PROCEEDINGS

for

Montana's Water Resources: Adapting to Changes in Supply and Demand

Montana Section American Water Resources Association
2011 Conference

October 6 – October 7, 2011
Hilton Garden Inn – Great Falls, Montana

Contents

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

THANKS TO ALL WHO MAKE THIS EVENT POSSIBLE!

- **The AWRA Officers**
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  David Donohue, Vice President – HydroSolutions, Inc.
  Russell Levens, Treasurer – Montana Department of Natural Resources and Conservation
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- **Montana Water Center** – **Meeting Coordination**
  Gretchen Rupp, Steve Guettermann, Nancy Hystad, and MJ Nehasil

And especially the conference presenters, field trip leaders, moderators, student judges and volunteers.

Eric Chase

David Donohue

Russell Levens

Gretchen Rupp

Steve Guettermann

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WEDNESDAY, OCTOBER 5, 2011

REGISTRATION *Lobby*

10:00 am – 7:00 pm REGISTRATION
Pre-conference registration available at http://water.montana.edu/awra/registration/

FIELD TRIP

1:00 pm – 5:00 pm **Belt Creek Area and Madison Aquifer Field Trip**
Bus leaves Hilton Garden Inn promptly at 1 pm, returns at 5 pm
Dinner on your own.

THURSDAY, OCTOBER 6, 2011

REGISTRATION *Lobby*

7:30 am REGISTRATION
Preconference registration available at http://water.montana.edu/awra/registration/

7:45 Coffee in the Lobby

OPENING SINGLE SESSION *Sweet Grass & Bear Paw Rooms*

8:15 am WELCOME, INTRODUCTIONS & ANNOUNCEMENTS
Dave Donohue – *Montana Section AWRA Vice President*
Russell Levens – *Montana Section AWRA Treasurer*
Bill Battaglin – *U.S. Geological Survey, Colorado Water Science Center & AWRA President-elect*

8:40 WATER POLICY INTERIM COMMITTEE (WPIC) UPDATE
Joe Kolman – *Staff Research Analyst*

9:15 KEYNOTE SPEAKER
Gina Loss – *National Weather Service*

9:45 *BREAK*

10:00 KEYNOTE SPEAKER
Wayne Nelson-Stastny – *US Fish & Wildlife Service*

11:15 *BREAK for lunch*

ORAL PRESENTATIONS

SESSION 1 (Concurrent) ***Sweet Grass Room***
CHANGING ENVIRONMENTS

Moderator: Stephanie Johnson – *Houston Engineering*

12:30 pm	Fabian Nippgen. *Landscape Structure And Climate Influences On Runoff In The Rocky Mountain Northwest.*
12:50	Marco Maneta. *Effect Of Changes In The Temperature Regime Of Mountain Catchments On The Generation Of Spring Floods.*
1:10	Paul Stoy. *Evapotranspiration Observations From A Global Eddy Covariance Network: What Hundreds Of Measurement Towers Worldwide Can Teach Us About Water Resources In Montana.*
1:30	Bryan Swindell. *Trees As Streamflow Gages: 800 Years Of Water Supply Data For The Bighorn Basin.*
1:50	Bill Battaglin. *Potential Effects Of Climate Change On Colorado Snowpack: A Tale Of Two Ski Areas.*
2:10	Smith, Tyler. *Using Experimental Data From The Tenderfoot Creek Experimental Forest To Inform Hydrologic Model Structure.*
2:30	*BREAK*

SESSION 2 (Concurrent) ***Bear Paw Room***
GROUNDWATER

Moderator: Steve Parker – *Montana Tech*

12:30 pm	James Swierc. *Helena Area Ground Water Sampling Program.*
12:50	Andrew Bobst. *A Hydrologic Study Of The North Hills.*
1:10	Julie Ahern Butler. *Scratchgravel Hills Groundwater Investigation.*
1:30	Angela Frandsen. *Acid Mine Drainage Monitoring Results For The Upper Tenmile Creek Mining Area.*
1:50	John LaFave. *Quality And Age Of Water In The Madison Aquifer, Cascade County, Montana.*
2:10	Tom Osborne. U*nderground Coal Gasification Research And Development In The Powder River Basin.*
2:30	*BREAK*

SESSION 3 (Concurrent) ***Sweet Grass Room***
HYDROLOGIC DATA AND MODELING

Moderator: Katherine Chase – *USGS*

2:45 pm	

SESSION 4 (Concurrent) ***Bear Paw Room***
GEOCHEMISTRY AND WATER QUALITY

Moderator: Angela Frandsen – *CDM*

2:45 pm	Anita Moore-Nall. *Elevated Lead In The Bighorn River May Be Linked To Groundwater Distribution Through Reactivated Precambrian Fault Systems.*

3:05 Matt Blank. *Using Hydrodynamic Modeling And Fish Passage Windows To Evaluate Barriers In River Systems Under Changing Climate Regimes.*

3:25 William Kleindl. *A Comparison Of Conditional Assessments Across Scale.*

3:45 Lucy Marshall. *Addressing Computational Paradigms In Modeling Hydrological Processes At The Catchment Scale.*

4:05 Kevin Chandler. *Modeling Aquifer Responses To Urban Sprawl, West Billings Area, Montana.*

4:25 Anna Bergstrom. *Watershed Structure And Stream Network Geometry: Implications For Water And Solute Transport.*

3:05 Bill Henne. *Using Stable Isotopes Of Oxygen And Dissolved Inorganic Carbon To Trace Respiration And Photosynthesis Processes Under Ice Cover At Georgetown Lake, Montana.*

3:25 Marissa Darvis. *Sources Of Dissolved Oxygen To Support Microbial Activity In Groundwater Close To And Distant From River Recharge Zones: A Study From The Nyack Aquifer Near West Glacier Montana.*

3:45 Joshua Lee. *Arsenic Cycling And Geochemistry Of The Warm Springs Ponds.*

4:05 Leslie Piper. *The Stoichiometry Of Uptake: Dual Nutrient Uptake Kinetics From Ambient To Saturation.*

4:25 Rick Mulder. *Potential Toxicity Of Sediment Bound Pyrethroid Insecticides In Urban Streams And Drains Of Billings.*

POSTER SESSION & SOCIAL HOUR *Little Belt Room & Lobby*

5:00 – 7:00 pm AWRA 2011 POSTER PRESENTATIONS

1. Dustin Anderson. *Effects Of Geology And Landforms On Riparian Water Availability.*
2. Stuart Baker. *Landscape, Management, And Climate Controls On Suspended Sediment Dynamics In 6 Adjacent Headwater Catchments.*
3. Simon Bierbach. *Results From Ten Years Of Groundwater Monitoring In And Around Coalbed Methane Development In Montana.*
4. Daniel Blythe. *Potentiometric Surface Map Of The Shallow Hydrologic Unit, Carbon And Stillwater Counties, Montana.*
5. Elizabeth Bramlett. *Using Geochemical Tracers To Trace Groundwater Interactions With Georgetown Lake, Granite County, Montana.*
6. Allison Brown. *Using Stable Isotopes To Track Contamination Of The Madison Aquifer By Coal Mine Drainage In The Stockett-Sand Coulee Area: Year 2.*
7. Samantha Caldwell. *Location And Linkage On A Floodplain Landscape: Spatial Drivers Of Ecosystem Function.*
8. Matthew Elsaesser. *Gray Water Display.*
9. Lauren Gordon. *Comparison Of Pore Water Chemistry In Ponds Underlain By Mine Tailings Vs. Natural Soil: Warm Springs Ponds, Montana.*
10. Sunni Heikes-Knapton. *Citizen monitoring in the Madison.*
11. Adam Johnson. *High Resolution Spatial And Temporal Monitoring Of Soil, Atmosphere, And Vegetation Interaction In A Natural Mountain Environment.*
12. Katie Jorgensen. *Hydrologic Modeling To Monitor Possible Impacts Of Climate Change In The North Fork Of Elk Creek Experimental Watershed.*

13. Bart Manion. *The Interactive Water Use And Resource Conservation Center Overview (IWURC Center Overview)*.
14. Jennifer McBroom. *Lake Helena Watershed Restoration Project*.
15. Anita Moore-Nall. *Elevated Lead In Water Shows A Direct Relationship To The Lake Basin Fault System Of Southcentral Montana*.
16. Karen Newlon. *Wetland Mapping, Assessment, And Monitoring In Montana: The Comprehensive Approach Of The Montana Natural Heritage Program*.
17. James Rose. *Physical Characteristics Of The Flathead Valley Deep Aquifer.*
18. Molly Smith. *An Assessment Of Drought Climatology, Vulnerability, And Mitigation In The Clark Fork Fiver Basin Of Montana*.
19. Padraic Stoy. *Hydrologic And Landscape Controls On Nitrogen Export From Montane Watersheds*.
20. Linda Vance. *A GIS-based Approach To Characterizing Riparian Integrity Along The Yellowstone And Missouri River Corridors*.
21. Kirk Waren. *Groundwater Models Developed For The North Hills Study Area, Located At The North End Of The Helena Valley, Lewis And Clark County, Montana*.

BANQUET

Sweet Grass & Bear Paw Rooms

7:00 pm **Banquet**

8:00 **Banquet Speaker**
Chris Boyer – *Kestrel Aerial*
Aerial Photographs of Historic Flooding.

8:30 **Water Legend Presentation**

8:45 **Photo Contest**
Dave Donohue

FRIDAY, OCTOBER 7, 2011

7:45 am Coffee in the Lobby

SESSION 5 (Concurrent) *Sweet Grass Room*

WATER RESOURCES INFORMATION SOURCES AND DECISION SUPPORT SYSTEMS

Moderator: Matt Blank – *OASIS Environmental, Inc. and the Western Transportation Institute at Montana State University*

8:15 am

8:35 Phil Farnes. *How To Cherry-Pick Climatic Data.*

8:55 Patrick Byorth. *Montana In-Lieu Fee Aquatic Resource Mitigation Program: First Aid For Death By A Thousand Cuts.*

9:15 Stephanie Johnson. *Considering The Other End Of The Hydrologic Spectrum: Forecasting Drought In The Red River Basin Of The North.*

9:35 Jim Robinson. *Understanding Water Use In Montana - An Experiment In Geospatially Enabling The DNRC Water Rights Database.*

9:55 Tom Patton. *Montana's National Ground Water Monitoring Network Pilot: Findings and Results.*

10:15 BREAK

SESSION 6 (Concurrent) *Little Belt Room*

SURFACE WATER AND RUNOFF

Moderator: Tom Osborne – *Hydro Solutions, Inc.*

8:15 am Marc Spratt. *Potential Peak Flow Management Within The Clark Fork Basin, Montana.*

8:35 Kelsey Jencso. *Hierarchical Controls On Catchment Runoff Generation: Topographic Hydrologic Connectivity, Vegetation, And Geology.*

8:55 Chris Welch. *Snow Hydrology: Effects Of Mountain Pine Beetle On Snowpack Characteristics.*

9:15 Katherine Chase. *Streamflow Statistics For Unregulated And Regulated Conditions For The Yellowstone River And Selected Tributaries.*

9:35 Larry Dolan. *Milk-St. Mary Rivers Basin Study.*

9:55 Elizabeth Meredith. *Identification And Quantification Of Baseflow Using Carbon Isotopes.*

10:15 *BREAK*

SESSION 7 (Concurrent) *Sweet Grass Room*

AQUATIC ENVIRONMENTS

Moderator: David Feldman – *MT DEQ*

10:30 am Joe Naughton. *Seasonal Effects Of Eutrophication And Hypoxia On The Relative Abundance Of Fishes In A Superfund Remediated Montana Stream.*

10:50 David Feldman. *Evaluating Macroinvertebrate Responses To Nutrients In A Prairie Stream Using Biometrics.*

SESSION 8 (Concurrent) *Little Belt Room*

SURFACE/GROUND WATER INTERACTION

Moderator: Andrew Bobst – *MBMG*

10:30 am Tim Covino. *Stream-Groundwater Exchange And Hydrologic Turnover At The Network Scale.*

10:50 John Mallard. *Instream Nutrient Concentrations: How Groundwater/Stream Water Exchange And Nutrient Uptake Can Interact In Stream Networks.*

11:10 Sandeep Pandey. *Conservational Strategies of Govindgarh Wetland, Central India.*

11:30 Kendra Kaiser. *Ecohydrology: Disturbance And The Intersection Of Vegetation Pattern And Landscape Structure.*

11:50 Michael Bias. *Monitoring And Evaluation Of Benthic Macroinvertebrates In The Big Hole River And Tributaries, Montana.*

11:10 Shawn Kuzara. *Groundwater Surface Water Interaction in the Alluvial Aquifer: Modeling the Middle Stillwater River Valley.*

11:30 Ginette Abdo. *Groundwater Surface-Water Interaction Within The Beaverhead River Valley North Of Dillon, Montana.*

11:50 Greg Bryce. *An Evaluation of Artificial Groundwater Recharge as a Conjunctive use Approach to Mitigating Surface Water Depletions.*

CLOSING PLENARY *Little Belt Room*

12:15 am CLOSING PLENARY

Announcements, Officers, Photo Contest Awards, Student Awards

12:45 pm ADJOURN

GROUND WATER ASSESSMENT PROGRAM STEERING COMMITTEE MEETING *Board Room*

1:00 pm Ground Water Assessment Program Steering Committee Meeting

KEYNOTE SPEAKER

Gina Loss

Senior Service Hydrologist
NOAA/National Weather Service – Great Falls Forecast Office
5324 Tri-Hill Frontage Road
Great Falls, MT 59404
Phone: 406-727-7671
Email: gina.loss@noaa.gov

Gina Loss has served as a meteorologist/hydrologist for the National Weather Service since 1986, with all but three of those yearsbeing with offices in Montana. For the last 10 years, she has served as the senior service hydrologist for the NWS Forecast Office in Great Falls, holding responsibility for the hydrology program for all of Montana east of the Continental Divide. During her tenure, she has witnessed the hydrologic extremes Montana can experience from floods to droughts. During significant events, she has been invited to join the Governor and his staff in town hall meetings to prepare Montana's citizens for flooding. She has been asked to staff the State Emergency Coordination Center providing on-site expertise, aiding in the decisions of various officials and first responders. She authored the weather and climate summary for the Governor's Request for a Presidential Disaster Declaration and co-authored the weather and climate summary for FEMA Region 8 for the 2011 Montana flood event. She was invited to appear on the CBS TV show, "Face the State" and the radio program "Voices of Montana" to discuss flooding concerns across the Montana as well as providing numerous other national, regional, and local media interviews.As a member of the Governor's Drought Advisory Committee, she contributes to the state's assessment of drought conditions. She earned her Bachelor of Science degree in Physical Geography with emphasis in Meteorology from Arizona State University.

Abstract

Montana's Flooding of 2011

Montana's flooding event of 2011 was extraordinary from many perspectives. From the extensive ice jams caused by persistent cold, to the rapid runoff from record-breaking plains snowfall, moving then to extreme rainfall events, wrapping up with the late season runoff from above average to record breaking mountain snow, there was no corner of the state untouched by this flooding this year.This was an event that challenged even the most experienced water managers in Montana.This presentation will review events leading up to Montana's 2011 flooding, the conditions that occurred and efforts that were made to minimize the flooding when possible.

KEYNOTE SPEAKER

Wayne Nelson-Stastny
MRNRC Coordinator - USFWS
USACE Gavins Point
PO Box 710
Yankton, SD 57078
Phone: (402) 667-2884, (605) 660-5349 cell
Email: Wayne_NelsonStastny@fws.gov

Position: USFWS - Acting Missouri River Coordinator, Missouri River Ecosystem Restoration Plan Co-Lead / Missouri River Natural Resources Committee Coordinator

Wayne brings a wealth of large river expertise from five years of Missouri River related work with the USFWS. He also has 15 years of work as a biologist and Missouri River Coordinator for the State of South Dakota and two years of research on salmon on the Columbia and Snake Rivers with USGS. Wayne received his B.S. and M.A. from the University of South Dakota while studying paddlefish in the Missouri River.From his office co-located within the USACE Threatened and Endangered Species Section, he serves as a lead on a variety of Missouri River Recovery related efforts.In his role as the Missouri River Natural Resources Coordinator with working with Missouri River Basin state fish and wildlife agencies, Wayne bridges many gaps in the Missouri Basin from his position with the USFWS.

