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# PROCEEDINGS

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for

## ***Montana's Water Outlook: CURRENT AND FUTURE CHALLENGES***

**21st Annual Meeting of the Montana Section of the American Water Resources Association**

Helena, Montana  
October 4th and 5th, 2004  
Red Lion Colonial Inn



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

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**THANKS TO ALL WHO MAKE THIS EVENT POSSIBLE!**

- **The 2004 AWRA Officers (pictured below)**

*David Salo, President, Beaverhead-Deerlodge National Forest*

*Chuck Dalby, Vice-President, Montana Department of Natural Resources and Conservation*

*Kate McDonald, Treasurer, Montana Bureau of Mines and Geology*

*May Mace, Montana Section Executive Secretary*



**In order, here's Chuck, May, Katie and Dave**

- **Montana Water Center, Meeting Sponsorship and Coordination**

***The Montana Water Center***

*Susan Higgins, Sue Faber and Molly Boucher, project managers*

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

**American Water Resources Association Montana Section**  
**21<sup>st</sup> Annual Meeting**  
**MONTANA'S WATER OUTLOOK: CURRENT AND FUTURE CHALLENGES**

**AGENDA**

("S" indicates a student presentation)

**MONDAY, OCTOBER 4, 2004**

**7:00 am – 5:00 pm    REGISTRATION, Red Lion Hotel Lobby, Helena**

**8:00 am**                    Meet in Red Lion Colonial lobby for optional **Field Trip** to burn areas near Canyon Ferry. Please bring a hard hat, boots and appropriate outdoor gear. Bo Stuart, Hydrologist with the Helena National Forest, and Chuck Parrett, Hydrologist with USGS, will be our tour guides.

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

**SESSION 1 (Plenary). CHALLENGES TO MONTANA'S WATER FUTURE, Ballroom**

**1:00 pm**                    -- Welcome and Introductions, David Salo, AWRA Montana Section President  
-- Water Center Welcome, Liz Galli-Noble, Assistant Director for Research  
-- Logistics and Announcements, Chuck Dalby, AWRA Section Vice President

**Moderator:    Susan Higgins, Montana Water Center**

**1:30 pm**                    Jane Jelinski, Director, MSU Local Government Center. *Challenges faced by local decision-makers making land-use and water-use findings.*

**2:05 pm**                    John Wheaton, Research Hydrologist, Montana Bureau of Mines and Geology. *Ground-water issues associated with coalbed methane in the Powder River Basin, Montana.*

**2:40 pm**                    **Break**

**Moderator:    Kate Miller, Montana Bureau of Mines and Geology**

**3:00 pm**                    **A Few Moments to Recognize the 2004 WATER LEGEND, then**

Thomas Patton, Montana Bureau of Mines and Geology, Butte. *Isolating long-term trends in water-level and climate records as a tool to evaluate the impact of climate on water wells.*

**3:30 pm**                    Mike Roberts, Montana Department of Natural Resources and Conservation, Helena. *Water management in the upper Big Hole.*

**4:00 pm**                    Jim Robinson and Chuck Dalby, Montana Department of Natural Resources and Conservation, Helena. *Historic channel and floodplain modifications of the upper Yellowstone River.*

- 4:30 pm** Chuck Dalby, Jim Robinson, and Jane Horton, Department of Natural Resources and Conservation, Helena. *Estimation of historic effects of channel modification on the upper Yellowstone River using a morphology-based sediment budget.*
- 5:00 pm** **Adjourn**
- 5:30 pm** **Poster Session:** Natatorium. Beer, wine, lemonade and appetizers on the house. Entertainment from Helena's acoustic group, "Irish Stew"
- 7:00 pm** **Banquet, State Capitol Room:** Western Barbeque (ticket required; options for vegetarians) Afterwards: Special announcements from the officers, photo contest (to include INCREDIBLE prizes for all who submit photos), and a slide show presentation on water management in MADAGASCAR. Also: View May Mace's artwork for raffle, proceeds to benefit AWRA Montana Section!

**TUESDAY, OCTOBER 5, 2004**

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

**Moderator: Joanna Thamke,  
U.S. Geological Survey, Helena**

**8:00 am** Investigation of microbial ecology structure and function on coalbed aquifers: Powder River Basin, Montana. Patrick Ball, University of Montana

**8:20 am S** Fisher Creek, MT and Rio Agrio, Argentina: A geochemical comparison of a mining-impacted stream in Montana with a geogenically-derived acidic river in Patagonia. Steve Parker, Montana Tech.

**8:40 am S** Geochemistry and stable isotope composition of H<sub>2</sub>S-rich mine waters in Butte, Montana: applications to bioremediation in the Berkeley Pit-Lake. Amber Henne and Chris Gammons, Montana Tech, and Simon Poulson, University of Nevada.

**9:00 am S** Algal bioremediation of the Berkeley Pit lake system: an in-situ test using limnocorrals. Grant Mitman and Nicholas Tucci, Montana Tech.

**9:20 am** Vacant, then break at **9:40**

**SESSION 3 (Concurrent).  
GROUND-WATER STUDIES  
Legislative/Judicial Room**

**Moderator: John LaFave, Montana Bureau of  
Mines and Geology**

**8:00 am** Bitterroot Valley ground-water quality. John LaFave, Montana Bureau of Mines and Geology.

**8:20 am S** Predicting ground-water nitrate concentration from land use. Kristin Gardner, Montana State University, and Richard Vogel, Tufts University.

**8:40 am** Drinking-water wells and septic education modules for small acreage (ranchette) owners. Tammy Crone, Gallatin Water Quality District.

**9:00 am S** Madison aquifer discharge to the Gallatin River and the Yellowstone National Park controlled ground-water area. Mark Schaffer, Montana State University.

**9:20 am** Meadowlark Park wetlands restoration project. Jenny Erickson, Montana Bureau of Mines and Geology.

**9:40 Break**

**SESSION 4 (Concurrent).  
FLOODPLAIN/CHANNEL MANAGEMENT  
Executive Room**

**Moderator: Mike McLane, Department of Natural Resources and Conservation**

**10:00 am** S Evaluation of riparian health assessment methods to assess conditions of perennial streams in two different geological provinces in the state of Montana. Travis Miller, Montana State University.

**10:20 am** Intermountain spring creeks: their conservation and restoration. Scott E. Gillilan, Gillilan Associates, Inc., Bozeman.

**10:40 am** Two-dimensional flood-plain modeling of Tenmile Creek near Helena, Montana. Katherine Chase, USGS, Helena.

**11:00 am** Determination of channel-morphology characteristics, bankfull discharge, and various design-peak discharges in western Montana. Sean Lawlor, USGS, Helena.

**11:20 am** Classification and quality criteria for streams of Montana's northern glaciated plains. Michael Suplee, Montana Department of Environmental Quality, and Vicki Watson, University of Montana.

**11:40 am** S Anabranch reaches on the lower Yellowstone River. Ryan McLane, Montana State University.

**SESSION 5 (Concurrent).  
SURFACE WATER QUALITY  
Legislative/Judicial Room**

**Moderator: Tammy Crone, Gallatin Local Water Quality District**

**10:00 am** Effect of alternative silvicultural treatments on snow accumulation in lodgepole pine stands, Montana. Scott Woods, Robert Ahl and Jason Sappington, University of Montana.

**10:20 am** Sediment contributions to the St. Regis River due to winter traction sanding along Interstate 90 at Lookout Pass. Jeff Dunn, Land & Water Consulting, Bozeman.

**10:40 am** S Travel distance and volume of forest road sediment below drivable drain dips in belt and glacial till parent materials in western Montana. Brian Parker, University of Montana.

**11:00 am** S Impacts of land use and cover change in soil hydraulic properties, Rondonia, Brazil. Katharine Schultz, Brian McGlynn and Helmut Elsenbeer, Montana State University.

**11:20 am** A computer program for estimating instream travel time and concentrations for potential contaminants from spills along the Yellowstone River. Peter McCarthy, USGS, Helena.

**11:40 am** Temperature, plants and oxygen: how does season affect constructed wetland performance? Otto Stein and Paul Hook, Montana State University.

**CLOSING PLENARY, Doors open into Ballroom**

**12:00** Announcement of Next Year's Officers, Student Awards, Raffle Winner, etc. . . .

**12:15 pm** Adjourn – Happy Trails!

**POSTER SESSION, MONDAY EVENING, OCTOBER 4, POOLSIDE**  
**"S" indicates student poster**

1. **Ground-water quality in Lockwood.** Rye Svingen, Montana Bureau of Mines and Geology.
2. **Poster by Justin Brown, Montana Bureau of Mines and Geology.**
3. **Age dating of the geologic units in the Belt, Montana area.** Shawn Reddish, Montana Bureau of Mines and Geology.
4. **Water levels and nitrate in Warne Heights, upper Summit Valley, Silver Bow County, Montana: a case study of bedrock aquifer vulnerability.** Camela Carstarphen and John LaFave. Montana Bureau of Mines and Geology.
5. **S Water quality survey of nitrate levels and coliform/coliphage presence in Helena Valley compared with regional geology, land usage, and well depth.** Emma Swingle and Sam Alvey, Carroll College, Helena, and Kathy Moore, Lewis and Clark County Water Quality Protection District.
6. **Estimated water use in Montana in 2000.** Michael Cannon, USGS.
7. **S Groundwater-surface water exchange across alpine-valley transition.** Timothy Covino and Brian McGlynn, Montana State University, and Richard Sojda and Brian Edwards, USGS Northern Rockies Science Center.
8. **Geochemical constraints on selection of coalbed methane product water strategies.** Ronald Drake, Drake Engineering.
9. **S Assessment of pre-re-naturalized groundwater exchange in two stream channels and riparian zones, Jocko Valley, western Montana.** Aaron Fiaschetti, University of Montana.
10. **The Wild Fish Habitat Initiative: a new resource for fish habitat restoration efforts.** Liz Galli-Noble and Molly Boucher, Montana Water Center.
11. **Feasibility study of implementing EPA's proposed ground water rule (GWR) sampling requirements for fecal indicators.** Steve Kilbreath and Joe Meek, Montana Department of Environmental Quality, and Kathy Moore, Lewis and Clark County Water Quality Protection District.
12. **Ground-water availability by depth and quality criteria in Yellowstone and Treasure counties, Montana.** John Olson, Montana Bureau of Mines and Geology.
13. **Treefall patterns in Western Montana riparian areas, and implications for woody debris recruitment modeling.** Ron Steiner and Jeff Light, Plum Creek Timber Company.
14. **S Impact of land use change on stream-water quality, Big Sky, Montana.** Kristin Gardner, Montana State University.
15. **Interactive CD-ROM training for water operations.** Ken Glynn, Montana Water Center.
16. **Whirling disease outreach.** Amy Rose, Montana Water Center.
17. **An aerial photo comparison of hailstone lake hydrology since 1941.** Jay Hanson, Montana Bureau of Mines and Geology.
18. **Rainfall events and their effect on severely burned areas of western Montana following the forest fires of 2000.** Ray Nickless, National Weather Service, Missoula.
19. **HACCP approach for potable water supply development from urban stormwater and saline aquifer.** James Swierc, University of Montana; and John Van Leeuwen, Peter Dillon, and Paul Pavelik, CSIRO Land and Water, Adelaide, Australia.
20. **Hydrology of alluvial gravels.** Dale Engstrom, University of Montana.
21. **S Collection of baseline groundwater data in Northern Park County.** Dixie Schopp and John Olson, Montana Tech, Butte.

*Challenges faced by local decision-makers: making land-use and water-use findings.* Jane Jelinski, Director, Local Government Center, Montana State University. Montana's local government officials are required to make land use decisions based on Montana's Subdivision and Platting Act [76-3-101], Montana's Planning and Zoning Acts [76-1-101], the Flood Plain and Floodway Management Act [76-5-301] and the Sanitation in Subdivisions Act [76-4-101]. These statutes are complex and in some cases, contradictory.

Local government officials are prohibited from adopting land use rules that are more stringent than state law unless they make a finding that the local standard "is achievable under current technology," [76-3-511(b)]. The written finding "must reference information and peer-reviewed scientific studies contained in the record that forms the basis for the governing body's conclusion. The written finding must also include information from the hearing record regarding the costs to the regulated community that are directly attributable to the proposed local standard or requirement." [76-3-511(3)].

