Pivot irrigation near Dillon, Montana.
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Montana Geology 2015

Groundwater in Montana

Montana Bureau of Mines and Geology

January

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December

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Nested monitoring wells in the Deer Lodge Valley with Tertiary sediments in the background. Photo by John LaFave, MBMG.

Stockwater well below Fort Union Formation outcrop, south of the Bull Mountains. Photo by Clay Schwartz, MBMG.

Flowing artesian well completed in Absaroka Group volcanics in the Cinnabar Basin. Photo by John LaFave, MBMG.

Giant Springs issuing from the Kootenai Formation near Great Falls. Photo by Thomas Patton, MBMG.

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Montana's Groundwater—It's All in the Geology

Introduction

Often called the "hidden resource," groundwater is one of Montana's most valuable natural assets. Every time you take a drink, water your lawn, irrigate your crop, fish, or boat down your favorite river…you are using groundwater!

In rural areas, groundwater provides most domestic, livestock, and ranch needs—and in some of Montana's more urban areas such as Missoula, Kalispell, and Sidney, it is the source for public water supplies. Also, high-capacity wells support irrigated agriculture in areas as diverse as eastern Sheridan and northern Blaine Counties (north-central and northeastern Montana) and the Flathead, Beaverhead, and Gallatin River Valleys (western Montana).

Streams are not isolated from groundwater either; inflow from surrounding aquifers provides about half of the total annual flow in a typical Montana stream. If your water needs are met from surface water, you are still using groundwater.

Montana's Geology and Aquifers

Understanding Montana's geology is the key to understanding our groundwater resource. In western Montana, mountainous areas separate intermontane basins. The yellow areas of "Quaternary—alluvium" (fig. 1) strikingly illustrate the basins. Gray areas labeled "Cambrian/Precambrian—sedimentary/igneous rocks" are the mountains. In the plains east of the Rocky Mountain Front, a single geologic formation may cover entire counties (for example, orange in fig. 1: "Tertiary—sandstone, siltstone, coal").

The rocks and sediments that we observe on the land surface and portray on geologic maps are controlled by the subsurface geology. As shown in figure 1, the geology between the mountainous west and the flat plains in the east differs greatly. Cross sections A–A' and B–B' (figs. 2a, 2b) are generalized illustrations of Montana's subsurface geology. In the west (fig. 2a), many faults and complicated folds separate the mountains from the intermontane basins. In the east (fig. 2b), the geologic formations are generally flat, with few faults.

In the western intermontane basins, groundwater occurs in near-surface alluvial aquifers hydraulically connected to streams as well as in deep confined to semi-confined aquifers found within thousands of feet of basin-fill materials (fig. 2a). These aquifers contain large amounts of groundwater and are highly productive and heavily utilized, as indicated by the densely grouped well locations west of the Rocky Mountain Front (fig. 3a). In the mountainous areas, less productive fractured bedrock aquifers supply most water needed for domestic purposes.

In the plains of eastern Montana, aquifers occur in layers of sedimentary sandstone and limestone, as well as in Quaternary alluvium along major streams. The dense groupings of wells visible in figure 3a show the alluvial aquifers (for example, along the Missouri and Yellowstone River Valleys), but scattered well locations highlight bedrock aquifers such as the Fort Union aquifer. Generally, well yields from eastern Montana aquifers are lower than yields from the western basin-fill aquifers, but nevertheless, groundwater is highly utilized.

