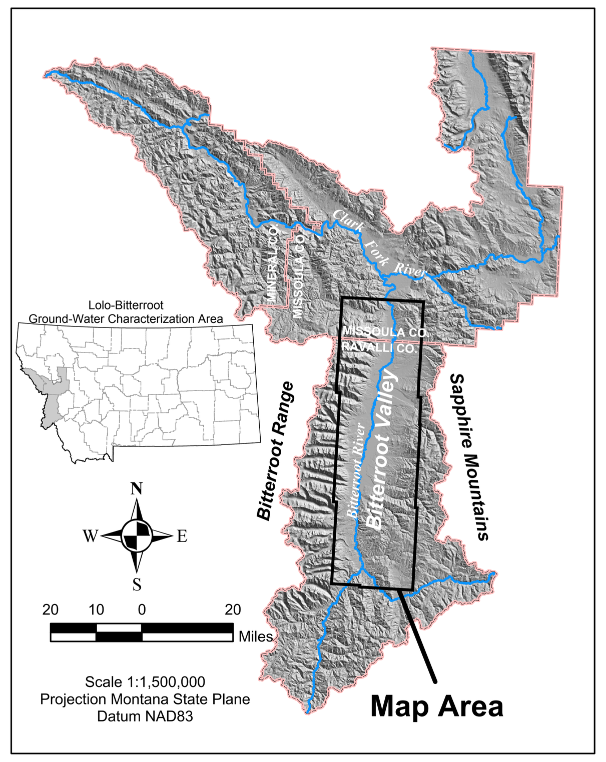
Lolo-Bitterroot Area



Ground-Water Quality of the Shallow Basin-Fill, Deep Basin-Fill, and Bedrock Aquifers, Bitterroot Valley, Missoula and Ravalli Counties, Southwest Montana

by
John I. LaFave

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 Montana Ground-Water Assessment Atlas 4.

INTRODUCTION

As part of the Montana Ground-Water Assessment Program, water quality was evaluated in the bedrock and basin-fill aquifers in the Bitterroot Valley in western Montana. This plate presents maps showing the distribution of dissolved constituents, as well as nitrate, arsenic, and radon in the shallow, deep, and bedrock aquifers of the Bitterroot Valley. Ground-water quality data for the northern part of the Lolo-Bitterroot area (Mineral and Missoula Counties) are presented on a separate plate (LaFave, 2006a).

The north-flowing Bitterroot River drains the 2,860 mi^2 valley in Ravalli County and part of Missoula County. The Bitterroot Valley is a structurally controlled intermontane basin framed by the Bitterroot Range on the west and the Sapphire Mountains on the east; the western and southern valley boundary is part of the Montana/Idaho border. Much of the Bitterroot drainage is within the Bitterroot National Forest.

The Bitterroot Valley is an area of rapidly growing population; the population of Ravalli County increased 44 percent (from 25,010 to 36,070) between 1990 and 2000. Most of the residents live on the valley floor between the towns of Darby in the south and Lolo in the north. Ground water supplies most domestic and public water supply needs.

Land use has long been dominated by irrigated agriculture (Kendy and Tresh, 1996). However, as noted by Briar and Dutton (2000), the conversion of agricultural land to residential home sites is the major land-use change occurring in the Bitterroot Valley. In Ravalli County, the amount of land in irrigated acreage has declined about 7 percent between 1993 and 2003 (Montana Agricultural Statistics Service, www.nass.usda.gov/mt).

GEOLOGIC SETTING

The Bitterroot Range rises prominently on the west side of the valley, with rugged peaks ranging from 9,000 ft in the north to 10,000 ft above sea level in the south. The Sapphire Mountains on the east side of the valley are more subdued, with rounded peaks generally less than 8,500 ft above sea level. The valley floor is characterized by a relatively flat Bitterroot River floodplain and nearby low river terraces 1 to 4 miles wide. The low terraces adjacent to the river are flanked by high terraces (McMurtrey and others, 1972), or high benches (Briar and Dutton, 2000) along the valley margin. The high benches are prominent topographic features especially on the valley's east side. The benches are about 3 to 6 miles in width, characterized by a gentle valley-ward slope from the mountain fronts, and their lower ends are truncated by scarps 50 to 150 ft high. The benches are remnants of Tertiary alluvial fans that have been deeply incised by the Bitterroot River and its tributaries. Some of the tributary stream valleys that separate the benches are 1 to 2 miles wide and relatively flat-floored.