This would all be well and good if local elected officials 1) were scientists, or 2) had scientists on staff to advise them. Obviously, this is not the case. The information that local elected officials rely on is provided by the developer's hired engineer, planner, lawyer, or consultant.

The challenge for the scientific community then, is to find a way to provide clear, credible and unbiased information to decision-makers in a format that a layman can understand, and can access in an efficient, time sensitive manner. Without this assistance, how is a city or county official going to determine whether a condition of approval is "achievable under current technology," or what it might cost, or how to locate and understand "peer-reviewed scientific studies?"

This session will be an informal discussion of the challenges local elected officials encounter while making land use decisions, and how water professionals can develop and communicate scientific information to inform those decisions.

*Ground-water issues associated with coalbed methane in the Powder River Basin, Montana.* John Wheaton, Montana Bureau of Mines and Geology, 1300 North 27<sup>th</sup> Street, Billings, Montana 59101, 406-657-2629, [jwheaton@mtech.edu](mailto:jwheaton@mtech.edu). Production of coalbed methane is a growing industry in many coal-bearing regions of the United States, and particularly in the Powder River Basin of Montana and Wyoming. This growth has been prompted by two features, (1) shallow coal beds that are inexpensive to drill, and (2) good quality water contained in the coals, enabling inexpensive disposal of water by direct release at the surface in the initially developed areas of the basin. Coalbed methane resources in Montana are considerably less than those in our neighboring state of Wyoming, where production began in 1987 and has rapidly grown since 1999. Production in Montana has not seen proportionate growth largely because of a less favorable geologic setting and concerns over the effects of water withdrawal and disposal.

Methane molecules are held in the cleats (small fractures) and micro-pores of coal, by weak physical bonds and hydrostatic pressure of water in the coalbed. Gas production is accomplished by pumping water from the coalbed; this reduces the hydrostatic pressure, allowing the methane to migrate from the coal into the water stream flowing to the well, where it separates from the water. This is a simple and clean process, however, the extraction and subsequent discharge of large volumes of water from coal beds has raised significant concerns.

Coal seams are vital aquifers for the agricultural community in southeastern Montana and a reduction in available ground-water resources is one part of coalbed-methane production. Ground-water monitoring begun by the Montana Bureau of Mines and Geology in the 1970's enables

prediction and modeling of many of the changes that will happen in the aquifers. Potential effects associated with water chemistry, water disposal, and other factors are being evaluated by the Bureau and numerous other governmental, academic, and industry groups. Advance planning accompanied by continual monitoring are critical to reach solutions agreeable to most parties involved.

*Isolating long-term trends in water-level and climate records as a tool to evaluate the impact of climate on water wells.* Thomas Patton, Senior Research Hydrogeologist, Montana Bureau of Mines and Geology, 1300 West Park Street, Butte, MT 59701, (406) 496-4153, [tpatton@mtech.edu](mailto:tpatton@mtech.edu). Time series of water-level measurements show changes in storage or pressure in aquifers near the measured wells. Climate is a primary control on ground-water levels, however when a water-level record is compared to climatic data, it can be difficult to link long-term trends in the water-level data to long-term trends in precipitation because other factors may affect water levels such as measurement error, pumping in the well, and downward trends caused by general over-pumping of the aquifer. Singular-Spectrum Analysis (SSA) helps isolate components such as 'slowly varying trends' (i.e. long-term water-level declines or recoveries caused by development; 6-10 year climate patterns), cyclic signals (i.e. annual water-level cycles caused by pumping and recovery; climate seasonality), and unstructured noise in water-level or climate records. Water-level records with periods of 20-30 years from statewide monitoring network wells in the Little Bitterroot Valley in northwest Montana display a slight long-term downward trend, annual changes related to pumping, and climatic patterns. Using SSA, long-term trends can be extracted from these water-level records for comparison to long-term trends in the climate record. Climate-controlled water-level change in the Little Bitterroot area corresponds best with Standardized Precipitation Index (SPI) values calculated for 30- to 36-month accumulation periods. The comparison indicates that how wet or dry it has been during the preceding 30 months may be controlling climate-based long-term upward or downward movement of water levels in these wells. If a general relationship between climate-related trends in ground-water levels and the wetness or dryness of the climate as measured by indices such as the SPI can be shown, it may be possible to use easily generated indices such as the SPI to predict the general direction of water-level change in wells.

*Water management in the Upper Big Hole.* Mike Roberts, Hydrologist, Montana Department of Natural Resources and Conservation, Helena, Montana. The Big Hole River Basin above Wisdom supports approximately 90,000 acres of irrigation. It also provides habitat to the last stronghold of the fluvial Arctic grayling. Drought and recent irrigation timing changes have resulted in extremely low flows in the reaches of the Big Hole River most important to grayling survival. In order for irrigation to continue and the grayling to survive, cooperative efforts among water users, the Big Hole Watershed Committee, and State and Federal agencies is critical. As well, it is imperative that the distribution of surface and groundwater resources be understood and quantified. Montana Department of Natural Resources and Conservation hydrologists have spent the past several years assessing surface water distribution and irrigation practices in the upper Big Hole in an effort to provide a technical understanding of water resources to all interested parties. To facilitate streamflow monitoring, a network of continuous recorders and staff gages was established. To identify natural and artificial gains and losses in river flow, synoptic flow measurement runs were conducted throughout the irrigation season. Monitoring results have provided information pertaining to the timing and magnitude of runoff and irrigation diversion relative to instream flows in reaches of the river critical to the survival of the grayling. This information is being used to develop and implement water saving measures with individual water users as well as provide a basis for basin-wide water management planning.

***Historic channel and floodplain modifications of the upper Yellowstone River. Jim Robinson<sup>1</sup> and Chuck Dalby<sup>2</sup>.*** The relationship between geomorphic channel type and channel and floodplain modifications was examined by integrating geomorphic channel classification (i.e., modified Montgomery-Buffington) with an historic inventory of linear floodplain constrictions (i.e., dikes, levees, road prisms, etc.) and channel training structures (i.e., riprap, jetties, barbs, etc.). Historic aerial photos (1954, 1973, 1999) were examined in stereo for the channel and adjacent floodplain extending 87 river miles from Gardiner, MT to Springdale, MT; channel and floodplain modifications were mapped on corresponding channel mosaics according to eight subreaches. Dikes, levees and road prisms increased 265 percent (from 34, 700 to 92,250 feet) between 1954 and 1999, riprap increased 400 percent (from 27,400 to 111,260 feet), while point structures, (i.e., barbs and jetties) increased 600 percent (from 47 to 292).

The spatial distribution of present day structures was grouped and examined according to geomorphic channel type. Results show a correlation between frequency of structures and channel type: *anabranched/braided*, *anabranched*, and *pool-riffle* channels together contain that largest concentration of dikes, riprap and barbs - 76 percent, 71 percent and 81 percent, respectively within 51 percent of the total channel length. The most abundant channel type, *plane bed*, common in the reaches upstream of Pine Creek and downstream from Livingston, also contains significant percentages of the total amounts of riprap and barbs - 22.6 percent and 15.5 percent respectively. Channel segments exhibiting forced morphologies (i.e., conversion from one channel type to another, either from human intervention or natural conditions) comprise 17 miles (19%) of the entire 87-mile long study segment. Channel-type conversions typically occur in the *anabranched* or *anabranched/braided* segments, where channel training structures or bedrock exposures force either a *pool-riffle* or *plane bed* morphology. These forced morphologies are associated with 76 percent of the linear floodplain structures (dikes), 50 percent of the linear channel training structures (riprap), and 47 percent of the point features (barbs). Most of the conversions occur in developed areas - either through the Livingston urban segment or as a result of transportation infrastructure.

***Estimation of historic effects of channel modification on the upper Yellowstone River using a morphology-based sediment budget. Chuck Dalby,<sup>3</sup> Jim Robinson<sup>4</sup>, Jane Horton<sup>5</sup>.*** To better understand geomorphic effects of historic channel modification (e.g. levees, riprap, jetties), we developed morphology-based "gravel" sediment budgets for segments of the upper Yellowstone River with varying amounts of lateral channel constraints. Objectives of the analysis were to: 1) compare the relative geomorphic effects of near-100 year floods occurring in 1974 and 1996-97, 2) identify effects of lateral constraint on channel stability (aggradation/degradation trends), and 3) define contemporary (1948 to 1999) rates of flood-plain turnover for different geomorphic channel types.

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Data collected through stereo-photo interpretation and reconnaissance-level fieldwork were used to map bankfull and low-water planimetric features (e.g. channel bankline, gravel bars, islands) on partially rectified, digital photo mosaics of the channel. Successive traces of historic channel features (1948, 1973, 1974 and 1999) were then analyzed in a GIS to estimate areas (and volumes where possible) of erosion, deposition or no change. Study segments were divided into cells encompassing approximately one meander wavelength, and estimates of total erosion and deposition, and net change, were used to assess channel stability trends over time.

Preliminary results indicate that flood-plain turnover rates and lateral channel stability vary as a function of geomorphic channel type. Also, unmodified channel segments display the highest turnover rates, with values decreasing along a gradient from the least stable (anabranching-braided) to most stable (plane bed and cascade) channel type. Turnover rates in laterally constrained channels vary as a function of the amount, duration and effectiveness of lateral constraint, with rates in the most heavily constrained channel segments similar to those of unmodified plane-bed and cascade channels. Channel response to confinement includes local incision, though this is generally limited by the coarse, cobble-boulder bed-material. In addition, the influx of coarse bed-material during the 1996-97 floods partially masks long-term channel response to lateral constraint.

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#### CONCURRENT SESSION 2, Tuesday, October 5, 2004: *MINING AND WATER QUALITY*

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*Investigation of microbial ecology structure and function in coalbed aquifers: Powder River Basin, Montana.* Patrick Ball, University of Montana. Coalbed methane (CBM) is a potential source of fuel in many coal rich areas such as the Powder River Basin (PRB) located at the northeastern Wyoming and southeastern Montana border. Demand for this natural resource has sent many gas producers to the region where vast amounts of the nation's potential reserves are located.

Once assumed to be important only in the early stages of development of coal (early stage coalification), it is now recognized that the microbial community has a significant impact on the production of secondary biogenic methane. These findings are based primarily on isotopic fractionation studies of carbon species present in gases originating from coal. The microbial communities responsible for biogenic methane production (methanogenesis) from substrates such as hydrogen, acetate, formate and CO<sub>2</sub> in subsurface coalbed seams are of intense interest. These microbial consortia are a crucial component of enhanced and prolonged (i.e. sustainable) methane generation from preformed coalbeds. Additional impacts of this system arise as the search for strategies to reduce atmospheric CO<sub>2</sub> levels continues. One possible long-term solution may be subsurface sequestration of CO<sub>2</sub> (a major greenhouse gas) and eventual conversion to recoverable CH<sub>4</sub> by autotrophic biogenesis. In order to engineer and exploit sustainable methane recovery, we must develop a more complete understanding of the microbial ecology of CBM environments. An important initial step in this process is to identify the types, abundance, and activities of the microbial populations present. From this information, we can construct a conceptual model of the functioning of the microbial community relevant to methane production and develop sound strategies for management of CBM resources.

Through the use of molecular methods and a fundamental understanding of ecological concepts present between diversity, abundance and activity of microbial species, delineating their functional roles in complex environments is possible. In order to obtain this, surveys aimed to address such questions must be conducted in contextual experimental structure. Culture-independent studies designed to correlate changes in microbial community structure and function within complex ecosystems due to environmental perturbations, can enhance our understanding of the links between the microbial community ecology and their functional potential and stability.

*Fisher Creek, MT and Rio Agrio, Argentina: A geochemical comparison of a mining impacted stream in Montana with a geogenically derived acidic river in Patagonia.* Stephen Parker, Montana Tech of the University of Montana. This work was completed in collaboration with Chris Gammons, Montana Tech, and David Nimick, USGS, Helena, MT. Fisher Creek is within the New World Mining District and is about 10 km from the northeast corner of Yellowstone National Park. Acid rock drainage from natural and mining related sources yields low pH waters that are high in metals concentrations. The principal mine drainage contribution to Fisher Creek comes from the Glengarry adit, near the headwaters of the watershed. Streambed surfaces are stained with the red-orange coloration indicative of the precipitation of ferric oxy-hydroxides. There are also large ferricrete deposits which indicate that natural mineral weathering has contributed acidic iron loaded water to this drainage prior to mining activities. The pH values increase progressively downstream from the mining related point sources, indicating that neutralization takes place as the waters move down gradient from its source due to tributary and groundwater inflow. Extensive investigations along Fisher Creek took place during the summers of 2002 and 2003.

