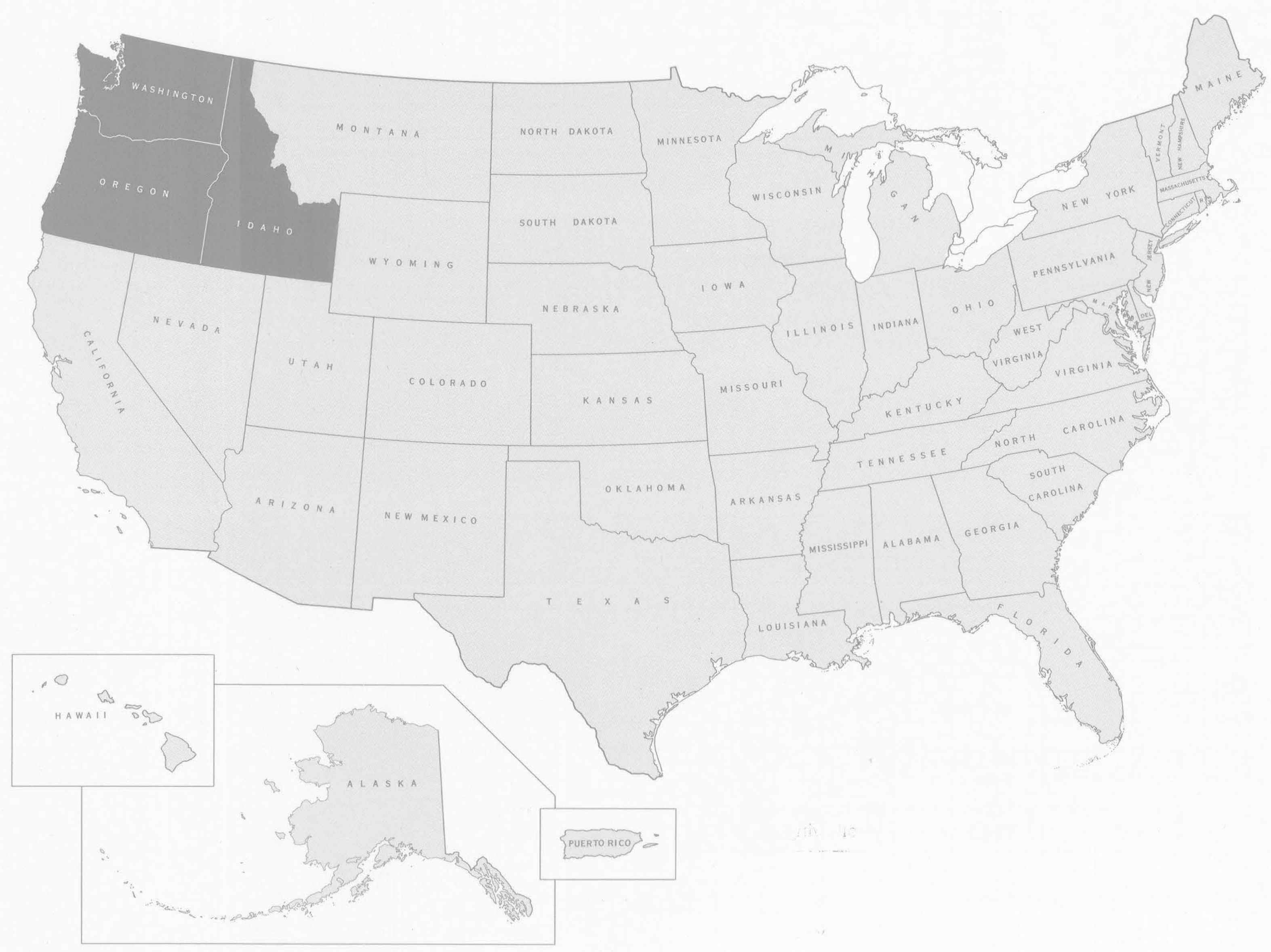
GROUND WATER ATLAS OF THE UNITED STATES

SEGMENT 7

Idaho
Oregon
Washington



HYDROLOGIC INVESTIGATIONS ATLAS 730–H
U.S. Geological Survey

Reston, Virginia
1994

GROUND WATER ATLAS OF THE UNITED STATES
Hydrologic Investigations Atlas 730–H

FOREWORD

The Ground Water Atlas of the United States presents a comprehensive summary of the Nations's ground-water resources, and is a basic reference for the location, geography, geology, and hydrologic characteristics of the major aquifers in the Nation. The information was collected by the U.S. Geological Survey and other agencies during the course of many years of study. Results of the U.S. Geological Survey's Regional Aquifer-System Analysis Program, a systematic study of the Nation's major aquifers, were used as a major, but not exclusive, source of information for compilation of the Atlas.

The Atlas, which is designed in a graphical format that is supported by descriptive discussions, includes 13 chapters, each representing regional areas that collectively cover the 50 States and Puerto Rico. Each chapter of the Atlas presents and describes hydrogeologic and hydrologic conditions for the major aquifers in each regional area. The scale of the Atlas does not allow portrayal of minor features of the geology and hydrology of each aquifer presented, nor does it include discussion of minor aquifers. Those readers that seek detailed, local information for the aquifers will find extensive lists of references at the end of each chapter.

An introductory chapter presents an overview of ground-water conditions Nationwide and discusses the effects of human activities on water resources, including saltwater encroachment and land subsidence.

Robert M. Hirsch

Robert M. Hirsch

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, *Secretary*

U.S. GEOLOGICAL SURVEY
Robert M. Hirsch, *Acting Director*

CONVERSION FACTORS

For readers who prefer to use the International System (SI) units, rather than the inch-pound terms used in this report, the following conversion factors may be used:

Multiply inch-pound units	*By*	*To obtain metric units*
	Length	
inch (in)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
billion gallons per day (Bgal/d)	3.785	million cubic meters per day (Mm^3/d)
	Transmissivity	
foot squared per day (ft^2/d)	0.0929	meter squared per day (m^2/d)
	Temperature	
degree Celsius (°C)	9/5 (°C)+32=°F	degree Fahrenheit (°F)

Sea Level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

ATLAS ORGANIZATION

The Ground Water Atlas of the United States is divided into 14 chapters. Chapter A presents introductory material and nationwide summaries; chapters B through M describe all principal aquifers in a multistate segment of the conterminous United States; and chapter N describes all principal aquifers in Alaska, Hawaii, and Puerto Rico.

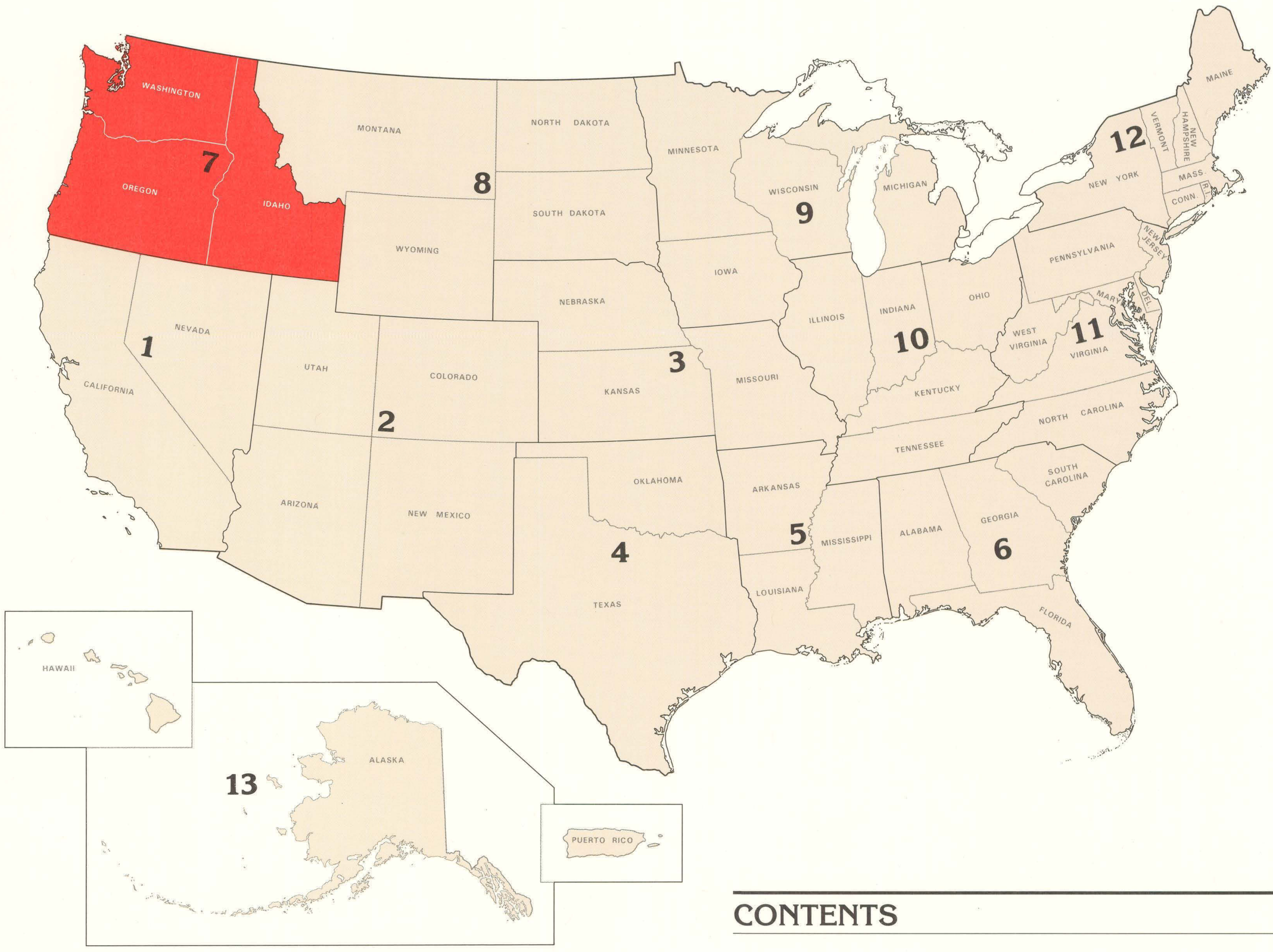
Segment Number	*Chapter content*	*Hydrologic Atlas Chapter*
—	Introductory material and nationwide summaries	730–A
1	California, Nevada	730–B
2	Arizona, Colorado, New Mexico, Utah	730–C
3	Kansas, Missouri, Nebraska	730–D
4	Oklahoma, Texas	730–E
5	Arkansas, Louisiana, Mississippi	730–F
6	Alabama, Florida, Georgia, South Carolina	730–G
7	Idaho, Oregon, Washington	730–H
8	Montana, North Dakota, South Dakota, Wyoming	730–I
9	Iowa, Michigan, Minnesota, Wisconsin	730–J
10	Illinois, Indiana, Kentucky, Ohio, Tennessee	730–K
11	Delaware, Maryland, New Jersey, North Carolina, Pennsylvania, Virginia, West Virginia	730–L
12	Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont	730–M
13	Alaska, Hawaii, Puerto Rico	730–N

Ground Water Atlas of the United States

Segment 7

Idaho, Oregon, Washington

By R. L. Whitehead



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Cartographic design and production by Caryl J. Wipperfurth and Paul B. Christensen

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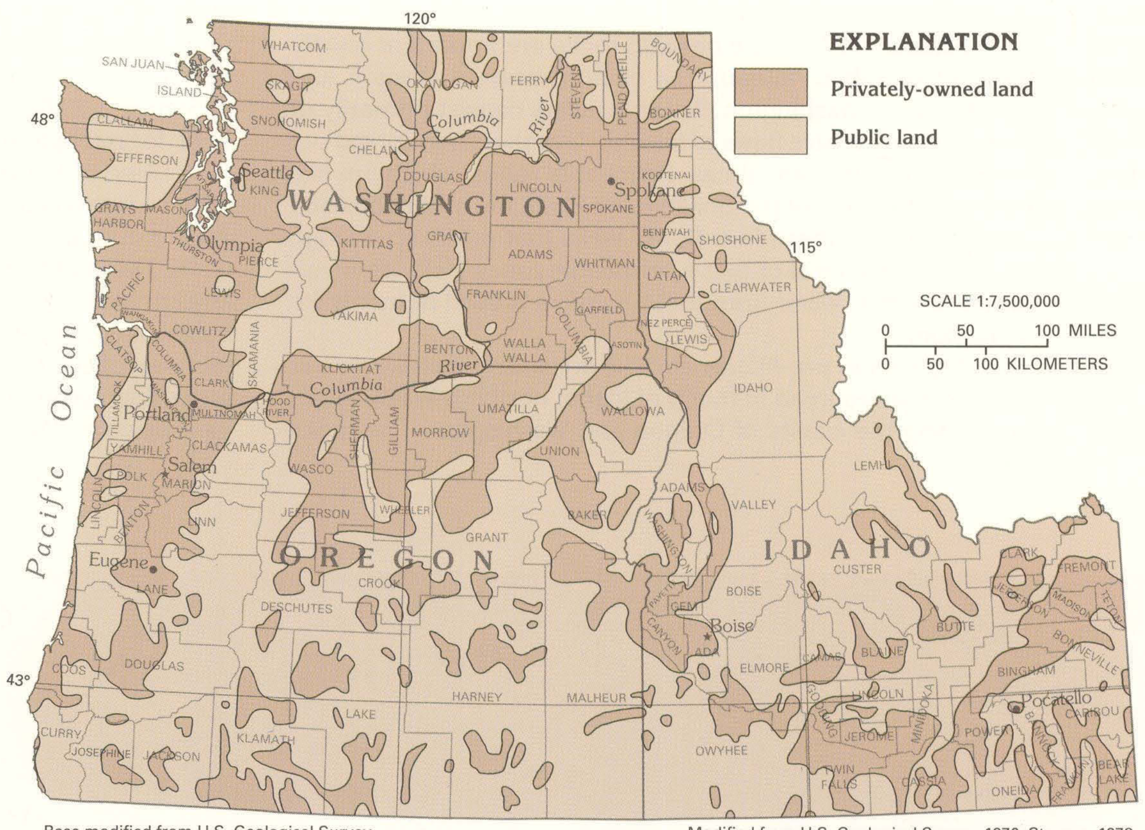
Regional summary

INTRODUCTION

The States of Idaho, Oregon, and Washington, which total 248,730 square miles, compose Segment 7 of this Atlas. The area is geologically and topographically diverse and contains a wealth of scenic beauty, natural resources, and ground and surface water that generally are suitable for all uses. Most of the area of Segment 7 is drained by the Columbia River, its tributaries, and other streams that discharge to the Pacific Ocean. Exceptions are those streams that flow to closed basins in southeastern Oregon and northern Nevada and to the Great Salt Lake in northern Utah. The Columbia River is one of the largest rivers in the Nation. The downstream reach of the Columbia River forms most of the border between Oregon and Washington. In 1990, Idaho, Oregon, and Washington had populations of 1.0 million, 2.8 million, and 4.9 million, respectively. The more densely populated parts are in lowland areas and stream valleys. Many of the mountains, the deserts, and the upland areas of Idaho, Oregon, and Washington lack major population centers. Large areas of Idaho and Oregon are uninhabited and are mostly public land (**fig. 1**) where extensive ground-water development is restricted.