The bedrock exposed in the mountains surrounding the Bitterroot Valley also underlies the valley (fig. 1). Bedrock, as defined here, consists of well-cemented or indurated rock that is commonly fractured. The bedrock of the valley's west side is composed of granite and layered gneiss of the Idaho Batholith. The Sapphire Mountains to the east and the northern Bitterroot Range are made up of metacarbonates, argillites, and quartzites of the Belt Supergroup (Smith, 2006).

The basin-fill deposits consist of unconsolidated to semiconsolidated Tertiary and Quaternary sediments that are as much as 3,000 ft thick (Smith, 2006). Tertiary deposits occur at the surface along the valley margin and overlie the bedrock at depth; along the valley margin the deposits are dominated by clay-rich sediments (often described as "blue clay" in driller's logs) with interbeds of poorly sorted sand and gravel (fig. 1). Near the valley center coarse-grained alluvium deposited by an ancestral Bitterroot River occurs at depth and, in places, at or near the land surface (Lonn and Sears, 2001). Quaternary basin-fill deposits include Pleistocene glacial outwash, alluvial and terrace deposits associated with major drainages in the valley, and recent sand and gravel deposits in the floodplain of the Bitterroot River and its tributaries.

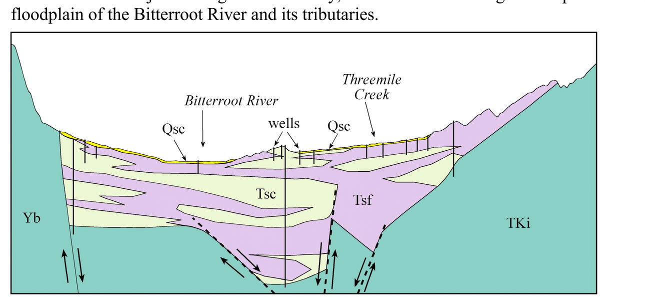


Figure 1. Generalized geologic cross section across the Bitterroot Valley showing the relationship between bedrock (Yb: Belt Super Group, TKi: Tertiary and Cretaceous intrusives) and basin-fill deposits (Tsc: Tertiary coarse-grained, Tsf: Tertiary fine-grained, Qsc: Quaternary coarse-grained). See Map Area for the location of the cross-section line.

HYDROGEOLOGIC SETTING

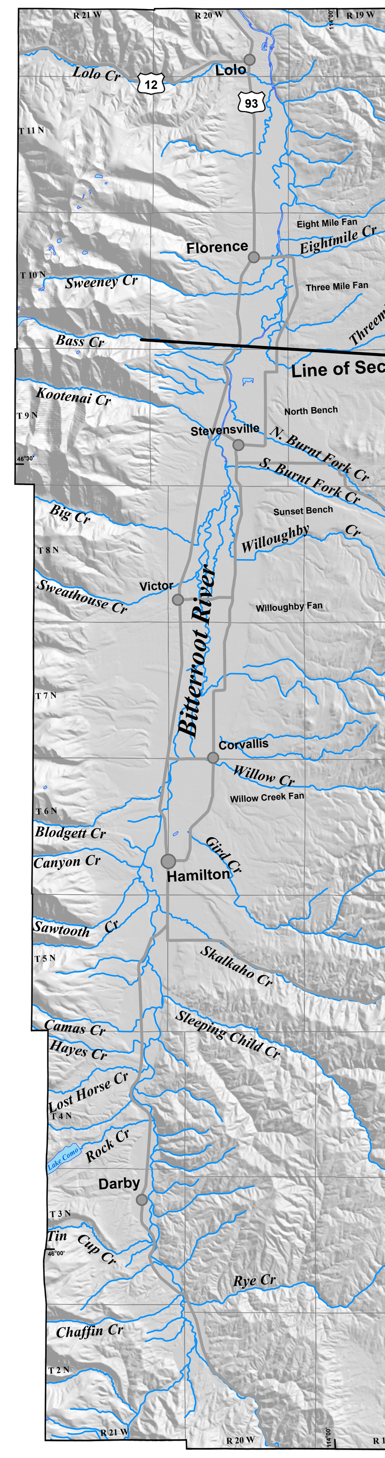
Exploitable ground-water resources in the Bitterroot Valley occur in the fractured bedrock (igneous intrusive rocks, metasedimentary rocks) and the basin-fill deposits. For the purposes of this plate, aquifers were generalized into three units based on the properties of the aquifer material (primary 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 shallow basin-fill aquifers are developed in surficial alluvial sediments, generally within 50 ft of the land surface. Ground water in the shallow aquifers is under water-table conditions, and is characterized by local flow systems where ground water moves from local drainage divides toward adjacent valley bottoms. The water table is a subdued representation of the land surface and is typically within 5 to 40 ft of the land surface (LaFave, 2006b).

