exciting, reliable and accessible? *Michelle White, Montana Water Center, MSU and Karen Filipovich, Montana Watercourse, MSU, Bozeman.* There are numerous benefits of volunteer monitoring programs, including enhanced awareness of local water resource issues and potential pollution problems, pollution prevention training, collection of baseline data, and the collection of information on streams that otherwise may not be assessed. The way in which volunteer monitoring data are used depends on the goals and objectives of the group, as well as the level of training and rigor associated with data collection. Several states use volunteer monitors to identify areas in need of extensive monitoring and restoration; other states utilize volunteer monitors to supplement information collected by state agencies and enhance partnerships among government, community groups, and local stakeholders. Given the limited resources available in Montana for the collection of water quality information, volunteer monitors offer an opportunity to supplement the state's water quality database while enhancing public awareness about conservation of our natural resources. Not all volunteer groups are capable of collecting reliable data; with proper training, supervision, and appropriate quality control, however, citizen volunteers can collect meaningful data. We will discuss the pros and cons of the use of volunteer monitors for the collection of reliable water quality information, and the type of data collection that is appropriate for volunteers. The Blue Water Task Force of the Gallatin watershed will be used as a model for Montana. We also will discuss the tools currently available and additional elements still needed to make rigorous volunteer monitoring a reality in Montana.

SESSION 7

Musings regarding how we describe channel plan form. *Stephan G. Custer, Department of Earth Sciences, Montana State University, Bozeman, MT 59717-348; 406-994-6906, uessc@montana.edu.* One of the bases of stream classification is channel plan form. The earliest of these is the very widely used classification developed by Leopold and Wolman (Braided, meandering and straight). This classification, while widely used, is flawed in that different criteria are used to identify the channel pattern. The classification can be better systematized by recognizing the criteria and developing a matrix with end members. One axis is channel sinuosity. One axis is bar type. This matrix makes a systematic descriptive scheme and is a good pedagogic tool which helps students recognize different channel plan forms. Two interesting problems arise when one uses the matrix. The first has to do with the existence of some combinations of sinuosity and bar condition. For example, many believe sinuous channels with braids do not exist, but with recent challenges to common wisdom regarding the controls of the braided channel form is not out of the question.

The second problem has to do with whether islands should be included in the matrix. When islands are present a common pattern name applied is anabranching. Anabranching channels are better considered as channel systems and should not be included in the matrix. Some anabranching systems have channels that are separated by miles. In such cases the channel reaches in each channel element may have different plan form and different classification. Even where channels are not separated by great distances, reach sinuosity may differ substantially from one thread to the next. For this reason, anabranching channels should not be included in the continuum of channel plan forms. Anabranching channel systems are common in Montana. An important question relates to the processes that are responsible for such channel systems. There have been many hypothesized causes including tectonics, geohistoric sediment pulses caused by glaciation or other climatic changes. Many Montana streams are anabranching and processes outside human control may dominate them.

Measurement and prediction of 3-D velocity field in medium to high gradient streams and culverts with implications on fish movement. *Matt Blank, 507 Cobleigh Hall, MSU, Bozeman, MT 59717, (406) 222-3920 (h), (406) 994-6651 (w), mattblank@imt.net or blank@montana.edu.* Many streams in Western Montana are fairly high gradient with large substrate. Often these types of streams have road crossings with culverts. Fish passage through culverts

and fish movement in the natural stream are partially controlled by the velocity distribution. This study focuses on measuring the hydraulic environment, modeling velocity fields and assessing fish movement through natural stream reaches in medium to high gradient (2 to 8%) streams with large substrate and through culverts. The study is in progress and will continue through 2004.

Research into fish passage through culverts has been ongoing for decades. Past studies have shown there is a delicate relationship between passing water through culverts and maintaining a hydraulic environment that allows fish to move freely through the structure. Defining a culvert crossing as passable or impassable is a difficult process. The USFS has developed physical criteria to assess passage status of a structure and there are software programs, such as FishXing, that perform an analysis of culvert hydraulics and compare the hydraulic environment to fish swimming capabilities for assessing passage.

More recent research in field settings is providing some evidence that fish may be able to pass through culvert hydraulic environments that would be considered impassable by some present assessment criteria and models. This type of information points to the need for more detailed field study of culvert hydraulics, natural stream hydraulics and fish movement in both.

The methods used in this project include field measurements, computer modeling both as validation of field data and simulation of larger and smaller flows (flows that are difficult to measure in field), and physical measurement of passage by mark-recapture fisheries studies. The field measurements include estimation of the 3-dimensional velocity field in the natural stream and culvert with an estimate of the turbulence structure using an acoustic Doppler velocimeter (ADV). Computer modeling is being performed using CFX-5, a code that uses computational fluid dynamic principles to estimate velocity fields. Mark-recapture studies in the culvert and the natural stream provide information about whether a structure is passable, and what the flow rate is when fish move through the reach. Finally, fish passage or movement is assessed by combining field measurements, computer simulated velocity fields and mark-recapture data. Different metrics used to assess fish passage potential include turbulent kinetic energy (TKE) and percent passable area.

The results of this study will provide some insight about factors limiting fish passage through culverts and the hydraulic environment in the natural stream during various stages of fish movement. It also will provide an assessment of how well CFD can predict velocity fields in these settings. Finally, the hydraulic environment when fish moved through the structure or stream reach is estimated.

US Highway 93 fish passage project. *Darren Baune, MS Candidate in Civil Engineering at Montana State University, D_Baune@hotmail.com, 406-994-7034.* Reconstruction of highway US 93 between Evaro and Polson has been a high priority for many years. The road is not designed for present demand and as a result, it is considered one of the most dangerous stretches of highway in Montana. The area is home to threatened or endangered grizzly bear, lynx, wolverine, cutthroat trout and bull trout species as well a host of other species. In addition, wildlife-car interactions have been identified as a major risk factor for highway safety in this area. As a result, the US 93 Project is designed with 42 wildlife-crossing structures that provide passage under or over the highway. Wildlife crossings structures are common in Europe and are in limited use in Canada; however, they are not commonly used in the United States. Thus, the US 93 Project represents a major step in the evolution of highway design in the United States.