The Rio Agrio (sour river) is located near Caviahue, Argentina and its source waters are derived from acidic, metals loaded geothermal springs on the flanks of the Copahue Volcano. The source water is about 80 °C and pH 1.5 and contains about 2300 ppm of iron, 200 ppm Al, 5 ppm As, 5 ppm Zn and about 14000 ppm of sulfate. This water forms the acidic Rio Agrio which flows into Lago Caviahue, a large lake with a pH of about 2.6 and a depth of 90m. The lower Rio Agrio after leaving the lake flows downstream and at the same time becomes progressively neutralized. Red-brown iron crusts and ferricretes are evident along the river, similar to the pattern seen in many mining impacted streams of the Rocky Mountain West. The Rio Agrio-Lago Caviahue system has a well established biological community including a variety of algae and microbes that have colonized these acidic waters. Many researchers have come to the Caviahue area to use the Rio Agrio system as an interesting laboratory for studying organisms in extreme environments. Investigations along several reaches of Rio Agrio took place in March of 2004 while attending a conference in Caviahue on "Geogenically Acidic Waters".

This presentation will compare and contrast some of the geochemistry of the Fisher Creek and Rio Agrio aquatic systems. There are a number of similarities between these two acidic, metals loaded systems despite the differences in the origins of their source waters. One of the principal geochemical differences between the two systems is the lack of detectable copper concentrations in Rio Agrio. In Fisher Creek the average dissolved Cu concentration in the pH 3.5 reach is about 350 ppb and in the lower section at a pH of about 6.8 the average Cu concentration was about 100 ppb. These concentrations are well above the aquatic life standard and there is very little visible evidence of aquatic plants. At Rio Agrio in the pH 3.2 stretch studied there are ample algae growing on all surfaces and even ducks diving in the water.

*Geochemistry and stable isotope composition of  $H_2S$ -rich mine waters in Butte, Montana: applications to bioremediation of the Berkeley Pit-lake.* Amber Henne<sup>1,\*</sup>, Christopher H. Gammons<sup>1</sup>, Simon Poulsen<sup>2</sup>

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Groundwater being pumped from the flooded West Camp underground mine workings of Butte, Montana, is elevated in hydrogen sulfide ( $H_2S$ ), has a circum-neutral pH, and has high arsenic but otherwise low metal concentrations. The daily flux of  $H_2S$  and As pumped from the extraction well are each estimated at roughly 0.1 kg. Isotopic analysis of coexisting aqueous sulfide and sulfate confirms that the  $H_2S$  was produced by sulfate-reducing bacteria (SRB). The  $H_2S$ -rich mine water is not confined to the immediate vicinity of the extraction well, but is also present in flooded mine

shafts up to 1 km away. This implies that SRB are well-established throughout a large portion of the flooded West Camp mine complex. The West Camp is separated by a groundwater divide from the more extensive East Camp flooded mine complex, which currently drains to the Berkeley pit-lake. None of the East Camp wells sampled to date are elevated in H<sub>2</sub>S, implying that SRB are scarce or absent.

The West Camp mine waters are close to equilibrium saturation with amorphous FeS, amorphous ZnS, siderite, rhodochrosite, calcite, and goethite, but are undersaturated with orpiment (As<sub>2</sub>S<sub>3</sub>). The higher solubility of orpiment relative to other metal sulfides allows concentrations of dissolved arsenic (~ 100 µg/L) that are well above human health standards. Concentrations of dissolved organic carbon, nitrate, and ammonia are near or below detection limits, whereas phosphate is low, but detectable. Consistent with this nutrient-starved environment, concentrations of total bacteria, heterotrophic bacteria, and SRB in the water being pumped from the extraction well are low. It is envisioned that most of the SRB responsible for H<sub>2</sub>S production are present as biofilms attached to the flooded mine walls, as has recently been described from a flooded Pb-Zn mine in Wisconsin (Labrenz et al., 2000: Science, 290, 1744-1747).

The West Camp waters differ markedly from the acidic and heavy metal-rich mine waters of the nearby acidic Berkeley pit-lake. Although establishment of a viable population of SRB in the Berkeley pit-lake would improve its water quality (as has been documented in acidic pit-lakes in Germany), this is considered an unlikely event. At the present time, the low pH (~ 2.6), high metal concentration (Zn ~ 600 mg/L; Cu ~ 150 mg/L), and abundance of ferric iron in both dissolved and solid form make the deep pit-lake inhospitable to SRB. These conditions are unlikely to change in the future, barring a drastic change in how the pit is managed (for example, addition of massive quantities of lime or organic carbon, or in-pit disposal of alkaline mill tailings).

*Algal bioremediation of the Berkeley Pit lake system: an in-situ test using limnocorrals.* Grant G. Mitman PhD. ([GMitman@mtech.edu](mailto:GMitman@mtech.edu), Montana Tech, (406) 490-3177, Dept. of Biology, 1300 W. Park St, Butte MT, 59701) and Nicholas J. Tucci ([NJTucci@mtech.edu](mailto:NJTucci@mtech.edu), Montana Tech, (406) 490-5041, 1300 W. Park St., Butte MT, 59701) Through various metabolic, physiological, and biochemical processes, algae have the potential to reduce soluble metal ions in acid mine waters. During laboratory experimentation, conducted at Montana Tech of The University of Montana, it has been demonstrated that algal species endemic to the Berkeley Pit Lake System have the potential to reduce soluble metal concentrations as much as 50 percent in small tissue culture flasks and Imhoff cones. The Berkeley Pit Lake is located in Butte, Montana, near the headwaters of one of the largest U.S. Environmental Protection Agency Superfund sites in the United States. The Berkeley Pit is a former open-pit copper mine that operated from 1955 and until 1982. In 1982, the mine's dewatering pumps were shut off, and the open pit began filling with acidic groundwater. The pit has a lateral extent of approximately 1.8 kilometers (km) by 1.4 km across the rim, and is more than 542 meters deep. The water is 275 meter (m) deep, and is rising at a rate of about 8 m/year, representing roughly 1140 billion liters of pH 2.7, metal laden, contaminated water. To properly test bioremediation potential of algae in the Berkeley Pit system, an In-Situ experiment will be performed in early June 2004, using nine, 1m--by--3m polyethylene acid/metal resistant limnocorrals.

Limnocorrals are an enclosed experimental apparatus, open at the top and closed at the bottom, used to simulate actual physical, chemical, and biological conditions of the lake environment within a controlled volume of water, allowing for biomanipulation of one to several aspects of the natural environment. Manipulation in this experiment will consist of nitrification of limnocorrals using nitrate and phosphate concentrations to stimulate algal growth. It is hypothesized that if properly nitrified, dissolved metal concentrations in the Berkeley Pit will decrease due to increasing algal biomass. The primary goal of this project is to set up a replicate set of three limnocorrals, using nitrification as variable. Specifically, one will be nitrified with 5 mg/L nitrate and 2 mg/L Phosphate, one set with 10mg/L nitrate and 4mg/L phosphate, and one set used as a control. This

set of three will be replicated three times (nine limnocorrals total). To document the importance of algal nitrification in bioremediation effectiveness, the nitrified limnocorrals will be compared to non-nitrified limnocorrals and open water. To measure and document conditions during the experiment, an array of physical, chemical and biological information will be collected. All variables will be combined in a bioremediation matrix design, using quantitative chemical analysis of samples to determine the interrelationships of the variable to each other at the end of the experiment. Project termination is scheduled for early September 2004, at which time all data will be combined and explained in an oral presentation format. This work is being performed under the Mine Waste Technology Program, funded by the U.S. Environmental Protection Agency (EPA) and jointly administered by the EPA and the U.S. Department of Energy under Contract No. DE-AC22-96EW96405.

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**CONCURRENT SESSION 3, Tuesday, October 5, 2004: GROUNDWATER STUDIES**

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*Bitterroot Valley ground-water quality. John I. LaFave, Montana Ground-Water Assessment Program, Montana Bureau of Mines and Geology, 1300 W. Park St. Butte, MT 59701, [jlafave@mtech.edu](mailto:jlafave@mtech.edu).* As part of the Montana Bureau of Mines and Geology Lolo-Bitterroot Ground-Water Characterization study, the distributions of dissolved solids, nitrate, and arsenic were mapped in the basin-fill and bedrock aquifers of the Bitterroot Valley in southwest Montana. Between March 1998 and October 2000, 161 samples were collected from 138 wells. Cations, anions and trace metal were analyzed in 110 of the samples, and 51 of the samples were analyzed for nitrate only. Ground-water samples were obtained from the three principal hydrogeologic units within the valley: 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).

These data were supplemented by existing water-quality data from 125 other sites; in addition, field measurements of specific conductance from 243 sites were used to further characterize the distribution of dissolved solids. The results indicate that most ground water in the Bitterroot valley is of good quality. Measured dissolved-solids concentrations in all the aquifers were generally less than 500 milligrams per liter (mg/L), most samples were a calcium-bicarbonate type water. Dissolved solids concentrations in unconfined shallow alluvial aquifers were noticeably less (median concentration = 126 mg/L) than deep and fractured bedrock aquifers (median concentrations = 262 and 274 mg/L, respectively).

The median dissolved-solids concentration of ground-water samples from the east side of the valley (315 mg/L) was more than twice that of samples from the west side of the valley (120 mg/L). The difference between the east and west sides of the valley reflects the difference in bedrock composition and in precipitation between the Bitterroot (west side) and Sapphire (east side) Mountains. The Bitterroot Mountains are composed primary of Tertiary and Cretaceous intrusive rocks and receive about twice as much precipitation as the Sapphire Mountains which are composed mostly of meta-sediments of the Belt Supergroup.

Nitrate concentrations from 249 sites ranged from not detected to 12.1 mg/L-N; the concentration in one sample was greater than the MCL of 10 mg/L. The estimated background concentration of 2.0 mg/L-N was exceeded at 43 (17 percent) sites.

Arsenic concentrations from 191 sites ranged from not detected to 21.5 micrograms per liter (ug/L); six samples exceeded the MCL of 10 ug/L. The six sites with MCL exceedences and nine others with elevated arsenic concentrations (greater than 5.0 ug/L) are clustered east-southeast of

Corvallis (on the east side of the valley) and coincide with the Willow Creek Stock, a granodiorite intrusive. The coincidence of the elevated arsenic with the localized intrusive suggests that the arsenic is naturally occurring and is controlled by geology.

*Predicting groundwater nitrate concentration from land use. Kristin Gardner<sup>1\*</sup> and Richard Vogel<sup>2</sup>*

<sup>1</sup>*Watershed Hydrology Research Group*

*Montana State University*

*Bozeman, MT 59717*

<sup>2</sup>*WaterSHED Center*

*Department of Civil and Environmental Engineering*

*Tufts University, Medford, MA*

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Groundwater nitrate concentrations on Nantucket Island, Massachusetts were analyzed to assess the effects of land use on groundwater quality. Exploratory data analysis was applied to historic groundwater nitrate concentrations to determine spatial and temporal trends. Maximum likelihood Tobit and logistic regression analyses of explanatory variables that characterize land use within a 1000-foot radius of each well were used to develop predictive equations for nitrate concentration at 69 wells. The results demonstrate that historic nitrate concentrations downgradient from agricultural land are significantly higher than nitrate concentrations elsewhere. Tobit regression results demonstrate that the number of septic tanks and the percentages of high-density residential, undeveloped and forestland within a 1000-foot radius of a well are reliable predictors of nitrate concentration in groundwater. Similarly, logistic regression revealed that the percentages of forest, undeveloped and low-density residential land are good indicators of groundwater nitrate concentration greater than 2 mg/L.

Simultaneously to groundwater sampling, a survey of residential land use practices sent to Nantucket homeowners indicated the need for public education in two main areas: lawn care and septic tank maintenance. The percentage of survey respondents who fertilize their lawn is 49.8, while those who fail to pump or inspect their septic system within 2 to 5 years is 35.9 percent.

