Hydrogeologic Framework of the Southern Part of the Flathead Lake Area, Flathead, Lake, Missoula, and Sanders Counties, 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 Flathead Lake 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 Flathead Lake Area the reader is referred to Part A (descriptive overview) and other Part B maps of the Montana Ground-Water Assessment Atlas No. 2.

INTRODUCTION

The southern part of the Flathead Lake area, generally within the Flathead Indian Reservation, includes several intermontane valleys, including the Mission, Little Bitterroot River, Camas Prairie Basin, Swan, and Jocko valleys, and many smaller tributary valleys along the Flathead River, such as Irvine Flats (fig. 1). Elevations range from greater than 9,000 ft in the Mission Range to about 2,500 ft above sea level along the Flathead River where it exits the Flathead Indian Reservation in Sanders County.

Geologic units exposed in the mountains surrounding the valleys include Proterozoic Belt Supergroup rocks, Tertiary igneous rocks, Tertiary conglomerate, sandstone, and siltstone, and Quaternary glacial and post-glacial sediments (fig. 2; Mudge and others, 1982; Harrison and others, 1986; Ostenaa and others, 1990; Smith and others, 2000). Belt Supergroup rocks core most ranges, with Tertiary volcanic and intrusive rocks common only in the Hog Heaven Range at the northern end of the Little Bitterroot River valley (Lange and Zehner, 1992). Sedimentary rocks and loosely consolidated sediment of Tertiary age have been incompletely mapped in the area. However, reconnaissance work shows that the upper parts of many small tributary valleys in the Salish Mountains are composed of Tertiary strata (P. C. Ryan, written comm., 1999).

Intermontane valleys between the bedrock-cored mountains are filled by Tertiary sediments and sedimentary rocks, local accumulations of pre-glacial sand and gravel, a variety of glacial sediments, and post-glacial alluvium and minor eolian accumulations (fig. 3). Glacial sediments mantle bedrock in the mountains north of the Polson moraine, where the last glacial advance of the Flathead Lobe of the Cordilleran ice sheet ended, and along many drainages in the Mission Range, which were once occupied by valley glaciers (figs. 1, 2).

The maps included here show the depths to, thicknesses of, and proportions of sand and gravel in sediments that contain basin-fill aquifers in the southern part of the Flathead Lake area. Data were gathered from descriptive water-well logs, surface exposures of sediments (Levish, 1997), and some previously published geophysical studies (LaPoint, 1971; Boettcher, 1982). Hydrogeologic units were defined based on surficial geologic map units, stratigraphic position, and drillers' log data (fig. 4). The maps include:

- Figure 5 – depth below ground surface to a locally mappable deep alluvial unit in the Mission and Little Bitterroot River valleys;
- Figure 6 – thickness of Glacial Lake Missoula sediments above the deep alluvium; and
- Figure 7 – relative coarseness of Glacial Lake Missoula sediments above the deep alluvium.

Sufficient hydraulic continuity between the deep alluvium, permeable zones in much of the Glacial Lake Missoula sediment, and shallow alluvium (figs. 3, 4), allow the entire sequence to be considered a single, regional, ground-water flow entity. The ground-water flow system for the Glacial Lake Missoula sediments, deep alluvium, and fractured bedrock, and some Tertiary sedimentary rocks, based on wells completed at depths greater than 75 ft below ground surface, is presented in LaFave (2002). Inset into the Glacial Lake Missoula sediments are surficial sand and gravel deposits which may be aquifers. The location of those deposits is shown as "Qal" on figure 2. Thicknesses of this shallow alluvium are up to 150 ft near the Polson moraine but generally are less than 50 ft in other areas (Smith, 2002b).

BASIN-FILL STRATIGRAPHY

The intermontane valleys in southern part of the Flathead Lake area are structurally down-dropped relative to the uplifted Salish, Mission, Swan, and Jocko mountain ranges. Bedrock is about 2,000 ft below the surface in the structurally deepest parts of the Mission valley, near the Polson moraine (Smith, 2002a), however the depth to bedrock is shallower in the southern and central parts of the valley. Depths to Belt bedrock in the Jocko, Camas Prairie Basin, and Little Bitterroot River, and southern Mission valleys are poorly known. In these valleys, consolidated silt, clay, sandstone, and conglomerate of probable Tertiary age were penetrated in the bottom of well bores, especially in the Camas Prairie Basin, Irvine Flats, tributary valleys along the Little Bitterroot River, and in the southern Mission valley (Slagle, 1988; P. C. Ryan, written comm., 2000). The bottom portions of the deepest boreholes in the Jocko Valley penetrated reddish-colored clayey and silty conglomerates that may be correlative to a section of Tertiary sedimentary rocks that are at land surface in the northwestern part of that valley.

In most areas of the Mission and Little Bitterroot River valleys, the deep alluvium (probably of Quaternary age) rests on either Tertiary sedimentary rocks or bedrock. This unit, which is not known to be exposed at the surface and is recognized only in well bores, consists of gravel, sand, and minor silt and can produce large volumes of water where it is greater than 20 ft thick. Reported yields from about 700 water wells completed in this unit range from 2 to 2,500 gallons per minute (gpm) with an average of 100 gpm and a median of 40 gpm. The deep alluvium is known as the Lonepine aquifer in the Little Bitterroot River valley. Locally in T. 19, 20, and 21 N. in the Mission valley, a few wells have been drilled entirely through the deep alluvium into bedrock. In these wells the deep alluvium was as much as 77 ft thick. However, most wells are completed between 10 and 20 ft below the top of the unit.

