

**Montana Ground-Water Assessment Atlas No. 1, Part B, Map 8**  
**October 1998**  
**Revision 1 - Dec. 16, 1998**

**Montana Bureau of Mines and Geology**  
**A Department of Montana Tech of The University of Montana**

**Dissolved Constituents\* Map for the Shallow Hydrologic Unit,  
Lower Yellowstone River Area: Dawson, Fallon, Prairie, Richland,  
and Wibaux Counties, Montana**

**by**



**John I. LaFave and Thomas W. Patton**

Note - this map was originally published at a scale of 1:250,000 but the page sizes have been modified to fit the size of the paper in your printer. A full sized 36" X 45" colored print of this map can be ordered from the Office of Publications and Sales of the Montana Bureau of Mines and Geology, 1300 West Park Street, Butte, MT 59701.



Phone: 406-496-4167      E-mail: <http://mbmgsun.mtech.edu>

Explanation



Well sampled for this study:

-  Dissolved constituents < 2,000 mg/L
-  Dissolved constituents > 2,000 mg/L











Well with historic water analysis:

-  Dissolved constituents < 2,000 mg/L
-  Dissolved constituents > 2,000 mg/L

Inventoried well used to estimate dissolved-constituents concentration from specific conductance:

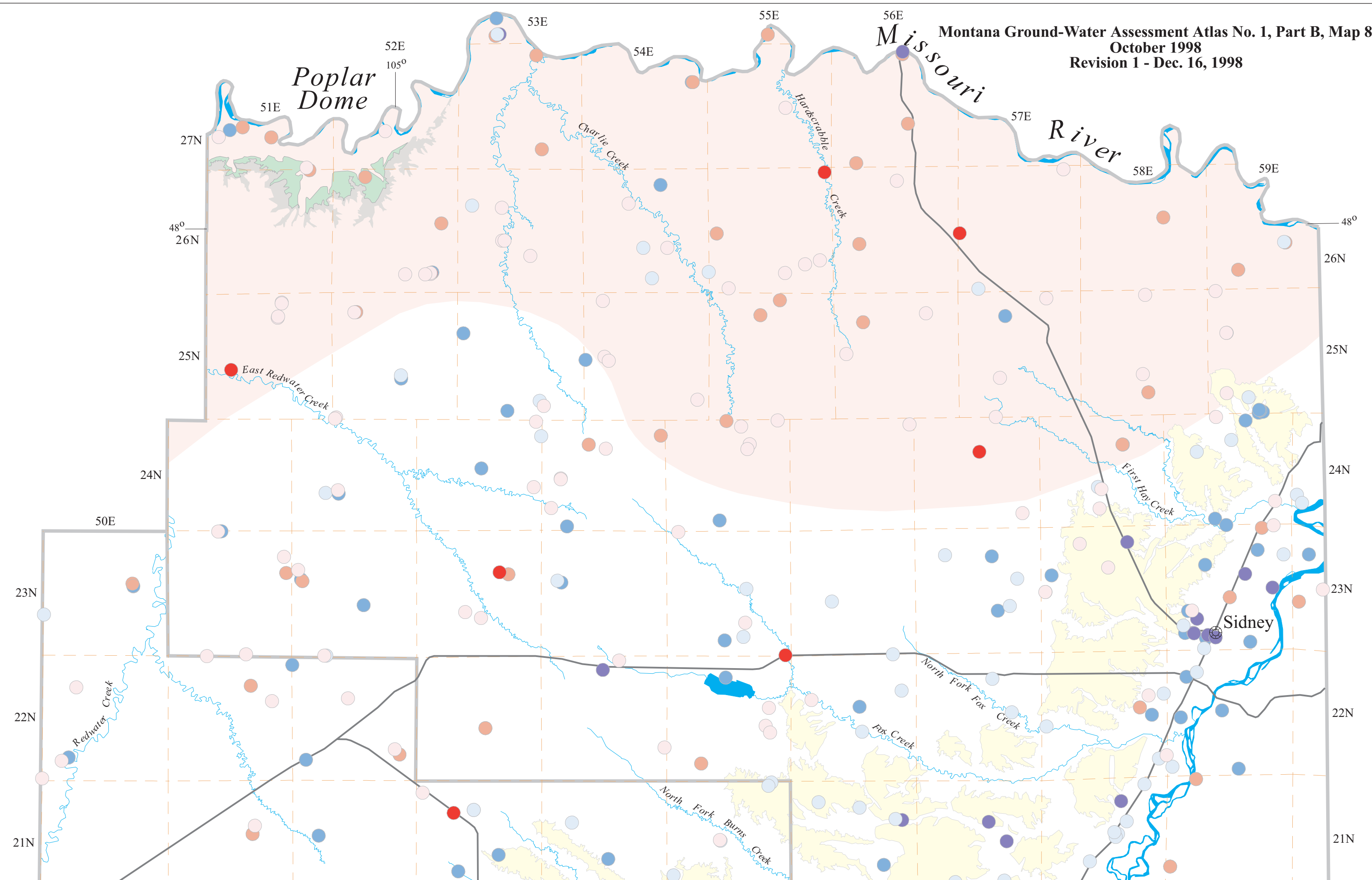
-  Estimated dissolved constituents < 2,000 mg/L
-  Estimated dissolved constituents > 2,000 mg/L

