Montana Bureau of Mines and Geology
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Montana Ground-Water Assessment Atlas 4, Part B, Map 7
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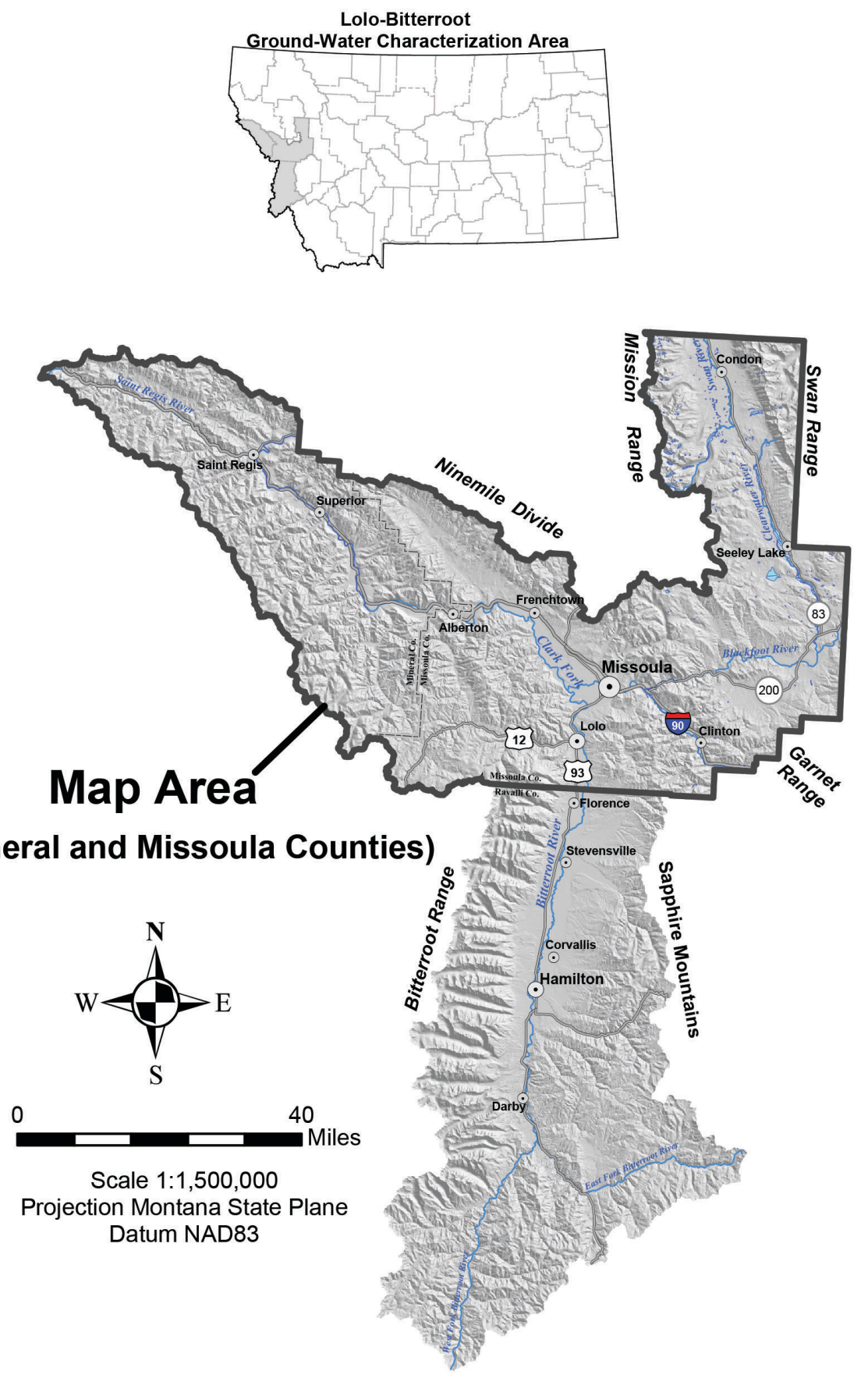

Ground-Water Quality in Basin-Fill and Bedrock Aquifers, Mineral and Missoula Counties, Western Montana

By

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Author's Note: This map is part of the Montana Bureau of Mines and Geology (MBMG) Ground-Water Assessment Atlas for the Lolo-Bitterroot Area. 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 Lolo-Bitterroot Area the reader is referred to Part A (descriptive overview) and Part B (maps) of the Montana Ground-Water Assessment Atlas No. 4.

INTRODUCTION

As part of the Montana Ground-Water Assessment Program, water quality was evaluated in Mineral and Missoula Counties in western Montana. This plate presents maps showing the distribution of dissolved constituents, nitrate, and arsenic in the bedrock and basin-fill aquifers. Ground-water quality data for the southern part of the Lolo-Bitterroot area (Ravalli County, the Bitterroot Valley) are presented on a separate plate (LaFave, 2005).

The mapped area is drained by the Clark Fork River and its tributaries. The area consists of bedrock-cored mountains, intermontane valleys, and canyons that host major streams. Most of the area is mountainous and part of the Lolo National Forest. Valley bottoms and canyons are the primary areas of habitation and ground-water development. Basin-fill aquifers within the valleys and bedrock aquifers along the valley margins supply water to all the municipalities and most residences.