The combined results of the groundwater nitrate data analysis and the residential survey of Nantucket homeowners has implication for policy to: (1) reduce fertilizer pollution, (2) reduce pollution from septic systems, and (3) increase open space. The methodology and results outlined here provide a useful tool for land managers in communities with shallow water tables overlain with highly permeable materials to evaluate potential impacts of development on groundwater quality.

*Drinking water wells and septic system education modules for small acreage (ranchette) owners. Tammy Crone, Gallatin Local Water Quality District, Bozeman, and David Martin, Montana Department of Natural Resources and Conservation.* As a resource professional, you may be asked to make public presentations on drinking water, wells and/or septic systems. One possible drawback could be that you may not have the time to put together a quality presentation for a public meeting. Two PowerPoints, a drinking water/wells and septic systems have been developed. Each module covers the basic resource issues, and installation maintenance surrounding drinking water (wells) and septic systems, and are laced with practical tips for the average homeowner.

The PowerPoints are designed with colorful backgrounds that will make presentations to audiences interesting and engaging. The basic concepts are presented in non-technical terms. The modules are designed to be easily adapted to meet local needs and topics. Combine these modules with handouts and your technical expertise, and you have a powerful teaching tool.

The target audience is small acreage or ranchette owners. However, it easily is adapted for realtors, government officials, or any audience that needs good basic conceptual information on these issues. The AWRA presentation will include an overview of the modules and how to use them.

The main topics of the Drinking Water and Wells Module includes the ground water and watershed connection, water well basics, ground water pollution sources, protecting your drinking water supply, water well testing, how to test your drinking water, and well maintenance tips.

The Septic module covers the basics of septic systems including site evaluation, Septic Systems 101 (or how septic systems work), descriptions of the main types of systems, reasons for septic system failure, and tips on maintaining your system.

These exciting materials can make you the hit of any public presentation.

***Madison aquifer discharge to the Gallatin River and the Yellowstone National Park controlled groundwater area.*** Mark Schaffer, Senior Thesis, Montana State University, Department of Earth Science. Thermal features in Yellowstone National Park are supplied water from aquifers that are recharged from beyond the Park's boundary. In 1993 the Yellowstone Controlled Ground Water Area (YCGA) was created to protect the groundwater system associated with these thermal features. Big Sky, Montana is located immediately outside of the YCGA boundary. The boundary's location, and associated groundwater system, was defined by a literature-based review of the area's hydrogeology. Since the conception of the YCGA, ground water development in Big Sky has increased dramatically. In order to be certain Big Sky's groundwater development and exclusion from the YCGA will not deplete recharge to the thermal features of Yellowstone National Park, field-testing of the literature-based review was conducted.

This study tested a critical assumption used to delineate the boundary near Big Sky. The boundary is positioned based on the assumption that the Madison Aquifer was recharged where it contacted the Gallatin River. To test this assumption two seepage runs were conducted at the aquifer-river interface to calculate change in the river's discharge due to the aquifer's influence. Both seepage runs indicate the river gained approximately 70 cfs were it contacts the Madison Aquifer. Temperature data was used to further assess the aquifer-river interaction. Riverbed temperatures were elevated at the aquifer-river contact and spring discharge temperatures were consistently higher than the mean annual air temperature. These results indicated that the assumption concerning the boundary near Big Sky is incorrect. Field-testing indicated the Madison Aquifer contributes water to the Gallatin River. The ramification of this finding, relative to Big Sky's exclusion from the YCGA, is discussed. Ultimately, this paper suggests that the YCGA boundary should remain unchanged due to hydrogeologic reasoning. Additionally, the aquifer's discharge to the Gallatin River is highlighted as a significant contributor to the river's base flow. The aquifer's contribution was approximately twenty percent of the 2003 discharge at the Gallatin Gateway USGS monitoring site. The importance of this discharge to downstream water users and the river's ecology warrants further study and suggestions are made for future work.

***Meadowlark park wetlands restoration project.*** Jenny Erickson, Research Assistant, Montana Bureau of Mines and Geology, Billings, MT Meadowlark Park is located in Billings Heights about ½ mile south of Lake Elmo. The park is being assessed for development as an enhanced wetland. The wetland is currently undeveloped and has been partially filled with road sweepings and other fill material. Most of the water flowing through the wetland is derived from the Billings Bench Water Canal which is located upslope and a few hundred yards west of the proposed enhanced wetland. A recently started MBMG project is designed to assess the hydrology and geology of the wetland. This information will help land managers develop and maintain a healthy wetland based on sound scientific data. Landowners in the neighborhood have differing opinions as to the development of a wetland at this location. Many nearby landowners are concerned of wetland development since they believe this would damage property and reduce property values, while others see benefits to wildlife and natural resources in the development of wetland habitat in this urban setting.

Results of preliminary observations indicate that the wetland will not significantly impact ground-water levels in neighborhoods near the proposed park. Ongoing research at the site will characterize the hydrogeologic conditions in and around the park, map ground-water/surface-water interconnection, and monitor ground-water fluctuations and surface-water flow through the wetland.

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**CONCURRENT SESSION 4, Tuesday, October 5, 2004: FLOODPLAIN/CHANNEL MANAGEMENT**

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*Evaluation of riparian health assessment methods to assess conditions of perennial streams in two different geological provinces in the State of Montana.* Travis Miller, 105D Branegan Ct, Bozeman, Montana 59715, 406-570-5928, [TravisMiller@montana.edu](mailto:TravisMiller@montana.edu)

Null Hypotheses:

1. Proper Functioning Condition (PFC), NRCS health status assessment score, and Greenline composition (bank stability) inventory methods are closely linked to local conditions of fish habitat and water quality regardless of basin physiographic province.
2. Fish habitat parameters and aquatic macroinvertebrate assemblages will correlate strongly with the local riparian health assessment monitoring procedures and show no difference between western and eastern Montana streams.

Basin Vs Local: The evaluation of streamside or riparian health has become of great interest to land managers, rehabilitation specialists, and outdoor recreational users. These interests coincide with the desire to maintain or restore stream ecosystems. Riparian and upland management policies throughout Montana and the Northern Rocky Mountain region are driven by the assumption that high ecological condition in riparian areas is indicative of good trout habitat and unimpaired water quality. However, there is conflicting evidence for basin scale characteristics versus local riparian conditions as being the primary influence on riparian zone characteristics. Most riparian assessment methods focus on local riparian parameters.

General Description: This study will collect data on 5 streams in the Northern Rocky Mountains (western Montana) and 5 streams in the Northern Great Plains (eastern Montana) including measurements of in-stream habitat and morphological features. Each stream section will be divided into 4 reaches, and riparian condition will be evaluated using Proper Functioning Condition, NRCS health status, and Greenline composition assessment methods. In-stream habitat conditions such as pool/riffle ratio, vegetative overhang, undercut, entrenchment ratio, and substrate along with macroinvertebrate population characteristics will set the baseline for evaluating in-stream habitat and ecosystem health.

Observations: Present observations indicate that the riparian health assessment scores and instream measures are a good representation of instream conditions found in western streams. However, compared to eastern streams the instream measures vary widely from reach to reach and from stream to stream, and appear to have a weak correlation with the riparian health assessment scores. Complete analysis will be done in the spring of 2005. Detailed comparisons of field data will be presented at the annual AWRA meeting in Helena.

**Intermountain spring creeks: their conservation and restoration.** Scott E. Gillilan, Principal, Gillilan Associates, Inc. 205 Haggerty Lane, Suite 170, Bozeman, MT 59775 406.582.0660 e-mail: [scott@gairesources.com](mailto:scott@gairesources.com). In contrast to exhaustively classified, inventoried, examined, studied and manipulated freestone streams, cool groundwater fed creeks, or spring creeks, have been relatively understudied. While healthy spring creeks are rare in our region, they can be the most biologically productive and unique aquatic ecosystems in the world. Because healthy spring creeks frequently sustain extraordinary trout fisheries, they also impart a great deal of economic value to land

through which they flow. Emerging research also suggests spring creeks are potentially significant refugia for trout and native fisheries in systems where under stress from land use problems, whirling disease and drought.

A generally accepted observation is that spring creeks in our region are perhaps the most seriously degraded stream type. This may be in part explained by the fact that the majority of spring creeks in the Intermountain region, a semi-arid environment, tend to be in lower gradient valleys dominated by finer grained and often fertile soils. The dependable water supply and fertile soils made these areas attractive first to pioneer homesteaders, and began an agricultural use legacy that extends to modern days. While not a blanket condemnation of agriculture stewardship, this legacy has unfortunately included: dewatering; riparian clearing for pasture; bank trampling and over grazing; and pollution. Therefore, the conservation and restoration of spring creek environments will be inextricably linked to better stewardship of agricultural landscapes and watersheds.

Degraded spring creeks in the region almost predictably share the following: a high width:depth ratio; poor competence; a plane bed form; and an excessive sediment and/or nutrient supply. These conditions typically limit macroinvertebrate and macrophytic diversity and biomass, increase thermal gain in summer and cooling in winter, and impose limits to overall fisheries habitat. Further observation suggests that spring creeks do not "self-recover" as readily as freestone systems even with change in land management practices. The spring creeks of our region are: 1) positioned in the landscape in a way that makes them vulnerable to degradation, 2) very sensitive to disturbance and 3) have poor resilience or self-recovery attributes once degraded. From a resource conservation perspective, active restoration measures may therefore be warranted.

Observation of numerous spring creek projects suggests that many fail to meet long-term objectives. An inability to manage incoming sediment seems the most common problem. Other projects fail on inception via the introduction of unnatural hard elements (rootwads, rocks, logs, hardened "bioengineered" banks), with little natural channel deformability, the creation of out of context habitat, and poor aesthetics. In contrast, we believe that spring creeks have restoration potential far exceeding freestone environments and have the highest chance of success utilizing sod-based channel design and construction techniques.

*Two-dimensional flood-plain modeling of Tenmile Creek near Helena, Montana. Katherine J. Chase, Hydrologist, U.S. Geological Survey, 3162 Bozeman Ave, Helena, MT 59601, [kchase@usgs.gov](mailto:kchase@usgs.gov).* A two-dimensional flow model is being developed for the Tenmile Creek flood plain north of Helena, Montana, by the U.S. Geological Survey, in cooperation with the Federal Emergency Management Agency (FEMA), in order to refine previous estimates of flood-plain boundaries. Tenmile Creek, which has a perched channel and a relatively small channel capacity, has overflowed its banks and flooded parts of the Helena Valley on many occasions. Streamflow that exceeds the capacity of the channel (about the 10-year flood) moves northeast from Tenmile Creek across the Helena Valley. Historically, floods have inundated agricultural and urban areas from the channel north to the canal north of Sierra Road, and from Green Meadow Drive east to Interstate 15. Flow rates, depths, and velocities are unknown for this overflow area, and the current FEMA flood-plain boundaries are based on aerial photos of the 1981 flood, which was greater than the 500-year flood.

Flood-plain boundaries and flow rates, depths, and velocities are necessary for flood-plain regulation, land-use planning, drainage improvements, and flood mitigation in the Helena Valley. Traditional hydraulic models used for flood-plain studies are not designed to simulate two-dimensional flows like those in the Tenmile Creek flood plain. Therefore, the Surface-Water Modeling System (SMS) and the Depth-Averaged Flow and Sediment Transport Model (Flo2DH) will be used to estimate the amount of flow that leaves the main

channel and to estimate flood boundaries, depths, and velocities for the overflow area north of the main channel. The graphics-based SMS computer program manages input and output data for the surface-water model. Flo2DH is a computer program that simulates two-dimensional flow in rivers, estuaries, and coastal waters. The results of the two-dimensional flood-plain model simulations will be published as part of a FEMA Flood Insurance Restudy.

*Determination of channel-morphology characteristics, bankfull discharge, and various design-peak discharges in western Montana. Sean M. Lawlor, Hydrologist, U.S. Geological Survey, 3162 Bozeman Avenue, Helena, MT 59601, [slawlor@usgs.gov](mailto:slawlor@usgs.gov).* Stream-restoration projects using natural stream designs typically are based on channel configurations that can accommodate a wide range of streamflow and sediment-transport conditions without excessive erosion or deposition. Bankfull discharge is an index of streamflow considered to be closely related to channel shape, size, and slope (channel-morphology). Because of the need for more information about the relation between channel morphology, bankfull discharge, and other peak discharges, the U.S. Geological Survey (USGS) in cooperation with the Montana Department of Transportation and the U.S. Department of Agriculture—Lolo National Forest, conducted a study to collect channel-morphology and bankfull-discharge data at gaged sites and use these data to improve current methods of estimation of bankfull discharge and various design-peak discharges at ungaged sites.