Surface water is abundant in Idaho, Oregon, and Washington, though not always available when and where needed. In some places, surface water provides much of the water used for public-supply, domestic and commercial, agricultural (primarily irrigation and livestock watering), and industrial purposes. In arid parts of Segment 7, however, surface water has long been fully appropriated, chiefly for irrigation. Ground water is used when and where surface-water supplies are lacking.

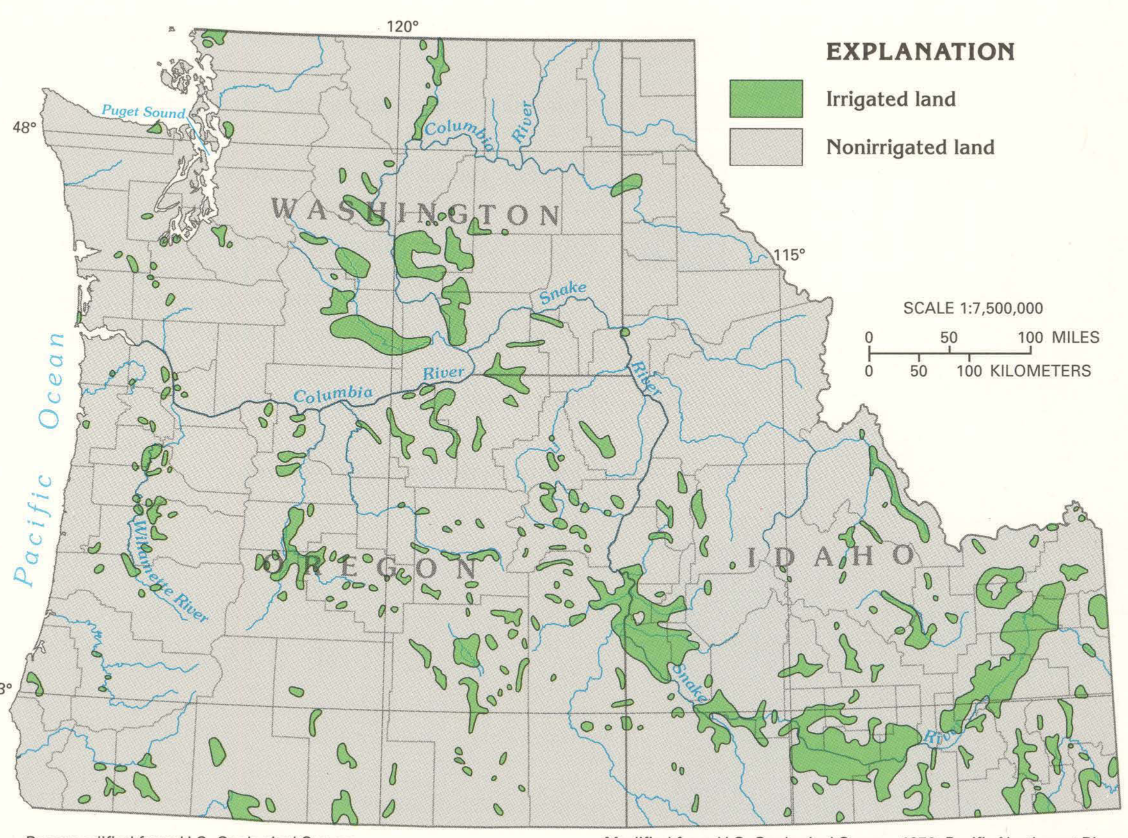
Ground water is commonly available to shallow wells that are completed in unconsolidated-deposit aquifers that consist primarily of sand and gravel but contain variable quantities of clay and silt. Many large-yield public-supply and irrigation wells and thousands of domestic wells are completed in these types of aquifers, generally in areas of privately owned land (**fig. 1**). In many places, deeper wells produce water from underlying volcanic rocks, usually basalt.



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1972

Modified from U.S. Geological Survey, 1970; Stevens, 1978; and U.S. Bureau of Land Management, 1982

Figure 1. *Privately owned land composes 36 percent of Idaho, 48 percent of Oregon, and 80 percent of Washington.*



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1972

Modified from U.S. Geological Survey, 1970; Pacific Northwest River Basins Commission, 1971; and Lindholm and Goodell, 1986

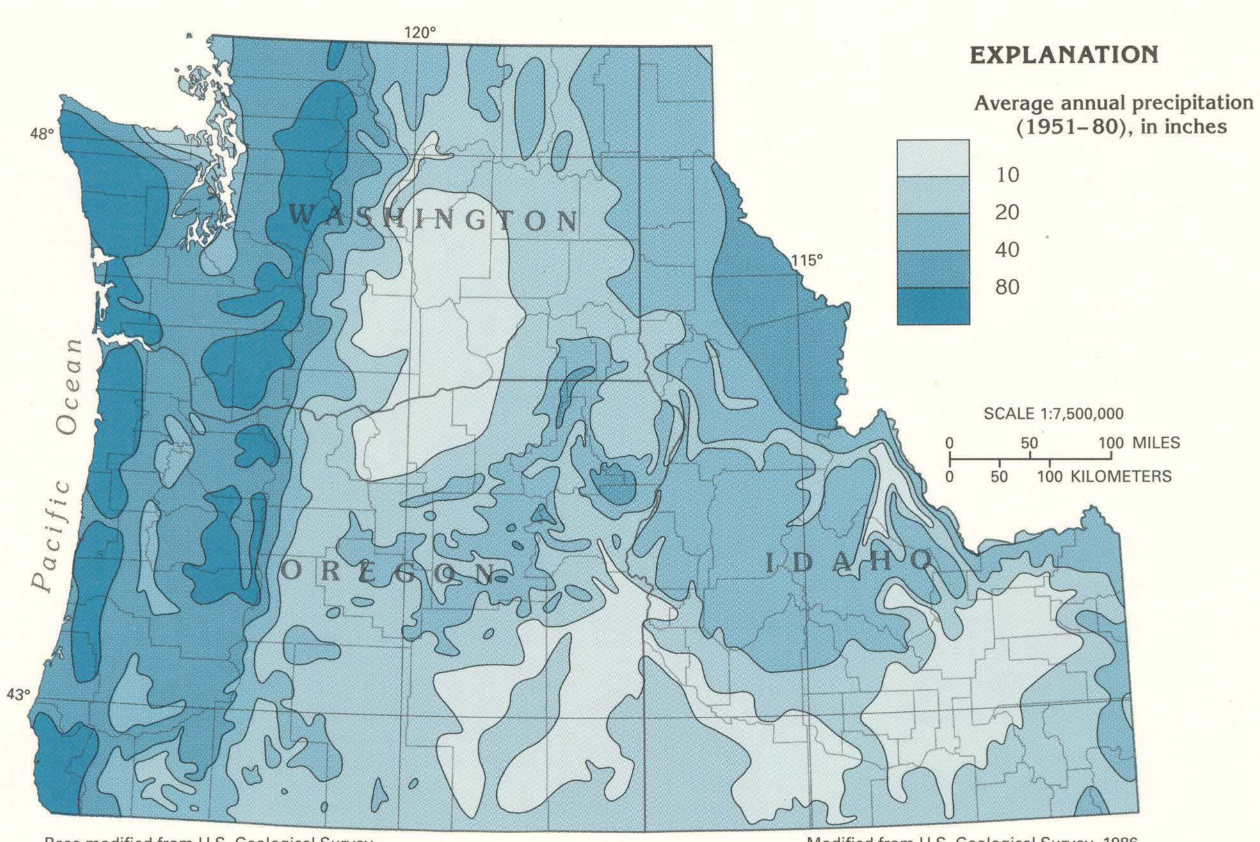
Figure 2. *Most irrigated land is on lowlands and terraces adjacent to main streams because the streams are the principal source of the irrigation water.*

Most irrigation (**fig. 2**) is on lowlands next to streams and on adjacent terraces. Generally, lowlands within a few miles of a main stream are irrigated with surface water diverted by gravity flow from the main stream or a reservoir and distributed through a system of canals and ditches. In some areas, water is pumped to irrigate lands farther from the stream at a higher altitude. Along the Snake and Columbia Rivers, large pumping systems withdraw billions of gallons of water per day from the rivers to irrigate adjacent uplands that are more than 500 feet higher than the rivers. Elsewhere, irrigation water is obtained from large-capacity wells, where depth to water might exceed 500 feet below land surface.

Aquifers in Idaho, Oregon, and Washington, as in most other States, differ considerably in thickness and permeability, and well yields differ accordingly. Ground-water levels in a few areas have declined as a result of withdrawals by wells. State governments have taken steps to alleviate declines in some areas by enacting programs that either limit the number of additional wells that can be completed in a particular aquifer (Ground-Water Management Area) or prevent further ground-water development (Critical Ground-Water Area).

Segment 7 includes some of the driest parts of the Nation, as well as some of the wettest. Average annual precipitation (1951–80) ranges from less than 10 inches in arid parts of Idaho, Oregon, and Washington to more than 80 inches in the western parts of Oregon and Washington (**fig. 3**). Most storms generally move eastward through the area. The eastward-moving air absorbs the moisture that evaporates from the Pacific Ocean. As this air encounters the fronts of mountain ranges, it rises, cools, and condenses. Accordingly, the western sides of the mountain ranges receive the most precipitation. Much of the annual precipitation moves directly to streams as overland runoff. Some of the precipitation is returned to the atmosphere by evapotranspiration, which is the combination of evaporation from the surface and transpiration from the plants. A small part of the precipitation infiltrates the soil and percolates downward to recharge underlying aquifers.

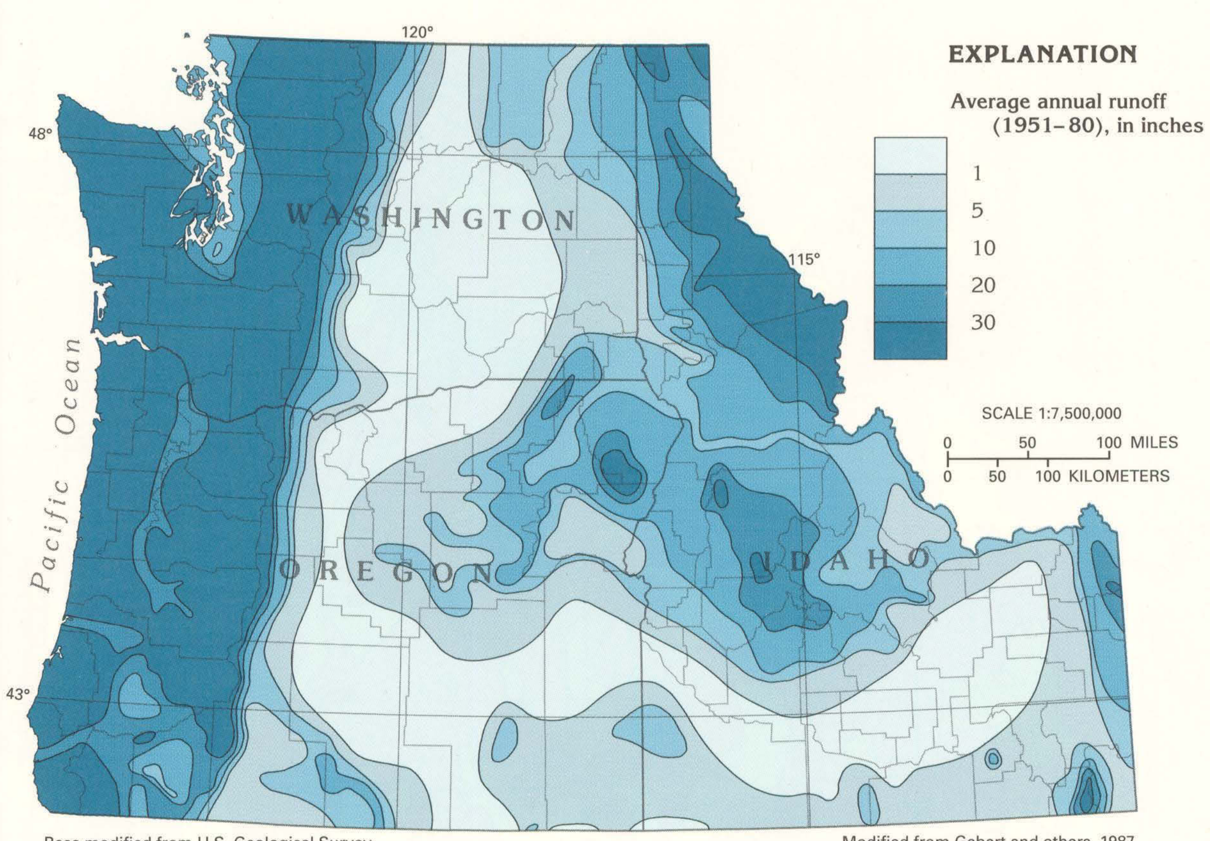
Average annual runoff (1951–80) in the segment varies considerably (**fig. 4**), and the distribution of the runoff generally parallels that of precipitation. In the arid and the semiarid parts of Segment 7, most precipitation replenishes soil moisture, evaporates, or is transpired by vegetation. Little is left to maintain streamflow or to recharge aquifers. In the wetter parts, much of the precipitation runs off the land surface to maintain streamflow, and because evaporation is usually less in wetter areas, more water is available to recharge aquifers. Precipitation that falls as snow generally does not become runoff until spring thaws begin. Reservoirs constructed on major streams to mitigate flooding and to store water for irrigation, hydroelectric-power generation, and recreation also affect the timing of runoff. The runoff is stored and subsequently released during drier periods to maintain downstream flow.