GEOLOGIC SETTING

Bedrock, as defined here, consists of well-cemented or indurated rock that is commonly fractured. Most of the bedrock is made up of metacarbonates, argillites, and quartzites of the Proterozoic Belt Supergroup; there are localized occurrences of Paleozoic rocks in the northwest part of the Missoula Valley and along the Clark Fork Valley downstream from Missoula (Smith, 2005a).

Tertiary sediments range from unconsolidated to strongly consolidated and include claystone, shale, siltstone, sandstone, locally thick conglomerate, coal, and volcaniclastic sedimentary rocks (McMurtrey and others, 1965; Smith 2005a). Tertiary sedimentary rocks fill most of the valleys and are extensive in the subsurface. These sediments typically have low permeability and where they underlie Quaternary alluvium form a basal confining unit. Locally, permeable Tertiary sandstones and conglomerates are aquifers. Surface exposures of the Tertiary deposits prominently flank the northeast and southeast sides of the Missoula Valley; exposures are also found in the Potomac and Ninemile Valleys.

Quaternary basin-fill deposits include older (Pleistocene) alluvium and lacustrine deposits associated with glaciation, and recent (Holocene) sand and gravel deposits in the floodplains of the major river valleys. Glaciers deposited glacial till, which is mostly clayey and silty gravel. Bedded silt and clay were deposited in the valley regions during stands of Glacial Lake Missoula, and form confining layers within the basin-fill deposits. Sand and gravel interbedded with and overlain by bedded silt and clay deposits were deposited before glaciation and during flood events when Glacial Lake Missoula drained. The uppermost sand and gravel in stream valleys are less than 50 ft thick in most areas and represent stream deposition during and after waning phases of glaciation (Smith, 2005b).

DISSOLVED CONSTITUENTS

Water quality may be characterized by the type and concentrations of its dissolved constituents. For this map the dissolved-constituents value is the sum of the major cations (Na, Ca, K, Mg, Mn, Fe) and anions (HCO_3, CO_3, SO_4, Cl, SiO_2, NO_3, F) expressed in milligrams per liter [as distinguished from total dissolved solids (TDS) determined as residue at 180°C]. To highlight areal patterns, dissolved-constituents concentrations are presented in three categories on the Dissolved Constituents Map: high (greater than 500 mg/L, red symbols), medium (between 250 and 500 mg/L, blue symbols), and low (less than 250 mg/L, white symbols). The laboratory data were supplemented by estimates of dissolved-constituents concentrations derived from specific-conductance measurements made at an additional 236 wells. The specific-conductance (SC) measurements were used to estimate dissolved constituents (DC) according to the equation: $DC = A \times SC$ (Hem, 1992). The value of A was determined to be 0.92 based on a straight line regression.

Dissolved-constituents in ground water are a result of the initial chemistry of the recharge water and subsequent interactions of that water with soils and aquifer materials. Increased residence time and physical contact between ground water and the aquifer materials increases the potential for the water to react, resulting in increased dissolution of minerals. The dissolved-constituents concentration provides a general indicator of water quality; the lower the concentration, the better the water quality. Typically, water does not become too salty to drink until the dissolved-constituents concentration reaches about 2,000 mg/L. All of the sampled ground water was well below this threshold; the water is of good quality for drinking and other uses.

The dissolved-constituents concentrations ranged from 35 to 1,294 mg/L, with an average concentration of 300 mg/L and a median of 280 mg/L. Of the 417 sites with measured or estimated values, 93 percent (387 sites) had concentrations less than 500 mg/L. Most samples having concentrations greater than 500 mg/L (23 of 29) were from wells completed in deep basin-fill or bedrock aquifers. There was no difference between dissolved constituents in water from either basin-fill or bedrock aquifers (fig. 1).

GROUND-WATER QUALITY

The major ions in all waters from the aquifers consist predominantly of calcium, magnesium, and bicarbonate; sodium, sulfate, and chloride contents are low (fig. 2). There is no discernable difference in general chemical composition between basin-fill and bedrock aquifers. However, data show that land use in two heavily populated valleys—Missoula valley and near the town of Seeley Lake—may be impacting water quality (Woessner, 1988; LaFave, 2002) (see section on Nitrate). A sodium-bicarbonate signature is apparent for 18 of the analyses; the wells where these samples were obtained do not appear to be related hydrologically (they are not close together, or along similar flow paths). Seven of the samples are from fractured bedrock aquifers, 9 are from deep aquifers in Tertiary sediments, and the remaining 2 are from shallow aquifers.

NITRATE

Nitrate (NO_3) is an essential nutrient for plant life, yet is potentially toxic to humans (especially infants) when present in drinking water at concentrations greater than 10 mg/L. High levels of nitrate in well water typically indicate contamination from septic tanks, fertilizers, land application of animal wastes, or other nonpoint sources. On this map nitrate is reported as the sum of nitrite and nitrate as nitrogen. Nationally, background nitrate concentrations in ground water are commonly less than 2–3 mg/L (Halberg and Keeney, 1993). Nitrate concentrations greater than 2.0 mg/L may indicate effects of human activities (USGS, 1999).