The deep alluvium in the Little Bitterroot River valley (the Lonepine aquifer) likely represents a pre-glacial or outwash stream deposit that is continuous throughout much of that valley (Meinzer, 1916; Donovan, 1985; Abdo, 1997), but is isolated from other alluvium found below lake deposits in the Sullivan Flats area (Briar, 1987). The deep alluvium in the Mission valley may be similar to the Lonepine aquifer, in that it was deposited by pre-glacial or glacial streams. The unit is overlain in many areas by lake sediments deposited in Glacial Lake Missoula, which covered many valleys in western Montana during the last glacial period (Pardee, 1910; Alt, 2001).

The deep alluvium is generally overlain by beds of silty and clayey gravel and thick beds of silt and clay with minor silty sand and gravel, which are referred to here as Glacial Lake Missoula sediments (fig. 4; Levish, 1997). In the Little Bitterroot River valley, the deep alluvium is directly overlain by a thick sequence of Glacial Lake Missoula silt and clay that generally is not an aquifer. In the Mission valley, determining the contact between deep alluvium and the Glacial Lake Missoula sediments from water-well driller logs is not always possible. Interfingering between units makes correlations between wells difficult, especially in the northern and southern parts of the valley where wells do not reach into Belt bedrock. Reported yields from about 1,200 water wells completed in the Glacial Lake Missoula sediments range from 1 to 1,500 gpm with an average of 45 gpm and a median of 20 gpm. Glacial Lake Missoula sediments correlative to the sequence that overlies the deep alluvium is well exposed along the canyon walls of the Flathead River downstream of the Kerr Dam (fig. 1).

Silt and clay were deposited in Glacial Lake Missoula above the deep alluvium in the Little Bitterroot River valley and Camas Prairie Basin. In the Valley View Hills area of the Mission valley, exposures suggest that till (silty and clayey gravel deposited directly by glacial ice) may overlie the deep alluvium locally in the subsurface. However, the well data are insufficient to make a distinction between till and gravelly glacial-lake deposits. The glacial-lake deposits, which fill much of the valleys, are overlain by shallow alluvium along river valleys, glacial-meltwater stream deposits (outwash), and eolian sand. The shallow alluvium may contain shallow ground water (fig. 4). Reported yields from about 570 water wells completed in the shallow alluvium range from 1 to 1,000 gpm with an average of 55 gpm and a median of 20 gpm. Locally, this shallow ground-water system may be hydraulically connected to water in the deeper units.

The sequence of unconsolidated geologic units (from older to younger–deep alluvium, local till deposits, glacial-lake deposits, and sand and gravel at the land surface) represents deposition during one or more glacial-ice and glacial-lake advance and retreat cycles. The deep alluvium was likely deposited both before and during glacial advance. The uppermost beds of the deep alluvium most likely were deposited as outwash by meltwater streams in front of the glacier that advanced southward (Smith and others, 2000). Thick till was deposited locally by the Flathead glacier near to and north of the Polson moraine and where valley glaciers extended westward out of the Mission Range into the valley (Alden, 1953; Boettcher, 1982; Richmond, 1986; Slagle, 1988; Levish, 1997). Till was deposited by earlier advances of the Flathead glacier that extended south of the Polson moraine (Olson, 1998), but the distributions and ages of these deposits are poorly known.

Glacial-lake deposits of Glacial Lake Missoula were deposited south of, and possibly locally north of, the Polson moraine and within the Little Bitterroot River, Camas Prairie Basin, and Jocko valleys and their tributaries. Some silty and clayey glacial-lake sediments north of the Polson moraine were deposited in a lake in front of the retreating glacier as the glacier receded from the moraine. This lake was impounded by the Polson moraine and by bedrock along the Flathead River near Kerr Dam. Glacial-lake deposits and underlying compact till may form local confining units that extend across parts of the Mission valley. The stratigraphy of the sequence is complex because of interbedding of sand, gravel, silt, and clay deposited by different processes in the lake. These processes include settling out of fine sediment in the glacial lake, stream delta progradation into the lake, subaqueous debris-flow sedimentation at the bottom of the lake, and transportation of sediment by icebergs within the lake (Levish, 1997).

Sand and gravel at ground surface includes thin alluvial fills (generally <50 ft thick) along the incised modern valleys of the Flathead River, Mud Creek, Little Bitterroot River, Jocko River, Crow Creek, and their tributaries, and eolian sand. The areas of shallow sand and gravel are mapped as Qal on figure 2 and discussed by Smith (2002b). Alluvial sediments were deposited across glacial-lake deposits and till after deglaciation as the rivers cut through the glacial deposits.