Wayne enjoys time spent with his wife, Jantina; daughter, Leona; son, Clay and English Cocker Spaniel, Sparkles. He enjoys all sorts of outdoor recreation,from hunting, fishing, paddling, hiking and gathering along the Missouri River to growing heirloom vegetables in an expansive garden.

Abstract

The Missouri River: A River of Change?

The U.S. Army Corps of Engineers, in partnership with the U.S. Fish and Wildlife Service, is conducting a collaborative long-term study authorized by the Water Resources Development Act of 2007 and due to be completed in 2013. This presentation will summarize current progress and provide insight to work to be done in the immediate future. The study, known as the Missouri River Ecosystem Restoration Plan and Environmental Impact Statement will identify the actions required to:

- mitigate losses of aquatic and terrestrial habitat;
- recover federally listed species under the Endangered Species Act; and
- restore the ecosystem to prevent further declines among other native species.

The study will result in a plan that guides the U.S. Army Corps of Engineers' mitigation, restoration, and recovery efforts for the Missouri River for the next 30 to 50 years. Additionally, the study will provide a blueprint for cooperating agencies from other federal agencies, Tribes, state governments and communities throughout the basin to pull from as they desire.

A key question is: How does MRERP relate to the Missouri River Recovery Program? The Missouri River Ecosystem Restoration Plan will compare existing Missouri River recovery program efforts to the alternatives developed as a part of the study. When completed, the preferred alternative from the Missouri River Ecosystem Restoration Plan will guide future recovery efforts throughout the Missouri River Basin.

And finally, the presentation will give an update on work the Corps and USFWS plans in the coming months related to this project. The planned work includes assessing:

- the natural resource condition for a representative group of native ecosystems and native species, including three federally listed species;
- all relevant existing natural resources, even those which may not be native or natural;
- the social, economic, and cultural resources of the study area;
- broad project goals and objectives to guide the alternatives development;
- the list of federal, state, and Tribal actions currently being conducted or planned that are intended to contribute towards ecosystem restoration of the Missouri River;
- a forecast of the "future without project" condition of the Missouri River ecosystem.

SPECIAL SPEAKERS

William A. Battaglin

Research Hydrologist
U.S. Geological Survey, Colorado Water Science Center
Box 25046, MS 415, DFC, Lakewood, CO, 80225
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Email: wbattagl@usgs.gov

Bill has been an active member of AWRA since 1993, serving on the board or directors, conference committees, publishing in JAWRA, and presenting papers at meetings. He has authored or co-authored eleven articles in JAWRA or other AWRA publications (even one in Water Resources Bulletin!) since 1990. His article, "Regression Models of Herbicide Concentrations in Outflow from Reservoirs in the Midwestern USA, 1992-1993" received the W. R. Boggess Award for the most outstanding JAWRA paper published in 1998. His latest JAWRA article, "Lagrangian sampling for emerging contaminants through an urban stream corridor in Colorado" was published in the February 2009 issue. Bill has given presentations or otherwise participated in 19 AWRA sponsored conferences or workshops. He served on the conference committee of the second AWRA symposium on GIS and Water Resources in 1996, and edited the proceedings. He served on the organizing committee for the specialty conference titled "Water Quality Monitoring and Modeling", held in San Antonio, TX in 2001. He served as the General Chair for the specialty conference titled "Emerging Contaminants of Concern in the Environment: Issues, Investigations, and Solutions", held in Vail, CO in 2007, and co-edited a JAWRA feature collection of papers from this conference. Bill was an AWRA director, serving a 4-year term that ended in 2007. Bill was an AWRA Colorado Section director in 2005-2007, President-Elect in 2008, and President 2009. Bill is currently (2011) the AWRA President-Elect, and will serve as President in 2012 and Past-President in 2013.

Bill received a B.A. in Geology from the University of Colorado, Boulder, in 1984, and a M. E. in Geological Engineering, from the Colorado School of Mines, in 1992. He began his professional career in 1982, installing wells and measuring water-levels as a technician for the U.S. Geological Survey (USGS) in New Jersey. Bill returned to the USGS in 1985 as a hydrologist working on studies of groundwater supply and groundwater quality as a function of land use. In 1989, Bill transferred to the USGS office in Colorado to work on issues related to the occurrence of agricultural chemicals in midwestern water resources. He has helped design and conduct studies investigating the occurrence of pesticides in streams, reservoirs, groundwater, rain, and the air. He is currently working on investigations of the occurrence of glyphosate in midwestern streams, fungicides in potato growing regions, hypoxia in the Gulf of Mexico and its relation to nutrient flux of the Mississippi River, the effects of pesticides on amphibian populations in North America, the fate of emerging contaminants in Colorado surface- and groundwater, and the potential effects of climate change on Colorado snowpack.

Bill received a B.A. in geology from the University of Colorado, Boulder, in 1984, and a M. E. in geological engineering, from the Colorado School of Mines, in 1992. After several years as a USGS hydrologist, Bill transferred to the USGS office in Colorado to work on issues related to agricultural chemicals in midwestern water resources. He has helped design and conduct studies investigating the occurrence of pesticides in streams, reservoirs, groundwater, rain, and the air. Among other things, he is currently researching effects of pesticides on North American amphibians, the fate of emerging contaminants in Colorado surface- and groundwater, and potential effects of climate change on Colorado snowpack.

Joe Kolman

Staff for the Water Policy Interim Committee
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Joe Kolman has been an environmental policy analyst for the Montana Legislature for 7 years. He staffs the Water Policy Interim Committee as well as the Environmental Quality Council. Prior to working for the Legislature, he was a newspaper reporter in Montana, Nebraska, and Idaho. A native of Harlowton, he compares all rivers to the Musselshell.

Chris Boyer

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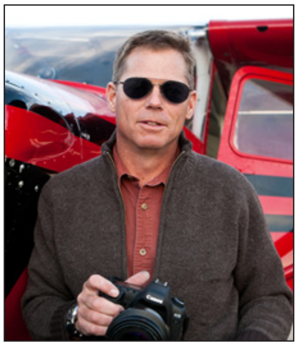

Commercial pilot, photographer, and geomorphologist Christopher Boyer came to Montana in the late eighties during the major geomorphic event known as the Anthropocene Consultant Flow, when an unconsolidated mass of hydrologists, geomorphologists and engineers cascaded into the major watersheds of the Northern Rockies. During his consulting career, Chris began using a rented aircraft and compact cameras to assist with mapping and assessments of river restoration projects. After purchasing an old Cessna and designing a belly-mounted camera system Chris left the consulting business to form Kestrel Aerial Services, Inc. and now provides aerial mapping, multi-spectral imaging, oblique photography and survey flying for conservation, agency, and private landscape management interests.

Abstract

Slide Show: Aerial Photographs Of Historic Flooding, Spring 2011 (or Montana's Water Resources: Do Changing Supplies Demand Adaptation?)

Aerial photographer Christopher Boyer has been and will continue to be aloft over the historic flood peaks along many Montana Rivers during the spring of 2011. During recent flights I have documented the crushing impacts of unprecedented flooding to homes, farms, and communities; and the transformations of river and floodplain habitat and landscapes.

The goal of this effort has been to create a database of imagery which will serve as a tool in future efforts to understand, manage, and inhabit Montana Floodplains into the future.

The slide show will rely entirely on imagery to portray the lateral extent of inundation on many Montana Rivers, capture the actual impacts as rivers flood public and private infrastructure and facilities, and to serve as a reminder that realistic risk-assessment methods are mandatory in effective floodplain management.

A selection of flood photos from the Musselshell River can be seen at http://www.kestrelaeral.com

Landscape Structure And Climate Influences On Runoff In The Rocky Mountain Northwest

Fabian Nippgen, Graduate Student, Montana State University, 334 Leon Johnson Hall, Bozeman, MT, 59717, 4069945705, fabian.nippgen@msu.montana.edu. Additional authors: Brian McGlynn, Montana State University; Lucy Marshall, Montana State University; Ryan Emanuel, North Carolina State University.

Climate variability and catchment structure (topography, geology, vegetation) can have a significant influence on the timing and quantity of water discharged from mountainous catchments. Understanding how these factors will combine to influence runoff dynamics poses significant challenges to water resource managers across the rocky mountain northwest. In this study we linked differences in hydrologic response between catchments and between years to metrics of landscape structure and climate using a simple transfer function rainfall-runoff modeling approach. A transfer function represents the internal catchment properties that convert a measured input (rainfall/snowmelt) into an output (streamflow). The main model parameter, mean response time, is defined as the time that it takes for water inputs to leave the catchment outlet from the moment it reaches the ground surface. We combined 12 years of precipitation and streamflow data from seven catchments in the Tenderfoot Creek Experimental Forest (Little Belt Mountains, southwestern Montana) with GIS based landscape analyses to quantify the first order controls on mean response times. Differences between responses in the seven catchments were related to the spatial variability in catchment structure (e.g. slope, distance from creek along a flow path, tree height). Annual variability was largely a function of maximum snow water equivalent. Catchment averaged runoff ratios exhibited strong correlations with mean response time while annually averaged runoff ratios were not related to any climatic metric. These results suggest that runoff ratios in snowmelt dominated systems are mainly controlled by topography but not by climatic variability. This approach provides a simple tool for watershed managers to assess the timing and availability of surface water discharge across diverse watersheds and climate conditions.

Effect Of Changes In The Temperature Regime Of Mountain Catchments On The Generation Of Spring Floods

Marco Maneta, Assistant Prof, University of Montana, Geosciences, 32 Campus Dr, Missoula, MT, 59812, marco.maneta@umontana.edu.

Many regions in the world rely on snowpack storage to satisfy the water demand for domestic, agricultural and industrial uses. Water in the snowpack is also needed to satisfy the ecological demand of the environment. Furthermore, an understanding of the snow storage and release cycle in mountain regions is necessary to interpret many geomorphologic processes in the channel, to maintain the quality of fish habitats and to enhance flood risk management or dam operation strategies. Because of the vulnerability of snow dominated systems to climate change, a significant body of research has focused on the effect of rising temperatures on the accumulation of snow and the timing and magnitude of spring floods. Earlier studies focused primarily on the effect of projected annual average air temperatures on the snow accumulation and melt process by analyzing measurements of snow depth and river discharge. Because of land use change and other human interference on rivers such as water diversions or dams, it was difficult for these studies to evaluate how much of the observed changes in the behavior of the watershed could be attributed to climate and what was a direct effect of the local human impact on the basin. The advent of more sophisticated tools and comprehensive models has not resolved this problem because these tools incorporate many interacting climate and hydrologic variables that simultaneously affect the response of the basin, making it difficult to isolate the relative impact of temperature on the generation of spring streamflow peaks. Average annual air temperature is only one of the many characteristics that define the temperature regime in mountain environments. Changes in the temperature lapse rate, winter-spring temperature range or the timing of spring temperatures may have a more severe impact on the snow-accumulation and subsequent spring release process than the tenths-of-a-degree projected increase in annual average temperatures for this century. This contribution to the Montana AWRA meeting presents a study of the sensitivity of spring peak flows in mountain catchments to changes in the temperature regime. The study is done on a synthetic catchment under simplified conditions. In this controlled setting, any change in the response of the basin can be unequivocally associated and interpreted with respect to the imposed changes in the temperature regime. Results show a complex interaction between temperature and catchment response and that under certain temperature regimes the lapse rate of air temperatures or the timing of spring temperature may have a stronger influence on the generation of spring floods than changes in the average air temperature.

Evapotranspiration Observations From A Global Eddy Covariance Network: What Hundreds Of Measurement Towers Worldwide Can Teach Us About Water Resources In Montana

Paul Stoy, Assistant Professor, MSU-Bozeman, LRES Department, MT, (406)994-05927, paul.stoy@montana.edu.

Evapotranspiration (ET) is often treated as a residual term in studies of the terrestrial water cycle, due in part to difficulties quantifying it in a field setting. The eddy covariance technique offers a means to observe ET directly, but not without methodological challenges and difficulties extrapolating observations from the scale of the turbulent flux footprint (usually tens to hundreds of meters) to the scales of interest for water cycle science, usually much larger in spatial extent. Here, I briefly explain the eddy covariance technique and introduce the global FLUXNET database with nearly one thousand site-years of half-hourly observations from over 250 globally-distributed flux towers. Focus is placed on ecosystem types characteristic of Montana including grasslands, alpine ecosystems and montane forests. A convergence in mean ET during the peak growing season from tropical to temperate ecosystems is demonstrated. Global ET is constrained by vapor pressure deficit (D) in a way consistent with the hypothesis that plant stomata operate to maximize carbon gain per unit water loss. Ongoing and future efforts to observe and extrapolate ET are discussed in the context of water resource challenges in Montana including observed changes to cold-season hydrology, insect outbreaks, and fire events.

Trees As Streamflow Gages: 800 Years Of Water Supply Data For The Bighorn Basin

Bryan Swindell, Montana State University, Earth Sciences Department, 211 N. Grand Avenue, Suite E, Bozeman, MT, 59715, (406) 223-7433, bryan.swindell@gmail.com. Additional authors: Stephen Gray, University of Wyoming; Gregory Pederson, USGS.

Growth rings from long-lived, precipitation-sensitive conifers have been used around the world to successfully reconstruct prehistoric streamflow. In the western United States, the period of record captured by the USGS stream gage network is typically not long enough to characterize the natural hydrologic variability of a given basin. Tree-ring reconstructions offer a robust way to extend these gage records, thereby redefining what is 'normal' for a watershed. Such reconstructions often reveal extreme wet and dry periods of varying timescales never experienced in the 20th century, thereby providing water managers with new insights and the information needed to make better decisions. This presentation will offer a comprehensive set of streamflow reconstructions for several USGS gages in the Bighorn Basin, reaching as far back as AD 1200. The reconstructions paint a highly variable picture of runoff in the Bighorn, with many droughts and pluvials that exceed those witnessed during the last 100 years in both duration and magnitude. This variability will be discussed, and the relationships between Bighorn Basin hydrology and larger climate dynamics will be briefly mentioned. Finally, implications for Bighorn Basin water supply management in the future will be discussed, with an emphasis on the adequacy of current water management policy.

Potential Effects Of Climate Change On Colorado Snowpack: A Tale Of Two Ski Areas

William A. Battaglin, Research Hydrologist, U.S. Geological Survey, Colorado Water Science Center, Box 25046, MS 415, DFC, Lakewood, CO, 80225, (303) 236-6872, wbattagl@usgs.gov.

The mountainous areas of Colorado are used for tourism and recreation, and provide water storage and supply for municipalities, industries, and agriculture. Recent studies suggest that water supply and tourist industries are at risk from climate change. Local stakeholders, from ski area operators and fishing guides to water supply managers, would like to know if the future will be the best of times…the worst of times…the winter of despair for Colorado's snowpack. In this study, a distributed-parameter watershed model, the

Precipitation Runoff Modeling System (PRMS) is used to identify the potential effects of future climate on hydrologic conditions for two Colorado basins, the East River at Almont and the Yampa River at Steamboat Springs, and at the sub-basin scale for two ski areas within those basins. Climate change input files for PRMS were generated by modifying daily PRMS precipitation and temperature inputs with mean monthly climate change fields of precipitation and temperature derived from five General Circulation Model (GCM) simulations using one current and three future carbon-emission scenarios. All GCM simulations of mean daily minimum and maximum air temperature for the East and Yampa River basins indicate a relatively steady increase of up to several degrees Celsius from baseline conditions by 2094. GCM simulations of precipitation in the two basins indicate little change or trend in precipitation but there is a large range associated with these projections. PRMS-projections of basin mean daily streamflow vary by scenario, but indicate a central tendency towards slight decreases, with a large range associated with these projections. Decreases in water content or changes in the spatial extent of snowpack in the East and Yampa River basins are important because of potential adverse effects on water supply and recreational activities. PRMS-projections of each future scenario indicate a central tendency for decreases in basin mean snow-covered area and snowpack water equivalent, with the range in the projected decreases increasing with time. However, when examined on a monthly basis, the projected decreases are most dramatic during fall and spring. Presumably, ski area locations are picked because of a tendency to receive snow and keep snowpack relative to the surrounding area. This effect of ski area location within the basin was examined by comparing projections of March snow-covered area and snowpack water equivalent for the entire basin with more local projections for the portion of the basin that represents the ski area in the PRMS models. These projections indicate a steady decrease in March snow-covered area for the basins, but only small changes in March snow-covered area at both ski areas for the three future scenarios until around 2050. After 2050, larger decreases are possible, but there is a large range in the projections of future scenarios. The rates of decrease for snowpack water equivalent and precipitation that falls as snow are similar at the basin and sub-basin scale in both basins. Results from this modeling effort show that there are a wide range of possible outcomes for future snowpack conditions in Colorado. The results also highlight the differences between projections for entire basins and projections for local areas or sub-basins within those basins.