Bankfull discharge and channel shape, size, and slope were determined at 41 active or discontinued USGS streamflow-gaging sites in western Montana. The recurrence interval for the bankfull discharge for this study ranged from 1.0 to 4.4 years with a median value of 1.5 years. Bankfull discharge at ungaged sites commonly is estimated using a regression equation for the 2-year design-peak discharge. Thus, estimates of the 2-year design-peak discharge from the regression equation need to be multiplied an adjustment factor to produce better estimates of bankfull discharge.

The relations between channel-morphology characteristics and various design-peak discharges were examined using regression analysis. The analyses showed that the only characteristics that were significant for all peak discharges were either bankfull width or bankfull cross-sectional area.

Regression relations between bankfull discharge and drainage area and between bankfull width and drainage area were examined for three ranges of mean annual precipitation. The results of the regression analyses indicated that both bankfull discharge and bankfull width were significantly related (p values less than 0.05) to drainage area and mean annual precipitation.

*Classification and quality criteria for streams of Montana's northern glaciated plains. Michael Suplee (MT Department of Environmental Quality, 1520 E. 6th Ave, PO Box 200901 Helena, MT 59620, 406-444-083, fax: 444-6836, [msuplee@state.mt.us](mailto:msuplee@state.mt.us)) and Vicki Watson (University of Montana Environmental Studies, Missoula, MT, 59812, [vicki.watson@umontana.edu](mailto:vicki.watson@umontana.edu) Watershed Health Clinic (c/oEVST), 406-243-5153, fax 406-243-6090)*

A selected group of streams of Montana's Northern Glaciated Plains were characterized physically, chemically and biologically to develop a classification system for these streams and to develop criteria for evaluating stream condition (particularly with respect to nutrients and stream algae). Sites on 10 streams in the Milk River basin were characterized in 2001, and sites on 11 streams in the lower Missouri basin were characterized in 2002 (3 of the Milk River sites were reassessed in 2002). Streams were classified into two groups based on morphometry and canopy/woody vegetation density. Stream morphology & flow pattern were related to watershed characteristics (especially soil permeability). Once streams were placed in one of the two groups, their condition was evaluated along an impact gradient from least impacted to most impacted (based on physical, chemical & biological evidence).

Study results suggested that stream incisement (downcutting) is a major stressor on aquatic life, and nitrogen appeared to be the nutrient that most limited aquatic plant growth in these streams. Based on the range of characteristics observed in these streams, criteria for nutrient and algae levels were proposed to delineate an unacceptable level of impact and degradation for these stream parameters.

*Anabranche reaches on the Lower Yellowstone River. Ryan McLane, 29 12<sup>th</sup> Street #4, Helena, MT 59601, 406-459-7724, [lostinthemts@yahoo.com](mailto:lostinthemts@yahoo.com), Student presenter, Work from undergraduate senior thesis (03-04), Former MSU Bozeman student.* Anabranche rivers are a system of multiple channels characterized by vegetated or otherwise stable alluvial islands that divide flows at discharges up to nearly bankfull. The islands are also described as being at least three times the channel width in length. Anabranche rivers are commonly referred to as a channel type, where the different channels are part of a larger single channel and large islands split the flow. However, anabranches are also considered a multi - channel system where each single channel can be considered as a separate channel type. In this way multi - channel rivers are systemic. These multi - channel systems have been documented on the Gallatin River and on the upper Yellowstone River in Montana. The lower Yellowstone River appears to have multi-channel systems as well although no published data exists to determine existence or prevalence. The controls on multi - channel systems, "anabranches", documented in other localities do not appear to exist on the lower Yellowstone River. Several causes for multi - channel system location exist for anabranches. *This study examines multi - channel system existence and lithologic controls on the lower Yellowstone River.*

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CONCURRENT SESSION 5, Tuesday, October 5, 2004: *SURFACE-WATER QUALITY*

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***Effect of alternative silvicultural treatments on snow accumulation in lodgepole pine stands, Montana, U.S.A.*** Scott W. Woods, Robert Ahl and Jason Sappington, University of Montana Department of Ecosystem and Conservation Sciences, Missoula MT 59812, tel. 406-243-5257, fax. 406-243-4845, e-mail: [swoods@forestry.umt.edu](mailto:swoods@forestry.umt.edu). Alternative silvicultural treatments such as thinning can maintain water yields, reduce wildfire hazards and restore the productivity and diversity of forested watersheds, but the hydrologic effects of these treatments are not well defined. We evaluated the effect of even thinning (SE) and group-retention thinning (SG), both with ~ 60 % basal area removal, on snow accumulation in Lodgepole pine stands at the Tenderfoot Creek experimental forest, west-central Montana. In 2003 and 2004, the snow water equivalent (SWE) close to the seasonal peak was measured at >250 locations in the SE and SG treatments, and a control. In both years, the mean SWE in the SE treatment was significantly higher than in the control and the SG treatment ( $P < 0.0001$ ). In contrast, the mean SWE in the SG treatment was not significantly different from the control. Spatial variability of SWE was up to 3 times higher in the SG treatment than in the SE treatment or the control. The increased snow accumulation in SE treatments is attributed to reduced interception. In the SG treatment, losses due to wind scour and evaporation offset gains due to reduced interception. These results demonstrate that thinning can have substantially different effects on snow accumulation depending on the spatial arrangement of the treatments. Future work includes measurement of snowmelt rates using lysimeters, and development of predictive models.

***Sediment contributions to the St. Regis River due to winter traction sanding along Interstate 90 at Lookout Pass.*** Jeff Dunn, Land & Water Consulting, 205 Haggerty Lane Suite 130, P.O. Box 1122, Bozeman, MT 59771, [jeff.dunn@landandwater.net](mailto:jeff.dunn@landandwater.net). Traction sand application along 34 miles of Interstate 90 between Lookout Pass and St. Regis is thought to be partially responsible for sediment-related water quality impairments within the St. Regis River. An assessment of the input, storage and transport of traction sand applied to Interstate 90 along the St. Regis River was

performed in 2003. This study was one component of a comprehensive watershed-wide assessment of all sediment sources in the St. Regis drainage basin undertaken in the development of the St. Regis River TMDL. Annual traction sand application rates were obtained from the Montana Department of Transportation. The storage and transport of traction sand were assessed based on the proximity of the interstate to the stream channel and the movement of traction sand on interstate fill slopes. The routing of traction sand through culverts, as well as the input of traction sand from bridge decks, was also estimated. Traction sand deposits were measured at 13 cross sections on fill slopes with gradients ranging from 10 to 60 percent and averaging 45 percent. Traction sand deposits on the 13 fill slope cross sections extended an average of 33 feet from the interstate shoulder, with a minimum extent of 25 feet and a maximum extent of 45 feet. Mean traction sand deposit depth was greatest at a distance of 10 feet from the interstate shoulder. The results of this assessment were used to estimate the amount of traction sand delivered to the St. Regis River on an annual basis from Interstate 90. The results were also used to identify areas in which the application of Best Management Practices would provide the greatest reduction in traction sand loading to the St. Regis River.

*Travel distance and volume of forest road sediment below drivable drain dips in belt and glacial till parent materials in western Montana.* , Brian R. Parker, University of Montana School of Forest and Conservation, Graduate Student, 535 N. 3<sup>rd</sup> W., Missoula, MT 59802 406.829.9188, [brp535@yahoo.com](mailto:brp535@yahoo.com). Forest road sediment is considered to be a chronic sediment source for many watersheds throughout the western US, negatively impacting water quality and fisheries habitat. Numerous studies have quantified road sediment travel distance and volume in highly erodible geologies, but minimal work has occurred in less erodible geologies, such as western Montana's Belt and glacial till. The focus of this study was to measure sediment travel distances below drivable drain dips of logging roads in these two geologies. Due to the extensive use throughout the region, drivable drain dips were the only run-off diversion investigated. Sediment travel distance was measured at 300 sites throughout western Montana. Related sediment plume volume data was measured at an additional 10 locations. All data was gathered from logging roads on Plum Creek Timber Company land within glacial till and Belt geologic provinces. Seven independent variables were recorded at each site in an attempt to find a significant correlation with sediment travel distance. Sediment travel distance was measured from time of drain dip construction by excavating shallow holes and assessing the presence of alluvially deposited road sediment below the outfall of the dip. Average sediment travel distance was found to 3.97 meters and 3.19 meters in the Belt and tills respectively. Travel distances were found to be 60% and 50% greater for mainline roads vs. spur road on belts and tills respectively. Analysis of related sediment plume volume data indicate a significant initial decline in volume over the length of the sediment plume, in Belt geologies approximately 80% of the sediment has been deposited in the first 50% of the total plume length; in glacial tills approximately 75% of the sediment is deposited within the first 50% of total plume length. Volume to mass data will produce average sediment quantities per unit road length which will assist in load allocations for the relevant geologies.

*Impacts of land use and cover change on soil hydraulic properties, Rondonia, Brazil.* Katharine Jane Schultz, Brian L. McGlynn, Helmut Elsenbeer, Montana State University. There is a great deal of concern in the scientific community and the popular media about the global impacts of tropical rainforest deforestation. Soil quality does not receive that same media coverage but is greatly affected by deforestation and is a major concern in the tropics, especially in areas undergoing rapid land use and land cover change. Deforestation can lead to changes in the hydrologic regime, loss of topsoil, increased sediment and nutrient loads in waterways, and decreased soil fertility. These impacts are often related to a soil's infiltration capacity and hydraulic conductivity ( $K_{sat}$ ). Our research site, Rancho Grande, Rondonia, Brazil, lies in the heart of the most rapid tropical rainforest deforestation in the world. Two watersheds of similar size, comparable topographic relief, and same soil type, were tested for differences in hydraulic conductivity. The two watersheds are differentiated by land use and land cover; one in a primary forest and the other in an actively grazed pasture. We measured infiltration capacity at 13

locations in the primary forest watershed and at 24 locations in the actively grazed pasture. Approximately 150 measurements of  $K_{sat}$  were made at regular depth intervals in both watersheds. Our research focuses on assessing the impact of land use and land cover change (primary rainforest to pasture/grazing) on soil infiltration capacity and subsurface saturated hydraulic conductivity. Statistically significant differences in infiltration capacity and hydraulic conductivity were detected between the pasture and forest sites at depths of 0, 12.5, and 20 cm. Differences between the two sites at depths of 50 and 90cm were not significant. These results demonstrate that the affect of land cover and land use change on soil hydraulic conductivity was confined to shallower depths in the soil profile. Coupled with ongoing watershed runoff studies at Rancho Grande, this research will help clarify how land cover change affects soil hydraulic properties and resulting runoff dynamics.

*A computer program for estimating instream travel time and concentrations of potential contaminants from spills along the Yellowstone River. Peter McCarthy, Hydrologist, U.S.*

*Geological Survey, 3162 Bozeman Ave., Helena, MT 59601, (406) 457-5934, [pmccarth@usgs.gov](mailto:pmccarth@usgs.gov).*

The Yellowstone River is the primary source of drinking water for Laurel, Billings, Lockwood, Forsyth, Miles City, and Glendive. Many other communities along the Yellowstone River obtain their municipal water from shallow alluvial aquifers adjacent to the Yellowstone River or its tributaries. Parts of the Yellowstone River valley serve as a primary east-west transportation corridor through Montana. Transportation infrastructure within this corridor includes Interstate Highways I-90 and I-94, Burlington Northern Railroad, and numerous State highways, county roads, and city streets, all of which cross or come within 500 feet of the Yellowstone River in many locations. Therefore, the Yellowstone River is especially vulnerable to contaminant spills, which could occur accidentally, or intentionally as acts of terrorism. The threat of contamination from such spills is a constant concern for water-resource managers and planners, municipal water-supply personnel, and emergency response teams.

