MBMG

Montana Bureau of Mines and Geology

Biennial Report of Activities and Programs

July 1, 2010 to June 30, 2012

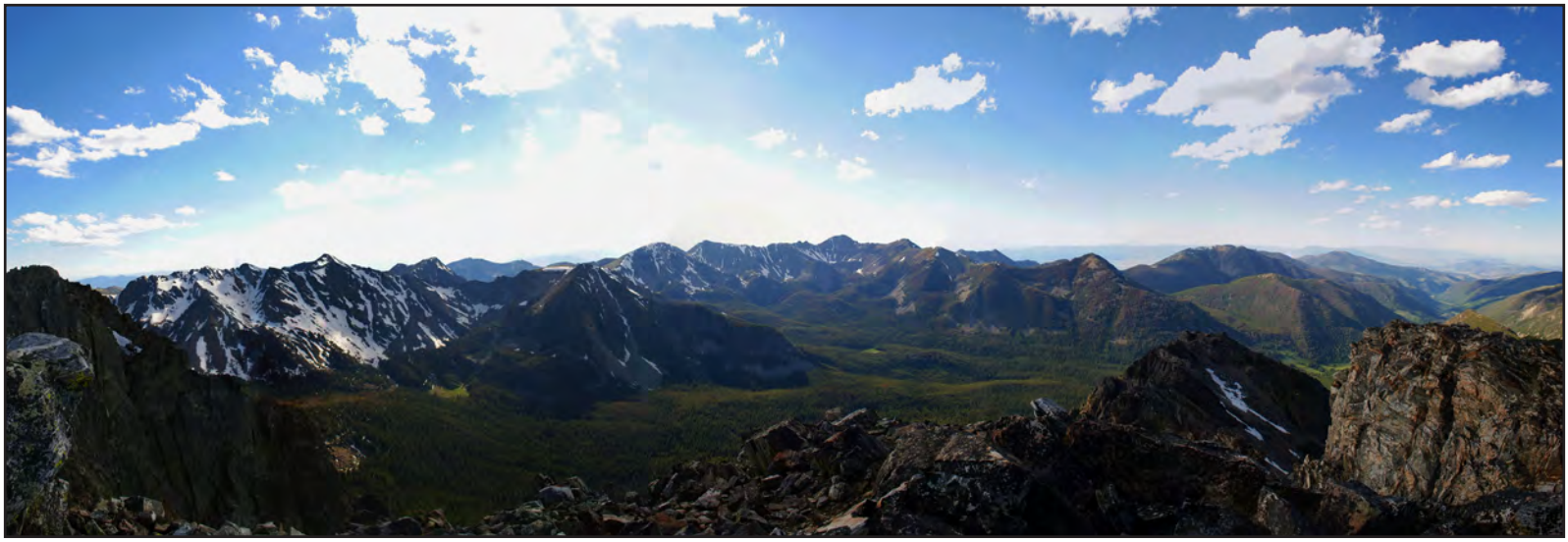

Photo by Ben Foster

A department of Montana Tech of The University of Montana

DIRECTOR'S INTRODUCTION

Photo by Lisa Wareham

The Montana Bureau of Mines and Geology biennial report is our opportunity to reflect on the many and varied achievements of a unique group of scientists, engineers, staff, and students. As a non-regulatory State agency within the Montana University System, we serve as Montana's geologic survey, addressing topics ranging from earthquake monitoring and geologic mapping to energy development and groundwater. Our working relationships with the citizens of Montana, their Legislators, and resource management agencies are paramount to our success.

The 2011 Montana Legislature faced the effects of a struggling world economy while attempting to maintain the quality of life in Montana. At a time when budget reductions were the norm, the new Ground Water Investigation Program, the Ground Water Assessment Program, and the MBMG in general were treated well by the Legislature and the Governor. Projects funded by outside contracts and grants showed a modest increase; these projects often rely on matching funds, and we expect to see continued growth in this category.

In this past biennium the MBMG saw more than 5 million hits on its website to provide 225,000 downloaded publications and 150 million records of data from the Ground Water Information Center database. In the coming biennium the demand for information related to mining, agriculture, subdivisions, earthquakes, and all things geologic will certainly increase. Not only will the demand increase, but the type of information requested is quickly evolving from paper to digital products that allow online, onscreen collocation of information related to water, minerals, land use, energy, and other geologic map features. Interaction and compatibility with other web-based sources of information will also become standard in the next few years; database design and data quality will likely be active topics in our discussions with other agencies.

Even in the face of the internet society, education through our publications, presentations at public meetings, hosted workshops, and one-on-one interactions will be our mainstay. A new feature in this biennial report is the list of advisory committees and boards that contribute to our success and those on which MBMG staff serve.

Change is an important, but sometimes bittersweet, part of growth for any group; the MBMG saw its share of new people coming on board as well as those who have moved on. Most notable this past biennium were the retirements of Marvin Miller (Assistant Director—45 years), Fred Schmidt (Driller and Computer Specialist—37 years), Dick Berg (Geologist and Curator —46 years), and of course my predecessor, Ed Deal (Director—14 years) who retired on October 1, 2012.

In Memoriam

Dr. Sidney L. "Sid" Groff, of Butte, died Jan. 17, 2011, in Butte. Sid started a distinguished career at the Montana Bureau of Mines and Geology in 1957; he was named chief of the Groundwater and Mineral Fuels Division in 1959. He became the Montana State Geologist and Director of the MBMG in 1971 and served until his retirement in 1983. Sid will be fondly remembered by the MBMG.

Survivors include his wife, Shirley Groff of Butte; brother, Fuzzy Groff of Victor; son, Jon Groff of Missoula; daughter, Billie (Tom) Oliver; grandsons, Tim Miller, Steve (Debbie) Miller and great-grandchildren, Kelsey and Jacob Miller, all of Columbia Falls; stepchildren, Delbert (Mary Jo) Hunt of East Helena, Marvin Hunt (Stacy) of Helena, and Dr. Michelle Hunt Olsen (Phil) Bismarck, ND; step-grandchildren include Clari Olsen of Kansas City, Nathan Hunt of Dillon, and Kayla Hunt of Missoula.

Mary Louise Rivenes died at her home in Wise River on Thursday, Oct. 28, 2010. Mary joined the Montana Bureau of Mines and Geology in 1991 and served in the Analytical Laboratory until shortly before her death. Mary helped to shepherd the lab through many changes in technology and procedures in her 19 years of service. She was well-loved and will be missed by those who had the privilege to work with her.

She is survived by her husband, Louie Rivenes of Wise River; son and daughter-in-law, Gary and Brenda Rivenes of Gillette, WY; daughter-in-law, Sandy Rivenes Campbell of Elko, NV.; grand-children, Ashley, Griff, Josh, Body, and Brady Rivenes; brother-in-law and sister-in-law Mike and Virginia Rivenes of Butte; and sisters Joyce, Phyllis, Karen, and Kathy.

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Clarence Schwartz, Groundwater Specialist

Retirees

Edmond Deal, *Director and State Geologist*
Marvin Miller, *Assistant Director*
Richard B. Berg, *Research Professor, Geologist*
Robert Bergantino, *Associate Research Professor, Hydrogeologist*
Fred Schmidt, *Assistant Research Professor, Hydrogeologist*

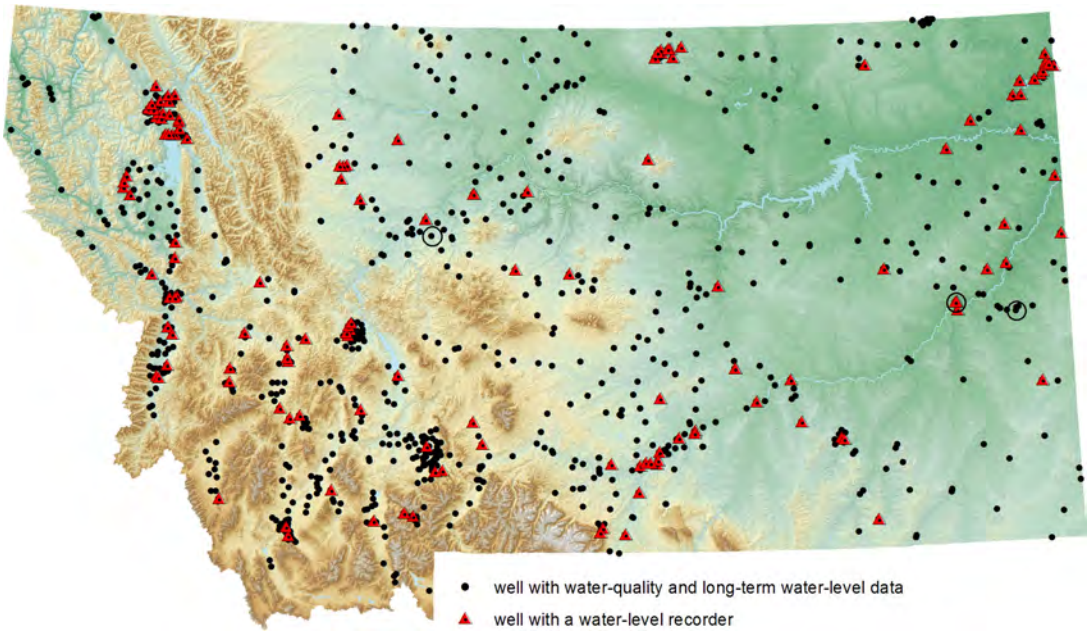
GROUND WATER ASSESSMENT

The Legislature established the Ground Water Assessment Program (85-2-901 et seq.) in 1991 after considering the recommendations of a Ground Water Task Force organized by the Environmental Quality Council. Statute specifically requires systematic monitoring and assessment of aquifers to improve understanding of Montana's groundwater resources. As part of a mandate to make groundwater information widely available, the Assessment Program includes the Ground Water Information Center (GWIC) database at the Montana Bureau of Mines and Geology.

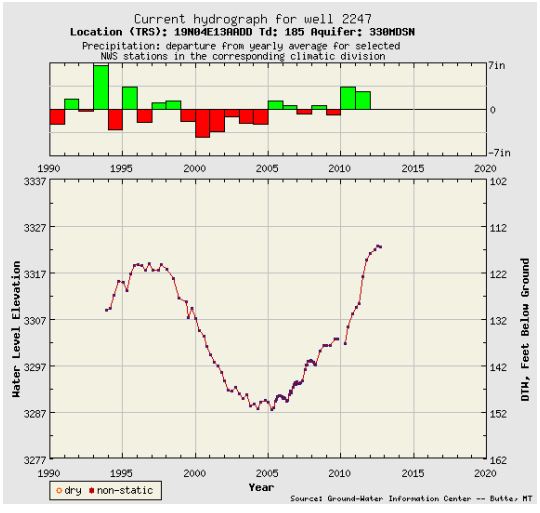
The Legislature also created an interagency Steering Committee that selects study areas, addresses the need for better coordination among State, Federal, and local government units, and oversees Assessment Program progress.

Ground Water Monitoring

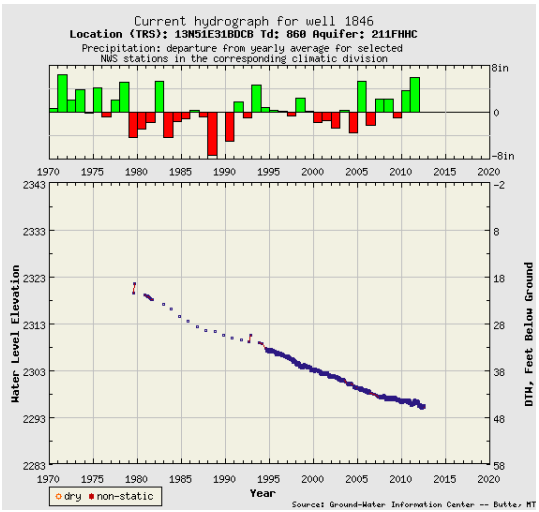
The Ground Water Monitoring Program collects quarterly water-level measurements from 944 strategically located wells as shown by the black dots on the map below; red triangles mark locations of continuous water-level recorders.



Long-term groundwater-level records are the only direct measure of how Montana's aquifers respond to seasonal, climatic, developmental, or land-use factors. Long-term groundwater hydrographs are similar to long-term records of stream flow and precipitation, and must be evaluated at decadal scales. For example, information from the Ground Water Monitoring Program helps people understand the response of groundwater levels to climatic conditions. The Madison Limestone is an important source of municipal, domestic, industrial, and stock water; it also is the source of many large springs, including Giant Springs at Great Falls. Long-term monitoring shows that the groundwater levels in the Madison Limestone are influenced by, and respond quickly to, climatic conditions (see hydrograph for well 2247, below, left).

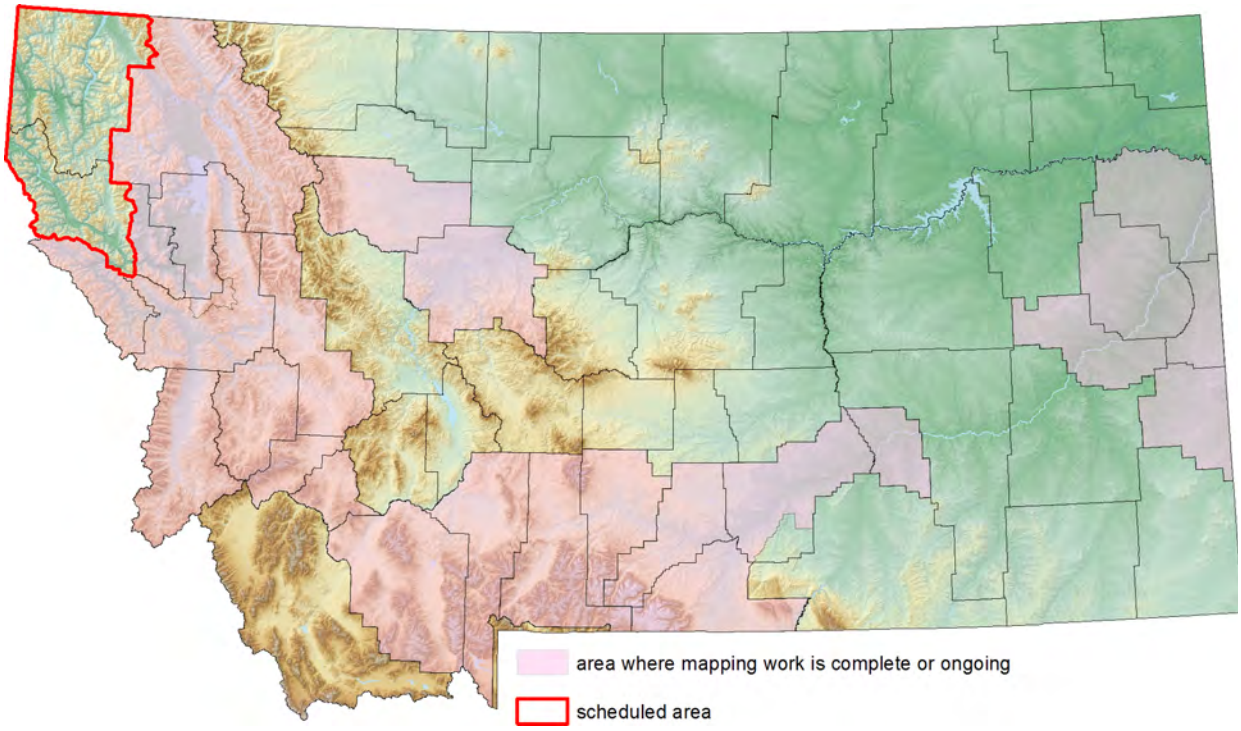


Long-term monitoring is also important for understanding the impact of energy production on water resources. Oil and gas development in eastern Montana has increased because of technological advances in horizontal drilling and hydraulic fracturing. Groundwater, in particular the Fox Hills–Hell Creek aquifer in eastern Montana, has been identified as a potential water source for hydraulic fracturing. The Ground Water Monitoring Program has stepped up monitoring efforts in the Fox Hills-Hell Creek aquifer to track water-level trends in response to development (see hydrograph for well 1846, right).