The most productive and extensive part of the shallow basin-fill aquifer is sand and gravel deposited along the floodplain of the Bitterroot River and its tributaries. These deposits are highly permeable and can yield large quantities of water to wells. Leakage from irrigation canals is a significant recharge source to the shallow basin-fill aquifer. Shallow basin-fill aquifers are also found within some Tertiary alluvial fan deposits on the high benches. These shallow-bench aquifers, mostly on the east side of the valley, are more localized and strongly dependent on recharge from irrigation.

Deep basin-fill aquifers are generally greater than 50 ft below the land surface and under confined to semi-confined conditions. Within the deep basin fill there are multiple permeable sand and gravel deposits separated by low-permeability fine-grained material. Although highly permeable zones in the deep basin fill may not be contiguous over large areas, there is sufficient hydraulic continuity between the sand and gravel layers to be considered a single entity in terms of ground-water flow on a valley-wide scale. The deep basin-fill aquifer is recharged by water percolating downward from shallow aquifers along the valley margins and from the fractured bedrock.

Map Area



EXPLANATION

Road
Stream
Lake
Township boundary
Section boundary
City or town

Description of simplified geologic units on water quality maps

Quaternary sediments
- alluvium, outwash
- alluvial fan deposits

Tertiary sediments and sedimentary rocks
- alluvium
- alluvial fan deposits

Bedrock
- Tertiary and Cretaceous igneous rocks
- Proterozoic Belt Supergroup rocks

The bedrock aquifers are exposed along the valley margins and the mountains surrounding the valley. At many locations the bedrock has sufficient fracture permeability to yield water to wells; however, the number, size, and orientation of the openings are unpredictable and can change abruptly over short distances, resulting in large variations in well yields and depths. In the Bitterroot Valley, about half of the roughly 900 wells completed in the fractured bedrock have been drilled in since 1995; this is a significant increase in development compared to earlier periods.

The bedrock aquifers are recharged by infiltration of rainfall and snowmelt. Low storage capacities in fractured-rock aquifers cause large seasonal and long-term water level fluctuations in response to stress from climate or development. In some places, ground water in the bedrock appears to be hydraulically connected to the basin-fill aquifers; therefore, the fractured bedrock transfers mountain-front recharge to the basin-fill deposits and represents an important recharge area to the valley's regional flow system.

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 September 1997 and July 2001 (Carstarphen and others, 2003) serve as the primary source of data for the water-quality maps presented here. Samples from 136 domestic, stock, municipal, and monitor wells were analyzed for major-ion and trace-metal concentrations by the MBMG Analytical Laboratory. Field measurements of specific conductance, pH, and temperature also were obtained at the sampled wells. To ensure acquisition 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. Data from an additional 74 ground-water samples collected by the MBMG, the U.S. Geological Survey (USGS), or University of Montana (UM) students between 1978 and 1995 were used to augment the primary data. The additional data improve the spatial distribution and enable a more comprehensive interpretation of the distribution of dissolved constituents, nitrate, arsenic, and radon concentrations.

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 of dissolved constituents within the valley, the 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, pink symbols), and low (less than 250 mg/L, blue symbols). The laboratory results from 210 wells were supplemented by estimates of dissolved-constituents concentrations derived from specific-conductance measurements made at an additional 286 wells. The specific-conductance (SC) measurements were used to estimate dissolved constituents (DC) according to the equation: DC = A x SC (Hem, 1992). The value of A was determined to be 0.92 based on a straight-line regression of the data.

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 in the Bitterroot Valley was well below this threshold.

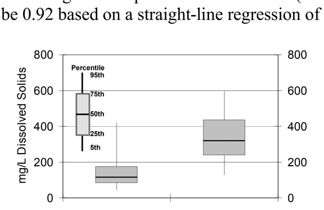
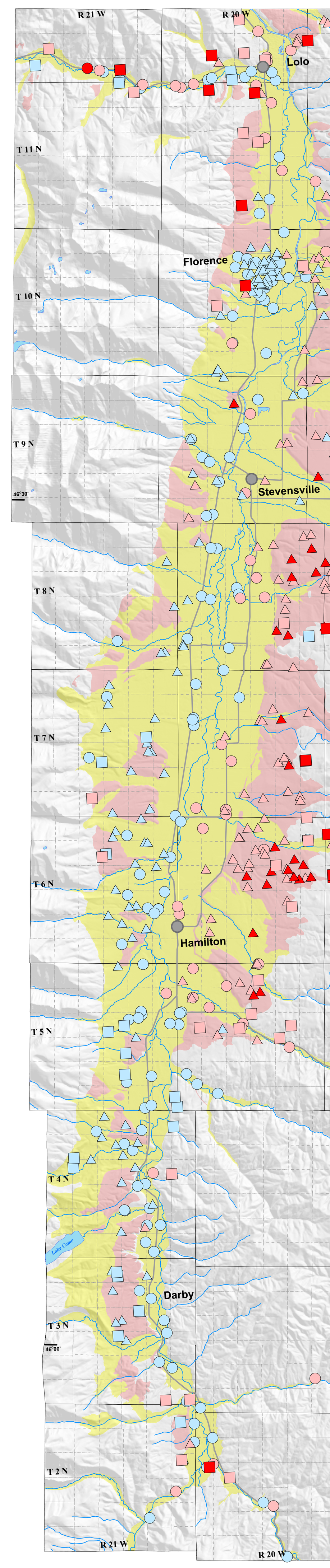