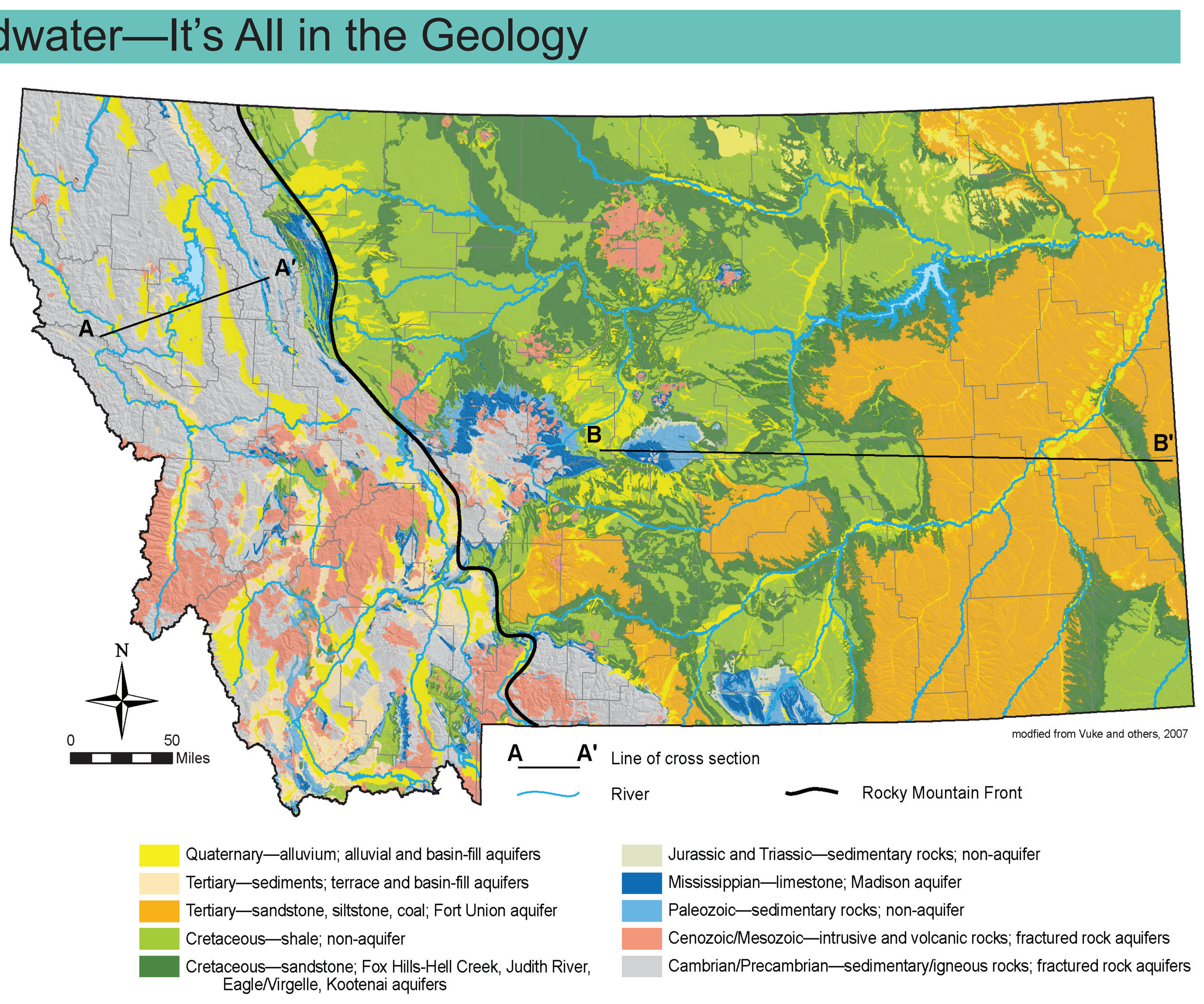

Figure 1. A generalized geologic map highlights the large geologic differences between eastern and western Montana. Cross sections along A–A' and B–B' further illustrate the differences by providing glimpses into subsurface structures that control how the surface geology appears. The subsurface geology also strongly controls groundwater flow within western Montana intermontane basins, and regionally through sandstone and coal aquifers in eastern Montana.