Ground Water Characterization Program

The Characterization Program provides basic information about aquifers within specific areas as prioritized by the Ground Water Assessment Steering Committee. Areas where the Characterization Program has worked, and will work, are shown on the map below.



Fieldwork is complete in the Gallatin–Madison area and is commencing in the Park–Sweet Grass area. The Steering Committee has selected the Lincoln–Sanders characterization area for future work. In Gallatin and Madison counties Characterization Program staff visited about 1,000 sites and sampled more than 300 wells and springs. Data collection was coordinated with the assistance of many groups, including The Big Sky Blue Water Task Force, The Gallatin Local Water Quality Protection District, The Madison Watershed, The Ruby Watershed, and The Yellowstone Controlled Groundwater Area Technical Oversight Committees.

In Park and Sweet Grass Counties, collaborative investigations are being planned with the Shields Valley Watershed group and the Park County Conservation District to establish baseline water-quality monitoring in areas of potential natural gas development.

Ground Water Information Center (GWIC)

GWIC customers seek groundwater data generated by MBMG projects, logs from water-well drilling, and results from water-quality sampling. GWIC offers geographic, address, subdivision, drainage basin, aquifer, and county searches which allow customers broad choice in how to retrieve data. Users can choose from 13 report formats to customize retrievals. During the last biennium GWIC staff completed a 'second pass' through the main body of well logs, scanning and attaching the document images to database records. The scanned images are popular with customers who may prefer to have an image of the well log in addition to GWIC's digital record.

Also during the last biennium GWIC staff continued to develop innovative ways to access and deliver information. The "Driller Web" tool remains a popular feature with water well drillers; 35 percent of the well logs were submitted electronically during the past 2 years. GWIC staff devised a GIS web service to deliver water well information; an ArcGIS web mapping application—which will integrate with existing data delivery systems—is slated for release by the end of 2012.

GWIC by the Numbers

- More than 24,454 registered users
- Currently about 3,600 sessions and 35,800 queries each month
- Information on 236,980 wells and boreholes
- Scanned images for 219,508 well log documents
- Results from 54,133 water-quality analyses for 16,779 sites
- 13.5 million water-level measurements

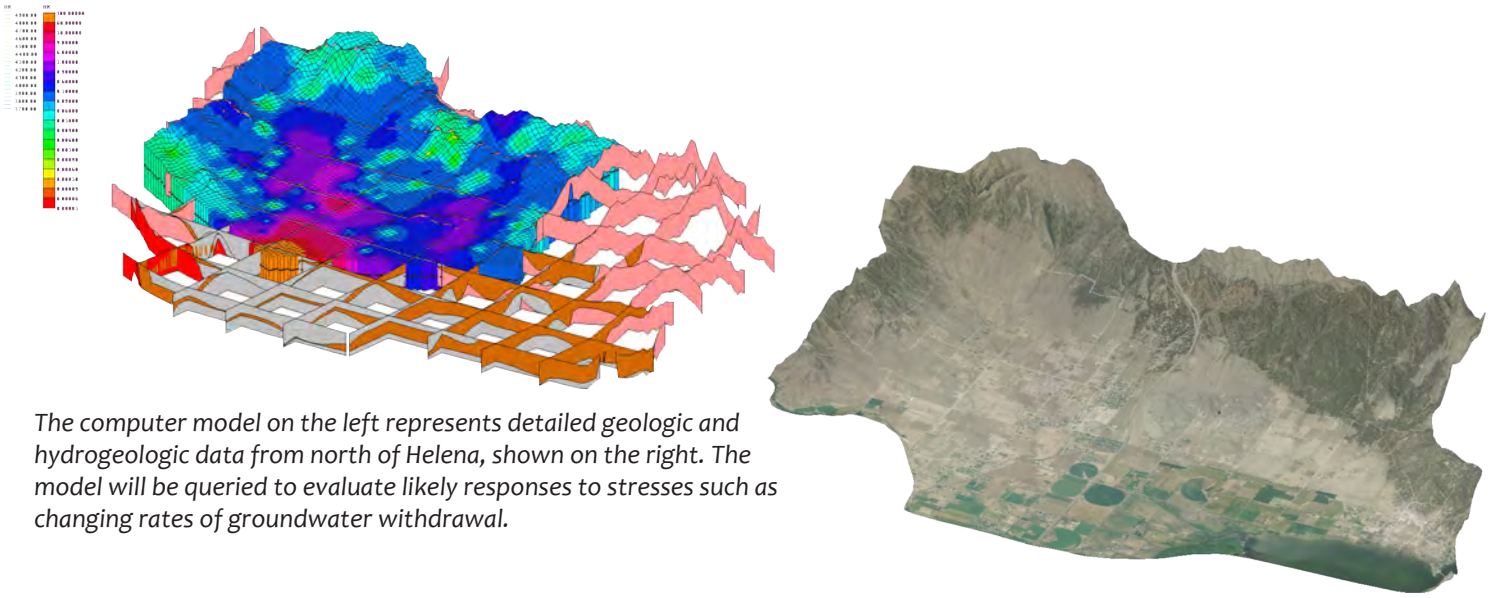
GROUND WATER INVESTIGATION PROGRAM

In Montana, groundwater is essential for safe drinking water supplies and for economic growth. On average, approximately 272,000,000 gallons (835 acre-feet) are extracted from Montana's aquifers every day. In many areas of the State, groundwater is the only reliable year-round source of water for household use and for livestock. Groundwater is also widely used for irrigated agriculture, and for lawns and gardens. In some settings, groundwater withdrawals could directly affect senior water-rights holders, stream flows, the availability of irrigation water, and the health of aquatic ecosystems. Efficient water management requires a well-founded understanding of the groundwater systems.

The Ground Water Investigation Program (GWIP) was established by the Montana State Legislature to provide scientific foundations for specific water management challenges. More information is available at:
http://www.mbmg.mtech.edu/gwip/gwip.asp

Program Products

Investigations are expected to take from 1 to 3 years to complete. Every GWIP investigation will produce a detailed report on the hydrogeologic system, and responses to current and anticipated stresses. A comprehensive set of hydrogeologic data is compiled for each site and is permanently available online through the Ground Water Information Center (http://mbmggwic.mtech.edu/). In addition, most projects will include a computer model that simulates specific hydrogeologic features and stress responses, and is available online for future test scenarios. These products are designed to provide a more detailed understanding of the groundwater system and tools which can then be used by regulators, senior water-rights holders, new water-rights applicants, and other stakeholders to make informed water management decisions and to help anticipate hydrogeologic effects from changes in land use.



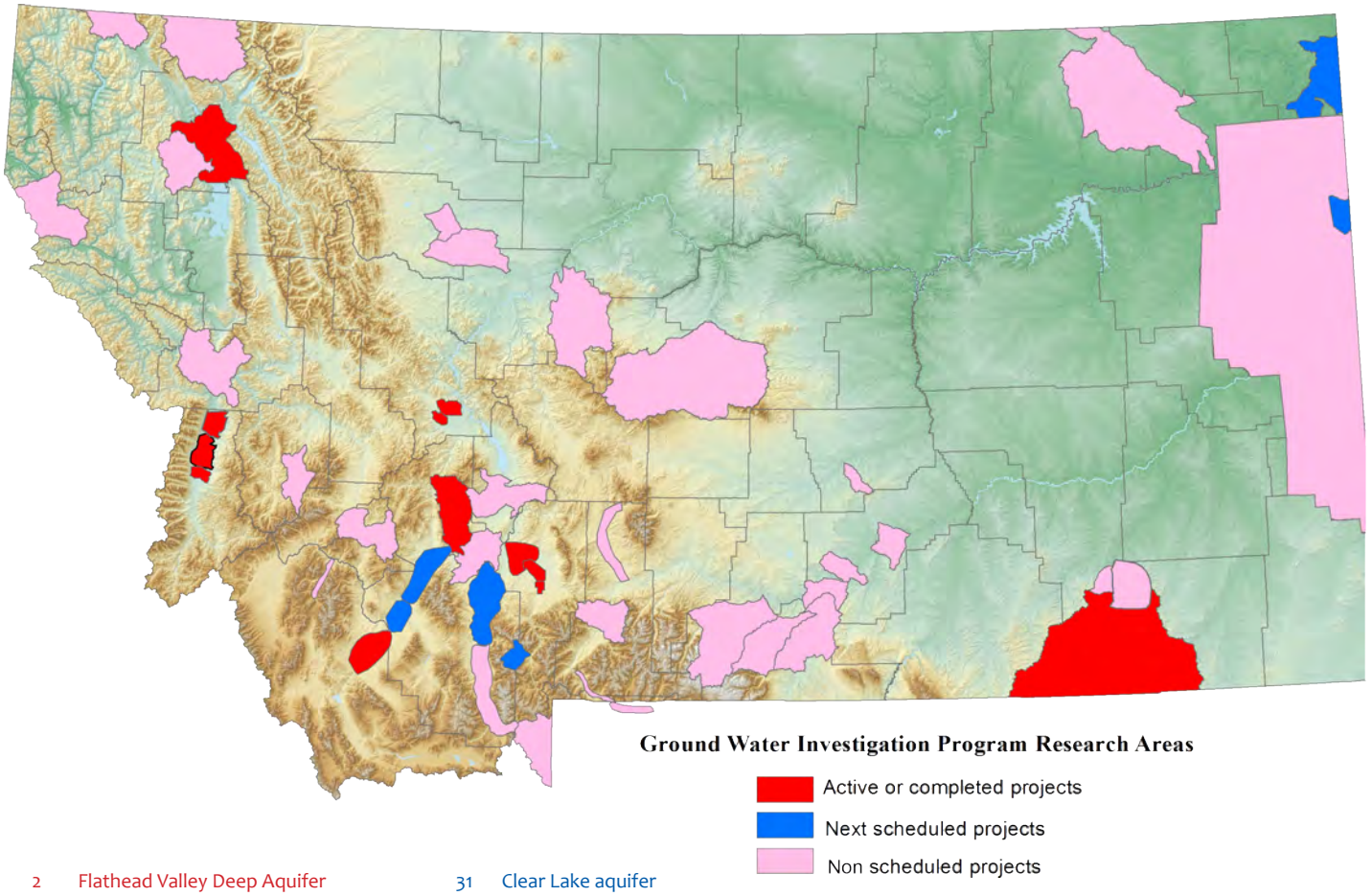
The computer model on the left represents detailed geologic and hydrogeologic data from north of Helena, shown on the right. The model will be queried to evaluate likely responses to stresses such as changing rates of groundwater withdrawal.

Current Research Questions

- Aquifer and stream response to changing land use from irrigated agriculture to subdivision
- Hydrogeologic viability of replacing surface-water diversion points with irrigation wells
- Groundwater sustainability in response to increasing subdivision demands
- Groundwater depletion related to energy development
- Changes in water quality due to increasing subdivisions
- Aquifer sustainability in response to increasing numbers of irrigation wells
- Viability of developing buried river channel aquifers
- Changes in spring discharge due to changes in irrigation practices
- Impact on stream flow of increasing groundwater withdrawals

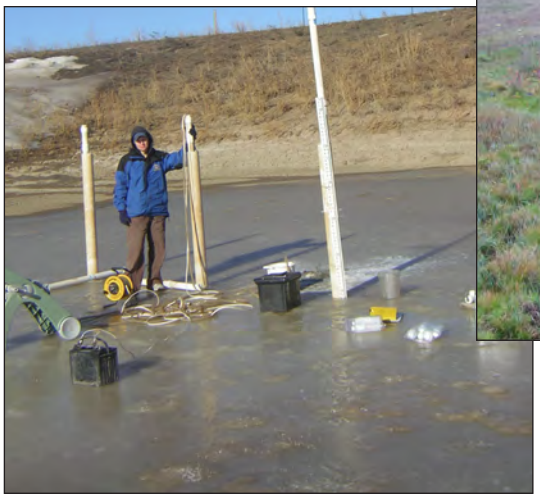
Program Status

Fifty projects have been nominated (see map below) and prioritized by the Ground Water Steering Committee. Prioritization is based on land use changes, anticipated growth in housing, agriculture, industry, and commercial activities.



