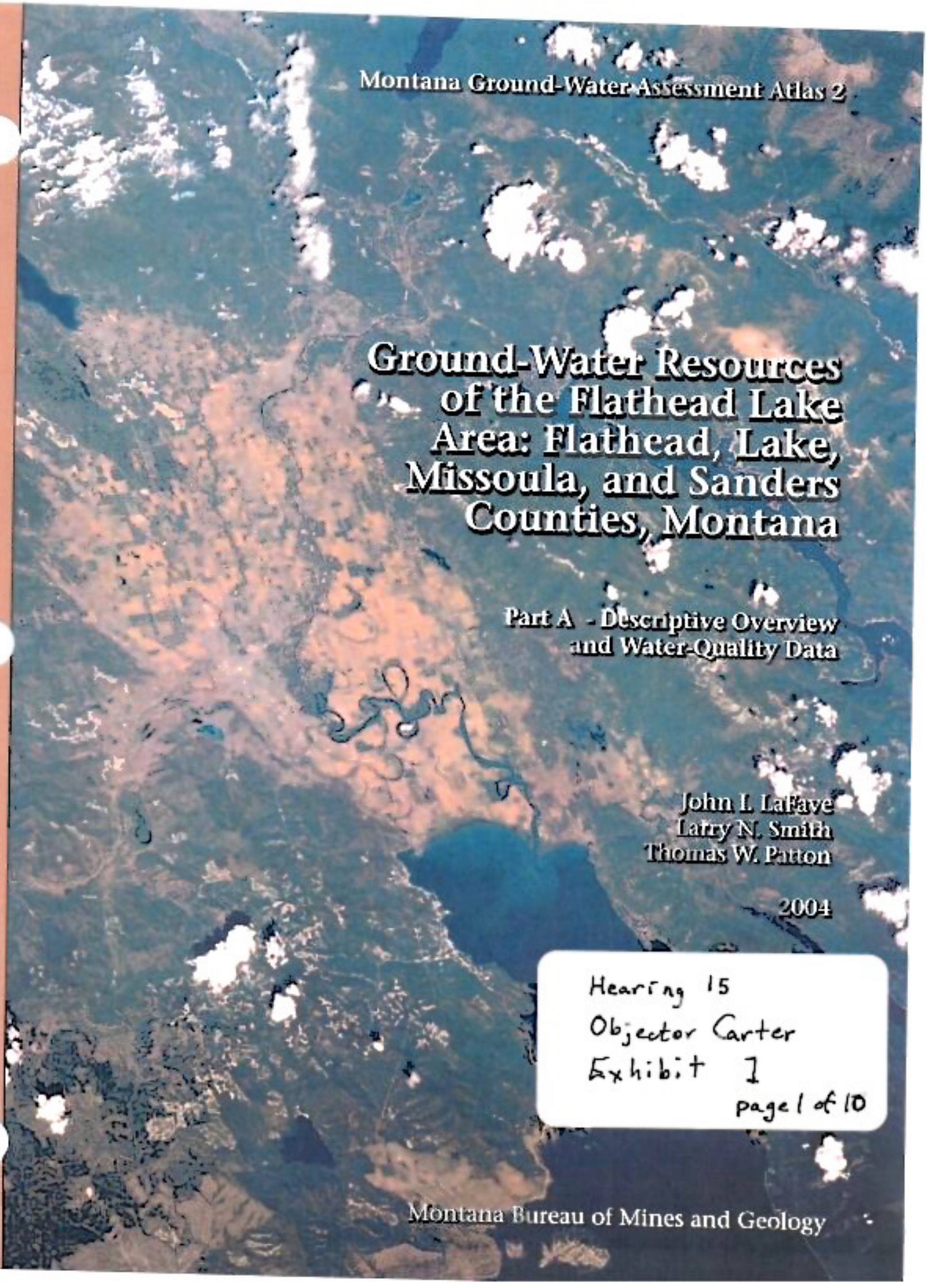

Montana Ground-Water Assessment Atlas 2

Ground-Water Resources of the Flathead Lake Area: Flathead, Lake, Missoula, and Sanders Counties, Montana

Part A - Descriptive Overview and Water-Quality Data

John I. LaFave
Larry N. Smith
Thomas W. Patton

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Exhibit I
page 1 of 10

Montana Bureau of Mines and Geology

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Part A*—Descriptive Overview and Water-Quality Data

by

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*The atlas is published in two parts: Part A contains a descriptive overview of the study area, along with water-quality data and an illustrated glossary to introduce and explain many specialized terms used in the text; Part B contains the 11 maps referenced in this document. The maps offer expanded discussions about many aspects of the hydrogeology of the Flathead Lake area. Parts A and B are published separately and each map in Part B is also available individually.

