

2004  
WESTERN SOUTH DAKOTA  
HYDROLOGY CONFERENCE

Program and Abstracts

---

**April 6, 2004**  
**Rushmore Plaza Civic Center**  
**Rapid City, South Dakota**

## TABLE OF CONTENTS

|   |    |
|---|----|
| About the Conference .....                      | 1  |
| Acknowledgments .....                           | 1  |
| Conference Program .....                        | 2  |
| Abstracts                                       |    |
| Session 1 – Hydrogeology and ground water ..... | 6  |
| Session 2 – Water quality .....                 | 13 |
| Session 3 – Hydrology potpourri .....           | 19 |
| Session 4 – Fire science .....                  | 29 |

# 2004 Western South Dakota Hydrology Conference

This program and abstracts book has been produced in conjunction with the 2004 Western South Dakota Hydrology Conference, held at the Rushmore Plaza Civic Center on April 6, 2004. The purpose of this book is to provide summaries of the presentations made during the conference.

The purpose of the 2004 Western South Dakota Hydrology Conference is to bring together researchers from Federal, State, University, local government, and private organizations and provide a forum to discuss topics dealing with hydrology in western South Dakota. This conference provides an opportunity for hydrologists, geologists, engineers, scientists, students, and other interested individuals to meet and exchange ideas, discuss mutual problems, and summarize results of studies. The conference consists of four technical sessions and a keynote luncheon speaker. The topics of the technical sessions include hydrogeology and ground water, water quality, hydrology potpourri, and fire science.

This year's conference is dedicated to the memory of Dr. John Paul Gries (1911-2003). Dr. Gries began teaching geology at the South Dakota School of Mines and Technology in 1936. He retired "on paper" in 1976 but continued his work as a Professor Emeritus and consulting geologist. In 1996, he authored *Roadside Geology of South Dakota*, which was published by Mountain Press Publishing Company of Missoula, Montana. Dr. Gries was a prolific author and received numerous honors for his extensive studies of geology and ground water. His knowledge of the geology and water resources of Black Hills area was pure gold that was tapped by everyone who came forth with questions. Thank you, Dr. Gries, for all your endeavors to further our knowledge base.

## ACKNOWLEDGMENTS

Many people have contributed to this conference. The many presenters are thanked for their contributions. The moderators are thanked for their help in streamlining the technical sessions. Keynote speaker, Julio Betancourt, is thanked for his time and perspectives.

Registration help by Sheri Meier (USGS) is greatly appreciated. Brenda Athow (USGS) provided computer support for the conference. Connie Ross (USGS) designed the conference web site, and Ella Decker (USGS) provided assistance in publishing this program and abstracts book. Jenifer Sorensen (South Dakota Engineering Society) is thanked for her help in coordinating the professional development hours.

The sponsoring organizations are thanked for support: South Dakota Department of Environment and Natural Resources, South Dakota Engineering Society, South Dakota School of Mines and Technology, U.S. Geological Survey, and West Dakota Water Development District. The chairpersons for this conference were J. Foster Sawyer (South Dakota Department of Environment and Natural Resources), Arden D. Davis (South Dakota School of Mines and Technology), Scott J. Kenner (South Dakota School of Mines and Technology), Janet M. Carter (U.S. Geological Survey), Daniel G. Driscoll (U.S. Geological Survey), and Van A. Lindquist (West Dakota Water Development District).

## CONFERENCE PROGRAM

**Tuesday, April 6, 2004**

**Alpine/Ponderosa Rooms**

**Rushmore Plaza Civic Center**

7:00 - 7:45 a.m. . . . . Registration  
7:45 - 8:00 a.m. . . . . Welcome, general information

### **Session 1 – Hydrogeology and Ground Water (2 PDH)**

**8:00 - 10:00 a.m.**

**Alpine/Ponderosa Rooms**

Moderator: **J. Foster Sawyer**, Hydrologist, South Dakota Department of Environment and Natural Resources, Rapid City, South Dakota

#### **Presentations**

8:00 - 8:20 a.m. - [1-1] Rahn, *Hydrogeology of lower Spearfish Canyon*  
8:20 - 8:40 a.m. - [1-2] Miller, *Vulnerability mapping (1:24,000) of the Madison aquifer near Rapid City, South Dakota*  
8:40 - 9:00 a.m. - [1-3] Lisenbee, *Geologic atlas of the Rapid City West 7.5-Minute Quadrangle*  
9:00 - 9:20 a.m. - [1-4] Long, *Estimating ground-water age using tracer data and a mixing model*  
9:20 - 9:40 a.m. - [1-5] Putnam, *Tracing streamflow loss to the Madison aquifer with fluorescent dyes*  
9:40 - 10:00 a.m. - [1-6] Ohms, *The status of groundwater lakes in Wind Cave, Wind Cave National Park, South Dakota*  
10:00 - 10:15 a.m. . . . . Refreshment break

**Session 2 – Water Quality (2 PDH)**

**10:15 a.m. - 12:05 p.m.**

**Alpine/Ponderosa Rooms**

Moderator: **Dr. Arden Davis**, Professor and Chairman, Geology and Geological Engineering Department, South Dakota School of Mines and Technology, Rapid City, South Dakota

**Presentations**

- 10:15 - 10:35 a.m. - [2-1] Schwickerath, *Water quality monitoring and HSPF modeling to develop a TMDL for Spring Creek*
- 10:35 - 11:05 a.m. - [2-2] Goodman, *Coal bed methane development – South Dakota’s role*
- 11:05 - 11:25 a.m. - [2-3] Hoyer, *Potential changes in water quality due to future coal bed methane development—The Belle Fourche River, South Dakota, case study*
- 11:25 - 11:45 a.m. - [2-4] Erickson, *Response of the fish communities in Bear Butte Creek following closure of the Gilt Edge Mine*
- 11:45 - 12:05 p.m. - [2-5] Moran, *Ground-water quality affects the availability of drinking water in the United States*

12:05 - 1:30 p.m. . . . . Luncheon

**Rushmore H Room**

**Keynote speaker: Julio Betancourt (1.0 PDH)**

Research Scientist, U.S. Geological Survey, Tucson, Arizona

[jlbetanc@usgs.gov](mailto:jlbetanc@usgs.gov)

[http://www.paztcn.wr.usgs.gov/julio\\_cv.html](http://www.paztcn.wr.usgs.gov/julio_cv.html)

Title: ***The Historical, Climatic and Socioeconomic Context for U.S. Megadrought***

Severe, multiyear and multibasin droughts play key roles in natural landscape responses to climate variability, and could manifest the impacts of ongoing and future climate change. In the context of longer, hotter growing seasons and greater resource demands, such droughts could compromise international and interstate water agreements, urban growth, rural lifestyles, tourism, fuels and fire management, and conservation/restoration efforts. This presentation will place the recent downturn (1999-2003) in western U.S. precipitation in a historic and climatic context to evaluate the probability and socioeconomic risks of megadrought.