2 Flathead Valley Deep Aquifer
6 Florence and Eight Mile and Three Mile Creeks
7 Hamilton
12 North Hills
13 Scratchgravel Hills
16 Manhattan
17 Belgrade
18 Four Corners
33 Coalbed Methane-Powder River
35 Lower Beaverhead River West Bench
37 Boulder River Valley
41 Stevensville-Bitterroot River

31 Clear Lake aquifer
32 Sidney buried river channel aquifer
36 Big Sky
39 Madison River Valley Ennis to Three Forks
40 Upper Jefferson River valley
43 Beaverhead River to Twin Bridges-Jefferson River



GEOLOGIC MAPPING

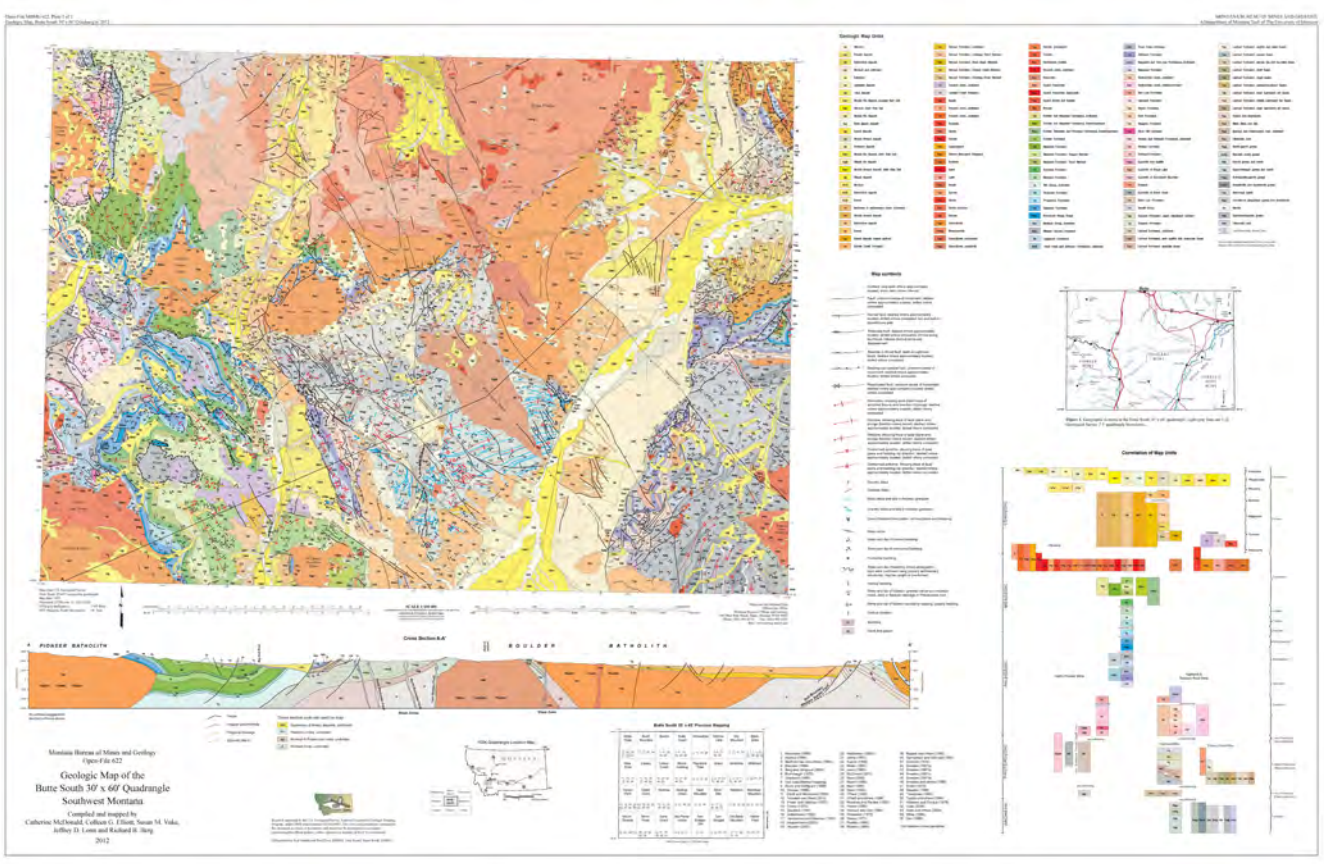
STATEMAP and EDMAP

Reliable, detailed geologic information is essential to making good decisions about the complex issues that affect Montana's water, land, and mineral and energy resources. During the last biennium, the Montana Bureau of Mines and Geology published eight new geologic maps based on field mapping conducted through the STATEMAP Program, a component of the National Cooperative Geologic Mapping Program. U.S. Geological Survey funding for STATEMAP is awarded through an annual competitive grant process that requires matching State dollars and completion of all funded maps within 1 year. Map areas are prioritized by a STATEMAP Advisory Committee, composed of representatives from several Montana industries, universities, and Federal, State, and Tribal agencies. The committee's main priority is for the MBMG to eventually complete geologic mapping of the entire State at 1:100,000 scale as 30' x 60' quadrangle geologic maps. The MBMG has completed 1:100,000-scale mapping in eastern and central Montana, so the recent focus is on western Montana. During the last biennium, the Missoula East 30' x 60' quadrangle was completed and published, and the Butte South and Dearborn River 30' x 60' quadrangles and a revised version of the Bozeman 30' x 60' quadrangle were prepared for publication. Field mapping is underway in the Butte North and Elliston 30' x 60' quadrangles, and is nearly complete in the Salmon 30' x 60' quadrangle, which will be published during the next biennium.

Another priority established by the STATEMAP Advisory Committee is the production of large-scale maps that focus on particular geologic issues, transportation corridors, or areas where development is occurring or is anticipated. During the last biennium 12 geologic maps of this type were published for the Purcell Mountains in northwestern Montana, the Beaverhead and Pioneer Mountains in southwestern Montana, and the Canyon Ferry Lake area in west-central Montana. Many other large-scale geologic maps were also prepared for publication in 2013, including maps in the Helmville–Avon and Butte–Anaconda areas, the Helena and Clarkston Valleys, a map that transects the Madison Range, and a landslide map of the Big Sky area on a LiDAR hillshade base.

The MBMG also published two maps prepared by university students funded by EDMAP, a program related to STATEMAP that partially funds geologic mapping by students under the direction of their geology professors.

All of the published STATEMAP and EDMAP products are available for free download from the MBMG website.

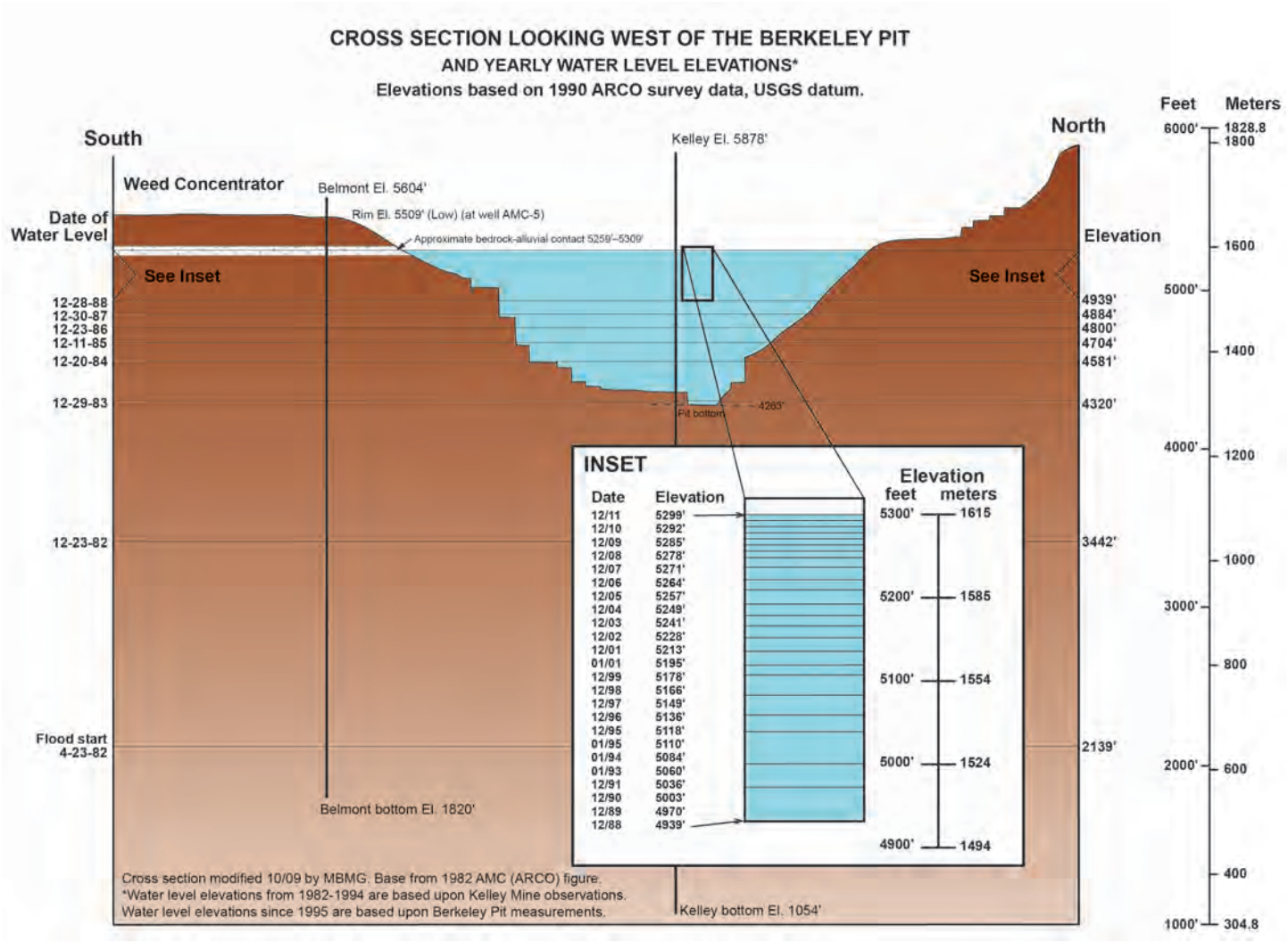


Butte South geologic map, MBMG Open-File Report 622.

ENVIRONMENTAL HYDROGEOLOGY: TECHNICAL ASSISTANCE PROGRAMS

The MBMG works in concert with State and Federal agencies, conservation districts, water-quality districts, and local communities to monitor, identify, and propose solutions to groundwater problems. Current projects run the spectrum from environmental problems associated with historic mining practices to water-quality issues related to organic waste-water chemicals in groundwater and waste-water-system effluent.

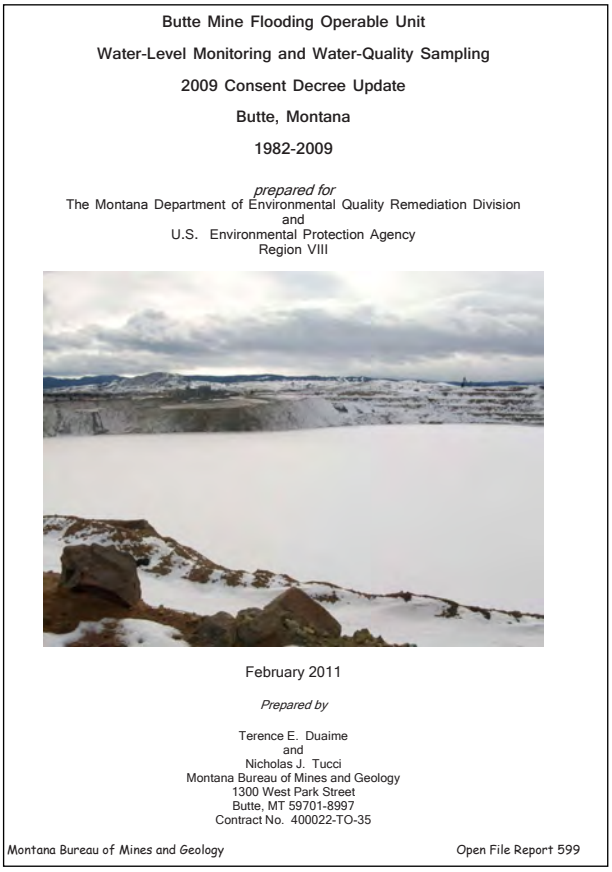
Montana has a rich history of natural resource development and corresponding environmental problems. Many of these problems are the result of mining practices dating to the late 1800s and early 1900s, which predate environmental and mining regulations. State and Federal agencies have very proactive programs to address these environmental problems, many of which are water-related. Since first receiving funding from the 1983 Montana Legislature (H.B. 819), the MBMG has been actively involved with groundwater monitoring and sampling associated with the flooding of the underground mines and the Berkeley Pit, in Butte, MT. Since flooding first began in April 1982, water levels in the underground mines have risen over 3,150 feet (see figure below). Monitoring and sampling also include tracking water-level increases and water quality in the Berkeley Pit as it fills with water. The Berkeley Pit currently contains over 41.7 billion gallons of acidic (pH ~2.6), metal-laden water, and the water in the pit is more than 1,000 feet deep. Current projections are for the bedrock water levels (including underground mines and the Berkeley Pit) to reach the point that water from the pit/underground workings will need to be pumped and treated in early 2023. Four years prior to that date the parties responsible for pumping and treating the water (ARCO, Washington Corp., and Montana Resources) will evaluate treatment technologies and implement any necessary upgrades to the current water treatment system. These parties currently operate a treatment plant that captures water before it can flow into the pit, thus slowing the pit's filling rate.



The monitoring network consists of: 74 groundwater sites, 29 of which are equipped with transducers for semi-continuous (1-hr interval) water-level monitoring; the Berkeley Pit, and 3 surface-water sites. Water-quality samples are collected annually and semi-annually from 48 of the monitored sites for inorganic chemical analysis. An annual report is prepared summarizing the past year changes, comparing trends or changes to previous data. These reports are available online through the MBMG web-site. All water-level and water-quality data collected are publicly available through the MBMG Groundwater Information Center (GWIC) webpage.

Topics Currently Being Investigated

- Acid mine-drainage mitigation through land-use changes and source control at an abandoned underground coal mine, Belt
- Inventory of placer mining operations in western Montana
- Groundwater monitoring of flooding underground mines and the Berkeley Pit
- Long-term monitoring of groundwater associated with the Anaconda Smelter Superfund site
- Assisting restoration option evaluation in the Upper Clark Fork River Basin
- Long-term monitoring of chromium concentrations in groundwater at the Mouat chromium repository, Columbus, MT
- Evaluation of arsenic sources in groundwater, Upper Deer Lodge Valley, MT
- Metal concentrations in storm-water runoff, Mill Creek drainage, Anaconda, MT
- Groundwater issues relating to Butte Priority Soils Superfund site
- Blacktail Creek bromide tracer study
- Geochemical evaluation of groundwater associated with mine waste, Butte, MT
- Geothermal resource inventory of Montana


Butte Mine Flooding Operable Unit

Water-Level Monitoring and Water-Quality Sampling

2009 Consent Decree Update

Butte, Montana

1982-2009

prepared for
The Montana Department of Environmental Quality Remediation Division
and
U.S. Environmental Protection Agency
Region VIII

February 2011

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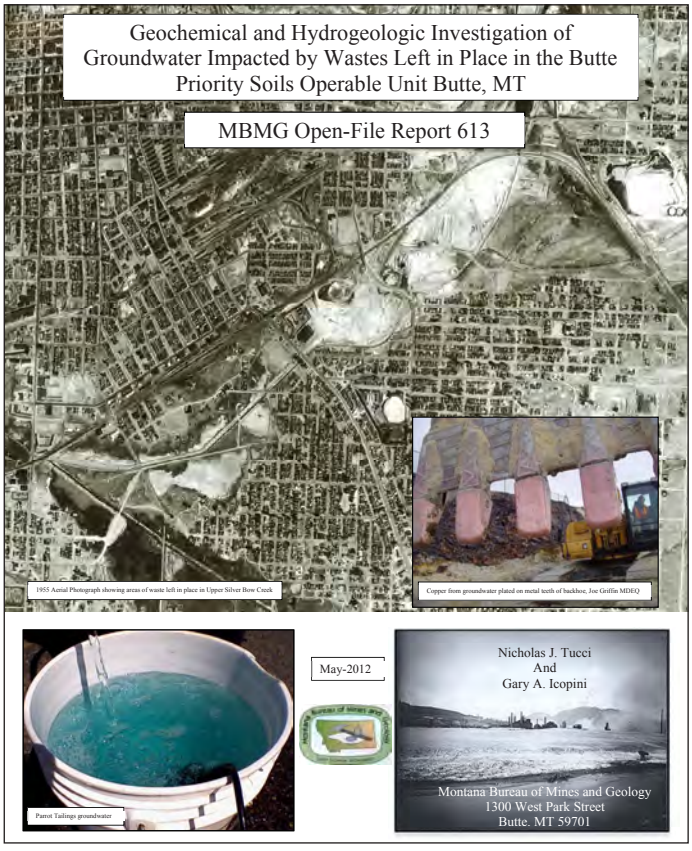
Montana Bureau of Mines and Geology — Open File Report 599



ENERGY RESOURCES

A dragline removes overburden and exposes the coal seam at Western Energy's Rosebud Mine near Colstrip, MT.