Many of the animal crossings are expansions or reconstructions of existing stream crossing structures. For example, many small box or pipe culverts will be replaced with 12 ft high by 22 ft wide box culverts. These large box culverts will enable large and small animals to cross the highway without endangering their lives and, more importantly, the lives of the humans utilizing the highway. A unique aspect of this design is that these new structures will allow the stream to maintain a more natural morphology and thus should allow fish, as well as large terrestrial wildlife to pass the highway.

The focus of this presentation is on the research being done on the fish passage aspects of these wildlife crossings. The primary goal of this project is to develop a baseline analysis of current conditions that promote or hinder fish passage at US 93 stream-highway crossings in the hope that this leads to 1) more meaningful design of improved fish crossing structures and, 2) a database to assess the success or failure of the re-designed crossings. Objectives to achieve this goal include 1) collection of stream habitat, fish population, stream hydraulic, and culvert hydraulic data at two or more specific structures 2) collection of less extensive habitat and hydraulic data at additional structures 3) analysis of these data using programs such as HEC-RAS, Culvert-Master and Fish-Xing and, 4) reporting of the results in Master of Science Professional Paper. If this study is followed with a similar post-construction project, a comparison of the before and after conditions would provide a valuable case study for improved highway fish passage techniques.

The state of floodplain management in western Montana: an Association of Montana Floodplain Managers report. *Scott Gillilan, AMFM Chair & President, Gillilan Associates, Inc. and Karl Christians, AMFM Executive Officer & DNRC State Floodplain Manager.* Floodplain management in Montana is rapidly evolving and becoming an increasingly important aspect of city and county government management. This rapid pace of change is partly driven by municipalities acknowledging and facing liability issues either voluntarily or through the legal system. Another significant driver is increasing development pressures in the 100-year floodplain. An increasingly complex management and regulatory environment has resulted with many communities becoming overwhelmed. This has occurred simultaneously with decreases in state and Federal support for floodplain management in general. In this presentation, these issues are addressed and questions posed relating to the immediate future of FEMA floodplain management in Montana.

Fluvial geomorphology and geomorphic channel classification of the Upper Yellowstone River, Gardiner to Springdale, Montana. *Chuck Dalby, Jim Robinson, Jane Horton, Michael Roberts, Larry Dolan and Paul Azevedo, Montana DNRC.* We mapped and described physical channel characteristics and fluvial geomorphology of an 80-mile segment (40 miles in detail) of the upper Yellowstone River, between Gardiner and Springdale, Montana. Work was conducted as part of cooperative investigations of historic and possible future "cumulative effects" of channel modification (e.g. dikes, levees) and bank stabilization (e.g. riprap, jetties) on channel stability and physical channel attributes. Contemporary data were collected on: low-water and bankfull-- channel hydraulics (width, depth, slope), channel pattern, and gravel-bar and island characteristics; and low-water--, surface and subsurface particle-size distribution, woody-debris abundance, and natural and human channel confinement. These data were used, in conjunction with information on 1948-1999 channel changes, to develop a modified version of the Montgomery-Buffington channel classification applicable to the upper Yellowstone River. Channel classification provides an objective framework for sampling geomorphic strata, assessing channel stability and channel changes, and for a variety of channel management actions (e.g. permitting, monitoring design).

The classification recognizes seven distinct channel types and their spatial distribution is largely controlled by Paradise Valley glacial history; Pinedale glaciation has strongly influenced the current-day distribution of valley and channel slopes, lateral channel confinement, sediment size and location of sediment sources. Very stable, entrenched, bedrock, cascade, and plane-bed channels occur mainly between Gardiner and Mill Creek and have changed little since 1948 (49 % of channel length). Pool-riffle and anabranching (multiple-thread) channels occur throughout the downstream drainage (40% of length), are more dynamic and locally show significant change in response to the 1974 and 1996-97 floods (~100yr events). Anabranching/braided channels are located in several segments between Pine Creek and Mission Creek (11% of channel length) and are the most dynamic with the largest rates of lateral migration and occurrences of rapid lateral change (avulsion). Predominately alluvial (sand, gravel, cobble) channel reaches partly affected by natural obstructions (bedrock) or alluvial reaches significantly affected by bank stabilization were delineated as a special class of externally forced alluvial channel morphology. Of the total channel length between Gardiner and Springdale, about 14 % (12 miles) was classified as strongly affected by channel modification (riprap, levees, etc); another 6 % (4.9 miles) was affected by combined natural and human constraints.

CLOSING PLENARY SESSION

Climate change and precipitation map for Montana. *Phil Farnes, Hydrologist, Snowcap Hydrology, P.O. Box 691, Bozeman, MT 59771-0691, farnes@montana.net, 406-587-8393*

Climate change: In recent years, there has been a lot of discussion about global warming and speculation as to the consequences. Actual records from climatological stations with around 100 years of record were analyzed to determine how temperatures and precipitation have changed over the last century. Only stations that were not moved and those that had substantially complete data were analyzed. Stations that were originally in town but were later moved to the airport or those stations that have been converted to Automated Surface Observation System (ASOS) were not used. Since climatological records were obtained daily by observers, those stations with the longest records were in the older cities and towns. The National Weather Service (NWS) did not enter records prior to 1948 electronically. Montana is fortunate that Joe Caprio, formerly Montana State climatologist, entered the pre-1948 records electronically for many of the Montana stations.

Comparisons have been made for annual and seasonal temperature and precipitation for stations in Montana and northwestern Wyoming. Many Montana snow courses have been measured since the mid-1930's. Three snow courses that were established in Glacier National Park (GNP) in 1922 are still being measured on May 1. Only the snow courses that have been measured manually since the 1930's and have not been relocated were analyzed. Only the April 1 snow water equivalent (SWE) (May 1 for GNP snow courses) was analyzed as reduction in manual measurements due to implementation of the SNOTEL network has eliminated most of the early-season manual surveys and most of the snow courses that were co-located with SNOTEL sites. Annual values are used to obtain 5-year moving averages to help visualize trends.

One has to be careful in analyzing data downloaded from the web as station changes and changes in methods of measurement have not been identified and may indicate trends that are associated with differences in data collection or location more than real changes in temperature and precipitation trends. Techniques and equipment used to obtain daily manual measurements are thought to be compatible over the past 100 years at climatological stations and over the past 70-80 years at snow courses.