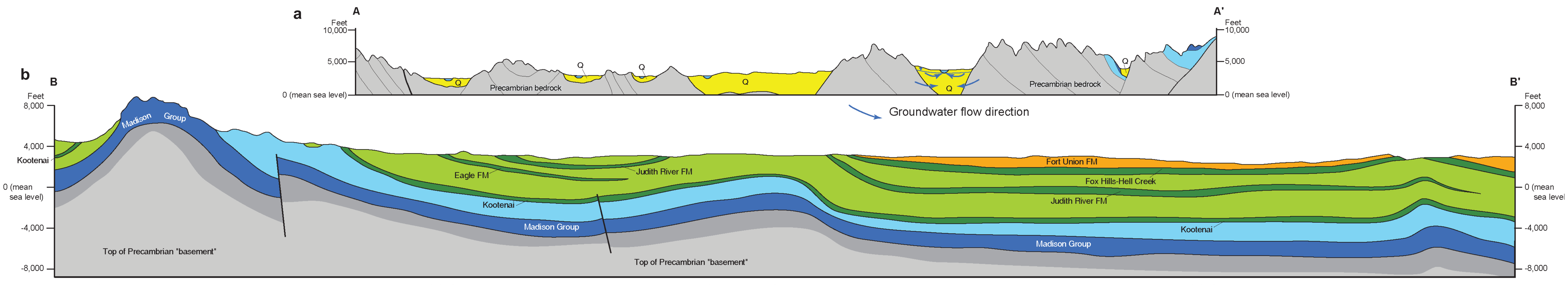

Figure 2. Generalized cross sections illustrating Montana geology. (a) Cross section A–A' illustrates the complexly folded and faulted geology that results in western Montana's intermontane basins. (b) Cross section B–B' shows eastern Montana's regional flat-lying aquifers and non-aquifers. Groundwater occurs in the Tertiary Fort Union Formation, Cretaceous sandstones (Fox Hills, Judith River, Kootenai, and Eagle Formations) and the Mississippian Madison Group.

Our Groundwater Resources

Groundwater Use and Wells

About 200,000 wells in Montana (fig. 3a) withdraw roughly 285 million gallons of groundwater per day for domestic, stock, industrial/commercial, irrigation, and public water supply uses (U.S. Geological Survey, 2014). Slightly more than 90 percent of wells provide water for domestic or stock use; less than 10 percent provide water for the other purposes. Although there are many more domestic and stock-water wells, they account for only 12 percent of the annual groundwater withdrawals. Irrigation, public water supply, and industrial wells—a small percentage of the total wells—account for 88 percent of withdrawals (figs. 3b, 3c).