Coal Availability Studies

With approximately 120 billion tons, Montana leads the nation in demonstrated coal reserves, consistently produces about 4 percent of the nation's supply, and ranks 5th in annual coal production. Five surface mines and 1 underground mine produced about 42 million short tons in 2011 and 45 million short tons in 2010.

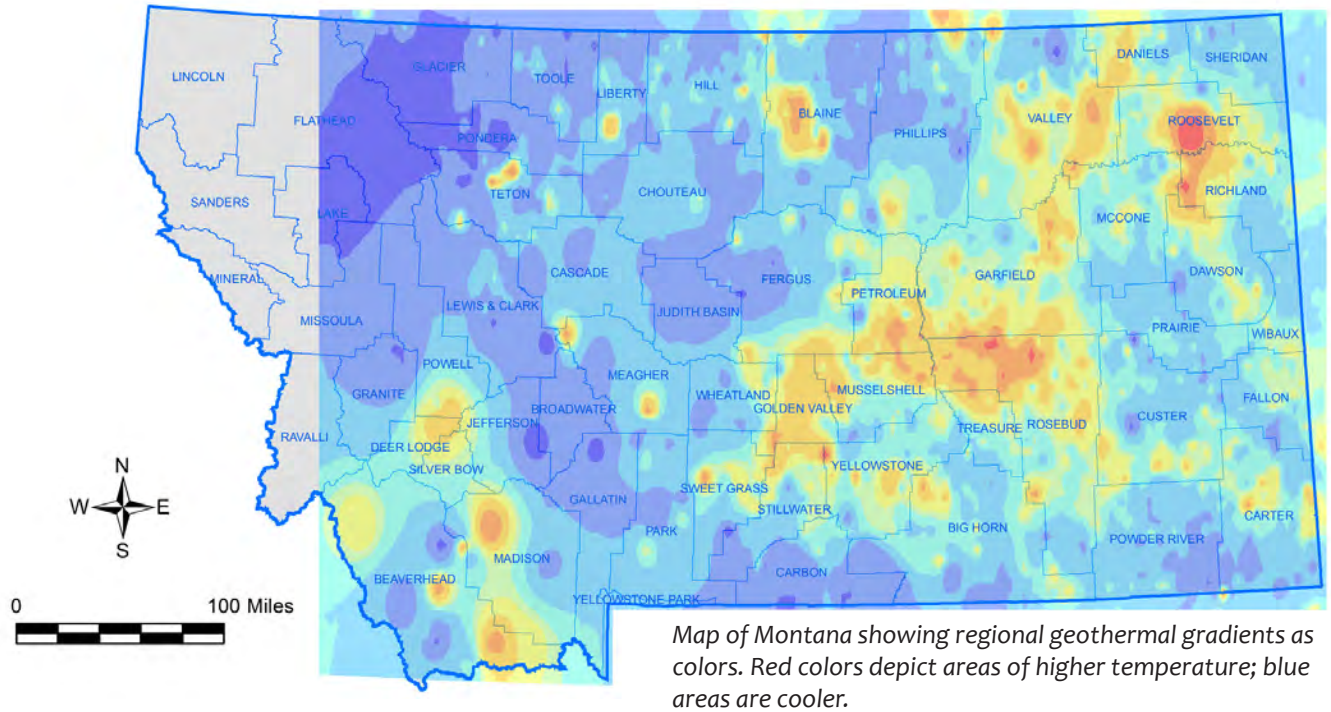
Montana's largest coal fields, such as the Otter Creek coal deposit, are found in the Powder River Basin (PRB) in southeastern Montana. The MBMG has conducted several coal availability studies that more accurately determine the quantity and distribution of mineable reserves. These studies were combined into a regional Coal Resource Assessment of the entire Montana PRB in cooperation with the USGS. Current and accurate coal resource estimates are essential for use in making local, State, and Federal energy and land-use policy decisions.

Geothermal Energy

Geothermal energy is heat that radiates from the Earth's interior. Because temperature generally increases with depth, groundwater deep in the subsurface is heated as it migrates through rock layers. Hot water and steam can be produced to the surface and utilized in heat exchangers or steam turbines to generate electrical power. Geothermal energy is an enormous resource that is both clean and sustainable.

Analysis of temperature data recorded in petroleum wells provides information on regional geothermal "hot spots," and identifies areas of higher temperature that could be utilized as geothermal energy sources for driving electric generators.

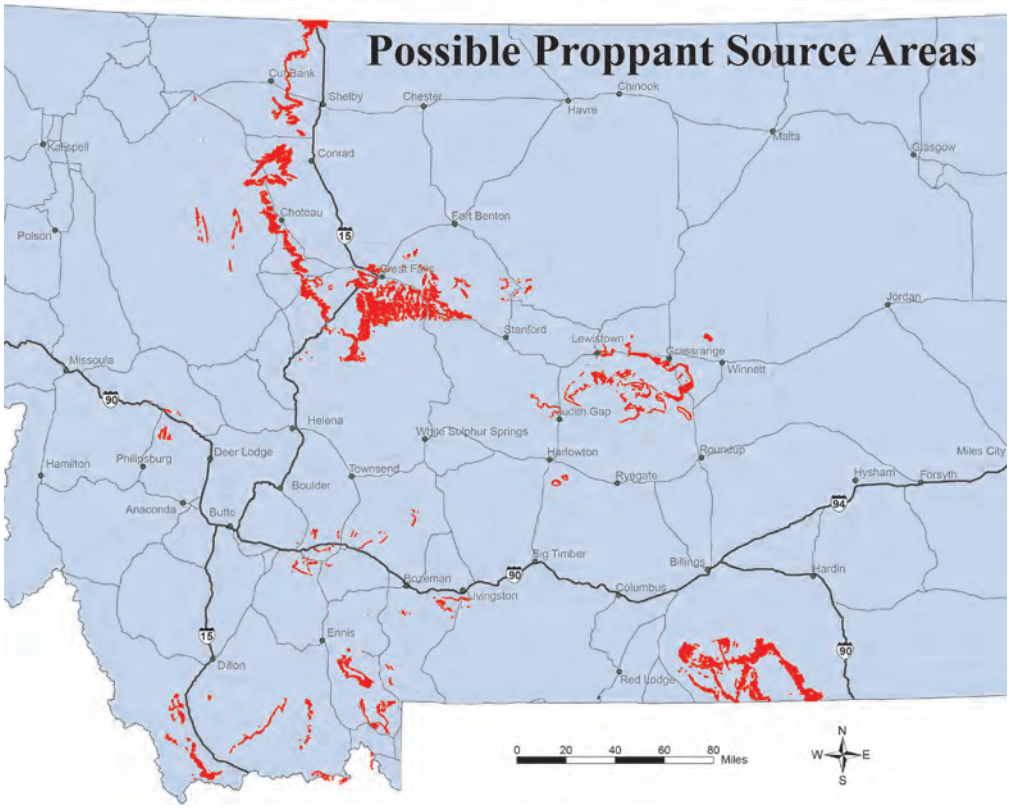
One cost-effective way to produce geothermal energy is to extract heat from the water that is co-produced from existing oil wells. Over time, many oil fields become depleted and the ratio of produced oil to water gradually decreases until the field is no longer economically viable. These depleted oil fields could be converted to water production and used as geothermal energy sources without additional drilling costs.



Map of Montana showing regional geothermal gradients as colors. Red colors depict areas of higher temperature; blue areas are cooler.

Hydraulic Fracturing Resources

Hydraulic fracturing ("fracking") is a critical component of drilling and completing productive wells in shale oil reservoirs such as the Bakken Formation in Eastern Montana. The fracking process relies heavily on massive injections of water and chemicals at high pressure to fracture, or crack the rocks. Sand and other "proppants" are pumped into wells and used to hold the cracks open once pressure is released. Fracking is an expensive process and local sources for frack sand would help to reduce well costs. The MBMG has identified several geologic formations as potential frack sand sources.



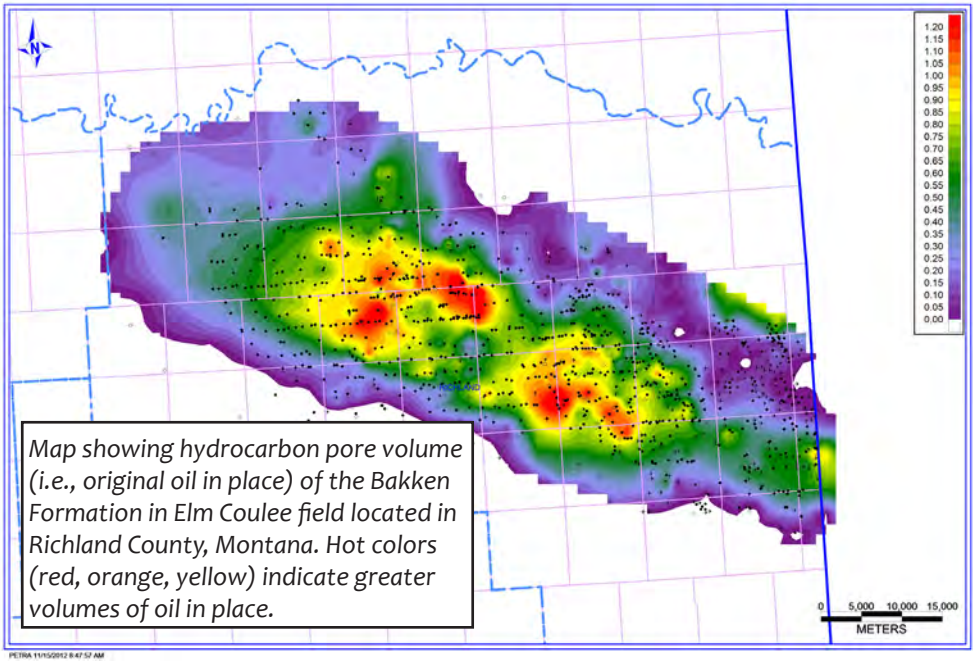
Preliminary map of sand deposits that have potential for use as fracking proppants.

Elm Coulee Field (Bakken) Reservoir Model

The Bakken Formation in eastern Montana and western North Dakota hosts one of the most important, rapidly developing oil resources in the United States. Montana's largest "Bakken" field—the Elm Coulee field in Richland County—contains over one billion barrels of oil and has been producing since the early 2000s.

It is expected that only about 5–10% of the original oil in place will be recovered during initial pumping or the primary recovery phase of Elm Coulee. To recover additional oil, enhanced oil recovery (EOR) processes must follow. These usually include injecting fluids such as carbon dioxide (CO_2) or water to mobilize additional oil so it can be captured by producing wells.

The MBMG and the Montana Tech Petroleum Engineering department have jointly developed a computer-based Elm Coulee reservoir model that will be used to test and simulate EOR methods, operations, and results. Simulating reservoir behavior prior to EOR will improve reservoir performance, increase oil recovery, and extend the life of the Elm Coulee field.



Map showing hydrocarbon pore volume (i.e., original oil in place) of the Bakken Formation in Elm Coulee field located in Richland County, Montana. Hot colors (red, orange, yellow) indicate greater volumes of oil in place.

EASTERN MONTANA PROJECTS

from our Billings field office

Groundwater Monitoring around Energy Development

Oil and Gas

Possible impacts to the Fox Hills–Hell Creek aquifer resulting from the current energy development in eastern Montana and North Dakota are being evaluated through a computer-generated groundwater model. The MBMG and scientists from Idaho National Laboratories started working jointly on this 3-year project in spring 2012. Recently collected data show substantial water-level declines in this important aquifer. In some cases this decline has left ranchers without stock water. Numerous wells completed in the Fox Hills–Hell Creek aquifer are being used to supply industrial water for hydraulic fracturing. The modeling efforts will be used to replicate the current conditions and simulate the aquifer's response to predicted increases in water use. The MBMG/INL team is also coordinating their efforts with USGS and the North Dakota State Water Commission through monthly phone conference meetings and a data-sharing website.

Impacts of Oilfield Development to Water Resources in Eastern Sheridan County

The MBMG has worked with the U.S. Geological Survey and the U.S. Fish and Wildlife Service documenting impacts of oil development on water resources. The work has documented contamination from water co-produced with hydrocarbons. Ongoing work has influenced handling of production water 10 times as salty as sea water. A Contamination Index developed by the MBMG over 20 years ago uses field values to determine the ratio of CL/SC. CI ratios greater than 0.035 typically indicate contamination from water co-produced with hydrocarbons. Recently completed projects have documented wetlands, lakes, and groundwater contaminated by oilfield wastes.

Coal and Coalbed Methane

The 40-year history of MBMG monitoring around coal mines provides significant information on the aquifers in the area and is looked to internationally as a groundwater monitoring model. The subsequent expansion into coalbed-methane monitoring has strengthened the monitoring effort, providing a more comprehensive understanding of the regional hydrologic system. These ongoing monitoring efforts complement short-term, intensive investigations into aquifers that are experiencing increased use or quality issues.

An intensive isotope and chemistry profile of the region's coal aquifers and streams was initiated this year to provide a clearer understanding of the role coal aquifers play in surface-water flows in the Powder River Basin. This study will be completed on the Tongue River, the Powder River, Hanging Woman Creek, and Otter Creek, all streams that flow through coalbed-methane fields or are sourced from coal aquifer springs (such as Otter Creek).

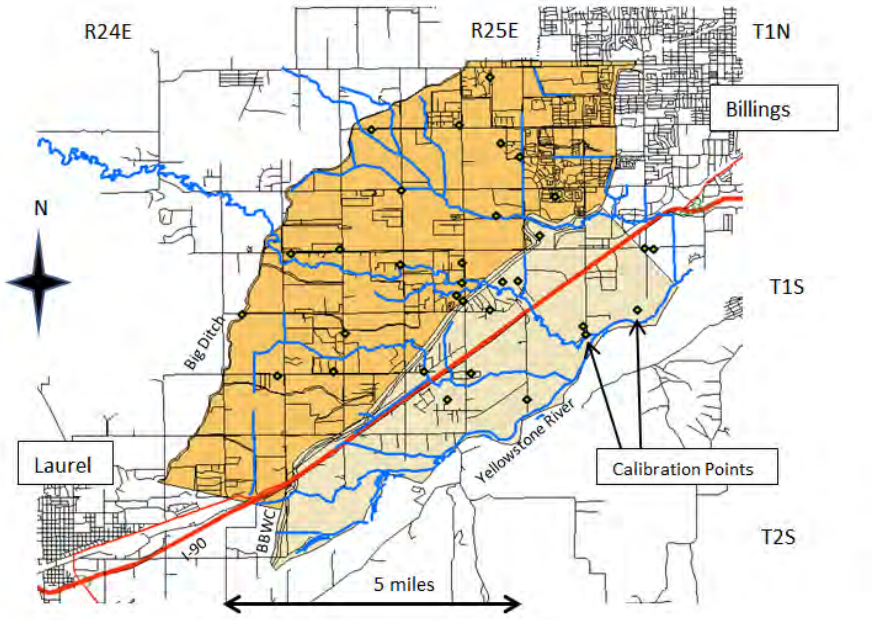
Upcoming Project Areas

- Big Horn County—The effect from irrigation practices on the quality of groundwater
- Carbon County—Quantifying alluvial groundwater from irrigation sources and identifying recharge to public water supplies
- Cascade County—Madison and overlying aquifer recharge sources.
- Eastern Montana—Groundwater model of the Fox Hills Aquifer
- Powder River County—Bedrock contributions to streams and rivers
- Richland County—Water development potential of buried channel aquifers near Sidney and Crane
- Rosebud County—Effects of wildfire on groundwater resources
- Sheridan County—Groundwater management of irrigation development from the Clear Lake aquifer
- Stillwater County—The source of recharge to and the quality of major bedrock aquifers

Modeling Aquifer Response to Urban Sprawl, West Billings Area, Montana

Sponsored by Yellowstone Conservation District

The MBMG completed a study and groundwater flow model of the shallow aquifer in the West Billings area in early 2012. Most of the water users in the West Billings area rely on shallow groundwater for residential and agricultural uses. The aquifer recharge is mainly from agricultural flood irrigation supplied by large canals from the Yellowstone River. As the land is converted from flood-irrigated cropland to residential developments, recharge to this important aquifer is diminishing as the groundwater use is increasing. In the 21-square-mile model area, approximately 180 acres of cropland were lost per year between 1996 and 2009. Water-level data collected from 1999–2000 and 2009–2011 were used to calibrate a transient flow model to the recorded aquifer conditions. The model was then used to simulate future aquifer conditions, assuming development continues at the recent rate. The 50-year predictive simulations suggest water use from the primary aquifer will surpass recharge in the years between 2030 and 2040.