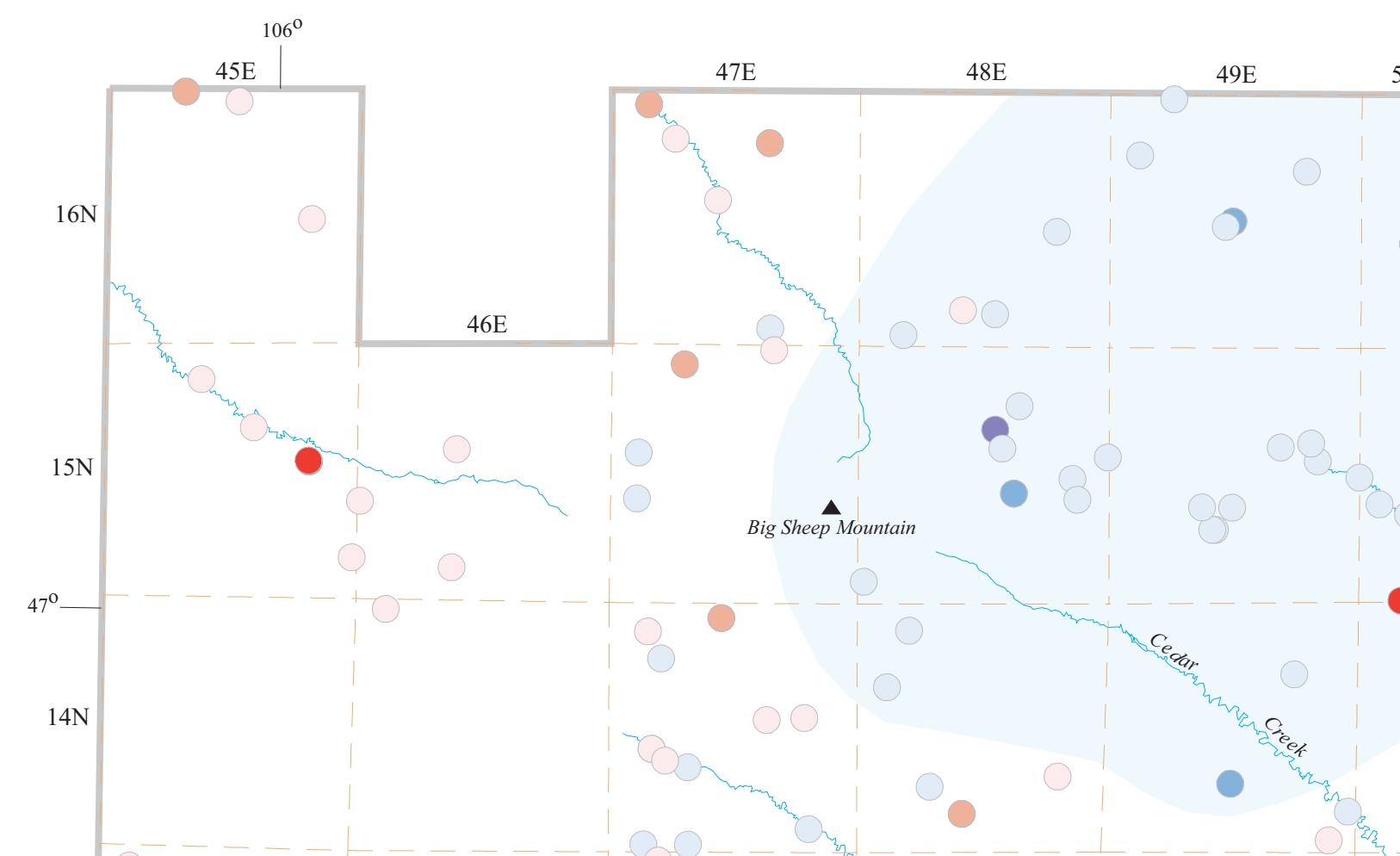
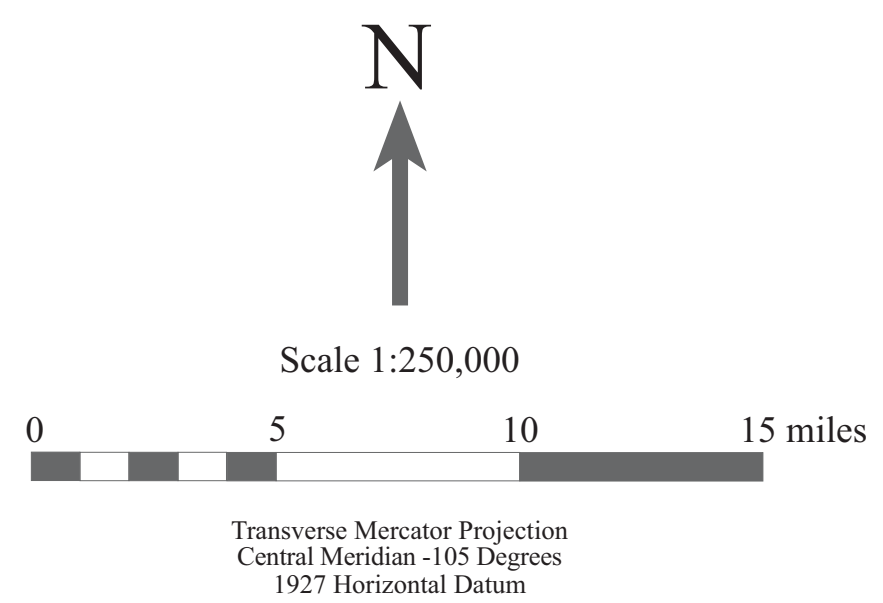
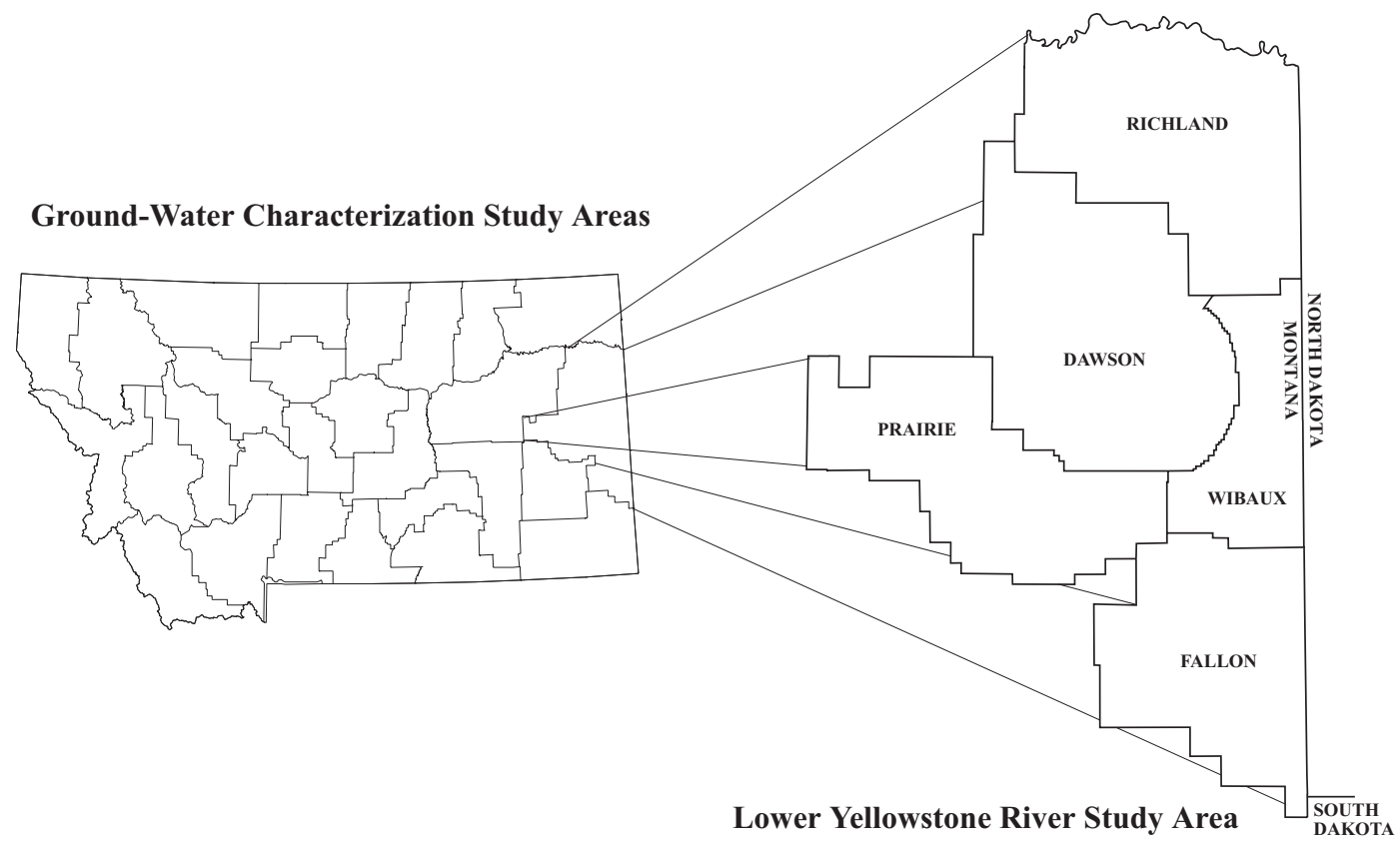
Note: Dissolved constituents are expressed as the sum of major cations and anions in mg/L and includes all reported bicarbonate.