**Session 3 – Concurrent Session in Alpine Room**  
**Hydrology Potpourri (1.5 PDH)**  
**1:30 - 2:50 p.m.**

Moderator: **Derric Iles**, State Geologist, South Dakota Department of Environment and Natural Resources, Geological Survey Program, Vermillion, South Dakota

**Presentations**

- 1:30 - 1:50 p.m. - [3-1A] StripedFace-Collins, *Preliminary assessment of natural spring potential to enhance drought recovery on South Dakota Tribal lands*
- 1:50 - 2:10 p.m. - [3-2A] Carpenter, *Recent updates to National Weather Service data access services*
- 2:10 - 2:30 p.m. - [3-3A] Sieverding, *Lakota Ranch subsurface dam and hydrologic study within an alluvial valley, Hermosa, South Dakota*
- 2:30 - 2:50 p.m. - [3-4A] Roeser, *Peak-flow estimates and process controls for select South Dakota Rivers*

**Session 3 – Concurrent Session in Ponderosa Room**  
**Hydrology Potpourri (1.5 PDH)**  
**1:30 - 2:50 p.m.**

Moderator: **Daniel G. Driscoll**, Chief of Hydrologic Studies, South Dakota District, U.S. Geological Survey, Rapid City, South Dakota

**Presentations**

- 1:30 - 1:50 p.m. - [3-1P] Davis, *A limestone-based process for removal of arsenic from drinking water*
- 1:50 - 2:10 p.m. - [3-2P] Fivecoate, *Characterization of limestone used in the removal of arsenic from water*
- 2:10 - 2:30 p.m. - [3-3P] Waisanen, *Use of Pfafstetter codes for hydrologic modeling: A Cedar River example*
- 2:30 - 2:50 p.m. - [3-4P] Shmagin, *The view on South Dakota groundwater levels regime in connection with hydroclimatology of the central territory of the conterminous U.S.*
  
- 2:50 - 3:10 p.m. . . . . Refreshment break

**Session 4 – Fire Science (1.5 PDH)**  
**3:10 - 4:50 p.m.**  
**Alpine/Ponderosa Rooms**

Moderator: **Janet Carter**, Hydrologist, U.S. Geological Survey, Rapid City, South Dakota

**Presentations**

- 3:10 – 3:30 p.m. - [4-1] Liou, *Assessment of post-fire hydrologic hazards in the 2002 Hayman, Missionary Ridge, and Coal Seam areas of Colorado*
  - 3:30 – 3:50 p.m. - [4-2] Ohlen, *Applications of satellite data for fire science*
  - 3:50 – 4:10 p.m. - [4-3] Driscoll, *Effects of the 1988 Galena Fire on streamflow characteristics, Custer State Park, South Dakota*
  - 4:10 – 4:30 p.m. - [4-4] Nebelsick, *Watershed response following the Battle Creek Fire*
  - 4:30 – 4:50 p.m. - [4-5] Teller, *Developments in rapid-deployment gage technology*
  
  - 4:50 - 5:00 p.m. .... Closing remarks
-

---

**TUESDAY, APRIL 6, 2004**  
**SESSION 1**  
**8:00 - 10:00 A.M.**

**HYDROGEOLOGY AND GROUND WATER**

---



## **Hydrogeology of Lower Spearfish Canyon**

**Perry H. Rahn**

Emeritus Professor, Department of Geology & Geological Engineering,  
South Dakota School of Mines and Technology, 501 E. St. Joseph Street,  
Rapid City, SD 57702, [Perry.Rahn@sdsmt.edu](mailto:Perry.Rahn@sdsmt.edu)

Barrick Gold Corporation diverts Spearfish Creek into a tunnel in the lower portion of Spearfish Canyon. The water is taken through the tunnel and an aqueduct to Hydro #1, a hydroelectric power plant built by Homestake Mining Company in 1911. Just below the tunnel diversion site, the streambed crosses outcrops of the Madison Limestone and the Minnelusa Formation. While pre-diversion data is scanty, it appears that most of the water in Spearfish Creek continued past sinkhole zones in these formations to the present town of Spearfish. However, some recharge to these two aquifers most likely occurred in this reach prior to 1911. This recharge is believed to have supported the springs at the D.C. Booth Fish Hatchery. The tunnel diversion leading to Hydro #1 began in 1911, and the D.C. Booth Fish Hatchery springs failed approximately 5 years later, presumably because the springs were no longer being recharged in the upstream sinkhole zone. If, in the future, the tunnel diversion is abandoned and Spearfish Creek is returned to its natural condition, Spearfish Creek water should again recharge the two aquifers, and within approximately 5 years the D.C. Booth springs should flow again.

## **Vulnerability Mapping (1:24,000) of the Madison Aquifer near Rapid City, South Dakota**

**Scott L. Miller**

South Dakota School of Mines and Technology, Department of Geology and Geological Engineering, 501 East St. Joseph Street, Rapid City, SD 57701, [slmgmiller@rushmore.com](mailto:slmgmiller@rushmore.com)

**Arden D. Davis**

South Dakota School of Mines and Technology, Department of Geology and Geological Engineering, 501 East St. Joseph Street, Rapid City, SD 57701 [arden.davis@sdsmt.edu](mailto:arden.davis@sdsmt.edu)

**Alvis L. Lisenbee**

South Dakota School of Mines and Technology, Department of Geology and Geological Engineering, 501 East St. Joseph Street, Rapid City, SD 57701 [alvis.lisenbee@sdsmt.edu](mailto:alvis.lisenbee@sdsmt.edu)

**Reko G. Hargrave**

South Dakota School of Mines and Technology, Department of Geology and Geological Engineering, 501 East St. Joseph Street, Rapid City, SD 57701 [rghargrave@rushmore.com](mailto:rghargrave@rushmore.com)

**Larry D. Putnam**

U.S. Geological Survey, 1608 Mountain View Road, Rapid City, SD 57702 [ldputnam@usgs.gov](mailto:ldputnam@usgs.gov)

**Andrew J. Long**

U.S. Geological Survey, 1608 Mountain View Road, Rapid City, SD 57702 [ajlong@usgs.gov](mailto:ajlong@usgs.gov)

The City of Rapid City, South Dakota, is located within the Rapid Creek watershed in the east-central Black Hills and relies heavily on the Mississippian Madison aquifer for drinking-water supplies, utilizing several wells and springs. The aquifer locally consists of limestone and dolomite and contains well-developed paleo- and recent karst. Previous work indicates surface water recharges the aquifer from the adjacent Spring Creek watershed to the south and Boxelder Creek watershed to the north. Spring Creek and Boxelder Creek lose all their flow to karst sinkholes in the aquifer except during periods of high discharge (greater than approximately 28 ft<sup>3</sup>/sec for Spring Creek and 50 ft<sup>3</sup>/sec for Boxelder Creek). Ground water from these watersheds converges on wells and springs in the Rapid City area several miles away. Dye-tracer tests for this area indicate ground-water velocities are on the order of 300 meters per day (1,000 feet per day) and residence times can range from a few days to several months. Based on this information, Rapid City and surrounding suburban water supplies are extremely susceptible to contamination. A database of 323 wells, geologic maps, fractures, faults, geologic structures, water-quality data, and dye-tracer tests are being analyzed to develop a geologic model to better define local ground-water flow paths and characterize susceptibility zones. Structure contours were constructed and depths to aquifer were determined. Inherent aquifer susceptibility was combined with human influences to develop a vulnerability map (1:24,000) for the Madison aquifer for the Rapid City area.

