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

by

John I. LaFave

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

Inventoryed 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 greater than 2,000 mg/L

 County boundary
 Township boundary
 County seat
 Major road
 Principal stream

Outcrop and subcrop 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.
Introduction

The purpose of this map is to show the distribution of dissolved constituents in the ground water of the Deep Hydrologic Unit (DHU). The unit is defined as all aquifers and non-aquifers that occur at depths greater than 200 feet below land surface and lie stratigraphically above the regionally extensive claystone and shale in the upper Hell Creek Formation. The DHU encompasses mostly the lower part of the Fort Union Formation and, in places, the upper part of the Hell Creek Formation. The Fort Union and upper Hell Creek formations are a complex sequence of aquifer and non-aquifer materials.

Dissolved Constituents

Constituents concentrations derived from field measurements of specific conductance from an additional 112 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

Ground water sampled from the Deep Hydrologic Unit is predominately a sodium-sulfate or sodium-bicarbonate-type water; in most samples there was relatively little calcium, magnesium, or chloride.

Ground water sampled from north and northeast part of the study area (shaded red on the map) is predominately a sodium-sulfate or sodium-bicarbonate-type water; there is very little calcium or magnesium.

Ground water in the area south of the Yellowstone River, west of the Cedar Creek Anticline, and around Glendale is predominately a sodium-bicarbonate-type water.

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constituents to other calcium salts—gypsum (CaSO₄) and calcite (CaCO₃)—allowing them to continue to be dissolved. Dissolution of these minerals, which are common in the Fort Union Formation, brings more sulfate and bicarbonate, respectively, into solution. Sulfate is also derived from the oxidation of sulfide minerals present in the Fort Union Formation. The area shaded red on the map coincides with low water-table altitudes in the deep ground-water flow system and represents a ground-water discharge area. Typically, water in the discharge area will have a relatively higher degree of mineralization (higher dissolved constituents) than water in the rest of the aquifer (Fetter 1994).

The areas with the lower concentrations of dissolved constituents are south of the Yellowstone River, west of the Fort Union Formation, and primarily of the upper Hell Creek Formation. The low concentrations of dissolved constituents in the area above the Yellowstone River are likely due to less mixing, and combination with other ions, give water a bitter taste. Ground water from aquifers with high sulfate concentrations may also have a “rotten egg” odor due to hydrogen sulfide (H₂S) 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.”

A high concentration 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
Acknowledgements

Well owners who allowed collection of the data necessary to make this map, and the people who collected the data are all gratefully acknowledged. Reviews of this report by Wayne Voast, Jon Reiten, and Bob Bergantino improved its quality.

Data Sources

Map source: [Map Source]
Water may be characterized by the type and concentration of dissolved constituents. The concentration of dissolved constituents is the sum of the major cations (Na, Ca, K, Mg, Mn, Fe) and anions (HCO₃, SO₄, CO₃, CI, SO₄, NO₃, F) expressed in milligrams per liter (mg/L). This analysis shows the general distribution of dissolved constituents in the deep basin 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 become too salty to drink until the dissolved constituents reach about 2,000 mg/L. Therefore, for this map a dissolved-constituents concentration of 2,000 mg/L was used as a red line between water having low-dissolved constituents (blue symbols) and that having high-dissolved constituents (red symbols). Most ground water in the Lower Yellowstone River area has relatively high concentrations of dissolved constituents, of the 83 ground-water analyses used in this study, the average was about 2,100 mg/L for the sample sites and 900 wells are completed in the DHU and composed, approximately 12% of all wells in the area. Ground water from the deeper data sets were used to justify sampling the units at 200 feet below land surface. Most reported well yields are less than 15 gallons per minute.

### Sample Sites and Water-Quality Data

Three sets of data on dissolved constituents in ground water are presented on the map: laboratory analyses obtained as part of this study, laboratory analyses from earlier studies, and water-quality data obtained from 28 domestic, stock, and monitoring wells were analyzed for major ions and trace metals between April 1995 and October 1995 for the sampling sites. Although the water chemistry was uniform throughout the area, the data were limited in extent and at least three-well-casing volumes were removed. Analyses were performed by the Montana Bureau of Mines and Geology (MBMG) Chemical Laboratory.

In addition to the samples collected for this study, 55 ground-water samples collected by the MBMG or the U.S. Geological Survey prior to this study were also used. These laboratory data were supplemented by estimated dissolved-

Cedar Creek, Antelope, and around Glacier. Although data are sparse, they show that the dissolved constituents content in these areas is generally less than 2,400 mg/L; the average concentration from 18 samples is 1,350 mg/L (see previous illustration). The lower concentrations (less than 2,000 mg/L) indicate that the dominant ions in solution with minor amounts of sulfur (figure 3). There are no clear trends with respect to the vertical distribution of dissolved constituents because no specific conductance data were available for all the samples. Most of the variability in the dissolved-constituents concentration occurs in the upper two hundred feet of the unit (200 ft below land surface); there is no noticeable increasing trend in the dissolved constituents concentration with depth.