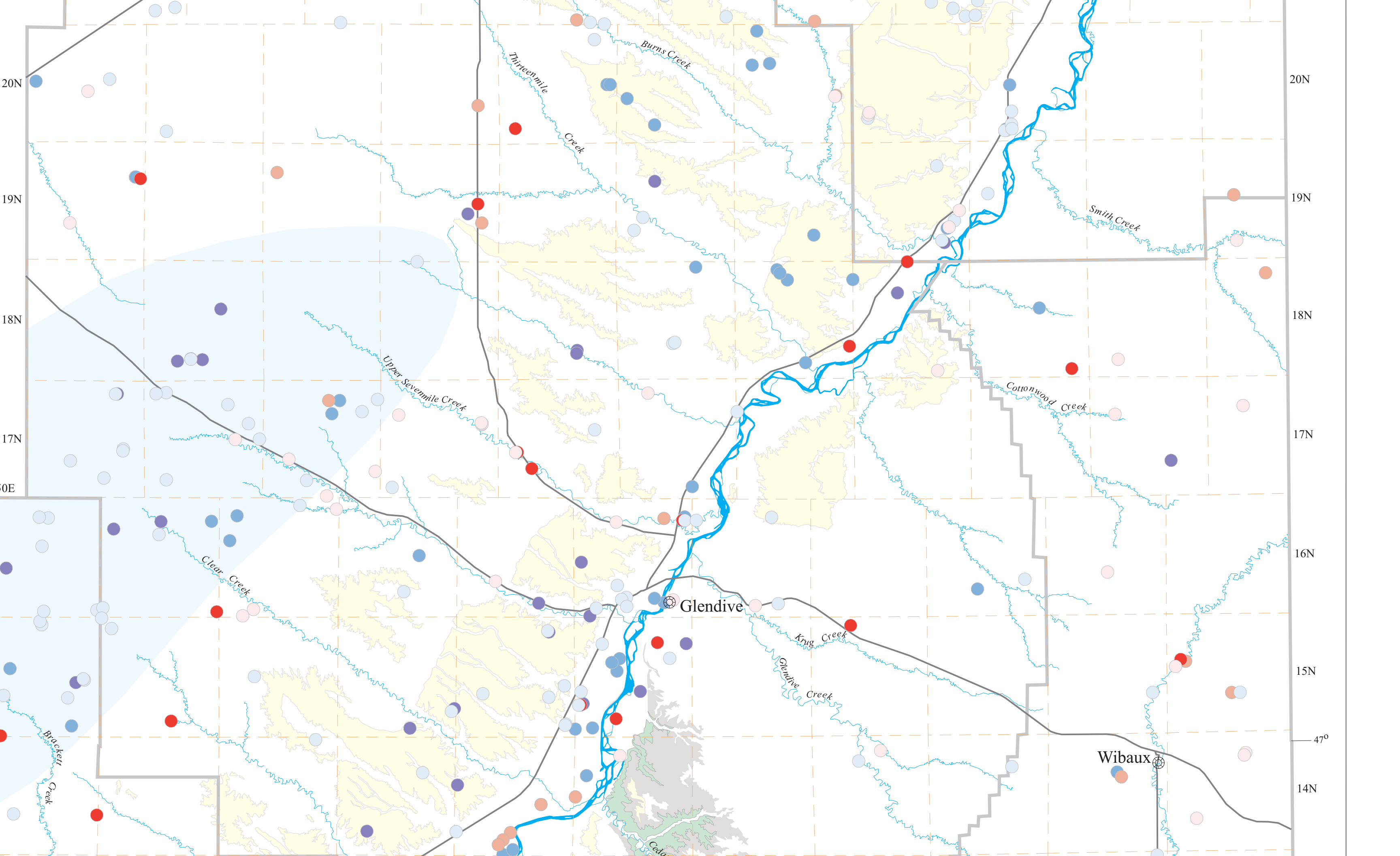
-  Area where dissolved-constituents concentrations are generally less than 2,000 mg/L
-  Area where dissolved-constituents concentrations are generally greater than 2,000 mg/L
-  Upland sand and gravel terrace
-  County boundary
-  Township boundary
-  County seat
-  Major road
-  Principal stream
-  Outcrop of the Pierre Shale
-  Outcrop of the Fox Hills Formation

**Author’s Note:** This map is part of the Montana Bureau of Mines and Geology (MBMG) Ground-Water Assessment Atlas for the Lower Yellowstone River Area ground-water characterization. It is intended to stand alone and describe a single hydrogeologic aspect of the study area, although many of the area’s hydrogeologic features are interrelated. For an integrated view of the hydrogeology of the Lower Yellowstone River Area the reader is referred to Part A (descriptive overview) and Part B (maps) of the Montana Ground-Water Assessment Atlas No. 1.

Geographic information system production by Joel Hall and Larry Smith. Digital cartography by Don Mason.









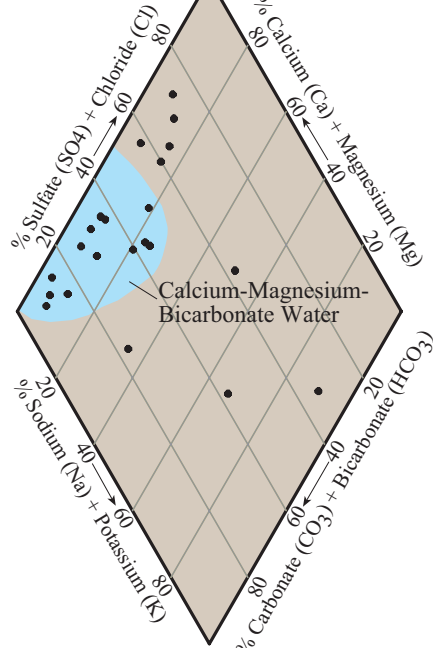


Figure 1. Ground water sampled from the Big Sheep Mountain area is predominately a calcium-magnesium-bicarbonate-type; there is little sodium or chloride, but sulfate predominates in a few samples.