Figure 2. Ground water on the east side of the valley is more mineralized than on the west side.

Overall, the dissolved-constituents concentration of ground water is low, indicating good quality water. The dissolved-constituents concentrations ranged from 26 to 1,374 mg/L, with an average concentration of 243 mg/L. Of the 496 sites with measured or estimated values, 91 percent (453 sites) had concentrations less than 500 mg/L. Most samples with concentrations greater than 500 mg/L (23 of 29) were from wells completed in deep basin-fill or bedrock aquifers. Dissolved-constituents concentrations differ between the east and west side of the valley, and between the shallow basin-fill, deep basin-fill, and bedrock aquifers. Generally, the dissolved-constituents concentration on the east side of the valley is twice that of the west side (median east = 114 mg/L, median west = 317 mg/L; fig. 2).

Dissolved Constituents



shallow deep bedrock
Dissolved-constituents concentration
less than 250 mg/L
250 - 500 mg/L
greater than 500 mg/L
Scale 1:200,000
Projection Montana State Plane
Datum NAD83
0 1 2 3 4 5 Miles

The basin fill on the east side of the valley contains more fine-grained Tertiary deposits, derived from argillites and metasediments in the Sapphire Mountains, than the west side, where basin-fill materials are derived from igneous and high-grade metamorphic rocks of the Idaho batholith. The fine-grained Tertiary deposits contain more soluble minerals and will transmit water more slowly than coarser grained alluvium. Furthermore, the Sapphire Mountains receive 50–75% of the annual precipitation of the Bitterroot Range (Briar and Dutton, 2000), limiting the amount of recharge water on the east side of the valley as compared to the west side.

In general, water from the bedrock aquifers along the east margin of the valley had greater dissolved-constituents content than the basin-fill aquifers (fig. 3). In the basin fill, shallow aquifers generally had lower dissolved-constituents concentrations than the deep aquifers.

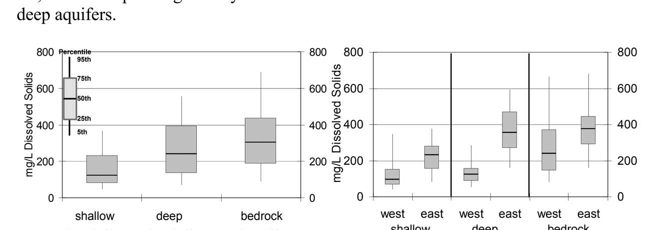


Figure 3. Overall, the dissolved solids content is consistent between the shallow, deep, and bedrock units. However, in each unit the concentrations are greater on the east side of the valley.

GROUND-WATER QUALITY

Despite the differences in dissolved-constituents distribution, the main chemical constituents in Bitterroot Valley ground water were uniform. Almost all the water had a calcium-bicarbonate signature; sodium, sulfate, and chloride content is low (fig. 4). Eleven samples had a sodium-bicarbonate signature; wells from where the samples were obtained do not appear to be related hydrologically (they are not close together or along a similar flow path), however, seven of the samples were from fractured bedrock aquifers. There was no discernable difference in chemical composition between ground water from east and west sides of the valley. Nor were there discernable evolution trends along the ground-water flow paths.

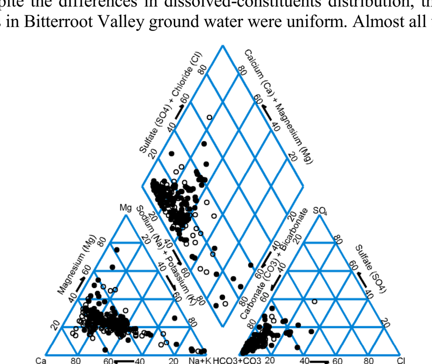


Figure 4. Despite the difference in dissolved-constituents concentration between the east and west side ground waters, the major-ion composition is generally the same. (open circles = east side, closed circles = west side, meq/l = milliequivalents per liter).