The nitrate concentration map is based on results from 199 sites; 166 of the sites were sampled as part of this investigation, and the remainder were sampled as part of other MBMG or USGS investigations conducted between 1979 and 1996. The concentrations were grouped into four reporting ranges: 1) not detected or detected at concentrations less than 0.5 mg/L (white symbols), 2) low level, less than 2 mg/L, which reflects natural background occurrences or minor land use influences (blue symbols), 3) impacted, 2 to 10 mg/L, which reflects elevated concentrations most likely due to land-use influences (pink symbols), and 4) elevated, greater than 10 mg/L, which is the EPA Maximum Contaminant Level (MCL) for nitrate (red symbols).

Nitrate was detected at a concentration greater than 0.5 mg/L in water from 40 percent (79 of 199) of the sites; 8 percent (17 sites) had concentrations greater than or equal to 2 mg/L (impacted). Two sites had nitrate concentrations greater than the MCL of 10.0 mg/L; a shallow well near Seeley Lake had a concentration of 27.0 mg/L and a shallow well on the southeastern end of the Missoula Valley had a concentration of 11.4 mg/L. Median values in the basin-fill and bedrock units were less than 1 mg/L (fig. 3).

Nitrate was detected in all the wells sampled beneath the city of Missoula (between the Clark Fork and Bitterroot Rivers) and most of the wells in and downgradient of the town of Seeley Lake (see inset maps). Nitrate may enter ground water from point and nonpoint sources, including fertilizer, manure, septic systems, and disposal of municipal waste and soil nitrogen. Many parts of the Missoula valley and Seeley Lake were or are unsewered. The observed increase in nitrate concentrations below these urbanized parts of the study area suggests that septic-system effluent and/or lawn fertilizers may be sources of nitrate to the shallow aquifers.