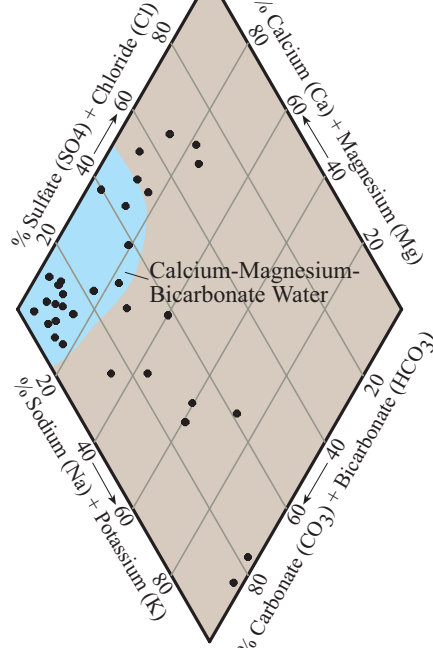


Figure 2. Ground water sampled from below the upland sand and gravel terraces is predominately a calcium-magnesium-bicarbonate-type; there is little sodium or chloride, but sulfate predominates in a few samples.

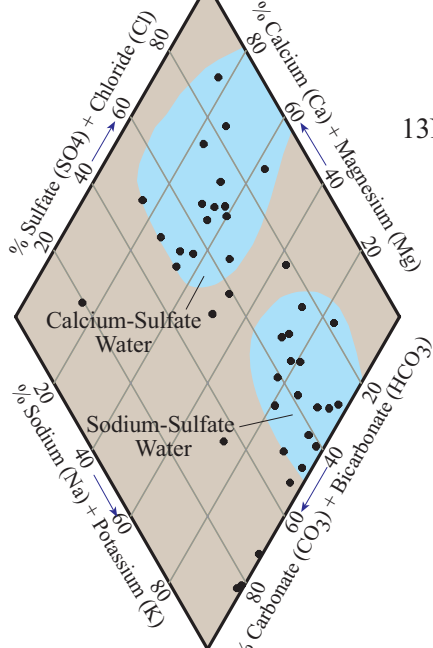
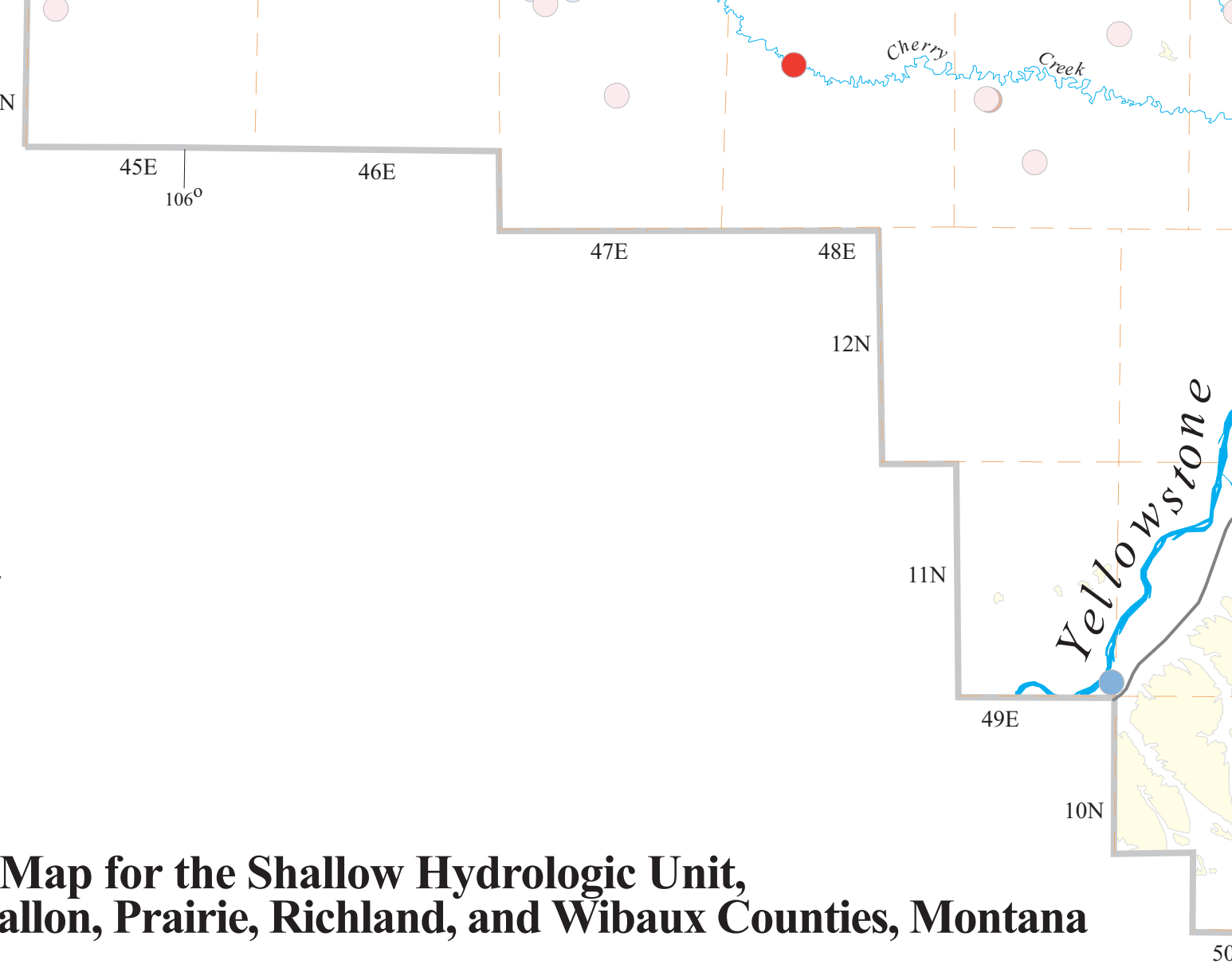


Figure 3. Ground water in the northern part of the study (red color on map) is a sodium- or calcium-sulfate-type; there is little bicarbonate.



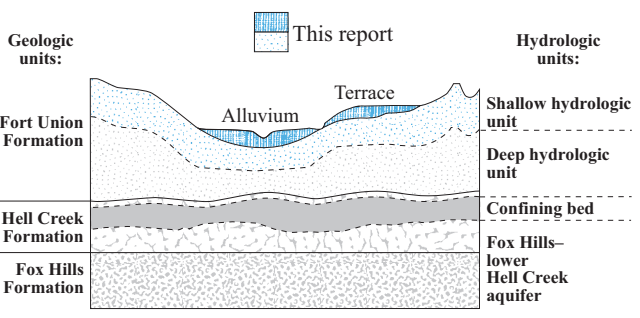
# Dissolved Constituents\* Map for the Shallow Hydrologic Unit, Lower Yellowstone River Area: Dawson, Fallon, Prairie, Richland, and Wibaux Counties, Montana

by

John I. LaFave and Thomas W. Patton

## Introduction

The purpose of this map is to show the distribution of dissolved constituents in the ground water of the Shallow Hydrologic Unit (SHU) in the Lower Yellowstone River study area. The unit consists of all aquifers and non-aquifers within 200 feet of the land surface, exclusive of the Fox Hills-lower Hell Creek aquifer.