One needs to keep in mind that even with changes in trends, the annual and seasonal variability is probably more significant than small changes over long time periods. Dry and wet years and warm and cold years will still be part of our climate even though trends over long periods may change. For example, it is not uncommon for annual precipitation to vary between 40 and 160 percent of average or annual temperatures to vary from -5 to +5 degrees F from average.

Precipitation Map: The only statewide precipitation map currently available for Montana is PRISM developed at Oregon State University (1961-1990) and the hand-drawn 1941-1970 I prepared in the 1970's. There needs to be a statewide map for the current base period which is 1971-2000. PRISM has problems with algorithms used to distribute precipitation and the scale of the digital elevation model (DEM). Steve Custer has attempted to use the Australian procedure ANUSPLINE to develop an average annual precipitation map. This method has some of the same problems as PRISM. University of Montana (UM) has developed MTCLIM which is probably the better model of the three for distributing known precipitation to unmeasured locations. UM has also developed DayMet which estimates daily precipitation. However, data provided by this method is for a non-standard base period. None of these models utilize all of the data that are available.

I propose that the graduated inverse square of the distance method be used. Advantages are that isohyets go through known precipitation points. Algorithms use nearest neighbors which is more sensitive to localized conditions than the 10-12 stations used by most of the other methods. Scale of the DEM should be such that the pixels are no more than 500 square meters with 100 or 200 square meter pixels being more desirable. Snow courses can be used to obtain estimated annual precipitation. Also, using data from storage gages, short (less than 30-year) and discontinued climatological stations will greatly increase the number of points with known precipitation and improve the resolution and accuracy of the final map. Once locations are identified, maps of monthly, seasonal and annual precipitation, temperature, snow loads, snowfall or generated data such as growing degree days or Keetch Byram Drought Index (KBDI) can be developed.

I would like to propose that NRIS (Natural Resource Information System) develop procedures to incorporate the data and mapping techniques into their system and be the distribution point for Montana. NWS (valley precipitation, temperature and snowfall), NRCS Snow Survey (mountain temperature, precipitation and snow water equivalent), and MSU Civil Engineering Department (snow loads) would provide averages for identified locations.

If Montana had a State Climatologist like all of the other states (Montana is one of two states that does not have such a position), this person could be the coordinator between NRIS and the other agencies. However, since Montana does not have such a position, possibly a State or Federal grant could be obtained to develop the algorithms and procedures and to implement the system. Some individual agencies that make extensive use of this data might also be able to contribute funds or services to implement the development of an accurate, reliable, and useable average annual precipitation map (or any other parameter) for Montana which can readily incorporate new averages when the base period is updated.

POSTERS

MWCC 2003 symposium: opportunities for landscapes and communities. *Karen Filipovich, Director, Montana Watercourse, MSU, Box 170575, Bozeman, MT 59717-0575, (406) 994-1910, (406) 994-1919 (fax);*

kfilipovich@montana.edu. The Montana Watershed Symposium is a unique event connecting scientists, engineers, and other practitioners with landowners and other local stakeholders. This December event offers state and regional perspectives, opportunities for networking, and an occasion to learn about and share the best science, policy, and locally driven models based on watershed approaches being implemented today. The MWCC Symposium will take place on December 8-9 at the Holiday Inn in Great Falls. More information about registration, booths, and scholarships is available by contacting Karen Filipovich (*kfilipovich@montana.edu*; 994-6671)

Copper Mountain Sports Park: alternative mine waste repository design to allow for redevelopment and reuse of land in Butte, Montana. *B. Archibald and C. Stilwell*. Reclamation of mine waste areas and design of mine waste repositories and covers must take into consideration regulatory, technical, and end-use issues. Presented here is how a unique approach was taken to design and construct a mine waste repository that met all regulatory requirements while constructing a multi-purpose recreational complex for the community, called Copper Mountain Sports Park. Presented are the project summary, redevelopment process to develop the park from the waste repository, and the repository cap design.

The Clark Tailings were a historic tailings impoundment approximately one mile southwest of Butte, Montana. The 25-hectare site contained 800,000 m³ of mine waste and is adjacent to the old Butte municipal landfill. Because of the proximity to the local landfill, EPA allowed the Clark Tailings to be removed from the regional Superfund project area. A combined remedy for the mine waste and municipal landfill was performed under RCRA jurisdiction. To accommodate the development of a park and to speed-up completion of a nearby Superfund project on Silver Bow Creek, 650,000 m³ of mine waste from Lower Area One were consolidated at the site. The waste placement and repository cover designs considered plans for future redevelopment into a recreational complex, which included large irrigated areas for turf-grass ballfields, play areas, park buildings, and parking areas. Though the cap was designed to meet the prescriptive regulatory requirements, many alternative features were incorporated, including using locally available soil to meet strict infiltration barrier requirements. Waste placement and the final cover were designed in 1997 and constructed in 1997 and 1998. Park improvements were completed in 2001, and the community is currently enjoying the Copper Mountain Sports and Recreation Complex.

Ground water assessment and monitoring (GWAAMON) in eastern Montana. *Clay Schwartz, Montana Bureau of Mines and Geology (Billings), 406-657-2702, cschwartz@mtech.edu*.

Monitoring of ground water resources has become a priority in natural resource management in Montana. Over 300 wells are monitored for static water levels on a quarterly basis with many being monitored monthly. Electronic data loggers and Stevens paper recorders also record water levels. Ground water is sampled on a periodic basis for water quality analysis and review. Methods of monitoring, monitoring site locations, water quality, ground water assessment, monitoring issues and program data are reviewed.

Potentiometric surface map of the basin-fill and fractured-bedrock aquifer system in Bitterroot Valley, Ravalli County, Montana. *John I. LaFave, Montana Ground-Water Assessment Program, Montana Bureau of Mines and Geology, 1300 W. Park St. Butte, MT 59701, jlafave@mtech.edu*. As part of the Montana Bureau of Mines and Geology Lolo-Bitterroot Ground-Water Characterization study, the potentiometric surface of the aquifer system in the Bitterroot Valley was mapped to assess patterns of ground-water flow.