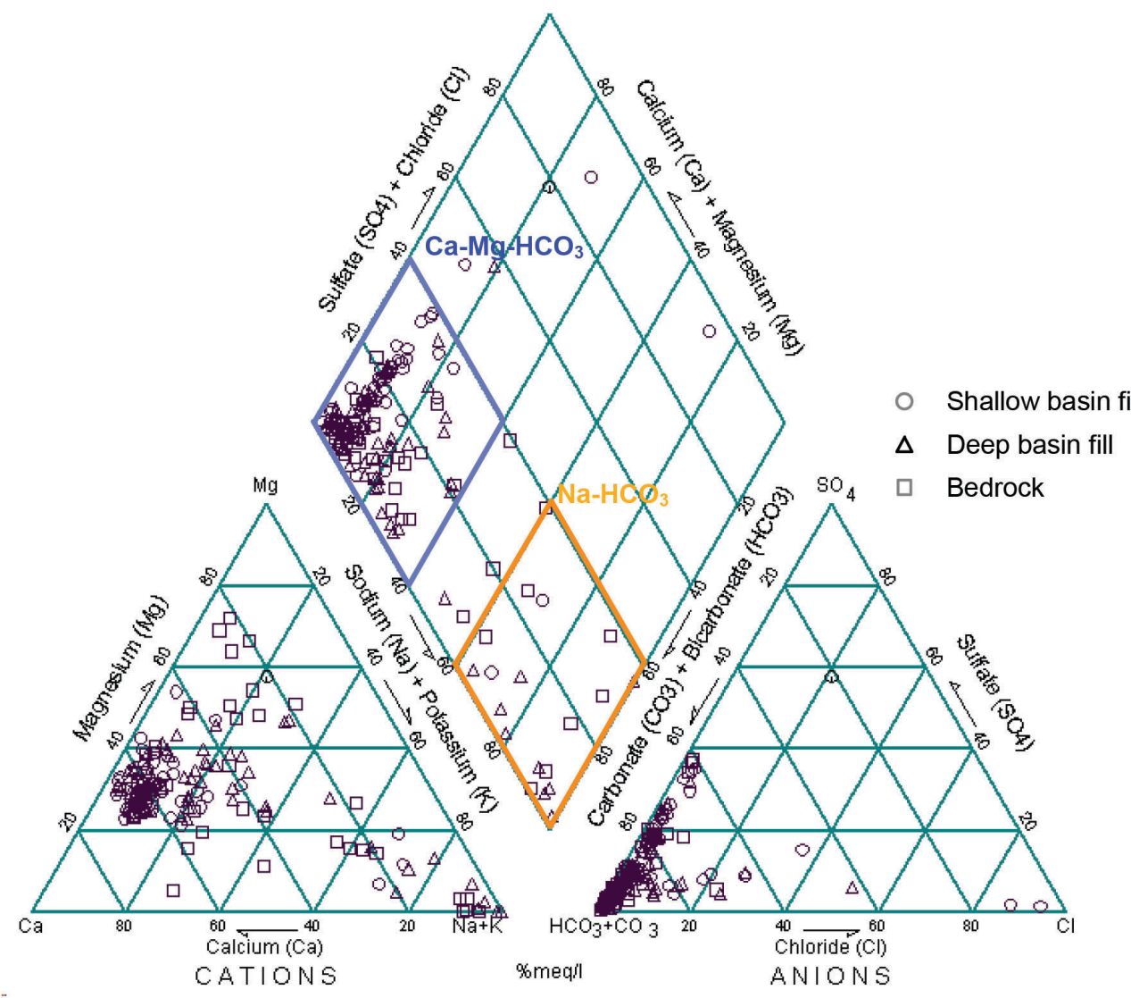
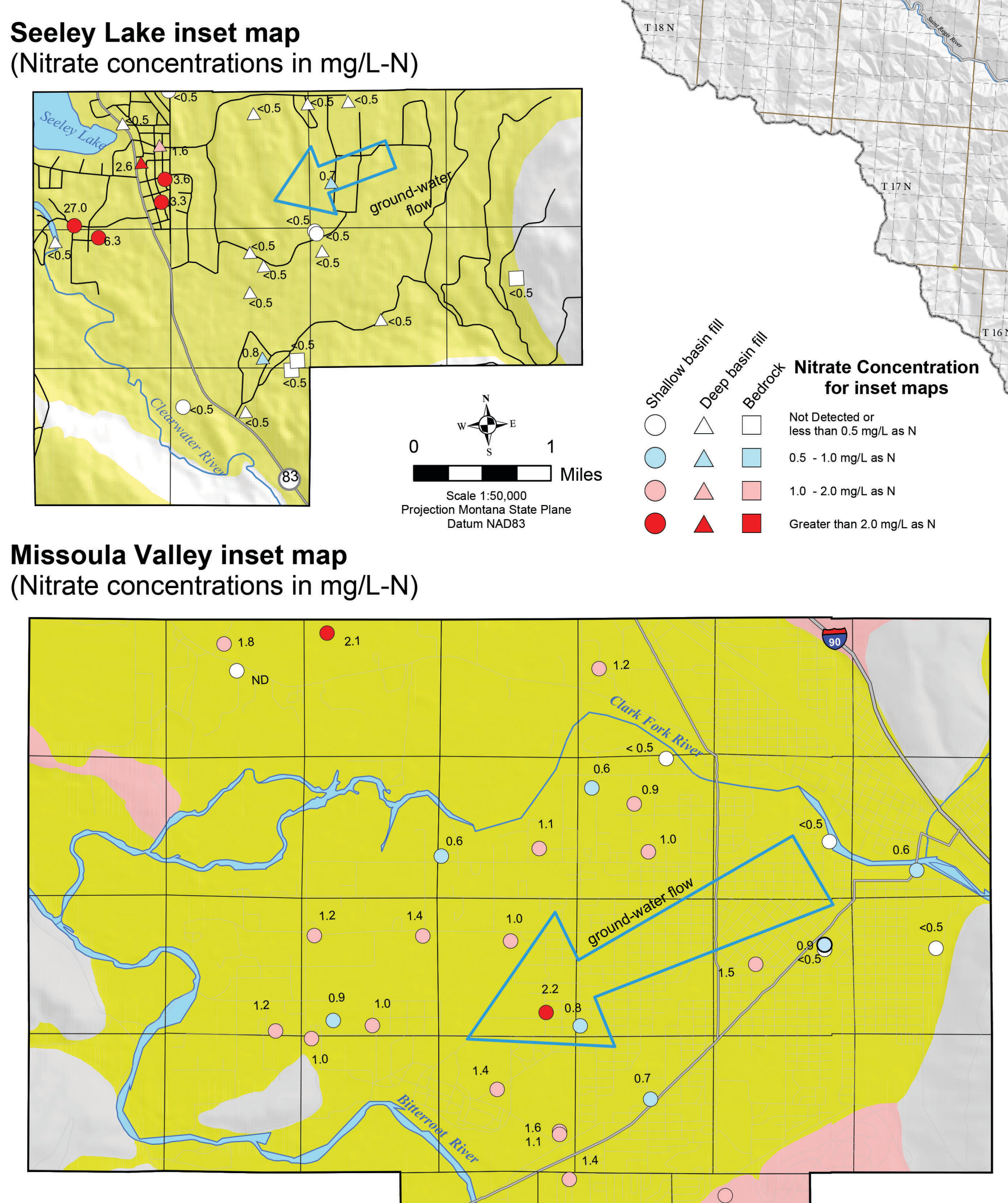


Figure 2. In the basin-fill and bedrock aquifers, the water composition is predominately a $Ca\text{-}Mg\text{-}HCO_3$ type water. A few samples, mostly from deep basin-fill or bedrock aquifers, had a $Na\text{-}HCO_3$ type composition. meq/l - milliequivalents per liter.

Nitrate



Nitrate concentrations in the aquifers beneath Seeley Lake and Missoula are greater than those found in undeveloped areas. The elevated concentrations suggest that urban land use has impacted ground-water quality.