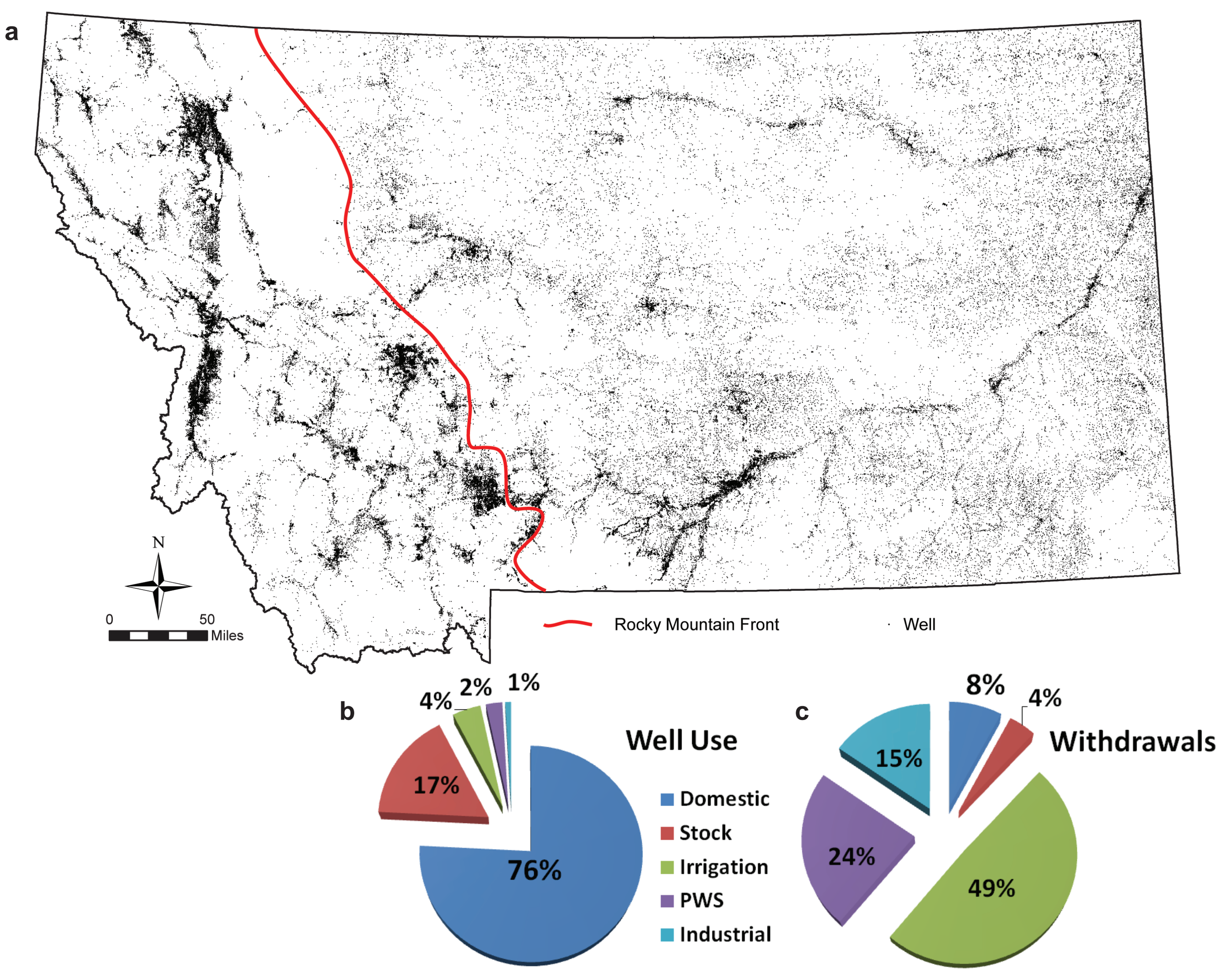

Figure 3. (a) The distribution of water wells reflects Montana's geology and, because so many of Montana's citizens rely on groundwater, the population distribution. In western Montana, wells are concentrated in the valleys and produce water from: (1) near-surface aquifers in sand and gravel and (2) deep confined to semi-confined aquifers in basin-fill. In eastern Montana, wells obtain water from layers of sandstone, coal, and limestone. Linear groups of wells show where aquifers within sand and gravel line the major stream valleys. (b) Most Montana wells provide water for domestic and stock use. (c) The largest annual withdrawals are for irrigation and public water supply.

Surface-Water/Groundwater Interaction

Groundwater and surface water interact so completely that they are essentially one resource. Because groundwater withdrawals were historically minor relative to surface-water use (only about 3 percent of water withdrawals are from aquifers), interconnection between surface water and groundwater did not previously present widespread management challenges. However, basin closures, drought, and escalating demand have resulted in increased groundwater development and increased recognition of how development can impact stream flow.

Effective water management requires a quantitative understanding of surface-water/groundwater interaction. Depending on the local hydrogeology, land use, distance from the stream, and scale of development, stream/aquifer interactions can be technically challenging to quantify, and impacts from proposed new groundwater withdrawals can be difficult to accurately predict.

Computer-based groundwater flow models (fig. 5) provide one tool to help managers predict how hydrologic systems (surface-water/groundwater together) respond to long-term factors such as changing land use, variable climate, and increasing groundwater withdrawal.

Acknowledgements

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References

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Vuke, S.M., Porter, K.W., Lonn, J.D., and Lopez, D.A., 2007, Geologic Map of Montana: Montana Bureau of Mines and Geology Geologic Map 62, 73 p., 2 sheets, scale 1:500,000.

The Montana Bureau of Mines and Geology plays a leading role in collecting and disseminating information about Montana's groundwater. Through its Geologic Mapping, Ground Water Assessment, Ground Water Investigations, Coal Hydrology, and Environmental Hydrogeology programs, the MBMG develops the essential information necessary for responsible and sustainable groundwater development. All of the MBMG's groundwater data are accessible through its Ground Water Information Center online database (http://mbmggwic.mtech.edu).

Tracking Montana's Groundwater Resources

Since 1993, the MBMG has been collecting systematic groundwater-level data from a 900-well statewide network (fig. 4); some wells have been regularly monitored since the 1950s. The network covers the State's major aquifers and includes wells that range from <10 feet to >3,600 feet deep.

Water levels in many Montana aquifers follow natural seasonal patterns, typically rising each spring and early summer in response to snowmelt, precipitation, and run-off. Water levels decline during the late summer and fall because of decreased recharge coupled with storage loss to streams, wells, and plants. In addition to the seasonal response, hydrogeologists have long recognized that water levels respond to other stresses such as pumping (response may occur in hours or days), climate variability or drought (response may occur in years to decades), and widespread development (response occurs at varying time scales). Montana's long-term network is beginning to show where and which aquifers are impacted by these different stresses (fig. 4), highlighting the value of long-term, decadal-length records. Without continued monitoring, Montanans would have no data about these important issues.