Using Experimental Data From The Tenderfoot Creek Experimental Forest To Inform Hydrologic Model Structure

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This study introduces a new conceptual hydrologic model that blends recent advancements in hydrologic process understanding and quantitative modeling. The model extends the empirical findings of Jencso et al. [2009], who found a strong correlation between the duration of shallow groundwater connectivity across hillslope, riparian, and stream zones (HRS) and the upslope accumulated area (UAA) associated with each transect (r2 = 0.91). This relationship, when extrapolated to the entire study area, resulted in a connectivity duration curve (CDC) that was very strongly correlated to the flow duration curve (FDC) of the watershed (r2 = 0.95). Incorporation of these findings into a simple runoff model was achieved by rethinking patterns of watershed response from a stream-centric standpoint. We aim to quantify the control landscape topology/topography exerts on hydrologic connectivity. A semi-distribution approach was taken to discretize the watershed according to the distribution of UAA along the stream network. Discharge from each discretized landscape unit is proportional to the duration that it is hydrologically connected to the stream. Stream discharge is a result of the frequency of hydrologic connections along the stream network. This model represents a significant departure from traditional conceptual hydrologic models as it quantifies the extent to which hydrologic connectivity across the watershed's landscape controls runoff response. The model was applied to the Stringer Creek watershed of the Tenderfoot Creek Experimental Forest (TCEF), located in central Montana, USA. Detailed field observations collected by Jencso et al. [2009] were used to inform the underpinnings of the model and to corroborate internal consistency of the model's simulations. For this application, the model shows good agreement between the observed and predicted stream discharge as well as between the observed and simulated connectivity duration curves. The ability of the model to simulate internal dynamics without conditioning the parameters on these data indicate the potential of this model to apply to other hydrologic conditions and transferred to additional watersheds of varying topographic structure.

SESSION 2 GROUND WATER AND MINING INVESTIGATIONS

Helena Area Ground Water Sampling Program

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The Lewis & Clark Water Quality Protection District (LCWQPD) began implementation of a long-term ground water monitoring program in the Fall of 2009. The program included semi-annual sampling from 25 wells in the LCWQPD Monitoring Well network, which includes 9 single wells and 8 nested well sets (16 total wells), and incorporated compilation of a database with existing water quality data. In Summer 2011, the sampling program expanded to include additional shallow ground water monitoring wells from previous USGS studies, and shallow piezometers installed at surface water monitoring locations in the central valley. The goal of the project is to characterize current ground water quality across the Helena Valley, with an emphasis on identifying nutrient impacts to shallow ground water. The nutrient data from the six semi-annual sampling events show relatively stable major ion chemistry. The primary analytes of concern identified with the sampling program include nitrate and nutrients; and arsenic, selenium and uranium. The presentation will incorporate all of the current data with preliminary results from the Summer 2011 field program.

A Hydrologic Study Of The North Hills

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The North Hills Study Area is located approximately 8 miles north of Helena, Montana, on the northern edge of the Helena Valley. Precipitation ranges from less than 10 inches in the valley to 16 inches at the ridge top. In recent years there has been substantial home construction in this area and many of these homes use individual water wells and septic systems. Due to increasing cumulative effects of pumping, there are concerns regarding the long-term capacity of aquifers to supply water, and the potential for contamination of aquifers by septic effluent. Controlled groundwater areas were designated in this area by the Montana Department of Natural Resources and Conservation from 2002-2006 and from 2008-2010 to address these concerns. The purpose of this study is to develop an improved understanding of the hydrogeologic system in the area of the North Hills to provide a sound basis for groundwater management decisions in this area. New test-well data and short-term water-level and water-quality monitoring will improve the conceptual model of the area, and a numerical groundwater model has been built to evaluate the effects of current groundwater development. Our work shows that the aquifer productivity, and consequently groundwater availability, is limited in the upland area of the North Hills. In the central portion of the study area, data show that sustained drawdown is developing in the sub-divisions west of the interstate, and north of the irrigation canal. Groundwater-quality samples were collected from75 wells; results show 1 exceedance of the drinking water standard for nitrate (10 mg/l). Surface water samples were collected at 30 sites; results show 9 exceedances of the drinking water standard for arsenic (10 mg/l). Exceedances of the aquatic life standards for cadmium and nitrate were also measured in surface waters.

Scratchgravel Hills Groundwater Investigation

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The Scratchgravel Hills Study Area is located approximately 3 miles northwest of Helena, Montana. The eastern portion of the study area coincides with the western edge of the Helena Valley, which is a relatively flat alluvial plain. The remainder of the Scratchgravel Hills is semi-mountainous terrain comprised of five bedrock formations. Development in this area has been controversial since the subdivision of the Green Meadow Ranch in August of 1972. More recently (2005), a relatively dense subdivision (0.4 acres per dwelling) was proposed in the south-central portion of the study area. Concerns have arisen regarding the long-term capacity of the area aquifers to supply water as well as the potential for contamination of these aquifers by septic effluent. Due to these concerns, the Montana Department of Natural Resources and Conservation established a Controlled Groundwater Area in a portion of the Scratchgravel Hills in April 2008. The purpose of this study was to develop an improved understanding of the hydrogeologic system and help provide data for groundwater management in the Scratchgravel Hills area. This includes improving the conceptual model and developing a numerical groundwater flow model. Because previous work is limited to each proposed subdivision, our work was aimed toward building a baseline understanding of such conceptual model components as aquifer properties, groundwater gradients, and seasonal variation in groundwater levels for the entire area. Our results will help quantify and delineate the availability of groundwater within the study area including the local alluvium, which can produce significant volumes of water, and other local hydrostratigraphic units (granite, argillite, and dolomite) that do not always provide adequate water. Water-quality samples were collected at 32 sites throughout the study area; concentrations exceeded primary drinking water standards for nitrate at three sites and arsenic at five sites.

Acid Mine Drainage Monitoring Results For The Upper Tenmile Creek Mining Area

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This presentation will summarize the collection and analysis of acid mine drainage data from three mines, along with the application of analytical results to evaluation and design of treatment systems. The Upper Tenmile Creek Mining Area Superfund Site in Montana contains approximately 150 abandoned mines, some of which have degraded surface water quality of Tenmile Creek and its tributaries. Water from the Upper Tenmile Creek watershed is part of the City of Helena's municipal water supply. Reclamation has been conducted on the larger sites and has reduced erosion from waste rock piles to nearby streams. Reclamation has not addressed the approximately 37 adits that discharge acid mine drainage (AMD) and impact or have the potential to impact surface water. AMD from three adits, the Susie, Lee Mountain, and Red Water, are considered Principal Threat Wastes by EPA. In general, principal threat wastes are those source materials considered to be highly toxic or highly mobile that generally cannot be contained in a reliable manner or that would present a significant risk to human health or the environment should exposure occur. In order to prioritize the AMD sites for clean up and collect preliminary design information, the adits were monitored twice per year for five years. The adits with the worst water quality exhibited a low pH and high concentrations of arsenic, cadmium, lead, and zinc, while others showed little water quality impairment. The adits were ranked based on contaminant mass loading to the watershed. The study confirmed the magnitude of the loading from the Lee Mountain, Susie, and Red Water adits as the top three sources of contaminant loads measured, as well as prioritizing other adit discharges to be addressed. These adits will undergo further design evaluations for source control of AMD though infiltration reduction, collection, and treatment to reduce impacts to surface water quality in Upper Tenmile Creek.

Quality And Age Of Water In The Madison Aquifer, Cascade County, Montana

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The Madison Limestone occurs under most of central and eastern Montana. Where it is close to, or exposed at the surface it is a productive aquifer and an important source of municipal, domestic, industrial, and stock water; it also is the source of many large springs, including Giant Springs at Great Falls. The Madison aquifer is heavily utilized in Cascade County. Data from the Montana Ground-Water Information Center (GWIC) show that about 800 wells, roughly 75 percent of all Madison wells statewide, utilize the Madison aquifer in Cascade County. Most of the wells are located between the Little Belt Mountains and the Missouri River. As part of the Montana Ground-Water Assessment Program's Cascade-Teton study, 58 wells and springs that produce water from the Madison Limestone were sampled for major ions and trace metals; samples from 16 sites were also analyzed for tritium, and samples from Giant Springs and a nearby Madison well were analyzed for chlorofluorocarbons (CFC's) and carbon-14 activity. Historic analyses for 35 other Madison wells in Cascade County were obtained from the GWIC database. The results show that the water quality and ages are variable. The overall composition generally differed between a Ca-HCO_3 and Ca-SO_4 type water. Total dissolved solids concentrations ranged from 192 to 5,992 milligrams per liter (mg/L), with a median concentration of 509 mg/L, slightly greater than the USEPA SMCL of 500 mg/L. Dissolved arsenic was detected in 76 percent of the samples, concentrations ranged from below the detection limit to 193 micrograms per liter (ug/L) with a median of 1.0 ug/L; six samples exceeded the 10 ug/L USEPA MCL. Nitrate was detected in 67 percent of the samples. Sixteen samples had concentrations between 2 and 10 mg/L, suggesting land-use impacts, and three samples exceed the USEPA MCL of 10 mg/L. Water from Giant Springs and 13 of the wells had detectable tritium; concentrations ranged from 1.4 to 20.4 tritium units (TU). Most of the values were in the 6 to 20 TU range and most likely represent water recharged within the past 30 years. Two samples did not have detectable tritium indicating recharge more than 60 years ago. CFC's and tritium were detected in the samples from Giant Springs and a 470 foot-deep Madison well (FWP well) approximately 1,200 feet up-gradient. The results returned CFC ages of 23 and 26 years, respectively. The ages are consistent with the tritium values of 10.1 and 10.2 TU. The younger age of the spring water probably reflects the fact that it is a mixture of Madison water and overlying, younger, Kootenai water. Radiocarbon dating of samples from the FWP well and Giant Springs returned values of close to 50 percent modern carbon (PMC) (47.48 and 49.38 PMC, respectively), apparently indicating very old water. However, because it is a carbonate aquifer, it is likely that half of the dissolved inorganic carbon is derived from carbonic acid (H_2CO_3) with modern 14C activity, and half from the carbonate ($CaCO_3$) that has no 14C activity. Therefore, the results suggest modern water and are consistent with the CFC and tritium results.

Underground Coal Gasification Research And Development In The Powder River Basin

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The U.S. Geological Survey estimates that the Powder River Basin (PRB) of Wyoming and Montana contains 510 billion tons of coal in place, but over 95 percent is too deep to be economically extractable with current technologies. These so-called deep coals lay 500 to 2,000 feet below the surface, and can be utilized in Underground Coal Gasification (UCG). UCG is an in-situ mining method that utilizes injection and production wells drilled from the surface and linked together in the coal seam. Once linked, air and/or oxygen is injected and the coal is ignited in a controlled manner to produce hot, combustible gases, which are captured by the production wells. This process is conducted below the water table, allowing water to flow into the gasification zone and participate in the formation of synthetic gas, known as syngas. Syngas is brought to the surface and cleaned for power generation and liquid hydrocarbon formulation. Linc Energy Ltd (Linc) is an Australian-based company that has been active in the Surat Basin, near Chinchilla, Queensland for over 10 years with UCG and Gas to Liquids (GTL) demonstration projects. Linc began operations in the PRB in 2010 and currently holds coal leases on 296,000 acres in Wyoming, Montana, North Dakota and Alaska. Linc is currently in the design and permitting process for the Wyoming UCG Demonstration Project 10-miles west of Wright, which would be a 90-day trial gasifier consuming about 1,980 tons of coal in the Wyodak coal bed, lying approximately 1,100-feet below surface. The project permit application is to be reviewed and authorized by the Wyoming Department of Environmental Quality (WDEQ) under a Research and Development License. UCG demands an intimate understanding of site hydrogeology and groundwater chemistry. At its 1-square mile demonstration site, Linc installed 25 baseline groundwater characterization wells, five in each of the five principal aquifers within, above and below the Wyodak coal bed. Each well was sampled four times for a suite of 283 inorganic and organic parameters. Hydrostatic pressure trends of each aquifer have been logged manually and electronically. Gasifer operating pressure will be maintained lower than the hydrostatic pressure to enable an inward gradient into the gasifer cavity and prevention of gas leakage. Detailed aquifer testing will be performed to obtain the principal components of the transmissivity tensors in the coal, which is important to the orientation of the gasifer. Two rings of trend and excursion wells will be installed around the gasifer, with the close-in trend wells providing early warning of potential contaminant migration during operation. The outer ring of excursion wells have upper contaminant levels (UCLs) specified in the permit based on statistical analysis of the baseline data. A decommissioning phase following UCG operation recovers contaminants from the cavity with steam and water until groundwater restoration is achieved.

SESSION 3 HYDROLOGIC DATA AND MODELING

Using Hydrodynamic Modeling And Fish Passage Windows To Evaluate Barriers In River Systems Under Changing Climate Regimes

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Connectivity is vital for fish and other aquatic species to persist and thrive in river and stream environments. Increasing connectivity by removing or reducing barriers is one of the most promising adaptive management strategies for addressing the impacts of climate change on water ecosystems. Over the past decade, interest in the effect of barriers on aquatic systems has grown; accordingly, various passage assessment techniques have been used to determine whether a structure is a barrier, to what species it acts as a barrier and under what flow conditions. Recent research has shown that determining the status of a barrier is not trivial, and that different methods are often not congruent in their classification of barriers. The presentation will describe an assessment technique that used 3-D hydrodynamic measurements and modeling to assess potential barriers to upstream fish movement. The approach quantified the 3-D velocity field using acoustic Doppler measurements and/or computational fluid dynamics. A range of potential paths through the barrier were identified using an algorithm that estimates energy paths. Passage along the paths was assessed by combining the swim speed–fatigue time relationship with the 3-D velocity field. Passage windows were developed to determine the flow range and amount of time that a structure may be acting as a barrier to upstream movement of selected fish species. Examples of how passage windows can be used to evaluate how barriers respond to climate change scenarios, specifically changes in the magnitude and timing of runoff or increases in water temperature, will be presented.

A Comparison Of Conditional Assessments Across Scale

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In 2011, EPA is conducting a nationwide assessment of wetland condition. Their approach is to (1) determine regional and national ecological integrity of wetlands, (2) promote collaboration across jurisdictional boundaries, (3) build state and tribal monitoring and analyses capacity, (4) achieve a statistically-valid set of wetland data, and (5) develop baseline information to evaluate progress. To achieve these goals, EPA is developing a series of conditional assessment models to evaluate different wetland classes over large regions. Rapid Assessment Method models (RAM) have been developed across the country to facilitate EPA's effort. Montana MT-DEQ's Rapid Assessment Method (MTRAM) is one such model. In separate efforts, we recently finished two rapid assessment models at two very different scales. One model was developed for the Jicarilla Apache Nation in Northwest New Mexico. The Jicarilla Rapid Assessment of Function (JRAF) is local in scale and was developed to assess the current functions of riverine wetlands adjacent to the Navajo River and use that information to prioritize and design restoration projects to improve poorly functioning reaches, and systematically monitor those projects. The second model was developed for Glacier National Park (GNP). The Natural Resource Condition Assessment for Glacier National Park (NRCA) is watershed in scale and was developed to provide an assessment of several focal elements within the park, including aquatic resources, as part of the long-term assessment and monitoring efforts. As with the RAM's our two models are comprised of a series multi-metric models that assess the condition of biotic and abiotic attributes of an ecosystem. However, as the assessment is changed in scale from local to watershed (and beyond), it is necessary to make adjustments to the approach, data collection and analysis, and application. We compare three separate approaches (JRAF, NRCA, and a RAM) to assess condition of aquatic ecosystems. First, we provide a direct comparison between the JRAF and a RAM model . Following the development of JRAF, an opportunity arose to perform side-by-side comparisons of JRAF to the California Rapid Assessment Method (CRAM). The CRAM developers wished to test if their model has broad application throughout the west. Our comparison assessed the potential range of CRAM and highlights the fundamental differences between these two models. Following this, we compare these approaches to the information one can derive from a watershed scale assessment such as the NRCA.