West Billings study area northern and southern model areas.

Water Availability from the Madison Aquifer in Central Montana

Sponsored by the Cascade County Commission

The Mississippian Madison Limestone underlies most of central Montana and is a very important regional aquifer, in terms of extent and water supplied. The Madison Limestone crops out at land surface along the flanks of the Little Belt, Little Snowy, and Big Snowy mountains and is used as an aquifer for municipal, domestic, agricultural, and industrial uses. The aquifer discharges to Giant Springs, Big Springs, and Brooks Warm Springs. These springs support major fish hatcheries, natural fisheries, a municipal water system, and bottled water companies.

Recharge to the Madison aquifer in central Montana is currently being studied by the MBMG, in a project sponsored by the Cascade County Commission. Stream-flow and water-quality measurements on streams crossing Madison Group outcrops indicate losses that confirm the findings of earlier studies.

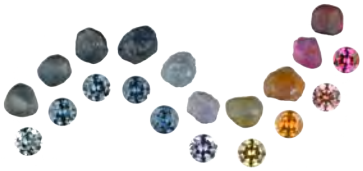
The MBMG is also measuring groundwater quality and quantity in a scattering of wells across the project area north of the Little Belts near Great Falls; water quality is quite variable here. Areas of good water quality and quantity may delineate preferential flow paths between recharge zones in the mountains and discharge zones delineated by large springs.

Roosevelt County Background Water Quality

Local concerns about oil & gas development and its potential impacts on groundwater prompted the MBMG to collect water samples from 10 stock and domestic water wells in Roosevelt County. The samples were analyzed for major constituents, minor constituents, Dissolved Organic Carbon (DOC), and Total Petroleum Hydrocarbons (TPH). Inorganic and trace constituents did not indicate impacts of oil development; however, TPH concentrations above detection limits were identified in half of the samples. It was initially postulated that these wells were affected by hydrocarbon contamination, but on further examination it appears that natural organic compounds associated with the weathering of coal and related plant materials are the likely source of TPH in Fort Union aquifer water. Thus, the presence of organic compounds in groundwater may not be the best indicator of contamination. In previous work, the MBMG has developed a contamination index based on chloride concentration and specific conductance for the Williston Basin; this has become a reliable indicator of contamination of potable aquifers from deep aquifers associated with hydrocarbon production and may be useful in other areas.

Sheridan County Water Reservation

The MBMG has worked closely with the Sheridan County Conservation District managing the Clear Lake aquifer. This aquifer system is composed of buried channel deposits associated with the ancestral Missouri River and overlying glacial outwash. Groundwater management has allowed steady growth in irrigation development. The MBMG provides technical advice and sits on an advisory committee that recommends water permit allocations.



MINERAL MUSEUM

The Mineral Museum on the Montana Tech campus began in 1901 with the purchase of 177 specimens within six months of the founding of the Montana School of mines in 1901. Today, the MBMG curates over 12,000 specimens from all over the world, with new acquisitions every year.

In fact, 250 new specimens were added to the permanent collection this past biennium; these include a new display of minerals from the Coronado Resource LLC mine at Silver Star, MT. We were also excited to acquire an iron-nickel meteorite from southwest Montana, weighing in at 32 pounds. This meteorite has been placed in one of our 9 new display cases. The museum continues to attract many visitors to the Tech campus; we had more than 14,000 individual visitors as well as more than 3,550 students in groups.

In addition to hosting the Montana Crystal Collectors annual meeting, several popular workshops, hosted by MBMG staff, were conducted. Dr. Dick Berg and the Museum staff presented several mineral identification sessions, Ginette Abdo and John Foley hosted a fossil workshop, and Dr. Colleen Elliot hosted an earthquake workshop featuring a new earthquake display detailing real-time monitoring and seismic hazards in Montana.

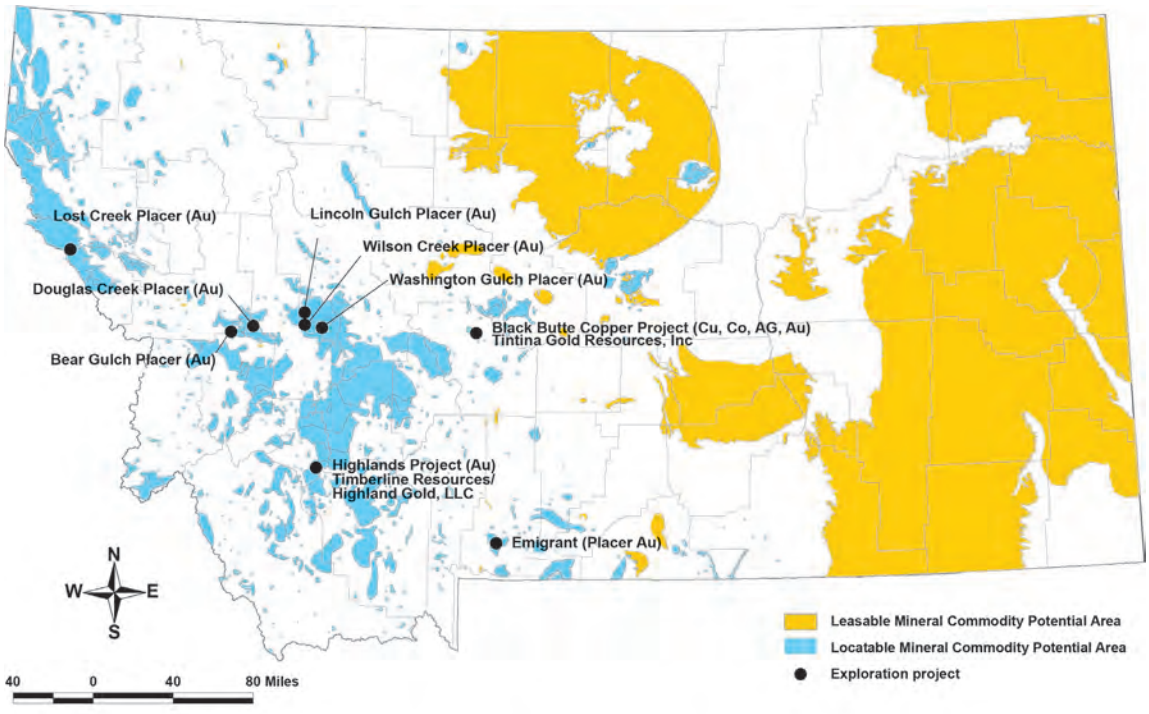
MINING AND MINERAL-RELATED ACTIVITIES

Major mines generally maintained previous production rates, and many expanded their future reserves. Commodity prices remained strong to support the industry; however, rising petroleum and steel prices increased operating costs related to fuel, equipment, blasting agents, and many miscellaneous items. Mine disasters within the coal industry on the east coast triggered a new round of changes within the safety standards for the industry. The changes have added to the challenge for larger companies and greatly affected the small miner industry.

There has been quite a surge in production from gold-bearing mill and mine waste. The higher gold prices, coupled with the new ability of Barrick's Golden Sunlight operations to accept ore from underground mines in the area, has resulted in a sizable industry in cleaning up old inactive mine sites without the need for government funding. There is new interest in exploration of abandoned mine sites for possible reactivation of mine production, which may be a boon to some of the rural counties within 100 miles of the Golden Sunlight mine.

Further exploration of past producers has resulted in permitting of operations of mid-sized underground gold and copper mines. Most challenges for the final permits appear to be related to dewatering of the orebodies to allow development; water quality has lately been less of a concern than the effects on water rights. There is potential for a sizeable copper mine to be developed in Meagher County and a gold property near Butte in Silver Bow County to be permitted in the near future. Overall, however, money for mineral development has remained tight in the international market, with an uncertain future.

Placer exploration near Garnet. Note placer drift timbers from the previous century along bottom of the gravel.



Exploration in Montana–2011

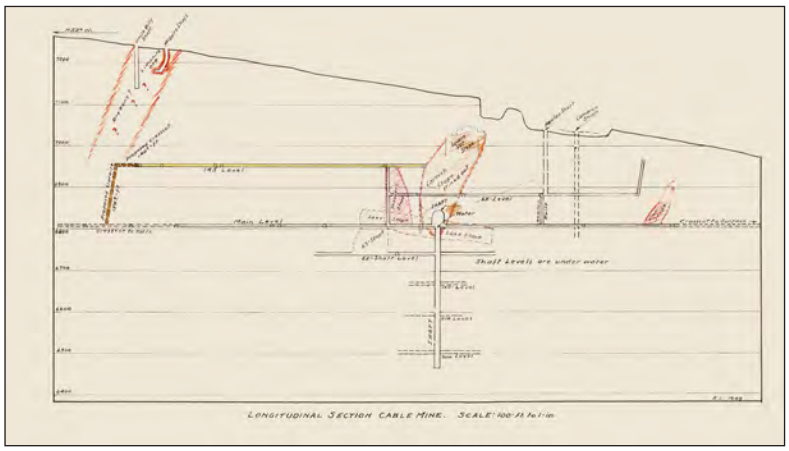
Placer gold operations have shown a sizeable increase in interest and activity. Exploration has tremendously increased in 2012 and will result in many new operations in the future.

The MBMG has had an active part in providing assistance to the smaller operations through the small miner program, geologic mapping, and water programs to provide information to companies and agencies for their permitting process.

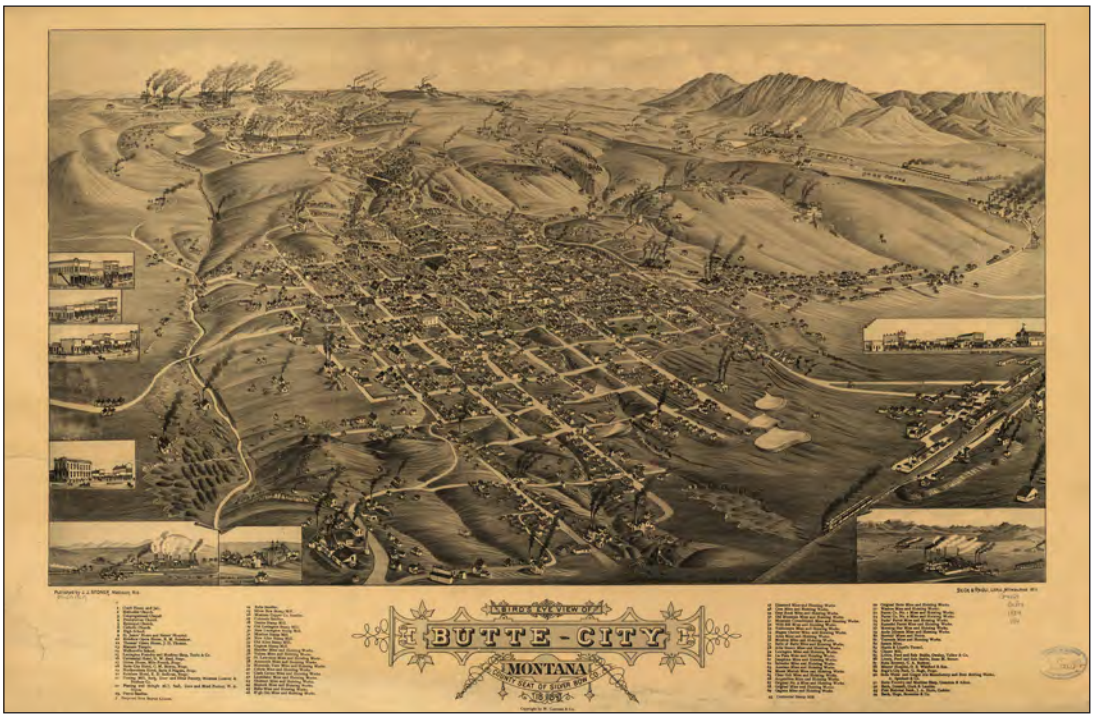
DATA PRESERVATION

During the 19th, 20th, and 21st centuries, an enormous financial investment in natural resource development and environmental monitoring generated a tremendous volume of geologic, geophysical, engineering, and water data. Over time, much of the data has been forgotten, lost, or destroyed, becoming unavailable as a valuable and cost-effective reference for current public and private users. In 2005, the Energy Policy Act directed the Secretary of the Interior, through the USGS, to establish the National Geological and Geophysical Data Preservation Program (NGGDPP) to archive geologic and other natural resource data and compile a digital catalog of archived material from across the nation.

The MBMG has accepted donated data from public and private entities for many years. Beginning in 2008, using NGGDPP funds, the MBMG assessed the size and condition of its existing data collections, inventoried them, and purchased scanning equipment to begin scanning and rescuing data from loss, destruction, or media degradation. To date, more than 1,700 of 4,500 mining property files (containing over 14,000 pages of information) and 1,200 of 6,500 mining and engineering maps have been digitized. Other MBMG collections include 200,000 aerial photos, seismic records dating back to 1980, and oil, gas, and more than 230,000 water well logs. Of specific interest are difficult-to-catalog hand samples, thin sections, and polished rock sections from the Butte underground mines.