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1972

Modified from U.S. Geological Survey, 1986

Figure 3. *Average annual precipitation (1951–80) in the form of rain and snow is extremely variable. Precipitation is greatest in areas of high altitude and on the western, or windward, sides of mountain ranges.*



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1972

Modified from Gebert and others, 1987

Figure 4. *Average annual runoff (1951–80) depends on the quantity of precipitation. Timing of the runoff, which can vary greatly, depends on the form of precipitation and the holding period of runoff in reservoirs.*

AREAL DISTRIBUTION OF AQUIFERS

All aquifers in Segment 7 were assigned to one of five general types (**fig. 5**) depending on their geologic and hydrologic characteristics. Three of the aquifer types generally consist of one kind of rock; the other two types of aquifers, however, consist of two or more different kinds of rocks.

Of the five types, the most prolific aquifers are those in unconsolidated deposits that consist primarily of alluvial sand and gravel that fill large to small basins in all three States in Segment 7. These aquifers are important sources of water for public-supply, domestic and commercial, agricultural, and industrial needs because of their location in generally flat lowlands where human activities are concentrated. Some of these aquifers in southern Oregon and Idaho are part of an extensive group of basin-fill aquifers that extend southward, and are called the Basin and Range aquifers. These aquifers are described in segments 1 and 2 of this Atlas.

Aquifers in Pliocene and younger basaltic rocks characterize the Snake River Plain of southern Idaho and southeastern Oregon. Numerous extensive flows of basaltic lava have spread out from vents in and near the Snake River Plain. Permeable zones at the tops and the bottoms of these flows yield large volumes of water to irrigation wells. These aquifers also discharge about 1 million gallons per day to springs in the walls of the Snake River Canyon.

Although aquifers in undifferentiated volcanic and sedimentary rocks are present in all three States, they are found primarily in southern Idaho and Oregon. These undifferentiated rocks include beds of volcanic ash and tuff, basalt, silicic volcanic rocks, and semiconsolidated to consolidated sedimentary rocks that contain small to large quantities of volcanic material. The rocks are complexly interbedded, and their permeability is extremely variable.

Aquifers in Miocene basaltic rocks are important chiefly in the Columbia Plateau area of northeastern Oregon and southeastern Washington. These aquifers consist primarily of numerous extensive flows of basaltic lava that have spread out from fissures in many areas. Permeable zones, which are like those in the flows of the Snake River Plain, are at the tops and the bottoms of these lava flows. Wells that are deep enough to penetrate several of these permeable zones yield large volumes of water. Water from these aquifers is used primarily for irrigation.

Aquifers in pre-Miocene rocks are widely distributed but are most widespread in much of Idaho, northern Washington, and along the coasts of Oregon and Washington. The rocks composing these aquifers are extremely variable and include several types of igneous and metamorphic rocks, consolidated sedimentary rocks of marine and nonmarine origin, and volcanic rocks. Accordingly, the permeability of these aquifers varies greatly. The aquifers in pre-Miocene rocks are present mostly in mountainous areas, and water from wells completed in these aquifers is used mostly for domestic and agricultural (livestock watering) supplies.

Some aquifers in Segment 7 are parts of regional aquifer systems that have an areal extent of thousands to tens of thousands of square miles. An aquifer system consists of two or more aquifers that are hydraulically connected and that function as a single aquifer system. The regional aquifer systems in Segment 7 (**fig. 5**) supply varying volumes of freshwater to wells for multiple uses.

Three of the regional aquifer systems shown in **figure 5** have been studied under the U.S. Geological Survey's Regional Aquifer-System Analysis (RASA) Program as of 1993. Studies of two additional aquifer systems, the Puget–Willamette Trough and the Northern Rocky Mountains intermontane basins, were under way but not completed as of 1993. The objectives of each RASA study are to describe the ground-water-flow system under natural (undeveloped) conditions and as it exists today, to analyze changes in the system, to integrate the results of previous hydrogeologic studies of the system, and to provide the ability to evaluate the effects of future ground-water development on the system. The three aquifer systems that have been studied are the Great Basin, the Snake River Plain, and the Columbia Plateau. The Basin and Range aquifers in Segment 7 coincide with part of the Great Basin aquifer system, the rest of which is in Segments 1 and 2 of this Atlas; the Snake River Plain and the Columbia Plateau aquifer systems are entirely within Segment 7.

There are two general types of regional aquifer systems. One type consists of an extensive set of aquifers and confining units that might locally be discontinuous but that function hydrologically as a single aquifer system on a regional scale. In Segment 7, the Snake River Plain, the Columbia Plateau, and the Puget–Willamette Trough aquifer systems are examples of this type. The second type consists of a set of virtually independent aquifers that share common hydrologic characteristics. In this type of aquifer system, common hydrologic factors and principles control the occurrence, the movement, and the quality of ground water; accordingly, the study of a few representative aquifers provides understanding of the aquifer system. The Great Basin and the Northern Rocky Mountains intermontane basins aquifer systems in Segment 7 are examples of this type.

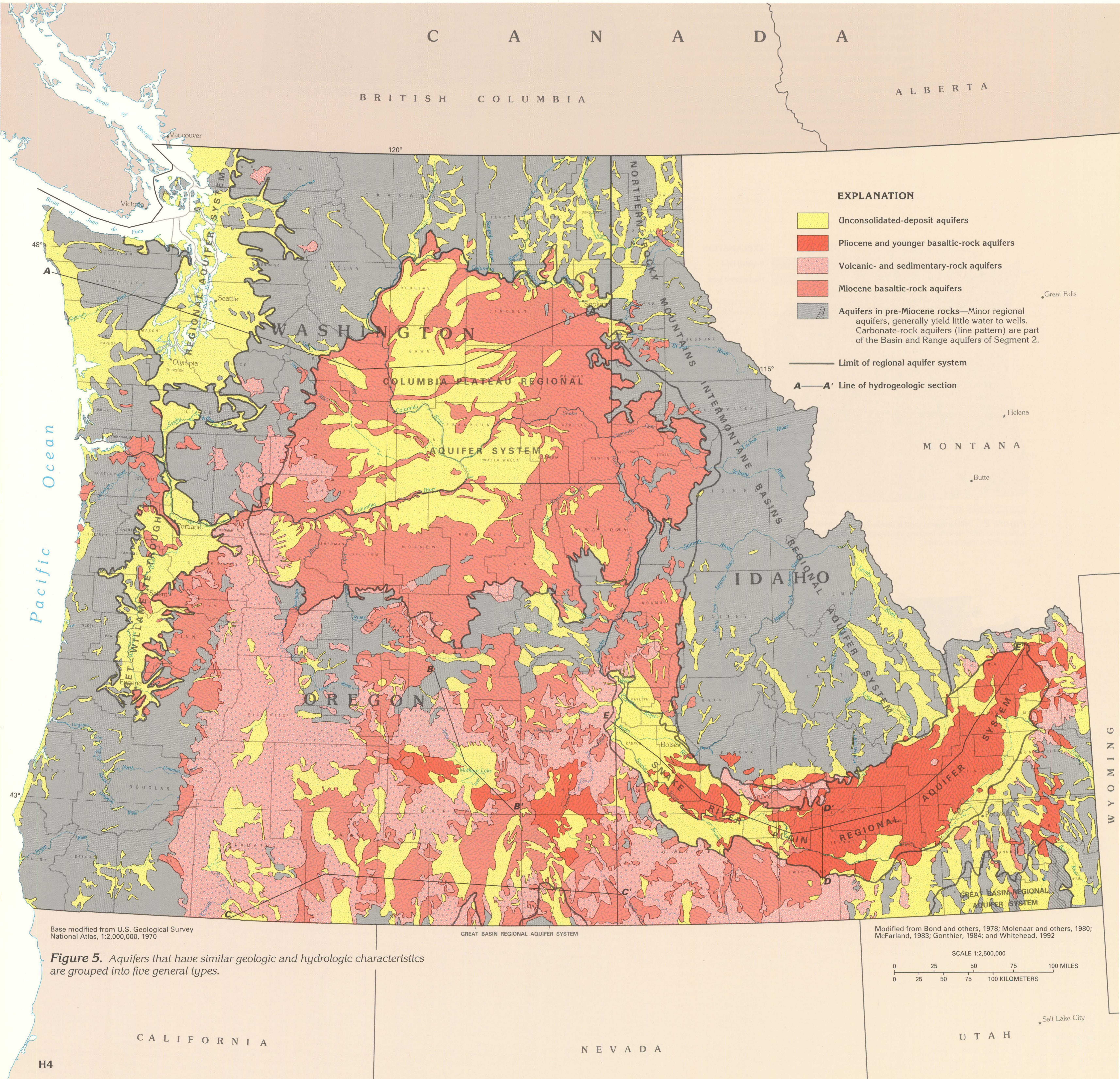


Figure 5. *Aquifers that have similar geologic and hydrologic characteristics are grouped into five general types.*

Structural Basins and Aquifers

Thick sequences of unconsolidated deposits and volcanic rocks compose the major aquifers that occupy large structural basins in Segment 7 (**figs. 6–10**).

Some of these basins are synclines, such as the ones shown in **figures 6 and 7**. In the Basin and Range area, faults that extend to great depths bound alternating upthrown and downthrown blocks of the Earth's crust (**fig. 8**). The downthrown blocks, or grabens, have been partially filled with alluvium derived from bedrock hills of the upthrown blocks, or horsts, that separate the grabens. Some faults between these horsts and grabens either are open conduits or are filled with large rock fragments. Ground water that has circulated to great depths and has become heated can move upward along these faults as geothermal water. Other faults, which are filled with extremely small rock fragments, are barriers to ground-water movement.

Complex interbedding of unconsolidated deposits and volcanic rocks exists in some places, especially in areas where numerous episodes of volcanic activity have taken place. One such area is the Snake River Plain in Idaho (**figs. 9 and 10**). This geologic complexity is reflected by a complex ground-water-flow system.

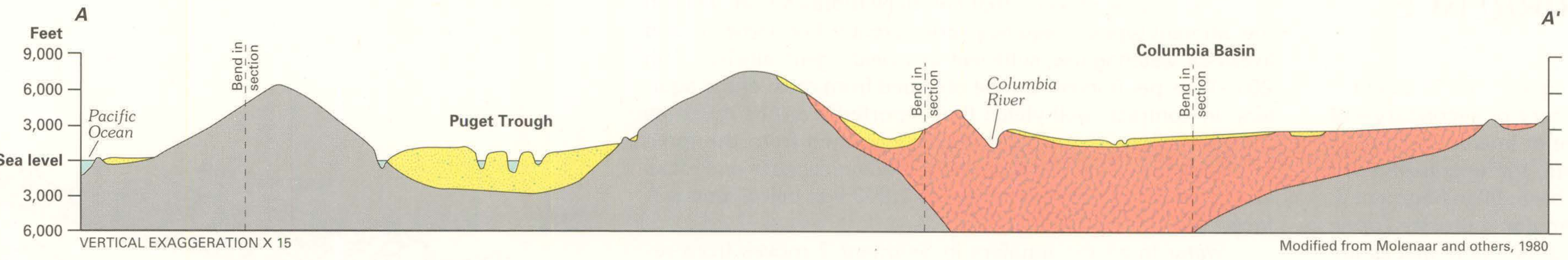


Figure 6. Structural basins in western and eastern Washington are filled with either unconsolidated-deposit aquifers or Miocene basaltic-rock aquifers that are partly overlain by unconsolidated-deposit aquifers. The Puget Trough is filled with unconsolidated-deposit aquifers that collectively are as much as 3,000 feet thick and that might be consolidated in their lower part. The Columbia Basin is filled with Miocene basaltic-rock aquifers that are overlain in places by unconsolidated-deposit aquifers; their combined thickness is more than 10,000 feet in the area of this section but can be as much as 15,000 feet thick elsewhere. The line of the section is shown in figure 5.