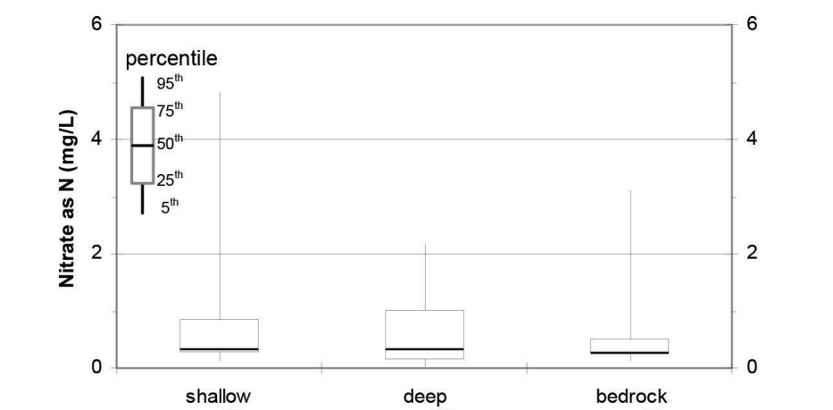
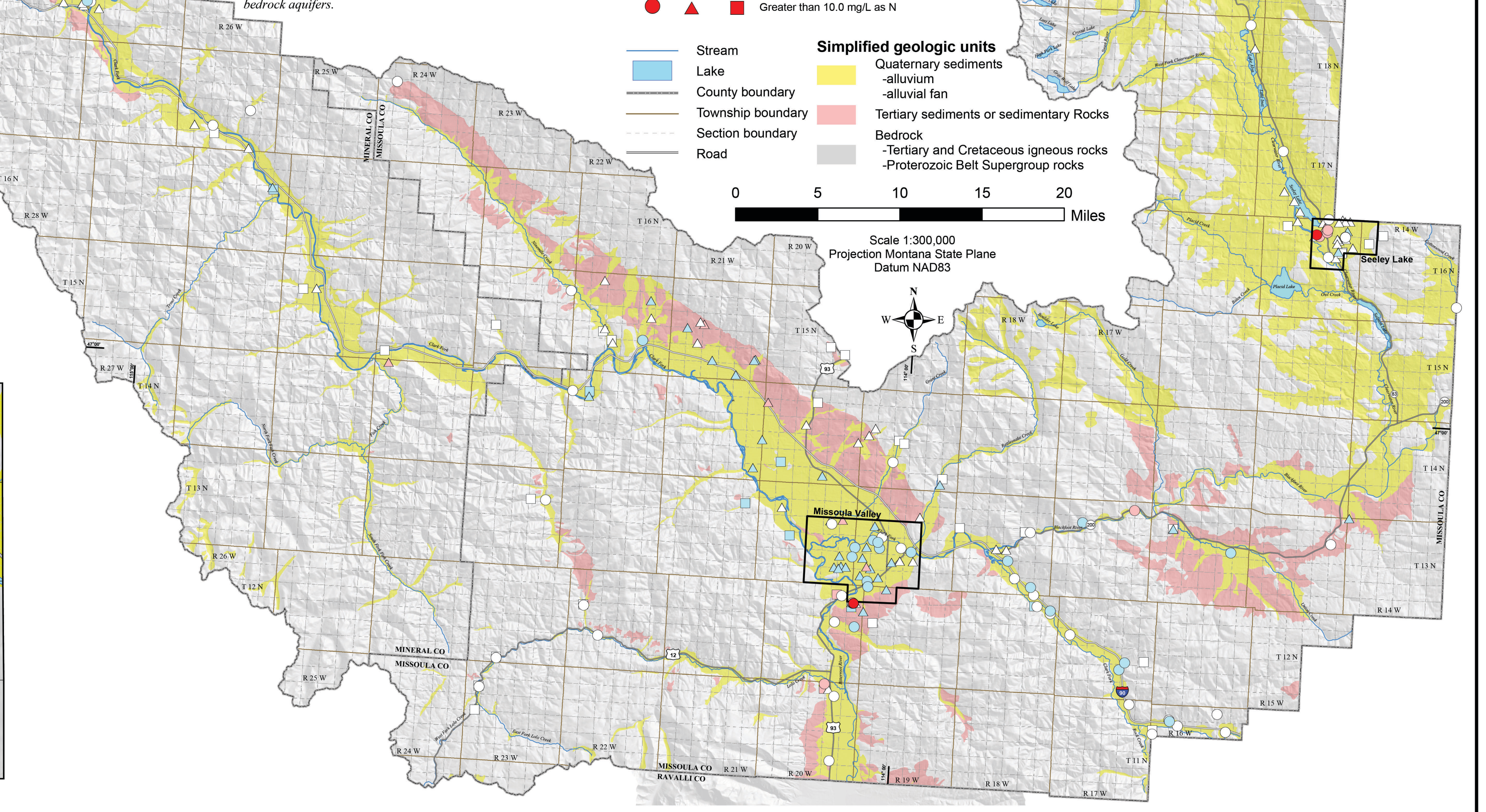


Figure 3. Nitrate was generally not detected, or detected at concentrations less than 2.0 mg/L-N in the basin-fill and bedrock aquifers.



