2005
WESTERN SOUTH DAKOTA
HYDROLOGY CONFERENCE

Program and Abstracts

April 12, 2005
Rushmore Plaza Civic Center
Rapid City, South Dakota

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2005 Western South Dakota Hydrology Conference

This program and abstracts book has been produced in conjunction with the 2005 Western South Dakota Hydrology Conference, held at the Rushmore Plaza Civic Center on April 12, 2005. The purpose of this book is to provide summaries of the presentations made during the conference.

The purpose of the 2005 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 climate, water quality, hydrology potpourri, surface water, and hydrogeology.

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. The help by many students from the South Dakota School of Mines and Technology with presentations and lights is greatly appreciated. Keynote speaker, Thomas Durkin, 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.

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), Van A. Lindquist (West Dakota Water Development District), and Jenifer Sorensen (South Dakota Engineering Society).

CONFERENCE PROGRAM

Tuesday, April 12, 2005
Alpine/Ponderosa Rooms
Rushmore Plaza Civic Center

7:15 - 8:00 a.m. . . . . Registration
8:00 - 8:15 a.m. . . . . Welcome, general information

Session 1 – Climate (2 PDH)
8:15 - 10:00 a.m.
Alpine/Ponderosa Rooms

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

Presentations

8:15 - 9:00 a.m. - [1-1] Toddy, *Drought in the Dakotas–Impacts and outlook–How bad are we really?*

9:00 - 9:20 a.m. - [1-2] Bunkers, Carpenter, Czepyha, Murphy, and Rudge, *A comparison of the 2000-2004 regional drought and 1995-1999 pluvial period*

9:20 - 9:40 a.m. - [1-3] Driscoll, *Drought perspectives for South Dakota and the Western United States*

9:40 - 10:00 a.m. - [1-4] Stetler, *Quantifying warming trends using record high temperatures*

10:00 - 10:20 a.m. . . . . .Refreshment break

Session 2 – Water Quality (1.5 PDH)
10:20 a.m. - 11:40 a.m.
Alpine/Ponderosa Rooms

Moderator: **Dr. Scott Kenner,** Professor and Chairman, Civil and Environmental Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota

Presentations

10:20 - 10:40 a.m. - [2-1] Stone and Heglund, *Pharmaceuticals in water supplies*

10:40 - 11:00 a.m. - [2-2] Williamson, Kimball, Runkel, and Walton-Day, *Quantification of mass loading to Strawberry Creek near the Gilt Edge Mine, South Dakota*

11:00 - 11:20 a.m. - [2-3] Foreman, Hoyer, and Kenner, *Physical habitat assessment and historical water quality analysis on the White River, South Dakota*

11:20 - 11:40 a.m. - [2-4] Hoyer, Kenner, and Banda, *Coal Bed methane development and intermittent streams, Cheyenne River, Wyoming*

11:40 a.m. - 1:10 p.m. . . . . Luncheon

Rushmore H Room
Keynote speaker: Thomas Durkin (1.0 PDH)
South Dakota Space Grant Consortium, South Dakota School of Mines and Technology
Thomas.Durkin@sdsmt.edu
Title: ***Mars Mania: The Search for Signs of Water***

Session 3 – Concurrent Session in Alpine Room
Hydrology Potpourri (1.5 PDH)
1:10 - 2:50 p.m.

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

Presentations

1:10 - 1:30 p.m.	-	[3-1A] Lu, Rykhus, and Kwoun, *Application of interferometric synthetic aperture radar (InSAR) to study ground-surface deformation above aquifer*
1:30 - 1:50 p.m.	-	[3-2A] Capehart, Zheng, Hjelmfelt, Farley, Davis, and Kenner, *Regional modeling of hydrologic systems in complex terrain*
1:50 - 2:10 p.m.	-	[3-3A] Green and Stetler, *Effects of terrain and soil variability on slope stability*
2:10 - 2:30 p.m.	-	[3-4A] Sorensen, Davis, Dixon, and Webb, *Engineering design considerations for using limestone-based material to remove arsenic from water*
2:30 - 2:50 p.m.	-	[3-5A] Long and Putnam, *Transfer-function modeling of hydraulic head response and watershed runoff for the Madison Limestone near Spearfish, South Dakota*

Session 3 – Concurrent Session in Ponderosa Room
Surface Water (1.5 PDH)
1:10 - 2:50 p.m.

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

Presentations

1:10 - 1:30 p.m.	-	[3-1P] Deering and Kenner, *Evaluating flow regime management using river 2D and ArcGIS*
1:30 - 1:50 p.m.	-	[3-2P] Fontaine, Pease, and Nebelsick, *Impact of burn severity on flooding in small, forested watersheds*
1:50 - 2:10 p.m.	-	[3-3P] Thompson, *StreamStats: A Web-based application for stream information developed by the U.S. Geological Survey*
2:10 - 2:30 p.m.	-	[3-4P] Schwickerath and Hoyer, *Belle Fourche River watershed restoration implementation, Belle Fourche River, South Dakota*
2:30 - 2:50 p.m.	-	[3-5P] Anderson, *Western South Dakota reservoir storage—Present and past*