Addressing Computational Paradigms In Modeling Hydrological Processes At The Catchment Scale

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This project was aimed at linking complex conceptualizations of watershed processes with statistical tools for representing uncertainty in hydrological models and simulated scenarios. We implemented the Distributed Hydrology Soil-Vegetation model (DHSVM) for a watershed in central Montana. DHSVM is a physically based hydrologic model that models the dynamics of hydrology, vegetation, soil and topographical effects to predict sediment yields, water balance and channel discharge. For model optimization and calibration, we explored the use of surrogate models that avoid having to run the 'expensive' model during the many optimization iterations that may be necessary makes automatic calibration feasible. We demonstrate the feasibility of using radial basis approximating functions in Bayesian optimization and uncertainty analysis of the model simulations. The modeling framework enabled scenario analysis related to climatic variability and change. We implemented these methods at the Tenderfoot Creek Experimental Forest (TCEF) in central Montana, an experimental watershed with multi-scale field observations and a complexity of environmental processes due to complex terrain, seasonal variability in climatic forcing, and diversity in physical characteristics affecting watershed processes (vegetation, aspect, topographic convergence/divergence, geology) across nested sub-watersheds. Our modeling results show that the model may be efficiently calibrated with relatively few model simulations performed, greatly enhancing the potential robustness of the model predictions.

Modeling Aquifer Responses To Urban Sprawl, West Billings Area, Montana

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The west-Billings area in Yellowstone County has experienced tremendous growth and development. Most of the new homes being built are in areas beyond municipal services and these residents are dependent on shallow aquifers for their only source of potable water. These aquifers are primarily recharged by flood irrigated agriculture land which is disappearing with increasing residential development. The loss of aquifer recharge puts future ground-water availability and quality at risk. The purpose of the transient ground-water model of the West Billings area in Yellowstone County is to provide a planning tool for managing the rapid growth and urbanization that is occurring. Alternatives such as agricultural easements, green belts and artificial recharge could potentially offset recharge losses. However, it is not currently known how much recharge is required to sustain the aquifer or where critical recharge areas are. Also it is not presently known how fast and where ground-water declines will likely occur. The transient ground-water flow model is being used to simulate the reduction in agricultural recharge and to find possible answers to these unknowns. The MODFLOW based ground-water model was constructed using Groundwater Modeling Systems 7.0 (Aquaveo GMS, 2009). Hydrogeologic information obtained by previous investigations (Olson and Reiten, 2002) and data collected in 2009-2010 were used to constrain the model parameters. The stratigraphy of the model area was interpolated from approximately 190 well logs recorded for area wells. Monthly water levels measured at 29 sites and periodic stream and drain ditch flows were used to calibrate the transient model. Simulations were run to determine the potential impacts of reduced flood irrigation and increasing ground-water demand for lawn irrigation. Preliminary results indicate that certain zones of the model area are at greater risks for substantial aquifer depletion with continued land-use change.

Watershed Structure And Stream Network Geometry: Implications For Water And Solute Transport

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Watershed managers and scientists are often faced with predicting timing and magnitude of water and solute export from watersheds. Watershed structure and stream network geometry can influence timing and magnitude of water and associated solute movement through the watershed. Structure partially controls the redistribution of water within the watershed and the resulting spatial distribution of water delivery to the stream network. Network geometry controls the distances that water and associated solutes travel to the watershed outlet. An understanding of how these structural (watershed) and geometric (stream network) characteristics of watersheds combine to influence the delivery of water and associated solutes to a watershed outlet can facilitate improved interpretation of watershed outlet observations. We analyzed six watersheds in the Sawtooth Mountains of central Idaho, USA ranging in size from 11 to 63 km^2 to explore the interactions between watershed structure and network geometry. The width function is a common tool for graphically representing network geometry as the frequency of distances traveled to the outlet. We built upon this method by incorporating local inputs, or the magnitude of water entering the stream network at a given steam reach, a measure of watershed geometry. We used an empirically derived relationship between velocity and discharge (given by local inputs) to calculate a distribution of stream network travel times. This travel time function is a tool which combines watershed structure and network geometry and has implications for discharge magnitude, timing of water and solute export, and solute and contaminant transport.

SESSION 4 GEOCHEMISTRY AND WATER QUALITY

Elevated Lead In The Bighorn River May Be Linked To Groundwater Distribution Through Reactivated Precambrian Fault Systems

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The Bighorn River in Montana was a declared 303d impaired waterway once it passes through the Crow Reservation due to elevated lead and mercury. Data from the U. S. Geological Survey National Uranium Resource Evaluation (NURE) database was examined using Geographic Information System analysis to look at the distribution of lead in watersheds that contribute to the Bighorn River in northern Wyoming and Montana. This study revealed several hydrologic basins in the Montana portion of the Bighorn hydrologic basin with high elevations of lead in water. At least 20 springs had levels of lead greater than 1000 ppb and the highest lead in the watersheds examined was 5250 ppb in a stream sample. All samples with lead greater than 200 ppb also had cobalt associated with them. Abandoned Uranium/Vanadium mines are hosted in the Madison Limestone along the crest of a large south-plunging anticline in the Pryor Mountains. The uranium deposits show a structural relationship to a zone of fractures that trend roughly N 65o W and lie within the watersheds with high lead values. These fractures parallel the general trend of the Nye-Bowler Lineament. The Nye-Bowler Lineament is characterized by a core of northwest-southeast trending faults, folds and volcanic domes that is overprinted by a set of smaller north-northeast trending normal faults. Further examination of NURE data, examining the whole state of Montana, reveals a distinct pattern of high lead with associated cobalt in an area bound on the southwest by the Nye-Bowler Lineament and on the northeast by the parallel Lake Basin fault zone that extends east of Billings, Montana. The Lake Basin fault zone is the eastern segment of the roughly 300km long Lewis and Clark Lineament that can be traced from Coeur d' Alene, Idaho to east of Billings, Montana. A few high lead values follow this trend in the western part of the state. The highest concentrations of lead occur along the Lake Basin fault zone, with 63 samples having lead values ranging from 6000 ppb to 23,890 ppb along an 80 kilometer portion of the lineament northwest of and extending southeast of Billings. The 63 high lead samples along the Lake Basin fault zone have cobalt values ranging from 300 ppb to 1869 ppb and all the samples with lead greater than 200 ppb have cobalt associated with them. The fault-bounded block of samples has a distinctly different chemistry than those samples outside the lineaments. The high lead samples lack strontium, sodium, silica, barium, potassium, aluminum and have much lower concentrations of uranium than the no lead samples. The samples with no lead have strontium values ranging from 1500 ppb to 13,000 ppb just north of the Lake Basin fault zone. Lead appears to be mobilized and distributed through these reactivated Precambrian faults and localized within a distinct structural pattern, the southeastern portion of which may be contributing lead to the Bighorn River.

Using Stable Isotopes Of Oxygen And Dissolved Inorganic Carbon To Trace Respiration And Photosynthesis Processes Under Ice Cover At Georgetown Lake, Montana

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Georgetown Lake is a shallow (5 to 10 meter), man-made lake and prodigious trout fishery in southwestern Montana. Previous studies have shown that severe DO depletion occurs throughout the lake each winter under ice cover. Here we report the results of monthly chemistry and stable isotope sampling at two sites through the winter of 2010-2011. By mid-winter, both sampling sites had established a robust vertical profile with the following characteristics: a) a rapid lowering of dissolved oxygen (DO) concentration to values near zero about 1 meter above the bottom, with a simultaneous increase in ?18O-DO; b) an increase in alkalinity, CO2 partial pressure, and dissolved inorganic carbon (DIC) with depth, with a decrease in ?13C-DIC; and c) an increase in ammonium, H2S, silica, phosphate, Ca2+, Mn2+ and Fe2+ towards the lake bottom. These trends are consistent with a combination of aerobic and anaerobic respiration, coupled with dissolution of calcite in lake sediment. However, the shallower of the two sites investigated had a less steep slope of ?18O-DO vs. DO concentration, suggesting that below-ice photosynthesis was partly offsetting consumption of DO by respiration. Photosynthetic, purple, H2S-oxidizing bacteria were observed at the shallow site, but not at the deeper site. The ability of photosynthesis to continue during the 6+ months of ice cover could well be a critical reason why fish survive the winter season in Georgetown Lake. However, the lake is near an ecological tipping-point, and is vulnerable to increased residential development and associated nutrient loads.

Sources Of Dissolved Oxygen To Support Microbial Activity In Groundwater Close To And Distant From River Recharge Zones: A Study From The Nyack Aquifer Near West Glacier Montana

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Dissolved oxygen (DO) and dissolved inorganic carbon (DIC) are particularly important to groundwater chemistry because they have a major influence on redox potential and pH, which in turn control the mobility and reactivity of a host of chemical species. However, the mechanisms that consume DO in groundwater (e.g., biotic or abiotic) are often ambiguous. Previous work reported by these authors has used stable isotopes of DO and DIC to follow spatial and seasonal changes in the concentration of DO and DIC at the Nyack floodplain aquifer along the Middle Fork of the Flathead River near West Glacier, Montana. The changes in concentration of DO over a short, well constrained flow path (~ 100 m) near the main recharge zone has shown a relatively rapid decrease in DO combined with an increase in DIC. These observations are explained by microbial respiration coupled with dissolution of calcite from cobbles in the aquifer matrix. When the above results are compared to data from wells distributed over the entire floodplain (several km) a much slower rate of O2 consumption with distance was observed when compared to the zones near the river recharge. Here we present mass balance calculations to show that approximately equal amounts of O2 may be contributed to the aquifer by diffusion/infiltration from the vadose zone when compared with advection from the river recharge zone. Additionally, diffusion across a narrow air-water interface can be shown to contribute to the presence of anomalous stable isotope compositions found in the groundwater distal to the recharge zone. Possible contributions of isotopically DO from other processes, such as isotopic exchange and radial oxygen loss from plant roots in or near the water table, are compared and evaluated.

Arsenic Cycling And Geochemistry Of The Warm Springs Ponds

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Hydrogeochemistry of arsenic in Warm Springs Ponds Joshua Lee and Chris Gammons Dept. of Geological Engineering, Montana Tech, Butte, MT Preliminary results are reported from an ongoing project investigating arsenic cycling and geochemistry within the Warm Springs Ponds Operable Unit (WSPOU), near Anaconda, Montana. Dissolved arsenic concentrations at the outlet of the WSPOU rise during the Summer and Fall months. The purpose of this study is to examine the mechanisms of arsenic release. The following mass balance equation summarizes our current understanding of how arsenic moves through the WSPOU system: Jsw-in + Jgw-in + Jdiffusion = Jsw-out + Jgw-out. In this equation J is the flux of arsenic (e.g., mole/day) into or out of the ponds, sw stands for surface water advection, gw stands for groundwater advection, and Jdiffusion is the flux of arsenic diffusing upwards from sediment pore water into the overlying surface water. A series of field experiments conducted in Pond 2 and the West Wet Closure (WWC) are being used to estimate Jgw-in and Jdiffusion. Iron-stained sediment along the south shore of both ponds indicates probable areas of upwelling groundwater. A combination of piezometers and seepage meters fashioned from sawn off 55-gal plastic drums are being used to estimate Jgw-in in these areas. The diffusive flux is being determined by two methods: (1) directly, by use of flux chambers; and (2) indirectly, by use of sediment pore water samplers (peepers). The flux chambers are open-bottomed tanks placed over the pond sediment in a location where the vertical gradients in hydraulic head are negligible. Changes in the concentration of solutes over time (hours to days) inside the tank can be used to directly calculate the diffusive flux. The chambers are stirred by pumping water through a closed loop of tubing connected to the tank. Peepers give a vertical array of closely-spaced, small-volume samples of pore water in the top 25 cm of sediment. The vertical gradient in solute concentration extracted from the peeper cells is then combined with Fick's Law to estimate the diffusive flux. Results obtained at this stage in the project suggest that the diffusive flux of arsenic is a significant factor in the overall mass balance equation. Upwards diffusion of As occurs in all months of the year, but is faster in Summer and Fall when pore water temperatures are higher. An important question that remains to be answered is whether or not As accumulates at the sediment-water interface during certain times of the year, and is released to the water column in other times of the year.

The Stoichiometry Of Uptake: Dual Nutrient Uptake Kinetics From Ambient To Saturation

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Nutrient uptake is a key ecosystem process that results in the reduction and transformation of available nutrients at a site. Decades of laboratory and field experiments have shown that nutrient uptake is dynamic with concentration of that nutrient. Stoichiometric theory suggests that uptake of a nutrient should also be related to the availability of other key nutrients, but to date little work has been done in this research area. We investigated the stoichiometry of uptake across wide ranges in concentrations and ratios of nitrate (NO3) and phosphate (PO4) by conducting independent NO3, PO4, and dual NO3 + PO4 slug injections in three streams in the West Fork of the Gallatin River watershed in August 2010. The individual additions of NO3 and PO4 each resulted in Michaelis-Menten uptake kinetics across the observed concentration range in all three streams. During the dual slug, uptake rates of each nutrient increased with the addition of the second nutrient, suggesting co-limitation by these two nutrients at all sites. The absolute and relative magnitudes of these increases in NO3 and PO4 uptake varied between sites, however, suggesting that these sites vary in the relative strengths of nitrogen (N) versus phosphorus (P) limitation. We present these results in the context of inter-site variations in epilithic N:P ratios to highlight the role of coupled N and P dynamics in controlling nutrient uptake and resulting patterns of nutrient availability in streams.

Potential Toxicity Of Sediment Bound Pyrethroid Insecticides In Urban Streams And Drains Of Billings

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During the summer of 2010 the Montana Department of Agriculture collected 31 sediment samples from streams, drains, and irrigation ditches in the Billings urban area for pyrethroid analysis. Pyrethroids are synthetic forms of pyrethrins, a natural insecticide produced by some species of chrysanthemum plants. Pyrethroids are largely insoluble, non-persistent chemicals, and are relatively immobile in the environment. They have high adsorption coefficients and bind tightly to the organic fractions in soils and sediment and have low risk of leaching to groundwater. Bound to soil particles, pyrethroids are prone to off-site transportation and deposition in surface waters following a precipitation or irrigation event. There were a total of 80 detections of 8 different pyrethroids in the sediment samples. Samples had a mean of 2.67 pyrethroid detections per sample. Pyrethroids detected included: bifenthrin, cyfluthrin, λ-cyhalothrin, cypermethrin, fenpropathrin, permethrin (cis- and trans-), allethrin and prallethrin. Bifenthrin and the cis- and trans- isomers of permethrin comprised 75% of all detections. Because pyrethroid toxicity is dependent on the amount of organic matter in the sediment a toxic unit (TU) analysis was performed to determine potential toxicity to aquatic macroinvertabrates. Calculated TUs ranged from 0.00 to 1.80 TUs with a mean of 0.32 TUs for all samples collected. Amweg et al. (2006) determined that a critical threshold existed at 0.4 TUs, although more recent studies have used a threshold of 1 TU to ascertain significant mortality to aquatic invertebrates (Hintzen et al., 2009; Weston and Lydy, 2010). Of the 31 sediment samples collected nine exceeded 0.4 TUs and two exceeded 1.0 TUs. Where detected, bifenthrin accounted for ~72% of sample toxicity while permethrin accounted for ~33% of sample toxicity. Detections of bifenthrin and permethrin isomers were nearly identical but bifenthrin has significantly greater toxicity.