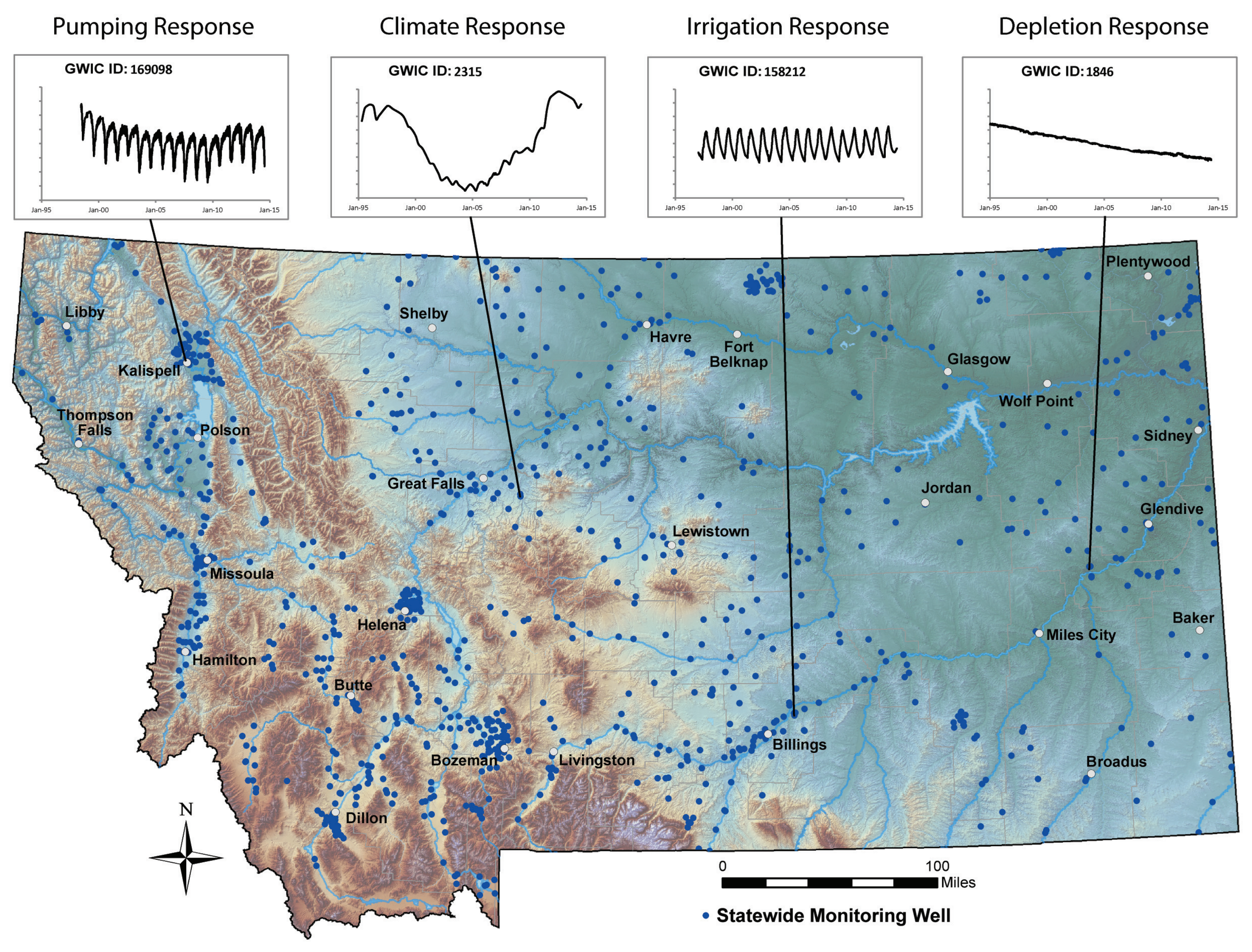

Figure 4. Groundwater levels are tracked in more than 900 wells across the State. Aquifers respond differently to differences in recharge, development, and land use. Systematic long-term water-level measurements provide a basis to assess groundwater storage changes and how different stresses may impact aquifer systems.