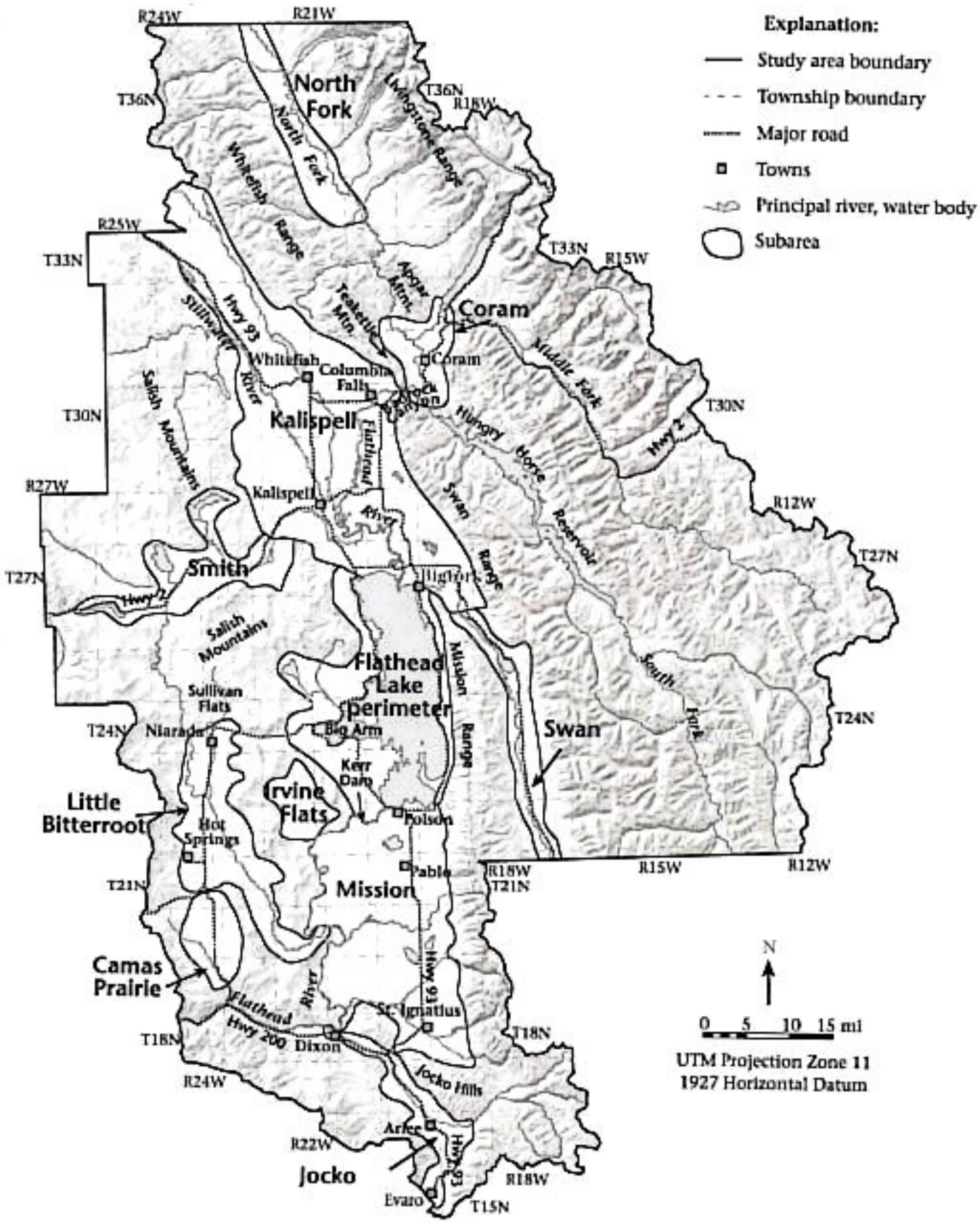

Figure 2. The Flathead Lake area ground-water characterization study covers all of Flathead and Lake Counties, and the parts of Missoula and Sanders Counties within the Flathead Indian Reservation. The 11 hydrogeologic subareas described in the atlas are shown, as are geographic names used in the text.

Intermediate and Deep Alluvial Aquifers

For this report, intermediate aquifers are defined as distinct water-bearing sand and gravel horizons bounded above and below by confining units; intermediate aquifers are generally local features of variable thickness that cannot be correlated across large distances. Intermediate aquifers occur in all the subareas, generally at depths greater than about 75 ft below land surface. The aquifers are in sand and gravel deposits and are generally confined to semi-confined by overlying low-permeability till or glacial-lake deposits. In some places they interfinger with, or are hydraulically connected to, other intermediate aquifers or deep alluvial aquifers.

Deep alluvial aquifers are sequences of sand and gravel (deep alluvium) that are widespread and correlative beneath the confining units. Deep aquifers are extensively used in the Kalispell, Little Bitterroot, and Mission subareas. The intermediate and deep alluvial aquifers are the most utilized aquifers in the Flathead Lake area, and form the major ground-water flow systems in many subareas.

Tertiary Aquifers

Most Tertiary sedimentary rocks consist of shale and mudstone, and are confining units or marginal aquifers. In a few subareas, especially the North Fork, the Tertiary sedimentary rocks contain discontinuous, permeable water-saturated sandstones and conglomerates that locally serve as aquifers. Although there are apparently great thicknesses of Tertiary deposits in many of the subareas, the materials generally occur at great depths, preventing them from being encountered by water wells or used as aquifers. Within the Flathead Lake area, only 1 percent of all wells are completed in Tertiary units, and average reported well yields are less than half the average yields reported for wells completed in other aquifers.

Bedrock Aquifers

In general, within the Flathead Lake area there is sufficient fracture permeability in bedrock (Belt Supergroup rocks) to yield water to wells. However, the number, size, and orientation of the openings are unpredictable and can change abruptly over short distances (fig. 11). Differences in fracture density result in large variations in well yield from place to place. Where bedrock fractures are directly connected to the land surface, bedrock aquifers can be susceptible to surface sources of contamination. However, in many areas ground water in the bedrock occurs under confined conditions where the bedrock is covered by low-permeability deposits or where the water-bearing fractures occur at depth and the water is under pressure. On a regional scale, it appears that bedrock fractures are interconnected.