Aquifers are saturated geologic materials that yield sufficient water to supply wells and springs. Non-aquifer materials also may be saturated but have low permeability and do not produce usable amounts of water to wells or

or the U.S. Geological Survey prior to this study were also used. These laboratory data were supplemented by estimated dissolved-constituents concentrations derived from field measurements of specific conductance from an additional 424 inventoried wells. The laboratory analyses and field measurements presented on this map are available from the Montana Ground-Water Information Center data base.

## Ground-Water Quality

### Dissolved Constituents

Water may be characterized by the type and concentration of its dissolved constituents. The dissolved-constituents value is the sum of the major cations (Na, Ca, K, Mg, Mn, Fe) and anions ( $\text{HCO}_3$ ,  $\text{CO}_3$ ,  $\text{SO}_4$ , Cl,  $\text{SiO}_3$ ,  $\text{NO}_3$ , F) expressed in milligrams per liter (mg/L). This map shows the general distribution of dissolved constituents in the shallow hydrologic unit based on chemical analyses of ground-water samples and field measurements of specific conductance.

The concentration of dissolved constituents provides a general indicator of water quality. Typically, water does not

Ground water beneath the localized occurrences of upland terraces along the Yellowstone River valley also has low concentrations of dissolved constituents and a chemical composition similar to that in the Big Sheep Mountain Area. The terraces (indicated on the map with yellow shading), which stand 10s to 100s of feet in altitude above the modern Yellowstone valley floor, are composed mostly of unconsolidated sand and gravel that may be as much as 130 feet thick (Smith 1998). North of Township 16 North, the terraces may be capped by a silty glacial till that is generally less than 5 feet thick. The sand and gravel terrace deposits have greater permeability and porosity than the underlying sandstones and mudstones of the Fort Union and Hell Creek formations, and represent important recharge areas where water can move easily from the land surface downward to the water table. Also, the sand and gravel that compose the terraces are, in general, less chemically reactive than the surrounding bedrock. This is reflected in the water chemistry; the median concentration of dissolved constituents from 33 samples obtained below the upland terraces is 800 mg/L, and the water is a calcium-magnesium-bicarbonate type (see previous illustration and figure 2).

In contrast, ground water in the northern part of the study area, close to the Missouri River, is more mineralized and has a different chemical signature. In the area shaded red on

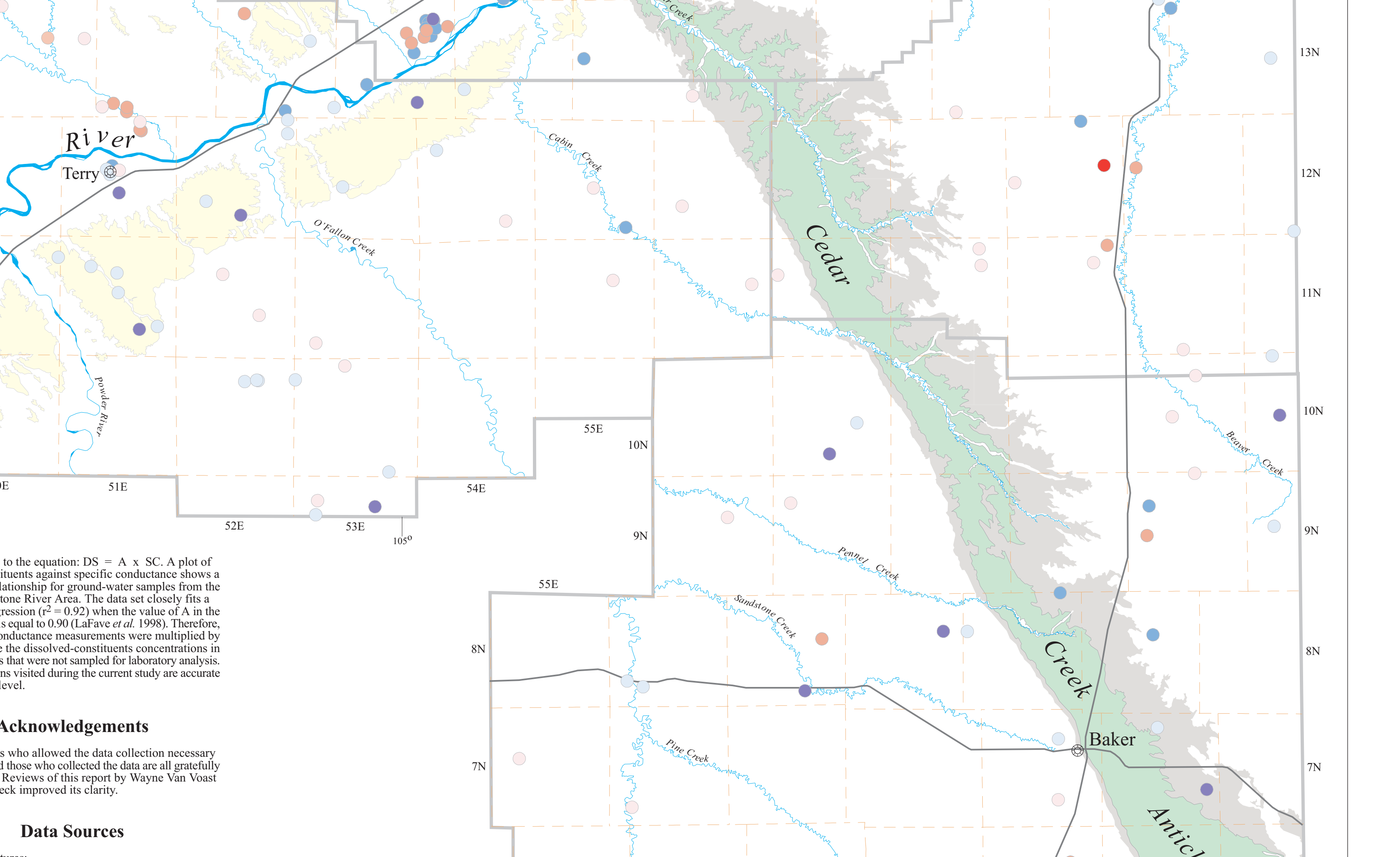
ranged from non-detectable (57 samples) to 44.5 mg/L-N. Nitrate is an essential nutrient for plant life, yet it is a potentially toxic pollutant when present in drinking water at excessive concentrations. Pregnant women and infants less than one year of age, are most at risk for nitrate poisoning if they ingest water, or formula prepared with water, having nitrate concentrations in excess of 10 mg/L-N. Nitrate poisoning can result in methemoglobinemia, or blue-baby syndrome, in which the ability of the baby's blood supply to carry oxygen is reduced to the point that suffocation can occur. Nitrate has natural as well as human-related sources. However, where nitrate contamination of ground water has been identified, it is usually related to a known or suspected nitrogen source (Madison and Brunett 1984). Significant human sources of nitrate include septic systems, agricultural activities (fertilizers, irrigation, dry land farming, livestock wastes), land disposal of wastes, and industrial wastes. Natural sources of nitrate include fixation of nitrogen in the soil and nitrogen-rich geologic deposits (generally shales). Nitrate enters the ground water system by leaching of surface or near-surface sources. Aquifers close to the land surface may lack protective overlying low-permeability materials and are susceptible to contamination from surface sources. The open intervals in all wells that had nitrate concentrations above the recommended limits were within 70 feet of the land surface.

