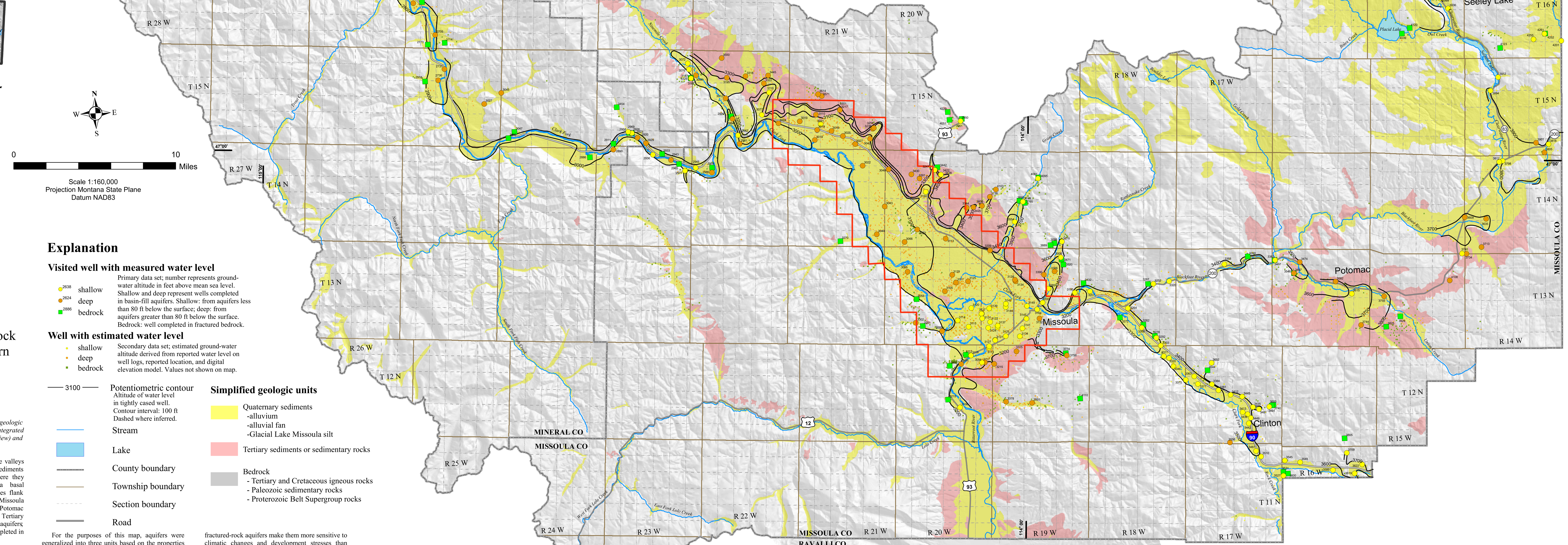
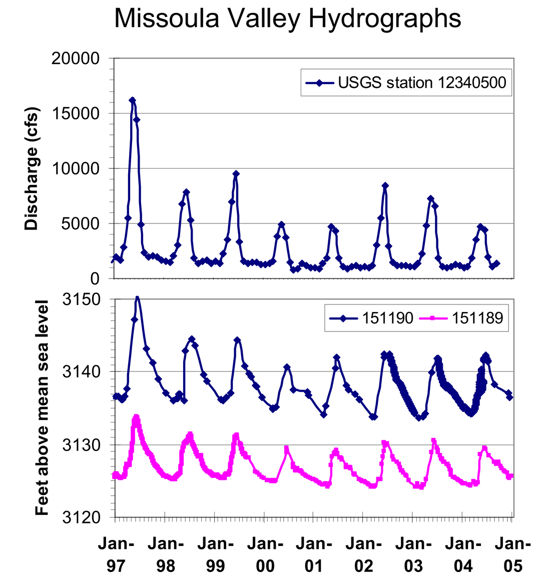