## **Geologic Atlas of the Rapid City West 7.5-Minute Quadrangle**

### **Alvis L. Lisenbee**

Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, [alvis.lisenbee@sdsmt.edu](mailto:alvis.lisenbee@sdsmt.edu)

### **Arden D. Davis**

Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, [arden.davis@sdsmt.edu](mailto:arden.davis@sdsmt.edu)

### **Colin J. Paterson**

Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, [colin.paterson@sdsmt.edu](mailto:colin.paterson@sdsmt.edu)

### **Larry D. Stetler**

Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, [larry.stetler@sdsmt.edu](mailto:larry.stetler@sdsmt.edu)

### **Scott L. Miller**

Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, [slmgmiller@netscape.net](mailto:slmgmiller@netscape.net)

### **Reko Hargrave**

Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, [rghargrave@rushmore.com](mailto:rghargrave@rushmore.com)

The Black Hills Development Corridor (Spearfish to Fairburn) is undergoing rapid urbanization in the eastern and northern Black Hills and adjoining plains. To aid in responsible planning and development in this region, faculty members and graduate students of the Department of Geology and Geological Engineering (SDSMT) are preparing several types of maps at 7.5-minute scale for inclusion in geologic atlases. This is a combined effort involving the SDSMT, the West Dakota Water Development District, the South Dakota Geological Survey, and the U.S. Geological Survey (EDMAP program).

The sequence of such a study begins with preparation of a geologic map. From the geologic base map and additional sources, e.g., the water well data base compiled over many years by Dr. J.P. Gries, derivative maps are prepared using a GIS. The Rapid City West Quadrangle is a pilot study in this effort. Such maps illustrate aspects of the economic resources (limestone – estimated as \$0.5 billion produced, gypsum, and sand), geologic hazards (Rapid Creek and lesser flood plains, sinkhole/karst collapse related to gypsum in the Spearfish Formation, and ground stability/landslides on unstable slopes), and ground water. Ground water-related maps include structure contour, depth to aquifer, aquifer vulnerability (e.g., areas of abundant septic systems near sinks in streams, etc.), and generalized flow paths for four aquifers (Deadwood, Madison, Minnelusa, and Minnekahta).

## **Estimating Ground-Water Age using Tracer Data and a Mixing Model**

**Andrew J. Long**

U.S. Geological Survey, 1608 Mountain View Road, Rapid City, SD 57702, [ajlong@usgs.gov](mailto:ajlong@usgs.gov)

**Larry Putnam**

U.S. Geological Survey, 1608 Mountain View Road, Rapid City, SD 57702, [ldputnam@usgs.gov](mailto:ldputnam@usgs.gov)

Ground-water age distributions were estimated for the Madison aquifer near the Black Hills, South Dakota, using a ground-water mixing model for chlorofluorocarbon (CFC) and tritium data. Age distributions indicate the response characteristics of a tracer or a potential contaminant and, thus, are useful for developing well-head protection programs. Madison aquifer water often is a complex mixture of waters of various ages. Model input functions include time-series data for atmospheric concentrations of four anthropogenic tracers:  $\text{CCl}_3\text{F}$ ,  $\text{CCl}_2\text{F}_2$ ,  $\text{C}_2\text{Cl}_3\text{F}_3$ , and tritium ( $^3\text{H}$ ). Predicted tracer concentrations were computed based on an estimated probability distribution of age and the input time-series data. Age distributions for 20 wells and springs were determined by comparing computed tracer concentrations to measured concentrations. Because the four input functions for CFCs and tritium in precipitation are unique, the use of multiple tracers helps to constrain the solution, especially if data are available for multiple sampling dates. These age distributions can be estimated for the fraction of water that has a mixed age of less than 50 years. The fraction of water older than 50 years can be estimated; however, the age distribution for that fraction cannot be estimated by using these methods. Generally, bimodal age distributions composed of the sum of two lognormal functions fit measured data quite well for the fraction of water less than 50 years old. Parameters of the lognormal functions were determined by using inverse modeling techniques that minimize the residuals of computed and measured tracer data.

The estimated age distribution of water from Cleghorn Springs is bimodal for water less than 50 years old. The distribution indicates that about 50 percent of the mixture is from 0 to 1 year old, 30 percent is from 10 to 30 years old, and the remaining 20 percent is more than 50 years old. In addition, the calibrated model can be used to predict the tracer concentrations for any selected time between 1950 and the present. For example, modeling results indicate that the tritium concentration of Cleghorn Springs probably peaked during 1963 with a value of about 2080 tritium units and that a second tritium peak occurred in these springs during 1978 with a value of about 180 tritium units.

## **Tracing Streamflow Loss to the Madison Aquifer with Fluorescent Dyes**

**Larry D. Putnam**

U.S. Geological Survey, 1608 Mountain View Road, Rapid City, SD 57702, [ldputnam@usgs.gov](mailto:ldputnam@usgs.gov)

**Andrew J. Long**

U.S. Geological Survey, 1608 Mountain View Road, Rapid City, SD 57702, [ajlong@usgs.gov](mailto:ajlong@usgs.gov)

**Scott L. Miller**

Ph.D. Student, South Dakota School of Mines and Technology, Department of Geology and Geological Engineering, 501 East St. Joseph Street, Rapid City, SD 57701, [slmgmiller@rushmore.com](mailto:slmgmiller@rushmore.com)

**Ericka Oberembt**

Student, South Dakota School of Mines and Technology, Department of Geology and Geological Engineering, 501 East St. Joseph Street, Rapid City, SD 57701, [oberembt@usgs.gov](mailto:oberembt@usgs.gov)

Streamflow loss to the Madison aquifer was traced to down gradient wells and springs by injecting fluorescent dyes in Spring Creek and Spearfish Creek in the Black Hills area of South Dakota. Three injections of fluorescein dye were made in Spring Creek during the spring of 2003. The first injection in Spring Creek was just above the streamflow loss zone when streamflow was about 21 cubic feet per second and there was streamflow throughout the entire reach of the loss zone. Two subsequent injections were made in specific sink holes in the Madison aquifer. Samples were collected daily for several months from 14 downgradient wells and springs and were analyzed with a laboratory fluorometer. Dye was detected in samples from six public-water supply wells with dye arrival times that ranged from several hours to 5 days. Ground-water velocities were as high as 1 mile per day and duration of detectable dye in well samples ranged from a few days to about 2 months.