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 excessive concentrations. High levels of nitrate in well water can indicate contamination from septic tanks, fertilizers, land application of animal wastes, or other nonpoint sources. On this map nitrate + nitrite concentrations in sampled water are reported as nitrogen (as N). 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 map showing nitrate concentration distribution in the Bitterroot Valley includes results from 246 sites; 162 of the sites were sampled as part of this investigation, and the remainder were sampled as part of other MBMG, USGS, or UM investigations (Norbeck and McDonald, 2001; Briar and Dutton, 2000; Uthman, 1988). The densely sampled area near Florence resulted from a ground-water resource evaluation conducted by the MBMG in 2001 (Norbeck and McDonald, 2001). The concentrations were grouped into four reporting ranges: 1) less than detection limit, 0.25 mg/L is the laboratory reporting limit, (white symbols), 2) low level, less than 2 mg/L (blue symbols), which reflects natural background occurrences or minor land-use influences, 3) impacted, 2 to 10 mg/L (pink symbols), which reflects elevated concentrations most likely due to land-use influences, and 4) elevated, greater than 10 mg/L (red symbols), which is the EPA Maximum Contaminant Level (MCL) for nitrate.

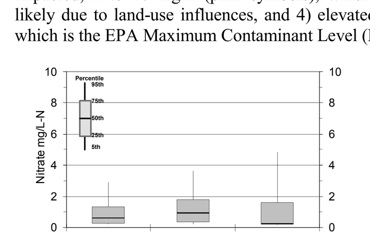


Figure 5. Median nitrate concentrations in all the hydrogeologic units were less than 1 mg/L-N.

Nitrate was detected at about 75 percent of the sites, and 17 percent (41 sites) had concentrations greater than or equal to 2 mg/L; only 1 site had an MCL exceedance. Median values in each of the hydrogeologic units were less than 1.0 mg/L (fig. 5). Samples from fractured bedrock aquifers showed the greatest range of nitrate values, and the one MCL exceedance came from a fractured bedrock aquifer.

ARSENIC

Arsenic is a trace element that can adversely affect human health when ingested at elevated concentrations. 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 or rhyolite, and with the sediments derived from these rocks. Elevated arsenic concentrations are also commonly associated with geothermal water and ground water that has been impacted by mining.

The map of arsenic concentration distribution in the Bitterroot Valley includes results from 182 sites; 135 of the sites were sampled as part of this investigation and the remainder were sampled as part of other MBMG or USGS investigations since 1994. The concentrations were grouped into four reporting ranges: 1) less than detection limit, 0.5 µg/L (white symbols), 2) low level, less than 5 µg/L (blue symbols), 3) elevated, 5 to 10 µg/L (pink symbols), which reflects elevated concentrations most likely due to geologic sources, and 4) concentrations greater than the health standard of 10 µg/L (red symbols) for public drinking water.

Arsenic was detected in water from only about one-third of the sampled locations (61 sites) in the Bitterroot Valley; concentrations ranged from less than the detection limit to a maximum of 21.5 µg/L. Although arsenic concentrations were generally low or not detected, 15 sites had elevated concentrations and 6 had MCL exceedances. The elevated arsenic concentrations are clustered around the Willow Creek drainage on the east side of the valley, suggesting a natural (geologic) source.

The bedrock surrounding the Willow Creek watershed is composed of a granite to granodiorite intrusive rock (the Willow Creek stock) that crops out in the central part of the drainage (Presley, 1971) and several other locations east of Hamilton as far south as Skalkaho Creek (the Skalkaho stock). The elevated arsenic concentrations appear to be associated with these igneous intrusions and basin-fill sediments derived from these stocks. Samples from the shallow and deep basin fill, as well as the bedrock aquifers, had elevated arsenic concentrations (fig. 6). Ground water derived from this part of the east side of the valley (T5N & 6N R20W) should be expected to have detectable arsenic concentrations.