Dissolved Constituents

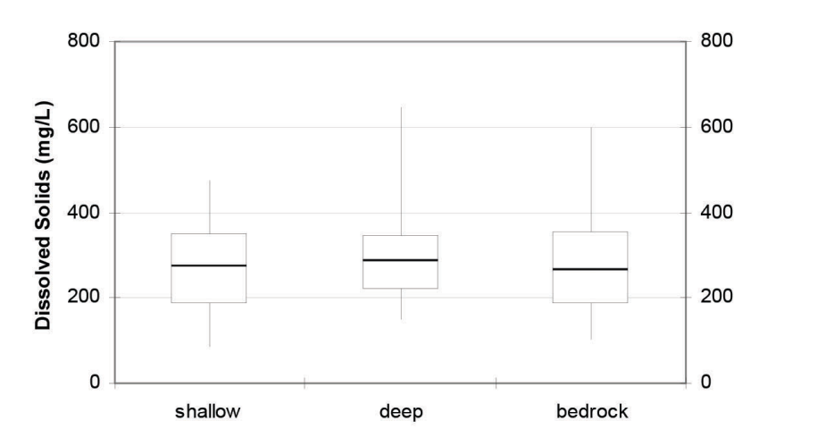
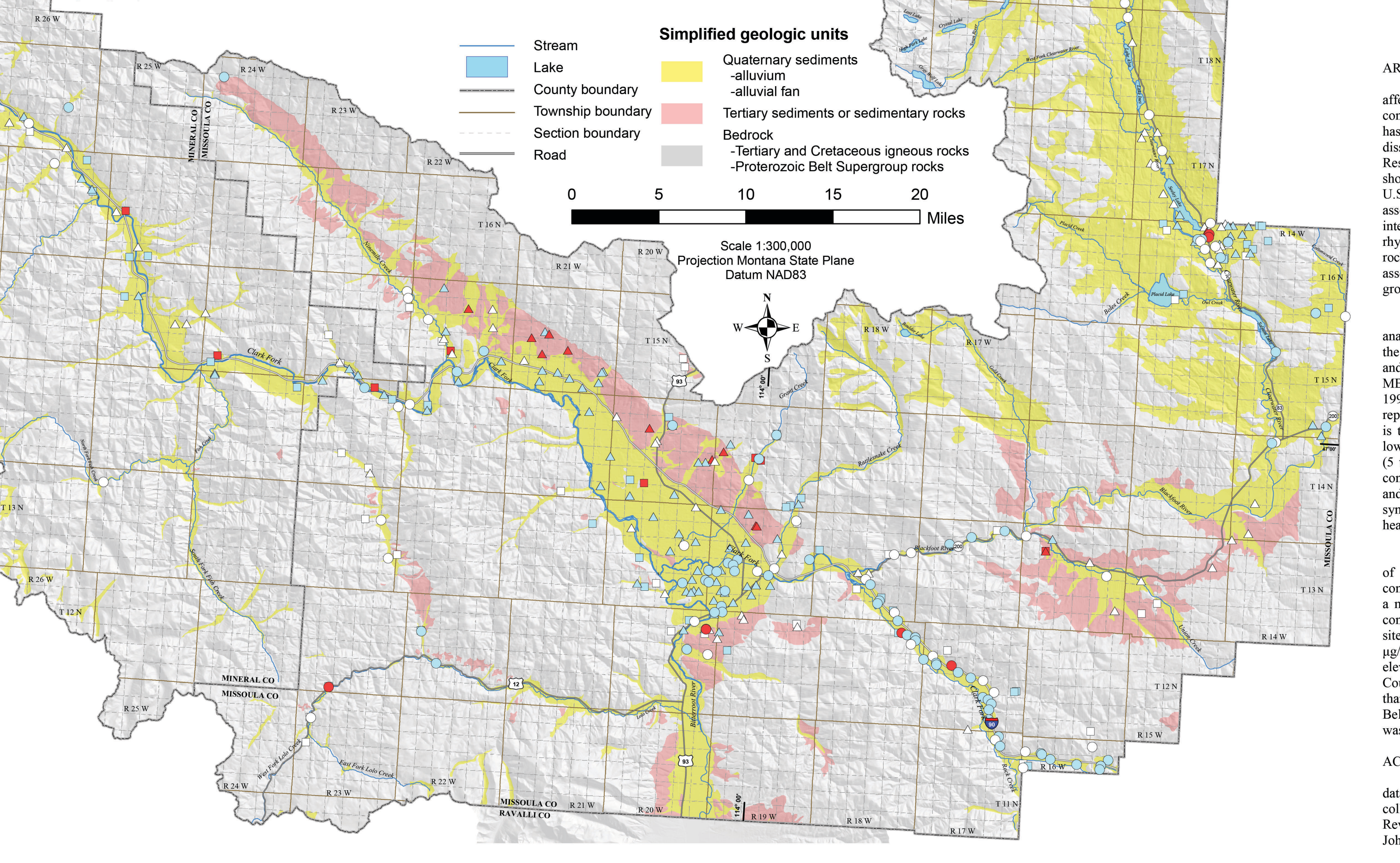


Figure 1. The dissolved-constituents concentrations are generally less than 500 mg/L in basin-fill and bedrock aquifers, indicating good quality water.



HYDROGEOLOGIC SETTING

Exploitable ground-water resources within the valley regions occur primarily in the basin-fill deposits and to a lesser extent in the fractured bedrock. There are records of about 9,400 wells in the mapped area; approximately 1,200 are completed in bedrock aquifers and the remainder are completed in basin-fill deposits. The basin fill contains multiple unconfined and confined aquifers with numerous discontinuous confining layers. In places, the confining layers hydraulically separate the aquifers; however, in most valleys water-level data from different depths suggest that the basin-fill aquifers are well-connected on a valley-wide scale. As with most intermontane basins, the basin-fill aquifers are the most productive and are important sources of municipal and domestic water (Kendy and Tresch, 1996).