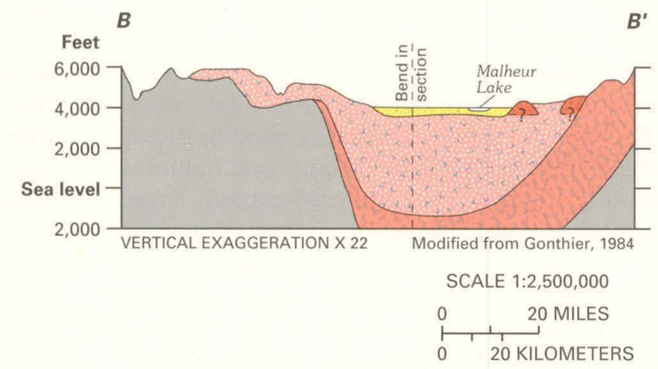


Figure 7. A deep synclinal basin in eastern Oregon is filled with Miocene basaltic-rock aquifers that are overlain by volcanic- and sedimentary-rock aquifers, which, in the upper part, are interbedded with unconsolidated-deposit aquifers. The line of the section is shown in figure 5.

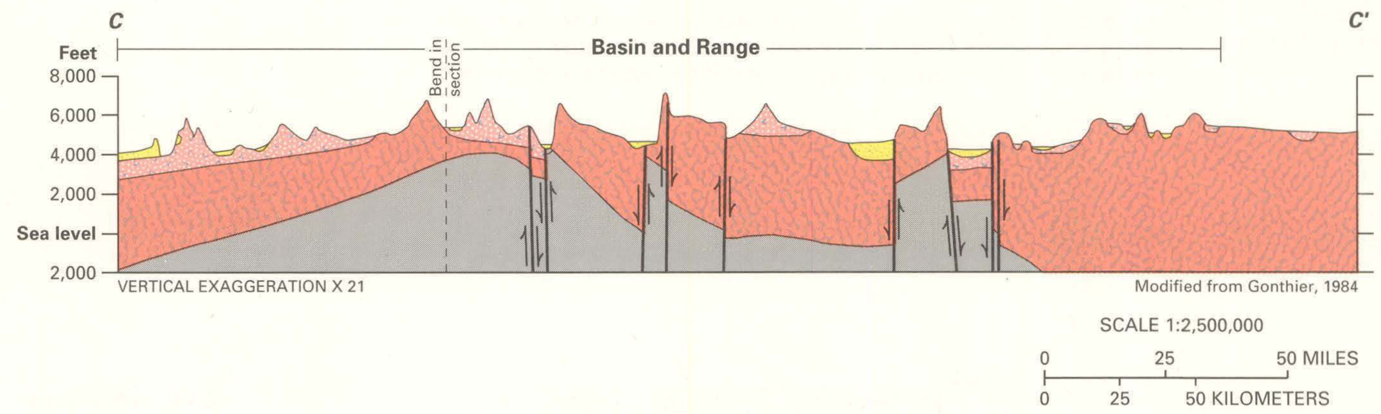
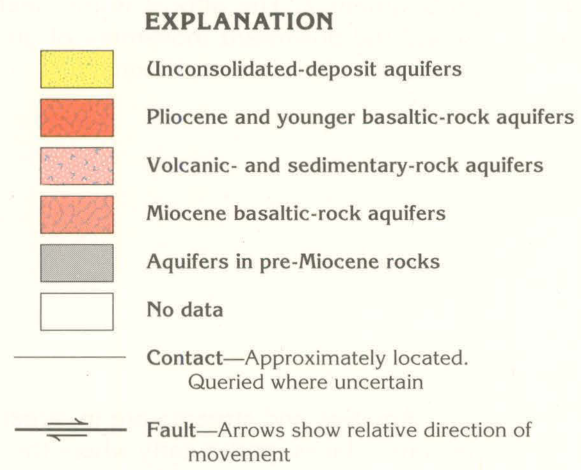


Figure 8. Four of the five aquifer types are displaced by major faults in the Basin and Range of south-central Oregon. Where the faults are either open or filled with large rock fragments, the faults are conduits for the movement of geothermal water. The line of the section is shown in figure 5.



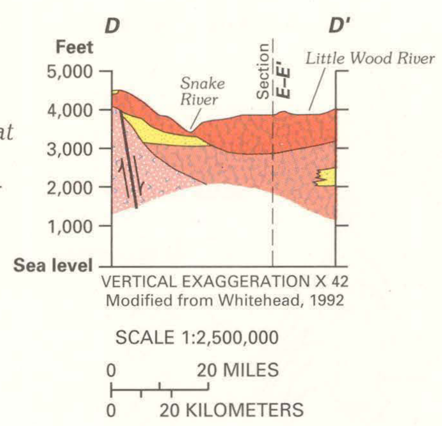


Figure 9. Unconsolidated-deposit aquifers commonly are interbedded with Pliocene and younger basaltic-rock and Miocene basaltic-rock aquifers at the margins of the eastern Snake River Plain. The basaltic-rock aquifers are thickest near the center of the Snake River Plain. The line of the section is shown in figure 5.

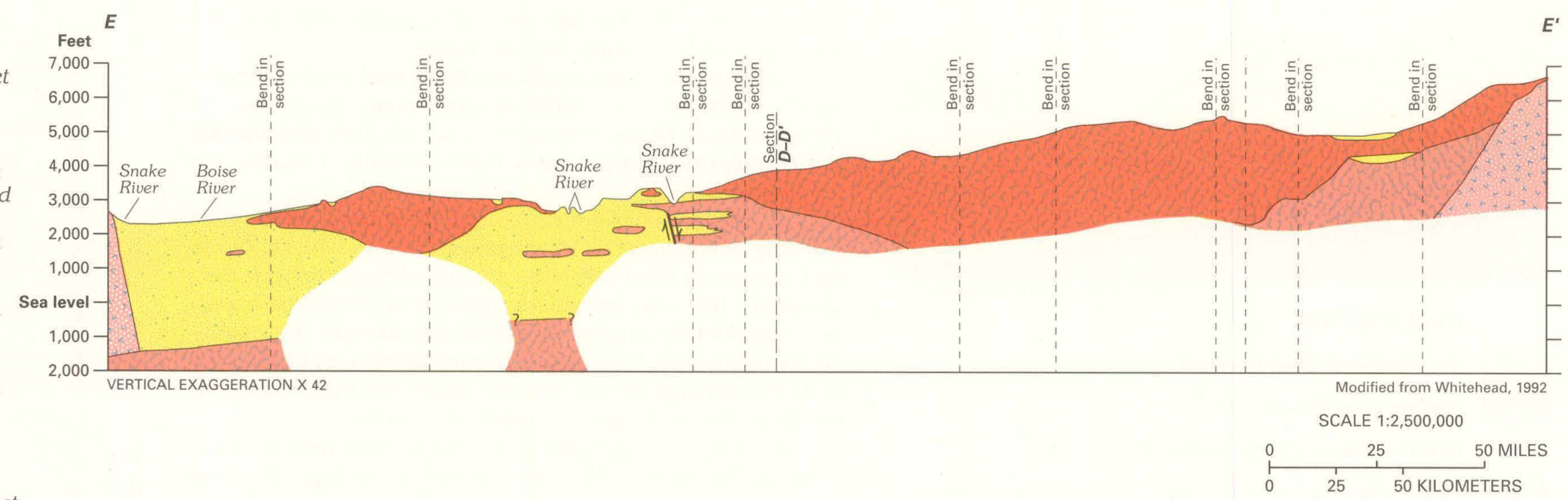
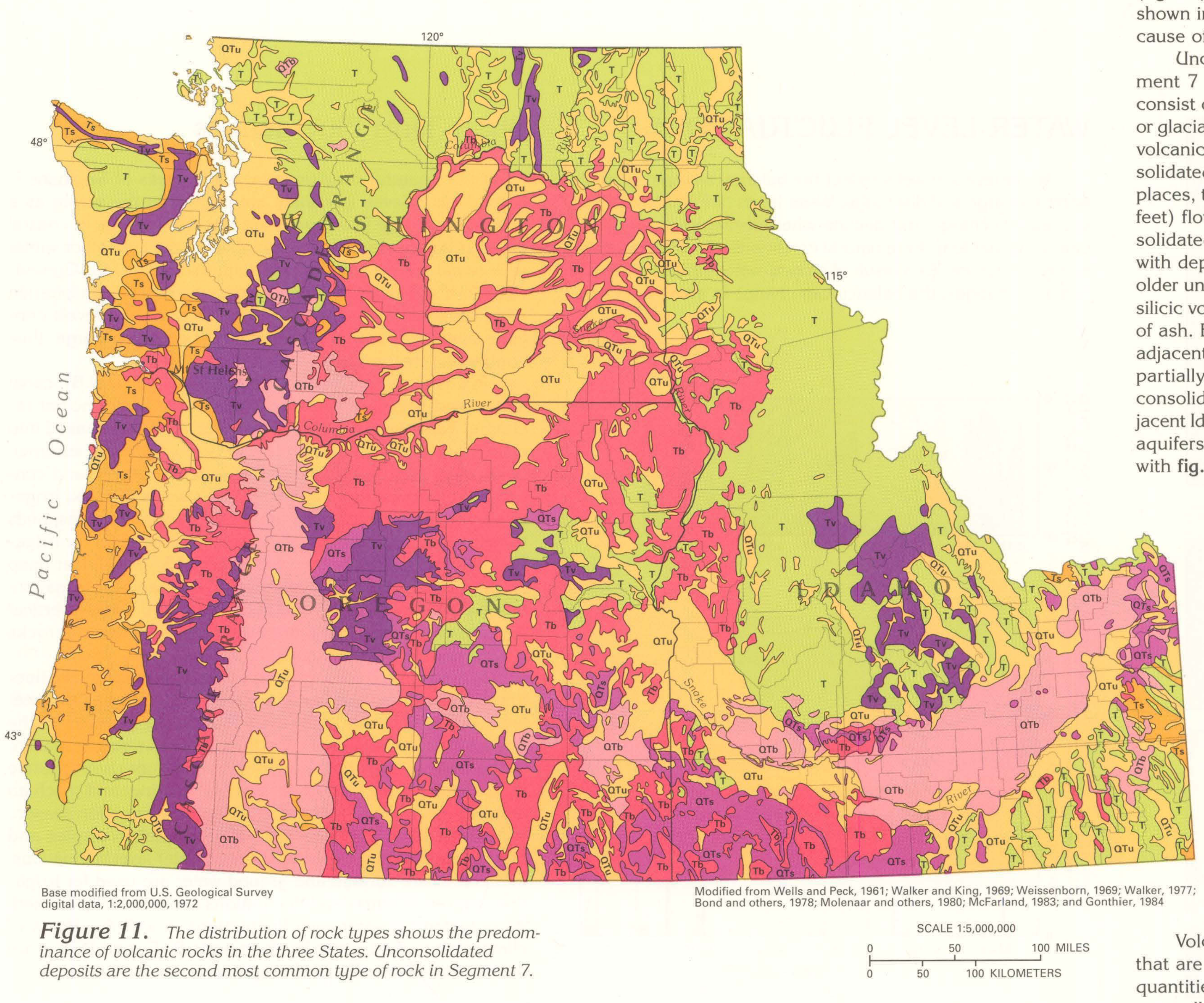


Figure 10. Unconsolidated-deposit aquifers, which collectively are about 4,000 feet thick in the area of the section and can be about 5,500 feet thick elsewhere, fill a deep structural basin in the western Snake River Plain. Pliocene and younger basaltic-rock aquifers are predominant in the eastern Snake River Plain. These aquifers are underlain by unconsolidated-deposit, volcanic- and sedimentary-rock, and Miocene basaltic-rock aquifers at the margins of the plain. On the basis of geophysical data, the Pliocene and younger basaltic-rock aquifers in the eastern Snake River Plain collectively might exceed 5,500 feet in thickness. The line of the section is shown in figure 5.

GEOLOGY

The rocks and unconsolidated deposits in Idaho, Oregon, and Washington range in age from pre-Tertiary to Holocene (**fig. 11**). Small outcrops of rocks younger or older than those shown in **figure 11** are present locally but are not shown because of the map scale.

Unconsolidated deposits extend over large areas in Segment 7 and differ considerably in age and grain size. They consist of younger, coarse-grained deposits of chiefly stream or glacial origin and older, fine-grained deposits of chiefly lake, volcanic, or eolian (wind blown) origin. In places, older unconsolidated deposits contain thick beds of volcanic ash; in other places, these deposits contain thin (a few feet to a few tens of feet) flows of basaltic or silicic volcanic rocks. Older unconsolidated deposits usually become increasingly compacted with depth. In southwestern Idaho and southeastern Oregon, older unconsolidated deposits are difficult to distinguish from silicic volcanic rocks where the latter are present as thick beds of ash. Except for eolian deposits in eastern Washington and adjacent Idaho, where these deposits generally are not even partially saturated, the unconsolidated deposits form the unconsolidated-deposit aquifers. In eastern Washington and adjacent Idaho, underlying Miocene basaltic rock forms the major aquifers—Miocene basaltic-rock aquifers (compare **fig. 11** with **fig. 5**).