VARIATION IN THE DEPTH TO THE DEEP ALLUVIUM

Erosion and deposition at the bottom and top of the deep alluvium and variation in land-surface topography cause the deep alluvium to be at different depths. In many areas the lateral limit of the deep alluvium is poorly constrained by well data; its approximate extent is shown by dashed lines on figure 5. It thins and decreases in depth near most valley margins. Depths to the deep alluvium are greatest in the area south and east of Polson, where the land surface is higher along the Polson moraine. If the deep alluvium in the Mission valley is genetically similar to the unit in the Little Bitterroot River valley, it may be thickest along buried valleys.

The existence of beds of sand and gravel within glacial-lake deposits can make definitive interpretations of the positions of the deep alluvium difficult in some areas, including from south of Crow Creek to Mission Creek. Well data are insufficient to prove continuity of the alluvium between Irvine Flats and the area west of the Valley View Hills, south to the Moiese Hills. Topography influences the contours near the Polson moraine and along the incised Flathead River valley south of Flathead Lake and north of its confluence with Jocko River.

GLACIAL LAKE MISSOULA SEDIMENTS

Glacial Lake Missoula sediments stratigraphically above the deep alluvium and below surficial sand and gravel deposits (Smith, 2002b) average about 250 ft in thickness in the southern part of the Flathead Lake area (fig. 6). These deposits are made up of predominantly silty glacial-lake sediments (figs. 3, 4; Levish, 1997) and an unknown amount of till, both of which extend beyond the known limits of the deep alluvium (figs. 5, 6). The Glacial Lake Missoula sediments are thickest along the Polson moraine and between the Flathead River and the Valley View and Moiese Hills. The thicknesses decrease significantly along the Flathead River where the river has cut a canyon through the basin fill. Well data were insufficient to map the Glacial Lake Missoula sediments in the Jocko Valley, Swan River valley, and Camas Prairie Basin.

Greater amounts of sand and gravel are disseminated in Glacial Lake Missoula sediments in the eastern Mission valley than in those near the Flathead River or in the Little Bitterroot River valley (fig. 7). This is likely because the sediment was transported into the valleys by the Flathead lobe of the ice sheet and by valley glaciers in the Mission Range. Sediment was carried into the Mission valley by streams emerging from beneath the ice and by deposition from melting ice and icebergs. Lobes of coarser sediment in the Polson moraine region (fig. 7) and incisions in the moraine suggest that much of the sediment carried from the Flathead lobe into the Mission valley emanated from near the eastern margin of the Polson moraine (Alden, 1953) and from near the present location of Kerr Dam (figs. 1, 7). The greater quantity of fine-grained glacial-lake deposits in the Little Bitterroot River valley and Irvine Flats than in other areas suggests a lack of nearby input of glacial meltwater and sediment into these valleys. These two areas, and possibly the Camas Prairie Basin, were sites where sedimentation mostly consisted of silt and clay settling out of the Glacial Lake Missoula water column.

The relative abundance of sand and gravel in the Glacial Lake Missoula sediments in the eastern Mission valley, compared with other areas, means that it is more likely that sand and gravel lenses or beds exist in this area. Intervals of water-permeable sand and gravel in the predominantly silty Glacial Lake Missoula sediments are locally productive intervals in water wells. In the Little Bitterroot River valley and Irvine Flats areas the lower percentage of sand and gravel reduces the possibility of successfully completing a well in the Glacial Lake Missoula sediments. Boreholes in the Little Bitterroot River valley occasionally penetrate saturated sand beds in the Glacial Lake Missoula sediments, called "heaving" or "quick" sands by some drillers, but these beds are rarely aquifers. Productive wells will not be possible at all locations in the eastern Mission valley, but people constructing wells should be aware that the possibility exists that they could complete a well at a shallower depth than that needed to reach the deep alluvium.

MAP USE

These maps can be used to help determine general drilling and completion depths for water wells where the deep alluvium or sand and gravel beds in Glacial Lake Missoula sediments of the Mission valley are drilling targets. The positions of the deep alluvium (fig. 5) and the relative coarseness of Glacial Lake Missoula sediments (fig. 7) are useful for siting new wells because in the most commonly used aquifers. The areas of relatively high sand and gravel content in the Glacial Lake Missoula sediments are possibly more sensitive to contamination by land-surface sources than the other areas. Because of the widespread occurrence of fine-grained glacial-lake deposits across the Little Bitterroot River valley, the Lonepine aquifer may be naturally protected from contamination in many places (Donovan, 1985, Abdo, 1997). Considering the number of water wells constructed in all of the valleys, good construction practices, sealing of annular spaces, and proper abandonment of unused wells are essential to continue protecting the quality of ground water.

MAP CONSTRUCTION

Lithologic logs for the wells used in the mapping were retrieved from the Ground-Water Information Center (GWIC) databases in 1996, incorporating data for most wells completed through 1995. In areas where mapping was problematic, especially in the Polson area, additional wells completed through 1999 were added to the data set. Water-well locations reported to a quarter-section or smaller area were used. Most well locations are as reported by drillers, although some locations were refined by comparison of anomalous geologic descriptions with street addresses of the property or by talking to the well owners. About 6% of the well locations were confirmed by field visits.