For the purposes of this map, aquifers were generalized into three units based on the properties of the aquifer material (primary porosity vs. secondary porosity in fractured rock), ground-water conditions (confined vs. unconfined), and position within the geologic framework. The three hydrogeologic units recognized are: 1) shallow basin fill, 2) deep basin fill, and 3) bedrock. Lithologic and static water-level data from well logs, in addition to well construction information, were used to distinguish between wells completed in the shallow and deep units.

The uppermost or shallow hydrologic unit is developed in surficial alluvial sediments generally within 80 ft of the land surface. Ground water in the shallow hydrologic unit is under unconfined, or water-table, conditions. Most wells classified as being in the shallow unit (circles on the maps) are less than 80 ft deep or have perforations within 80 ft of the land surface.

The deep unit consists of confined to semi-confined aquifers in the valleys that are generally deeper than 80 ft and underlie the shallow unit. Accordingly, wells that produce from aquifers greater than 80 ft deep are classified as being in the deep unit (triangles on the maps).

Bedrock aquifers occur around the valley margins. The occurrence of ground water in the bedrock is controlled by fractures. Where it is sufficiently fractured (permeable) and saturated, bedrock can yield water to wells (bedrock wells are indicated by squares on the maps).

SAMPLE SITES AND WATER-QUALITY DATA

Water-quality data collected by the Montana Bureau of Mines and Geology's (MBMG) Ground-Water Assessment Program between October 1997 and July 2001 (Carstarphen and others, 2003) serve as the primary source of data for the water-quality maps. Samples from 139 domestic, stock, municipal, and monitor wells were analyzed for major-ion and trace-metal concentrations by the MBMG Analytical Laboratory; additionally, samples from 27 other wells were analyzed for nitrate only. Field measurements of specific conductance, pH, and temperature also were obtained at the time the wells were sampled. To ensure acquisition of a representative sample, each well was pumped prior to sample collection until field parameters stabilized and at least three well-casing volumes were removed. Data from an additional 42 ground-water samples collected by the MBMG or the U.S. Geological Survey (USGS) between 1978 and 1997 were used to augment the primary data. The additional data improve the spatial resolution and enable a more comprehensive interpretation of the distribution of dissolved constituents, nitrate, and arsenic concentrations. The water-quality data used for compiling these maps as well as water well logs and site visit data are available from the Montana Ground-Water Information Center (GWIC, online at http://mbmggwic.mtech.edu/).

Arsenic

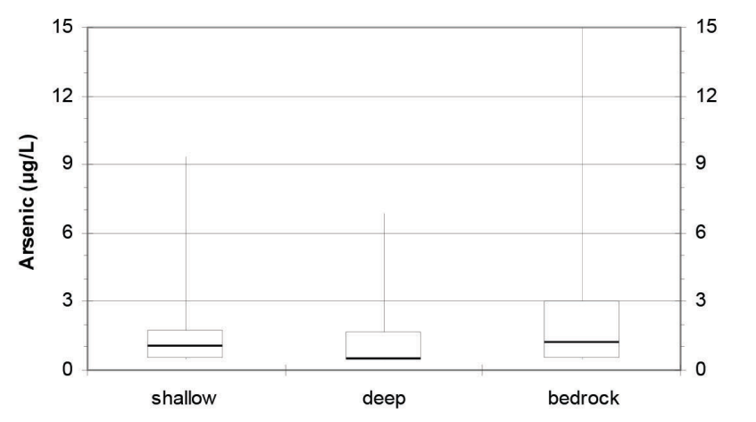
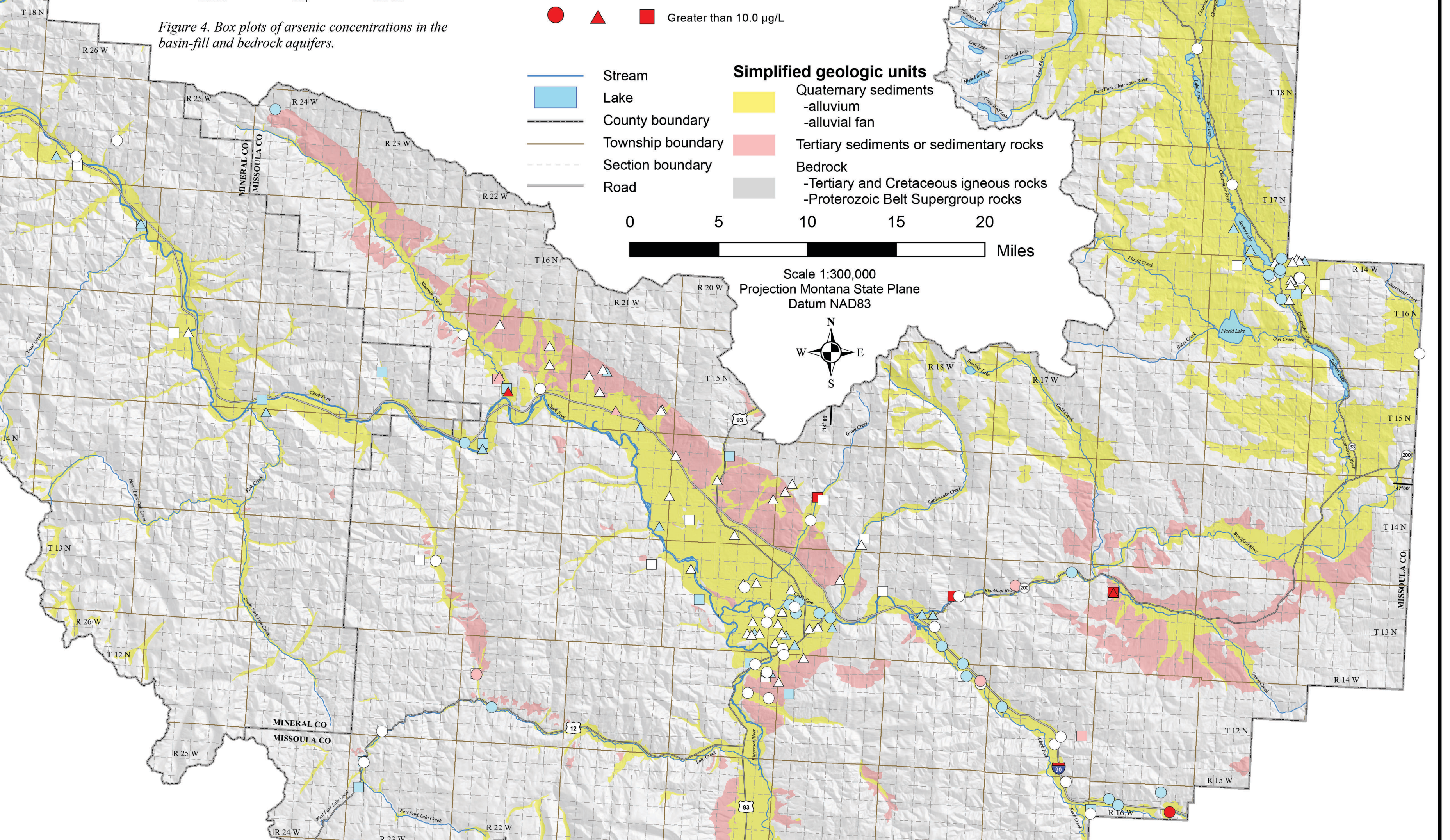