Aquifers occur in the Quaternary and Tertiary basin-fill deposits, and the fractured bedrock on the east and west sides of the Bitterroot Valley. The ground-water flow system consists of three hydrogeologic units: 1) shallow alluvium (Holocene sand and gravel, Pleistocene outwash and alluvium), 2) deep alluvium (Pleistocene deep alluvium, Tertiary sedimentary deposits), and 3) fractured bedrock (Tertiary volcanic and plutonic rocks, Cretaceous intrusive rocks, and Precambrian metasedimentary rocks).

Water levels were measured in 367 wells between 1997 and 2000. These data were supplemented by water-level measurements in 111 additional wells from other projects. Of the measured wells, 159 were completed in shallow alluvium, 264 in deep alluvium, and 55 in fractured bedrock. All the water-level data are stored in the Montana Ground-Water Information Center (GWIC) database, and are available online (<http://mbmgwic.mtech.edu/>). To construct the potentiometric surface map, the measured water levels were converted to altitude above mean sea level and contoured by hand. Where data were sparse, reported water levels from driller's logs and altitudes from topographic maps were used to assist the contouring.

Within the Bitterroot valley, ground water occurs under unconfined to confined conditions. Water levels range from above land surface (2 wells) to more than 270 feet below the land surface (4 wells, all on the east side of the valley). The water-level contours indicate a potentiometric surface that conforms to topography, with steeper gradients along the valley margins and flatter gradients in the valley proper. The potentiometric data indicate that on a regional, valley-wide scale, there is sufficient hydraulic continuity between the different aquifers to form a single ground-water flow system. Regional ground-water flow within the valley is away from the mountainous recharge areas toward the Bitterroot River in the center of the valley.

On this map, ground-water flow appears to be horizontal, but there are important vertical components of flow within the valley depending on position in the flow system and the geologic framework. Recharge areas (mountainous areas), discharge areas (river valleys), and places where low-permeability layers separate more permeable units (east-side benches) are settings where vertical flow occurs.

Characterization of surface-water/ground-water interaction: an investigation along the Spokane River, Idaho and Washington. Rodney R. Caldwell and Craig L. Bowers, U.S. Geological Survey

3162 Bozeman Avenue, Helena, Montana 59601, (406-457-5933 or 406-457-5935), caldwell@usgs.gov or clbowers@usgs.gov. Elevated trace-metal concentrations in the Spokane River of Idaho and Washington have raised concerns about potential contamination of ground water in the underlying Spokane Valley/Rathdrum Prairie aquifer, the primary source of drinking water for the city of Spokane and surrounding areas. A study conducted by the U.S. Geological Survey examined the interaction of water in the river and aquifer using hydrologic and chemical data along a losing reach of the Spokane River. The river and ground water were extensively monitored over a range of hydrologic conditions at a streamflow gaging station and 25 monitoring wells ranging from 8-1,000 m from the river. River stage, ground-water level, water temperature, and specific conductance were measured hourly to biweekly during water year 2001. Water samples were collected on a near-monthly basis from the Spokane River during 1999-2001 and were collected up to nine times from the monitoring wells during 2000-01. Additional regional ground-water data were collected from more than 190 wells within 5 km of the study reach.

Hydrologic data indicate that the Spokane River recharges the Spokane Valley/Rathdrum Prairie aquifer along a 29-km reach between Post Falls, Idaho, and Spokane, Washington. Ground-water levels in the near-river aquifer (less than 125 m from the river) indicate variably saturated conditions beneath the river and a ground-water flow gradient away from the river. Calculated mean-monthly river losses ranged from near 2 to 23 cubic meters per second along a 11-km reach during water years 2000 and 2001.

Chemical and temperature data indicated that river recharge may influence ground-water chemistry as far as 900 m from the river, although most influences to ground water occur within 100 m of the river. The chemistry and temperature of river water and ground water from near-river wells were similar and exhibited similar temporal trends, whereas ground water from wells located farther from the river had higher ionic strength and more stable temperature and chemistry. The Spokane River does appear to be a local source of low-level concentrations of cadmium, copper, zinc, and possibly lead in the near-river ground water. Lag time between variations of water temperature and water chemistry in the river and in water from near-river wells may prove useful for estimating ground-water velocity and time of travel of chemical constituents to and through the aquifer.

A groundwater classification system for watershed planning and conservation of ecotones in basin fill sediments of the Rocky Mountain West. Scott M. Payne, KirK Environmental LLC, P.O. Box 636, Sheridan, MT 59749, 406-842-7224

kirkenv@3rivers.net. Watershed issues must be examined from above and below according to the Committee on Watershed Management et al. (1999). However, watershed management has generally under emphasized groundwater as a component of water resource conservation and rehabilitation (GAO 1991). Watershed research and management have focused on surface waters, minimizing the importance of the continuous interaction between surface water and groundwater (MacKenzie, 1996). This results in a need to develop a watershed level groundwater classification system (GWCS) that will, at a management decision level, appropriately represent groundwater connections to watershed hydrology and ecology. There are groundwater classification systems that treat groundwater as an isolated resource. These physical and chemical classification systems do not include aspects of watershed planning or conservation of biologic resources. Concepts of sustainable development are integrated into the mass balance equations, but traditional groundwater management rarely considers the needs of basin ecology. Kendy (2003) describes disastrous impacts from maximizing groundwater production for agricultural use in China, where developers ignored the need to balance the water budget of the entire hydrologic system. I am developing a GWCS that links hydrogeologic properties and flow systems to databases of watershed flora and fauna, land use, hydrology,

geology, and topography. The classification of watersheds and range of groundwater conditions are presented so that both skilled and unskilled practitioners benefit from the information and can apply the GWCS to specific settings and needs. A three tiered assessment system is proposed, with Tier 1 through Tier 3 being increasingly more rigorous in assessment requirements based on: 1) the type and extent of existing data, 2) economic considerations, and 3) the need to characterize and model complex groundwater, surface water, and biologic resources. In turn, groundwater is classified in terms of quantity, quality, human influences, and biologic connections. A working version of my GWCS is completed and calibration studies involving a departure analyses are underway to compare results and refine the GWCS. I am applying the departure analysis to a number of watersheds located in the Rocky Mountain and Basin and Range provinces. A Tier 1 assessment is also being completed in the Ruby Watershed of Southwest Montana. A preliminary summary and map of selected findings for the Ruby Watershed are presented to demonstrate a Tier 1 assessment. My research will result in a Ph.D. dissertation that can be published as a GWCS guidance document. In addition, my research will identify new opportunities to develop GWCSs for other geographic areas and geologic settings.