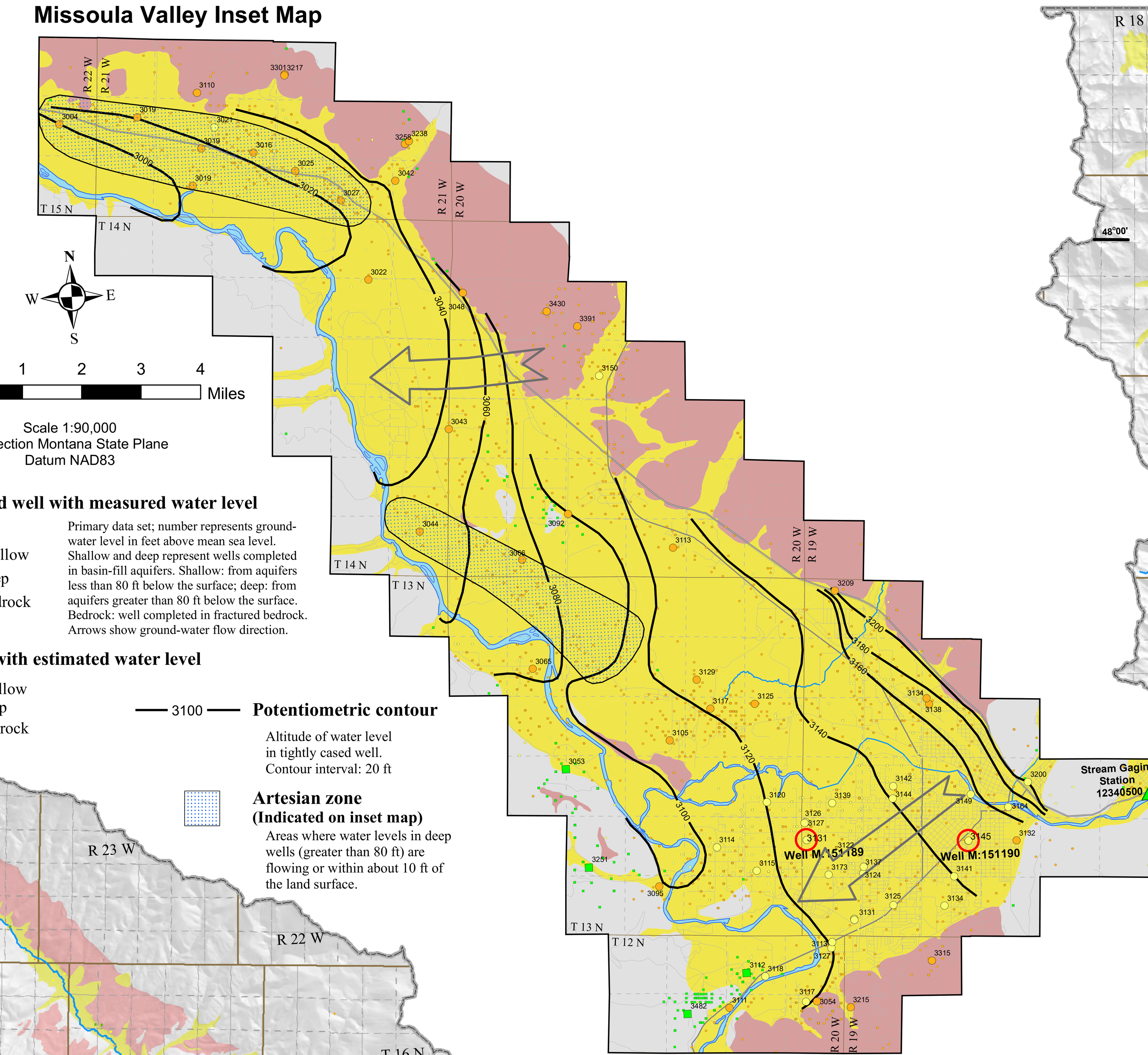