Potentiometric-surface mapping shows that ground water in the bedrock along valley margins also is in hydraulic communication with intermediate and deep alluvial aquifers (see Part B, maps 2, 4). Because the mountains trap most of the moisture received in the study area, water moving from the mountains to deeply buried valley deposits by way of fracture systems is an important source of ground-water recharge to the valleys (fig. 20).

Ground-Water Flow Systems

A ground-water flow system consists of a single aquifer or a combination of aquifers and confining beds that function regionally to transmit ground water from recharge areas to discharge areas. Shallow ground-water flow systems are generally limited to single shallow aquifers where ground water is under unconfined conditions, and correspond closely to the areas of shallow alluvium. Ground water flows from higher topographic positions over short distances (generally <2 mi) to nearby streams or lakes. Where shallow aquifers are in hydrologic connection with underlying aquifers they can serve as important sources of recharge to deep flow systems.

Deep ground-water flow systems are present in the Kalispell and Mission subareas, where ground water flows from high altitudes in mountainous bedrock aquifers along the valley margins (regional topographic highs, which serve as drainage basin divides) toward discharge areas in deep and intermediate sand and gravel aquifers in the valley bottoms (regional topographic lows). In the Kalispell and Mission subareas the deep ground-water flow systems are overlain by shallow, local flow systems. While the shallow and deep flow systems are generally separated by confining units, the separation is not present in all areas and shallow and deep systems may be locally hydraulically connected.

Hydrogeology of Subareas

Kalispell

The Kalispell subarea (fig. 2) is a north-northwest-trending intermontane basin that lies north of Flathead Lake and is bounded by the Whitefish Range to the north and the Swan and Salish Ranges to the east and west, respectively. It is the largest basin in the study area, covering about 700 sq mi and home to about 70,000 people.

The Kalispell valley has a flat floor where surface elevations range from just less than 2,900 ft above sea level at Flathead Lake to 3,000 ft near Whitefish and Columbia Falls. The Swan Range, with peaks higher than 7,000 ft above sea level, rises abruptly from the east side of the valley floor; peaks in the Whitefish Range are generally between 5,500 and 6,500 ft above sea level, and peaks in the Salish Mountains to the west are generally less than 5,000 ft above sea level. The valley is drained by the Flathead River and its tributaries, Ashley Creek, the Stillwater River, the Whitefish River, and the lower reaches of the Swan River. Ground water, obtained from the basin fill and the bedrock that frames the valley, supplies most municipal, domestic, and agricultural water needs.

Exposed sediments in the Kalispell subarea are mostly till, glacial-lake deposits, outwash, and post-glacial alluvium deposited along the major stream courses (see Part B, map 6). Partially consolidated siltstone, carbonaceous shale, sandstone, and conglomerate also occur in the subsurface northwest of Columbia Falls and northeast of Whitefish, and are possibly equivalent to the Tertiary Kishenehn Formation. These rocks have been penetrated by a few water wells and by a hydrocarbon-exploration well. Geophysical surveys provide estimates of depths to lithified bedrock of about 3,000 ft in the Kalispell valley west of the northernmost Swan Range, and about 800 ft near the northern end of Flathead Lake (see Part B, map 7). The accumulation of more than 3,000 ft of basin-fill materials near the central axis of the valley suggests that part of the sedimentary fill was likely deposited during Tertiary time. However, drilling has not penetrated the entire basin-fill thickness in most of the valley.

There are more wells completed in the Kalispell subarea than in all the other subareas in the Flathead Lake area combined. Records from the GWIC database show that almost 10,300 wells have been drilled within the valley (fig. 22). Most of the wells (80 percent) are completed in the unconsolidated shallow, intermediate, and deep alluvial aquifers; the remaining wells are completed in bedrock aquifers around the valley's perimeter. Figure 22 shows that most wells less than 70 ft in depth are completed in shallow aquifers and represent about 25 percent of all wells drilled in the valley. About 75 percent of wells are completed at depths between 100 and 400 ft below land surface in the various aquifers of the deep flow system. Almost 40 percent of wells