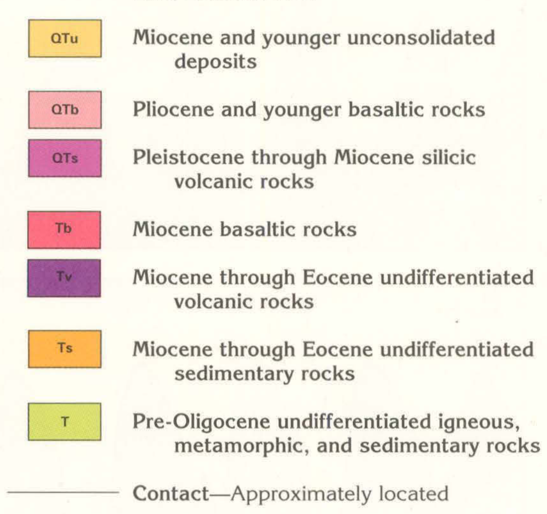


Figure 11. The distribution of rock types shows the predominance of volcanic rocks in the three States. Unconsolidated deposits are the second most common type of rock in Segment 7.

Volcanic rocks range in composition from basaltic rocks that are dense, fine grained, dark colored, and contain large quantities of iron and manganese to silicic volcanic rocks that generally are coarse grained, light colored, and contain large quantities of silica. Some basalt flows on the Snake River Plain in Idaho are less than 2,000 years old, as are some in the Cascade Range in Oregon and Washington. The latest volcanism was the 1980 eruption of Mount St. Helens in south-central Washington.

Pliocene and younger basaltic rocks are present chiefly in the Snake River Plain in Idaho and underlie much of the Cascade Range in Oregon. Pliocene and younger basaltic rocks are chiefly flows but, in many places in the Cascade Range, the rocks contain thick interbeds of basaltic ash, as well as sand and gravel beds deposited by streams. These flows and associated interbeds form the Pliocene and younger basaltic-rock aquifers.

Silicic volcanic rocks are present chiefly in southwestern Idaho and southeastern Oregon where they consist of thick flows interspersed with unconsolidated deposits of volcanic ash and sand. Silicic volcanic rocks also are the host rock for much of the geothermal water in Idaho and Oregon. In this chapter, these rocks are combined with some unconsolidated deposits and some Pliocene and younger basaltic rocks; this combination of rocks and deposits is referred to as the volcanic- and sedimentary-rock aquifers. The Pliocene and younger basaltic rocks included in these aquifers are those along the Cascade Range and in the adjacent eastern lowland in Oregon and Washington (compare **fig. 11** with **fig. 5**). These rocks are included in the aquifers because (1) they are seldom used as a source of water except locally in lowland areas, and (2) previous investigators have grouped these rocks with the silicic volcanic rocks and some unconsolidated sedimentary rocks on the basis of similar hydrologic characteristics and the hydraulic connection among the rocks.

Miocene basaltic rocks commonly are thick, solid flows that are widespread in southwestern Idaho, eastern Oregon, and south-central Washington. These flows form the Miocene basaltic-rock aquifers.

The undifferentiated volcanic rocks, which are present in all three States, are a heterogeneous mixture that ranges from basaltic to rhyolitic in composition and commonly are thick flows. These rocks can be similar to some younger volcanic rocks but usually are more dense and contain few fractures. These rocks form some of the aquifers in pre-Miocene rocks.

Undifferentiated consolidated sedimentary rocks, which are present primarily in western Oregon and southwestern Washington, consist chiefly of limestone, dolomite, sandstone, and shale. Because some of these rocks were deposited in a marine environment, they might contain saltwater, particularly west of the Cascade Range in Oregon and Washington. These rocks also form some of the aquifers in pre-Miocene rocks.

The undifferentiated igneous, metamorphic, and sedimentary rocks, which are present in all three States, generally are dense and contain few fractures. These rocks also form some of the aquifers in pre-Miocene rocks.

GROUND-WATER OCCURRENCE AND MOVEMENT

The occurrence of water in the aquifers in Segment 7 depends on the type of porosity—primary or secondary—of the deposits and rocks and the degree of interconnection of open spaces within them. For example, the unconsolidated deposits, which are present mostly as basin fill in Segment 7, have substantial primary, or intergranular, porosity (open spaces between individual grains), and the open spaces are well connected. The porosity in volcanic rocks depends on whether the rock is composed of fragmental material, such as tuff, cinders, and volcanic rubble with open spaces between fragments, or is a basalt flow with interconnected vesicles. Fragmental volcanic rocks have primary porosity much like that of unconsolidated deposits, and open spaces are well connected. Basalt flows have two types of porosity: primary, which is in zones at the tops and the bottoms of individual flows where interconnected open spaces were formed by gases escaping as the lava cooled and by cracking of the outer, solidified parts of the flows as the molten core continued to move; and secondary, which consists primarily of joints and fractures that formed as shrinkage cracks when the core cooled. These secondary open spaces are well developed and well connected in some flows and are able to store and transmit large volumes of water. Most of the porosity in consolidated sedimentary, igneous, and metamorphic rocks is secondary and resulted from tectonic activity. These secondary open spaces generally are not well connected. Another form of secondary porosity in all the consolidated rocks is produced by faulting. Faults are large-scale secondary open spaces where they are filled with coarse-grained rock fragments.

The volume of water that can be withdrawn from wells in the different types of aquifers varies greatly. For domestic and livestock-watering use, sufficient well yields, generally less than 20 gallons per minute, can be obtained from most of the aquifers. In contrast, well yields that reportedly are as much as 19,000 gallons per minute can be obtained from the most productive aquifers. Depth to water-yielding deposits and rocks can range from a few feet to about 1,200 feet below land surface.

Water in all the aquifers in Segment 7 moves from recharge areas down the hydraulic gradient to discharge areas. Many of the aquifers in the three-State area are exposed at land surface and receive recharge directly from precipitation on outcrop areas. Other aquifers are buried and are recharged by downward leakage from overlying aquifers. In some places, certain aquifers receive recharge as lateral flow from adjacent aquifers. Lateral recharge is a characteristic of some aquifers that fill the many structural basins in Segment 7. For example, where the unconsolidated-deposit aquifers in basins are separated by a mountain range that consists of volcanic- and sedimentary-rock aquifers, water can move from one basin at a high altitude through these aquifers to another basin at a lower altitude (**fig. 12**).

Discharge from the aquifers is by evapotranspiration, leakage to adjacent aquifers, withdrawals from wells, movement of water to surface-water bodies, and discharge from springs. Springs are particularly important as discharge points in the walls of the Snake River Canyon in Idaho. Permeable and almost impermeable rocks are complexly interbedded in places in Segment 7. The almost impermeable rock layers might retard the downward movement of ground water and create perched water-table conditions.

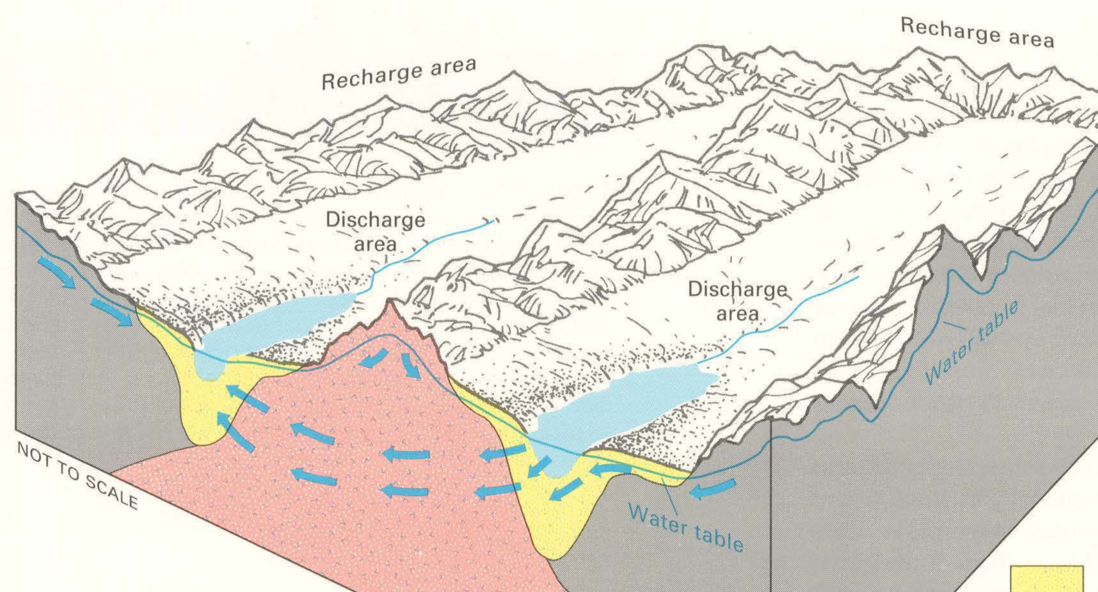


Figure 12. *Recharge from adjacent basins is possible. Ground water will move from one basin to another under appropriate conditions. The basin on the right contains unconsolidated-deposit aquifers with the water table at an altitude higher than that in similar aquifers in the basin on the left. The mountain range separating the basins is composed of volcanic- and sedimentary-rock aquifers. Water movement takes place because of the existence of a hydraulic gradient from right to left in the diagram.*

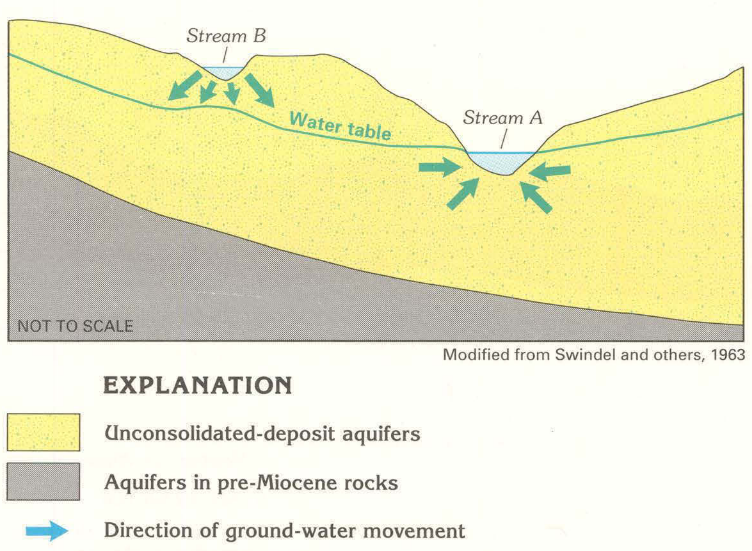


Figure 13. *Aquifers and streams are hydraulically connected. Stream A is below the water table and gains water from the aquifer; the stream will flow until the water table declines below the streambed. Stream B is above the water table and loses water to the aquifer; the stream might be dry during droughts.*

Aquifers and streams are in direct hydraulic connection in some places, particularly where the aquifers in the stream valleys consist of unconsolidated deposits (**fig. 13**). Water can move either from the aquifer to the stream (gaining stream labeled *A* in **fig. 13**) or from the stream to the aquifer (losing stream labeled *B* in **fig. 13**), depending on the altitude of the water level in the stream and the aquifer.

Geologic structures (faults and folds) can affect the movement of ground water. Although only major structures are shown in **figure 14** because of the map scale, they demonstrate the complexity of structural features in Idaho, Oregon, and Washington.

Some fault zones are extremely permeable and might be the only conduits for water movement in some rocks. Other fault zones are filled with clay and are almost impermeable. Generally, the more consolidated and less weathered a rock is, the greater the chance that faults will increase the permeability of the rock. Open faults in consolidated rocks are conduits for recharge in mountainous areas and permit deep infiltration of water to geothermal heat sources.

Uplifting, folding, faulting, and subsidence have left their marks in Segment 7. The area contains some high mountain peaks, including Borah and Hyndman Peaks in Idaho; Mount Hood in Oregon; and Mounts Adams, Baker, Rainier, and St. Helens in Washington. Volcanic and seismic activity has taken place in the area as recently as the 1980's. The violent eruption of Mount St. Helens in May 1980 removed about 0.3 cubic mile of rock from the mountain. During 9 hours of eruption, about 540 million tons of ash were spread over an area of about 22,000 square miles.