Missoula Valley Hydrographs



Leakage from the Clark Fork River provides an estimated 80 to more than 90 percent of the recharge to the Missoula Valley aquifer (Woessner, 1988; Miller, 1991); other sources include underflow through Hellgate Canyon and precipitation. Hydrographs from wells 151189 and 151190 show that the magnitude and timing of water-level fluctuations are closely tied to Clark Fork River discharge. Annual ground-water level fluctuations in wells located between the Clark Fork and Bitterroot Rivers are 5 to 10 ft; however, water-level changes are greatest in wells near the Clark Fork River (well 151190) and become muted in wells downgradient along the flow path (well 151189).

Missoula Valley Inset Map



Visited well with measured water level

- shallow
- deep
- bedrock

Primary data set; number represents ground-water level in feet above mean sea level. Shallow and deep represent wells completed in basin-fill aquifers. Shallow: from aquifers less than 80 ft below the surface; deep: from aquifers greater than 80 ft below the surface. Bedrock: well completed in fractured bedrock. Arrows show ground-water flow direction.

Well with estimated water level

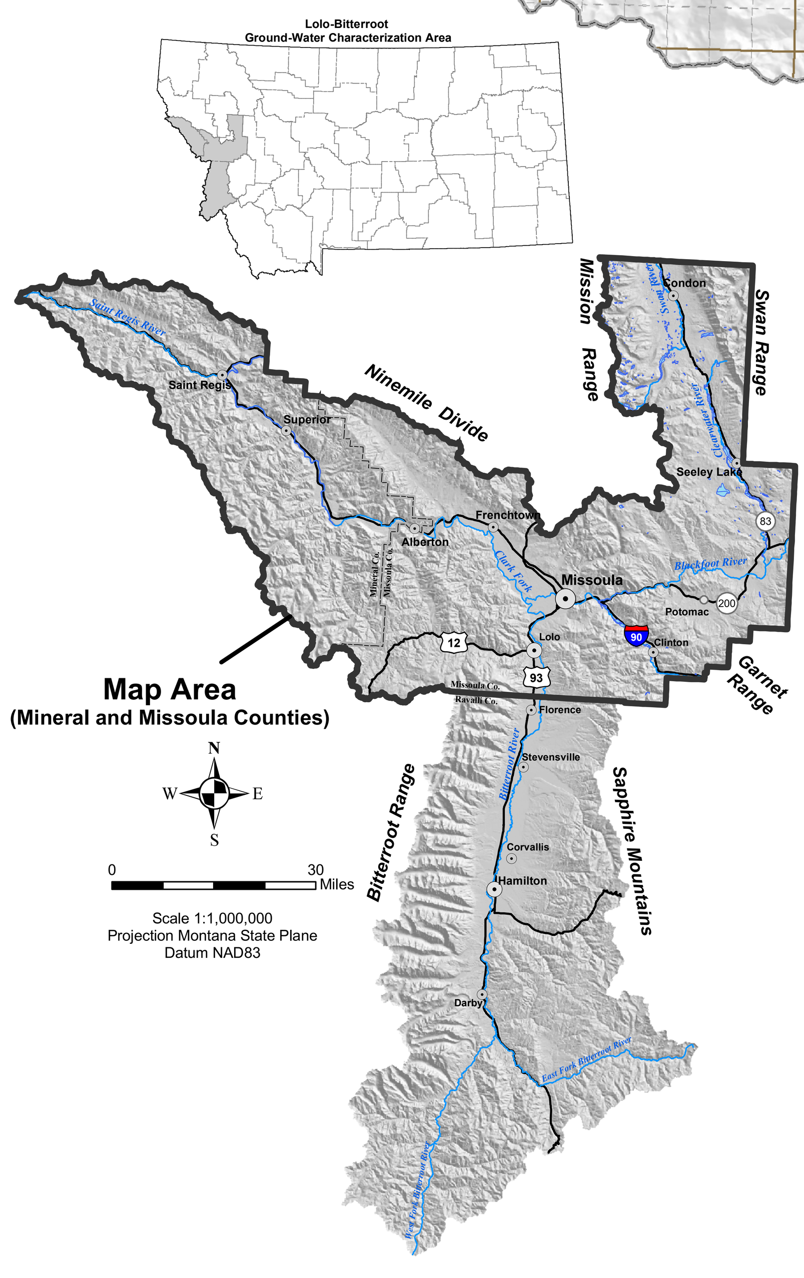
- shallow
- deep
- bedrock

— 3100 — **Potentiometric contour**

Altitude of water level in tightly cased well.
Contour interval: 20 ft

Artesian zone
(Indicated on inset map)

Areas where water levels in deep wells (greater than 80 ft) are flowing or within about 10 ft of the land surface.



Potentiometric Surface of the Basin-Fill and Bedrock Aquifers, Mineral and Missoula Counties, Western 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.