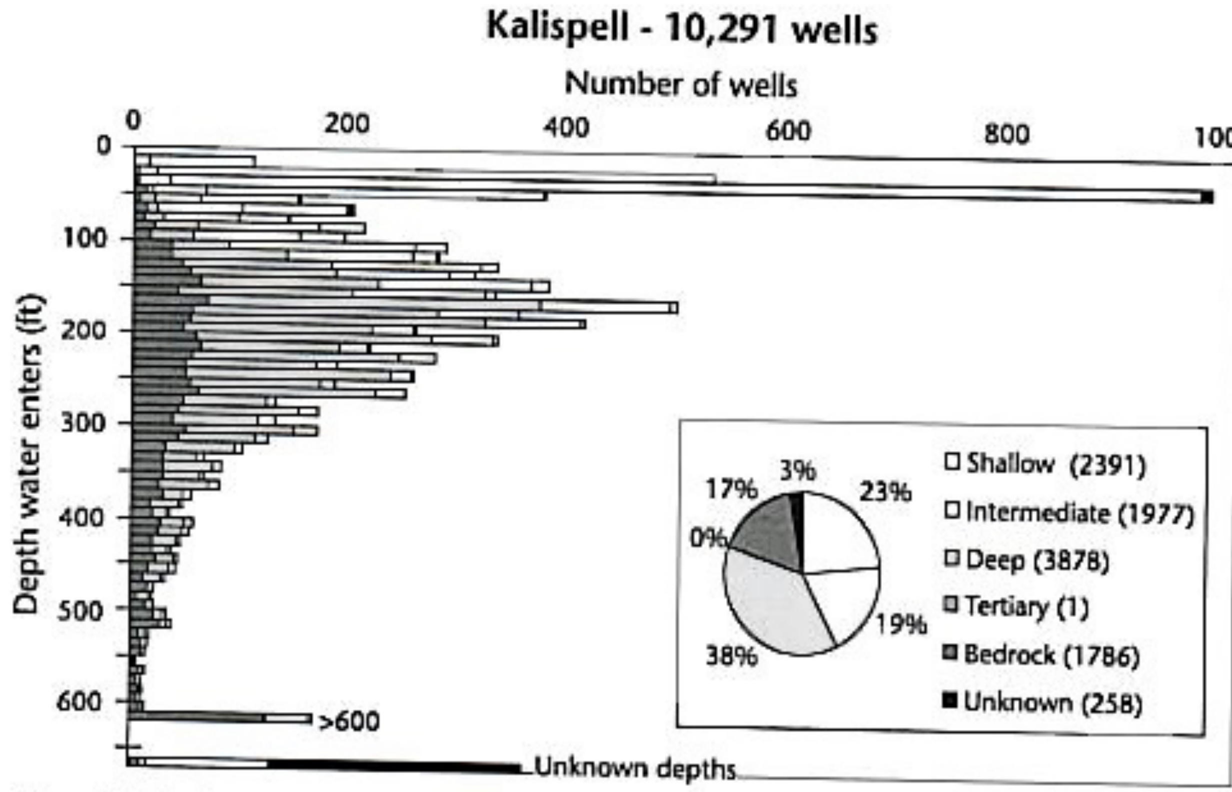

Figure 22. The bimodal distribution of well depths in the Kalispell subarea clearly reflects the use of shallow aquifers, such as the Evergreen aquifer, and also deep alluvial aquifers. The inset pie chart shows the percentages of wells developed in each aquifer. Most wells get water from intermediate, deep alluvial, and bedrock aquifers in the deep flow system.

drilled to depths of more than 100 ft are completed in the deep alluvium.

Designations of aquifers in this report correspond, with some modifications, to aquifers named by Konizeski and others (1968). Shallow aquifers in this report include the "floodplain," "sand," and "perched" aquifers of Konizeski and others (1968). The perched aquifers are shallow aquifers that are periodically drained during dry years or seasons. The "shallow" and "deep artesian" aquifers of Konizeski generally correspond to the intermediate and deep aquifers defined here. Recent potentiometric-surface measurements show that the aquifers are generally connected, and the intermediate and deep aquifers are now recognized as parts of a single, confined, deep ground-water flow system. The Precambrian aquifer of Konizeski and others (1968) is called the bedrock aquifer in this report.

Shallow Aquifers

Shallow aquifers and locales that are especially important in the Kalispell subarea (fig. 23) are the alluvium between the Flathead and Whitefish Rivers [informally known as the Evergreen aquifer (Noble and Stanford, 1986)], the alluvium and glacial outwash on the east side of the Kalispell subarea between the Swan Range and the Flathead River (east-side aquifers), the delta vicinity immediately north of Flathead Lake (Delta aquifer), and the glacial outwash of the Lost Creek fan west of the Stillwater River (Lost Creek aquifer). In addition to supplying water to wells, the east-side aquifers and the Lost Creek aquifer may provide recharge to the deep ground-water flow system. Scattered occurrences of shallow aquifers outside those named are mostly along stream valleys.

Yields from shallow aquifers (fig. 24a) are comparable to those from other units but exhibit the most variability; the median reported yield from 1,730 wells is 30 gallons per minute (gpm), but 230 reported yields are greater than 100 gpm. Median depths in the Evergreen and east-side aquifers are 25 and 35 ft, respectively, and in many places the shallow aquifers rest on relatively impermeable till and glacial-lake deposits that separate them from more deeply buried intermediate and deep alluvial aquifers. The rate of ground-water development in shallow aquifers has been steady at about 200 wells per 5-yr period; more than 1,000 wells have been drilled during the past 25 yr (fig. 24b). The ability to complete shallow, highly productive wells makes the near-surface aquifers attractive.

Shallow aquifers are intrinsically susceptible to surface sources of contamination. The water table is commonly within 20 ft of the land surface. The aquifer materials are highly permeable, allowing rapid movement of water (and any associated contamination) from the land surface to the aquifer. Furthermore, as the land surface in the valley becomes more developed, potential sources of point and non-point source contamination will increase.

Evergreen Aquifer

The Evergreen aquifer, composed of shallow alluvium overlying low-permeability silt and clay, occupies approximately 40 sq mi between the Whitefish and Flathead Rivers (fig. 23). The median reported well depth is about 25 ft, but maximum reported depths to water are about 30 ft. The aquifer is very productive, with reported yields reaching 1,500 gpm, although the median reported yield is 30 gpm. The median reported static water level from 860 wells is 12 ft below the land surface. Ground water flows southward through the aquifer toward the confluence of the Whitefish and Flathead Rivers.

Permeability in the Evergreen aquifer can be very high. Two aquifer tests reported by Konizeski and others (1968) yielded a transmissivity of 174,200 ft^2/day (appendix B); Noble and Stanford (1986) estimated the bulk transmissivity of the aquifer to be in the range of 120,000 to 241,200 ft^2/day.