2:50 - 3:10 p.m. . . . . Refreshment break

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

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

Presentations

3:10 – 3:30 p.m.	-	[4-1] Sawyer, *Geologic map of South Dakota*
3:30 – 3:50 p.m.	-	[4-2] Rahn, *Chemical weathering and land denudation of the Paleozoic carbonate rocks in the Black Hills, South Dakota and Wyoming*
3:50 – 4:10 p.m.	-	[4-3] Putnam and Long, *Tracing ground-water flow with fluorescent dyes injected in Spring, Rapid, and Spearfish Creeks in the Black Hills, South Dakota*
4:10 – 4:30 p.m.	-	[4-4] Miller, Davis, Lisenbee, Hargrave, Putnam, and Long, *Vulnerability (risk) mapping of the Madison aquifer near Rapid City, South Dakota*
4:30 – 4:50 p.m.	-	[4-5] Lisenbee, *Aquifer vulnerability of the Inyan Kara Group, Black Hawk quadrangle, South Dakota*

4:50 - 5:00 p.m. . . . . Closing remarks

TUESDAY, APRIL 12, 2005
SESSION 1
8:15 - 10:00 A.M.

CLIMATE

Drought in the Dakotas – Impacts and Outlook
How bad are we really?

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As evident to all segments of society, the western Dakotas are in midst of a several year severe drought. While part of the climate of the area, extended droughts can severely affect the hydrology of the area and subsequently the society and economy. We will examine some of the larger-scale impacts of the current drought in comparison with previous droughts regarding snowfall, run-off, fire and agriculture. We will also compare the severity of this drought with previous droughts. Finally, can we claim to be in the midst of the next big drought? We will answer some questions regarding length of droughts and where we might be going.

A Comparison of the 2000-2004 Regional Drought and 1995-1999 Pluvial Period

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Most of northeastern Wyoming, the Black Hills, and western South Dakota are in the midst of a 5-year drought. Historical data indicates previous droughts which had similar or longer durations than present; however, a unique aspect of the current drought is it was preceded by an anomalously wet period from 1995-1999. For example, precipitation during the growing season (defined herein as April to October) was 16 to 26 inches above average for the 1995-1999 period, whereas growing season precipitation deficits have ranged from 6 to 16 inches from 2000-2004. The nature of this wet-dry contrast will be discussed with respect to the climatic record and societal impacts. This marked change from well above average to well below average precipitation makes the current drought appear relatively worse than it would have if it were not preceded by the pluvial period.

Drought Perspectives for South Dakota and the Western United States

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Severe drought conditions have existed throughout much of the western United States during recent years. A perspective on recent and long-term drought conditions is provided herein.

The recent drought conditions initially developed primarily in the upper Midwest and Pacific Northwest during 1999-2000, and since then have been highly variable and transient. Effects within the Missouri River Basin and the Colorado River Basin have been particularly severe. During recent months, substantial relief has occurred within some parts of the southwestern United States; however, drought conditions still prevail in many areas.

Within South Dakota drought conditions also have been variable. Drought conditions generally have been more severe in western than in eastern South Dakota, with a sharp demarcation in drought conditions near the Missouri River. Examination of streamflow records, however, indicates that hydrologic effects of current conditions are relatively mild compared with more prolonged droughts that occurred during the 1930s and 1950s.

Current drought conditions in the Missouri River Basin are the most severe since initial filling of the main-stem reservoir system was accomplished in 1967. Combined storage within the reservoir system currently is about 35 million acre feet, which is about one-half of maximum capacity. This is the lowest on record, and is about 10 percent lower than during the previous drought of 1988-92. Examination of runoff records for the Missouri River near Sioux City for 1898-2004 (adjusted for reservoir storage) provides insights regarding hydrologic effects of drought. Runoff deficits for 2000-04 and those during 1988-92 are generally comparable to deficits that occurred during the 1950s. However, deficit conditions during the 1950s persisted for about 8 years, compared with durations of about 5 years for both 1988-92 and for the current drought. The most severe conditions occurred during the drought of the 1930s, which persisted for about 12 years and resulted in deficits about twice as large as those for the subsequent droughts.

A multi-centurial perspective is provided by reconstructions of historic precipitation patterns that have been developed for many locations using various paleo-hydrologic methods. Such reconstructions indicate that climate conditions generally have been wetter than average during the last 200 years when settlement of the western United States has occurred. A 2000-year reconstruction for the El Malpais National Monument near Grants, New Mexico, indicates that severe droughts persisted for durations approaching 200 years during timeframes of about 300-500 and 1400-1600 A.D.