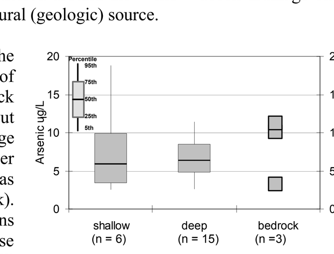


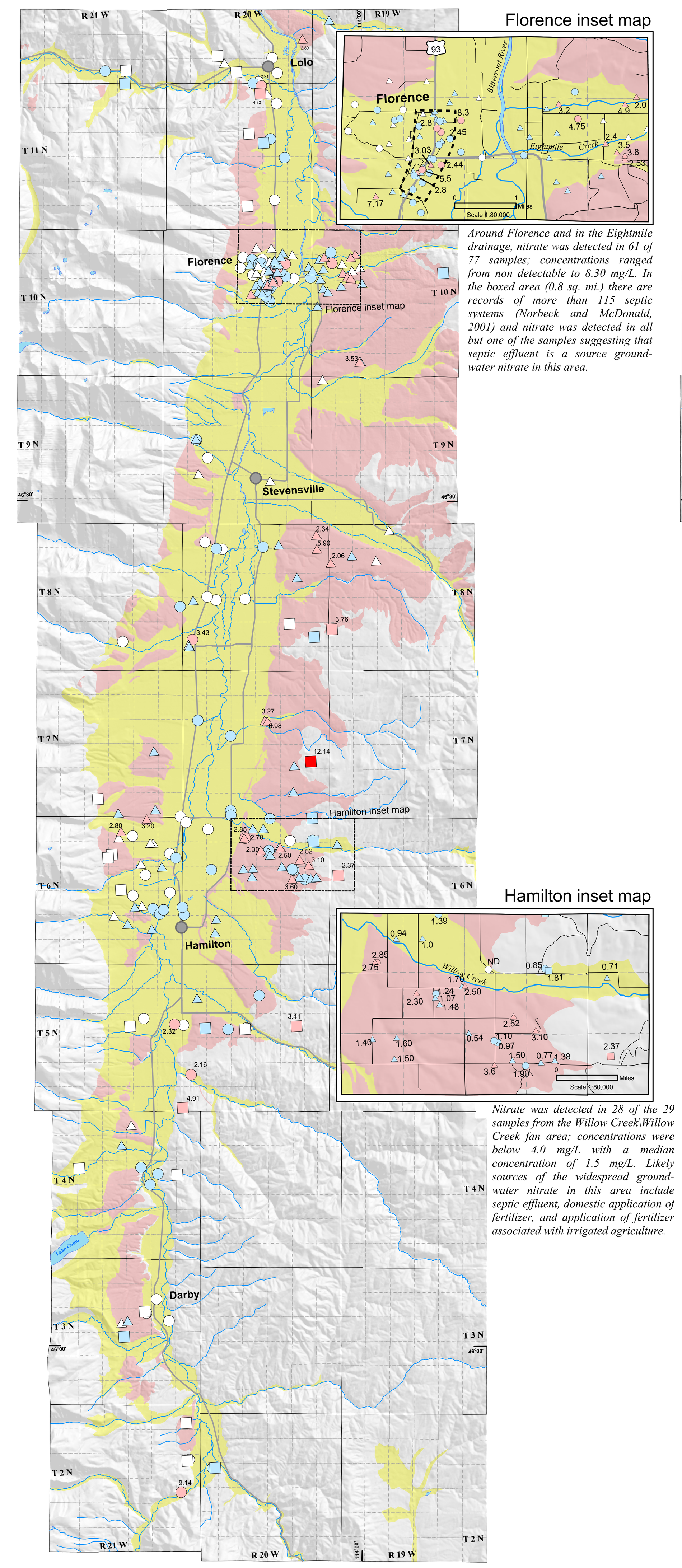
Figure 6. In the Willow Creek drainage, elevated arsenic concentrations occur in the shallow, deep, and bedrock units.

RADON

Radon is a naturally occurring radioactive gas that may cause cancer, and may be found in drinking water and indoor air. Radon from soil that seeps into homes is the biggest source of radon in indoor air, and presents a greater risk of lung cancer than radon in drinking water (EPA, 1999). The EPA estimates that radon released from drinking water accounts for less than 2 percent of radon in indoor air. Currently there is no drinking water standard for radon; however, the EPA is proposing an MCL of 300 Pico Curies per liter (pCi/L) for community water systems, and an alternative MCL of 4,000 pCi/L for community systems that have an EPA-approved Multimedia Mitigation Program (EPA, 1999). The proposed MCLs for radon will not apply to private wells.

The radon distribution map shows results from 8 wells sampled for this study and 37 other wells sampled by MBMG or the USGS between 1992 and 1995. The concentrations were grouped into three reporting ranges: 1) low, less than 300 pCi/L (blue symbols), 2) intermediate, between 300 and 1,000 pCi/L (pink symbols), and 3) high, greater than 1,000 pCi/L (red symbols).