How To Cherry-Pick Climatic Data

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Climatic data in Montana is highly variable with snowpack and seasonal stream flow varying from 50 percent of average to 150 percent of average. Monthly precipitation and temperature have a greater variability. Time of various climatic events in Montana, such as when snowpack starts to accumulate, when it reaches it season's maximum, when it melts out, when streams reach their annual peak flow, and when plants break dormancy have had a historical variation spanning about eight weeks. The trend of whether some variable is increasing or decreasing or holding level can be altered significantly by changing the dates of analysis. This technique is frequently used by researchers that desire to show how climatic changes are agreeing with their hypothesis. Several examples will be shown for such things as snowpack, precipitation, temperature, stream flow, reservoir storage, phenology, wildlife populations, fire effects, growing seasons and many others. Also, some of the excuses used to try to justify not using the entire record that is available will be presented. Researchers have an obligation to present all of the data and not try to obscure some of the data in order to justify their beliefs or for securing funding. Other variables may also be responsible for changes other than climate change and this needs to be pointed out rather than trying to identify that all of the variability is due just to climate change.

Montana In-Lieu Fee Aquatic Resource Mitigation Program: First Aid For Death By A Thousand Cuts

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Healthy, high-functioning wetlands, riparian areas, and floodplains help maintain ecological resiliency in aquatic systems affected by changing climate. Although §404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act have long required mitigation for impacts to wetlands, navigable waters and their tributaries, as well as floodplains, such impacts have largely gone unmitigated resulting in death by a thousand cuts. In May 2010, the Army Corps of Engineers (Corps) Helena Regulatory Office issued the Montana's first Stream Mitigation Procedure (MTSMP). The MTSMP establishes a process and requirement for quantifying acceptable compensatory mitigation for projects that would result in more than minimal adverse impacts to a stream as part of the Corps' Clean Water Act Regulatory Program. In cooperation with the Montana Department of Environmental Quality and the U.S. Environmental Protection Agency, Trout Unlimited's Montana Water Project is incubating a non-profit organization that will sponsor an In Lieu Fee (ILF) Aquatic Resource Mitigation Program that may collect compensatory mitigation fees and use those funds to complete qualified mitigation projects. We anticipate that by the end of 2012, the ILF program will be providing an additional source of habitat restoration and protection funds for projects across Montana. At the current time, a prospectus is being developed for the new ILF program. We anticipate that the draft prospectus will be provided to the Corps by the end of June. A final version of the prospectus is anticipated by the end of September. The completed prospectus will set the stage for developing a draft and final version of the ILF Instrument which will include all requisite elements for the ILF program including: service area, accounting procedures, legal responsibility provisions, default and closure provisions, reporting protocols, compensation planning framework, advance credits, method for determining credits, draft fee schedule, and ILF program account. The operation of the ILF program will be overseen by an Interagency Review Team (IRT), which will be directly involved in the development of project performance criteria and provide feedback to the Corps and the ILF sponsor regarding eligible mitigation projects. The ILF program offers restoration practitioners an additional funding source for eligible aquatic resource restoration and protection projects with a goal of offsetting the loss or degradation of our streams, riparian areas, wetlands, and other aquatic resources.

Considering The Other End Of The Hydrologic Spectrum: Forecasting Drought In The Red River Basin Of The North

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Drought is a pervasive and perennial problem across the United States and throughout the world. The economic impacts from drought are substantial. Mitigating damages from drought requires developing technically feasible methods and techniques which can be implemented operationally, to accurately forecast drought and convey these forecasts in near-real time to affected stakeholders. The goal of the Regional Drought Decision Support System (RDDSS) is to incorporate methods and techniques developed by the National Weather Service research and operational staff to communicate drought risk to diverse stakeholder groups. The project involves the development and use of drought forecast products to communicate risk for agricultural producers and water supply users, including products derived around forecasted soil moisture states. Setting these products in the context of permitted water use, local drought management plans, and observed hydrologic/meteorological conditions, provides a basis upon which decisions can be made. The RDDSS exists as a collection of reports and applications accessible through a publically-available website (http://gis.rrbdin.org/rddss-noaa/home.html). The System makes up one component of a larger regional decision support system for the Red River Basin of the North (see www.rrbdin.org).

Understanding Water Use In Montana - An Experiment In Geospatially Enabling The DNRC Water Rights Database

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Chief among the initiatives intended to characterize water use in Montana is the development of a geospatially enabled version of the DNRC Water Rights Database (WRDB). The WRDB contains a variety of water use information associated with individual water rights (e.g. means of diversion, purpose, flow rate, volume, priority date, period of use, etc.), including geographic information such Point of Diversion (POD) and Point of Use (POU). These data are vital to water resource managers, but POD and POU data have a major limitation – they are spatially represented as centroids of the legal land description maintained in the WRDB. This representation is suitable for generalized visual reference on a map, but it cannot serve as a parameter for in-depth modeling or spatial analysis. Geospatial enabling of the WRDB involves mapping PODs to the National Hydrography Dataset (also referred to as the POD2NHD project). The goal is to provide water use information with sufficient accuracy to allow meaningful geographic queries of PODs and POUs within a given basin. To accomplish this, DNRC has partnered with the USGS and the Montana State Library, Natural Resource Information System (NRIS), to determine the level of effort required to update and publish the high resolution (1:24,000) version of the National Hydrography Dataset (NHD) with mapped PODs as an associated dataset. The linear referencing capabilities of the NHD, combined with linear flow routing capabilities such as can be developed using ArcHydro (Maidment, 2004), allows investigators to examine water resource events such as PODs in terms of their upstream and downstream relationships. This type of analytical capability is crucial to making informed water resource management decisions. Ultimately, it is envisioned that other Montana resource agencies, such as the Department of Environmental Quality (DEQ) and the Department of Fish, Wildlife and Parks (DFWP), will also migrate their event data to a common NHD base. After preliminarily testing several basins, the lower Tongue River Basin (Water Rights Basin 42C) was selected for further development. The initial editing process involves examining individual PODs in the context of a variety of datasets: CIR photography from 2005 and 2009 NAIP; USGS Topographic Quads in DRG format; Water Rights Mapper data generated by the DNRC water rights adjudication process; source name match (GNIS); and synthetic drainage and hillshade layers generated using IFSAR elevation data supplied by Intermap Technologies, and either taking No Action, manually snapping the point to the appropriate point on the NHD Manually Place to NHD, or manually connecting the point to the NHD via a connector feature class, Placed on Proposed

NHD. Initial efforts to migrate the 6,928 PODs in 42C to the NHD yielded the following results: • 2474 PODs (35.7%) = No Action, primarily from groundwater sources, means of diversion are wells; • 3717 PODs (53.7%) = Manually Placed to NHD, these are mostly on-stream dams (1438), livestock direct from source (940), and dikes used to divert or spread water (553); and • 329 PODs (4.7%) = Placed on Proposed NHD, these are mostly livestock direct from source (146), dams (73), and spring boxes (46). Although an effort was made to locate the PODs as accurately as possible, the primary consideration was topological accuracy – in other words, providing POD locations and associated edits that maintain upstream and downstream relationships. Future efforts will be focused on using this information to understand the relationship between water supply and water use within individual watersheds.

Montana's National Ground Water Monitoring Network Pilot: Findings And Results

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In 2007 the Advisory Committee on Water Information (ACWI) created a Subcommittee on Groundwater (SOGW) and asked it to develop and encourage implementation of a national groundwater quantity and quality monitoring network (NGWMN). In 2009, the SOGW produced its report: A National Framework for Ground Water Monitoring in the United States, which described how consistent water-level and water-quality data for the nation's principal, major, or other important aquifers could be collected from existing non-federal monitoring programs via cooperative agreements. SOGW recommended water-level measurement and water-quality sampling frequencies for NGWMN sites, but recognized that many issues including data management, field practices, network design, and implementation costs remained; pilot studies to evaluate these issues were implemented in Illinois-Indiana, Michigan, Montana, New Jersey, and Texas. Additionally, data from the pilot study networks were to become available through a map-based interface on a U.S. Geological Survey hosted 'Groundwater Data Portal'. Each time the portal receives a data request, it queries the appropriate state databases 'on-the-fly' and delivers mediated, consistently formatted data. Montana completed its voluntary (self-funded) 1-yr effort in January 2011 and found that about 70 percent of its 950+/- statewide monitoring wells would be suitable NGWMN sites. Montana's data management and field practices were generally compatible with the national framework guidance. However, spatial and operational data gaps between Montana's current network and the conceptual NGWMN became apparent, including the need: for additional wells to improve the spatial distribution of monitoring sites across aquifers, for more frequent static water level measurements in some wells, and for generally increased water-quality sampling frequencies. Montana estimated that 'one-time-only' costs to fill NGWMN spatial and baseline data collection gaps would be from about $310,000 (to acquire baseline water-quality data in existing wells) to $2.1 million (to fill spatial gaps, gather baseline water quality in existing wells, and collect baseline water-level and water-quality data in new wells), depending on how many of the 'gaps' were filled. Ongoing NGWMN-Montana operational costs would range from $150,200 to $458,000 annually depending on whether only existing wells at current monitoring frequencies were included, or if monitoring frequencies were upgraded to SOGW recommendations and spatial gaps were filled. To control NGWMN startup costs, Montana recommended that the SOGW focus on reconciling field practices and data management issues between the many potential cooperators, get the NGWMN functional using existing sites, and then move on to the challenges of filling spatial, baseline data, and operational gaps.

SESSION 6 SURFACE WATER AND RUNOFF

Potential Peak Flow Management Within The Clark Fork Basin, Montana

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Managing water implies its storage. Water storage can occur on the surface in reservoirs, lakes, and snowpack and in the ground via infiltration or injection. Traditional water management has stored high flows in lakes and reservoirs to provide flood control, irrigation, hydropower generation, fish flows and habitat, and recreation. Two of the largest storage reservoirs in the US portion of the Columbia River basin are located in Montana, Lake Koocanusa which is created by Libby Dam on the Kootenai River and the Hungry Horse Reservoir created by the Hungry Horse Dam on the South Fork of the Flathead River. In 2024, the Columbia Treaty between the US and Canada expires. This treaty has facilitated management of the system of dams in the Columbia River basin in Canada and the US, particularly for flood control, hydropower, and flows needed by threatened and endangered anadromous fish stocks. The Clark Fork River Basin Task Force is considering ways to manage the basin water supply by storing high spring flows in the ground to provide flood control and mitigation for new water development. In conjunction with the Montana Bureau of Mines and Geology, the Task Force is proposing to conduct an analysis to determine how much water might be stored in Clark Fork basin aquifers, where it might be stored, and who might benefit from the storage. This presentation will discuss this analysis.

Hierarchical Controls On Catchment Runoff Generation: Topographic Hydrologic Connectivity, Vegetation, And Geology

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Understanding the relative influence of catchment structure (topography and topology), underlying geology, and vegetation on stream network hydrologic connectivity and runoff response is key to interpreting catchment hydrology. Hillslope-riparian-stream (HRS) water table connectivity serves as the hydrologic linkage between a catchment's uplands and the channel network and facilitates the transmission of water and solutes to streams. While there has been tremendous interest in the concept of hydrological connectivity to characterize catchments, few studies have quantified hydrologic connectivity at the stream network and catchment scales with observational data. Here, we examine how catchment topography, vegetation, and geology influenced patterns of stream network HRS connectivity and resultant runoff dynamics across 11 nested headwater catchments in the Tenderfoot Creek Experimental Forest (TCEF), MT. This study builds on the empirical findings of Jencso et al. (2009) who found a strong linear relationship (r2 = 0.92) between the upslope accumulated area (UAA) and the annual duration of shallow ground water table connectivity observed across 24 HRS transects (146 groundwater recording wells) at one TCEF catchment. We applied this relationship to the entire stream network across 11 nested catchments to quantify the frequency distribution of stream network connectivity through time and quantify its relationship to catchment-scale runoff dynamics. Each catchment's hydrologic connectivity duration curve (CDC) was highly related to its flow duration curve (FDC) and the slope of the relationship varied across catchments. The slope represents the streamflow yield per unit connectivity (Conyield). We analyzed the slope of each catchment's CDC-FDC relationship or Conyield (annual, peak, transition and baseflow periods) in multiple linear regression models with common terrain, land cover-vegetation, and geology explanatory variables.

Snow Hydrology: Effects Of Mountain Pine Beetle On Snowpack Characteristics

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The future of water resources in the west is tenuous, as climatic changes have resulted in earlier spring melts that have exacerbated summer droughts. Associated with climate changes to the physical environment are changes to the biological environment that may impact snow dynamics; namely via the massive outbreaks of Mountain Pine Beetle, (MPB; Dendroctonus ponderosae) and other herbivores that have devastated several million hectares in the western U.S. and Canada. If snow accumulation and melt are determined by the physical environment of the snowpack, and forest canopies define in part this physical environment, how might recent insect outbreaks alter Montana's water resources? An expected outcome of MPB infestation is an increase in shortwave flux density at the snow surface due to a less dense canopy. Combined with a corresponding decrease of snow reflectance (albedo) from litterfall, we hypothesize that snowpacks in MPB-infested canopies will melt more rapidly. However, more snow is also expected to accumulate over the winter due to decreased canopy interception, resulting in a larger spring freshet. We measured depth, snow water equivalent, and energy fluxes in two forested snowpacks and one clear-cut snowpack in the Tenderfoot Creek Experimental Forest in the Little Belt Mountains of West-central Montana. One of the forested ecosystems is undergoing the initial phases of MPB attack with observed pitch tubes and a green canopy. The other has advanced to the red stage of attack as it succumbs to MPB infestation. Data from the initial field season of 2010-2011 will be presented and will focus on measurement and model results at the plot scale with an eye toward future measurement and modeling investigations at the watershed scale.

Streamflow Statistics For Unregulated And Regulated Conditions For The Yellowstone River And Selected Tributaries

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The Yellowstone River is the longest free-flowing river in the lower 48 states. The Yellowstone drains about 70,000 square miles as it flows more than 670 miles from its origin south of Yellowstone National Park in Wyoming, to the confluence with the Missouri River in North Dakota. The Yellowstone River supports a wide variety of agricultural, domestic, industrial, and recreational uses and, in some areas of Montana, is a blue-ribbon trout stream. Major floods in 1996 and 1997 intensified public debate over the effects of human activities on the Yellowstone River. In 1999, the Yellowstone River Conservation District Council (YRCDC) was formed to address conservation issues on the river. The YRCDC is partnering with the U.S. Army Corps of Engineers (Corps) to conduct a cumulative effects study (CES) on the mainstem of the Yellowstone. The CES is intended to provide a basis for future management decisions in the watershed. Streamflow statistics, such as flow-frequency and flow-duration data calculated for unregulated and regulated flow conditions, are necessary for many aspects of the CES. The U.S. Geological Survey is working with the YRCDC and the U.S. Army Corps of Engineers to calculate streamflow statistics for unregulated and regulated flow conditions for the Yellowstone River and selected tributaries from 1928 to 2002. Unregulated streamflow represents streamflow conditions that might have occurred during the 1928-2002 study period if there had been no water-resources development in the basin. Regulated streamflow represents estimates of flow conditions during the 1928-2002 study period if the level of water-resources development existing in 2002 was in place during the entire study period. Unregulated and regulated streamflow statistics will be compared to determine the effects of water-resources development on Yellowstone River streamflows. Additionally, analyses of trends in unregulated flows will document the likely effects of climatic variability on streamflow during the study period.

Milk St. Mary Rivers Basin Study: Planning for Future Changes in Supply and Demand

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The Montana Department of Natural Resources and Conservation is working with the U.S. Bureau of Reclamation to develop a hydrological model of the Milk-St. Mary River system from the headwaters of the St. Mary River, to the mouth of the Milk River near Nashua. The model is being developed with the RiverWare software, and represents the various components of the river system (rivers, reservoirs, canals, diversion structures, etc) as objects, and uses rules to simulate operations of the system. Model input is hydrologic and irrigation data for the 1959-2009 periods, and the model runs on a daily time-step. The model is being developed for planning work related to the Milk-St. Mary River System Basin Study as part of the Water for America program. The purpose of this study is to use model to investigate the potential effects of climate change on future water supplies, and the adequacy of the existing infrastructure to meet increasing water demands. The study will include modeling water supplies and demands under a future climate, and investigating options, such as infrastructure or management improvements, that can be used to meet future water needs. This presentation will give an overview of the model, and present preliminary results.