Quantifying Warming Trends Using Record High Temperatures

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Analysis of the 1947-2002 daily high temperature record for Rapid City, SD reveals two periods of increased warming, 1974-1976, and 1987-1989. Record high daily temperatures were used to quantify warming trends based on the premise that if warming were not occurring, the frequency of record high temperatures would decrease with time. Data were analyzed by month and averaged for the 55 year period. The number of record setting daily high temperatures (RSDHT) decreased from more than 30 per month to less than 5 per month in the first 6 years of record. Between 1955 and 1975 most months had two to three RSDHT per year, although two months showed seven record setting days in one of the 20 years. Eight months showed an increase in RSDHT between 1974 and 1976 and nine months showed an increase to five or more RSDHT per month between 1987 and 1989. February was an anomaly and did not show an increase during the later time period but had a doubling of record setting days in 1995. The month having the highest mean record high temperature was July at 101° F (± 10.5°). January had the lowest mean record high temperature at 60° F but also had the greatest variation in daily highs (± 18°). Statistically, the warmest months contained the lowest variation in record highs and the coolest months had the highest variation in record highs. June had the largest increase in RSDHT in 1988 at 11 new record highs with an average increase of 6.3° F above the previous record high. Overall, the highest recorded temperature was in 1973 at 110° F which was matched again in 1989. Only six days have a yearly maximum high temperature below 100° F and 15 days have a high temperature equal to or greater than 105° F.

TUESDAY, APRIL 12, 2005
SESSION 2
10:20 A.M. - 11:40 A.M.

WATER QUALITY

Pharmaceuticals in Water Supplies

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Recent studies have shown that pharmaceuticals and personal care products (PPCPs), including many classified as endocrine disrupting compounds (EDCs), are ubiquitous within waterways of the United States. A recent study by the USGS (Kolpin et al. 2002) found 80% of streams studied contained measurable concentrations of PPCPs. Further, regulatory agencies may not fully comprehend the ecological effects that PPCPs may have on the environment. The source of PPCPs resides primarily from effluent discharges of treated wastewater from treatment facilities, including rural septic systems. Reports of PPCP contamination within domestic water supplies have raised substantial concern among public and regulatory agencies; however very little is known about the fate and transport of these compounds during drinking water and wastewater treatment. Research underway at SDSM&T is seeking to determine the extent of PPCP contamination within Rapid Creek near Rapid City, South Dakota, and to monitor the removal efficiencies of PPCPs within the Rapid City wastewater treatment plant.

Reference

Kolpin, D. W., E. T. Furlong, et al. (2002). "Pharmaceuticals, hormones, and other organic wastewater contaminants in US streams, 1999-2000: A national reconnaissance." Environmental Science & Technology **36**(6): 1202-1211.

Quantification of Mass Loading to Strawberry Creek near the Gilt Edge Mine, South Dakota

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Several remedial actions have taken place at the Gilt Edge mine in the Black Hills of South Dakota, but questions remain about a possible connection between some of the pit lakes at the mine site and Strawberry Creek along fracture zones. Spatially-detailed chemical sampling of stream and inflow sites occurred during low-flow conditions in June 2003 as part of a mass-loading study by the U.S. Geological Survey to provide information on loading to the stream. Loading to the stream resulted in distinct chemical changes along the study reach. Discharge was calculated using a sodium-bromide tracer injection, and the flow increased by 25.3 liters per second along the study reach, with 9.73 liters per second coming from three tributaries and the remaining increase coming from dispersed, subsurface inflow. Mass loading of base metals mostly occurs at the beginning of the study reach, where there is a discharge pipe from the Gilt Edge mine, and those metal loads are substantially attenuated downstream. However, additional loadings of metals occur in the vicinity of the Oro Fino shaft and another 200 meters farther downstream. Fracture zones are near the stream at both of these locations and may indicate loading. In particular, the loading downstream from the Oro Fino shaft has a unique chemical character that could be similar to water in the pit lakes in the mine area. The loading from these downstream sources, however, is small in comparison to that from the initial mine discharge, and does not appear to have a substantial effect on Strawberry Creek.

Physical Habitat Assessment and Historical Water Quality Analysis on the White River, South Dakota

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The White River was listed on South Dakotas 1998 303(d) list of impaired water bodies for exceedances of water quality standards for total suspended solids (TSS) and fecal coliform bacteria. This projects goals were to separate natural background and man-induced loading for TSS and fecal coliform bacteria using historical gage data and stream physical habitat assessment and biological sampling. Ten sites were established for assessment of the physical habitat and biologic integrity following the Environmental Monitoring and Assessment Program (EMAP), beginning near the headwaters and distributed to the mouth, including two tributary streams. An index of biologic integrity (IBI) was created for the benthic macroinvertebrates and periphyton samples using a multimetric approach. A large amount of historical gage data is available for the White River, dating as far back as 1928 at a station near the mouth of the river. A statistical analysis of the historic data set was performed to characterize the conditions in the watershed and to develop a Total Maximum Daily Load (TMDL) summary report. Below the Badlands region, the median TSS concentration is 1,118 mg/l with upper and lower quartiles of 154 mg/l and 5,688 mg/l. At the same station, the fecal coliform median is 200 colony forming units (cfu)/100 ml with upper and lower quartiles of 30 cfu/100 ml and 1,850 cfu/100 ml. Because of the large natural background of TSS in this system, the TSS standard of 158 mg/l is not attainable. Best management practices (BMP) are expected to reduce the TSS loading by a minimal amount. BMPs for fecal coliform can be implemented to reduce the water quality standard of 2,000 cfu/100 ml. We anticipate BMPs for fecal coliform reduction, such as a grazing management system, off-site water, and riparian vegetation stabilization, will also reduce the TSS loading slightly.