Fluorescein and rhodamine WT dyes were injected in Spearfish Creek just above the streamflow loss zone during the spring of 2003. Streamflow was only about 6 cubic feet per second; therefore, streamflow existed only in the upper reach of the loss zone where flow disappeared into the aquifer. Samples were collected daily for several months from 12 downgradient wells and springs. Dye was detected in samples from three public-water supply wells with dye arrival times that ranged from 6 days to about 4 months. Ground-water velocities were as high as one-third mile per day and dye is still being detected to date in samples from these wells.

## **The Status of Groundwater Lakes in Wind Cave, Wind Cave National Park, South Dakota**

**Marc J. Ohms**

Physical Science Technician, Wind Cave National Park, RR1 Box 190, Hot Springs, SD 57747,  
[Marc\\_Ohms@nps.gov](mailto:Marc_Ohms@nps.gov)

Wind Cave obtains a depth great enough to intersect the water table, providing a unique monitoring opportunity. This area of the cave, known as the Lakes, was discovered in the 1960's. The park has monitored the level of the Lakes since their discovery. During the mid-1990's the level rose dramatically, and a new lake at a higher elevation appeared. Access to the Lakes has not been possible since 1999, because the new lake has completely blocked the cave passage leading to them. The level of this new lake has been continuously monitored since its formation.

Although many dye traces conducted above the cave to drip water sites within the cave have been positive, the Lakes have had negative results. Radioactive isotopic studies of water from the new lake indicate the water is old water (pre-bomb testing). Precipitation and level fluctuations of nearby wells and streams have been compared to both the new lake and the Lakes with interesting results. The comparisons indicate great variability in the aquifer, and raise questions regarding flow paths and aquifer vulnerability in the Wind Cave region.

---

**TUESDAY, APRIL 6, 2004**  
**SESSION 2**  
**10:15 A.M. - 12:05 P.M.**

**WATER QUALITY**

---

## **Water Quality Monitoring and HSPF Modeling to Develop a TMDL for Spring Creek**

### **Patrick Schwickerath**

Civil and Environmental Engineering Department, South Dakota School of Mines & Technology,  
501 E. St. Joseph St., Rapid City, SD 57701-3995, [pschwickerath@yahoo.com](mailto:pschwickerath@yahoo.com)

### **Thomas A. Fontaine**

Civil and Environmental Engineering Department, South Dakota School of Mines & Technology,  
501 E. St. Joseph St., Rapid City, SD 57701-3995, [Thomas.Fontaine@sdsmt.edu](mailto:Thomas.Fontaine@sdsmt.edu)

### **Scott J. Kenner**

Civil and Environmental Engineering Department, South Dakota School of Mines & Technology,  
501 E. St. Joseph St., Rapid City, SD 57701-3995, [Scott.Kenner@sdsmt.edu](mailto:Scott.Kenner@sdsmt.edu)

Assessment of non-point source pollution is a critical water resource issue in South Dakota. The development of Total Maximum Daily Loads (TMDLs) for impaired waterbodies is a fundamental component of South Dakota's program to meet Clean Water Act goals. The number of waterbodies in the Black Hills on the 303(d) list (requiring TMDLs) is approximately 40, indicating a significant need in the next 10 years for watershed assessments to identify pollution sources and restoration alternatives. For example, Spring Creek was listed on the 1998 303(d) list because high levels of fecal coliform exceeded standards for immersion recreation between the creek headwaters and the inlet of Sheridan Lake. We will illustrate the use of monitoring and modeling in the development of a TMDL and restoration options, using Spring Creek as an example. The TMDL for the impaired reach of Spring Creek was developed using a watershed approach. The watershed was modeled using BASINS and HSPF because these models accurately simulate the critical hydrologic processes as well as point and non-point sources of coliforms, and the transport of these bacteria. Several combinations of Best Management Practices (BMPs) were modeled in an attempt to develop restoration options to reduce coliform concentrations to acceptable levels. The combination of BMPs that reduced concentrations to acceptable levels included reducing stream access, reducing the number of failing septic systems, a litter control program, buffer zones and filter strips, and an animal waste management program. After BMPs are implemented, monitoring of the coliform concentrations in the impaired reach of Spring Creek will continue to evaluate the effectiveness of the BMPs. If monitoring indicates that bacteria levels have not been reduced to meet standards for the beneficial uses of Spring Creek, additional BMPs will be implemented.



## **Coal Bed Methane Development – South Dakota’s Role**

**Jeanne Goodman**

South Dakota Department of Environment and Natural Resources, 523 East Capitol Street,  
Pierre, SD 57501, [Jeanne.Goodman@state.sd.us](mailto:Jeanne.Goodman@state.sd.us)

Coal bed methane is a gas produced as water is pumped from coal releasing the pressure on the coal seams. As the gas separates from the water, the gas is piped away and collected. The produced water is often discharged to the land surface if NPDES permits are issued that allow the discharge.

The quality of the water produced with coal bed methane varies. Much of the water is of a quality that is used for stock watering and meets federal and state drinking water standards. However, parameters that effect irrigation are of primary concern to the landowners downstream of the discharges.

Development of coal bed methane in Wyoming is producing water that is discharged into tributaries of the Belle Fourche and Cheyenne Rivers. Because the Belle Fourche and Cheyenne Rivers flow into South Dakota, the South Dakota Department of Environment and Natural Resources is working with the Wyoming Department of Environmental Quality to address potential water quality impacts in these river basins. DENR continues to review proposed discharge permits, collect monthly stream samples, and support a water quality study in the upper Cheyenne River as coal bed methane development continues.

# Potential Changes in Water Quality Due to Future Coal Bed Methane Development–The Belle Fourche River, South Dakota, Case Study

**Dr. Dan Hoyer**

RESPEC, 3824 Jet Drive, Rapid City, SD 57703, [dan.hoyer@respec.com](mailto:dan.hoyer@respec.com)

The Belle Fourche River is a natural stream that drains parts of Butte, Lawrence, and Meade Counties in South Dakota and flows to the Cheyenne River in Meade County and ultimately to the Missouri River. The Belle Fourche watershed is approximately 2,100,000 acres (3,300 square miles) in size in South Dakota and approximately 2,400,000 acres (3,700 square miles) in Wyoming.

The Powder River coal bed methane development is within the Belle Fourche River Watershed. A large portion of the development is above Keyhole Reservoir. Table 1 summarizes the cumulative production to date. Potential changes in the Belle Fourche River due to coal bed methane discharges may include an increase in flow and a change in chemistry. The Total Suspended Solids (TSS) concentration in Belle Fourche River at the Wyoming and South Dakota state line is flow controlled, not sediment source controlled. Thus increase in flow rate will result in an increase in TSS concentration and load. Developing flow versus TSS relations provide tools to evaluate current and potential future changes. In addition, an increase in flow may change the geomorphologic character of the stream, causing the stream to become less stable. The geomorphologic changes could occur over longer periods of time (10-30 years). The regulation of flow by Keyhole Reservoir will significantly influence this potential change.