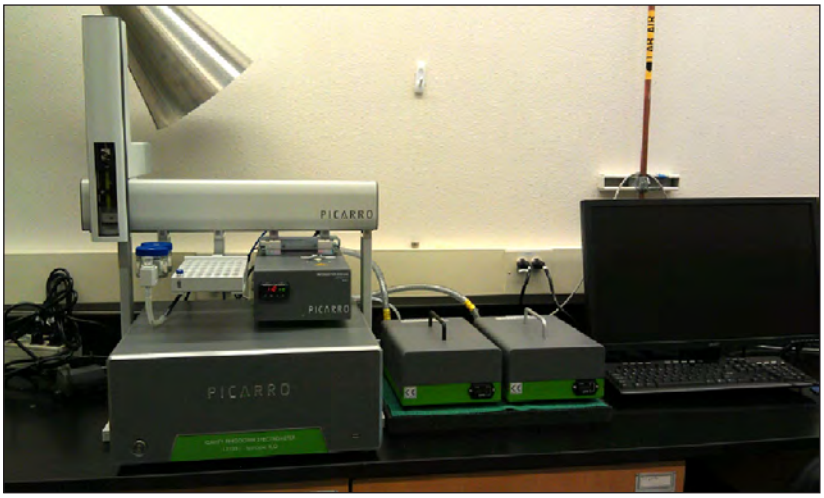


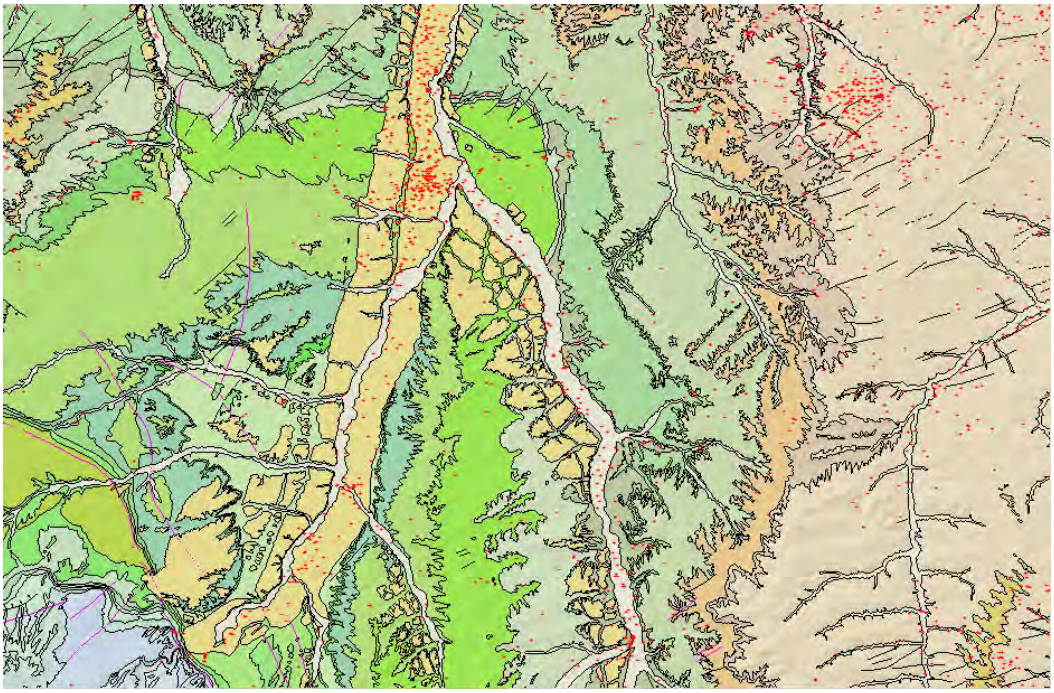
Current mineral commodity prices are high, causing high demand for electronically delivered archived data; at the same time new data are becoming increasingly available for rescue and archiving as 'boomer-age' mineral resource professionals retire. In 2012, the MBMG created a Data Preservation Committee, consisting of major data-archive users, librarians, USGS personnel, and MBMG staff to guide data preservation policy, mining archives webpage development, and future program development. The committee met in August 2012 and will meet again in March 2013. A primary committee concern is how to maintain MBMG's data preservation effort in the face of reduced federal funding.



ANALYTICAL LAB

The Analytical Laboratory provides organic and inorganic analyses in support of the MBMG's research projects. The laboratory has added new capability, with the acquisition of a Picarro Isotopic Water Analyzer, L2130-i, which will allow for water isotope analysis. The Picarro L21030-i provides both δ18O and δD stable isotope ratios useful to characterize groundwater flow systems. Also in this biennium, all data have been transferred to a new Laboratory Information Management System.





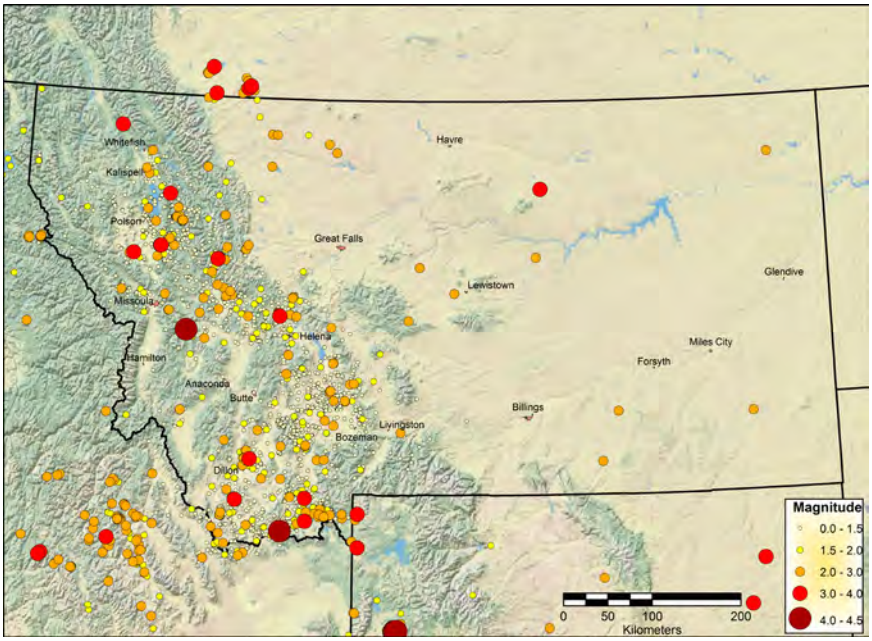
GIS LAB

The staff in the GIS Lab are actively engaged in a number of projects. The STATEMAP program continues to be the largest single project, while many other projects are active. STATEMAP products are frequently updated to reflect new information or to integrate other data.

We have made GWIC available as a "data service," and are continuing efforts to make MBMG GIS data available via the web. Other assignments include Superfund remediation/monitoring projects, geothermal heat reservoir modeling, and the Ground Water Investigation Program (GWIP), all programs or projects with an active GIS component.

EARTHQUAKE STUDIES

Western Montana has a history of large, damaging earthquakes and remains seismically active. Most of these earthquakes (including the 1925 magnitude 6.6 Clarkston earthquake centered north of Three Forks, and the magnitude 6.3 and 6.0 Helena earthquakes in 1935) occur 3 to 10 miles deep along faults that do not extend to the Earth's surface. The seismic hazards associated with these "blind" faults cannot be evaluated with traditional surficial mapping of faults and are best studied with data from a permanent network of seismograph stations. As the population and infrastructure of earthquake-prone western Montana continues to grow, the exposure to seismic hazards—the risk—increases.

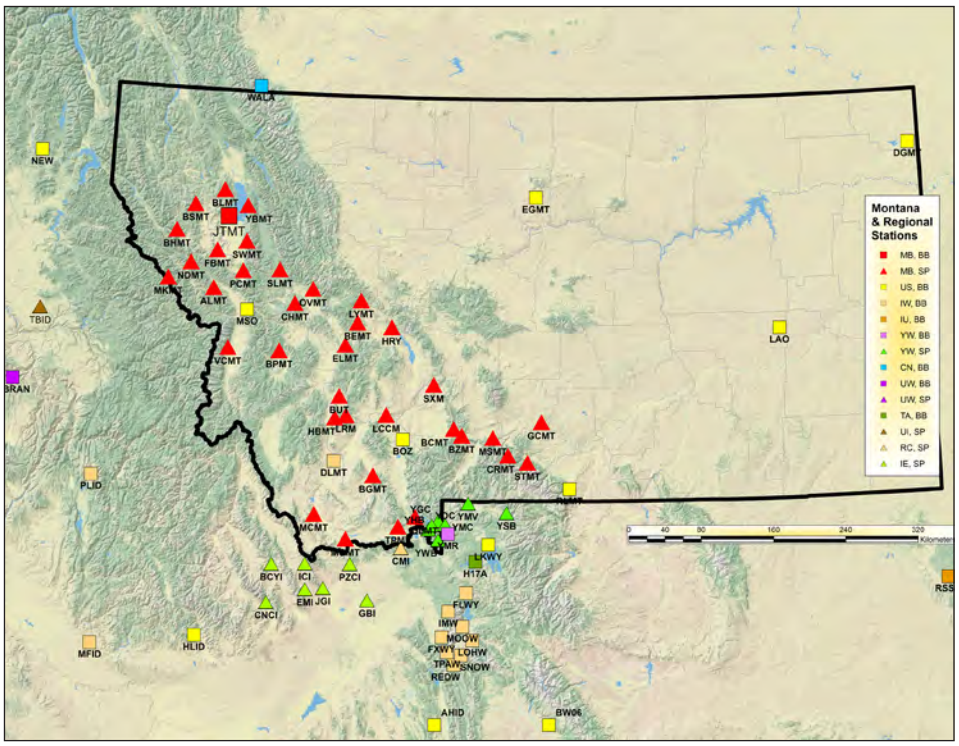


Epicenter locations for 3,368 earthquakes located by the MBMG from July 1, 2010 to June 30, 2012.

The MBMG operates a network of 38 seismic monitoring stations throughout western Montana, the most seismically active region of the State. Four additional stations operate in less active eastern Montana. Other regional seismic monitoring centers in Yellowstone National Park, central Idaho, and southern Canada exchange seismic data with the MBMG and provide additional monitoring coverage near Montana's borders. In cooperation with the U.S. Geological Survey, the MBMG will be incorporating seven strong-motion seismic monitoring instruments previously operated by the USGS into the Montana seismic network and also recently upgraded three analog seismograph stations to digital instrumentation.

The MBMG currently records a total of 150 channels of seismic data from 85 local and regional stations. Data from this network are used to detect and report earthquake locations and magnitudes for significant earthquakes within 2½ to 3 minutes of their occurrence to the National Earthquake Information Center. State and Federal agencies (Montana Disaster and Emergency Services, Montana Dam Safety Program, Confederated Salish and Kootenai Tribes Safety of Dams Program, and the U.S. Geological Survey), the media, and the public use this information. As part of its routine earthquake cataloging procedure, the MBMG determined times, locations, and magnitudes for 3,368 earthquakes with magnitudes ranging from -0.4 to 4.5 from July 1, 2010 to June 30, 2012.

Real-time views of seismograms from the MBMG network are available on the MBMG Earthquake Studies Office website (http://mbmgquake.mtech.edu/), along with a listing of recent earthquakes and other information about seismic hazards in Montana.



Seismograph stations connected in real time to the Earthquake Studies Office and used to locate earthquakes during 2012. Square symbols indicate digital broadband seismographs and triangles indicate short-period seismographs. Network codes are: MB, MBMG; US,USGS National; IW, USGS Intermountain West; WY, University of Utah Yellowstone; IE, Idaho National Labs; RC, BYU Idaho; UI, University of Idaho; CN, Canadian national.

INFORMATION SERVICES

The Information Services Division is responsible for creating, editing, and distributing MBMG publications and reports to the public, both through our Publication Sales office and the MBMG's website.

Visit the MBMG site, http://www.mbmg.mtech.edu, or come see us in the Natural Resources Building.

New publications in this biennium:

Geologic Maps

GM 55, Cambrian-Devonian stratigraphy along the southwest Montana transverse zone and tectonic history of the Willow Creek fault system, 40 p., 1 sheet, Thomas, W.A., 2011.

Ground-Water Atlas Series

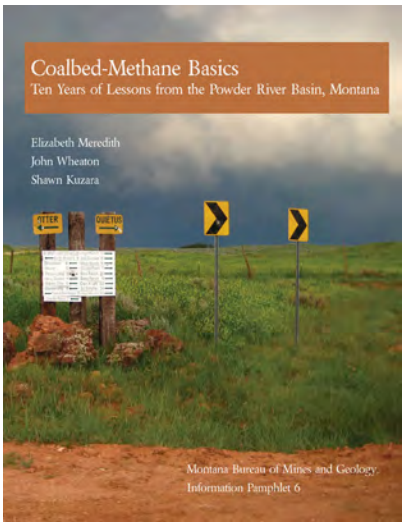
GWAA 5B-03, Potentiometric surface map of basin fill and selected bedrock aquifers: Deer Lodge, Granite, Powell, and Silver Bow Counties, Montana, 1 sheet, Waren, K.B., and LaFave, J.I., 2011.

GWAA 7B-01, Data for water wells visited during the Cascade–Teton Groundwater Characterization Study, 1 sheet, 1:275,000, Carstarphen, C.A., Smith, L.N., Mason, D.C., LaFave, J.L., and Richter, M.G., 2011.

Informational Pamphlets

IP 6, Coalbed Methane Basics: Ten years of lessons from the Powder River Basin, Montana, 29 p., Meredith, E., Wheaton, J., and Kuzara, S., 2012.

IP 7, Coalbed Methane: The role of the Montana Bureau of Mines and Geology, 4 p., Meredith, E. Bierbach, S., and Johnson, L., 2011.



Open-File Reports

MBMG 594, Petrography and chemical analyses of a core from the Devonian prairie evaporite, Sheridan County, Montana, 11 p., Berg, R.B., 2010.

MBMG 595, Baseline groundwater evaluation near a proposed *in situ* leach uranium mine in Carter County, Montana, 18 p., Meredith, E., 2010.

MBMG 596, Agricultural practices used in source control of acid mine drainage problems, central Montana, 91 p., Duaime, T.E., Sandau, K., and Smith, G., 2011.

MBMG 597, Geologic map of the Circle 30' x 60' quadrangle, Dawson, McCone, and Prairie counties, eastern Montana, 1 sheet, 1:100,000, Vuke, S.M., Hargrave, P.A., and Smith, L.N., 2011.

MBMG 598, Geologic map of the Selway Mountain 7.5' quadrangle, Beaverhead County, Montana, 1 sheet, 1:24,000, Lonn, J.D., Burmester, R.F., McFaddan, M.D., and Lewis, R.S., 2011.

MBMG 599, Butte Mine Flooding Operable Unit water-level monitoring and water-quality sampling 2009 consent decree update, Butte, Montana 1982–2009, 147 p., Duaime, T.E., and Tucci, N.J., 2011.

MBMG 600, 2010 Annual coalbed methane regional groundwater monitoring report: Powder River Basin, Montana, 130 p., 6 sheets, Meredith, E., Kuzara, S., Wheaton, J.R., Bierbach, S., Chandler, K., Donato, T., Gunderson, J., and Schwartz, C., 2011.

MBMG 601, Geologic map of the Dickie Peak 7.5' quadrangle, southwest Montana, 1 sheet, 1:24,000, McDonald, C., 2011.

MBMG 602, Geologic map of the Silver City 7.5' quadrangle, southwestern Montana, 6 sheets, 1:24,000, Hargrave, P.A., Bregman, M., and Lonn. J.D., 2011.

MBMG 603, Geologic map of the Austin 7.5´ quadrangle, central Montana, 10 p., 1 sheet, 1:24,000, Berg, R.B., and Lonn, J.D., 2011.