Coal Bed Methane Development and Intermittent Streams, Cheyenne River, Wyoming

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The Wyoming part of the Cheyenne River Watershed is approximately 5,270 square miles, 3,000 feet in elevation and receives an annual precipitation of 1014 inches with 75 percent falling between April and September. Snowfall varies from 3065 inches.

The ownership of the Watershed is mostly private with some federal and state lands. The Thunder Basin National Grasslands is in the center of the Watershed area. The predominant land uses are seasonal livestock grazing, with some flood irrigation, coal bed methane, coal mining, wildlife habitat with secondary uses of oil and gas, sand mining, recreation, and fossil excavation.

A portion of the Powder River coal bed methane (CBM) development is within the Cheyenne River Watershed. Over 600 CBM wells are discharging an average of 10 cubic feet per second (cfs) within primarily the upper portion of the Watershed. This portion of the Watershed is dominated by intermittent streams with a median flow of 0.25 cfs. CBM well discharges may increase stream flow and change water chemistry. An increase in flow changes the geomorphologic character of the stream. Environmental Monitoring and Assessment Program (EMAP) protocols, along with Schumms channel evolution model and Rosgens stream classification techniques, were used to evaluate stream geomorphology, riparian habitat, benthic macroinvertebrate, and periphyton assemblages. Measured discharges from the CBM wells and resulting flow in the tributaries before and during discharge were evaluated to estimate the change in flow normalized by drainage area.

The chemistry of CBM water is dependent on the coal seam produced. In the Cheyenne River Watershed, the CBM water is primarily calcium bicarbonate and the natural surface water is calcium-sodium sulfate. Dissolved constituents in the receiving water are altered due to CBM discharge. Trilinear plots were used to evaluate these changes.

TUESDAY, APRIL 12, 2005
LUNCHEON
11:40 A.M. - 1:10 P.M.

MARS MANIA: THE SEARCH FOR SIGNS OF WATER
(RUSHMORE H ROOM)

Mars Mania: The Search for Signs of Water

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After a seven-month journey, Spirit and Opportunity (two identical 408 lbs rovers) successfully landed on opposite sides of Mars in January 2004. Upon Spirits landing on 1/4/04, Mars was located about 106 million miles from Earth, compared to a distance of 64 million miles at launch on 6/10/03. However, the spacecraft traveled 303 million miles to get there. Successfully hitting the target zone was akin to threading a needle located 15 miles away!

Both rovers have eight radioisotope heaters (each containing a 0.1 ounce plutonium dioxide pellet) to keep the battery and electronics warm enough to operate during the extremely cold temperatures at night, which can dip to -157^{o} F. The two rovers are larger, more mobile, and better equipped than the1997 Mars Pathfinder rover. Each rover serves as a robotic field geologist, carrying sophisticated instrumentation to search for evidence about whether past environments at selected sites were wet enough to be hospitable to life. While there is no liquid water on the surface of Mars today, the record of past water activity can be found in the rocks, minerals, and landforms, particularly in those that can form only in the presence of water. Each rover carries a high-resolution Panoramic Camera, several types of spectrometers for geologic analyses, a microscopic imager, magnets for collecting magnetic dust, and a rock abrasion tool for exposing fresh surfaces on rocks. Additionally, ground truthing activities are being carried out by the rovers to validate remote sensing observations made by instruments that survey Martian geology from orbit.

The rovers are still operating after a year on the surface. The goal of the mission has been achieved. Using the toolkits on the rovers, scientists have collected at least five kinds of evidence indicating significant amounts of water in Mars past: 1) tiny concretions likely formed in an aqueous environment, 2) high amounts of sulfur, chlorine, and bromine that are associated with mineral salts deposited in brines as they evaporate, 3) jarosite, a hydrated iron sulfate mineral that typically forms in acidic lakes or hot springs, 4) vugs of randomly oriented cavities in the rock that look very similar to those found on Earth where minerals that once formed in brines are later redissolved by water, 5) structure such as crossbedding and ripple marks, indicating that sediments were deposited in flowing water. The rovers, first delicately coddled and treated with kid gloves at the start of the mission, are now being pushed to the limits of their technology and have proven to be true workhorses.

TUESDAY, APRIL 12, 2005
SESSION 3A
1:10 - 2:50 P.M.

HYDROLOGY POTPOURRI
(ALPINE ROOM)

Application of Interferometric Synthetic Aperture Radar (InSAR) to Study Ground-Surface Deformation Above Aquifer