Identification And Quantification Of Baseflow Using Carbon Isotopes

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Six locations along Otter Creek in southeastern Montana and a nearby monitoring well completed in the Knobloch coal were sampled and analyzed for carbon isotope ratios. Between where it becomes a perennial stream near the town of Otter to where it meets the Tongue River near the town of Ashland, Otter Creek crosses the Knobloch coal outcrop. The carbon isotope ratio of the creek becomes progressively more similar to that of the Knobloch coal aquifer in samples collected down-gradient from the town of Otter. The isotope ratio of the stream changes from -10.5 to -8.9o/oo, reflecting the influence of the Knobloch coal aquifer baseflow contribution which has a carbon isotope value of +3.9o/oo. The dissolved inorganic carbon concentrations of the ground water and surface water are similar (approximately 90 mg/L), which allowed the use of the simplified, first-order, two-end-member mixing equation. Using carbon isotope ratios, calculations of the fraction of water contributed by the Knobloch coal aquifer indicate that approximately 11% of the surface water in Otter Creek at its mouth near Ashland was originally Knobloch coal aquifer ground water.

SESSION 7 AQUATIC ENVIRONMENTS

Seasonal Effects Of Eutrophication And Hypoxia On The Relative Abundance Of Fishes In A Superfund Remediated Montana Stream

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Fish populations of Silver Bow Creek downstream from Butte, Montana were extirpated by more than a century of contamination from local mining and municipal wastes, but remediation of the stream has been ongoing for more than a decade. Six species of fish are now present in the stream, including three in the family Salmonidae. To evaluate the success of remediation in reestablishing stream fish populations, we conducted spatially continuous electrofishing and mobile antenna surveys of PIT-tagged fish in 28 km of Silver Bow Creek and two tributary streams in July, August, and December 2010. Concentrations of heavy metals, ammonia, and dissolved oxygen (DO) were monitored in corresponding stream sections. Within 6 km of the Butte wastewater treatment plant outfall, ammonia concentrations reached toxic levels (NH3-N ? 1.48 mg/l) during each survey period in 2010 and hypoxia (DO < 2 mg/l) was evident in July and August of 2010. Preliminary analysis suggests that salmonid abundance was substantially reduced in the hypoxic zones during those surveys, but catostomid abundance did not appear to be affected. During December 2010 surveys, hypoxia was not detected, but ammonia concentrations remained elevated. Salmonid abundance patterns in December 2010 surveys were similar to July and August 2010 surveys, but catostomid abundance increased as hypoxia waned, despite elevated ammonia concentrations. It appears that toxic metal concentrations and loads in Silver Bow Creek have been reduced; however, despite signs of improvement, water quality continues to be a major factor influencing the distribution of fish taxa. In 2011, the study area will expand downstream to include an additional 10 km in Silver Bow Creek as well as 5 km of the German Gulch tributary.

Evaluating Macroinvertebrate Responses To Nutrients In A Prairie Stream Using Biometrics

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The Montana Department of Environmental Quality currently uses macroinvertebrate populations as indicators of water quality (i.e. biometrics). In order to accurately depict biometric responses to different stressors, data must be collected along a gradient from high quality (i.e. reference sites) to low quality (i.e. stressed sites). This study focused on nutrients as the stressor, and instead of sampling different stream sites along the gradient from reference to stressed, we decided to dose a prairie stream (Box Elder Creek, Carter County, MT) with varying levels of nitrogen and phosphorus using a control and two different treatments. We will then measure the impact and recovery over time. The nutrient dosing will occurred summer 2010, and the recovery will be measured periodically through 2014. The purpose of this presentation will be to provide an overview of how macroinvertebrate populations responded to the dosing event.

Conservational Strategies of Govindgarh Wetland, Central India

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Govindgarh lake formerly known as Viswanath lake and Raghuraj lake, a historical lake of Central Provinces in Rewa, India, constructed 154 years back with an area of 324 hect. and a depth of 89.70 foot, is presently under stress due to increasing pollutant loads and lack of management. The blanketing of the lake surface by water weeds Eichornia crassipes and enlarging mesh of the aquatic plants like Pistia, Vallisnaria, Hydrila etc. at an alarming rate, have altered the ecology of the wetland giving rise to eutrophication like condition. The exploitations of wetland water for domestical purposes like bathing and washings, sanitation activities, improper drainage, addition of garbage and agricultural waste, have altogether polluted the lake water up to a high extent. The present study is based on the identification of the main causes of the enrichment of the nutrients and to elucidate remedial measures to protect and preserve the water quality of the wetland. In order to study the present condition of the wetland a site survey was carried out along with the personal interactions and group discussions with local people. The physico-chemical analyses of water sample reveals presence of enormous amount of dissolved mineral salts, phosphates, nitrates, suspended solids, calcium, magnesium, organic residues, toxic metals etc., thus enriching the lake and making favorable for the growth of water borne pathogens, weeds and other macrophytes. The study also concludes that there is a lack of environmental awareness in the region and the increasing anthropogenic activities have further resulted in domestical and agricultural waste generation, creating unhygienic conditions and the lake water pollution. Among the remedial measures there is a need of raking of the submerged and floating aquatic floras. However, regarding the water hyacinth (Eichornia crassipes) management there is a need to explore the potential conversion of this water weed to fertilizer, food, fuel, paper, fiber, and energy.

Ecohydrology: Disturbance And The Intersection Of Vegetation Pattern And Landscape Structure

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Watershed ecohydrology is a function of the intersection of vegetation pattern and landscape structure. The hydrologic implications of vegetation disturbance depend on the spatial extent and pattern of change on this ecohydrologic template. Here we investigate this intersection with a focus on a recent mountain pine beetle (Dendroctonus ponderosae) epidemic that is increasingly affecting areas in the Rocky Mountains. Our research area was the Tenderfoot Creek Experimental Forest (TCEF), near White Sulfur Springs, MT. We calibrated QuickBird remote sensing imagery with leaf level measures by developing a spectral library for TCEF vegetation. The spectral library was used to determine which vegetation indices were optimal for differentiating between stages of infestation; thereby maximizing the information obtained from the QuickBird image. These indices were applied to the QuickBird imagery to establish baseline mortality, and the extent and magnitude of infestation across the watershed. In addition, we calculated LiDAR based topography and vegetation structure indices for joint topographic, vegetation, and disturbance analyses. We seek to determine which forest stands are most susceptible to beetle infestation, and how these infestation patterns are related to hydrologic, topographic, and forest ecosystem compositional characteristics. Our efforts to monitor vegetation mortality across space and time provide a context for assessing the drivers of mountain pine beetle infestation and how outbreak patterns may affect watershed ecohydrology via energy, water, and biogeochemical cycles.

Monitoring And Evaluation Of Benthic Macroinvertebrates In The Big Hole River And Tributaries, Montana

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Macroinvertebrate-based surveys are often conducted to assess a stream's biological health. We monitored and evaluated benthic macroinvertebrate (BMI) assemblages in the Big Hole River and important tributaries to assess if BMI assemblages were correlated with observed seasonal grayling distributions and implemented conservation measures improved stream biological health. This study was conducted on the upper Big Hole River and tributaries in southwest Montana from 2007 to 2010. Most of the habitat occupied by grayling in the Big Hole River and its tributaries is on privately owned lands. The recovery of grayling in the system is linked to the active involvement of primarily private landowners and their cooperation. Techniques used to collect, process, and analyze macroinvertebrate samples followed guidelines established in the Montana RBP (Rapid Bioassessment Protocols). We sampled three times per year (June, August, and October) among 19 locations. We provide results from a critical assessment of environmental quality that can be used to identify limiting factors, for detecting impacts from physical alterations, sediment deposition, nutrients and toxicants, and to document successful mitigation of environmental degradation in the upper Big Hole River basin.

SESSION 8 SURFACE/GROUND WATER INTERACTION

Stream – Groundwater Exchange And Hydrologic Turnover At The Network Scale

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Increasingly, streams and groundwater are viewed as a single resource, and are now known to be continuously interacting and exchanging water. Typical stream – groundwater studies have focused on hyporheic scale exchanges, which occur at smaller spatial (meters) and temporal (minutes) scales, but have neglected the influence of larger scale (kilometers and days to years) interactions in controlling the movement of water and solutes across watersheds and stream networks. At these larger scales, the bidirectional movement of water between streams and groundwater leads to hydrologic turnover – or the fractional turnover of streamwater – which has important implications for hydrological and biogeochemical processes and exert influence over streamwater composition, hydrologic mass balances, and solute, nutrient, and pollutant transport downstream. We used consecutive conservative tracer injections (chloride, Cl-) across 10 stream reaches to investigate hydrologic gains and losses in the 11.7 km^2 Bull Trout Watershed of central Idaho, USA. We found strong relationships between reach discharge, median tracer velocity, and gross hydrologic loss to groundwater systems across the continuum of stream types and sizes in the watershed. Next, we implemented these empirical relationships within a watershed scale network model to simulate hydrologic gains, losses, and fractional turnover of streamwater from the headwaters to the outlet of the 11.7 km^2 watershed. We demonstrate that hydrologic gains and losses, and streamwater turnover exert strong controls on streamwater composition and solute transport throughout the stream network. Furthermore, we assess proportional contributions of watershed runoff to streamwater composition and the relative influence these contributions have on compositions observed across the stream network. These dynamics provide insight into the internal mechanisms that partially control the hydrologic and biogeochemical signals observed along stream networks and at watershed outlets.

Instream Nutrient Concentrations: How Groundwater/Stream Water Exchange And Nutrient Uptake Can Interact In Stream Networks

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Stream network nutrient concentrations can be influenced by both physical and biological processes. Watershed and stream network scale assessment of where and to what degree groundwater/surface water exchange and biological uptake modify stream water signatures is therefore critical for understanding basic watershed hydrology and biogeochemistry and for aiding and improving management decisions made at watershed or regional scales. To address this challenge, we developed an empirically based network scale model to simulate hydrologic turnover, concentration-dependent nutrient uptake kinetics, and nutrient concentration across stream networks. Exchange and uptake parameters were determined by conservative and nonconservative tracer addition experiments in the Bull Trout Watershed of central Idaho. We simulate physical exchange of stream water and dissolved nutrients with groundwater (hydrologic turnover) and additionally concentration-dependent biological uptake. Our model allowed us to quantify these processes at the watershed scale and estimate the resulting nutrient concentration across the stream network. Application of our model to six adjacent watersheds (including Bull Trout) with variable geometries indicated that both hydrologic turnover biological uptake are influenced by watershed and stream network structure. Our work suggests that the interaction of these biological and physical processes can modify and subsequently stabilize stream nutrient concentrations, and additionally that watershed and stream network structure can control the specific spatial patterns in nutrient concentration.

Groundwater Surface Water Interaction in the Alluvial Aquifer: Modeling the Middle Stillwater River Valley

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The study area is located in a thin alluvial valley along the Stillwater River west of Absarokee MT, and encompasses about 4,155 acres of land. Irrigation dominates the hydrology of the study area and unlined ditches convey water across the valley floor. The alluvial aquifer consists of a thin highly conductive sand and gravel layer confined below by shale and semi-confined above (in some areas) by soft clay. The local population depends entirely upon groundwater for potable water. The homes are beyond municipal services and obtain their water from individual domestic wells, and most of these wells are concentrated in the center of the thin alluvial valley. Because the demand for water is increasing and land use is changing, there is potential for groundwater resources in the valley to become stressed and over utilized in some locations, which could limit availability of groundwater and reduce in-stream flows. The primary threat to the alluvial aquifer would be a land-use change from agriculture to residential. The alluvial aquifer could be impacted by lack of recharge during the irrigation season, possibly resulting in dry wells. The river could also be impacted by reduced groundwater discharge during summer baseflow conditions. Many different field methods were used to examine the interaction between groundwater and surface water in the study area. Based on stable isotopes of water, the bedrock aquifer is recharged from low altitude rain or snow that has been partially evaporated. In contrast, the alluvial groundwater and the river water are non-evaporated, and the isotopic compositions suggest these waters are sourced from precipitation at higher elevations along the Beartooth Plateau. River water is diverted onto the fields and is the dominant source of groundwater in the alluvium. Water levels in the alluvial aquifer responded rapidly to changes in ditch flow, indicating a close connection between surface water and groundwater. Synoptic surveys concluded the Stillwater River gains water from the alluvial and bedrock aquifers. Steady state and transient groundwater flow models were created with Groundwater Modeling System software using MODFLOW to simulate the flow of groundwater through the alluvial aquifer. Projective simulations were used to determine if adequate groundwater would be available if the valley was no longer irrigated. The models determined that a water level head drop of up to 18 feet in the alluvial aquifer would occur if irrigation did not recharge the aquifer. The river baseflow would also be impacted by a reduced groundwater discharge of about 8%. Less fresh, cool groundwater discharging to the river during summer low-flow periods could have adverse effects on aquatic life. Because of the close connection between irrigation water, shallow groundwater, and river water, the alluvial aquifer in the study area is very sensitive to changes in land use. This also implies that the aquifer is highly vulnerable to surface contamination, which would likely occur if the region were to become thickly settled.

Groundwater Surface-Water Interaction Within The Beaverhead River Valley North Of Dillon, Montana

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The Beaverhead River valley from Dillon, Montana to Beaverhead Rock is mainly supported through agriculture. Irrigation relies heavily on water diverted from the Beaverhead River through the East Bench and West Side Canals. During drier years, irrigation wells are used to supplement water needs. The Beaverhead River basin has been closed to new surface water appropriations since 1993. Several wells in the area are currently in the permitting process which has resulted in conflicts between senior and junior groundwater and surface-water rights holders. A primary concern is that groundwater withdrawals will result in stream depletion by inducing flow away from the stream or by capturing stream recharge. The Montana Bureau of Mines and Geology under the Ground Water Investigation Program is studying the potential effects of pumping high capacity irrigation wells on the depletion of groundwater and surface water. This was completed by i) establishing a groundwater and surface water monitoring network ii) conducting aquifer tests to evaluate aquifer properties, iii) collecting water quality samples to help characterize the aquifers and to provide insight on groundwater-surface water interactions, and iv) examining the role of the East Bench and West Side Canals on groundwater recharge through monitoring shallow groundwater near the canals and measuring canal water loss. Groundwater and stream hydrographs and water chemistry samples indicate that the floodplain alluvial aquifer and the Beaverhead River are in direct connection with one another. Tritium samples indicated that the deeper Tertiary aquifer was much older.

An Evaluation of Artificial Groundwater Recharge as a Conjunctive use Approach to Mitigating Surface Water Depletions

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Groundwater withdrawals in unconfined and semi-confined aquifers are capable of producing significant surface water depletions that extend beyond the irrigations season (off-season). Using induced groundwater storage is one alternative to mitigate for off-season depletions. Squaw creek, located in the Bitterroot Valley, MT, has the potential to have off-season depletions from groundwater withdrawals. A field study and numerical modeling effort was conducted to evaluate artificial groundwater storage as a means to facilitate off-season mitigation on Squaw Creek. Field work was conducted to evaluate the groundwater and surface water interactions, with a focus on the streambed conductance of Squaw Creek. Three methods were used to evaluate streambed conductance: 1) Sieve Analyses, 2) Permeameter tests, and 3) temperature gradient modeling. An infiltration pilot test was conducted over a two week period to assess the amount of water the aquifer was capable of storing and the ability for Squaw Creek to receive the water. Groundwater levels were monitored in piezometers and surface water stage and flows were monitored regularly in Squaw Creek. Results from the pilot test indicate that the shallow aquifer in the vicinity of the pilot test was able to receive a significant amount of water; however water storage was limited due the high transmissive characteristics of the aquifer allowed for the water to be transported to squaw creek within hours of it being infiltrated. A numerical model was developed to evaluate induced groundwater storage over a long period and its capability to facilitate off-season mitigation on Squaw Creek. A system of ponds and streams were introduced into the model to simulate a possible infiltration scenario. Preliminary results of the modeling indicate that the aquifer is capable of receiving a significant amount of water; however the transport of the water to the stream is rapid. Induced groundwater storage has the ability to facilite off-season mitigation in areas where there is a significant distance to the surface water body or the off-season depletions only occur for a short period. However in high transmissive aquifers (typical of those found in intermontane basins), the rapid transport of the groundwater to surface water may limit the ability for induced groundwater storage as a mitigation alternative where infiltrated water is in close proximity to the depleted surface water body.