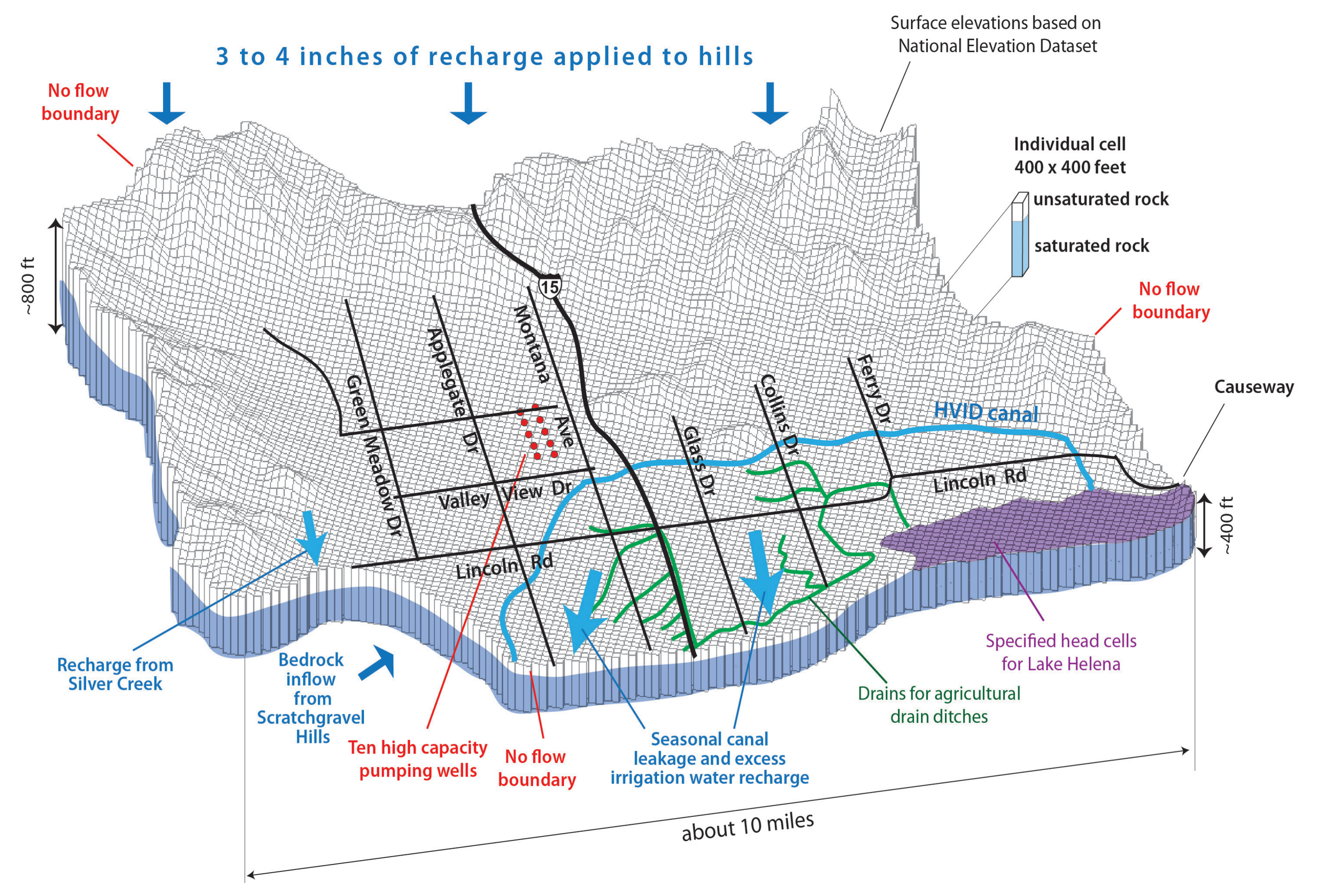

Figure 5. A conceptual view of a groundwater flow model for the North Hills area in the Helena Valley shows some of the factors hydrogeologists must relate to each other when trying to understand groundwater flow and how development or other factors play into aquifer performance.

Montana Bureau of Mines and Geology

Montana Tech of The University of Montana

Scope and Organization

The Montana Bureau of Mines and Geology (MBMG) was established in 1919 as a non-regulatory public service and research agency for the State of Montana, to conduct and publish investigations of Montana geology, including mineral and fuel resources, geologic mapping, and groundwater quality and quantity. In accordance with the enabling act, the MBMG conducts research and provides information.

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