Median monthly altitudes for long-term water-level measurements in the Evergreen aquifer (fig. 25) show that water levels rise annually 1 to 1.5 ft during the spring and early summer months, peaking in May or June in response to recharge from runoff, snowmelt, and rainfall. Water levels decline during the late summer when river flows decline and evapotranspiration and ground-water usage are highest. Water levels are lowest during the winter when recharge from the Flathead River and other sources is minimal. Comparison of monthly median water levels from wells with the monthly average flow of the Flathead River at Columbia Falls (fig. 25) shows good correlation between the timing of high water levels and Flathead River discharge. The correlation is in agreement with Noble and Stanford (1986), who showed that water-level fluctuations in the Evergreen aquifer appeared to be closely tied to the stage of the Flathead River. Deviations from the general pattern may occur during years of extremely high or low precipitation (e.g., 1996 precipitation was 60 percent above average), or changes in flow in the Flathead River.

The hydrographs do not show long-term water-level declines or increases, suggesting that the Evergreen aquifer is in hydraulic equilibrium: the water entering and leaving the aquifer on an

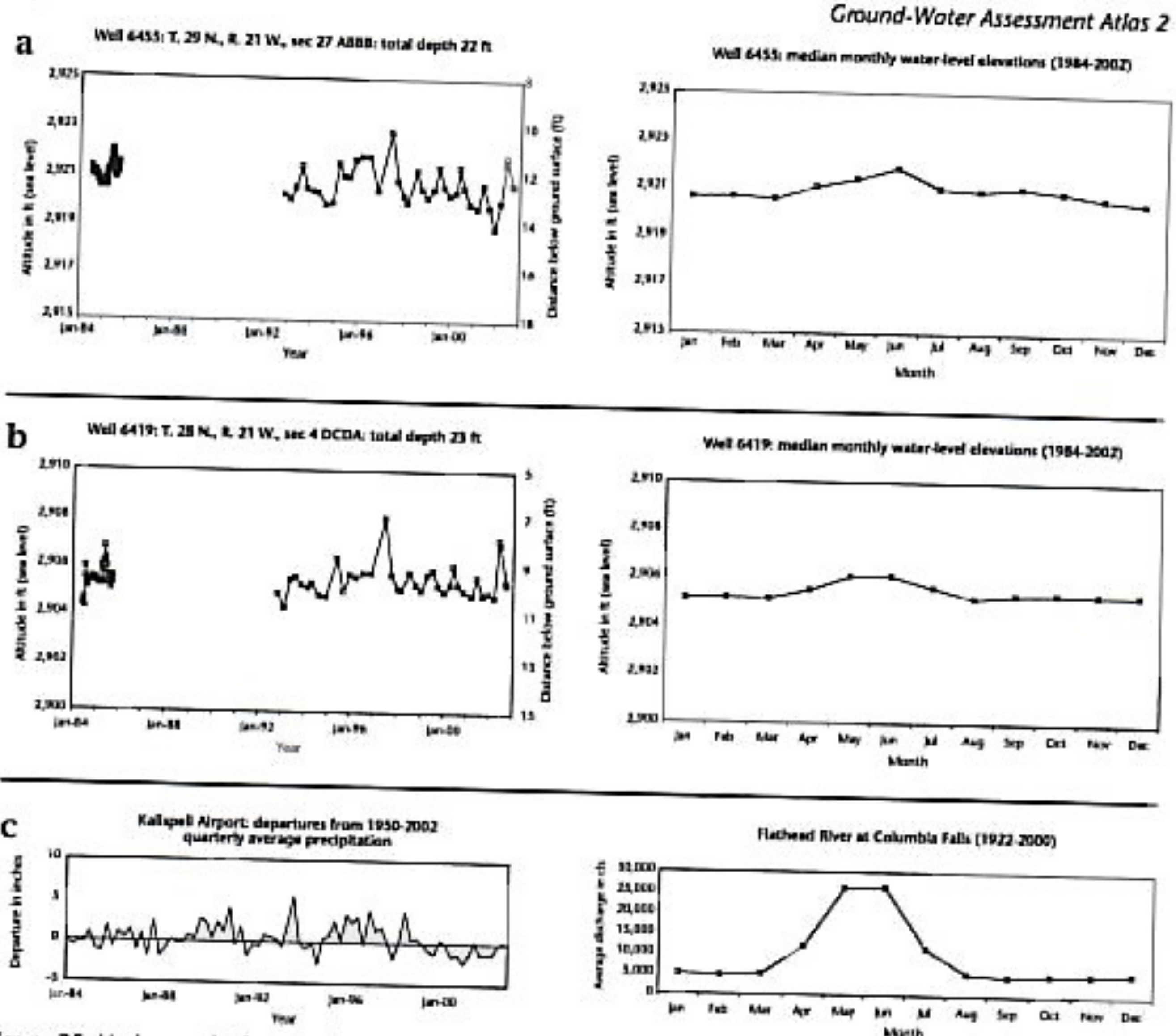

Figure 25. Hydrographs from wells completed in the Evergreen aquifer show consistent annual water-level responses that appear to be strongly influenced by surface water. No long-term declining or increasing trends are apparent in the records. (a) Well 6455; (b) well 6149; (c) average precipitation and discharge. Data for the Flathead River discharge at Columbia Falls from http://waterdata.usgs.gov/nwis/discharge.

annual basis is consistent (fig. 25). The water levels (representing aquifer storage) do not appear sensitive to climatic change, further suggesting that the aquifer is closely connected to discharge in the Flathead and possibly the Whitefish Rivers. Even though more than 800 wells have been completed in the Evergreen aquifer, the hydrographs show no evidence of impact from pumpage.