Thicknesses of sand and gravel deposits at the surface (Smith, 2002b), silty and clayey glacial-lake deposits, sandy and gravelly glacial-lake deposits, till, deep alluvium, and bedrock units were picked from each log. In general, sand and gravel units were described as such in the drillers logs and produced water to the wells while drilling (fig. 4). The silty and clayey glacial-lake deposits typically did not produce water while drilling; sandy and gravelly glacial-lake deposits were typically described as silty sand and silty gravel that produced water from a few beds. The deep alluvium was recognized in lithologic logs from about 440 wells. Percentages of coarse-to-fine grained glacial-lake deposits were calculated from data from about 1,250 wells, but only those wells that were at least 200 ft deep (626 wells) were used in figure 7.

Land-surface altitudes at well locations were obtained from U.S. Geological Survey digital elevation models (DEMs) using ArcInfo™ computer software for determining the elevation of subsurface units. Comparison of well-location altitudes determined in the field from topographic maps with those derived from the DEMs showed that the differences between calculated values and those field-determined values were generally less than 10 ft. The altitudes of the top of the deep alluvium were contoured by hand and then digitized. The depths to deep alluvium were calculated by subtracting the interpreted altitudes of the top of the unit from land-surface altitudes using ArcInfo™ software. The resulting depth grid was smoothed and contoured, using ArcInfo™. The contours were smoothed to reduce jagged traces and were partially redrawn by hand, especially near valley margins. Small irregularities exist in many contours, most of which are caused by abrupt changes in land-surface altitudes.

DATA SOURCES

Water-well driller logs and well locations are stored in the Ground-Water Information Center database at Montana Bureau of Mines and Geology (http://mbmggwic.mtech.edu). Ground-surface topographic data are from the 1:24,000-scale U.S. Geological Survey DEMs for western Montana. Public Land System Survey data, hydrography, and roads were obtained from Montana's Natural Resources Information System, Helena (http://nris.state.mt.us/).

ACKNOWLEDGEMENTS

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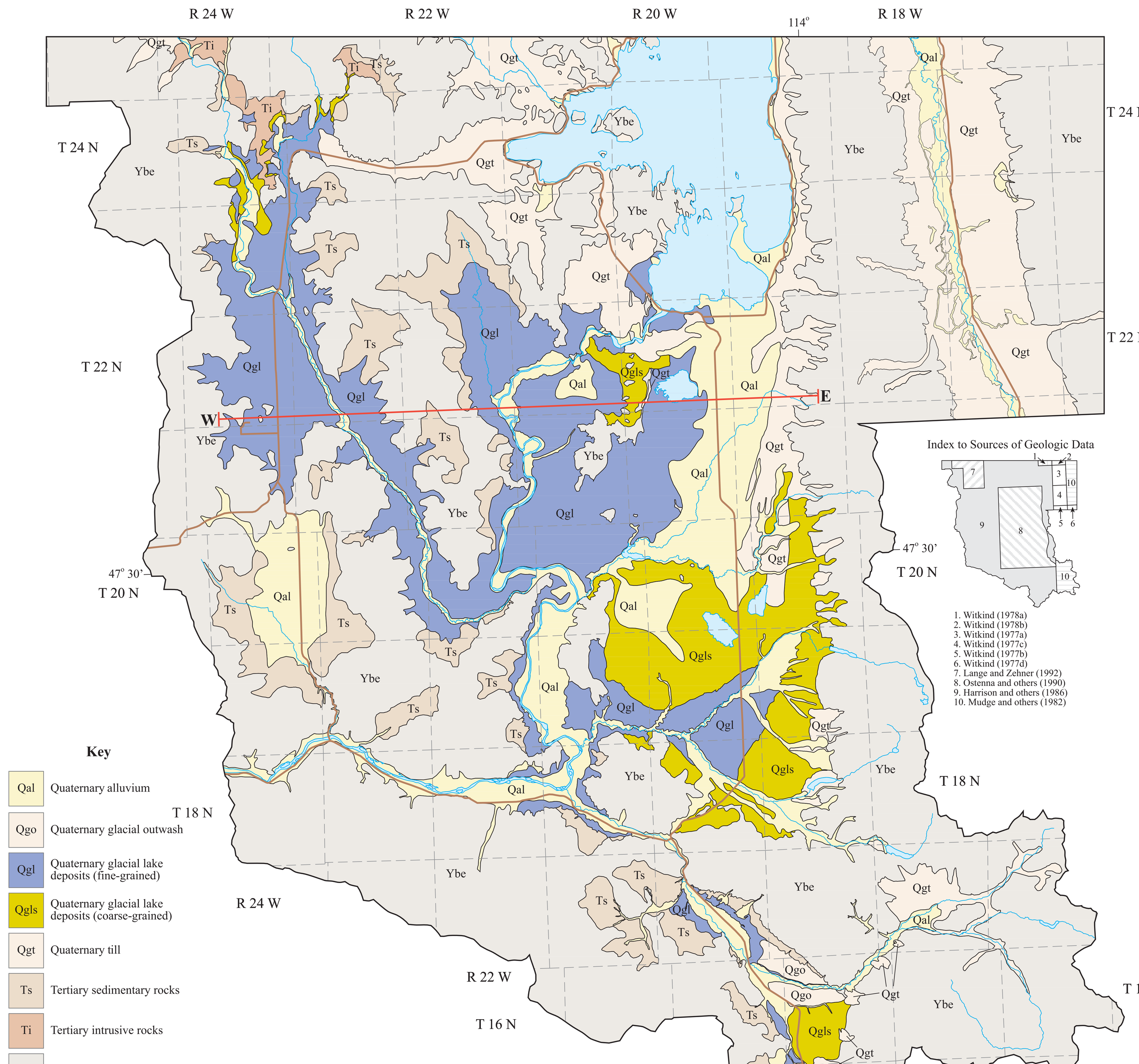