(DS) according to dissolved constituents. The map shows well-defined recharge areas. The Lower Yellowstone River valley is a straight-line recharge area above equation 1. The field specific-conductance is 0.90 to estimate the water from wells.

Well location to the 2.5-acre 1

Well owner for this map, and acknowledged. and Peter Norb

Geographic





springs. The aquifers vary in thickness and are laterally and vertically discontinuous over distances of 10s to 100s of feet where they are separated by non-aquifer materials or by topography. The bottom of the SHU is not defined by a continuous geologic or hydrologic marker but is transitional with the underlying Deep Hydrologic Unit (DHU) (LaFave 1998). Differentiating the two units simplifies hydrogeologic interpretations given the scale of this investigation and the available data. Differences in water quality and ground-water flow were used to justify separating the units at about 200 feet below the land surface.

Geologic deposits that generally are aquifers when saturated with water include the following:

- Sand and gravel deposits in the flood plain, low-lying benches, and terraces adjacent to and along the Yellowstone and Missouri rivers and their tributaries;
- Sandstone, clinker, and coal of the Fort Union Formation; and
- Sandstone in the upper Hell Creek Formation.

Non-aquifer materials are as follows:

- Glacial till and glacial lake-bed deposits in the northern part of the area;
- Silt and clay deposits within the flood plain and low-lying benches of the Yellowstone and Missouri rivers and their tributaries; and
- Shale of the Fort Union Formation.

Although the SHU consists of a variable sequence of aquifers and non-aquifers, there is sufficient hydraulic continuity to consider it a single entity in terms of ground-water flow.

Records in the Montana Bureau of Mines and Geology’s (MBMG) Ground-Water Information Center data base show that almost 7,400 wells (about 70% of total wells) obtain water from the SHU, making it the most utilized ground-water source in the study area. Of these wells, about 4,700 (65%) are completed within 100 feet of the land surface. Reported well yields are variable, reflecting the variable nature of the aquifers. In the sand and gravel aquifers, yields average about 35 gallons per minute (gpm). However, yields from aquifers in the Fort Union and Hell Creek formations average about 10 gpm. Reported water-level altitudes range between 58 feet above land surface and 180 feet below land surface.

## Sample Sites and Water-Quality Data

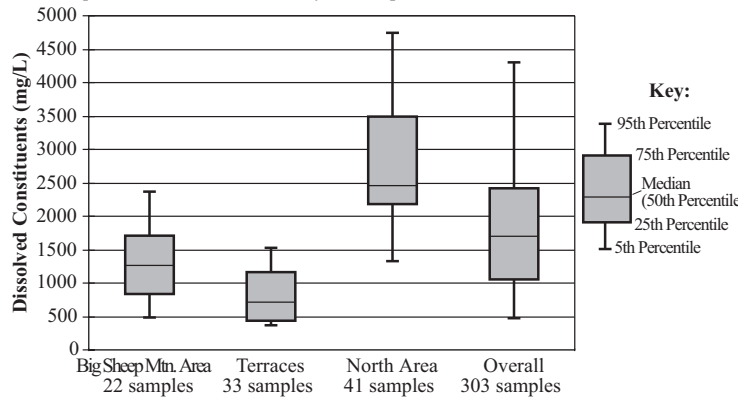
Three sets of data on dissolved constituents in ground water are presented: laboratory analyses obtained as part of this study, laboratory analyses from earlier studies, and values estimated from field data. Water from 90 domestic, stock, public supply and monitoring wells was analyzed for major ions and trace metals between September 1994 and May 1996. Field measurements of specific conductance, pH, and water temperature also were obtained from each of the sampled wells. To ensure collection of a representative sample, each well was pumped prior to sample collection until the field parameters stabilized and at least three well-casing volumes were removed. Analyses were performed by the MBMG Analytical Laboratory. In addition to the samples collected for this study, 213 ground-water samples collected by MBMG

has a different chemical signature. Typically, water does not become too salty to drink until the concentration of dissolved constituents reaches about 2,000 mg/L. Therefore for this map, a dissolved-constituents concentration of 2,000 mg/L was used to differentiate between water having low-dissolved constituents (blue symbols) and that having high-dissolved constituents (red symbols). Most ground water in the Lower Yellowstone River Study Area has relatively high concentrations of dissolved constituents; of the 303 ground-water analyses used in this study the median was about 1,670 mg/L.

The concentration of dissolved constituents in ground water is a result of the initial chemistry of the recharge water and the subsequent interactions with soils and aquifer materials. As water moves through an aquifer from areas of recharge to areas of discharge, the concentration of dissolved constituents generally increases. Additionally, the type (cations and anions) of constituents dissolved in the ground water will be controlled by the length of time that the water has been in the subsurface, the composition of the aquifer materials, and the controlling geochemical reactions (primarily dissolution, precipitation, oxidation-reduction, and ion-exchange). Concentrations of dissolved constituents in the shallow unit are highly variable, ranging in 303 samples from about 500 to more than 5,000 mg/L (see Table 1). The wide range in dissolved constituents reflects the variable mineralogic composition of the aquifers, different recharge sources, and variable residence times within the geologic materials.

Despite the range of dissolved constituents, there are some general patterns in the regional distribution of water quality. Ground-water recharge areas generally have “fresh” water (low dissolved constituents) with distinct ground-water chemistry (signatures). Ground water to the northeast of Big Sheep Mountain in northern Prairie and western Dawson counties, is generally low-dissolved constituents water (< 2,000 mg/L); the median dissolved-constituents concentration from 22 analyses is 1,280 mg/L. This area (blue shading on the map) represents a recharge area for the shallow flow system with relatively high water-table altitudes—greater than 2,800 feet (Patton *et al.* 1998).

**Note:** 95% of the samples in each set had concentrations less than or equal to the values indicated by the 95th percentiles. Five percent of each sample set had concentrations less than or equal to the values indicated by the 5th percentiles.