Effects Of Geology And Landforms On Riparian Water Availability

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Studies in the 1960's and 70's have shown that water takes various flow paths from hill slopes to the stream channel due to the local geology and that streams are continuously gaining and losing water to groundwater aquifers . Recent studies have shown that the geology and landforms function as drivers of groundwater and surface-water exchange. These can mitigate ecosystem processes via ground water availability to shape riparian processes; e.g. discharge, seasonality. However, most assessments fail to address these basic processes focusing instead on floristic composition and structure. We propose that groundwater surface-water exchange is a first order process and that it dictates riparian water availability. We hypothesize that gaining reaches should have higher water table height and prolonged late season flow; losing reaches less storage and little to no late season flow. We tracked groundwater surface-water exchange using wells, piezometers and in-channel structures (mimic beaver dams) on an alluvial fan in the Gallatin valley. We established 4 transects of piezometers and groundwater wells. Each transect containing 2 piezometers placed in the channel 3-4m apart, and groundwater wells (averaging 5ft depth) were placed in the floodplain with at least 3 wells on each side of the stream channel. Hydraulic head was manually recorded while water temperature was captured through recording sensors. We propose that the underlying geology and landforms can serve as a tool to gain greater understanding of a properly functioning riparian ecosystem.

Landscape, Management, And Climate Controls On Suspended Sediment Dynamics In 6 Adjacent Headwater Catchments

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Understanding the relative influence of catchment structure (topography, geology, and vegetation), climate, and land use on sediment export is key for predicting stream water quality response to disturbance and land management. In snow melt dominated environments the majority of sediment transport typically occurs during spring melt. We investigated how variability in snowmelt runoff characteristics, catchment structure, and the spatial location of forest disturbance influenced suspended sediment (SS) export in the Tenderfoot Creek Experimental Forest (TCEF; Little Belt Mountains of Montana, USA). We quantified cumulative SS export across six adjacent catchments in the TCEF based on a 15-year data record of daily SS and discharge. 30-40% of two of these catchments were harvested in 2000 using multiple experimental treatments including patch and thin cuts, concentrated in upland blocks. We compared each catchment's annual SS load to metrics of landscape structure, derived from GIS based analysis of 1m LiDAR data, and annual snowmelt hydrograph characteristics. Significant predictor variables of SS export across catchments included surface topography, concavity, and convexity, geologic strata areal extent, and spatial patterns of vegetation and deforestation. Annual temporal differences in SS were related to the magnitude and duration of the snowmelt hydrograph and landscape connectivity. A 100 percent increase in average annual SS export was observed in the two treated catchments for the nine years following harvesting, over the five years pre-harvest. Our results suggest that runoff characteristics and their intersection with landscape structure and disturbance patterns lead to differential sediment export rates across catchments. These findings have implications for predicting steam water quality response to forest disturbance and making informed watershed management decisions across complex terrains.

Results From Ten Years Of Groundwater Monitoring In And Around Coalbed Methane Development In Montana

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Coalbed methane (CBM) is held in coal seams by adsorption on the coal by weak bonding and water pressure. Reducing water pressure by pumping groundwater from coal aquifers allows methane to desorb. Groundwater is typically pumped at a rate and scale that reduces water pressure (head) to a few feet above the top of each coalbed over large areas. The extraction and subsequent management of CBM production water has raised concerns about potential loss of stock and domestic water supplies due to groundwater drawdown and impacts to surface water and soils from water management practices. The reduction of hydrostatic pressure in coal aquifers during coalbed-methane production may affect yield from wells and discharge rates of springs sourced in the developed coalbeds. The magnitude, geographic extent, and duration of this drawdown are primary focuses of the regional monitoring program. Montana currently has 824 CBM wells that produced methane, water, or both during 2010. The Montana Bureau of Mines and Geology (MBMG) has been monitoring groundwater quality and quantity in and around CBM fields since 1999. The MBMG regional CBM groundwater monitoring program includes inventories of groundwater resources and regular monitoring at 239 wells, 15 springs, and 2 streams. The current monitoring network consists of a combination of pre-existing monitoring wells installed during the late 1970s and early 1980s in response to actual and potential coal mining, recently installed monitoring wells specific to CBM impacts, domestic wells, stock wells, and springs. Water levels from CBM wells are also provided by CBM producers to the MBMG monitoring program. Monitored units include coalbeds, adjacent sandstone units, and alluvium. This program provides potentiometric and water-quality data, and will continue to be active through the duration of CBM production and the post-production groundwater recovery period. After 10 years of CBM production, groundwater levels within the producing area have been lowered to near the top of coalbeds. The 20 foot drawdown contour extends approximately 1.5 miles from CBM development. No measurable drawdown has been observed beyond 4 miles from the edge of development. In areas where CBM wells have been shut in, recovery has been rapid, with 73-82% recovery occurring after 5-7 years (Meredith et al., 2009). The MBMG has installed monitoring sites consisting of nested wells which monitor several aquifers in one location. The majority of these nested well sites do not show vertical migration of water level drawdown outside of the coal aquifer. The rate of water coproduced from individual CBM wells in Montana has not followed Bureau of Land Management predicted production. Early average production rates are approximately half of the predicted rates and production rates level off much sooner than predicted. Because of these lower production rates the total amount of CBM water produced is just over half of the predicted amount. Since January 2009, the number of CBM producing wells, and the corresponding barrels of coproduced water, has dropped.

Potentiometric Surface Map Of The Shallow Hydrologic Unit, Carbon And Stillwater Counties, Montana

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The potentiometric surface for groundwater within approximately 400 feet of the land surface (shallow hydrologic unit-SHU) in the Carbon-Stillwater groundwater characterization study has been mapped using water levels taken from inventoried wells between August 2002 and November 2005. For economic reasons, most wells utilize the SHU and residents of Carbon and Stillwater counties rely heavily on the groundwater resource. Generalized potentiometric surface contours mimic topography, with groundwater divides relatively consistently beneath major topographic ridges. Overall, groundwater moves north from the Beartooth Plateau, a broad fault-bounded uplift cored by Precambrian crystalline rocks toward the Yellowstone River Valley. Yellowstone River tributaries: Clarks Fork of the Yellowstone, Red lodge Creek, Rock Creek, Rosebud Creek and the Stillwater River have cut valleys into the SHU that accept groundwater discharge. The southern part of the study area is structurally complex near the east-west Nye-Bowler lineament. Some water-level altitude data suggest that the Nye-Bowler and other faults mapped throughout the Carbon-Stillwater study area may be barriers to groundwater flow. The Lake Basin subarea, located north of the Yellowstone River, is topographically subdued relative to the landscape south of the river. In the Lake Basin subarea, there are relatively few drainages that intercept groundwater flow resulting in a more uniform potentiometric surface. A few miles north of the Yellowstone River valley, a northwest-southeast topographic ridge and groundwater divide separate southward groundwater flow towards the Yellowstone River from northward groundwater flow into the Lake Basin area.

Using Geochemical Tracers To Trace Groundwater Interactions With Georgetown Lake, Granite County, Montana

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Regional and local heterogeneities in montane catchment including faults, folds and fractures, can cause problems when characterizing groundwater-lake interactions. In this study, geochemical tracers such as Radon, stable isotopes of the water molecule, and major ion chemistry were used to identify how groundwater exchanges with Georgetown Lake. Major chemistry and stable isotopes were used to determine groundwater inputs on a whole-lake scale, but 222Rn was used to track groundwater seepage at point locations at the lake. Sampling primarily took place during winter months when the lake was frozen to ensure that degassing of 222Rn was negligible. Radon concentrations vary spatially around the lake and range from less than 3.5 to 193.0 pCi/L. Elevated radon was predominantly along the eastern shore, and 222Rn was typically low along the western side of Georgetown Lake. These findings suggest that groundwater flow to the lake primarily enters from the eastern side of the lake. However, there was one location along the western shore with a concentration of 9,562 pCi/L. Samples collected adjacent to this elevated sample had very low Radon activity suggesting that the elevated sample was collected in a narrow fracture zone with groundwater discharging into the lake. Hydrogen sulfide and ammonium were also present in several of the samples collected from the lake during winter months. Concentrations of H2S- vary spatially with lower concentrations on the eastern shore of the lake ranging from non-detectible to 0.09 mg/L and along the western shore and near the dam concentrations vary from 0.1 to 1.99 mg/L. The lower samples along the eastern shore are probably controlled by low H2S- groundwater discharging to the lake. Ammonia concentrations vary around the lake with a minimum concentration of 0.01 mg/L and a maximum concentration of 4.0 mg/L, and NH4+ concentrations generally mimic H2S in the lake.

Using Stable Isotopes To Track Contamination Of The Madison Aquifer By Coal Mine Drainage In The Stockett-Sand Coulee Area: Year 2

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The Stockett-Sand Coulee area, south of Great Falls, Montana was extensively mined for coal in the late 1800's through the early 1950's. These mines were mainly underground and covered very large areas. After closure, the mine portals were sealed and the workings became flooded. Many of the mines have drains that are sources of acid mine drainage (AMD) which flows into dry streambeds and soaks into the ground. People living in the area rely on the Madison Limestone, which is located several hundred feet below surface, for their drinking water. The first year of this study was used to determine if AMD from the coal mines was contaminating the Madison aquifer. This preliminary study showed the potential of using stable isotopes to track sources of pollution near abandoned mine sites. The second year was a continuation of that study with the intention of increasing the data set and supporting results from the first year of the study. A total of 20 domestic water wells completed in the Madison and one well in the Swift Formation were sampled for water chemistry and stable isotope analysis, along with one sample from a local AMD seep, Kate's Coulee.

The S-isotopic composition of dissolved sulfate is a sensitive indicator of AMD contamination because the isotopic composition of AMD sulfate is very different from that of sulfate in the background Madison aquifer groundwater. The results of this study show that most of the wells sampled contain < 5% sulfate that could have come from AMD. However, five wells show a greater extent of contamination. Despite this contamination, the water quality is still good, which shows how the Madison Limestone can naturally buffer groundwater chemistry.

Location And Linkage On A Floodplain Landscape: Spatial Drivers Of Ecosystem Function

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Ecologists have long suggested that ecosystem functioning is organized by the biotic and abiotic structure of the environment, a paradigm in which pattern dictates process, and this functional response to variability in environmental patterns can be considered from a number of spatial scales. At the landscape scale, organisms and processes respond to patterns of spatiotemporal heterogeneity in dynamic habitat templates. Disturbances maintain the spatial heterogeneity of landscapes by periodically restructuring ecosystems and altering function at different hierarchical scales. Riverine flood plains are examples of spatially and temporally dynamic ecosystems structured largely by the intrinsic flood disturbance regime and migration of the river channel. Regular hydrologic disturbance and reorganization by fluvial processes create and maintain a mosaic of aquatic, semi-aquatic, and riparian landscape elements which are linked laterally and longitudinally. Active scour and early successional vegetation characterize 'parafluvial' floodplain zones, while 'orthofluvial' zones lack scouring flow and comprise late-stage vegetation stands. On the Nyack Flood Plain of the Middle Fork Flathead River in northwest Montana, springbrook streams are fed by upwelling groundwater from an alluvial aquifer and embedded in terrestrial systems of various seral stages. I hypothesize that ecosystem processes in spring brooks differ spatially across parafluvial and orthofluvial zones because landscape position dictates severity of flood disturbance and allochthonous inputs from contiguous terrestrial and groundwater systems. I suggest that differences in springbrook structural properties and exchanges with adjacent systems translate to altered ecosystem function, and predict differences in springbrook biogeochemical cycling of nutrients as a result of spatial distribution within the floodplain landscape. Natural flood plains are among the most biologically complex and diverse landscapes on Earth and contribute 25% of terrestrial ecosystem services (e.g., flood control, water supply, and nitrogen removal) although they cover only 1.4% of the land surface area. Flood plains are currently being lost or degraded and represent one of the most threatened landscapes worldwide. There is need for a greater understanding of the potential influence of river modification on ecosystem drivers.

Gray Water Display

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This gray water display goes over the legal history of gray water in Montana, what gray water is, how it can be reused, and gives examples of systems and policies. There is also a display tank of a reuse system that will be displayed with the tri-fold poster.

Comparison Of Pore Water Chemistry In Ponds Underlain By Mine Tailings Vs. Natural Soil: Warm Springs Ponds, Montana

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The West Wet Closure (WWC) and Hog Hole (HH) are two shallow ponds that are part of the active treatment area of the Warm Springs Ponds Operable Unit (WSPOU), near Anaconda, Montana. The WWC was built on top of old mine tailings from Silver Bow Creek, whereas the nearby HH was formed from a borrow pit and has no submerged mine waste. Both ponds receive surface water from Pond 3, the largest of the WSPOU ponds. The purpose of this study was to compare the chemistry of sediment pore water in the WWC and HH. Pore-water diffusion samplers, referred to as "peepers", were installed in both ponds simultaneously during April of 2011. Prior to deployment the samplers were loaded with deionized water and purged for two days with N2 gas. The samplers were then placed in the top 25 cm of sediment in about two to three feet of water. After a 3-week equilibration period, the peepers were retrieved and sampled on-site using an improvised glove-bag to prevent sample oxidation. Profiles of pH and Eh were collected immediately using microelectrodes that were inserted directly through the peeper membrane into the sample cells. Samples for ICP-metals analysis were withdrawn with a syringe needle and filtered through 0.2 µm syringe filters into pre-weighed plastic bottles. Additional samples were collected for alkalinity titration and colorimetric analysis of phosphate, ammonium, and dissolved sulfide. At a sediment depth of 20 cm, pore water in the WWC and HH had pH values of 5.9 and 6.7, respectively, which contrasts with an approximate pH of 9 in the overlying pond water. The WWC peeper cells had extremely high concentrations of dissolved Fe(II) (up to 1300 mg/L), Mn (up to 262 mg/L), and sulfate (up to 3600 mg/L), but low or undetectable concentrations of other trace metals and metalloids. In contrast, the HH peeper cells had very low Fe (< 0.5 mg/L), moderately high Mn (up to 12 mg/L), and concentrations of sulfate that decreased with depth below the sediment-water interface. The HH pore waters were strongly enriched in dissolved sulfide (up to 9.2 mg/L as S), whereas sulfide concentrations were too low to quantify for the WWC samples. The above results suggest that the pore water chemistry of the WWC is dominated by iron reduction, whereas the HH pore water is dominated by sulfate reduction. Since both ponds receive the same influent water, this difference must be caused by differences in the sediment. Based on sediment core digestions, the weathered mine waste underlying the WWC has a very high Fe content (average of 6.8 wt%) and a high total Fe/total S ratio (average of 4.8 on a mole basis). Because of the high Fe/S ratio, any reduced S formed by bacterial reduction is stored as insoluble Fe-sulfide minerals. In contrast, the lower Fe/S ratio of the natural soil in the HH sediment allows sulfide to accumulate as free H2S. Data collected to date are equivocal as to which environment has higher dissolved arsenic concentrations.

Citizen monitoring in the Madison

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Like many regions of the arid west, the Madison Watershed of southwest Montana is an area defined by availability and quality of surface water. Recently, community members are taking a heightened interest in the conditions of water quality and are stepping forward to undertake data collection and monitoring on 5 tributaries of the Madison River as part of the volunteer Madison Stream Team. Training and data collection was carried out for the first time in 2010, with 9 volunteers sampling a minimum of 2 times on select impaired waterways. Additional training and new volunteer recruitment took place in 2011 with 2 sampling events scheduled to take place. A standard suite of parameters were examined, including temperature, turbidity, DO, EC, pH, flow, and limited nutrient and coliform sampling. AWRA poster presentation will include summary of data from both years and information on training successes and challenges.