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Interferometric synthetic aperture radar (InSAR) is a remote sensing technology that can image ground surface deformation with centimeter to subcentimeter precision and spatial resolution of tens-of-meters over a relatively large region. The temporal and spatial distribution of surface deformation above aquifers, derived from InSAR images, provides important insights about the hydrodynamic properties of the underground reservoirs and the hydrogeologic structure of the aquifer. This paper illustrates two applications of InSAR to the study of hydrogeologic processes. First, based on InSAR analysis of ERS-1 and ERS-2 images, several centimeters of uplift is detected during the first half of 1993 in two areas of the San Bernardino ground-water basin of southern California. This uplift correlates with unusually high runoff from the surrounding mountains and increased ground-water levels in nearby wells. The deformation of the land surface identifies the location of faults that restrict ground-water flow, maps the location of recharge, and suggests the areal distribution of fine-grained aquifer materials. The results demonstrate that naturally occurring runoff and resultant recharge can be used with interferometric deformation mapping to help define the structure and important hydrogeologic features of a ground-water basin. Second, based on InSAR images from the ERS-1, ERS-2 and Radarsat-1 satellites, land subsidence is mapped over Al Ann, United Arab Emirates during 1993-1999. The subsidence is most likely induced by deformation of the aquifer system in response to changes in the groundwater table which is attributed to changes in recharge and pumping. The observed complex patterns of surface deformation also suggest poor permeability of the aquifer over the study area. These studies demonstrate that InSAR-derived ground-surface deformation images can be used to address potential infrastructure hazards associated with pumping and provide guidance on managing limited ground-water resources.

Regional Modeling of Hydrologic Systems in Complex Terrain

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A coupled modeling system developed for hydrologic processes in complex terrain is presented. The system is a union of four models, the Advanced Regional Prediction System, the NCAR Land Surface Model, the CASC2D surface hydrology model, and the MODFLOW ground water model. These models can be run using various configurations and at different scales, permitting flexibility across applications.

The capabilities and versatility of the coupled model system are demonstrated in the results presented. The first example, which demonstrates the surface hydrology component subjected to strong precipitation forcing, applies the model to a 500-year flood event (the 1972 Rapid City Flood). The second example is an extended cold season simulation for April 1999 for the South Dakota Black Hills.

Effects of Terrain and Soil Variability on Slope Stability

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This project explores the effects of soil strength parameters and accurate terrain models on slope stability. A colluvium-protected hill slope covers five Lower Cretaceous sedimentary deposits creating a resistant hogback trending N-S through Rapid City, SD. Elevations from a USGS 30-meter digital elevation model (DEM) were used to create numerous two-dimensional slope profile models. These geometric profiles, along with soil strength parameters, were analyzed using a slope stability program, STABL, to determine factors of safety at intervals along the slope. A sensitivity analysis of these parameters, including unit weight, cohesion, and friction angle, was performed to determine those parameters most influential in calculating the factor of safety. Based on the STABL results, a slope stability hazard map was created using Geographic Information Systems (GIS). More accurate two-dimensional slope models were derived from a 1-meter resolution terrain model, created from a Light Detection and Ranging (LIDaR) survey over part of the study area. Sensitivity analysis showed that cohesion and friction angle influenced stability to a much higher degree than soil unit weight. The resulting stability map was verified through a comparison with mapped slope failures. Higher resolution terrain data resulted in lower factors of safety, especially for shallow slides occurring on steeper slopes.

Engineering Design Considerations for Using Limestone-Based Material to Remove Arsenic from Water

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Arsenic concentrations in water and new methods of treatment are topics of ongoing research because of documented toxic effects on humans and the environment. The U.S. EPA has announced that the maximum contaminant level for arsenic, currently 50 ppb, will be lowered to 10 ppb in 2006. Lowering of the drinking water standard will put increased economic pressure on rural and small public water supplies. It is estimated that 30 (about 9 percent) of the states public systems would violate the 10 ppb standard.

This research has examined the applicability of using limestone-based material as a water filter media by: 1) characterizing the properties of the limestone-based material, 2) completing laboratory studies designed to quantify arsenic removal, 3) studying the chemistry of the removal process, 4) altering the material to improve arsenic removal efficiency, and 5) examining scale-up of the treatment process while considering engineering design constraints.

Through equilibrium and column studies, the arsenic removal efficiency of limestone has been evaluated. Granulation of powdered limestone through an agglomeration process was bench tested. A demonstration project in Keystone, South Dakota, has begun. Results indicate that limestone-based material works reasonably well in removing arsenic from ground water with naturally elevated arsenic levels. Engineering design constraints have been considered in the design of filter columns and filter media development.

Transfer-Function Modeling of Hydraulic Head Response and Watershed Runoff for the Madison Limestone near Spearfish, South Dakota

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Hydraulic head in an observation well open to the karstic Madison aquifer responds to recharge from direct precipitation and to streamflow recharge from Spearfish Creek in the northern Black Hills. This response of hydraulic head was modeled to help understand the effects of the two recharge sources separately.

The methods applied include a transfer-function (TF) model, which can model many natural systems where one or more signals are passed through a medium (or system) to produce an amalgamated response. TF modeling is a lumped-parameter approach and hence does not require the extensive parameterization often necessary for ground-water flow models. For the model described here, the signals are the two recharge sources, the medium is the aquifer, and the response is hydraulic head. Recharge from direct precipitation was estimated by adjusting measured precipitation according to an antecedent rainfall index and by accounting for winter snow pack. Streamflow recharge was estimated from measured streamflow (after adjusting for diversions) by assuming that all flow enters the Madison aquifer up to a maximum flow capacity. However, there was a period of missing data in the streamflow record, which was estimated by constructing a separate TF model for watershed runoff.