East-Side Aquifers

Aquifers along the east side of the Kalispell subarea occur in alluvium associated with the Flathead and lower Swan Rivers, surficial sand deposits (ice-contact stratified drift), and glacial outwash (Lake Blaine–Echo Lake vicinity). These shallow aquifers supply water to more than 500 wells (fig. 23). The surficial sand and outwash are locally interbedded with glacial-lake deposits and till, making the thickness and extent of the aquifers variable and difficult to define. Ground-water flow is generally from the western front of the Swan Range toward the Flathead River. Based on potentiometric surface, water quality, and geologic mapping (Part B, maps 2, 5), the east-side shallow aquifers appear to be hydraulically connected to the deep ground-water flow system and are important recharge sources to that system. Well depths in the east-side aquifers are as much as 160 ft, but the median is 35 ft. The median reported static water level is 20 ft below the ground surface. Wells reportedly yield as much as 1,000 gpm with a median yield of 25 gpm.

Water levels in the east-side shallow aquifers appear to have regular seasonal cycles and also respond to long-term climatic conditions (fig. 26). Water-level data from a surficial aquifer located about 1.5 mi south of Columbia Falls show that water levels generally peak in April or May and fluctuate no more than 3 ft annually. Data from a surficial aquifer in the Many Lakes area near the Lake of the Woods show that water levels generally change about 8 ft per year, peaking in July or August. Together, the hydrographs demonstrate response to climatic conditions. Water levels generally rose during a wet period that ended in 1997–98, but have generally fallen during the dry climatic cycle that began in 1998–99.

Delta Aquifer

The Delta aquifer consists of fine- to medium-grained sand deposited between the north end of Flathead Lake and the Flathead River (fig. 23), and is hydraulically separate from the Evergreen and east-side surficial aquifers. Ground-water flow direction in the Delta aquifer is controlled by seasonal stages in the Flathead River and Lake; generally flow is from the aquifer to the river and lake when lake and river levels are low, and from the lake and river into the aquifer when lake and river levels are high (Konizeski and others, 1968). Noble and Stanford (1986) conducted four aquifer tests in the Delta aquifer and reported transmissivities ranging from 1 to 3,700 ft^2/day (appendix B). Depths for about 135 wells completed in the aquifer are as much as 75 ft below land surface, but the median depth is 26 ft. The median reported depth to water is 16 ft. The productivity of the Delta aquifer is generally lower than that reported for other shallow aquifers; the maximum reported yield is 500 gpm and the median reported yield is 15 gpm.

Limited monitoring between 1985 and 1998, and since 1995 (well 6394), shows no long-term change in water levels, indicating water in storage has remained stable. Monthly median water levels show that water levels rise about 2 ft beginning in March and remain elevated through June of each year. Beginning in July, water levels fall about 2 ft and remain at the lower level until the following March (fig. 26).

Lost Creek Fan

The Lost Creek outwash fan is a thick accumulation of shallow alluvium deposited by glacial meltwater near the mouth of Lost Creek in secs. 8 and 17 of T. 29 N., R. 22 W. (Smith and others, 2000). More than 100 wells are completed in the aquifer (fig. 23); well depths are as much as 120 ft with a median of 40 ft. The median reported depth to water is 30 ft. Reported well yields are as much as 1,000 gpm, with a median yield of 25 gpm. Konizeski and others (1968) have shown that ground-water flow in the shallow aquifer near Lost Creek is generally to the east. In addition to eastward ground-water flow, water-level, water-quality, and well-log data from shallow and deep wells suggest that shallow ground water may be in hydraulic connection with the underlying deep alluvium and that downward components of flow may be an important recharge source for the deep ground-water flow system (see Part B, maps 2, 9).

Water levels from the northern part of the Lost Creek fan suggest that ground-water storage is influenced by climate (fig. 26). The hydrograph from a well measured between 1994 and 1997 shows an annual water-level cycle that rises from minimums each January to maximums each June. The annual cycle is overprinted on a period of generally rising water levels that ends in 1997 with a seasonal peak 13 ft higher than that in 1995. The rising water levels correspond with a wet climatic period that ended in mid-1997.

Intermediate and Deep Alluvial Aquifers

Intermediate aquifers are found near the base of glacial deposits (confining units) that separate shallow alluvial from deep alluvial aquifers. The intermediate aquifers are discrete water-bearing sand and gravel horizons separated by layers of silt and clay. Individual intermediate aquifers may have different water levels, suggesting hydraulic separation from each other and from the underlying deep alluvial aquifer. However, on a regional valley-wide scale, the local head differences between individual intermediate aquifers are minor. Water-level data also suggest that on a regional scale sufficient hydraulic continuity exists between intermediate aquifers and the deep alluvial aquifer to allow their consideration as a single ground-water flow entity. The "shallow artesian" aquifers of Konizeski and others (1968) correspond to some of the intermediate aquifers.

The deep alluvial aquifer occurs as a nearly continuous layer of sand and gravel (the deep alluvium) that underlies most of the Kalispell subarea. The deep alluvium rests on bedrock and/or Tertiary sedimentary rocks and is overlain, either abruptly or transitionally, by till and glacial-lake deposits.