Coal bed methane water discharged into the Belle Fourche River may change the dissolved constituents in the receiving water such as sodium, calcium, magnesium along with bicarbonates, carbonates, and sulfates. Trilinear plots can be used to evaluate current and potential future changes.

**Table 1. Coal Bed Methane Well Summary for Belle Fourche Watershed**  
(Summary Over Life of Well)

| Class              | Count | Gas (Mcf)   | Water (Barrels) |
|--------------------|-------|-------------|-----------------|
| Producing Wells    | 5,539 | 607,703,086 | 1,008,987,158   |
| Nonproducing Wells | 2,710 | 0           | 0               |

Note: All wells are located within the Upper Belle Fourche Watershed.

## **Response of the Fish Communities in Bear Butte Creek Following Closure of the Gilt Edge Mine**

**Jack Erickson**

South Dakota Department of Game, Fish and Parks, 3305 West South Street,  
Rapid City, SD 57702, [Jack.Erickson@state.sd.us](mailto:Jack.Erickson@state.sd.us)

Mining activity within the Bear Butte Creek watershed began with the gold rush of 1876 and concluded in 1998 when the Gilt Edge Mine ceased operation and subsequently was placed on EPA's Superfund National Priority List. Since 1997, the SDGF&P and the EPA have conducted fish population surveys within the Bear Butte Creek watershed to monitor the recovery of the longnose dace, mountain sucker and brook trout populations. Currently the State of South Dakota and the EPA are developing remedial objectives for the Gilt-Edge Mine that include objectives which will address native and non-native species within this watershed.

## **Ground-Water Quality Affects the Availability of Drinking Water in the United States**

**Michael J. Moran**

U.S. Geological Survey, 1608 Mountain View Road, Rapid City, SD 57702, [mjmoran@usgs.gov](mailto:mjmoran@usgs.gov)

The availability of ground water is an important issue because population growth and development in the United States continue to increase the demand for ground-water resources. About one-half of the U.S. population relies on ground water as a source of drinking water. Land-use practices, development actions, and other human activities have resulted in inadvertent contamination of ground-water resources and have effectively decreased the amount of ground water available for human consumptive use.

Although naturally occurring contaminants can adversely affect ground-water quality in some areas, most ground-water quality problems are anthropogenic in origin. Research has shown that ground-water quality is adversely affected by human development. Because the demand for ground water is usually higher in areas where population is larger and because development activities are more significant in these areas, the quality of ground water in highly populated areas becomes critical.

The U.S. Geological Survey's National Water-Quality (NAWQA) Program is a good source of large-scale ground-water-quality data for the United States. In the NAWQA Program, ground-water samples are analyzed for trace elements, nutrients, pesticides, and volatile organic compounds (VOCs). Data from the NAWQA Program indicate that more than 50 percent of ground-water samples from major aquifers across the United States may be contaminated by human activities.

VOCs are an important group of contaminants in ground water used as a source of drinking water because of the potential human health risks from these chemicals. Based on NAWQA data, as much as 50 percent of ground-water samples from major aquifers may be contaminated by VOCs. However, the concentrations are usually low and only about 2 percent of samples had concentrations of VOCs that exceeded a drinking water standard or health advisory.

If the current trends in U.S. population growth and economic development continue, there will be more demand for ground water and more ground water may be affected by anthropogenic activities. In the future, it will be important to understand the combined effects of population growth, increased demand for ground water, and increased anthropogenic activity on ground-water availability for drinking-water supply.

---

**TUESDAY, APRIL 6, 2004**

**SESSION 3**

**1:30 - 2:50 P.M.**

**HYDROLOGY POTPOURRI**

**(ALPINE ROOM)**

---

## **Preliminary Assessment of Natural Spring Potential to Enhance Drought Recovery on South Dakota Tribal Lands**

**Marla StripedFace-Collins**

Sinte Gleska University, Mission, SD, 57555, [marlacollins2001@yahoo.com](mailto:marlacollins2001@yahoo.com)

**E. M. Collins**

Sinte Gleska University, Sicangu Policy Institute, 221 East 2nd Street, PO Box 557, Mission, SD 57555-0557, [mcollins@SINTE.EDU](mailto:mcollins@SINTE.EDU)

For the past two years, drought conditions have existed in the Northern Plains including most of South Dakota. Supplies of surface and subsurface water of suitable quality for domestic, agricultural, and livestock needs as well as restorative applications have been inadequate and unavailable across large areas including the tribal lands. A survey of known natural springs beginning with the bison rangelands on Pine Ridge, Rosebud, and Lower Brule is being conducted, with the initial phase to be done by August 2004. A high-resolution aerial photographic analyses will be followed by resident interviews and detailed site assessments. GPS/GIS technology is being used to geo-spatially reference these springs.

In the second phase, detailed local geologic/lithologic interpretations will be prepared for each spring locale. Baseline data on water quality and supply potential is being accumulated by combining existing records with an ongoing program of monthly sampling and standard chemical analysis. Flow rate measurements will be conducted monthly. This baseline spring evaluation is the first step in a comprehensive ongoing water supply assessment within the Miocene/Oligocene White River-Arikaree and older formations in the White River watershed.

## **Recent Updates to National Weather Service Data Access Services**

**Dave Carpenter**

National Weather Service, 300 E. Signal Drive, Rapid City, SD 57701, [Dave.Carpenter@noaa.gov](mailto:Dave.Carpenter@noaa.gov)

The National Weather Service has initiated significant service improvement efforts to enhance access to the massive amounts of climatological and hydrological data collected by the government. Among these are the Advanced Hydrologic Prediction Service, the cooperative effort to produce the drought monitor, and the recently updated long range climate forecasts. A new initiative to "localize" the long range forecasts has also begun. A brief summary of these services and a description of how to access them will be provided.

## **Lakota Ranch Subsurface Dam and Hydrologic Study within an Alluvial Valley, Hermosa, South Dakota**

**Heidi Sieverding**

Geology and Geological Engineering Department, South Dakota School of Mines and Technology, 501 East St. Joseph St., Rapid City, SD 57701, [HSieverd@taz.sdsmt.edu](mailto:HSieverd@taz.sdsmt.edu)

**Larry Stetler**

Geology and Geological Engineering Department, South Dakota School of Mines and Technology, 501 East St. Joseph St., Rapid City, SD 57701, [larry.stetler@sdsmt.edu](mailto:larry.stetler@sdsmt.edu)

Lakota Ranch contains a perennial spring emanating from alluvium overlying the Triassic Spearfish Formation and discharging into Battle Creek. The spring discharge is relatively stable, however the discharge location will migrate upstream through the north-south trending valley during extended periods of rainfall. The discharge location does not migrate downstream beyond a certain location potentially due to upwelling deep aquifer ground water through bedrock fractures present within the valley. The alluvium is composed of interbedded clay, silt, sand and cobble/boulder lens, which extends to an average depth of 40 feet below the surface at the center of the valley. Monitor wells and a single pumping well have been installed in the alluvium. Pump tests yield an average flow of 8 gpm from the aquifer. The alluvial ground water level is six meters below the surface at the northern edge of the property and intersects the surface at the location of the spring. Ground water is sourced from combination of three aquifers: upwelling bedrock aquifers, alluvial fan deposits, and fluvial deposits. The relative contributions of these sources are variable related to precipitation. A subsurface dam was installed in order to elevate the water level within a head cut and washout. Due to equipment limitations, the dam was not installed deep enough to redirect the flow.