Modeling the response of hydraulic head has indicated that the Madison aquifer contains three separate storage components for precipitation recharge and at least one component for streamflow recharge. Modeling results indicated that an additional 10 cubic feet per second of streamflow recharge during a 6-month period would cause hydraulic head to rise by more that 13 feet during that period. Watershed-runoff modeling has identified a short-term storage component, which produces flashy peak flows, and a long-term storage component, which produces base flow.

TUESDAY, APRIL 12, 2005
SESSION 3P
1:10 - 2:50 P.M.

SURFACE WATER
(PONDEROSA ROOM)

Evaluating Flow Regime Management Using River 2D and ArcGIS

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Flow regime management practices have a critical impact on the health of urban fisheries and are a potential limiting factor for instream habitat. In 2000, the South Dakota Department of Game, Fish, and Parks began a four-year study on the brown trout (Salmo trutta) fishery in Rapid Creek through Rapid City, South Dakota. As a part of this study, the streams hydraulic habitat (depth and velocity) was simulated and analyzed using the two-dimensional model River 2D. This analysis was linked to operating procedures of Pactola Reservoir. Results are presented in the form of weighted useable area per 100 meters of stream over a range of discharges for four life stages: spawning, fry, adult and juvenile. Analysis of the results showed that the habitat availability for fry, juvenile and adult stages were comparable throughout the range of flows, with the fry stage being limiting by a small margin. Time-series analysis of the adult life stage showed that above Canyon Lake, where a limestone loss zone influences the flow regime, dry years and winter months are the limiting time periods. Below Canyon Lake the summer months and extreme wet years are critical. At high flows (discharges greater exceeding the 90-day average flow 10% of the time), mean velocities in the study area begin to exceed recommended values for resting velocities. This may cause displacement and an increase in energy expenditure. Recommendations for future management practices include assuring a minimum flow of 0.57 m^3/s above Canyon Lake and maintaining summer flows below 3.14 m^3/s. The conclusion of this study is that under the normal operating range (10% to 90% flow duration) of releases from Pactola, the suitability of depth and velocity habitat suitability based on depth and velocity is not adversely impacted.

Impact of Burn Severity on Flooding in Small, Forested Watersheds

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Damage to ground cover during forest fires often reduces the infiltration of rainfall, leading to increased runoff and flood risk during subsequent years. The objective of this study was to identify the factors impacting post fire flood risk, and to measure the change in infiltration rates as the ground surface recovers in the years following the fire. Prior research has involved test plot and small hillslope-scale experiments, often with rainfall simulators, to identify the most important factors leading to reduced infiltration and increased runoff after fires. Field monitoring at the small watershed scale was conducted after the Battle Creek Fire of 2002 in order to learn how to extend the results of the small scale research to larger drainage areas. Precipitation and streamflow gages were installed in six watersheds after the fire. Intense rainfalls and related peak discharges were monitored during 2003 and 2004. The results from the 2003 events indicated that 5-minute rainfall intensity, damage to the duff layer and vegetation, and rock content, were the most significant variables in the risk of post fire floods. Monitoring in 2004 was used to measure the recovery of damaged ground cover, and the impact of this recovery on the flood risk. The results from the 2004 data indicated that while vegetation has increased, and litter has decreased, there has not been a significant reduction in the flood risk. The recovery of the duff layer appears to be very important in restoring the pre-fire rainfall runoff relationship during major floods. These results from larger, field scale studies will help the U.S. Forest Service and other land managers in making decisions immediately after a severe fire to reduce the risk of flood and erosion damage.

StreamStats: A Web-Based Application for Stream Information Developed by the U.S. Geological Survey

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StreamStats is a Web-based application developed by the U.S. Geological Survey (USGS) to provide a variety of stream information, such as basin characteristics and available streamflow statistics to the public. Some applications requiring streamflow statistics include design of flood control structures, bridges and culverts, and general water-resources planning and management. Using a Web browser window, StreamStats users can point and click on a map to obtain previously determined flow statistics, basin characteristics, and site descriptions of gaging stations. Users also can point and click on any stream location in the map to obtain basin characteristics and estimates of streamflow statistics at ungaged sites. Watershed boundaries and physical and climatic watershed characteristics of ungaged sites are determined through the use of a Geographic Information System (GIS) utilizing both national and local data. Some of the GIS data utilized by StreamStats include a Watershed Boundary Dataset (WBD), a Digital Elevation Model (DEM), and the National Hydrography Dataset (NHD). Watershed parameters determined by StreamStats are then inserted into previously determined regression equations to estimate streamflow statistics. This automated and interactive method of estimating streamflow statistics is much faster than manual methods, and also provides repeatable results.