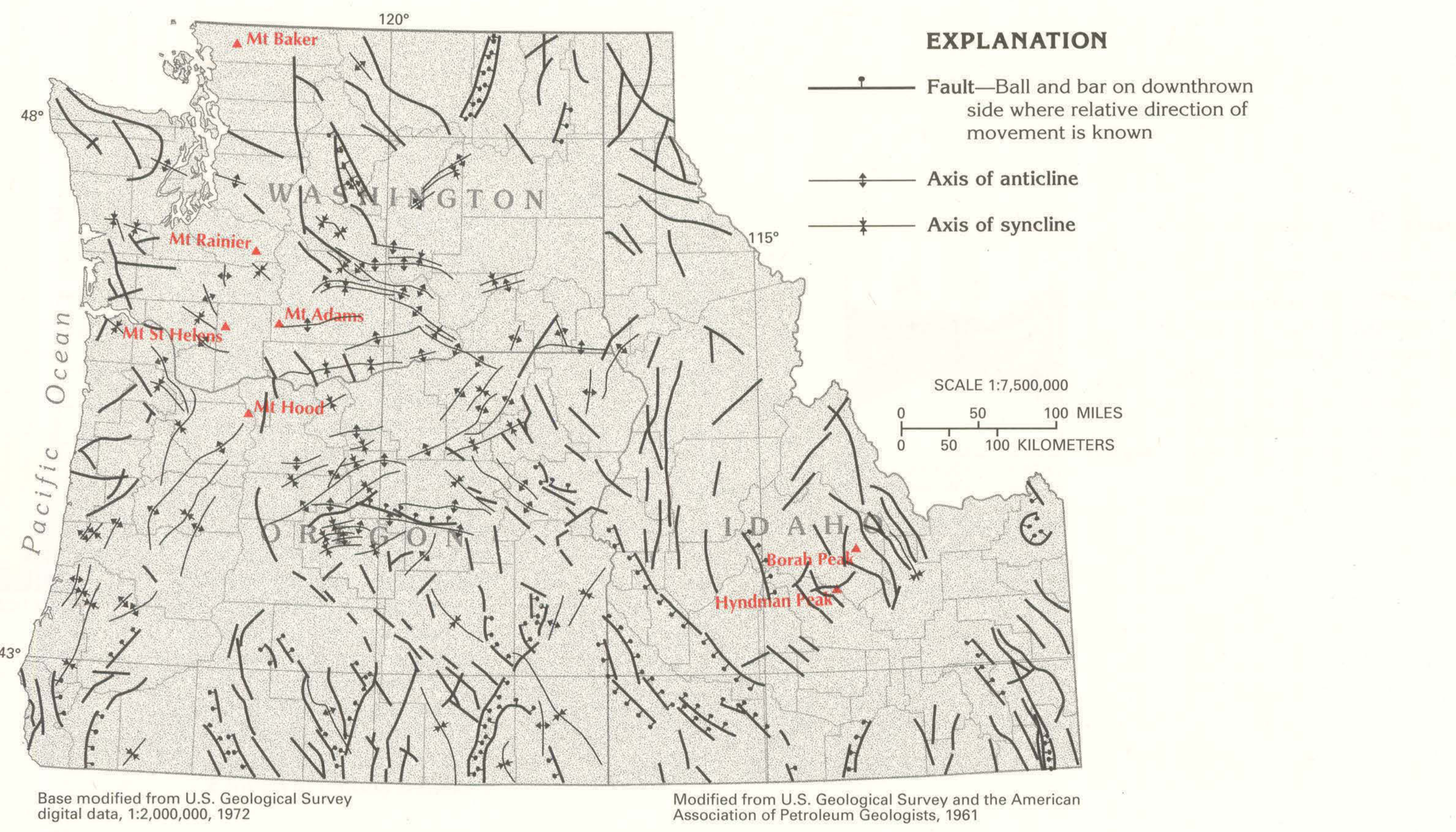
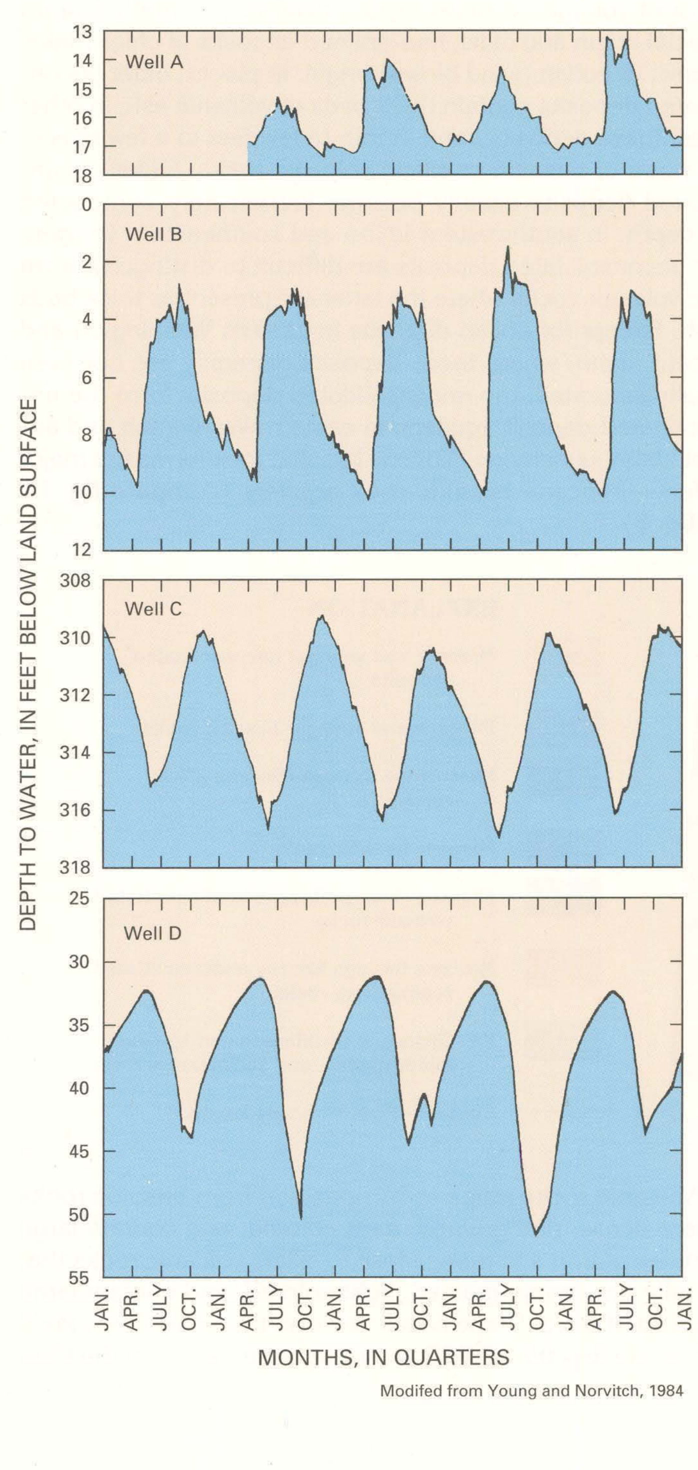


Figure 14. *Major geologic structures shape the land surface and affect the movement of ground water. Ground water can move upward from great depths or downward to great depths or both along some faults, whereas other faults are barriers to vertical and lateral ground-water movement. Ground water can move outward from the crests of anticlines or inward toward the troughs in synclines in aquifers that consist of basalt flows.*

Figure 15. *Ground-water levels fluctuate in response to various recharge and discharge sources. The hydrograph for well A reflects recharge from snowmelt during the spring and discharge by natural means during the summer; that for well B reflects shallow recharge by applied irrigation water from a surface-water source during the growing season; that for well C reflects deep recharge by applied irrigation water from a surface-water source during the growing season; and that for well D reflects recharge from snowmelt during the spring and discharge for irrigation during the growing season.*



WATER-LEVEL FLUCTUATIONS

Water levels in wells reflect the balance between ground-water recharge and discharge. Water levels rise when recharge exceeds discharge and decline when discharge exceeds recharge. Under long-term natural conditions, the two tend to be nearly in balance. As a result of ground-water development and climatic changes, the balance can change in either direction.

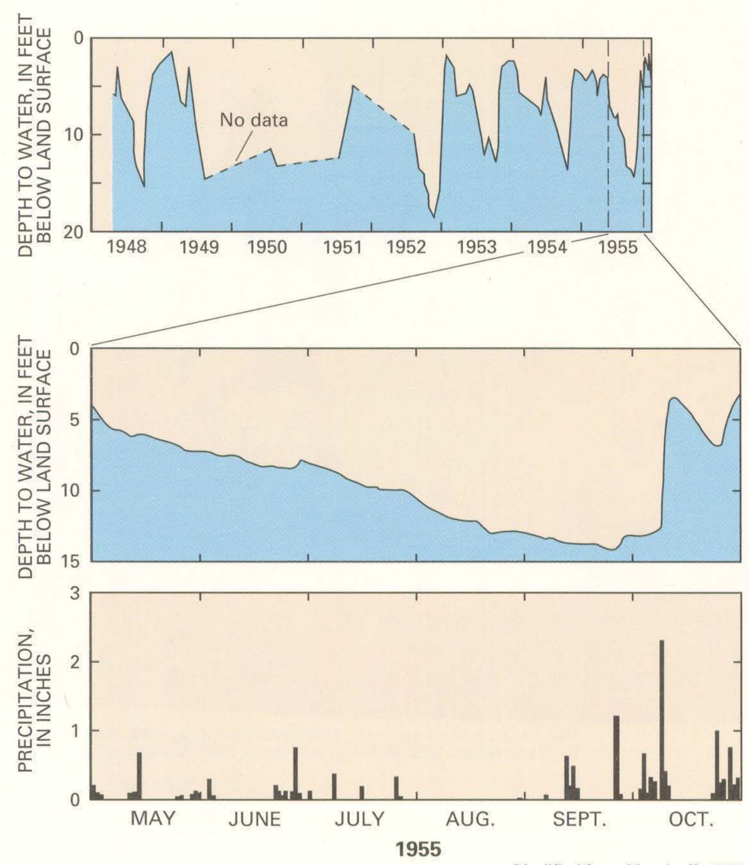


Figure 16. *Water levels in aquifers near the Pacific coast respond to variations in rainfall, particularly during the fall months.*

Short-Term Fluctuations

Under natural conditions in inland areas of Segment 7, ground-water levels generally are highest in the spring as a result of recharge from snowmelt (**fig. 15**, well A). In coastal areas, ground-water levels are highest in the late fall or winter as a result of recharge from precipitation (**fig. 16**). Ground-water levels decline through summer when evapotranspiration rates cause discharge to exceed recharge. Water levels continue downward until the next major seasonal recharge, thus completing the annual cycle.

In areas irrigated by surface water (**fig. 15**, well B), canal losses and seepage from fields constitute the principal recharge. Water levels begin to rise when water is released into canals and fields, reach a plateau throughout the summer, begin to decline at the end of the growing season, and continue to an annual low just before the start of the next irrigation season. Well B is 32 feet deep and the water level responds to recharge soon after distribution of surface water for irrigation begins. In comparison, well C (**fig. 15**) is 345 feet deep and the water level also responds to surface-water irrigation; however, response is delayed by about 4 to 6 weeks. Vertical percolation of water through unsaturated deposits and rocks is slow and delays recharge.

In areas irrigated by ground water, the annual cyclic fluctuations described above are reversed (**fig. 15**, well D). Water levels begin to decline at the start of pumping, generally in the late spring; continue to decline through the irrigation season, at the end of which time they begin an abrupt rise; continue to rise through the fall, winter, and early spring; and reach an annual peak just before the start of the next irrigation season.

The hydrographs in **figure 15** are ideal examples and clearly reflect the causes for short-term water-level fluctuations. In areas where surface and ground water are used for irrigation, causes of water-level fluctuations are less easily defined. As depicted by water-level fluctuations in well A, effects of climate also affect water levels in wells B, C, and D, but are overshadowed by effects of irrigation.

Long-Term Fluctuations

In addition to repetition of seasonal fluctuations, a long-term hydrograph (**fig. 17**) indicates trends in the balance or imbalance between aquifer discharge and recharge. Long-term water-level trends generally are caused by (1) long-term precipitation cycles (for example, several years of greater-than-normal precipitation followed by several years of less-than-normal precipitation), (2) continuing ground-water withdrawals in excess of available recharge, and (3) improvements in irrigation efficiencies, such as changing from furrow and flood irrigation to sprinkler irrigation, and sealing or lining earthen canals, thus reducing water-transmission losses and thereby decreasing recharge to an aquifer.

A long-term hydrograph of water levels in an observation well in Minidoka County, Idaho, is shown in **figure 17**. The 194-foot-deep well was completed in the Pliocene and younger basaltic-rock aquifer, which generally is unconfined underlying the Snake River Plain. The well is in an area where ground water is withdrawn for irrigation but is near an area irrigated with surface water diverted from the Snake River. The gradual long-term declining trend in ground-water level can be attributed primarily to less-than-normal precipitation, which determined the surface-water supply available for irrigation during the period 1951–62, and to decreased surface-water diversions and improvements in surface-water-irrigation efficiencies during the period 1963–80.

Replacing irrigated farmland with urban shopping centers, residential subdivisions, and other types of land use also can affect recharge rates to an aquifer. Mining activities can cause similar effects.

Reliance on ground water for public-supply, domestic and commercial, agricultural, and industrial purposes is increasing in Idaho, Oregon, and Washington. In the more arid parts of Segment 7, increased ground-water withdrawals generally cause ground-water levels to decline.