Figure 2. Generalized map of the distribution of geologic units in the southern part of the Flathead Lake area. Mountain areas are underlain by bedrock of the Proterozoic Belt Supergroup (Ybe) and Tertiary intrusive rocks (Ti). The upper ends of many valleys in the southwestern half of the area contain Tertiary sedimentary rocks (Ts), the distributions of which were mapped only approximately because the unit was not distinguished on previous maps. Valleys are covered by glacial deposits (Qgt), sediments that accumulated in Glacial Lake Missoula (Qgl and Qgls), and post-glacial (mostly stream) deposits (Qal).

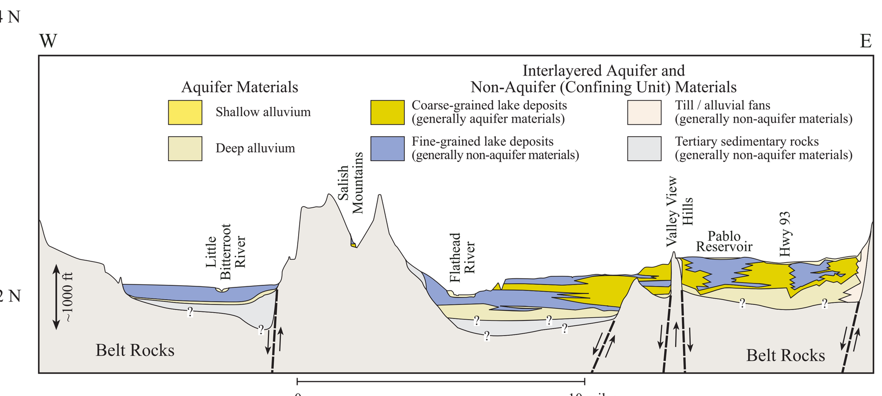


Figure 3. Diagrammatic, vertically-exaggerated cross sectional view of the topography and thicknesses of geologic units in the Mission and Little Bitterroot valleys. Inferred locations and directions of movement along basin-bounding faults are shown by heavy dashed lines and arrows.

Hydrogeologic unit	Stratigraphic position	Geologic map unit	Typical drillers log descriptions
shallow alluvium	at land surface	Qal Quaternary alluvium Qgo Quaternary glacial outwash	-fine tan sand; fine dry sand -sand & water; clay sand gravel & water -gravel; sand and gravel; gravel sand & cobblestone
Glacial Lake Missoula sediments	at land surface or below shallow alluvium	Qgl Quaternary glacial lake deposits (fine-grained)	-tan silty clay; orange clay; gray clay -sticky clay w/layers of sand
		Qgls Quaternary glacial lake deposits (coarse-grained)	-scattered gravel mixed in tan gray clay; clayey sand -gravel mixed in sand–some water -fine to medium sand seeps of water -gravel mixed in silty sand with clay stringers -gravel in tan silt matrix
		Qgt Quaternary till	-claybound gravel -cobblestones embedded in clay
deep alluvium	beneath Glacial Lake Missoula sediments	*--not exposed at land surface --*	-mixed gravel in sand–much water -cleaner gravel mixed in coarse sand, water
bedrock	at land surface or buried by other units	Ts Tertiary sedimentary rocks Ti Tertiary intrusive rocks	-light green and brown claystone -green and brown siltstone, clay, and coal -greenish hard conglomerate -volcanic bedrock
		Ybe Proterozoic Belt Supergroup	-broken gray rock with tan seams-water -blue-gray, tan, or green argillite -hard gray rock w/ a few fractures -fractured brown rock & some water

Figure 4. Hydrogeologic units were determined by comparison of descriptive drillers' logs of water wells with geologic maps in the area. Each of the hydrogeologic units are permeable to ground water, but the greater quantity of clay and silt in the Glacial Lake Missoula sediments make that unit somewhat less productive of water than either the deep or the shallow alluvium.