StreamStats is national in scope, but is being implemented on a state-by-state basis. StreamStats has been implemented for Idaho, and is under development in Washington, Oregon, Utah, Colorado, Kentucky, Tennessee, Mississippi, Pennsylvania, Vermont, New Hampshire, Connecticut, and Rhode Island. An earlier version of StreamStats also is available for Massachusetts. StreamStats in these states was implemented by the USGS in cooperation with various agencies. Match funding through the USGS Cooperative Water Program can, in some cases, be provided. The USGS Water Science Center for South Dakota is currently in discussions with cooperators regarding implementation of StreamStats. Although some geospatial data sets, such as the WBD, are at or near completion, additional needs may exist for expanding the availability of other geospatial data sets. For example, the accuracy of StreamStats in some areas of South Dakota may be improved with the availability of high-resolution NHD and 10-meter DEMs. Partnerships with groups interested in helping develop such data sets may help expedite implementation of StreamStats.

This presentation will highlight some of the capabilities of StreamStats and describe the GIS data it uses to delineate watershed boundaries and determine basin characteristics.

Belle Fourche River Watershed Restoration Implementation, Belle Fourche River, South Dakota

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The Belle Fourche River Watershed, located in western South Dakota, drains approximately 3,300 square miles. The river flows to the Cheyenne River in Meade County and ultimately to the Missouri River. The Watershed receives an annual precipitation of 1428 inches. Snowfall varies from 20165 inches.

The Belle Fourche River is identified in the 2004 Integrated Report for Surface Water Quality Assessment as impaired due to elevated total suspended solids (TSS) concentrations. The Total Maximum Daily Load (TMDL) report for this Watershed has been completed. Beginning in 2004, the Belle Fourche River Watershed Partnership began their Belle Fourche River Watershed Management and Project Implementation Plan. The goal of the implementation plan is to bring the Belle Fourche River into compliance for total suspended solids within 10 years and to implement additional Best Management Practice (BMP) recommendations from other TMDLs for waterbodies within the Watershed as they become available.

Some of the BMPs that were installed during this segment of the implementation include: one flow automation unit, replacing open irrigation ditches with pipeline, lining open irrigation ditches, installing pipelines to deliver water from the Belle Fourche Irrigation District (BFID) system to the fields, installing two irrigation sprinkler systems, and 3,000 acres of managed grazing. These BMPs resulted in an estimated 7 mg/L reduction in TSS. Another product of this segment of the implementation plan included a Ten-Year Belle Fourche River Watershed Strategic Implementation Plan and the Belle Fourche Irrigation District Water Conservation Plan. These two documents outline BMPs that are planned within the Watershed to reduce the TSS concentrations to levels that will support the beneficial uses assigned to the stream segments. Some of the major planned BMPs include: real-time stage/flow measuring devices for the BFID, nonused water storage ponds, grazing management systems, and irrigation sprinkler systems.

Western South Dakota Reservoir Storage – Present and Past

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The Bureau of Reclamations Rapid City Field Office manages Pactola, Deerfield, Angostura, Belle Fourche, Shadehill, and Keyhole Reservoirs. The beneficial uses of each of these reservoirs and their current status related to storage will be presented. Inflows, storage, and discharge releases are affected by different weather cycles. For example, at Pactola Reservoir, current dry conditions are affecting reservoir operations and storage when compared to previous dry periods because of changes in demands from Rapid City and irrigators.

TUESDAY, APRIL 12, 2005
SESSION 4
3:10 - 4:50 P.M.

HYDROGEOLOGY

Geologic Map of South Dakota

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Compilation of a new Geologic Map of South Dakota was an ongoing project for many years under the auspices of the South Dakota Geological Survey (SDGS). The last statewide geologic maps were published over 50 years ago, and a comparison of these historical maps with the new map illustrates the enormous amount of geologic data that has become available during the past 50 years. The new map incorporates information from previously published maps, unpublished maps, and original mapping by the authors where resolution of previous information was required. Geologic information for most of the area east of the Missouri River has been published by the SDGS in various geologic and hydrologic reports. Geologic data for western South Dakota varies from extremely detailed in some areas to reconnaissance-level in others.

The glacial geology of eastern South Dakota is exceedingly complex due to the number of glacial advances; therefore, many of the glacial advance lines have not been correlated. Those on the eastern side of the Missouri Coteau are relatively well known and dated, but those to the west are not. Because the ages of the various glacial advances are unknown in many areas of eastern South Dakota, the eastern portion of the map is essentially morphostratigraphic rather than chronostratigraphic. In western South Dakota, care was taken on the new compilation to more accurately portray Tertiary strata, surficial deposits, and structural features. In addition, understanding of the geology of the Black Hills area has greatly advanced with respect to geologic units of all ages. Efforts were made to retain as many formational entities as possible at the 1:500,000 scale.

Chemical Weathering and Land Denudation of the Paleozoic Carbonate Rocks in the Black Hills, South Dakota and Wyoming

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The chemical solution of limestone and dolomite is a major factor in the erosion of carbonate terrain. In the Black Hills calcium, magnesium, and bicarbonate solutes are removed by fifteen large springs whose average discharge totals 7.128 m^3/s. The product of discharge and total dissolved load (TDS) concentration of each of the fifteen springs discharging from the Madison Limestone and Minnelusa Formation was determined; it totals 193 million kg annually. Cascade Spring and Crow Creek remove almost half of this mass. Recharge to the carbonate belt occurs not only from precipitation but also from disappearing streams; the product of discharge and TDS concentration for eighteen major disappearing streams adds 18 million kg/year of solutes to ground water in the carbonate belt. The difference between the spring discharge and stream recharge is 175 million kg/year; this value provides an estimate of the chemical weathering over the 2,894 km^2 outcrop area of the Paleozoic carbonate belt. There is also dissolved load carried downdip through the aquifer estimated at 23 X 10^6 kg/year. Assuming calcium, magnesium, and bicarbonate solutes originate from the solution of 280 m thick dolomite, the rate of lowering of the land surface by chemical solution is 1.6 cm per 1,000 years.