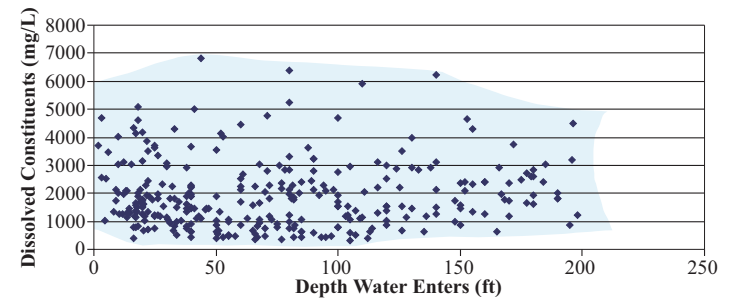
A trilinear diagram of the ground-water analyses from the Big Sheep Mountain Area (figure 1) shows that the dominant ions in solution are calcium, magnesium, and bicarbonate. The low concentration of dissolved constituents and the calcium-magnesium-bicarbonate signature indicates that the water has been in the ground-water system a relatively short period of time and, therefore, has had less time to dissolve and react with aquifer materials.

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Across the study area, most of the variability in the dissolved-constituents concentration occurs near the surface (upper 150 ft); however, there is a slight increasing trend in the dissolved constituents with depth. The high concentration of dissolved constituents in shallow wells reflects the variability of the near surface geologic materials, recharge from more mineralized bedrock sources, and in places near the Yellowstone River, irrigation return flows.



## Major Ions and Suitability for Water Use

Table 1 summarizes the results of 90 ground-water analyses performed as part of this study. For reference, the U.S. Environmental Protection Agency’s recommended maximum contaminant levels and secondary maximum contaminant levels for public water supplies are also presented. Constituents for which maximum levels have been set may pose a health threat at elevated concentrations. Secondary levels are set for aesthetic reasons—elevated concentrations of these constituents may be a nuisance (bad taste or odor, or staining) but do not normally pose a health risk.

Despite the relatively high concentration of dissolved constituents (average = 1,700 mg/L), ground water from the SHU is generally suitable for domestic and stock consumption. Recommended maximum levels were exceeded in some samples for nitrate, while nuisance levels of total dissolved solids, sulfate, sodium, iron, and manganese were common.

Although most samples did not contain detectable levels of nitrate, the maximum contaminant level of 10 mg/L-N was exceeded in 8 of the samples (about 9%). The concentrations

within 70 feet the land surface.

Sulfate is a natural constituent in eastern Montana ground water, especially in the bedrock aquifers of the Fort Union Formation. Dissolved sulfate is derived from the oxidation of pyrite in shales and coal common in the Fort Union and Hell Creek formations, and the dissolution of gypsum (CaSO<sub>4</sub>). Excessive sulfate can produce a laxative effect and in combination with other ions, give water a bitter taste. Ground water from aquifers with high sulfate concentrations may also have a “rotten egg” smell due to hydrogen sulfide (H<sub>2</sub>S) gas, which is formed by the bacterial reduction of sulfate in ground water. Hydrogen sulfide can corrode iron and steel and form ferrous sulfide or “black water.”

High concentrations of sodium may give water a salty taste, but for most other domestic purposes has little effect on the water use. Ion exchange reactions within aquifers are an important source of sodium in eastern Montana ground water. Clays interbedded in the aquifer material act as a natural water softener, removing calcium and magnesium from solution and exchanging it for sodium. Commonly, elevated concentrations of sodium are associated with low concentrations of calcium and magnesium. Sodium salts may cause foaming in boilers and high sodium concentrations may limit use of water for irrigation by destroying soil structures and impairing plant growth. The sodium hazard for irrigation is measured by the sodium-adsorption ratio (SAR), which indicates the abundance of sodium relative to calcium and magnesium, and provides an indication of the suitability of water for irrigation use. High SAR values indicate a greater abundance of sodium relative to calcium and magnesium and indicate that the water may present a sodium hazard to soils. SAR values below 10 are desirable for irrigation waters. In the 90 samples analyzed as part of this study, SAR values ranged from less than 1 to 84 with a mean of 10; the SAR exceeded 10 in 19 of the samples.

Iron and manganese are essential to plants and animals, but may cause unpleasant taste, odors and staining of plumbing fixtures. The primary source of iron and manganese in ground water is dissolution of minerals in the bedrock. Iron concentrations in well water may also be elevated (increased) by corrosion of iron well casings and from bacterial activity in and around the well screen. About 40% of the samples had iron concentrations above the secondary level of 0.3 mg/L, and about 60% of the samples had manganese concentrations above the secondary level of 0.05 mg/L.

## Map Construction

This map was constructed by classifying concentrations of dissolved constituents of ground-water samples into low or high groupings. A concentration of 2,000 mg/L was used to differentiate between low- and high-dissolved constituents water because this is generally the upper limit of water potability. Three data sets are plotted on the map. More than 300 wells are shown from which samples were collected for laboratory analysis. Of these, 90 were sampled as part of this study between November 1994 and May 1996 and represent the primary data set; 213 wells sampled between 1947 and 1994 (161 were sampled since 1973) represent the historic data set. These analytical data were supplemented by estimates of dissolved constituent concentrations derived from specific-conductance measurements made at an additional 424 wells during the current study. These estimated values represent the inventory data set. The specific conductance (SC) measurements were used to estimate dissolved constituents

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on and water-quality data for the primary and sets were obtained by Ground-Water n Program personnel; well location and water- the historic data set was obtained from the l Survey or Montana Bureau of Mines and All data used on this map are available from er Information Center (GWIC) at the Montana s and Geology, Montana Tech of The University tte.

References:

nd Wilde, E. M. 1998a. The preliminary geologic map on 30 x 60-min. quadrangle, Montana. Montana Bureau Geology 359. Scale 1:100,000.

nd Wilde, E. M. 1998b. The preliminary geologic map int 30 x 60-min. quadrangle, Montana. Montana Bureau Geology 358. Scale 1:100,000.

e-Foster, S. M., and Fullerton, D. S. 1994. Preliminary of the Glendive 30 x 60-min. quadrangle: Montana es and Geology Open-file Report 276. Scale 1:100,000.

study and interpretation of the chemical characteristics er. U.S. Geological Survey Water Supply Paper 2254.

i. Potentiometric surface map for the Deep Hydrologic ellowstone River Area, Montana. Montana Bureau of ology Ground-Water Assessment Atlas No. 1, Part B, 1:250,000.

Brunett, O. J. 1984. Overview of the occurrence of and water of the United States, in National Water 4—Water-Quality Issues: U.S. Geological Survey Paper 2275, p. 93–103.

C., LaFave, J. I., and Smith, L. N. 1998. Potentiometric or the Shallow Hydrologic Unit, Lower Yellowstone ontana, MBMG Ground-Water Assessment Atlas No. o 5. Scale 1:250,000.