The intermediate and deep alluvial aquifers are the most utilized sources of water in the valley, and well-log records show that about 60 percent of all wells in the Kalispell subarea are completed in these units. Wells completed in sand and gravel deposits greater than 100 ft, but less than about 200 ft, below land surface (fig. 22) may obtain water from either an intermediate aquifer or the deep alluvial aquifer. At depths greater than about 200 ft, almost all wells in the valley get water from the deep alluvial aquifer. Away from the margins of the valley, no well completely penetrates the

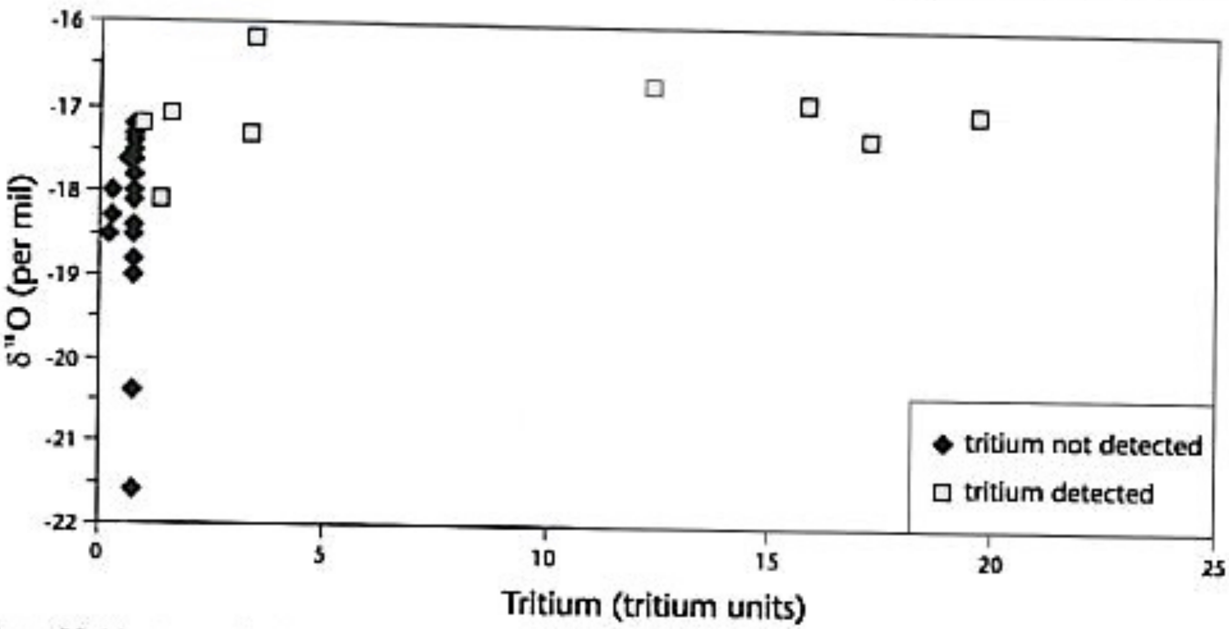

Figure 38. Most ground-water samples from the Kalispell subarea that had detectable levels of tritium also were enriched in $\delta^{18}O$, suggesting that younger water occurs on the east side of the valley (see figs. 36, 37).

radon in water. For the current study, samples for radon analysis were collected from 29 wells in the Kalispell subarea (1996–2000); data from 14 other wells sampled between 1992 and 1995 are also available (appendix D). Of the 43 samples, only one had a concentration less than the proposed public supply system MCL of 300 pCi/L; most were greater than 500 pCi/L, and the median concentration was 830 pCi/L. In a statewide survey, 73 percent of radon samples from ground water had concentrations greater than 300 pCi/L (Miller and Coffey, 1998). Radon concentrations in ground water from the Kalispell subarea show a strong correlation to aquifer materials. The median radon concentration in water from the bedrock (1,370 pCi/L) is about twice as high as the median radon concentration in water from the basin-fill deposits (675 pCi/L).

Summary (Kalispell Subarea)

Water levels in wells completed in shallow alluvium and near the edges of the deep flow system show annual responses consistent with runoff patterns, where water levels rise in response to recharge from precipitation or stream discharge during the spring and summer months before falling to seasonal lows in the winter months. Water levels from the central part of the deep flow system show annual responses consistent with summertime pumping, where water levels fall to lows in July and August of each year before recovering to highs in the fall and winter months. The onset of the pumping response appears to have occurred in the 1970s and early 1980s.

Inorganic water-quality data show that ground water in the Kalispell subarea is of generally good quality with dissolved-constituent concentrations between 300 and 600 mg/L. Potential water-quality problems are related to high iron concentrations in some aquifers, which can cause staining of clothing and fixtures. Nitrate concentrations are above expected background levels in the Lost Creek fan vicinity. Radon concentrations in the deep flow system are generally above the recommended MCL for public drinking water supplies.