The U.S. Geological Survey (USGS), in cooperation with Montana Department of Environmental Quality, initiated a study to develop a user-friendly computer program to rapidly estimate travel times and dispersion of spilled contaminants in the Yellowstone River. The program uses methods previously developed by the USGS that are based on results from many tracer studies throughout the United States. Required input data include the spill location, mass of contaminant spilled, estimated recovery ratio of the contaminant, and streamflows at gaging stations along the Yellowstone River and major tributaries. Thus, the program makes use of real-time data from streamflow-gaging stations along the Yellowstone River and its major tributaries. Estimates provided by the program include: (1) the instream travel time of a conservative solute through a river reach; (2) the rate of attenuation of the peak concentration of a conservative solute; and (3) the length of time required for a conservative solute plume to pass a point in the river.

*Temperature, plants, and oxygen: how does season affect constructed wetland performance?*

*Otto R. Stein<sup>1</sup> And Paul B. Hook<sup>2</sup>*

*<sup>1</sup>Department Of Civil Engineering and Center for Biofilm Engineering, Montana State University, Bozeman MT, USA 59717; <sup>2</sup>Department of Land Resources And Environmental Sciences, Montana State University, Bozeman MT, USA 59717*

The influence of temperature and plant-mediated oxygen transfer continues to draw attention from researchers, practitioners and regulators interested in the use of constructed wetlands (CWs) for wastewater treatment. Because the vast majority of research on constructed wetland performance has been conducted during periods of active plant growth, the true influence of temperature, season, and plant species selection on CW performance has not yet been evaluated adequately. In this paper, we briefly summarize changes in the understanding of these influences on wetland performance, and suggest that effects of temperature and oxygen transfer are not readily separable because both factors respond to seasonal cycles and because effects of one can offset the other. We further speculate that the net effect of seasonal variation in these factors is such that plant-mediated oxygen transfer affects water treatment most in winter. Results of controlled-

environment experiments conducted at Montana State University support these perspectives. Different plant species' capacities to oxidize the root zone responded differently to seasonal cycles of growth and dormancy, and species' effects on wastewater treatment were most pronounced in winter.

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## POSTER PRESENTATIONS

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1

***Ground-water quality in Lockwood.*** Rye Svingen, 1300 N 27<sup>th</sup> St Billings, MT 59101, (406) 657-2702, [Rsvingen@metch.edu](mailto:Rsvingen@metch.edu). Lockwood is an unsewered area of relatively dense population located just east of Billings across the Yellowstone River. The area has a history of bad water quality and nitrate impacts. The underlying aquifer consists of shallow alluvial terrace gravels that are vulnerable to contamination. Some of the Lockwood area is served by public water supply from the Yellowstone River. Septic systems are used to dispose of waste water. Nitrates are a common contaminate from septic systems, the nitrate concentrations in the ground water range from less than 1mg/L to 61mg/L. Dissolved constituent concentration appear to increase as a function of the thickness of the fine grained sediment overlying the aquifer. Near the river dissolved solids are less than 500mg/L, at the valley margin dissolved solids can be over 3,000mg/L.

The Montana Bureau of Mines and Geology is assessing the ground water in the Lockwood area as a part of a larger Yellowstone Valley project. The project extends from Billings to Pompeys Pillar, well inventory and ground water sampling is being used to assess the water quality. All data will be publicly available on the MBMG's GWIC data base and upon completion of the project; the data will be compiled into a publicly available report.

2

***Characterization of metal contamination in the riparian wetlands at the Headwaters of the Stillwater River, Montana.*** Steve Cook, Brian McGlynn, Joe Gurrieri, George Furness, Mary Beth Marks. Heavy metal contamination in riparian wetlands downstream of abandoned mines is a recognized problem in the western United States. However, the differentiation of pre- and post-mining contamination and the spatial locations of contaminated sediment deposition are often poorly documented.

We investigated the impact of mining activity on metal concentrations in a riparian wetland at the headwaters of the Stillwater River, Montana, situated just upstream of the Beartooth Wilderness Area. The wetland is located in the New World Mining District, which became active ~100 years ago. We sampled soils across a 100 hectare area on a 100 meter grid to develop an understanding of the aerial extent of metal contamination. We also installed monitoring wells and piezometers to determine primary groundwater gradients in the wetland complex. Our primary objective is to establish the geochronology of metal deposition, both aeriually and vertically, in the Stillwater Wetland.

We analyzed the soil samples with XRF (X-Ray Fluorescence), ICP (Inductively Coupled Plasma Electron Spectroscopy), and DRS (Diffuse Reflectance Spectroscopy). XRF is a tool designed for rapid soil metal characterization. We assessed the uncertainty of the XRF measured concentrations through comparison to ICP data. ICP analysis is considered an accurate and accepted method for determining the metal content of a soil sample, and allows determining the accuracy and precision of the XRF unit. The EPA 3050B protocol was followed for the ICP analysis. This protocol is similar to a total metals extraction, which allows comparison to that of the XRF.

Spatial mapping of metal concentrations in the wetland revealed that the highest concentrations are located along the stream channel and in the depressional areas of the wetland. This supports the hypothesis that the main mechanism of metal deposition is flooding events. These maps highlight the areas that will be examined in more detail, with samples selected for  $^{210}\text{Pb}$ - and  $^{14}\text{C}$  age dating. We will present initial results of the XRF and ICP analysis, along with spatial maps of metal concentrations within the wetland.

### 3

*Age dating of the geological units in the Belt, Montana area.* Shawn Reddish, Research Assistant, Montana Bureau of Mines and Geology, 1300 N 27th St Billings, MT 59101. MBMG conducted a ground-water study in the Belt area to determine possible water sources that recharge the Anaconda Company mine. Recharge to the Anaconda mine could be from two potential sources; the Kootenai or Madison aquifers. The overlying Kootenai Formation is up to 400 feet thick in the Belt area. The lower sandstone unit (Cutbank Sandstone Member) forms an aquifer directly overlying the targeted coal bed. The Kootenai Formation is highly fractured causing some degree of vertical hydraulic connection from the surface down to the underlying coal bed. The underlying Madison Formation is up to 800 feet thick. The Madison is a karst forming massive limestone bed. By determining the age of the ground-water and flow direction we can determine which aquifer may be supplying the acid mine discharge in Belt Montana.

Age dating of the water by testing for tritium and chlorofluorocarbons has indicated that the water in the Kootenai is around 20 years old, Madison water is around 50 years, and Acid drainage is less than 50 years. Therefore, additional well samples from ground-water and mine discharge will yield more details.

The Potentiometric surface of the Kootenai Formation indicates ground-water flows directly towards the Anaconda mine. Mapping also indicates a ground-water divide located about 3.5 miles south of the Anaconda mine. Only precipitation falling north of this divide has the potential to move towards the mine. The differences in water-level elevations in the Belt area indicate a downward gradient from the Kootenai into the Madison. Therefore, the Madison aquifer should not be recharging the mine.

### 4

*Water levels and nitrate in Warne Heights, upper Summit Valley, Silver Bow County, Montana: a case study of bedrock aquifer vulnerability.* Camela A. Carstarphen and John I. LaFave, Montana Ground-Water Assessment Program, Montana Bureau of Mines and Geology, 1300 West Park St., Butte, MT 59701, [ccarstarphen@mtech.edu](mailto:ccarstarphen@mtech.edu), [jlafave@mtech.edu](mailto:jlafave@mtech.edu). Warne Heights, 4 miles south of Butte, Montana, is located in the foothills of the Highland Mountains. This subdivision of 1- to 5-acre lots served by individual wells and septic-waste systems is located on fractured granitic bedrock. The bedrock is exposed at land surface and is the sole-source aquifer for the area. The Montana Bureau of Mines and Geology's Ground-water Characterization Program collected data for 2.5 years within and around Warne Heights to address local concerns about water quantity and quality. Concerns centered on availability of ground water, elevated nitrate concentrations in ground water, and sources of the nitrate. Water-level data indicate that: (1) ground-water flow directions generally follow topography and (2) the primary source of recharge is from the southeast. During summer months, a cone of depression is generated in the southern section of the subdivision, likely due to a combination of lawn irrigation and low aquifer permeability and porosity in that section of the subdivision. Nitrate concentrations, ranging from 0.9 to 11.60 mg/L-N, document not only temporal persistence of the nitrate but also its wide distribution. Analytical results from nitrogen and oxygen isotope samples confirm that the source of the nitrate is septic-system effluent. Presence of elevated nitrate levels in an upgradient well and the direction of ground-flow through Warne Heights also suggest that the nitrate sources likely include upgradient areas south of Warne Heights. Laboratory results of 12.90 TU from a tritium sample indicate that the ground-water is relatively young, and that the aquifer was last recharged within the past 5

years. These results highlight the vulnerability of fractured bedrock aquifers to surface conditions despite the depths to water of 70 to 300 ft.

5

*Water quality survey of nitrate levels and coliform/coliphage presence in the Helena Valley compared with regional geology, land usage, and well depth. Emma Swingle, Carroll College, 540 Peosta Ave. Helena, MT 59601. [eswingle@carroll.edu](mailto:eswingle@carroll.edu). Dr. Sam Alvey, Carroll College, and Kathy Moore, Lewis and Clark County Water Quality Protection District.* The quality of the ground water in the Helena Valley has come under question in recent years. High levels of nitrates have been observed at several locations without readily identifiable causes. Although most healthy adults tolerate elevated nitrate levels, they are known to interfere with oxygen binding in infants. Under the Safe Drinking Water Act, EPA guidelines recommend that drinking water contain nitrate levels of no more than 10 mg/L. Determining the source of nitrates found in the Helena Valley would assist in the management of current levels and aid in future development and planning. Possible nitrate sources include septic contamination of ground water and agricultural runoff. Additionally, regional geology, land usage, location of the local irrigation canal, and well depth likely influence nitrate levels.

The Helena Valley primarily consists of rural subdivisions, many of which predate modern well and septic system laws. If testing reveals wells that are positive for coliform or coliphage, septic contamination of the system has likely occurred. Coliform and the viruses that infect them are not pathogenic to humans, but they serve as indicators of fecal contamination. It is assumed that if pathogens of similar structure were introduced to the water supply, they could be transmitted in the same manner as coliform and coliphage. Coliforms must not be present in more than five percent of water samples taken to meet the legal limits set by the EPA. Ideally, the agency suggests a total coliform and coliphage goal of zero.

To search for correlations between the condition of drinking water and the regional geology and land usage, fifteen wells were sampled intermittently between May and August of 2004. The sites included both private and public wells located in alluvial aquifers and bedrock. Wells were selected based on owner compliance to testing, previous water quality problems, geological location, and accessibility. Tests conducted on each site include:

1. Nitrate levels
2. Somatic and F+ (male) coliphage
3. Total and fecal coliform

In addition, the geology and land usage of each site were recorded and all private wells were measured for well depth. All bacterial tests were completed at Carroll College in accordance to the USGS groundwater sample collection protocol. Nitrate testing was completed at a local commercial laboratory.

At the time of this writing, positive coliforms and high nitrate levels have been found. The results from this project may not be distinct enough to pinpoint a single cause of decreased water quality in the Helena Valley. However, these data will be compiled with data from surveys conducted by the Lewis and Clark County Health Department and the Montana Department of Environmental Quality. The compiled data may indicate significant correlations and provide a backbone on which to base future research.

6

*Estimated water use in Montana in 2000. Michael R. Cannon, Hydrologist, U.S. Geological Survey, 3162 Bozeman Ave, Helena, MT 59601, [mcannon@usgs.gov](mailto:mcannon@usgs.gov).* The future health and economic welfare of Montana's population is dependent on a continuing supply of fresh water. Montana's finite water resources are stressed by increasing water withdrawals and instream-flow requirements. Various water managers in Montana need comprehensive, current, and detailed

water-use data to quantify current stresses and estimate and plan for future water needs. Therefore, the U.S. Geological Survey, in cooperation with the Montana Department of Natural Resources and Conservation, estimated water use in Montana in 2000 for major categories of withdrawal and instream-flow uses.

In 2000, the citizens of Montana withdrew and used about 10,749 million gallons per day (Mgal/d) of water from Montana's streams and aquifers. Withdrawals from surface water were about 10,513 Mgal/d and withdrawals from ground water were about 236 Mgal/d. Agricultural irrigation accounted for about 10,378 Mgal/d or about 96.5 percent of total withdrawals for all uses. Withdrawals for public supply were about 136 Mgal/d, self-supplied domestic withdrawals were about 23 Mgal/d, self-supplied industrial withdrawals were about 61 Mgal/d, withdrawals for thermoelectric power generation were about 110 Mgal/d, and withdrawals for livestock were about 41 Mgal/d. Total consumptive use of water in 2000 was about 2,370 Mgal/d, of which about 2,220 Mgal/d (93.6 percent) was for agricultural irrigation.