Thickness of unconsolidated deposits, Lower River Area: Dawson, Fallon, Prairie, Richland, and ies, Montana. Montana Bureau of Mines and Geology Assessment Atlas No. 1, Part B, Map 2. Scale 1:250,000.

Colton, R. B., Stickney, M. C., Wilde, E. M., Robocker, stensen, K. C. 1986. Geology of the Baker and Wibaux quadrangles, eastern Montana and adjacent North ana Bureau of Mines and Geology Geologic Map No. 00,000.

vuke-Foster, S. M. 1994. Preliminary geologic map of l x 2-degree quadrangle: Montana Bureau of Mines Open-File Report 295. Scale 1:250,000.

issolved constituents differ slightly from total dissolved constituents value is the sum of the major Mg, Mn, Fe) and anions (HCO<sub>3</sub>, CO<sub>3</sub>, SO<sub>4</sub>, Cl, SiO<sub>3</sub>, in milligram per liter (mg/L). TDS is traditionally hing residue remaining after evaporating a known estimated by summing the major ions after multiplying CO<sub>3</sub>) concentration by 0.49 to account for loss to the evaporation. For example, about half of the bicarbonate n is converted to carbon dioxide during evaporation; escapes to the atmosphere and does not appear in the isidue. Therefore, TDS calculations generally total dissolved-ion concentration in solution especially concentrations are high. A more accurate measure of nts is obtained by summing the concentrations reported solved constituents.

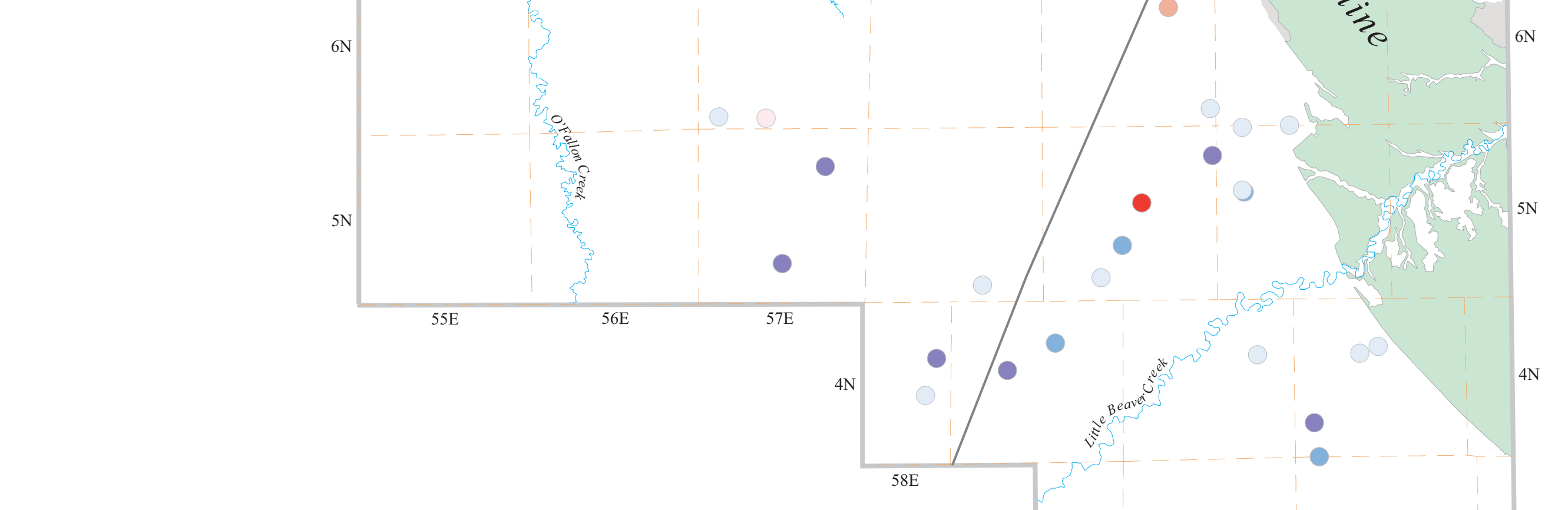


Table 1. Summary of water-quality data for wells sampled during this study in the Shallow Hydrologic Unit. Nuisance levels of total dissolved solids, sodium, sulfate, iron, and manganese are common. The recommended maximum levels for nitrate and fluoride were exceeded in some samples.

<u>Common Constituents</u>	<u>Number of Samples</u>	<u>Min</u>	<u>Mean</u>	<u>Max</u>	<u>SMCL</u>	<u>MCL</u>	<u>Number exceeding SMCL or MCL</u>
Dissolved Constituents—sum (mg/L)*	90	428	1713	5261	--	--	
Total Dissolved Solids (mg/L)**	90	283	1406	4942	500	--	75
Sodium (mg/L)	90	3.8	247	960	250	--	33
Potassium (mg/L)	90	1.1	5.7	19.2	--	--	--
Calcium (mg/L)	90	1.9	113	366	--	--	--
Magnesium (mg/L)	90	0.52	82.3	361	--	--	--
Chloride (mg/L)	90	0.5	19.1	178	250	--	0
Bicarbonate (mg/L)	90	229	605	1415	--	--	--
Carbonate (mg/L)	90	0	4.5	94.8	--	--	--
Sulfate (mg/L)	90	2.5	619	3150	250	--	58
Nitrate (mg/L as N)	90	<0.25	2.7	44.5	--	10	8
Fluoride (mg/L)	90	0.08	0.5	5	--	4	2
Iron (mg/L)	90	<0.003	0.9	8.5	0.3	--	38
Manganese (mg/L)	90	<0.002	0.2	1.7	0.05	--	53
<u>Selected Trace Elements</u>							
Arsenic (ug/L)	90	<1.0	1.8	23.1	--	50	0
Barium (ug/L)	90	4.5	48.3	794	--	1000	0
Chromium (ug/L)	90	<2.0	3.9	43.0	--	100	0
Copper (ug/L)	90	<2.0	4.0	26.8	--	1000	0
Nickel (ug/L)	90	<2.0	4.3	61.6	--	100	0
Selenium (ug/L)	90	<1.0	4.2	83.7	--	50	1
<u>Other Constituents</u>							
Sodium Adsorption Ratio (SAR)	90	0.1	10.4	83.8	--	--	--
Hardness as CaCO <sub>3</sub>	90	7.6	621	2289	--	--	--
pH	90	6.9	7.6	8.9	6.5 - 8.5	--	8

'--', No standard available or not applicable  
SMCL - U.S. EPA Secondary maximum contaminant level for public water supplies  
MCL - U.S. EPA Maximum contaminant level for public water supplies  
\* Dissolved Constituents is the sum of major cations (Na, Ca, K, Mg, MN, Fe) and anions (HCO<sub>3</sub>, CO<sub>3</sub>, SO<sub>4</sub>, Cl, SiO<sub>3</sub>, NO<sub>3</sub>, F) in mg/L.  
\*\*Total dissolved solids reported as equivalent to weight of evaporation residue.