The geographic variation in oxygen-18, tritium, and carbon-14 results and in dissolved-constituents concentrations suggests that recharge to the deep flow system is nonuniform. West-side ground water is older and slightly more mineralized than east-side ground water, and the flow system is more active on the east side. Surface water and shallow ground water entering the deep flow system from the west-facing slopes of the Swan Range are important recharge sources. Much of the deep flow system is protected by low-permeability till and glacial-lake deposits, but water-quality, water-level, and well-log data indicate that in at least two locales the deep flow system is open to the land surface and potentially easily contaminated. Near the Lost Creek fan, downward water-level gradients—in a thick accumulation of surficial outwash that rests on the deep alluvium without well-defined intervening zones of till or glacial-lake deposits—indicate that shallow aquifers may be directly connected to the deep flow system. Elevated nitrate concentrations in the

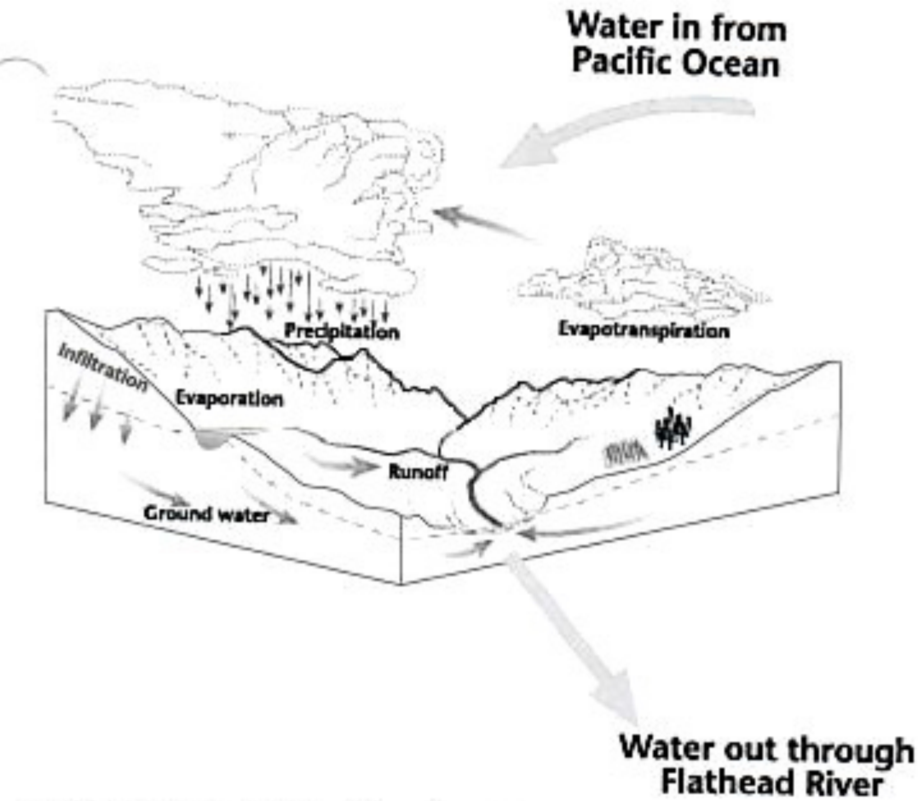

Figure G-7. The constant circulation of water between the ocean, atmosphere, and land is referred to as the hydrologic cycle. In the Flathead Lake area, most of the precipitation that enters the area is returned to the atmosphere by evaporation and evapotranspiration.

by plants, evaporate, infiltrate the ground surface, or run off (overland flow). The water that infiltrates the ground contributes to the ground water part of the cycle, a small but critical item in the hydrologic budget. Ground water flows through the earth until it discharges to a surface-water body (stream, spring, lake, or ocean), or is evaporated, or transpired. Runoff occurs when the rate of infiltration is exceeded. This water contributes directly to streams, lakes, or other bodies of surface water. Water reaching streams flows to the ocean where it is available for evaporation again, perpetuating the cycle.

Hydrologic Unit A body of geologic materials that function regionally as a water-yielding unit.

Ion An atom or group of atoms that carries a positive (cation) or negative (anion) electric charge. Atoms in liquid solutions are typically ions; these atoms are said to have been *ionized*.

Isotopes Atoms of the same element that differ in mass because of differing numbers of neutrons in their nuclei. Although isotopes of the same substance have most of the same chemical properties, their different atomic weights allow them to be separated. For example, oxygen-18 is heavier than oxygen-16, so water molecules containing oxygen-16 evaporate from a water body at a greater rate. See *Environmental Isotopes.*

Nitrate A mineral compound described by the anionic structure of NO_3^- that is soluble in water and stable in oxidized environments. Common analysis of the concentration is reported as milligrams per liter of nitrogen (N). Common sources of nitrate are decaying organic matter, sewage, natural nitrate in soil, and fertilizers. See related sidebar.

Overdraft Long-term withdrawal of water at rates greater than long-term recharge.

Oxygen-18 A stable isotope of oxygen, denoted as ^{18}O, with 8 protons and 10 neutrons. Oxygen-18 is heavy compared with the common isotope of oxygen (^{16}O). See *Environmental Isotopes.*

Permeability The capacity of a geologic material to transmit fluid (water in this report); also called *hydraulic conductivity.*

Potentiometric Surface A surface defined by the level to which water will rise in tightly cased wells (figs. G-1, G-2). The water table is a potentiometric surface for an unconfined aquifer.

Radioactive Half-Life The time over which half of a radioactive material (a parent) decays to another elementary material (a daughter product).

Radon Radon is a colorless, odorless gas produced by the radioactive decay of uranium found naturally in rocks and soil, and has been linked to lung cancer in humans (EPA, 1999). Radon in indoor air poses a health risk and accumulates by seepage into a structure from the soil and rock beneath its foundation. Water that contains radon is also a source of radon in indoor air, but the U.S. EPA estimates that radon released from drinking water accounts for less than 2 percent of that in indoor air. Currently no drinking water standard for radon exists. However, the U.S. EPA has proposed a 300 picoCuries per liter (pCi/L) MCL for community water systems, and an