High Resolution Spatial And Temporal Monitoring Of Soil, Atmosphere, And Vegetation Interaction In A Natural Mountain Environment

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When no snowpack is present, the soil surface is the interface through which heat and water moves between the atmosphere and the soil. The transfers through this interface sustain important environmental functions, including hydrological processes (e.g. soil moisture and temperature regimes, depth of the soil freezing front, evapotranspiration rates, recharge to the groundwater system or the production of runoff) and biological processes (e.g. dynamics of the soil microbial biomass, soil respiration, mineralization rates, fixation of atmospheric nitrogen into the soil or water and nutrient uptakes by roots). Changes in either the atmospheric forcing or the land cover (including changes in the duration of the snow cover) can deeply affect the environmental conditions of the soil, with important feedbacks to the entire ecohydrologic system that are not yet properly understood. A way to improve our understanding of the interaction between soil, vegetation and the atmosphere comes from the long term observation of some key soil state variables. The set-up of a research station installed last year, but intended to be permanent, is presented in this poster. The Lost Horse research station is located 29 km southwest of Hamilton, MT, at the head of Lost Horse Canyon in the Bitterroot Mountains. The site includes 12 soil pits monitoring, soil moisture, temperature, electrical conductivity and heat exchanges at the soil surface. The soil pits are arranged radially around an isolated Engelmann spruce. The tree is monitored by a sap flow system in order to investigate the interaction between soil climate and tree processes. A full meteorological station recording temperature, humidity, pressure, wind speed and direction, precipitation, snow depth, and solar radiation (incoming, net, and albedo) is located on site to monitor atmospheric forcing. The site is currently providing datasets for two ongoing studies in the Bitterroot Mountains. The first study is documenting the redistribution and lateral energy exchanges of soil water and thermal energy beneath a snowpack from late autumn through late spring, including the effect of the potential energy gradients resulting from root water uptake of large vegetation. Secondly, a climatic dataset is being collected to assist in the calibration and validation of an ecohydrological model for a forested catchment. A sample of the data collected datasets is included."

Hydrologic Modelling To Monitor Possible Impacts Of Climate Change In The North Fork Of Elk Creek Experimental Watershed

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This study hypothesizes the effects of global climate change on the hydrologic regime of West-Central Montana, focusing on the North Fork of Elk Creek, a 50 mi^2 Experimental Watershed. This is important to understand in snowmelt-dominated watersheds, as it is already well documented by current trends and future climate projections that the natural hydrologic regime is experiencing alterations. There have been shifts in the 20th century of the timing of snowmelt trending towards an earlier spring peak flows and declines in the overall snow water equivalent (Regonda et al., 2005; Mote et al., 2005; Hamlet et al., 2005). The goals for this study are to analyze for significant changes in the timing of important hydrologic events, and determine how discharge throughout the year will be altered, in the Elk Creek Experimental Watershed (ECEW). To address these issues, two hydrologic models are employed, and run using current meteorological data and downscaled climate-change scenarios. Snowmelt Runoff Model (SRM) is deterministic and conceptual and is used to generate streamflow in snowmelt dominated basins by the degree-day method (Martinec, 1985). The Variable Infiltration Capacity (VIC) hydrologic model is well suited for the project as well, it allows for snow accumulation and ablation process to be accounted for, where snowpack is represented by energy and mass balance equations (Liang et al., 1994; Gao et al., 2009). Data is gathered from two SNOTEL sites located within the watershed and streamflow collected directly on the North Fork of Elk Creek. The specific metrics that will be statistically analyzed are the overall hydrologic regime, frequency of high flows during winter and summer, mean annual flow, mean summer flow, trends in peak flow timing, monthly and seasonal precipitation trends, and trends in SWE and April 1 snowpack (Wenger et al., 2009; Regonda et al., 2005). These results can be useful for management purposes because changes in the way water is released from the mountains affects water storage, flooding, and overall watershed resilience such that current practices may need to be adjusted accordingly.

The Interactive Water Use And Resource Conservation Center Overview (IWURC Center Overview)

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The Interactive Water Use and Resource Conservation Center (IWURC Center) is an LC3 corporation, a low profit enterprise that facilitates investment in capital projects that provide social benefits. The IWURC Center will promote awareness of water resources and conservation issues, alternative energy technologies and sustainability/business approaches. As an educational facility for audiences of all ages, the Center will provide interactive exhibits, informative audiovisual presentations and engaging conservation workshops. The exhibits will serve as a storefront to showcase 6 local businesses that provide products and services that promote alternative energy and conservation and reuse of natural resources. The IWURC Center exhibits will consist of the following systems: • Household (grey) water filtration and reuse, • Rain-water harvesting, • Solar hot water heat, • Geothermal (ground source heat pump), • Solar photovoltaic electricity • Water purification • Storm water filtration The Center will also feature informational kiosks at each exhibit that explains • How the system functions, • Cost of the system in comparison to its conventional counterpart, (pay back period) • State and Federal tax incentives • Photos of past projects The Center will have a conference room/audio visual presentation area. To be successful and achieve its objectives, The IWURC Center is seeking support through: • Private investments • Sponsorship • Donations • In-Kind services Once established, the IWURC Center will generate revenue through sales and services of IWURC Center products, administrative assistance with private Foundation Program Related Investments (PRI's), leasing of the facility for community trade shows and seminars. Long term growth will occur as the IWURC Center is replicated in other communities. In the next year (2011) the IWURC Center will assemble a team of consultants to determine a Turn Key value for the Center and how to best expedite this growth potential and market transformation.

Lake Helena Watershed Restoration Project

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The Lake Helena Watershed Planning Area is located within the Upper Missouri River Water Basin, and drains approximately 620 square miles. The majority of the watershed (68%) is located within Lewis and Clark County, and the remaining 32% is in Jefferson County. The Lake Helena Watershed encompasses the watersheds of Silver Creek, Tenmile Creek, Prickly Pear Creek, and Lake Helena. The Lake Helena Watershed Group requested funding for the development of a Lake Helena Watershed Restoration Plan (Plan) in conjunction with: landowners, agencies, and interested stakeholders; a phased restoration project on the lower end of Prickly Pear Creek; both project effectiveness and continued volunteer monitoring of basin-wide impaired streams within the watershed; and educational and outreach activities. Through these efforts, the WQPD and the LHWG propose to: 1) develop a prioritization scheme and map for targeted areas of future restoration work; 2) fill in water quality data and information gaps through information exchange and monitoring; 3) measurably reduce temperature, sediment, metals, and nutrient loading; 4) restore Prickly Pear Creek to a functioning condition, 5) re-establish a healthy riparian zone along the stream segment from York Road to Sierra Road; and 6) extend outreach and education to all members, stakeholders, and public on the activities and issues of the watershed.

Elevated Lead In Water Shows A Direct Relationship To The Lake Basin Fault System Of Southcentral Montana

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Data from the U. S. Geological Survey National Uranium Resource Evaluation (NURE) database was examined using Geographic Information System analysis to look at the distribution of lead in water in Montana. All samples with lead greater than 200 ppb also had cobalt associated with them. Abandoned Uranium/Vanadium mines are hosted in the Madison Limestone along the crest of a large south-plunging anticline in the Pryor Mountains. The uranium deposits show a structural relationship to a zone of fractures that trend roughly N 65o W and lie within watersheds with high lead values. These fractures parallel the general trend of the Nye-Bowler Lineament. The Nye-Bowler Lineament is characterized by a core of northwest-southeast trending faults, folds and volcanic domes that is overprinted by a set of smaller north-northeast trending normal faults. The high lead values with associated cobalt reveal a distinct distribution pattern in an area bound on the southwest by the Nye-Bowler Lineament and on the northeast by the parallel Lake Basin fault zone that extends east of Billings, Montana. The Lake Basin fault zone is the eastern segment of the roughly 300km long Lewis and Clark Lineament that can be traced from Coeur d' Alene, Idaho to east of Billings, Montana. A few high lead values follow this trend in the western part of the state. The highest concentrations of lead occur along the Lake Basin fault zone, with 63 samples having lead values ranging from 6000 ppb to 23,890 ppb along an 80 kilometer portion of the lineament northwest of and extending southeast of Billings. The 63 high lead samples along the Lake Basin fault zone have cobalt values ranging from 300 ppb to 1869 ppb and all the samples with lead greater than 200 ppb have cobalt associated with them. The "fault-bounded" block of samples has a distinctly different chemistry than those samples outside the lineaments. The high lead samples lack strontium, sodium, silica, barium, potassium, aluminum and have much lower concentrations of uranium than the no lead samples. The samples with no lead have strontium values ranging from 1500 ppb to 13,000 ppb just north of the Lake Basin fault zone. Lead appears to be mobilized and distributed through these reactivated Precambrian faults and localized within a distinct structural pattern.

Wetland Mapping, Assessment, And Monitoring In Montana: The Comprehensive Approach Of The Montana Natural Heritage Program

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Wetlands provide critical biological and economic benefits such as plant and wildlife habitat, flood attenuation, and groundwater recharge, yet these systems are experiencing increasing pressures from human activities such as urbanization, agricultural development, and land conversion. The Clean Water Act requires states and tribes to monitor and report on the quality of waters within their states, including wetlands. Ecologists at the Montana Natural Heritage Program have been working to enhance the protection and management of Montana's wetland resources. We are creating statewide digital wetland and riparian mapping for use as a resource for management, planning, conservation, and restoration efforts. We are also developing wetland assessment methods to assess the ecological integrity of wetlands across the state. Wetland assessment and monitoring programs provide information on the ambient condition of wetland resources. They also provide the necessary tools to evaluate the effects of mitigation and restoration practices, to target wetland restoration and conservation efforts, and to track the impacts of land use decisions. Additionally, we are collaborating with several Tribes, watershed groups, and other partners across Montana to enhance their capacity to develop or improve their wetland programs.

Physical Characteristics Of The Flathead Valley Deep Aquifer

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The deep confined aquifer in the Flathead Valley is the most utilized aquifer in the valley, supplying high-capacity municipal and irrigation wells in addition to thousands of domestic wells. Rapid population growth and localized water-level declines in the deep aquifer have raised concerns about the long-term sustainability of the water supply. Characteristics of the deep aquifer system were monitored at 97 deep wells, 11shallow wells, and 7 lakes and springs. Data were compiled from DNRC records, from local groundwater consultants, the Montana Bureau of Mines and Geology Ground-Water Information Center Database, and a from previous MBMG-Ground Water Assessment Program study. The deep aquifer is composed of mixed and interlayered sand and gravel up to 3000 feet thick, but the deepest wells in the valley only penetrate the upper 1000 feet. Measured transmissivities of the deep aquifer range over three orders of magnitude, from <100 ft2/day to 98,000 ft2/day. The wide range of transmissivity is the result of the varied depositional nature of alluvium and glacial outwash material that forms the deep aquifer. Barometric efficiency of the deep aquifer ranged from zero to over 90-percent. Those areas with low barometric efficiencies correspond with areas where Smith (2000) mapped confining layers 100 feet thick or less. The wells around Echo Lake have low calculated barometric efficiencies and a downward vertical gradient, suggesting this area may be a major source of recharge entering the deep Flathead valley aquifer. The largest water-level fluctuations within the deep aquifer from 2009 through mid-2011 were around the city of Kalispell; which is also the area of the greatest concentration of wells drawing water from the deep aquifer. It appears that the recovery of aquifer water levels might be arrested short of the natural spring peak, or delayed due to high withdrawal rates from wells during the recharge/recovery period.

An Assessment Of Drought Climatology, Vulnerability, And Mitigation In The Clark Fork Fiver Basin Of Montana

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Precipitation patterns are cyclical and subject to variations over time and throughout a region. Such trends can easily be mapped, measured, and predicted by state and national indices. Drought prediction, which can trigger beneficial drought response mechanisms, relies on measuring levels of precipitation, yet reservoirs and irrigation networks insulate water users from short-term variations. However, projections of increased climate variability and long-term or multi-year drought may reduce surface water storage and draw down aquifers thereby reducing the effectiveness of the existing water infrastructure to meet users' water needs. Although the National Drought Mitigation Center recognizes that it "is clear that drought cannot be viewed solely as a physical phenomenon," existing drought mitigation infrastructures do not adequately integrate social and ecological vulnerabilities to drought (NDMC 2010). This assessment will synthesize historic, current, and predicted meteorological patterns with stakeholder – agricultural, municipal, hydropower, industrial, ecological, tribal, and recreational – perspectives of drought as a threat to their water security and pursuit of livelihood, health, and ecosystem production. Identifying natural variability and the socio-ecological relationship to water will create a foundation for the development of a comprehensive drought mitigation plan that will comply with the state requirement and promote ecological and social resiliency in the Clark Fork River basin.

Hydrologic And Landscape Controls On Nitrogen Export From Montane Watersheds

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Nutrient export from headwater streams contributes to loading to downstream reaches. Additionally, lateral inputs of water and solutes to streams first pass through the riparian zone before entering the stream network. Both loading from upstream and lateral sources, are partially controlled by landscape structure yet these dynamics remain poorly understood. We investigated stream and groundwater nitrogen dynamics across 3 transects, as well as at outlets of seven adjacent but diverse catchments with a range of landscape characteristics in the northern Rocky Mountains, Montana. We observed variability in export dynamics among different nitrogen species; including nitrate, ammonium, and dissolved organic nitrogen (DON). Furthermore, we assessed how these dynamics related to differences in hydrologic connectivity, riparian area, geology, and topographic structure. The majority of ammonium export occurred during the snowmelt period (April 15-July 15); in contrast greatest nitrate export occurred during baseflow periods. Annual stream export of nitrate ranged from 0.059 to 0.008 kg/ha across the study period and was highest in watersheds with the highest riparian buffering ratio, the ratio of upslope area draining into each 10 m reach of riparian area. The difference in stream export seasonality and mechanisms can help inform management decisions regarding water quality concerns.

A GIS-based Approach To Characterizing Riparian Integrity Along The Yellowstone And Missouri River Corridors

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After heads-up digitizing of valley bottoms, we used image segmentation software (eCognition) and the RandomForests™ machine learning technique to classify seven land cover types (Open Forest, Closed Forest, Riparian Emergent, Shrub-Scrub, Upland Emergent, Sandbar, and Russian Olive) and open water within river

valleys from 2009 NAIP imagery. We then used Montana Spatial Data Infrastructure GIS layers (transportation and structures) and Department of Revenue land use classifications to create a human alteration layer. Reach polygons were created based on geomorphology, hydrology, and length to serve as analysis and reporting units, and reach characteristics (channel length, sinuosity, valley width and area) were calculated. From these GIS layers, we developed both disturbance and condition metrics (e.g., % irrigated agriculture, structure density, road density, average patch size, density of natural vegetation mosaics, etc.), correlating specific condition metrics with disturbance factors. This analysis was carried out on all large rivers in Montana. Here we report on our findings for the Yellowstone and Missouri rivers in Montana.

Groundwater Models Developed For The North Hills Study Area, Located At The North End Of The Helena Valley, Lewis And Clark County, Montana

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As part of the Montana Bureau of Mines and Geology (MBMG) Ground-Water Investigation Program, a set of groundwater models has been developed for an area at the north end of the Helena Valley, in southwestern Montana. The North Hills Area Model replicates hydrogeologic conditions from the drainage divides bounding the North Hills along the north, west, and east edges of the study area southward to Lake Helena. The southern boundary of the model is in the Helena Valley in the vicinity of Silver Creek and the south shore of Lake Helena. This larger-area model applies a water budget that includes recharge from precipitation in the North Hills, seasonal recharge provided by the Helena Valley Irrigation District (HVID) Canal, irrigation activities near and down gradient of the canal in the Helena Valley, and seasonal recharge from irrigation and stream infiltration from Silver Creek. Groundwater discharge is to Lake Helena, agricultural drain ditches near Lake Helena, and pumping wells. The modeled pumping wells address an area of specific concern identified by the Montana Department of Natural Resources and Conservation (DNRC) and the Lewis and Clark County Water Quality Protection District (LCWQPD). This model simulates the groundwater flow system of the north end of the Helena Valley, but has some limitations because the observation well data are sparse in some areas of the model, and some water budget elements are based on estimates that are somewhat uncertain, particularly for the irrigated areas. Nevertheless, the model provides a product that can be used to assess the timing and magnitude of impacts of pumping or other hydrologic activities to Lake Helena and local groundwater flow. The Pediment Focus Model includes the hills and pediment generally above the HVID Canal. This model effort focuses on the specific problem area in the North Hills study area where the available groundwater-level data and concern about groundwater extractions are the greatest. Pumping wells are modeled in the same area of pumping as described above. Developing a groundwater model for the pediment up gradient of the canal simplified the water budget. Instead of having to quantify and model the seasonal groundwater recharge caused by the canal and irrigation activities below it, a specified head boundary is used to mimic the observed seasonal fluctuation of water levels in the aquifer in the vicinity of the canal. This model has a better distribution of observation well data and results in a product best suited to evaluate various scenarios in the area of highest concern.

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