## **Peak-flow Estimates and Process Controls for Select South Dakota Rivers**

### **Elizabeth Roeser**

M.S. Student, South Dakota School of Mines and Technology, Department of Geology and Geologic Engineering, 501 East St. Joseph St. Rapid City, South Dakota 57701, [eroeser@yahoo.com](mailto:eroeser@yahoo.com)

### **Dr. Larry Stetler**

South Dakota School of Mines and Technology, Department of Geology and Geologic Engineering, 501 East St. Joseph St. Rapid City, South Dakota 57701, [larry.stetler@sdsmt.edu](mailto:larry.stetler@sdsmt.edu)

### **Dr. Scott Kenner**

South Dakota School of Mines and Technology, Department of Civil and Environmental Engineering, 501 East St. Joseph St. Rapid City, South Dakota 57701, [scott.kenner@sdsmt.edu](mailto:scott.kenner@sdsmt.edu)

Stream restoration and urban planning have recently received tremendous attention resulting in the need for a greater understanding of stream behavior and channel evolution. Development of regional flow equations and local stream flow statistics is essential in understanding stream flow and control mechanisms necessary for proper engineering design, stream restoration, and water resource management. The objective of this project was to determine process controls for stream characteristics by development of stream flow statistics, development of a GIS database to assess regional relationships, and development of regional flow equations. Assessments were made on individual stream segments, over entire stream lengths, and for entire watersheds. Sixty-three USGS stream gaging stations were chosen for stream assessment along 34 streams and rivers within the state of South Dakota. Each of the 63 sites was visited and surveyed to determine stream profile, hydraulic geometry, and channel substrate characteristics. Specific field measurements included bankfull depth and width, flood-prone depth and width, local stream gradient, and substrate data. Stream classifications, development of hydraulic geometry relationships, and compilation of peak-flow magnitude estimates using USGS LP3 analyses were performed. Estimated bankfull flows were compared to bankfull flows calculated from field data to determine the accuracy of the estimated return periods for bank forming flows. A GIS database in conjunction with multiple linear regressions will be used to develop regional equations characterizing watershed stream behavior. The equations can then be used by engineers and planners to properly and efficiently design infrastructure.

---

**TUESDAY, APRIL 6, 2004**

**SESSION 3**

**1:30 - 2:50 P.M.**

**HYDROLOGY POTPOURRI  
(PONDEROSA ROOM)**

---

## **A Limestone-Based Process for Removal of Arsenic from Drinking Water**

**Arden D. Davis**

**Cathleen J. Webb**

**David J. Dixon**

**Terrence E. Williamson**

HydroTech Engineering, 3115 Stockade Drive, Rapid City, South Dakota 57702

Arsenic contamination in ground water is a major problem facing many areas of the United States and the world. Arsenic is a persistent, bio-accumulative toxin. Because of arsenic's toxicity and its links to cancer, the U.S. EPA recently announced the lowering of the maximum contaminant level (MCL) from 50 parts per billion to 10 ppb by the year 2006. In South Dakota alone, it is estimated that 18.6% of small and rural water supply systems will not be in compliance with this mandate. The American Water Works Association has estimated the cost of decreasing the arsenic standard to 10 ppb in South Dakota at \$8.25 million.

Research has shown that limestone-based materials can achieve arsenic adsorption of greater than 90%. The limestone-based technology appears to be an effective process that has great potential for source reduction. Limestone is readily available, and its use for arsenic removal could be relatively inexpensive. The technology could be adapted to small, rural water supply systems as well as domestic systems.

## **Characterization of Limestone Used in the Removal of Arsenic from Water**

**Roberta I. Fivecoate**

South Dakota School of Mines and Technology, 501 E. St. Joseph, Rapid City, SD 57701,  
[ista@rushmore.com](mailto:ista@rushmore.com)

**Jenifer L. Sorensen**

South Dakota School of Mines and Technology, 501 E. St. Joseph, Rapid City, SD 57701,  
[jensorensen@direcway.com](mailto:jensorensen@direcway.com)

**Arden D. Davis**

South Dakota School of Mines and Technology, 501 E. St. Joseph, Rapid City, SD 57701,  
[Arden.Davis@sdsmt.edu](mailto:Arden.Davis@sdsmt.edu)

**David J. Dixon**

South Dakota School of Mines and Technology, 501 E. St. Joseph, Rapid City, SD 57701,  
[David.Dixon@sdsmt.edu](mailto:David.Dixon@sdsmt.edu)

**Cathleen J. Webb**

Western Kentucky University, 1 Big Red Way, Bowling Green, KY 42101,  
[cathleen.webb@wku.edu](mailto:cathleen.webb@wku.edu)

**Sreedevi Dawadi**

Western Kentucky University, 1 Big Red Way, Bowling Green, KY 42101,  
[sree.dawadi@wku.edu](mailto:sree.dawadi@wku.edu)

Current research has shown that removal of arsenic from water sources can be accomplished with the use of limestone. Further studies have been conducted to differentiate between different limestones from three formations in the Black Hills region (Madison Limestone, Minnekahta Limestone, and Minnelusa Formation) as well as one limestone from Kentucky (Ste. Genevieve Formation). The first of these studies characterized the rocks as part of an effort to maximize the removal of the arsenic. Thin section analysis of the different limestones in the study gave information about the content of the material. X-ray diffraction of the different materials then was completed to show the varying compositions of minerals in the different limestones. This information is being compared to arsenic removal rates in order to increase efficiency.

## **Use of Pfafstetter Codes for Hydrologic Modeling: A Cedar River Example**

**Pamela J. Waisanen**

U.S. Geological Survey, SAIC, EROS Data Center, 47914 252nd Street,  
Sioux Falls, SD 57198-0001, [waisanen@usgs.gov](mailto:waisanen@usgs.gov)

**Kristine L. Verdin**

U.S. Geological Survey, SAIC, EROS Data Center, 47914 252nd Street,  
Sioux Falls, SD 57198-0001, [kverdin@usgs.gov](mailto:kverdin@usgs.gov)

**Susan K. Greenlee**

U.S. Geological Survey, EROS Data Center, 47914 252nd Street,  
Sioux Falls, SD 57198-0001, [sgreenlee@usgs.gov](mailto:sgreenlee@usgs.gov)

The Pfafstetter codification scheme provides a hierarchy of streams. This hierarchy, based on contributing area, is assigned to synthetic streams that are connected from the headwaters to the pour point of a watershed. The Pfafstetter codes can be used in hydrologic studies, to determine which areas along streams to include in or exclude from analysis. The Cedar River example, for identifying lands with high denitrification potential, is presented. Buffer widths for areas along the major streams were assigned by Pfafstetter codes. State soils data were queried for drainage characteristics, and land use categories were selected. EDNA (Elevation Derivatives for National Applications) slopes greater than 5 percent were then subtracted. The Pfafstetter codes provided a useful framework for identifying streams based on like contributing areas along streams in a 26-county study area.