Instream uses of water included hydroelectric power generation and maintenance of instream flows for conservation of wildlife and aquatic life, and for public recreational purposes. In 2000, about 74,486 Mgal/d was used at hydroelectric plants for generation of about 11,591 gigawatt-hours of electricity. Evaporation from large water bodies, although not a classified water use, accounts for a large loss of water in some parts of the state. Net evaporation from Montana's 60 largest reservoirs and regulated lakes averaged about 891 Mgal/d.

7

*Groundwater-surface water exchange across an alpine-valley transition. Timothy Covino<sup>1\*</sup>, Brian McGlynn<sup>1</sup>, Richard Sojda<sup>2</sup>, and Brian Edwards<sup>1</sup>*

<sup>1</sup>*Watershed Hydrology Research Group, Department of Land Resources and Environmental Sciences, Montana State University, Bozeman, MT*

<sup>2</sup>*USGS Northern Rocky Mountain Science Center, Bozeman, MT*

*\*Corresponding author/presenter for poster session; P.O. Box 5285, Bozeman, MT 59717; (406)994-5705; [tcovino@montana.edu](mailto:tcovino@montana.edu). The complex interactions of surface water and groundwater are gaining increasing recognition as an outstanding research need across the state of Montana, country, and world. Specifically, the role of transition zones between alpine headwaters and valley bottom river/lake/wetland systems, common across mountain-valley landscapes, in controlling stream flow quantity, timing, and water quality are poorly understood. In many valleys, streams change in both space and time from *gaining* water from groundwater to *losing* water to groundwater as they flow toward the valley-bottom. Alpine-valley transition zones play a key role in regulating the amount, timing, and quality of stream water that arrives in the valley bottom. As such, we hypothesize that valley transitions function as hydrologic and biogeochemical buffers, both groundwater recharge and discharge zones, and reflections of integrated local and alpine hydrologic and climatic processes. To investigate these hypotheses we installed a network of 24 wells, 20 nested piezometers, seven stream gauging stations, and recording soil temperature nests (10 depths in each of 12 nests) across a two kilometer reach of Humphrey Creek in southwestern Montana. This network allowed us to investigate the surface water and groundwater hydrology in the study reach and to further understand the spatial and temporal variability in surface-water/groundwater interactions. We collected regular stream and groundwater samples to determine the relative contributions of groundwater and alpine runoff to downstream hydrographs. Salt tracers were injected during various times of the year to further quantify and elucidate areas of groundwater recharge and discharge. Initial results have shown that groundwater recharge and discharge zones across an alpine-valley transition are dynamic. Strong groundwater recharge gradients occurred during snowmelt, but shifted to discharging water into the stream channel when alpine contributions declined. This shift in source water contributions had a marked effect on the chemistry of water found in the stream channel. Furthermore, groundwater table shape and storage were dynamic and responded to alpine snowmelt, yet rain events had little impact on groundwater recharge but caused short pulsed increases in stream flow. These research efforts will*

provide a better understanding of the role that transition zones play in buffering the quantity, quality, and timing of water delivered from alpine headwaters to rivers, lakes, and wetlands in valley bottoms. This new understanding will be directly relevant to understanding groundwater recharge controls, irrigation withdrawal impacts, irrigation return flow implications, the surface water and groundwater dynamics controlling moisture status in slope wetlands, and the importance of surface-water/groundwater connections in affecting water quality.

8



**Geochemical constraints on selection of CBM product water management strategies.** Ronald N. Drake, P.E., President, Drake Engineering Incorporated, 75 West Lincoln Road, Helena, MT 59602-9420, phone: 406-458-9288, e-mail: [rvdrake@onewest.net](mailto:rvdrake@onewest.net). CBM product water from Montana and Wyoming plays is chemically unstable and may exhibit profound changes in composition after withdrawal from the aquifer. Spontaneous changes in CBM product water composition are likely to impair its suitability for beneficial use on the landscape. Understanding the fundamental chemical behavior of CBM product water is key to designing and implementing successful water management strategies at any desired scale including site, local, watershed, and regional. Laboratory investigations confirm results of geochemical modeling that show equilibrium sodium adsorption ratio (SAR) is controlled by concentration of bicarbonate that suppresses solubility of calcium and magnesium. Liquid/gas mass transfer of carbon dioxide controls rate of approach to chemical equilibrium. Amendment of soil with gypsum exhibits limited efficacy for reducing the SAR of soil water derived from CBM product water.

9

**Assessment of pre re-naturalized ground water exchange in two stream channels and riparian zones, Jocko Valley, Western Montana.** Aaron Fiaschetti, Department of Geology, University of Montana, Contact at: 1210 Vine St., Missoula, Mt 59802, 406-728-1235, [Aaron\\_Fiaschetti@hotmail.com](mailto:Aaron_Fiaschetti@hotmail.com). The Confederated Salish and Kootenai Tribes have acquired a large track of riparian land in which the river, streams and wetlands have been degraded. The wetlands have been altered by drainage ditches, which have lowered the water table reducing the amount of functioning emergent wetlands. The main river channel has been straightened by levies to protect adjacent hay fields. Channel confinement on this site has caused incision of the river.

The goal of this research is to provide reference conditions of ground water / surface water exchange prior to re-naturalization efforts and to predict how possible restoration efforts will likely effect existing exchange rates. The Confederated Salish and Kootenai Tribes would like to reestablish pre-alteration riparian wetlands and more naturally functioning stream channels. Assessment of ground water/ surface water exchange requires the knowledge of the following parameters:

1. Quantify the flow of ground water, surface water and hyporheic water exchange in the study section of the river.
2. Model the ground water/surface water exchange in the river under pre-naturalized conditions and check conceptual model.

Gravel bars and point bars are important to the exchange of ground water and nutrients to the rivers. Within the study area a point bar and gravel bar have been heavily instrumented to detect groundwater/ surface water and nutrient exchange throughout the bar to the river.

10

*The Wild Fish Habitat Initiative: a new resource for fish habitat restoration efforts.* Liz Galli-Noble, Assistant Director for Research, Molly Boucher, Web Site Specialist, Montana Water Center, 101 Huffman Building, Montana State University, Bozeman MT 59717-2690, Phone: 406.994.7636; Email: [lg noble@montana.edu](mailto:lg noble@montana.edu). Habitat degradation is one of the principal reasons for the listing of wild fish as "threatened" or "endangered" under the Federal Endangered Species Act. Habitat degradation can exacerbate detrimental effects of fish predators, exotic competitors, and diseases such as whirling disease. In recent years, many techniques of fish habitat enhancement have been implemented, but project results have not been shared widely and their long-term efficacy is not well understood. Through the Wild Fish Habitat Initiative, the Montana Water Center and the USFWS Partners Program seek to augment the success of habitat restoration projects implemented within the Intermountain West (Colorado, Idaho, Montana, Nevada, Wyoming, Utah, and inland areas of California, Oregon, and Washington). This is accomplished through two activities: implementing a technology transfer program to provide technical information to landowners and project managers, and conducting targeted fisheries research related to habitat restoration techniques. The technology transfer program includes online bibliographic and restoration manual resources, as well as a regional case histories database of restoration projects. Research projects administered through the Initiative include investigations into thermal tolerances of westslope and Yellowstone cutthroat trout, the epidemiology and control of Bacterial Coldwater Disease, the effectiveness of devices for deflecting fish from irrigation diversions in western Montana, and the efficacy of various stream reclamation techniques.

#### Research Projects

Montana Cooperative Fishery Research Unit, Department of Ecology, Montana State University

1. *Evaluation of Entrainment Losses of Westslope Cutthroat Trout at Private Irrigation Diversions on Skalkaho Creek, Montana* (2002-2005). Alexander Zale and Thomas McMahon (PIs), Steve Gale (Graduate Student), Christopher Clancy (Montana FWP)
2. *Thermal Requirements of Westslope Cutthroat Trout* (2002-2004). Thomas McMahon and Alexander Zale (PIs), Beth Bear (Graduate Student), William Krise (USFWS)
3. *Bacterial Coldwater Disease in Westslope Cutthroat Trout: Hatchery Epidemiology and Control* (2002-2004). Eileen Ryce and Alexander Zale (PIs)
4. *Evaluation of the Efficiency and Efficacy of Non-Native Fish Eradication and Exclusion Techniques for Native Fish Restoration* (formerly Fan Creek Westslope Cutthroat Trout Restoration Project) (2003-2005). Alexander Zale (PI), Peter Brown (PhD Student), John Olson (Student Technician)
5. *Thermal Requirements of Yellowstone Cutthroat Trout* (2004-2005). Thomas McMahon and Alexander Zale (PIs), Cal Fraser (Wild Trout Laboratory)
6. *Evaluation of Habitat Restoration for the Conservation of Cutthroat Trout* (2004-2005). Alexander Zale (PI) and Brad Shepard (PhD Student)

11

*Feasibility study of implementing EPA's proposed Ground Water Rule (GWR) sampling requirements for fecal indicators.* Steve Kilbreath, Montana DEQ, PO Box 200901 Helena, MT 59620-0901. [skilbreath@st.mt.us](mailto:skilbreath@st.mt.us). Joe Meek, Montana DEQ and Kathy Moore, Lewis and Clark County Water Quality Protection District. Although ground water has historically been thought to be free of microbial contamination, recent research indicates that some ground water may be a source of waterborne disease. EPA is proposing a rule that specifies the appropriate use of disinfection in ground water and addresses other components of groundwater systems to assure public health protection. Currently only surface water systems and ground water under the direct influence of surface water, and systems with positive bacterial results are required to disinfect their water supplies. The 1996 amendments to the federal Safe Drinking Water Act (SDWA) require

EPA to develop regulations that require disinfection of ground water systems “as necessary” to protect the public health.

If adopted, the GWR will require public water supplies using undisinfected ground water from hydrogeologically sensitive aquifers to:

- Perform monthly source water monitoring for at least 12 months, and
- Sample for at least one of three fecal indicators (enterococci, fecal coliform and/or coliphage), and
- Implement treatment to ensure a 4-log virus inactivation/removal when fecal indicators are present.

Montana has 554 community water systems, 1011 transient non-community water systems, and 215 non-transient systems, non-community water systems that may be affected by this rule.

DEQ decided to test the sampling requirements spelled out by the GWR to determine how to implement the rule in Montana. Twelve public water supply wells and seven private domestic wells in both bedrock and alluvial aquifers are being sampled on a quarterly basis for enterococci, total and fecal coliform, coliphage and nitrate. Land use, well construction, soils and other factors will be analyzed to help answer the following questions:

- How would hydrogeologically sensitive aquifers be identified or defined?
- Could system operators be reasonably expected to take coliphage samples?
- Could laboratories in Montana set up to do routine coliphage sampling?
- What might the implications of the GWR be for small, rural systems in Montana?

Initial sampling results indicate that over 50% of the wells sampled were positive for coliphage. No positive bacterial samples were identified. Nitrate concentrations varied and did not appear to be correlated to the presence of coliphage.

## 12

*Ground-water availability by depth and quality criteria in Yellowstone and Treasure counties, Montana.* John L. Olson, Associate Research Hydrogeologist, Montana Bureau of Mines and Geology, 1300 N 27<sup>th</sup> St Billings MT. 59101. Finding ground water that is of adequate quality and within an acceptable depth can be a difficult challenge in many areas in Yellowstone and Treasure counties, Montana. Lack of available ground water can be a significant impediment to growth and development. Therefore understanding where ground water is available is essential to land owners, planners and developers.

Maps depicting ground-water availability by depth and quality have been developed for Yellowstone and Treasure counties by the Montana Ground Water Characterization Program. These maps will be published as part of the ground water atlas series for the Middle Yellowstone Area.

Much of the late-Cretaceous to early-Tertiary bedrock formations consist of thick sequences of non-water-bearing shale units. Ground water is usually available within interbedded sandstone formations but these formations can dip to more than 1,000 feet below land surface within a few miles of their outcrop. The most productive and reliable sources of ground water are alluvial aquifers within the Yellowstone River Valley. However, even within the river valley locations exist where the aquifers are not present or are too thin.