Figure 4. Box plots of arsenic concentrations in the basin-fill and bedrock aquifers.



ARSENIC

Arsenic is a trace element that can adversely affect human health when ingested at elevated concentrations in drinking water supplies. The EPA has set a MCL of 10 micrograms per liter (µg/L) for dissolved arsenic in public drinking water supplies. Research conducted by Welch and others (1988) showed that arsenic in ground water in the western U.S. is often naturally occurring and commonly associated with igneous rocks of acidic to intermediate composition, such as granite and rhyolite, and with the sediments derived from these rocks. Elevated arsenic concentrations are also associated with geothermal water and commonly with ground water that has been impacted by mining.

The map of arsenic distribution is based on analytical results for samples from 149 sites; 139 of the sites were sampled as part of this investigation, and the remainder were sampled as part of other MBMG or USGS investigations between 1986 and 1997. The concentrations were grouped into four reporting ranges: 1) less than detection limit (1.0 µg/L is the laboratory reporting limit, white symbols), 2) low level (less than 5 µg/L, blue symbols), 3) elevated (5 to 10 µg/L, pink symbols), which reflect elevated concentrations most likely due to geologic sources, and 4) MCL exceedance (greater than 10 µg/L, red symbols), which are concentrations greater than the health standard for public drinking water.

Arsenic was detected in water from about half of the sampled locations (74 of 149 sites); concentrations ranged from below detection limits to a maximum of 50.06 µg/L (fig. 4). Overall, arsenic concentrations were generally low or not detected; 15 sites had elevated concentrations (greater than 5.0 µg/L), and 6 had MCL exceedance. All of the elevated concentrations were detected in Missoula County. Of the 6 sites with concentrations greater than 10 µg/L, half were wells completed in fractured Belt bedrock, two were deep basin-fill wells, and one was a shallow well.

ACKNOWLEDGMENTS

Well owners who allowed collection of the data necessary for the map and the people who collected the data are all gratefully acknowledged. Reviews of this map by Tom Patton, Gary Icopini and John Metesh improved its clarity.

DATA SOURCES

Geographic Features

Population centers and roads are from 1:100,000-scale USGS Digital Line Graph files available from the Natural Resources Information System (NRIS) at the Montana State Library, Helena, Montana. Hydrography has been simplified from the 1:100,000 Digital Line Graph files. Township boundaries are from the U.S. Forest Service. The hillshade base was compiled from USGS digital elevation models (DEMs) for 1:24,000 quadrangle maps available from NRIS. Differences in the quality of the DEMs may result in artifacts such as mottled surfaces and horizontal striping in the hill-shade base. Geological data were simplified from a Hydrogeologic Framework Map compiled by Smith (2005).

Point Data

Well location and water-level altitude data were obtained by Ground-Water Characterization Program personnel. Altitudes of the points were determined from USGS 1:24,000 topographic maps. All point data used on this map are available from the Ground-Water Information Center (GWIC) at the Montana Bureau of Mines and Geology, Montana Tech of The University of Montana, Butte, Montana.

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