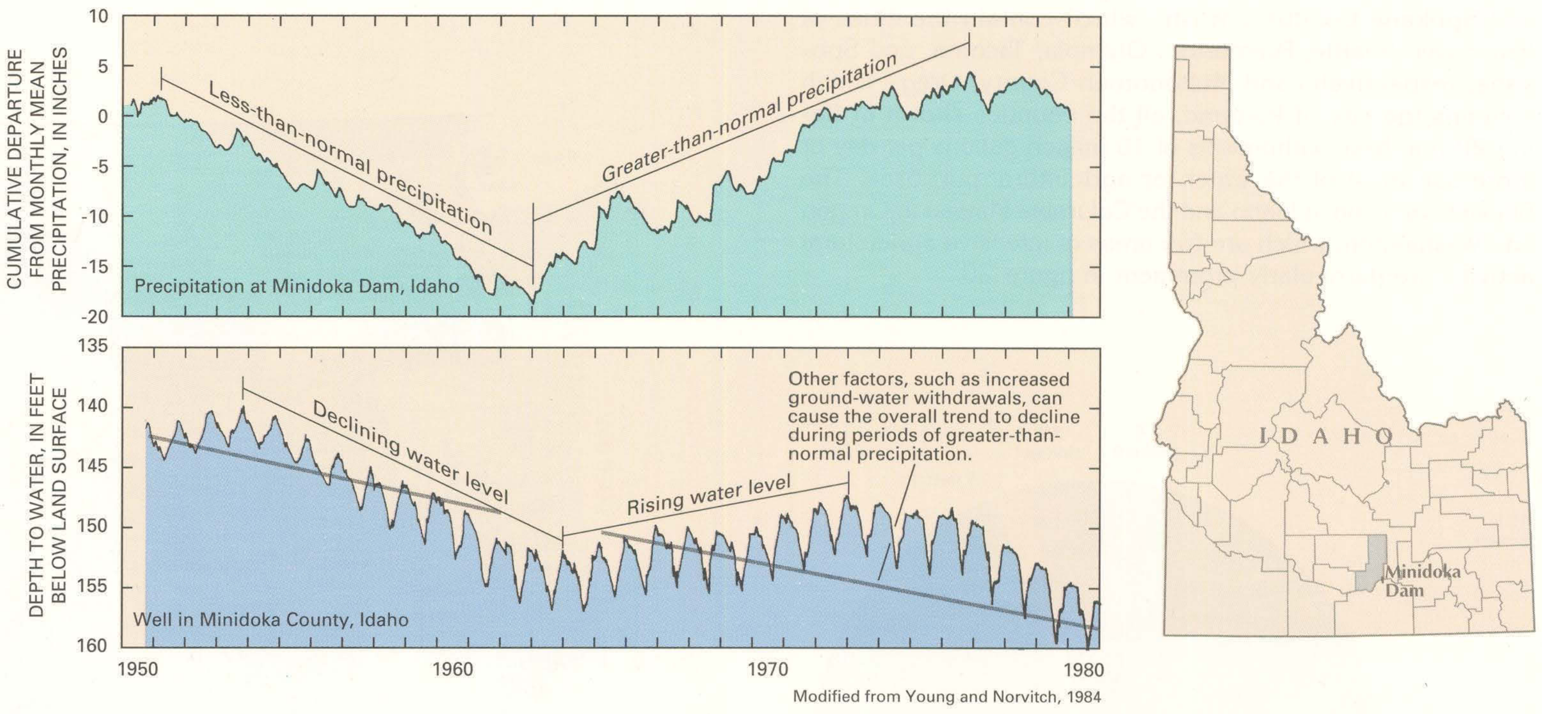


Figure 17. When ground-water discharge exceeds recharge, ground-water levels decline; the opposite also occurs unless other factors cause a long-term decline to continue. Water-level declines are common during periods of less-than-normal precipitation, such as during 1951–62. Even though water levels rise during periods of greater-than-normal precipitation, such as during 1963–76, the overall trend can be a decline because of other factors.

GROUND-WATER QUALITY

Ground water in Idaho, Oregon, and Washington generally is fresh (dissolved-solids concentration of 1,000 milligrams per liter or less) and chemically suitable for most uses. Because of sparse settlement in much of the area, little ground water has been contaminated as the result of human activities, except locally. Measured concentrations of dissolved solids in ground water (**fig. 18**) exceed 1,000 milligrams per liter only in scattered areas throughout the three States.

Under natural conditions, dissolved minerals in ground water are primarily a result of the chemical interaction between water and the deposits or rocks through which the water moves. The water partially dissolves some of the minerals as it moves from areas of recharge to areas of discharge. The longer the water is in contact with the minerals that compose the aquifer, the more mineralized the water becomes. Therefore, the exact chemical composition of the water at any given place is determined by the combination of the mineralogy of the deposits or rocks that compose the aquifer and the residence time of the water in the aquifer.

Some ground water contains large natural concentrations of particular minerals (saltwater) and is unfit for human consumption and many other uses. Saltwater can contaminate freshwater aquifers by entering either from the ocean in coastal areas or along faults in other areas. Natural contamination of ground water takes place slowly relative to contamination from human activities.

Ground water can be contaminated by numerous organic chemicals (especially pesticide residues or byproducts, oils, phenols, and solvents); metals (especially chromium, lead, and mercury); and compounds produced by a myriad of human activities. Contamination is classified as being from either a point or a nonpoint source. Point sources are specific local sites of a few acres or less and include industrial and municipal landfills; surface impoundments, such as lagoons, pits, and ponds; underground storage tanks containing petroleum, toxic chemicals, and wastes; spills of chemicals and petroleum products during transport or transfer operations; and injection or disposal wells that receive hazardous waste or wastewater. Nonpoint sources extend over broad areas of hundreds or thousands of acres and include fields treated with agricultural pesticides and fertilizers, concentrations of septic-tank drainfields and cesspools in suburban areas, saltwater or geothermal water encroachment, salt from highway deicing, animal feedlots, and mining operations.

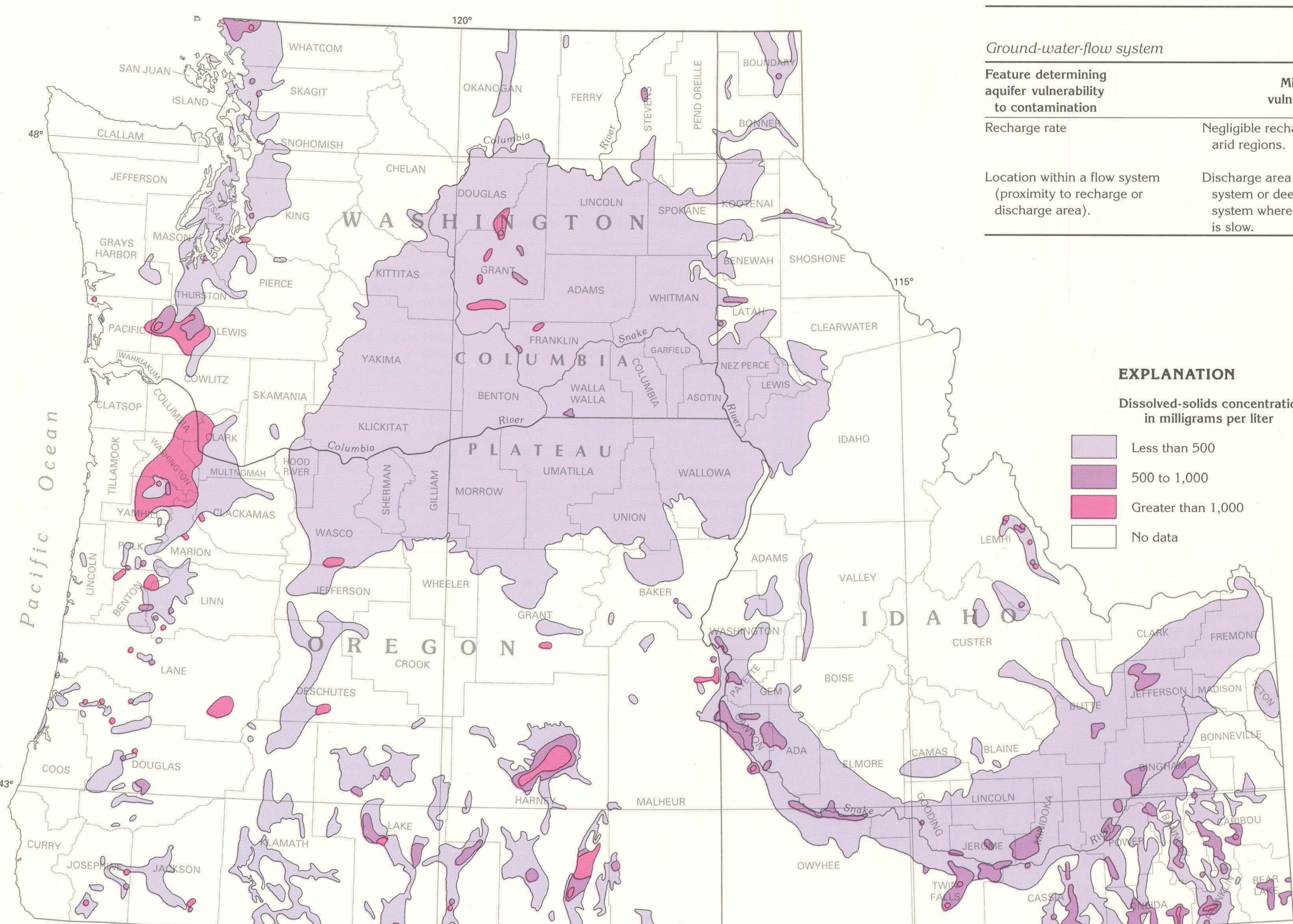
Shallow, unconfined aquifers with rapid recharge rates generally are most vulnerable to contamination from the land surface because of the rapid percolation of ground water along short flowpaths from the land surface to the water table. This rapid percolation means that the contaminated water is in contact with soil minerals for only a brief time; accordingly, there is little potential for the contaminants to be absorbed by the soil. Confined aquifers are usually deeply buried and are covered by a confining unit; as a result, they are much less vulnerable to contamination than are shallow, unconfined aquifers. The following table lists features that affect aquifer vulnerability to contamination and indicates the relative degree of vulnerability, which is based on characteristics of the features.

Hydrogeologic framework

Feature determining aquifer vulnerability to contamination	Minimal vulnerability	Substantial vulnerability
Unsaturated zone	Thick unsaturated zone overlying almost impermeable material, such as clay or organic materials.	Thin unsaturated zone overlying sand and gravel, limestone, and basalt.
Confining unit	Thick confining unit of clay or shale above aquifer.	No confining unit.
Aquifer properties	Minimal permeability, such as in silty sandstone or limestone.	Substantial permeability, such as in sand and gravel, cavernous limestone, or basalt.

Ground-water-flow system

Feature determining aquifer vulnerability to contamination	Minimal vulnerability	Substantial vulnerability
Recharge rate	Negligible recharge rate as in arid regions.	Rapid recharge rate as in humid regions.
Location within a flow system (proximity to recharge or discharge area).	Discharge area of a regional flow system or deep parts of that system where water movement is slow.	Recharge area of a regional flow system or area within the cone of depression of a pumping well or field.



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1972

Modified from Feth and others, 1965; VanDenburgh and Santos, 1965; and Parliman, 1987

SCALE 1:4,000,000

0 50 100 MILES

0 50 100 KILOMETERS

Figure 18. Dissolved-solids concentrations in ground water in Segment 7 generally are less than 1,000 milligrams per liter, which indicates that much of the water is fresh.

The concentration of dissolved solids in ground water provides a standard for categorizing the general chemical quality of the water. The dissolved-solids concentration is determined largely by the types of deposits and rocks through which the water moves and the length of time the water is in the aquifer, as well as by contaminants in the water. Secondary Federal drinking-water regulations recommend a maximum dissolved-solids concentration of 500 milligrams per liter. In some areas, however, water with a dissolved-solids concentration of as much as 1,000 milligrams per liter is used for human consumption. Dissolved-solids concentrations that exceed 500 milligrams per liter are common near coastal areas and in deep aquifers in Idaho, Oregon, and Washington (**fig. 18**). Most deep aquifers are overlain by shallower aquifers that contain water with smaller dissolved-solids concentrations. However, in some irrigated areas, water in shallow aquifers contains a large dissolved-solids concentration that resulted from percolation of the irrigation water, and in central parts of closed basins, evaporation concentrates minerals in shallow ground water.

Areas where dissolved-solids concentrations exceed 500 milligrams per liter (**fig. 18**) reflect (1) irrigation, chiefly on the Snake River Plain and the Columbia Plateau, (2) saltwater in underlying consolidated marine sedimentary rocks in Oregon and Washington, (3) evaporation in closed basins in south-central Oregon, and (4) geothermal water leaking into the cold freshwater system, chiefly in Idaho and Oregon.

FRESH GROUND-WATER WITHDRAWALS

Fresh ground-water withdrawals during 1985 were about 4,800 million gallons per day in Idaho, about 660 million gallons per day in Oregon, and about 1,220 million gallons per day in Washington (**fig. 19**). Categories of use in each State also vary. Withdrawals for agricultural (primarily irrigation) purposes exceed all other uses in each State. Withdrawals for irrigation are particularly large in Idaho. Withdrawals for public supply are largest in Washington, which is the most densely populated of the three States.

Fresh ground-water withdrawals by county vary as shown in **figure 20**. Rates of withdrawal are distributed evenly throughout some counties; however, most major withdrawal sites are for irrigation or public supply and, therefore, are denser in specific areas. Except for Clark, King, Kitsap, Thurston, Pierce, and Spokane Counties, Wash., which contain the cities of Vancouver, Seattle, Bremerton, Olympia, Tacoma, and Spokane, respectively, and Multnomah County, Oreg., which contains the city of Portland, all the counties shown in **figure 20** that have withdrawals of 10 million gallons per day or more use most of the water for agricultural purposes. The Snake River Plain in Idaho and the Columbia Plateau in Oregon and Washington, which are two areas of intensive agricultural activity, are particularly prominent in **figure 20**.