Tracing Ground-Water Flow with Fluorescent Dyes Injected in Spring, Rapid and Spearfish Creeks in the Black Hills, South Dakota

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Fluorescent dyes (fluorescein and rhodamine WT) were injected multiple times in Spring, Spearfish, and Rapid Creeks in the Black Hills of South Dakota during 2003 and 2004 to better understand the interaction between these streams and the ground-water system. These streams lose all or part of their flow as they cross the Madison Limestone outcrop. Because of the solution openings in the Madison aquifer, which are associated with these streamflow loss zones, downgradient public supply wells are very sensitive to potential contamination in these streams.

Multiple dye injections indicated variable traveltimes and dilution characteristics in the Madison aquifer. Dye traveltimes for detectable dye concentrations in water samples collected from wells completed in the Madison aquifer ranged from about 100 to 10,000 feet per day. Dilution of the dye observed in the water samples collected from wells compared to the concentration in the stream ranged from nearly no dilution to several orders of magnitude. Four different injections of dye in Spring Creek indicated some characteristics of direct conduit flowpaths and that ground-water velocities can vary with different recharge conditions or injection points. Preliminary results from the Rapid Creek injections indicated that dilution may be occurring as a result of a large quantity of ground-water storage near the loss zone. A fluorescein injection in Spearfish Creek that was followed 45 days later with a rhodamine WT injection indicated some of the complex ground-water mixing that occurs with different hydrologic conditions. Variations in ground-water flow in the unconfined parts of the aquifer associated with varying water levels may explain observed differences in dye tracing results.

Vulnerability (Risk) Mapping of the Madison Aquifer near Rapid City, South Dakota

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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 consists of limestone and dolomite and contains well-developed paleo- and recent karst that probably formed along a well-developed fracture system. Previous work indicates stream-related aquifer recharge from the watersheds of Spring Creek (to the south), Boxelder Creek (to the north), and Rapid Creek as well as direct recharge of the entire outcrop area west of Rapid City by precipitation. 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^3/sec for Spring Creek and 50 ft^3/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 years. Based on this information, Rapid City and surrounding suburban water supplies are extremely vulnerable to contamination. If contamination occurs, impacts could linger for many years. A database of 323 wells, geologic maps, fractures, faults, geologic structures, water-quality data, and dye-tracer tests is being analyzed to develop a geologic model to better define local ground-water flow paths and characterize susceptibility zones. Structure contour and depth-to-aquifer maps are completed for the Madison aquifer. Inherent aquifer susceptibility, combined with human influences, allow development of a vulnerability (risk) map (1:24,000 scale) for the Madison aquifer for the Rapid City area.

Aquifer Vulnerability of the Inyan Kara Group, Blackhawk Quadrangle, South Dakota

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A recently completed geologic map of the Blackhawk Quadrangle (Lisenbee and Hargrave, 2005) at 1:24,000 scale serves as the basis for aquifer vulnerability map preparation of the recharge areas of the Madison, Minnelusa, Minnekahta, Inyan Kara, and alluvial aquifers. The quadrangle, which includes portions of the Elk Creek and Box Elder Creek drainage basins, is undergoing rapid urbanization.

The Inyan Kara Group, composed of the Lakota (300 ft) and Fall River (150 ft) Formations, consists of interbedded sandstone and mudstone formed in channel, flood plain, estuarine, and marine deposits. Porous channel sandstone beds to 100 ft thick are lenticular, discontinuous, and enclosed in mudstone. The upper contact is gradational with the Skull Creek Formation (marine shale aquiclude) and difficult to pick accurately in cuttings from bore holes. The lower contact is sharp with the Morrison Formation (continental mudstone and sandstone aquiclude). Dips are 6^{o}-10^{o}NE, except in the steeply west-dipping limb of the northerly trending Piedmont anticline.

Recharge to the Inyan Kara occurs across 10.5 mi^2 from the northwest to southeast corners of the quadrangle along generally pine-tree covered ridges. The formation contains the first ground water reached by drilling in much of the NE quarter of the quadrangle, where depth-to-aquifer increases from zero on the west to 1200 ft in the NE, and the plains to the east. Water production is generally a few gallons per minute and the water quality is lessened by dissolved iron.

Aquifer vulnerability has increased with urbanization. Topographic maps indicate a single house on the aquifer in 1953, only two in 1971, and there are currently approximately 180 homes and septic tanks on approximately 7.5 mi^2 of the recharge area. Although this averages 24 septic tanks per mi^2, development-clusters occur in one to ten lots. In addition, a septic residue disposal site on the outcrop occupies an area of 2000 by 1000.