Ground-water quality can range considerably depending on aquifer depth and geochemical setting. Zones of highly mineralized water (primarily containing sulfate and sodium) are common in all of the aquifers. Typically the best water quality is found near recharge sources.

## 13

*Treefall patterns in western Montana riparian areas, and implications for woody debris recruitment modeling.* Ron Steiner<sup>[1]</sup> and Jeff Light<sup>[2]</sup>. As part of the adaptive management

program in Plum Creek Timber Company's Native Fish Habitat Conservation Plan, riparian treefall and harvest patterns were investigated at sites in western Montana. The first component of this study found that trees do preferentially fall downslope toward streams rather than in a random pattern. This downslope treefall bias is likely the result of differential crown development and is and appears to be positively correlated with hillslope angle. The second component of this study examined whether trees leaning away from streams in riparian areas are preferentially selected for harvest under Montana's Streamside Management Zone Law. These factors should be accounted for in models that simulate effects of timber harvest on recruitment of large woody debris to streams.

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## 14

*Impact of land use change on streamwater quality, Big Sky, Montana. Kristin Gardner<sup>1\*</sup>, Brian McGlynn<sup>1</sup>, Duncan Patten<sup>2</sup>, Denine Schmitz<sup>2</sup>*

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There is a growing need to quantify the impact of resort development on streamwater quality in mountain environments. The Big Sky community, situated in the northern Rocky Mountains of southwestern Montana, is a rapidly growing ski resort adversely affecting local streamwater quality (Baldwin, 1996). The West Fork River, a tributary of the Gallatin River draining from the Big Sky resort area, and two of its tributaries were placed on the State of Montana's 2002 list of impaired waters (303d) for nutrients. Nitrate ( $\text{NO}_3^-$ ) is a contaminant of particular concern because of its high mobility in soils and its association with human development; the primary sources of groundwater  $\text{NO}_3^-$  are domestic on-site sewage disposal and fertilizer (Puckett, 1994). Analysis of satellite images and aerial photos indicate significant land use/land cover change in the West Fork watershed since the development of the Big Sky resort. For example, coniferous forest area has decreased by thirty percent, while the number of residential buildings has more than tripled in the past decade. Comparison of baseline groundwater and surface water quality data from the West Fork taken prior to development to recent water quality and biological data indicate a fourfold increase in annual average stream and groundwater  $\text{NO}_3^-$  concentrations. Present  $\text{NO}_3^-$  concentrations in the West Fork are significantly higher (more than ten times) than those in the Gallatin River, above the West Fork/Gallatin confluence. These preliminary findings provide incentive to further investigate the impact of land use/land cover change on slopes and riparian areas on water quality in sensitive mountain environments. We are working to improve upon existing land use/land cover change impact studies, by integrating terrain analysis and the topology of land use/land cover change to determine the primary controls on development related nitrogen export to mountain streams.

Baldwin, D.O. 1996. *Hydrogeologic and Hydrochemical Investigation of Big Sky, Montana.*

Final report for the Department of Environmental Quality. September, 1996.

Puckett, L.J. 1994. Nonpoint and point sources of nitrogen in major watersheds of the United States. *U.S. Geological Survey Water Resources Investigations Report*, 94-4001.

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*Interactive CD-ROM training for water operations. Kevin Kundert and Ken Glynn, Montana Water Center, Montana State University, Bozeman. [kkundert@montana.edu](mailto:kkundert@montana.edu); [kglynn@montana.edu](mailto:kglynn@montana.edu), (406) 994-1772 <http://water.montana.edu>.*



## PROJECT SUMMARY

"Ground Water Systems - National Version 2003," is an innovative multimedia training program designed to entertain while it instructs. Our approach is to train operators and managers of small public ground water systems through a series of interactive activities. Developed in cooperation with numerous agencies and individuals, this training provides users with a basic working knowledge of small public ground water system operation.

Past: This training tool was initially funded by EPA Region 8 and the Indian Health Service and produced as a Montana-specific training application. It was demonstrated and tested in numerous workshops and at national conferences. It grew in popularity and was adapted to a national audience. 10,000 copies of Operator Basics 2002 were distributed and thousands of hardcopy versions were downloaded from the website every month. Some states purchased CDs in bulk to distribute to all their operators.

In 2003, we updated the ground water program and distributed another 10,000 copies through the National Drinking Water Clearinghouse. Many additional features were added to this version thanks to funding from the EPA Office of Ground Water and Drinking Water. Some states and organizations modified the program and content to meet their specific requirements including Montana, New Mexico, Pennsylvania and the National Tribal Environmental Council.

Present: Small public water system operators and the training organizations supporting them can order this program free of charge. The NDWC pays for shipment of small orders.

Future: In early 2005, surface water and waste water modules, as well as water system explorations, will join the ground water training on one comprehensive CD-ROM. We are slated to produce 20,000 copies for national distribution in the coming year. This program content will also be available as reusable "learning objects". States and organizations will easily be able to modify the content for their particular needs.

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*Whirling disease and outreach. Amy Rose, Whirling Disease Initiative Outreach Program Coordinator, Montana Water Center Bozeman MT 59715.* The purpose of this poster is to discuss the Whirling Disease Initiative, and highlight the newest area of the initiative, a formalized outreach program. The Whirling Disease Initiative was established by an act of Congress in 1997. Its purpose is to conduct research that develops practical management solutions to maintain viable, self-sustaining wild trout fisheries in the presence of the whirling disease parasite.

The Initiative has sponsored from nine to 20 research projects in each cycle. A research cycle generally runs from May of one year through December of the following year, allowing for two research field seasons. More than 100 research projects have been carried out by university, public-agency scientists, and private firms since 1997. More than \$8 million of Federal and matching funds has been expended or committed by these projects. Areas of research include: distribution and dissemination, parasites, oligochaetes, salmonids, ecology, diagnostic methods, and management and control.

General oversight of the Initiative is provided by the National Partnership for the Management of Wild and Native Coldwater Fisheries. The National Partnership is a consortium of organizations concerned with the status of wild and native fisheries in the United States—Federal and state

agencies, professional associations, and private advocacy organizations. The overall goal of the Partnership is to move biological research and management trials forward to make available to fishery managers practical options for controlling the disease. The National Partnership provides long-term direction.

Conducting outreach activities has been an ongoing, yet somewhat limited, effort since the inception of the Whirling Disease Initiative in 1997. Now, a concerted effort to disseminate whirling disease information is warranted. The primary audience to be served through the outreach program is technical professionals—fishery managers and administrators, hatchery operators and fish health professionals, researchers and agency land managers. The secondary audience comprises fishery I&E professionals, both within the agencies and in private organizations such as the Whirling Disease Foundation, Trout Unlimited and the Federation of Fly Fishermen. These technology transfer professionals in turn will serve and educate anglers and the general public.

Some outreach activities include: Make formal presentations at regional or national fisheries meetings. Make targeted visits to fishery managers at their workplaces. Respond to requests for information from biologists, agency personnel, and land managers. Disseminate applied management tools. Assess the current situation for whirling disease, including pertinent state laws and the true geographical scope and severity of the disease. Develop annual updates. Compile status-and-trend information. Compile state-by-state information on policies and regulations. Create and promote the authoritative whirling disease electronic resource that is an easy-to-use central information repository. Collaborate with the Whirling Disease Foundation, and build strategic alliances. Maintain communication links with researchers, project partners, technical advisors, fishery managers, and MSU. Report to project partners.

Some products include: Contact lists, an interactive whirling disease bibliography, expanded and interactive web site, technical handouts, media coverage, and a periodic newsletter.

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*An aerial photo comparison of hailstone lake hydrology since 1941. Jay Hanson, Research Assistant, Montana Bureau of Mines and Geology, 1300 N. 27<sup>th</sup> St. Billings, MT 59101.* A comparison was made of the changes in Hailstone Lake hydrology over the last 6 decades, using of aerial and satellite imagery. The images from each decade were compared to the Cumulative Departure from Normal Precipitation in Rapelje to show the lake response to the climatic conditions of the area.

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*Rainfall events and their effect on severely burned areas of western Montana following the forest fires of 2000. Ray Nickless, Hydrologist, National Weather Service, Missoula, MT.* Convective rainfall events in western Montana that occurred on high burn severity areas following the forest fires of 2000, resulted in flash flooding and debris flows. Typical summer thunderstorms produced excessive runoff while longer duration rainfall events produced no flooding. When threshold rainfall rates were met during the thunderstorm season of 2001, severely burned watersheds produced flooding while adjacent non-burned watersheds produced no flooding. Soils in high burn severity areas could not absorb the short burst of heavy rain that exceeded the threshold, however, soils were able to absorb long duration rainfall that exceeded more than one inch.

Antecedent conditions from previous rain events appeared to have no effect on producing excessive runoff on future non-convective events. A frequency analysis of 30 minute precipitation events revealed recurrence intervals of 5-10 years and 10-25 years. Indirect discharge measurements of post-storm events made by the United States Geological Survey and subsequent frequency analysis performed on the discharge data indicated 100 to 500 year recurrence intervals for the flood flows. Comparing the frequency of the rainfall events to the flood flow data clearly showed that the forest fires of 2000 had altered runoff potential from the watersheds. Debris and hyperconcentrated flows

in normally ephemeral draws demonstrated the energy and erosive potential of runoff produced from thunderstorms that hit high severity burn areas.

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**HACCP approach for potable water supply development from urban stormwater and saline aquifer.** *James Swierc - University of Montana, Missoula, Montana USA; John Van Leeuwen - CSIRO Land and Water, Adelaide, Australia; Peter Dillon - CSIRO Land and Water, Adelaide, Australia; Paul Pavelik - CSIRO Land and Water, Adelaide, Australia.* Potable water on the Northern Adelaide Plains, South Australia is obtained predominantly from surface water supplies due to the high salinity of local ground water resources. Urban growth has resulted in the use of innovative methods for harvesting scarce water resources. Urban storm water has been diverted into constructed wetlands at 34 locations across the area. Nine Aquifer Storage and Recovery (ASR) schemes have successfully been implemented as a method to store wetland treated water for later use to supplement non-potable supplies for irrigation and industrial use. An Aquifer Storage, Transfer and Recovery (ASTR) project is currently in development to supplement a potable water system. The ASTR Project will utilize wetlands as an initial treatment for storm water, followed by storage and transfer of the water through an aquifer. The transfer of water through the aquifer provides pathogen removal and also attenuates a range of organic substances

Numerical modeling of the aquifer system was used to determine the optimum system design comprising four injection wells in a diamond shape with two recovery wells centrally located within the system. The ASTR project plans to inject water into a Miocene Tertiary Limestone aquifer, locally referred to as the T2 aquifer, present beneath several interlayered shale and limestone layers. The T2 is approximately 50 meters thick, at a depth of 150 to 200 meters below ground surface. The Tertiary sequence is overlain by approximately 60 meters of quaternary alluvial deposits. The limestone has excellent, interconnected secondary dissolution porosity making it ideal for implementation in aquifer storage systems. Ambient water in the aquifer contains approximately 2,000 ppm TDS, which precludes its use for potable supplies. A period of pre-withdrawal aquifer conditioning will comprise injection of wetland treated storm water into the aquifer in order to create a bubble of acceptable water quality in the vicinity of the well system.

In order to prepare the system for operational use to supplement potable water supplies, a preliminary HACCP Plan was prepared for the system. The HACCP concept for public water supplies supports a multiple barrier approach to protect water quality for drinking water supplies. HACCP was originally developed for the food industry, and the concept recently been adopted by the World Health Organization for application to preserve water quality in potable water supplies. The HACCP Plan performs an analysis of the complete water system, from catchment to consumer. The plan includes an assessment of hazards to water quality, with an evaluation of risk from the hazards. Critical control points are identified where system monitoring results can be used to manage operation of the system. The HACCP risk assessment provides a qualitative assessment of the residual risk of hazards to the water system, based on barriers present that may mitigate the impacts to water quality from the hazards.

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**Hydrology of Alluvial Gravels.** *Dale Engstrom, University of Montana.* A number of hydrologic techniques were employed on alluvial gravels in the Nyack flood plain to evaluate meter-scale vertical and horizontal distribution of hydrologic properties. These techniques include pit dilution experiments and Geoprobe pneumatic slug tests to characterize the hydraulic conductivity distribution, both vertically and horizontally. Dye tracer experiments were performed to determine flow rates and to examine discrete flow path problems.