MBMG 604, Geologic map of the Goldstone Mountain quadrangle, Lemhi County, ID and Beaverhead County, MT, 1 sheet, 1:24,000, Lewis, R.E., Othberg, K.L., Stanford, L.R., Burmester, R.F., Lonn, J.D, and McFadden, M.D., 2011.

MBMG 605, Anaconda Smelter NPL site, Anaconda regional water, waste, and soils operable unit—2009 Groundwater Montoring Programs—5 year review sampling, 225 p., 1 sheet, 1:24,000, Duaime, T.E., and Icopini, G.A., 2011.

MBMG 606, Geologic map of the Peterson Lake 7.5' quadrangle, Beaverhead County, western Montana, 1 sheet, 1:24,000, Lonn, J.D., and Lewis, R.S., 2011.

MBMG 607, Geologic map of the Canyon Ferry Lake area, west-central Montana, 17 p., 1 sheet, 1:50,000, Vuke, S.M., 2011.

MBMG 608, Preliminary geothermal map of Montana using bottom-hole temperature data, Gunderson, J.A., 2011.

MBMG 609, Butte Mine Flooding Operable Unit water-level monitoring and water-quality sampling 2010 consent decree update, Butte, Montana, 1982–2010, 146 p., Duaime, T.E., and Tucci, N., 2011.

MBMG 610, Hydrogeologic investigation of the North Hills Study Area, Lewis and Clark County, Montana, interpretive report, 99 p., Waren, K., Bobst, A., Swierc, J., and Madison, J.D., 2012.

MBMG 611, Aquifers and streams of the Stillwater–Rosebud watersheds, 130 p., Kuzara, S., Meredith, E., and Gunderson, J., 2012.

MBMG 612, Hydrogeology related to exempt wells in Montana: A Report to the 2010–2012 Water Policy Interim Committee of the Montana legislature, 24 p., Metesh, J., 2012.

MBMG 613, Geochemical and hydrogeologic investigation of groundwater impacted by wastes left in place in the Butte Priority Soils Operable Unit, Butte, Montana, 198 p., 2 sheets, Tucci, N., and Icopini, G.A., 2012.

MBMG 614, 2011 Annual coalbed-methane regional groundwater monitoring report: Powder River Basin, Montana, 78 p., 6 sheets, Meredith, E., Kuzara, S., Wheaton, J., Bierbach, S., Donato, T., and Schwartz, C., 2012.

MBMG 615 a, Wolf Point—Top of Bearpaw Shale, 1 sheet, 1:250,000, Bergantino, R.N., 2012.

MBMG 615 b, Wolf Point—Top of the Judith River Formation, 1 sheet, 1:250,000, Bergantino, R.N., 2012.

MBMG 615 c, Wolf Point—Thickness of the Judith River Formation, 1 sheet, 1:250,000, Bergantino, R.N., 2012.

MBMG 615 d, Wolf Point—Top of the Claggett Shale, 1 sheet, 1:250,000, Bergantino, R.N., 2012.

MBMG 615 e, Wolf Point—Top of the Eagle Formation/Gammon Shale, 1 sheet, 1:250,000, Bergantino, R.N., 2012.

MBMG 615 f, Wolf Point—Top of basal Colorado, 1 sheet, 1:250,000, Bergantino, R.N., 2012.

MBMG 615 g, Wolf Point—Top of the Kootenai Formation, 1 sheet, 1:250,000, Bergantino, R.N., 2012.

MBMG 615 h, Wolf Point—Thickness of the Kootenai Formation, 1 sheet, 1:250,000, Bergantino, R.N., 2012.

Miscellaneous Publications

MISC 44, Montana Bureau of Mines and Geology 2011 Calendar: White Cliffs of the Missouri, Montana, 2010.

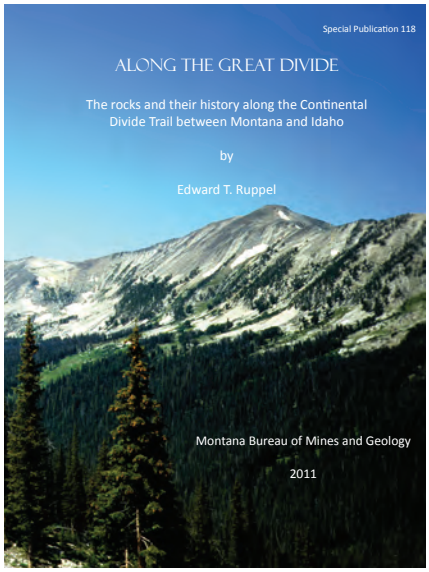
MISC 45, Clay and shale reports of Montana, Berg, R.B., 2011.

MISC 48, Montana Bureau of Mines and Geology 2012 Calendar: Beaverhead Mountains, 2011.

Reports of Investigation

Report of Investigation 20, Petrography and chemical analyses of a core from the Devonian Prairie evaporite, Berg, R. B., 2010.

Report of Investigation 21, Salt cedar and Russian Olive in Treasure County, Montana: Transpiration rates and soil salt concentrations, 78 p., Meredith, E., and Wheaton, J., 2011.



Special Publications

Special Publication 118, Along the Great Divide—The rocks and their history along the Continental Divide Trail between Montana and Idaho, 80 p., Ruppel, E.T., 2011.

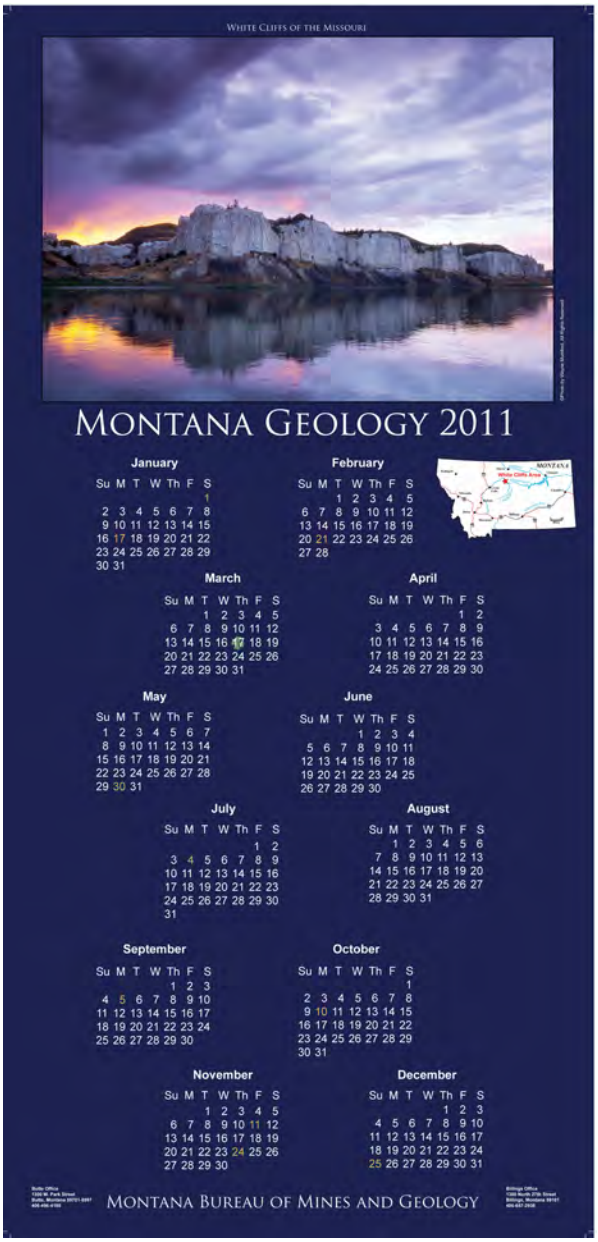
Special Publication 119, Surface materials map of the Black Mountain 7.5' quadrangle, Lewis & Clark and Jefferson counties, southwestern Montana, 1 sheet, 1:24,000, Berg, R.B., 2012.

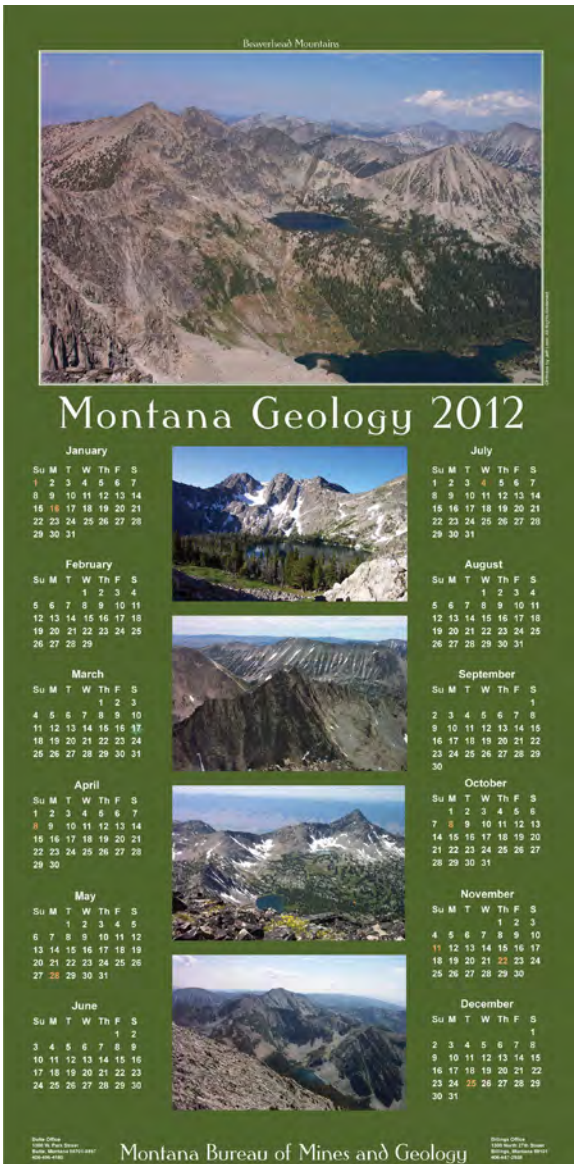
EDMAP Series*

**The EDMAP series is part of the USGS National Cooperative Geologic Mapping Program. The maps are produced by geology students from various colleges and universities. MBMG staff may provide mentoring and assistance.*

EDMAP 8, Geologic Map of the Esmeralda Hill 7.5' Quadrangle, Lewis and Clark County and Powell County, Montana, 1 sheet, 1:24,000, Balgord, E.A., Mahoney, J.B., Potter, J.J., Pignotta, G.S., Wittkop, C., King, N.E., Ihinger, P.D., Hardel, B.G., and Kadulski, B., 2010.

EDMAP 9, Geologic map of the Dunn Creek, 7.5' quadrangle, west-central Montana, 1 sheet, 1:24,000, MacLaurin, C., Mahoney, J. B., Guy, A., Forgette, M., Kjos, A., Wittkop, C., Kohel, C., Balgord, E., Barber, B., and Ihinger, P.D., 2010.





Information Services Statistics for this Biennium

Publication Sales:

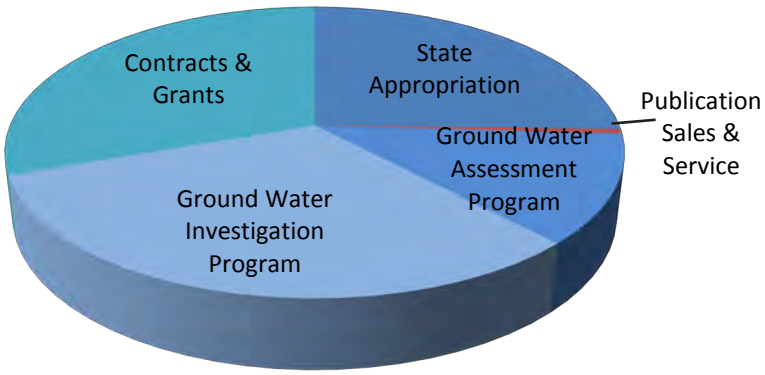
- 1,419 titles
- 13,290 items sold

Data downloaded:

- 730 titles
- **229,797 files**

FINANCES

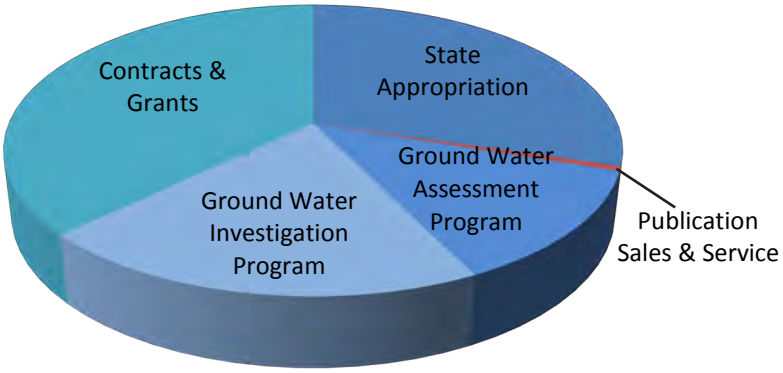
FY 2011

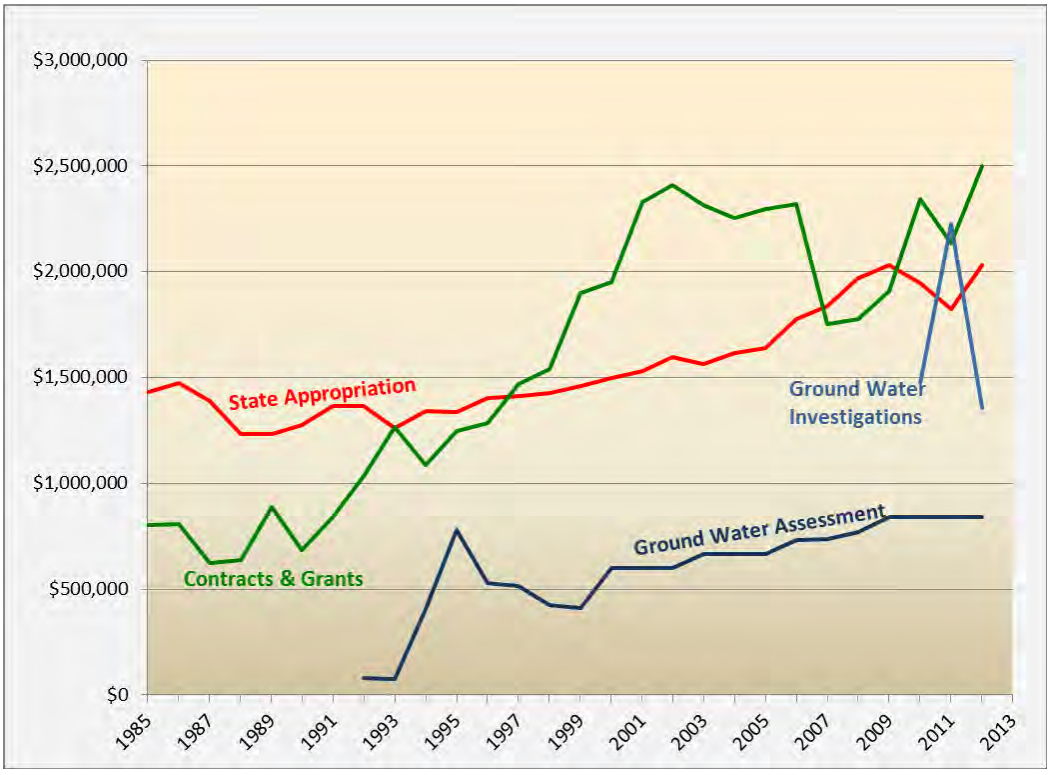


The Montana Bureau of Mines and Geology was established in 1919 to compile and publish information relative to the geology of Montana. The main office is on the campus of Montana Tech in Butte and a second office is on the Montana State University-Billings campus. Our staff is composed of about 65 permanent employees in Butte and Billings, and about 30 students from Montana Tech, University of Montana, Montana State University, and MSU-Billings.