Explanation

Visited well with measured water level

- 2638 shallow
- 2624 deep
- 2886 bedrock

Primary data set; number represents ground-water altitude in feet above mean sea level. Shallow and deep represent wells completed in basin-fill aquifers. Shallow: from aquifers less than 80 ft below the surface; deep: from aquifers greater than 80 ft below the surface. Bedrock: well completed in fractured bedrock.

Well with estimated water level

- shallow
- deep
- bedrock

Secondary data set; estimated ground-water altitude derived from reported water level on well logs, reported location, and digital elevation model. Values not shown on map.

— 3100 — Potentiometric contour
Altitude of water level in tightly cased well.
Contour interval: 100 ft
Dashed where inferred.

Stream

Lake

County boundary

Township boundary

Section boundary

Road

Simplified geologic units

Quaternary sediments
-alluvium
-alluvial fan
-Glacial Lake Missoula silt

Tertiary sediments or sedimentary rocks

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

INTRODUCTION

As part of the Montana Ground-Water Assessment Program, water levels were measured in bedrock and basin-fill aquifers in Mineral and Missoula Counties in western Montana to assess directions of regional ground-water flow. This plate presents a potentiometric surface map of the basin-fill and bedrock aquifers constructed from water-level measurements made mostly between 1998 and 2000. The map also shows the distribution of wells in the mapped area.

The potentiometric surface represents the altitudes to which water will rise in wells penetrating the aquifer. Ground water moves down the slope of the potentiometric surface, from higher altitude to lower altitude, perpendicular to the contours. Water levels for the southern part of the Lolo-Bitterroot Ravalli County (Ravalli County, the Bitterroot Valley) are presented on a separate plate (LaFave, 2006).

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

The bedrock exposed in the mountains also underlies the valleys. 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, 2006a).

The basin-fill deposits consist of Tertiary and Quaternary sediments. Tertiary sediments range from unconsolidated to strongly consolidated and include claystone, shale, siltstone, sandstone, locally thick conglomerate, coal, and volcaniclastic rocks (McMurtrey and others, 1965; Smith 2006a).

Tertiary sedimentary rocks fill most of the valleys to thicknesses up to 2,500 ft. These sediments typically have low permeability and where they underlie Quaternary alluvium form a basal confining unit. Prominent Tertiary benches flank the northeast and southeast sides of the Missoula Valley; exposures are also found in the Potomac and Ninemile Valleys. Locally, permeable Tertiary sandstones and conglomerates are aquifers; however, there are relatively few wells completed in Tertiary sediments.

Quaternary basin-fill deposits (up to 300 ft thick) 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 till, which is mostly clayey and silty gravel. Bedded silt and clay were deposited in the valleys 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 deposits in stream valleys are less than 80 ft thick in most areas and represent stream deposition during and after waning phases of glaciation (Smith, 2006b).

HYDROGEOLOGIC SETTING

Exploitable ground-water resources within the valley regions occur primarily in the Quaternary basin-fill deposits and to a lesser extent in the Tertiary basin fill and fractured bedrock. There are records of about 9,400 wells in the map area; approximately 1,200 are completed in bedrock aquifers and the remainder are in basin-fill deposits. The basin fill contains unconfined aquifers and sequences of 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. The basin-fill aquifers are the most utilized sources of municipal and domestic water (Kendy and Tresch, 1996). The median reported well yields from the basin-fill aquifers are about three times greater than median well yields from bedrock aquifers (fig. 1).

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 (fig. 2). 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 (yellow circles on the map) 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 (orange circles).

Bedrock aquifers occur around the valley margins. The occurrence of ground water in the bedrock is primarily controlled by fractures. Where it is sufficiently fractured (permeable) and saturated, bedrock can yield water to wells (green squares). 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. The lower permeability inherent to fractured-rock aquifers is reflected in lower well yields—the median reported yield is 10 gpm (fig. 2). Additionally, lower storage capacities inherent to fractured-rock aquifers make them more sensitive to climatic changes and development stresses than basin-fill aquifers.

POTENTIOMETRIC SURFACE

This map depicts the regional ground-water flow system in the bedrock and basin-fill aquifers. The potentiometric surface represents the altitudes to which water will rise in wells. Ground water moves down the slope of the potentiometric surface, from higher altitude to lower altitude, perpendicular to the contour lines. Ground-water flow paths are generally away from the mountains toward the center of the valleys.