### 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 concentrations because this is generally the upper limit of water potability. Three classes were used, with less than 200 mg/L representing the primary data set; 200-500 mg/L representing the secondary data set, and geological setting of the sample well. For these analyses, the maps have been separated into areas with high and low concentrations above the secondary level of 0.3 mg/L, and about 25% of the samples had manganese concentrations above the secondary level of 0.05 mg/L.
References


Table 1. Summary of water-quality data for wells sampled during this study in the Deep Hydrologic Unit. Nuisance levels of total dissolved solids, sodium, sulfate, iron, and manganese are common. The recommended maximum level for fluoride was exceeded in 3 samples.

<table>
<thead>
<tr>
<th>Common Constituents</th>
<th>Number of Samples</th>
<th>Min</th>
<th>Mean</th>
<th>Max</th>
<th>SMCL</th>
<th>MCL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved Solids (mg/L)</td>
<td>28</td>
<td>553</td>
<td>1625</td>
<td>3192</td>
<td>500</td>
<td>28</td>
</tr>
<tr>
<td>Sodium (mg/L)</td>
<td>28</td>
<td>37</td>
<td>506</td>
<td>1104</td>
<td>250</td>
<td>28</td>
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<tr>
<td>Potassium (mg/L)</td>
<td>28</td>
<td>0.5</td>
<td>10.0</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Calcium (mg/L)</td>
<td>28</td>
<td>0.7</td>
<td>45.6</td>
<td>262</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Magnesium (mg/L)</td>
<td>28</td>
<td>2.8</td>
<td>28.9</td>
<td>185</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Chloride (mg/L)</td>
<td>28</td>
<td>3.0</td>
<td>11.6</td>
<td>35.0</td>
<td>250</td>
<td>0</td>
</tr>
<tr>
<td>Bicarbonate (mg/L)</td>
<td>28</td>
<td>444</td>
<td>896</td>
<td>1600</td>
<td>--</td>
<td>--</td>
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<tr>
<td>Carbonate (mg/L)</td>
<td>28</td>
<td>0</td>
<td>26.6</td>
<td>106</td>
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<td>--</td>
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<tr>
<td>Sulfate (mg/L)</td>
<td>28</td>
<td>2.5</td>
<td>559</td>
<td>1590</td>
<td>250</td>
<td>17</td>
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<tr>
<td>Nitrate (mg/L)</td>
<td>28</td>
<td>&lt;0.25</td>
<td>&lt;0.25</td>
<td>4.50</td>
<td>10</td>
<td>8</td>
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<td>Fluoride (mg/L)</td>
<td>28</td>
<td>&lt;1.0</td>
<td>1.6</td>
<td>5.0</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Iron (mg/L)</td>
<td>28</td>
<td>0.01</td>
<td>0.6</td>
<td>3.7</td>
<td>0.3</td>
<td>12</td>
</tr>
<tr>
<td>Manganese (mg/L)</td>
<td>28</td>
<td>&lt;0.01</td>
<td>0.1</td>
<td>0.3</td>
<td>0.1</td>
<td>--</td>
</tr>
<tr>
<td>Selected Trace Elements</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic (ug/L)</td>
<td>28</td>
<td>&lt;1.0</td>
<td>0.7</td>
<td>4.3</td>
<td>--</td>
<td>50</td>
</tr>
<tr>
<td>Barium (mg/L)</td>
<td>28</td>
<td>6.8</td>
<td>46.3</td>
<td>184</td>
<td>--</td>
<td>100</td>
</tr>
<tr>
<td>Chromium (mg/L)</td>
<td>28</td>
<td>&lt;2.0</td>
<td>5.0</td>
<td>22.8</td>
<td>--</td>
<td>100</td>
</tr>
<tr>
<td>Copper (mg/L)</td>
<td>28</td>
<td>&lt;2.0</td>
<td>6.6</td>
<td>15.3</td>
<td>--</td>
<td>100</td>
</tr>
<tr>
<td>Nickel (mg/L)</td>
<td>28</td>
<td>&lt;2.0</td>
<td>3.5</td>
<td>45.2</td>
<td>--</td>
<td>100</td>
</tr>
<tr>
<td>Selenium (mg/L)</td>
<td>28</td>
<td>&lt;1.0</td>
<td>1.2</td>
<td>5.2</td>
<td>--</td>
<td>50</td>
</tr>
</tbody>
</table>

Other Constituents

| Sodium Adsorption Ratio (SAR) | 28 | 0.5 | 45 | 75 | -- | -- |
| Hardness as CaCO₃ | 28 | 2.8 | 230 | 1420 | -- | -- |
| pH | 6.9 | 8.4 | 9.1 | 6.5 - 8.5 | -- | 12 |

*: 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 (HCO₃, CO₃, SO₄, Cl, SO₃, NO₃, F) in mg/L
**Total dissolved solids reported as equivalent to weight of evaporation residue.