The effects of the Fridley Fire on snow water equivalent, depth and density. *Robert Campbell and Kristin Neibling, Earth Sciences Montana State University, Bozeman, MT 59717-3480, robnmo@juno.com.* The literature has reported that fire influences the amount of snow on the ground in forests. This effect was studied as part of a class project in Earth Sciences 450, Snow Dynamics and Accumulation at three sites in the Pine Creek Drainage burned by the Fridley Fire. Three 120m snow-courses were sampled on northwest to northeast facing slopes of 12 degrees and 6600', 10 degrees and 6300' and 8 degrees and 6400'. The open canopy and burned canopy sites showed similar average depths, 43.69cm and 42.69cm, densities, 0.292g/cc and 0.286g/cc and SWE 12.8cm and 12.2cm. On the third site, where fire burned the underbrush but left the canopy intact (40-50% coverage), the average depth 20.38cm, density 0.208g/cc and SWE 4.4cm were much lower than for the open and burned canopy sites. Statistical analysis of the data shows there is no significant difference between open and burned canopy sites and shows there is a significant difference between these sites and the site with canopy present. Snowfall accumulation and density are higher where the canopy is open or has been burned than for areas where some of the canopy remains. Possible implications from this fire include decreased sublimation loss and increased spring melt and run-off melt rates in response to shade loss in the burned area.

Analysis of natural thermal pulses in a floodplain aquifer: interpreting aquifer properties and relative flowpath lengths along the Umatilla River, Oregon. *Brian R. Boer, Dept. of Geology, University of Montana, Missoula MT, 59812, brian.boer@umontana.edu, (406) 542-2688; William W. Woessner, Dept. of Geology, University of Montana, Missoula MT, 59812; Steven A. Thomas, Eco-Metrics Inc., Pendleton, OR; Scott O'Daniel, Confederated Tribes of the Umatilla Indian Reservation, OR & University of California, Santa Barbara; Geoffery Poole, Eco-Metrics Inc. Tucker, VA & Pendleton, OR*

Alicia Arrigoni, University of California, Santa Barbara; and Leal Mertes, University of California, Santa Barbara. Characterizing the thermal regime of relatively pristine streams is an important first step in developing temperature standards that adequately protect salmonid habitat. An ongoing project, Data-Rich Decision Support Environment for the Development of Water Temperature Standards and TMDLs in the Pacific Northwest (NASA), is combining remote sensing, ground-based data collection and numerical modeling to decipher the factors controlling the thermal complexity within the Umatilla River floodplain in northeastern Oregon.

While the thermal regime of floodplain aquifers are of inherent and intrinsic interest to the study, the analyses of thermal data also provide another means of determining important hydrogeologic parameters such as groundwater flow velocities, hydraulic conductivity, and relative lengths of flowpaths. Numerous floodplain wells were instrumented with partitioned vertical arrays of temperature loggers, and natural pulses of heat derived from fluctuating river temperature were observed moving along flowpaths. Heat capacity of the basalt alluvium and thermal dispersivity of the aquifer were determined from laboratory studies and thermal push-pull tests. These data were used to determine the average linear velocity (V), and hydraulic conductivity (K) was calculated using V , known gradients (i), and an estimated value of effective porosity (n_e). Hydraulic conductivity values calculated in this way were 1-2 orders of magnitude ($1000 + m/d$) higher than values derived from aquifer pumping tests (50 to $100 + m/d$).

DNRC Renewable Resource Grant and Loan Program. *Deeda Richard, DNRC, Helena.* Each biennium, Montanans have the opportunity to benefit from grant funds to enhance the renewable resources of our state.

Renewable Resource Grants: Applications are accepted from state and local governments and their subdivisions for projects that provide for the conservation, management, development, or preservation of renewable resources. Grants up to \$100,000 are available for qualifying projects.

Emergency Grants: For projects that require immediate attention, emergency grants of up to \$30,000 are available. The project must prevent substantial damage or legal liability and it cannot be the result of inadequate operation and maintenance.

Project Planning Grants: These grants are available on an "open-cycle" basis and until the biennial appropriation is expended. Like the renewable resource grants, planning grants must provide for the conservation, management, development or preservation of renewable resources in Montana. The grants will pay for 50% of the engineering costs up to a maximum of \$10,000. Applicants must provide 50% of the cost of the study from non-grant sources.

Renewable Resource Loans: These loans are also available to state and local governments and their subdivisions. Loans are limited by the ability to repay within 20 years. Applicants may apply for a combination grant and loan with a single application.

Private Grants and Loans: For qualifying projects, private grants and loans are available to individuals or groups for qualifying projects. Funding limits for grants are \$5,000 or 25% of the total project costs, whichever is less. Loans are limited based on the applicant's documented ability to repay the loan, and loans must be secured with real property.

Evaluation Process – The Renewable Resource Grant applications are reviewed and ranked by DNRC's review team. Applications are ranked using a point system. The evaluation criteria include: financial feasibility, technical merit, management plan, environmental evaluation, and resource and citizen benefits. Based on this ranking, DNRC makes recommendations to the Montana Legislature. The legislature in turn makes the final decision on the ranking and funding of grants. Grant funds are available the following July, after a grant agreement is completed.

How to Apply – Applications are due by May 15th of each even-numbered year. Loan applications are accepted year-round and award is based on availability of funds. Applications may be obtained by contacting the Resource Development Bureau at DNRC or from our website. (Info. at display).

Types of Eligible Projects are:

- Public infrastructure projects for water supply, wastewater, and solid waste.
- Projects to construct or repair works for the purpose of irrigation, flood prevention, drainage, or the supply of water for public, domestic, industry, livestock, or fire prevention.
- Projects for the preservation or benefits of fish and wildlife, improvement of public recreation opportunities, and renewable energy projects.
- Projects for the protection of watersheds that help improve water quality; projects that control erosion, restore riparian zones, and help plan for the management of surface and ground water sources.