Nitrate

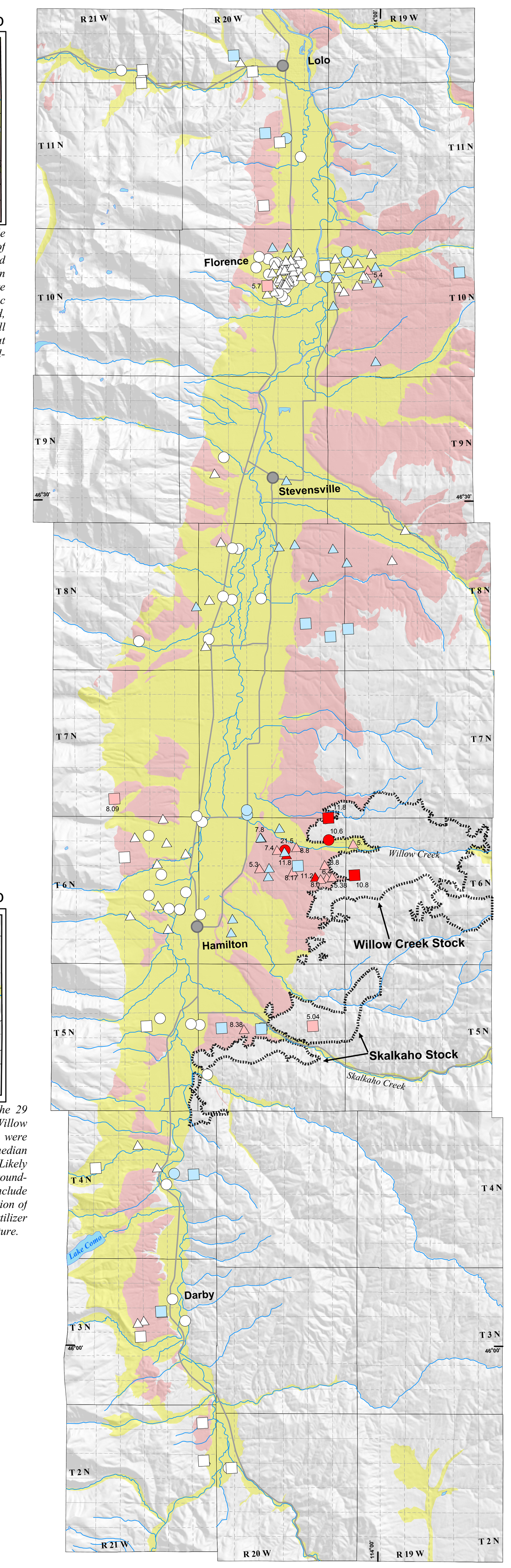


Around Florence and in the Eightmile drainage, nitrate was detected in 61 of 77 samples; concentrations ranged from non detectable to 8.30 mg/L. In the boxed area (0.8 sq. mi.) there are records of more than 115 septic systems (Norbeck and McDonald, 2001) and nitrate was detected in all but one of the samples suggesting that septic effluent is a source ground-water nitrate in this area.

Nitrate was detected in 28 of the 29 samples from the Willow Creek/Willow Creek fan area; concentrations were below 4.0 mg/L with a median concentration of 1.5 mg/L. Likely sources of the widespread ground-water nitrate in this area include septic effluent, domestic application of fertilizer, and application of fertilizer associated with irrigated agriculture.