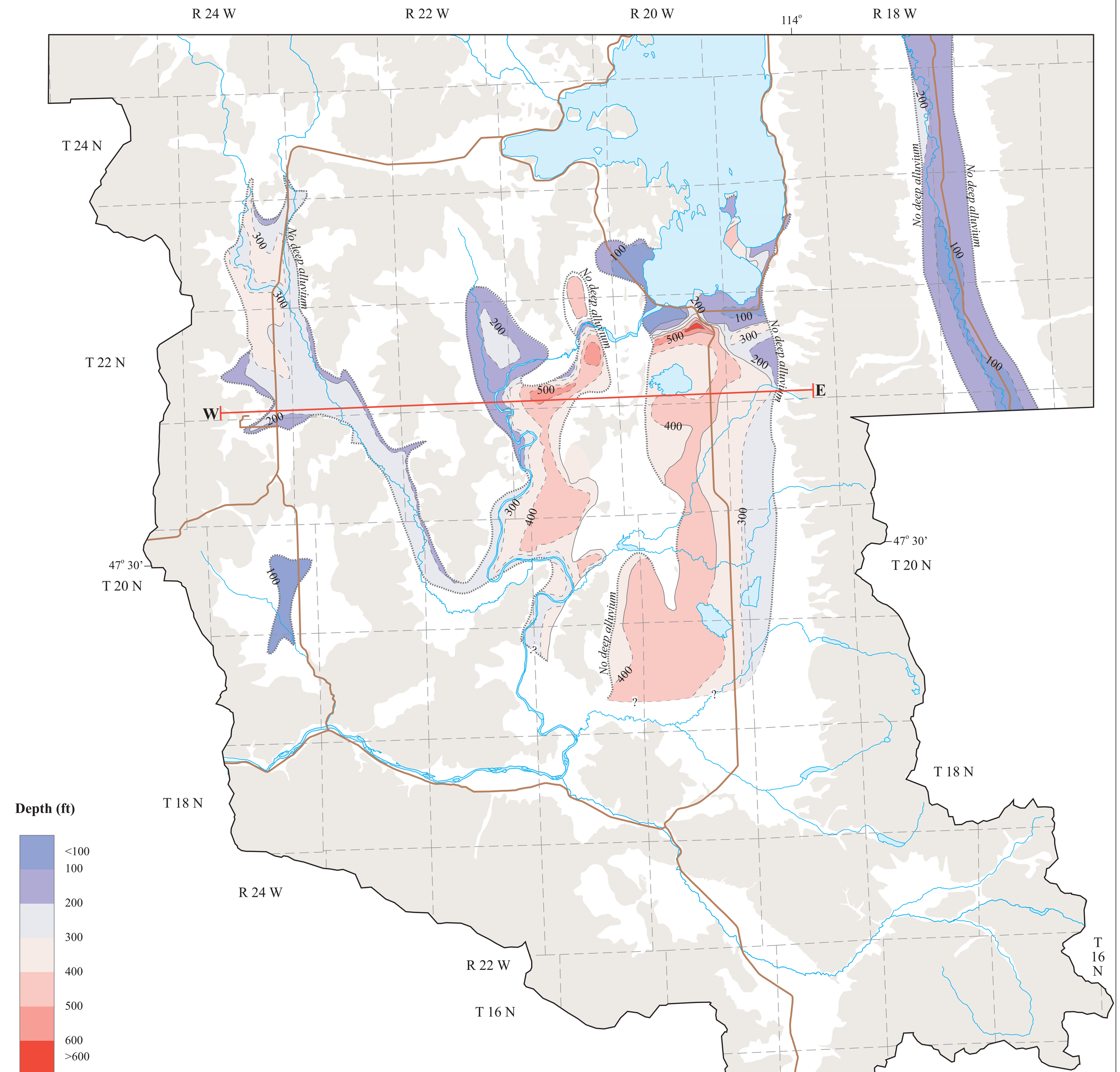
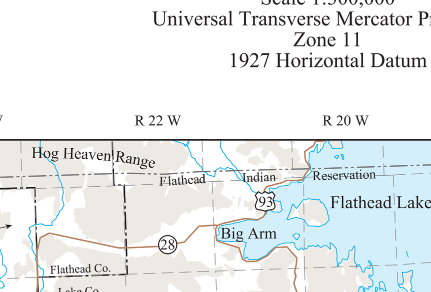


Figure 5. Depth to the deep alluvium. The deep alluvium is the main aquifer in the Little Bitterroot River valley and an important aquifer along the Flathead River and in the Mission valley. Reported yields of water wells completed in the unit are the greatest of any unit in the area, averaging 100 gallons per minute (gpm). Existence of the unit in the south of its mapped extent is unknown due to few deep wells in these areas.

Explanation (for all figures)

- Contour line, dashed where approximate; heavy short dash indicates approximate boundaries of mapped unit.
- Major roads
- Principal streams and water bodies
- Township boundaries
- Cross-section location
- Belt Supergroup bedrock at land surface



Ground-Water Characterization Program Study Areas

Scale 1:300,000
Universal Transverse Mercator Projection
Zone 11
1927 Horizontal Datum