Geology of alluvial aquifers along the Clark Fork River from St. Regis to Missoula, Montana. *Larry N. Smith, Montana Bureau of Mines and Geology, Montana Tech of The University of Montana, Butte, MT 59701, 496-4379, lsmith@mtech.edu.* Alluvial aquifers in the Clark Fork River valley are the major sources of ground water in the greater Missoula region. My recent geologic mapping from Missoula to the Flathead River shows an alluvial sequence of gravels above, within, and below glacial-lake silt units. The positions of erosional and depositional landforms in the valley further suggest that most of the valley fill accumulated during multiple catastrophic glacial-lake drainage events of Glacial Lake Missoula.

Evidence of high-energy, rapidly changing depositional environments is present in stream cuts and gravel pits downstream of Huson, Montana. The deposits are stratified and contain locally extensive <2 foot-thick interbeds of laminated silty clay. One exposed paleovalley contains a possible basal debris flow of cobble- to very coarse boulder-sized clasts. Imbricated boulder-sized clasts and planar cross-stratified gravel, with set heights of 6 to >100 feet, display down-river and up-tributary paleocurrents, indicating a high-energy, high-volume alluvial environment. The contact between alluvium and overlying glacial-lake silt shows soft-sediment deformation, suggesting a rapid transition in depositional conditions. The glacial-lake silt unit is overlain by thin (mostly <6 foot) gravel deposits on strath terraces and fans, and alluvium in channels and floodplains.

Landforms within the narrow valley below Huson include bedrock channels, strath terraces, flats covered by glacial-lake silts, streamlined alluvial bars and eddy bars with crests 300–560 feet above river level, and scablands and gulch fills as high as 890 feet above river level. The large-scale landforms represent erosion and deposition by

catastrophic draining of one or more early, high stands of (~4200 foot) Glacial Lake Missoula. Glacial-lake silt seen along the valley, such as at the surface of the Missoula Valley, and silt within the Missoula Valley aquifer (unit 3 of Morgan, 1986) was deposited on top of earlier flood deposits. These silt units represent later and much lower lake stands than the subjacent flood deposits.

Morgan (1986) described the basin-fill sequence in the Missoula Valley aquifer as four units: (1) gray, green, brown, and red clay and silty sand; (2) sand and gravel; (3) tan to yellow silty clay; and (4) sand and gravel. Mapping and my interpretations of well-log data support correlating unit 1 with Tertiary sedimentary rocks. Unit 2 correlates with Glacial Lake Missoula flood deposits, fills a paleochannel in the Frenchtown area, and is the major aquifer in the Missoula Valley. Unit 3 was likely deposited as lake beds in a stand of Glacial Lake Missoula. Unit 4 includes flood deposits, outwash, and recent alluvium. If these correlations are correct, and if they correlate to well-dated multiple flood deposits in Washington and Oregon (Benito and O'Connor, 2003), the alluvial deposits in the Missoula Valley aquifer could have been entirely deposited by multiple floods between 19,000 and 13,000 ¹⁴C yr B.P.

References:

Benito, G., and O'Connor, J.E., 2003, Number and size of last-glacial Missoula floods in the Columbia River valley between the Pasco Basin, Washington, and Portland, Oregon: *Geological Society of America Bulletin*, 115, p, 624–638.

Morgan, W.F., 1986, *Geological interpretations of the alluvial aquifer, Missoula Basin, Montana: Missoula, University of Montana, B.S. thesis*, 31 p.

Groundwater modeling at Milltown Reservoir to predict impacts of dam removal. Brick, C.M., Clark Fork Coalition, P.O. Box 7593, Missoula MT 59807, (406) 542-0539, chris@clarkfork.org;

Woessner, W.W., Department of Geology, University of Montana, Missoula, MT 59812. We developed a groundwater model of the alluvial gravel aquifer in the Milltown area to predict potential impacts of dam and sediment removal on groundwater flow and river-aquifer interaction. The objectives of the model were to: (1) predict changes in groundwater flow direction, (2) estimate water level decline in the aquifer, (3) estimate changes in groundwater flux, and (4) investigate changes in groundwater-river interaction.

Existing data from numerous sources were used to first calibrate the model to known conditions for a single point in time (steady state for May 1993). Subsequently, the calibration was checked using reservoir drawdown data from August 2002. Model calibration is reasonably good, with a maximum difference between observed and calculated head of 3.7 ft, an average difference of 1.5 ft and an overall error of 2.9%

Simulation of dam and sediment removal includes two scenarios: the remedial design in EPA's proposed plan, and the restoration design proposed by the State NRD Program. The model predicts minor change in flow direction, mainly shifting from north to northwest within the reservoir area, and shifting slightly south in the area north of the dam. The calibrated model shows flow directions strongly controlled by bedrock topography, especially in the area downstream of the dam. Under the dam and sediment removal scenario, groundwater flux in the reservoir area would decrease about 1,000,000 ft³/day, and the water table would drop 5-6 feet in Milltown, 3-5 feet in West Riverside, and 2-3 feet in Piltzville. In the NRDP's restoration scenario, the river remains a losing stream, although the head difference between the river and the aquifer (about 3 feet) is within the uncertainty of the model. In the EPA's remediation scenario the model predicts that the river would become a gaining stream through the confluence. The remediation scenario was run using order-of-magnitude differences in riverbed conductivity to predict the maximum amount of water that the river might gain from the contaminated aquifer.

Watershed characterization of abandoned mined lands in upper Prickly Pear Creek, west-central Montana. Joanna Thamke, jothamke@usgs.gov, *Water Resources Discipline, Helena, Montana*;

Terry Klein, tklein@usgs.gov, *Geologic Discipline, Denver, Colorado*; David Harper, david_harper@usgs.gov, *Biological Resources Discipline, Jackson, Wyoming U.S. Geological Survey*.