## **The View on South Dakota Groundwater Levels Regime in Connection with Hydroclimatology of the Central Territory of Conterminous U.S.**

**Dr. Boris A Shmagin**

Research Associate, Water Resources Institute SDSU, Ag Engineering 211  
Box 2120, Brookings, SD 57007, [Boris\\_Shmagin@sdstate.edu](mailto:Boris_Shmagin@sdstate.edu)

Long-term stream flow records (1935-1987) from sixty-four U.S. Geological Survey gauging stations within seven major hydrologic units (HUC 4, 7-12) were analyzed using multivariate statistics. Factor analysis of average annual flow revealed five patterns of river runoff within five distinct regions of the territory. This factor model reflected 63% variance of initial matrix. Every group of watersheds obtained as a factor was presented by one gauging station with time series of annual discharges (1- 06810000, 2- 08095000, 3- 07018500, 4- 04079000 and 5- 07221000). For the same time interval streams represented by patterns 1, 2 and 4 have increase of values and those represented by 3 and 5 have a decrease. The positive trend for pattern 1 is statistically significant. For each of the five stream patterns, regression equations were obtained from indices of global atmospheric circulation. The equations contain from one to four variables (predictors) and have coefficients of correlation from 39% to 69%. The stream flow for South Dakota may be recognized under influence of Factor 5 and 4 with no significant increase for period of observations. Twelve USGS ground water monitoring wells with longest observation intervals for South Dakota were analyzed using factor analysis. The trends of main patterns of stream flow were compared with seasonal trends for ground water wells. Stream runoff is the most appropriate regional indicator for hydroclimatological processes. The hydrological regionalization of the Central Conterminous U.S. presented in this paper puts the results of ground water level regimes analysis for South Dakota in a more general picture.

---

**TUESDAY, APRIL 6, 2004**

**SESSION 4**

**3:10 - 4:50 P.M.**

**FIRE SCIENCE**

---

## **Assessment of Post-Fire Hydrologic Hazards in the 2002 Hayman, Missionary Ridge, and Coal Seam Wildfire Areas of Colorado**

**John Liou**

Federal Emergency Management Agency, DFC Building 710, Box 25267,  
Denver, CO 80225-0267, [John.Liou@dhs.gov](mailto:John.Liou@dhs.gov)

**John G. Elliott**

U.S. Geological Survey, DFC Building 53, Box 25046, MS 415, Denver, CO 80225,  
[jelliott@usgs.gov](mailto:jelliott@usgs.gov)

**Mark E. Smith, Hydrologist, P.E.**

U.S. Geological Survey, DFC Building 53, Box 25046, MS 406, Denver, CO 80225,  
[mesmith@usgs.gov](mailto:mesmith@usgs.gov)

The 2002 wildfires in Colorado left thousands of acres of rugged forestland vulnerable to rapid rainfall runoff and erosion. The greatest threat to riverine areas within and downstream from the burned areas is from flooding and debris flows. The Federal Emergency Management Agency (FEMA), the U.S. Geological Survey (USGS), and the U.S. Bureau of Reclamation (U.S. BOR) collaborated to evaluate the increased, post-fire hazards in the Hayman, Missionary Ridge, and Coal Seam wildfire areas. FEMA is using estimates of post-fire flood elevations along large perennial streams and estimates of debris-flow inundation depths on alluvial fans to characterize post-fire hazards in populated areas. These hazard maps represent conditions that are expected to exist during the next several years, prior to substantial recovery of the burned watersheds.

Initial, post-fire assessments of the three burned areas determined that sediment-laden water flooding was the principal hazard along the main stem of the South Platte River in the Hayman area (Colorado Front Range), and along Mitchell Creek in the Coal Seam area (Glenwood Springs, Colo.). Mud and debris flows were the principal hazards in smaller, perennial and ephemeral streams in the Coal Seam and Missionary Ridge (Durango, Colo.) areas.

The rainfall-runoff model HEC-HMS (Hydrologic Engineering Center – Hydrologic Modeling System; U.S. Army Corps of Engineers, 2001) was used for watershed modeling, hydrograph generation, and water-flood routing. The Soil Conservation Service (SCS) Curve Number Loss method was used to characterize watershed response to the 100-year rainfall. Watershed models for the South Platte River (Hayman Fire) and Mitchell Creek (Coal Seam Fire) first were calibrated to pre-burn, 100-year flood conditions using published (if available) or derived regional equations for peak flows in those areas. Following calibration, post-burn watershed parameters (runoff curve number, initial abstraction, and lag time) were adjusted to characterize post-burn conditions (degree of burn severity). Computed water flows in the South Platte River Basin (Hayman Fire) also were increased using a sediment-bulking factor to account for volumetric increases caused by accelerated erosion in affected watersheds. Model results indicated that post-burn, 100-year peaks would increase 2 to 44-fold over pre-burn, 100-year peaks in affected watersheds of the South Platte River, and 2 to 21-fold over pre-burn, 100-year peaks in affected watersheds of the Mitchell Creek Basin.

Post-fire, 100-year flood elevations and hazard maps for affected main-stem reaches of the South Platte River (Hayman Fire) were determined on the basis of normal-depth computations for 20 channel cross sections surveyed in a 30-mile reach through the burned area and downstream to Waterton Canyon near Denver.



## **Applications of Satellite Data for Fire Science**

**Don O. Ohlen**

SAIC, EROS Data Center, 47914 252<sup>nd</sup> Street, Sioux Falls, SD 57198, [ohlen@usgs.gov](mailto:ohlen@usgs.gov)

Fire is an integral part of ecosystem processes and years of fire exclusion have resulted in landscape changes that have altered fire regimes, fuel loadings, and vegetation composition and structure. As a consequence, the number, size, and intensity of wildfires have significantly changed from the historic conditions, sometimes with catastrophic consequences. Satellite remote sensing research and applications are important for providing required data for mapping fire fuels, assessing fire effects, and monitoring fire danger. Land management agencies, scientific communities, and citizenry affected by wildland fires can benefit from research and development of consistent and accurate geospatial fire data, maps, and assessments produced at various scales.

The need to develop spatial information and technology lies in a fire's natural cycle: fire danger and live fire monitoring, post-fire mapping of burn scars and analysis of fire effects, fire fuels characteristics and mapping. These activities form the core of the USGS EROS Data Center (EDC) fire research and development. The two fire research projects discussed here exemplify these core EDC projects. The LANDFIRE project is a multi-agency, inter-disciplinary research and development activity designed to develop a consistent and accurate methodology capable of producing geospatial data of vegetation conditions, fire fuels, risks, and ecosystem status at the national, regional, and local scales for implementation of the National Fire Plan.