Funding for the MBMG comes from five categories: (1) a biennial appropriation from the State's general fund to maintain core programs; (2) a biennial appropriation from the State's general fund for the Ground Water Investigation Program; (3) biennial appropriations from the State's special accounts for the Ground Water Assessment Program; (4) contracts and grants derived through agreements with a variety of Federal, State, and local organizations to address specific issues of mutual interest to the sponsoring organization and the MBMG; and (5) income from sales of MBMG publications.

FY 2012





The long-term trend for the four major sources of funding continues upward at a modest rate (see chart at left). The generosity of the Montana Legislature and Governor is reflected in the steady growth of the core geologic programs as well as the recent addition of the new groundwater program. Many of the projects under contracts and grants rely on partial state support (matching funds); growth of the MBMG in this area will continue to reflect that relationship.

COMMITTEES

The Montana Bureau of Mines and Geology endeavors to provide sound scientific maps and reports for use by many segments of society. An important component of our activities is the decision process to determine topics and geographic areas of our research; advisory groups and steering committees are critical to that process. The MBMG gratefully acknowledges the many individuals and agencies who participate on these committees.

Advisory Committees

Ground Water Assessment Steering Committee (for Ground Water Assessment Program and Ground Water Investigation Program)

VOTING MEMBERS

Ms. Amy Bamber, MT Department of Agriculture
Mr. Evan Hammer, Natural Resource Information System, MT State Library
Mr. Russell Levens, Department of Natural Resources and Conservation
Mr. Richard Mulder, MT Department of Agriculture
Mr. Eric Regensburger, Department of Environmental Quality

EX OFFICIO MEMBERS

Mr. Joe Kolman, Environmental Policy Office
Mr. James Halvorson, Oil & Gas Conservation Division
Dr. Stephan G. Custer, Montana University System
Ms. Maureen Connor, Montana Association of Counties Appointee
Mr. Jeff Baumberger, U.S. Bureau of Reclamation
Mr. Peter Bierbach, Bureau of Land Management
Mr. John Kilpatrick, U.S. Geological Survey
Mr. Robert Wintergerst, USDA Forest Service Region 1 RO
Mr. Jason Gildea, U.S. Environmental Protection Agency
Mr. Walt Sales, Governor's appointee – Agricultural Water Users
Mr. Tad Dale, Governor's appointee – Industrial Water Users
Ms. Jane Holzer, Montana Salinity Control Association, Governor's appointee – Conservation Organization
Mr. Scott Cooney, Governor's appointee – Development Representative

State Map Advisory Committee

Dr. Stephan Custer, Montana State University
Mr. Steven J. Czehura, Montana Resources
Mr. Michael Garverich, Natural Resources Conservation Service
Mr. James W. Halvorson, Montana Board of Oil and Gas Conservation
Dr. Marc Hendrix, The University of Montana
Ms. Teresa Kinley, MT Dept. of Natural Resources & Conservation
Mr. Chad Lee, MT Dept. of Agriculture
Ms. Bonnie Lovelace, MT Dept. of Environmental Quality
Mr. Seth Makepeace, Confederated Salish and Kootenai Tribes
Mr. Patrick Pierson, US Forest Service
Dr. Edward T. Ruppel, Retired Montana State Geologist
Ms. Joanna Thamke, US Geological Survey
Mr. David Williams, Bureau of Land Management
Mr. Robert Wintergerst, US Forest Service

Yellowstone Controlled Ground Water Area Technical Oversight Committee

Dr. Steve Custer (chair), Montana State University (retired)
Mr. Marvin Miller, Montana Bureau of Mines and Geology
Mr. Russell Levens, Department of Natural Resources and Conservation
Mr. John Kilpatrick, US Geological Survey
Dr. Robert Fournier, USGS (retired) for National Park Service

Data Preservation Committee

Ms. Ann St. Clair, Montana Tech
Ms. Mitzi Rossillion, Butte-Silver Bow Archives
Mr. Dave Frank, US Geological Survey
Mr. Ted Antonioli, Consultant Geologist

Ginette Abdo and John Wheaton of the MBMG demonstrate the effects of well pumping on groundwater flow for the Legislative Water Policy Interim Committee and others.

The MBMG thrives on its interaction with citizens and agencies throughout Montana. Serving on various advisory committees and boards gives us an opportunity to learn about many issues facing the State and provide information on quite a range of topics.

Committees on which MBMG staff serve:

Acid Drainage Technology Initiative-Metal Mining Sector
Board of Environmental Review
Board of Oil and Gas
Butte Mine Flooding Public Education (Pit Watch)
Coalbed Methane Protection Program
DNRC Technical Advisory Council on Coalbed Methane
Future Fisheries
Montana Board of Water Well Contractors
Montana Mining Association
Montana Section of the American Water Resources Association
Montana Water Center
Sheridan County Water Reservation Technical Advisory Committee
Tobacco Root Geological Society
Watershed Coordination Council
Williston Area Aquifer Models Consortium
Yellowstone TOC
Yellowstone Volcano Observatory

MBMG GRANTS AND CONTRACTS

IN EFFECT DURING THIS BIENNIUM

Blacketter, D., *Natural Resources Building Geothermal Investigation*, US Dept. of Energy

Bobst, A., *Boulder River Valley Groundwater,* Jefferson County

Bowler, T., *Montana Pole Superfund Site Remedial Action*, MT Dept. of Environmental Quality

Buckley, L., *BN Somers Site*, MT Dept. of Environmental Quality

Chandler, K., *Montana Water Center Modeling ET,* Montana Water Center

Delaney, M., *National Geological & Geophysical Data Preservation Program: Phase IV*, US Geological Survey

Delaney, M., *National Geological & Geophysical Data Preservation Program: Phase V*, US Geological Survey

Duaime, T., *Agricultural Practices Used in Source Control of AMD Problems in Central Montana (Belt-Anaconda Mine)*, MT Dept. of Environmental Quality; US Natural Resource Conservation Service

Duaime, T., *Evalution of Arsenic Sources in Groundwater, Upper Deer Lodge Valley, MT,* Atlantic Richfield Company

Duaime, T., *Anaconda Regional Water, Waste and Soils Stormwater Monitoring,* MT Dept. of Justice

Duaime, T., *Big Hole River Natural Resource Damage Program,* MT Dept. of Justice

Duaime, T., *Buffalo Gulch Storm Water,* Atlantic Richfield Company

Duaime, T., *Butte Mine Flooding Consent Decree Monitoring*, MT Dept. of Environmental Quality

Duaime, T., *Natural Resource Damage, Upper Clark Fork River,* MT Dept. of Justice

Duaime, T., and Icopini, G., *Rocker Timber Framing,* MT Dept. of Environmental Quality

Duaime, T., and Berzel, M., *Crystal & Bullion Mines Water Quality and Adit Discharge Monitoring*, MT Department of Environmental Quality; US Environmental Protection Agency

Duaime, T., and Buckley, L., *Idaho Pole NPL Site GWIC Data Consolidation*, MT Dept. of Environmental Quality

Duaime, T., and Gerbrandt, H., *Review of Institutional Controls/Land-Use Options at the Mouat (Columbus, MT) Superfund Site*, MT Dept. of Environmental Quality

Duaime, T., and Icopini, G., *Anaconda Regional Water, Waste and Soils, Long-Term Groundwater Monitoring, 2010–2013*, Atlantic Richfield Company

Duaime, T., and Icopini, G., *Long-Term Groundwater Monitoring at the Mouat (Columbus, MT) Superfund Site*, MT Dept. of Environmental Quality

Duaime, T., and Tucci, N., *Butte Priority Soils Groundwater Evaluations*, Atlantic Richfield Company

Gunderson, J., *National Coal Resource Data System, Compilation, Collection and Correction of Coal Resource*, US Geological Survey

Gunderson, J., *USGS National Geologic Carbon Dioxide Sequestration Assessment,* US Geological Survey

Gunderson, J., *National Coal Resource Data System,* US Bureau of Land Management

Gunderson, J., *Resource Assessment of Deep Coals in Eastern Montana: Potential Targets for Commercialization by In Situ Gasification*, MT Board of Research and Commercialization Technology; Great Northern Properties

Icopini, G., *Geothermal Assessment and Outreach*, MT Dept. of Environment Quality; MT Dept. of Commerce

Icopini, G., *Geothermal Energy Data,* MT Dept. of Environmental Quality

Icopini, G., *National Geothermal Data System*, Arizonal Geological Survey; Dept. of Energy

Icopini, G., *Organic Wastewater Chemicals in Ground Water and Blacktail Creek, Summit Valley, Montana*, MT Water Center, MSU; US Geological Survey

Kuzara, S., Chandler, K., and Meredith, E., *Sustainable Water Supplies from Madison Aquifer*, MT Dept. of Natural Resource Conservation

McCulloch, R., *Geologic Resources and Mineral Potential,* US Bureau of Land Management

McDonald, C., and Elliott, C., *FEMA/BSB Pre-Disaster Mitigation Plan for Silver Bow County, Montana*, Butte-Silver Bow; US Federal Emergency Management Agency; MT Disaster and Emergency Services

Meredith, E., *Baseline evaluation near a proposed in situ leach uranium mine in Carter County, Montana*, Carter County Conservation District; MT Dept. of Natural Resource Conservation

Meredith, E., *Coalbed Methane Investigation*, Treasure County CD

Meredith, E., *Coal Mines Investigation,* US Bureau of Land Management

Meredith, E., *Quantification of Coal-Aquifer Baseflow in Montana Rivers Using Carbon Isotopes*, MT Water Center, MSU; US Geological Survey

Meredith, E., *Tongue River Reservoir Groundwater Resource Assessment*, MT Fish, Wildlife, and Parks

Meredith, E., and Wheaton, J., *Montana Regional Coalbed Methane Groundwater Monitoring Program*, Big Horn CD; MT Dept. of Natural Resource Conservation

Meredith, E., and Wheaton, J., *Site Evaluation for Disposal of Coalbed Methane Produced Water, continuation*, US Bureau of Land Management

Metesh, J., *Mineral Material Inventory,* US Forest Service

Metesh, J., *Placer Inventory,* US Bureau of Land Management

Metesh, J., *Yellowstone Controlled Ground Water Area Monitoring Program,* National Park Service

Metesh, J., *Yellowstone National Park Database Administration,* National Park Service

Michalek, T., *Ground-Water Assessment Tools for National Forest Service Properties*, US Forest Service

Patton, T., and Blythe, D., *Natural Resources Conservation Service Technical Services: Stock Water Supply Location and Flowing Well Rehabilitation Reports*, US Natural Resource Conservation Service

Patton, T., and Buckley, L., *ARCO/GWIC Data Reconciliation*, Atlantic Richfield Company

Reiten, J., *Eastern Roosevelt County;* Eastern Roosevelt County CD; MT Dept. of Natural Resource Conservation

Reiten, J., *Fox Hills/Hell Creek Aquifer Model,* Idaho National Laboratory

Reiten, J., *Remediation of Hailstone Reservoir on Hailstone National Wildlife Refuge*, US Fish & Wildlife Service

Reiten, J., *Results of Water Quality Assessment, Clear Lake Aquifer,* Sheridan County CD; MT Dept. of Natural Resource Conservation

Reiten, J., *Sheridan County Groundwater Management*, Sheridan County CD; MT Dept. of Natural Resource Conservation

Reiten, J., *Stratigraphic Controls on Brine Movement in the Prairie Pothole Region*, US Geological Survey

Reiten, J., and Chandler, K., *Irrigation Potential of Ground Water Underlying the Lower Yellowstone Valley in Richland County*, Richland County CD; MT Dept. of Natural Resource Conservation

Reiten, J., and Chandler, K., *Modeling Aquifer Response to Urban Sprawl, West Billings Area, Montana,* Yellowstone CD; MT Dept. of Natural Resource Conservation

Reiten, J., and Chandler, K., *Rock Creek*, Carbon County CD; MT Dept. of Natural Resource Conservation

Stickney, M., *Flathead Seismic Monitoring System*, Confederated Salish Kootenai Tribes

Stickney, M., *Montana Regional Seismograph Network*, US Geological Survey

Stickney, M., *Operation of the Montana Regional Seismograph Network*, US Geological Survey

Stickney, M., U*pgrade of Selected Montana Regional Seismograph Network Stations*, US Geological Survey/ ARRA

Tucci, N., *Blacktail Creek Bromide Tracer Investigation*, MT Dept. of Justice

Tucci, N., *Butte Area One Fingerprint Study*, MT Dept. of Justice

Tucci, N., *Butte Priority Soils Groundwater Evaluation and Technical Assistance,* MT Dept. of Environmental Quality; US Environmental Protection Agency

Tucci, N., *Evaluation of Water Supply Wells at Sunburst, Montana*, Town of Sunburst; MT Dept. of Natural Resource Conservation

Tucci, N., and Icopini, G., *Aquifer Test Evaluation—Metro Storm Drain Portion of Upper Silver Bow Creek Drainage,* MT Dept. of Justice

Tucci, N., and Icopini, G., *Geochemical and Hydrogeological Investigation of Groundwater Impacts from Historic Mining Wastes, Butte Area-One,* MT Dept. of Justice

Vuke, S., and McDonald, C., *STATEMAP FY11*—Funded through the National Cooperative Geologic Mapping Program, US Geological Survey

Vuke, S., and McDonald, C., *STATEMAP FY12*—Funded through the National Cooperative Geologic Mapping Program, US Geological Survey

Wheaton, J., *Critical Resource Assessment: Alluvial Aquifers of Northern Big Horn County,* Big Horn CD; MT Dept. of Natural Resource Conservation

Wheaton, J., *Aquifers and Streams in the Stillwater-Rosebud Watershed, Stillwater County, Montana,* Stillwater Conservation District (CD); MT Dept. of Natural Resource Conservation

Wheaton, J., and Meredith, E., *Eastern Montana Coal Lands Ground Water Evaluation*, US Bureau of Land Management

Wheaton, J., and Meredith, E., *Montana Regional Coalbed Natural Gas Ground Water Monitoring Partnership*, US Bureau of Land Management

Wheaton, J., and Meredith, E., *Salt Cedar transpiration quantification near Hysham, MT,* Treasure County Weed Control and MT Dept. of Environmental Quality

Wheaton, J., and Meredith, E., *Groundwater surface water interaction in the northern Big Horn Valley*, Big Horn Conservation District; MT Dept. of Natural Resource Conservation

Photo by Mike Stickney

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