The upper Prickly Pear Creek watershed encompasses the upstream 15 miles of Prickly Pear Creek, south of Helena, Montana. The headwaters of Prickly Pear Creek and its tributaries (Beavertown Creek, Clancy Creek, Dutchman Creek, Golconda Creek, Lump Gulch, Spring Creek, and Warm Springs Creek) are primarily in the Helena National Forest, whereas the central part of the watershed primarily is privately owned or Bureau of Land Management property. Four mining districts are present in the upper Prickly Pear Creek watershed: Alhambra, Clancy, Colorado, and Golconda. These districts contain polymetallic and precious-metal deposits that were mined beginning in the 1860s. Placer gold deposits in the large streams were extensively mined in the late 1800s and early 1900s.

Numerous prospects, adits, tailings piles, mills, dredge piles, and mines (mostly inactive) are located throughout the watershed.

As part of a cooperative effort with Federal land-management agencies, the U.S. Geological Survey (USGS) is using an integrated-science approach to characterize the upper Prickly Pear Creek watershed which includes the assessment of the sediment chemistry, water quality, and aquatic health. This integrated approach can be used to identify important pathways of metals movement, thereby guiding resource-management decisions. Watershed characterization in terms of geology, water, and biology will facilitate planning of restoration efforts and development of a monitoring plan to document cleanup effectiveness.

Data were collected during 2000-02 in the upper Prickly Pear Creek watershed to: (1) characterize the streambed sediment, water quality, and biology throughout the study area; (2) determine temporal variations in streambed sediment, water quality, and biology; (3) monitor diel variations in water quality; (4) determine metal loads and sources; (5) define the effects of metals on fish populations within the watershed, and (6) assess the fate of mining-related contaminants in a small unnamed reservoir in upper Lump Gulch. Sediment samples were collected at 77 streambed sites and lakebed sediment cores were collected at 6 sites. Routine water-quality samples were collected at 45 sites located throughout the watershed. Seventeen of the 45 sites were sampled synoptically to determine principal sources of metal loads to upper Prickly Pear Creek. At three sites, water-quality samples were collected at least hourly for diel (24-hour) investigations. Biologic samples—including biofilm, aquatic vegetation, benthic macroinvertebrates, and fish tissue—were collected in various combinations at 14 sites. Fish-survival experiments were conducted at four sites within the watershed.

Reports of data and interpretations by the USGS within the upper Prickly Pear Creek watershed are in various stages of publication. Routine water-quality data collected by the USGS within the watershed is available electronically on the internet at <http://waterdata.usgs.gov/mt/nwis>. A report containing data collected throughout the watershed during 2000 and a summary of the geology, mineral deposits, and previous work has been published electronically by Klein and others (2001). A report that compiled data collected throughout the watershed during 2001 also has been published electronically by Klein and others (2003). A report that compiles data collected during 2002 and characterizes the upper Prickly Pear Creek watershed is planned for electronic release in the near future. Two site-specific characterization studies within the watershed were conducted by the USGS: one in the Middle Fork Warm Springs Creek watershed and the other in the Frohner Meadows area. A report containing data collected during 2000-01 in the Frohner Meadows area has been published electronically by Klein and others (2003). A report describing the hydrology, water quality, and geochemistry of the Frohner Meadows area is in preparation. A report describing arsenic, metal loads, and source areas within the Middle Fork Warm Springs Creek watershed has been published by Cleasby and others (2003).

References:

- Cleasby, T.E., Thamke, J.N., and Nimick, D.A., 2003, Arsenic and metal loads and source areas in the Middle Fork Warm Springs Creek Watershed, Jefferson County, Montana, June 2001: U.S. Geological Survey Water-Resources Investigations Report 03-4153, 33 p.
- Klein, T.L., Cannon, M.R., and Fey, D.L., 2003, Hydrogeologic water-quality, and geochemical data for the Frohner Meadows area, upper Lump Gulch, Jefferson County, Montana: U.S. Geological Survey Open-File Report 03-248, 57 p. (Available on the internet at <http://pubs.usgs.gov/of/2003/ofr-03-248/>)
- Klein, T.L., Thamke, J.N., and Farag, A.M., eds., 2001, Water-quality, biology, and streambed sediment data and preliminary geochemical interpretations for streams in the upper Prickly Pear Creek watershed, Montana, 2000: U.S. Geological Survey, Geologic Division, Open-File Report 01-280, 59 p. Available on the internet at <http://pubs.usgs.gov/of/2001/ofr-01-0280/>
- Klein, T.L., Thamke, J.N., Harper, D.D., Farag, A.M., Nimick, D.A., and Fey, D.L., 2003, Water-quality, bed-sediment, and biological data for streams in the upper Prickly Pear Creek watershed, Montana, 2001: U.S. Geological Survey Open-File Report 03-032, 102 p. Available on the internet at <http://pubs.usgs.gov/of/2003/ofr-03-032/>

Natural stream channel design for Silver Bow Creek near Butte, Montana. *W. H. Bucher, G. Fischer, L. Cawfield, Maxim Technologies, Inc., Helena, Montana.* Mining wastes deposited along Silver Bow Creek downstream of Butte, Montana are being removed under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). The Record of Decision for this 26-mile long site requires that the floodplain and stream be reconstructed as a naturally functioning system to the extent possible. Maxim Technologies, Inc., and Mussetter Engineering, Inc., acting as the design contractor for the Montana Department of Environmental Quality, have designed a naturally

functioning stream and floodplain. The objective is to design a channel and floodplain that are initially stable under the expected range of flows yet will deform gradually after vegetation is reestablished. The design approach is based on fluvial geomorphological principles reinforced with extensive hydrologic, hydraulic, and sediment transport modeling. Important elements of the design are selection of the appropriate grades and stream cross-sections, selection of appropriate bed materials, analysis of vertical and lateral stability of the channel, floodplain design, and wetland design. Over the years the design has evolved to include more pools, greater channel variability, large woody debris in the banks, and shallow-water wetlands for improved aquatic habitat.