Ground water generally originates as precipitation in the mountains and valleys where it infiltrates through the soil and rock. Leakage of water from streams and irrigation canals is also an important source of ground-water recharge. Mountain-front recharge can be a significant source of water to basin-fill aquifers because the mountains receive much more precipitation than valleys. Where fractured-bedrock aquifers are hydraulically connected to the basin-fill aquifers, water is transferred from the fractured bedrock to the adjacent and lower-lying basin-fill aquifers.

MAP USE

The map is useful for estimating the general direction of ground-water flow, identifying areas where flowing artesian wells might occur, and estimating the water-level altitude in non-flowing wells. If the approximate land-surface altitude at a location is known (for example, determined from a topographic map), the corresponding point on the potentiometric surface map can be found and the altitude of the potentiometric surface estimated. Subtracting the potentiometric surface altitude from the land surface altitude yields the approximate level at which water will stand in a well.

METHODS

The maps were constructed by hand contouring measured water-level altitudes. The primary data were obtained from 362 wells mostly visited between 1998 and 2000 (Carstarphen and others, 2003). Visited wells were selected on the basis of availability, information on well logs, access, geographic location, and geologic setting. Well locations were determined using a Global Positioning System (GPS) receiver and plotted on U.S. Geological Survey (USGS) 1:24,000 topographic maps. Land-surface altitudes were determined from the 1:24,000-scale maps and are generally accurate to +/- 5 to 10 ft (based on 10- and 20-ft contour intervals).

Additionally, reported water levels from driller's logs were used to estimate ground-water elevations. The supplemental data were used in areas where the primary data were sparse, and also helped confirm the shape of the potentiometric surface(s) in areas of dense primary data coverage. Map accuracy is affected by data distribution, field measurement errors, accuracy of well locations, and errors in interpretation. Points at which water levels have been measured are distributed unevenly across the map, and map accuracy is greater near points of measurement.

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 report by Tom Patton and John Metesh improved its clarity.

DATA SOURCES

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 hillshade base. Geological data were simplified from the Hydrogeologic Framework Map compiled by Smith (2006a).

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. Water-well logs and inventory data are available from the Montana Ground-Water Information Center (GWIC, online at 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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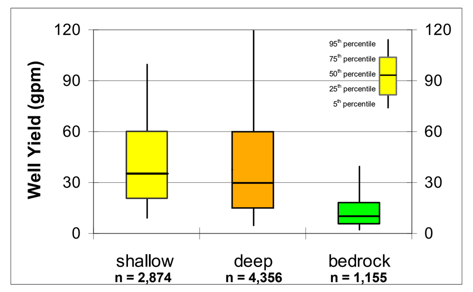

Figure 1. Aquifers in the shallow and deep basin-fill aquifers are generally productive; median and average yields are greater than 30 gallons per minute. However, in the Missoula Valley yields greater than 1,000 gallons per minute are reported for more than 75 wells in the shallow and deep basin fill. Yields from wells in the fractured bedrock are much less, with a median of 10 and an average of 14 gallons per minute.

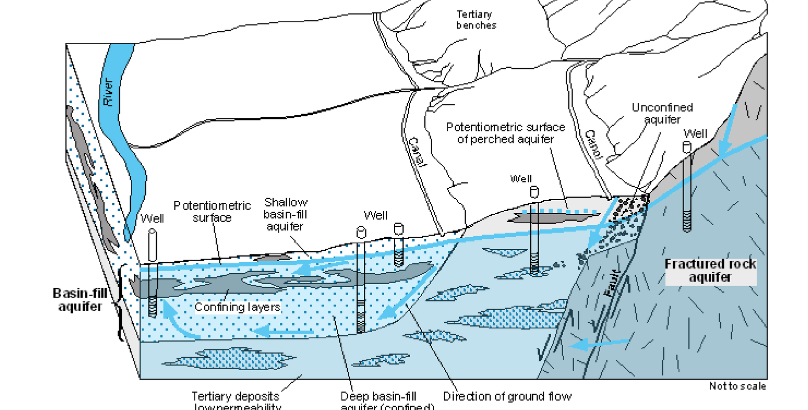

Figure 2. Schematic block diagram showing the relationship between shallow and deep basin-fill aquifers and fractured-bedrock aquifers in the intermontane basins of Mineral and Missoula Counties.