The mapping of wildfires using satellite imagery has been shown to provide valuable information to resource management personnel addressing long term ecological monitoring and immediate post-fire rehabilitation and stabilization needs. The importance of burned area mapping to both land management and scientific investigation requires that the mapping efforts be systematic, validated, and comparable across different ecosystems and time scales. Researchers at the U.S. Geological Survey (USGS) EROS Data Center and USGS Biological Resources Discipline, in cooperation with the National Park Service, conduct research on effects of fire as measured with remotely sensed data and deliver a suite of standardized burn products to users.

## **Effects of the 1988 Galena Fire on Streamflow Characteristics, Custer State Park, South Dakota**

**Daniel G. Driscoll**

U.S. Geological Survey, 1608 Mountain View Road, Rapid City, SD 57702, [dgdrisco@usgs.gov](mailto:dgdrisco@usgs.gov)

**Janet M. Carter**

U.S. Geological Survey, 1608 Mountain View Road, Rapid City, SD 57702, [jmcarter@usgs.gov](mailto:jmcarter@usgs.gov)

The Galena Fire burned about 16,788 acres of primarily ponderosa pine forest during July 5-8, 1988, in the Black Hills area of South Dakota. The fire burned primarily within the Grace Coolidge Creek drainage basin and almost entirely within the boundaries of Custer State Park. A U.S. Geological Survey gaging station with streamflow records dating back to 1977 was located along Grace Coolidge Creek within the burned area. About one-half of the gaging station's 26.8-square-mile drainage area was burned. The drainage basin for Bear Gulch, which is a tributary to Grace Coolidge Creek, was burned severely, with complete deforestation occurring in nearly the entirety of the area upstream from a gaging station that was installed in 1989. A study to evaluate effects of the Galena Fire on streamflow was initiated in 1988, and streamflow and precipitation data were collected through water year 1998.

The effects of the Galena Fire on annual-yield characteristics of Grace Coolidge Creek were evaluated primarily from comparisons with long-term streamflow records for Battle Creek, which is hydrogeologically similar and is located immediately to the north. Annual yield for Grace Coolidge Creek increased by about 20 percent as a result of the fire.

Substantial increases in peak-flow characteristics for severely burned drainages were visually apparent from numerous post-fire field observations. Various analyses of streamflow data indicated substantial increases in peak-flow response for burned drainage areas; however, quantification of effects was particularly difficult because peak-flow response diminished quickly and returned to a generally pre-burn condition by about 1991. Field observations of vegetation and analysis of remotely sensed data indicated that establishment of grasses and forbs occurred within a similar timeframe. Comparison of pre-fire peak flows to post-1991 peak flows indicates that these grasses and forbs were equally effective in suppressing peak flows as was the predominantly ponderosa pine forest that existed prior to the Galena Fire.

Numerous peak-flow events with small recurrence intervals occurred within burned areas through 1990. Peak-flow events for Bear Gulch during this period were about one to two orders of magnitude larger than corresponding peaks for a small control drainage located along Grace Coolidge Creek upstream from the burn area. The small peaks do not provide quantitative information applicable to estimation of peak-flow magnitudes for larger events, however. Peak-flow events for Bear Gulch that occurred during 1991-98 were similar in magnitude to those for the control drainage. A short-term increase in peak-flow potential also was documented for the longer-term gaging station located along Grace Coolidge Creek; however, peak-flow response was less pronounced than for Bear Gulch, which had nearly complete deforestation within a much smaller drainage area.

## **Watershed Response Following the Battle Creek Fire**

### **Daniel D. Nebelsick**

South Dakota School of Mines and Technology, 501 E. St. Joseph, Rapid City, SD 57701,  
[daniel.nebelsick@sdsmt.edu](mailto:daniel.nebelsick@sdsmt.edu)

### **Thomas A. Fontaine**

Associate Professor, South Dakota School of Mines and Technology, 501 E. St. Joseph,  
Rapid City, SD 57701, [Thomas.Fontaine@sdsmt.edu](mailto:Thomas.Fontaine@sdsmt.edu)

### **Monte L. Williams**

Forest Hydrologist, Black Hills National Forest, Supervisor's Office, 25041 North Highway 16,  
Custer, SD 57730, [mlwilliams01@fs.fed.us](mailto:mlwilliams01@fs.fed.us)

Forest fires often result in severe flooding and erosion damage caused by the removal of groundcover. Land managers need to predict post fire flood risk in order to plan rehabilitation projects. To improve post fire flood predictions, conditions following the Battle Creek fire have been studied to obtain a relationship between burn severity and runoff response. The fire started near Keystone, South Dakota on August 16, 2003, and consumed 12,450 acres of the Black Hills. Hillslopes and watersheds representing a variety of burn severities were selected and set up to monitor rainfall and runoff. Twenty-three passive flow measuring devices were placed at the outlet of watersheds in 6 main basins, two of which were unburned. The watersheds varied in size from 10 to 750 acres. A network of 14 tipping bucket rain gages was established throughout the 6 basins. A burn severity map was developed by combining satellite imaging with ground survey data. The burn severities were grouped into low, moderate, and high severities, which serve as indicators of the condition of the groundcover (vegetation, litter, and duff). The Battle Creek Fire occurred late in the fire season, and the area did not receive any significant rainfall until the instrumentation was in place. Discharges were recorded for 5 events throughout the summer of 2003. Relations between discharge, precipitation intensity, and other physical watershed characteristics were developed using regression analysis. Results indicate that there is a direct link between rainfall runoff and the condition of groundcover. Low and moderate burn areas with high percentages of ground cover produced little to no flow, whereas high burn areas had greatly increased runoff. Increased rock content also contributed to higher runoff rates. These results can be used to identify areas that are most in need of flood protection and watershed treatments.

## **Developments in Rapid-Deployment Gage Technology**

**Ralph W. Teller**

U.S. Geological Survey, 1608 Mountain View Road, Rapid City, SD 57702, [rwtteller@usgs.gov](mailto:rwtteller@usgs.gov)

Rapid-deployment gage technology has evolved from the need for real-time hydrologic data collection for unscheduled events at ungaged sites. The first rapid-deployment gages were developed for use during flood events to supplement the streamflow-gaging network. Prepackaged gages could be trucked to specific sites during a major flood event, installed in a few hours, and begin transmitting data within a day. The South Dakota District developed several prototype gages for the MetWarn system in Rapid City. During the last three fire seasons, similar gage technology was adapted for collection of precipitation data for post-fire rainfall/runoff evaluation. This technology was used successfully in South Dakota after the Battle Creek and Grizzly Gulch Fires, and in Colorado after the large Missionary Ridge Fire near Durango. Today, newer and smaller gage packages, combined with more efficient high-data-rate instrumentation, provide hydrologists with new tools to collect and evaluate a broad spectrum of real-time hydrologic data within hours of notification.