Characterization of the Judith River aquifer in Treasure and Yellowstone counties, Montana. *John L. Olson, 1300 N 27th St, Billings, MT 59101, 406-657-2929, Jolson@mtech.edu.* The Judith River aquifer is a source of ground water in central Yellowstone and northeastern Treasure counties. The aquifer consists of water saturated sandy shale and sandstone within the Judith River Formation. The total thickness of the Judith River Formation ranges from 250 to 350 feet. The aquifer is underlain by the Claggett Shale and where present is overlain by the Bearpaw Shale. The Judith River outcrops generally north and east of Billings and north of Laurel. Within the outcrop area ground water is encountered at depths ranging from 16 feet (in valleys) to 400 feet (along ridges). However, depths plunge to greater than 1,000 feet within 2 to 4 miles north of the outcrop. Regionally the Judith River aquifer dips 5 to 8 degrees towards the Bull Mountain Basin, which is centered north of Yellowstone County. The aquifer is also cut by the Lake Basin Fault Zone, which is a series of northeast trending faults.

Ground-water flow in the Judith River aquifer is generally directed towards the Yellowstone River valley with a gradient of 0.005 to 0.007 ft/ft. Locally ground-water flow paths may be complicated by vertical displacement of the aquifer in the Lake Basin Fault Zone. Most wells yield between 3 and 10 gallons per minute, which is adequate for household and stockwater uses but inadequate for municipal and irrigation purposes.

Ground water in the outcrop area consists of a calcium-magnesium-sulfate water with a dissolved constituent concentration of between 500 and 2,500 mg/l. Where the aquifer is covered by the Bearpaw shale, water quality deteriorates to a highly mineralized sodium-sulfate water with dissolved constituents concentrations between 3,000 to 5,000 mg/l. Water with dissolved constituent concentrations of over 3,000 mg/L is generally unsuitable for most uses without significant treatment.

Ground-water characterization of shallow aquifers in the Many Lakes Area, Flathead Valley, Montana.

Gregory W. Lorensen, Montana Bureau of Mines and Geology, Montana Tech of the University of Montana, 1300 West Park St. Butte, MT 59701, gwlorenson@mtech.edu. Nutrient loading to Flathead Lake is a growing concern in the Flathead Valley. One source of nutrient loading could be from shallow ground-water discharges. Nutrients from septic tanks and those applied to agricultural lands represent potential sources to shallow ground water. As more houses are built over shallow aquifers and more nutrients are applied to agricultural land, nutrient loading could increase. This study focused on the shallow aquifer below the Many Lakes Area east of Kalispell, Montana. The work was done in conjunction with a Montana Bureau of Mines and Geology investigation of shallow ground water in the selected areas of the Flathead Basin.

Two cross sections were created using lithologic descriptions from well logs. The cross sections indicate that the subsurface geology in this area is complex because the area is underlain by heterogeneous glacial deposits. Most of the wells in the shallow aquifer were less than 70 ft. During June 2002, 24 wells and 2 springs located in the Many Lakes area, northwest of Bigfork, were inventoried. Water levels and field parameters, including specific conductance, pH, field nitrate and nitrite, redox, and temperature were measured at each site. The water-level measurements were used to establish the direction of ground-water flow and helped determine if water from the shallow aquifer could actually reach the Flathead River. Field chemistry data were used to characterize the water quality in the shallow aquifer.

Maps of potentiometric surface, distribution of specific conductance, and nitrate were compiled. Ground water in the area flows to the west, from the mountains towards the Flathead River (which flows into Flathead Lake). The overall ground-water chemistry of the area is fairly uniform and shows the ground water to be low in dissolved solids. The specific conductance of the aquifer ranges from 200 to 546 uS/cm with an average around 350 uS/cm. Field nitrate concentrations ranged from non-detectable to 7.5 mg/L with an average of 1.0 mg/L.

Development of an updated microbial standard for Montana's surface waters. *David L. Feldman and Randall Apfelbeck, Montana Department of Environmental Quality.* In 1984, the United States Environmental Protection Agency published its recommendation to states for freshwater microbial standards. This document updated human

health standards in recreational freshwater from the original set that were published in 1968. The new microbial standard allows states a choice between *Escherichia coli* and Enterococci as indicator of other microbes detrimental to human health that are found in water. The Montana Department of Environmental Quality prefers to use the *E. coli* standard with a geometric mean of 126 colony-forming units/ 100ml of water sample collected. The Department believes that this level will protect the maximum number of recreational swimmers, waders and other water users in Montana's waters. The Coli-ert® system was used to evaluate microbial concentrations in the field. After conducting a statewide survey of *E. coli* concentrations during summer 2003, the highest *E. coli* concentration was measured at the Musselshell River at Mosby, MT, (2419.6 cfu/100ml) and the lowest concentration was found at the Blackfoot River (1.0 cfu/100ml). The statewide geometric mean for *E. coli* concentrations was 39.8 cfu/100ml in this study. The Department is planning to replace the current fecal coliform standard to the *E. coli* in 2004. Future surveys may be used to better understand the range of *E. coli* concentrations found in Montana.

A continued study of the hydrogeologic characterization of AMD production along Belt Creek near Belt, Montana.

Shawn Reddish, 1300N 27th St Billings, MT 59101, 657-2702, sreddish@mtech.edu.

Decades of underground coal mining have resulted in acid mine drainage (AMD), which is contaminating ground-water and surface-water resources at Belt. The Anaconda mine is the largest mine in the area and was developed in 1895. Coal was extracted from a 6-foot thick seam in the Morrison Formation. Although mining ended about 50 years ago, water with a pH of 2.94 is still issuing from mine workings near Belt. The acid mine drainage is lowering the pH of Belt Creek and adding metals to it.

Water levels at 15 wells and springs are measured monthly to monitor the fluctuations of local aquifers. Several of these wells and springs will be sampled for tritium and then chlorofluorocarbons to determine the age of the water. By determining the age of water in the mine workings, methods can be developed to reduce recharge to the acid producing mine workings.

Stream flows at 11 sites are also measured monthly in the study area. Differences in flows can determine the gain or losses of surface-water to local aquifers. Field parameters including measuring specific conductivity, pH, oxidation-reduction, and dissolved oxygen are also taken at each site.

There are also monitors recording the flow and metals discharging from the mine. The flow rate is around 0.28 cubic feet per second (cfs). Other research in the area in 1994-95 stated the flow averaged 0.3 cfs. Discharge out of the mine appears to be relatively steady. However, large rain events do cause the discharge to rise significantly indicating a local source of recharge.