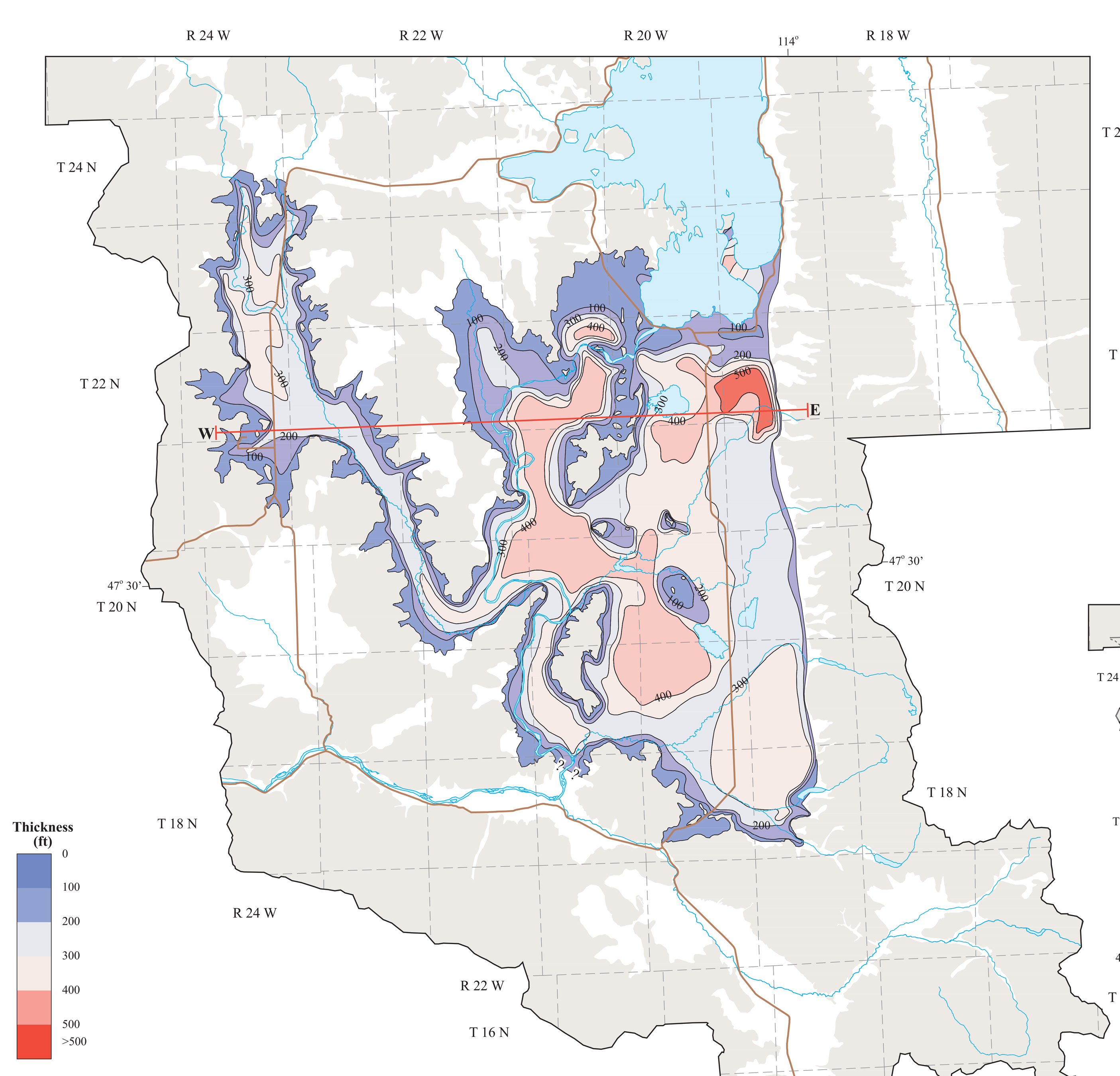


Figure 6. Thickness of Glacial Lake Missoula sediments that overlie the deep alluvium or bedrock, and underlie the shallow alluvium in the Mission and Little Bitterroot River valleys. The Glacial Lake Missoula sediments are dominated by silty and clayey beds, but where sandy and gravelly beds occur the unit can produce significant quantities of water (fig. 4).