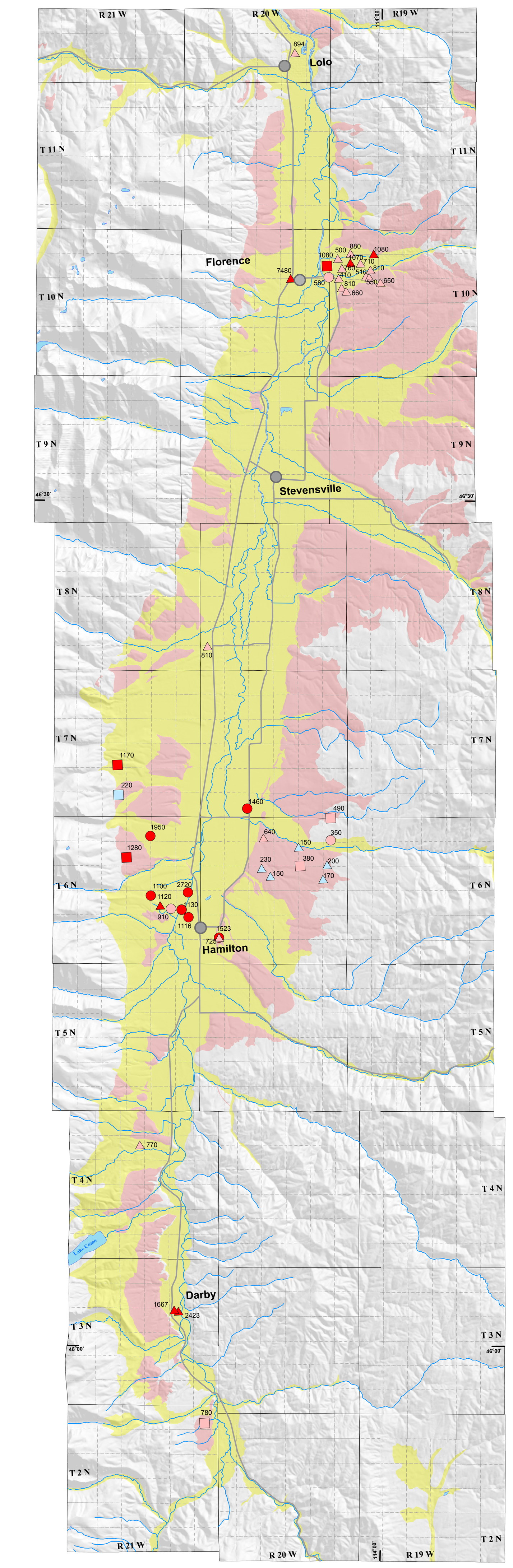
shallow deep bedrock
Nitrate concentration
(Concentrations greater than 2.0 mg/L are labeled on the map.)
not detected
less than 2 mg/L-N
2 - 10 mg/L-N
greater than 10 mg/L-N
Scale 1:200,000
Projection Montana State Plane
Datum NAD83
0 1 2 3 4 5 Miles

Arsenic



shallow deep bedrock
Arsenic concentration
(Concentrations greater than 5.0 µg/L are labeled on the map.)
less than 1 µg/L
1 – 5 µg/L
5 – 10 µg/L
greater than 10 µg/L
Outline of Willow Creek and Skalkaho Stocks
Scale 1:200,000
Projection Montana State Plane
Datum NAD83
0 0.9 1.8 2.7 3.6 4.5 Miles

Radon



shallow deep bedrock
Radon concentration
(Concentrations labeled on map.)
less than 300 pCi/L
300 - 1,000 pCi/L
greater than 1,000 pCi/L
Scale 1:200,000
Projection Montana State Plane
Datum NAD83
0 1 2 3 4 5 Miles

Radon concentrations ranged from 150 to 7,480 pCi/L. Of the 45 samples, 87 percent (39 sites) had radon concentrations greater than the proposed MCL of 300 pCi/L; the median concentration was 810 pCi/L. Only one site had a concentration in excess of the alternative MCL of 4,000 pCi/L. On a state-wide basis, 73 percent of wells that were tested for radon had concentrations greater than 300 pCi/L (Miller and Coffey, 1998).

The radon concentrations in the Bitterroot Valley do not vary greatly between aquifer materials (fig. 7). Most of the samples were from wells in the deep basin fill (31 sites) and the average was 991 pCi/L. Samples from the shallow basin-fill aquifers (10 sites) had an average of 1,198 pCi/L; samples from fractured bedrock aquifers (4 sites) had an average radon concentration of 863 pCi/L. Based on the limited sampling, radon should be expected in Bitterroot valley ground water, and concentrations greater than 300 pCi/L are probably typical.

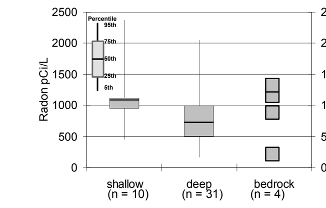


Figure 7. Radon concentrations are generally greater than 500 pCi/L.

For more information about radon and possible home treatment options the reader is referred to Miller and Coffey (1998), EPA (1999), and the U.S. Environmental Protection Agency web site (www.epa.gov, search on "radon").

ACKNOWLEDGMENTS

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

SOURCES OF DATA

Population centers and roads are from 1:100,000 scale U.S. Geological Survey (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 quad maps available from NRIS. Differences in the quality of the DEMs may result in artifacts such as mottled surfaces and horizontal striping in the hillshade base.

Well-location and water-quality data were obtained by MBMG, USGS, and UM personnel. Well locations are accurate to the 2.5-acre level (to within +/- about 300 ft). All water-quality data used on this map are available from the Ground-Water Information Center (http://mbmggwic.mtech.edu) at the Montana Bureau of Mines and Geology, Montana Tech of The University of Montana, Butte, Montana.

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