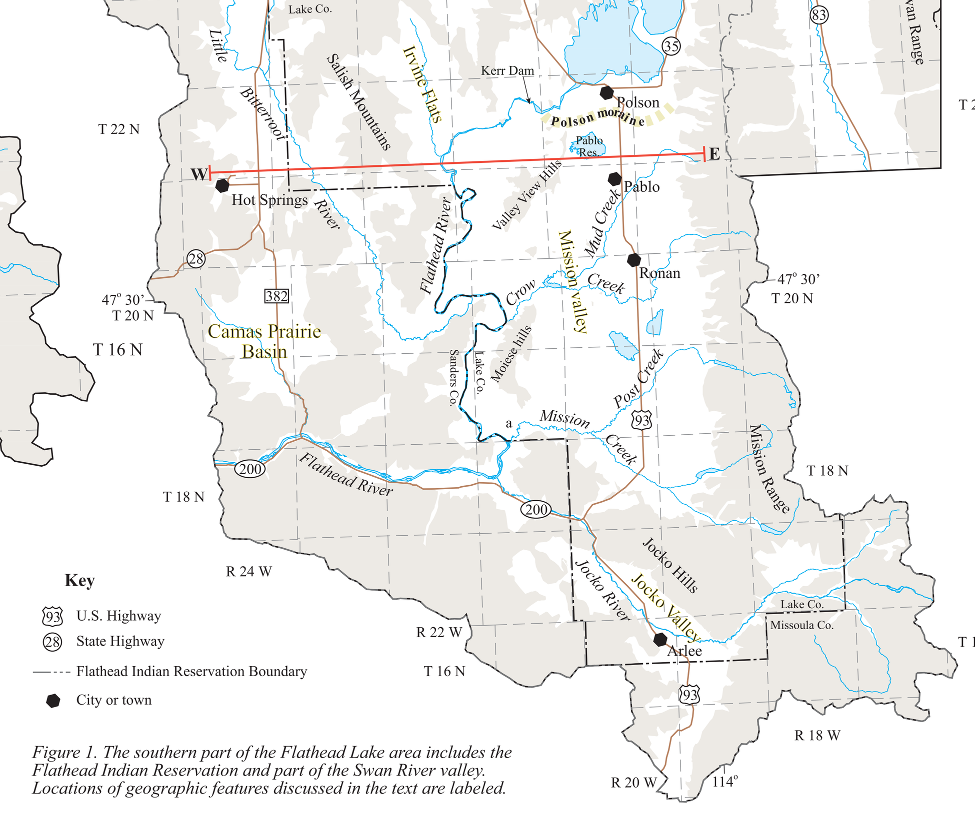


Figure 1. The southern part of the Flathead Lake area includes the Flathead Indian Reservation and part of the Swan River valley. Locations of geographic features discussed in the text are labeled.

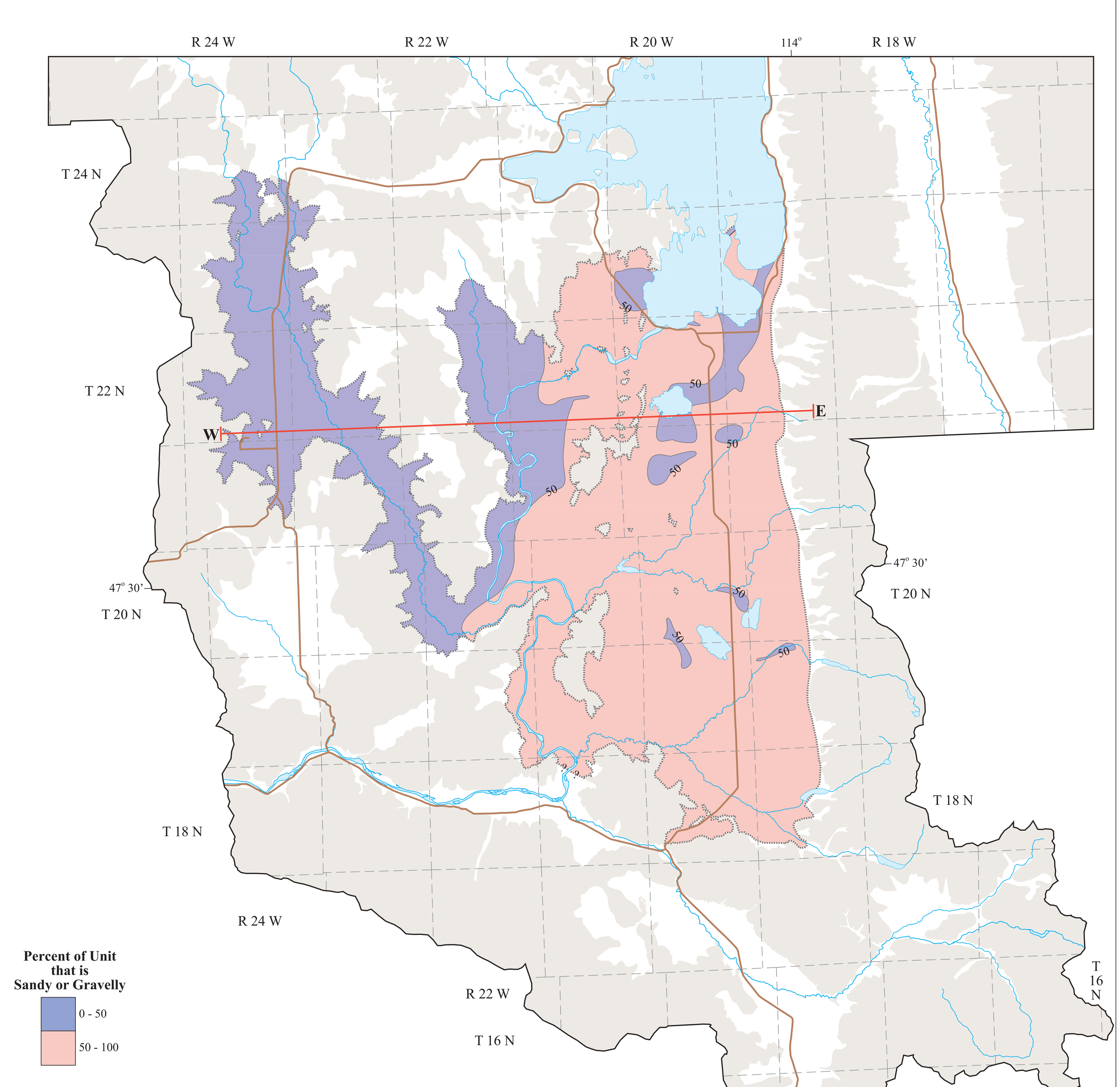


Figure 7. Percent of sandy and gravelly beds in the silty and clayey Glacial Lake Missoula sediments in the Mission and Little Bitterroot River valleys. Few of the sands and gravels are described as being well-sorted, most of the beds contain mixtures of silt and clay in with sand and/or gravel (fig. 4). All of the water wells completed in the Glacial Lake Missoula sediments are in the Mission valley where a greater proportion of the sequence is composed of sand and gravel. However, not all beds containing sand and gravel are aquifers (produce water to wells).