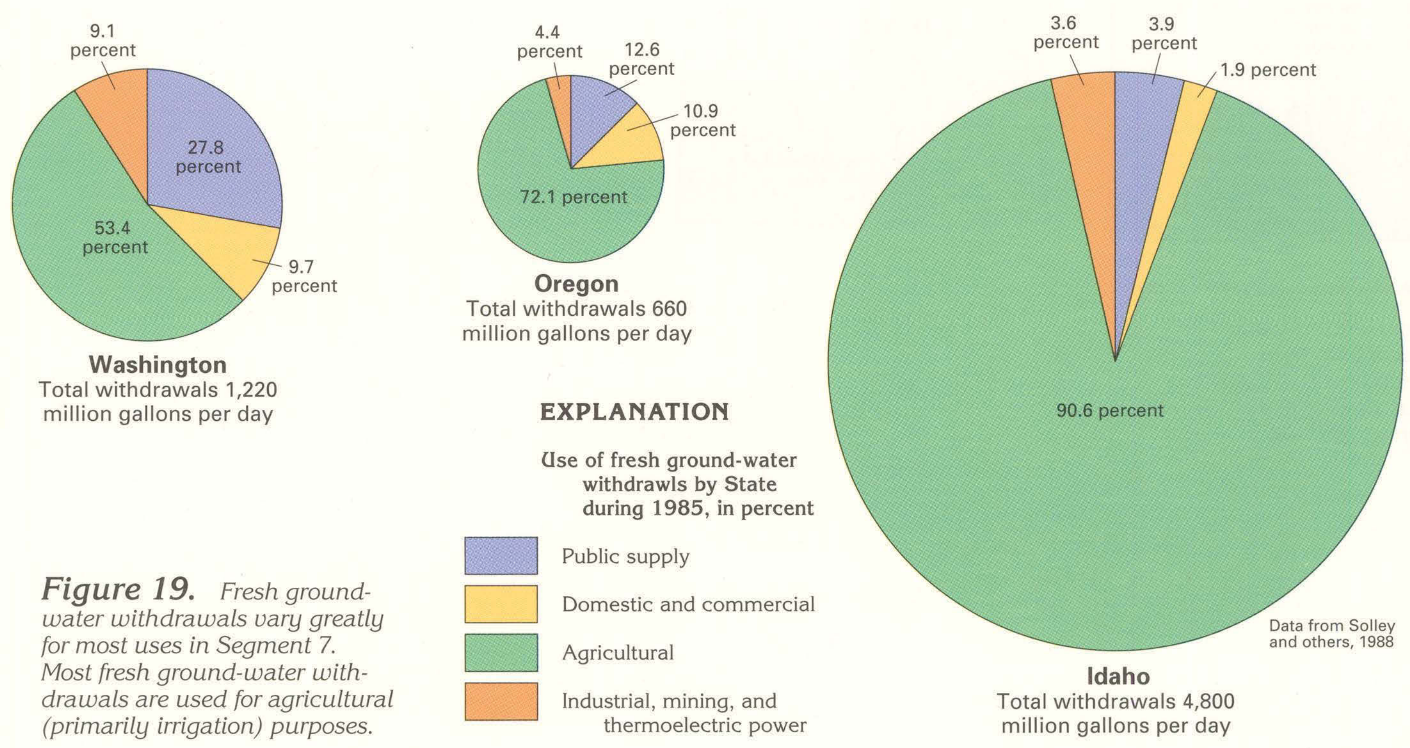


Figure 19. Fresh ground-water withdrawals vary greatly for most uses in Segment 7. Most fresh ground-water withdrawals are used for agricultural (primarily irrigation) purposes.

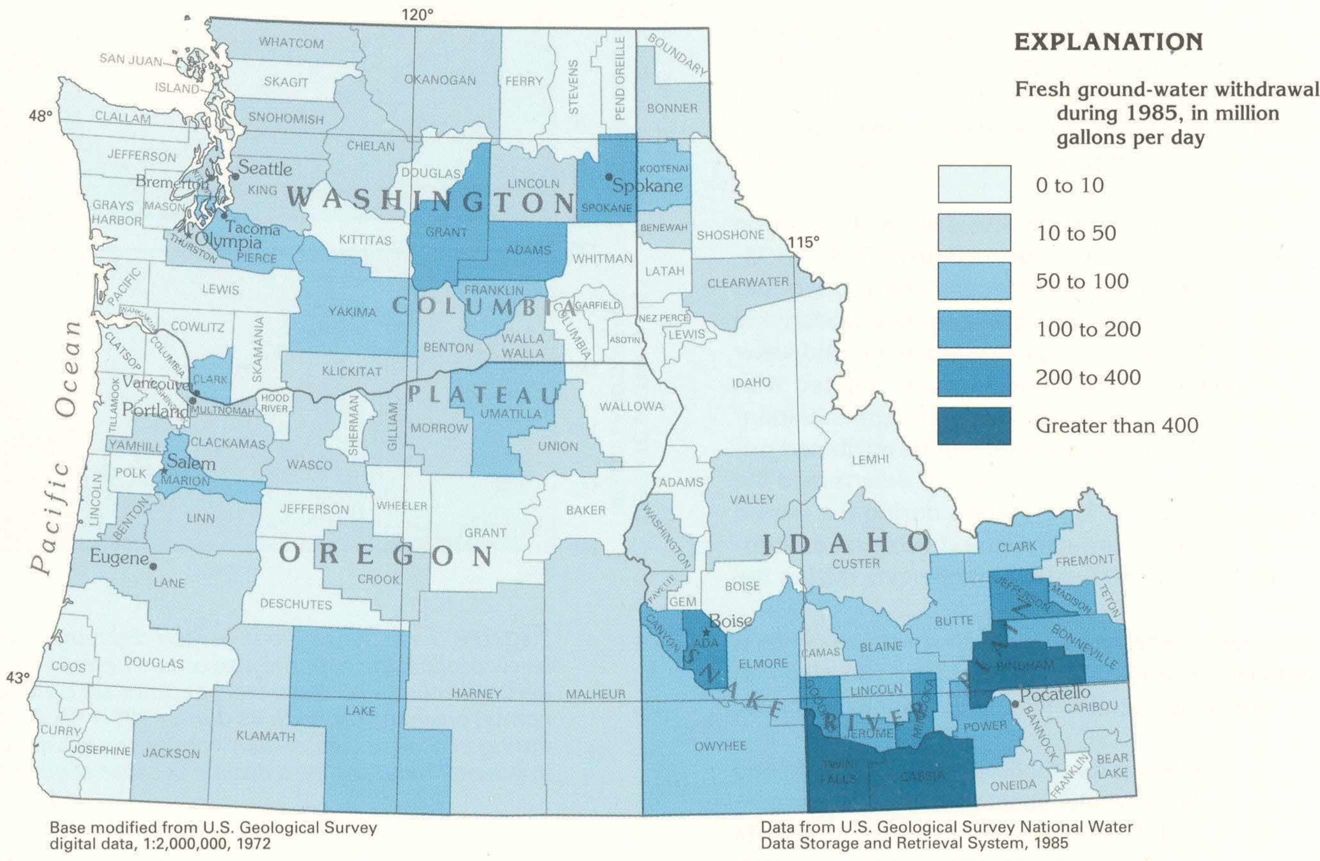
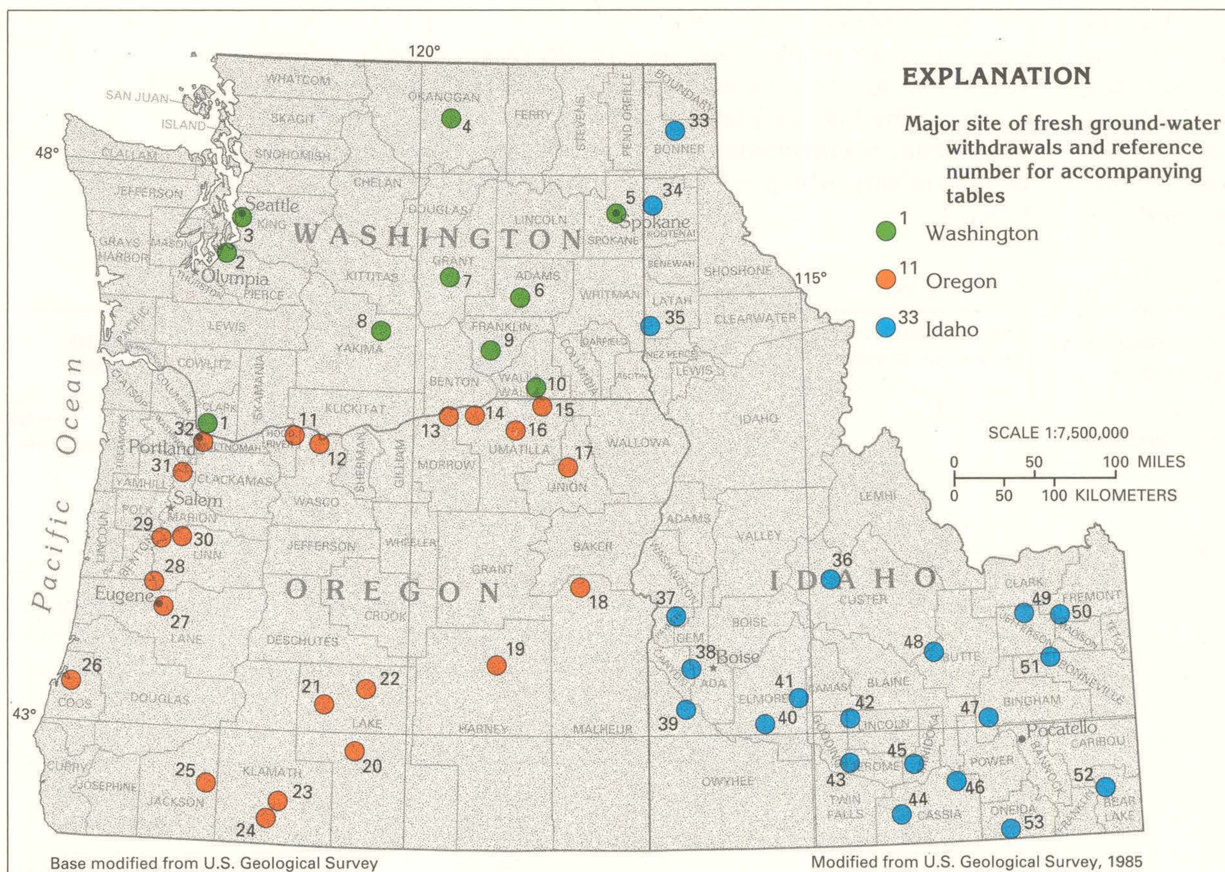


Figure 20. Except for population centers in Washington, most of the fresh ground-water withdrawals in counties where more than 10 million gallons per day is withdrawn are used for agricultural purposes.

Figure 21. Most major withdrawals of fresh ground water are in specific areas, and the water is used mostly for public-supply and agricultural (primarily irrigation) purposes.



Major withdrawal sites in Oregon

Site number	Geographic area	Aquifers[1]	Principal uses
11	Hood River (springs)	C	Public supply.
12	Northern Wasco County	A, D	Irrigation.
13	Eastern Morrow County	A, D	ditto
14	Western Umatilla County	A, D	ditto
15	Milton–Freewater area	A, D	ditto
16	Pendleton	A, D	Public supply.
17	Grande Ronde Valley	A, D	Irrigation.
18	Cow Valley	C	ditto
19	Harney Valley	A, B, C	ditto
20	Ana River Springs	A	ditto
21	Fort Rock Valley	A, C, D	ditto
22	Christmas Lake Valley	A, C	ditto
23	Klamath Basin	C	ditto
24	Klamath Falls	A, C	Public supply.
25	Big Butte Springs (Medford)	A, C	ditto
26	Coos Bay–North Bend	A	ditto
27	Eugene-Springfield area	A	Irrigation, public supply.
28	Harrisburg–Halsey area	A	Irrigation.
29	Corvallis–Albany area	A	ditto
30	North Santiam area	A	ditto
31	French Prairie–Molalla area	A	ditto
32	Portland area	A	Irrigation, public supply.

[1] A, Unconsolidated-deposit aquifers; B, Pliocene and younger basaltic-rock aquifers; C, volcanic- and sedimentary-rock aquifers; and D, Miocene basaltic-rock aquifers.

Major withdrawal sites in Washington

Site number	Geographic area	Aquifers[1]	Principal uses
1	Clark County	A	Industrial.
2	Pierce County	A	Public supply.
3	King County	A	ditto
4	Okanogan County	A	Irrigation, industrial.
5	Spokane County	A	Public supply, irrigation.
6	Adams County	D	Irrigation.
7	Grant County	A, D	ditto
8	Yakima County	A, D	Industrial, public supply.
9	Franklin County	A, D	Irrigation, public supply.
10	Walla Walla County	A, D	ditto

[1] A, Unconsolidated-deposit aquifers; and D, Miocene basaltic-rock aquifers.

Major withdrawal sites in Idaho

Site number	Geographic area	Aquifers [1]	Principal uses
33	Idaho Panhandle	A	Public supply, irrigation.
34	Rathdrum Prairie	A	Public supply, industrial, rural domestic.
35	Moscow–Lewiston area	D	Industrial, public supply, irrigation.
36	Salmon River Basin	A	Public supply, irrigation.
37	Payette–Weiser River Valleys	A, D	ditto
38	Boise Valley	C	Irrigation, public supply, industrial, rural domestic.
39	Murphy area	C	Irrigation.
40	Mountain Home–Bruneau area	C	ditto
41	Camas Prairie	A	ditto
42	Big and Little Wood River Valleys	A	Irrigation, public supply.
43	Central Snake River Plain	B	Aquaculture, irrigation.
44	Cottonwood–Oakley Fan area	C	Irrigation.
45	Rupert–Burley area	B	ditto
46	Raft River Valley	A	ditto
47	American Falls–Blackfoot area	B	Irrigation, aquaculture.
48	Big and Little Lost River Valleys	A	Irrigation, public supply, industrial.
49	Mud Lake area	B	Irrigation.
50	Henrys Fork–Teton Valleys	A	Irrigation, public supply.
51	Upper Snake River Valley	B	ditto
52	Bear River Basin	A	ditto
53	Curlew Valley	A	Irrigation.

[1] A, Unconsolidated-deposit aquifers; B, Pliocene and younger basaltic-rock aquifers; C, volcanic- and sedimentary-rock aquifers; and D, Miocene basaltic-rock aquifers.

Most of the water is withdrawn at specific sites (**fig. 21**). Large-scale irrigation projects account for most of the withdrawals, but those for public supply also are important. The tables accompanying **figure 21** list the major withdrawal sites by name and aquifer and indicate the purpose for which the water is used.

UNCONSOLIDATED-DEPOSIT AQUIFERS

Unconsolidated-deposit aquifers (**fig. 22**), which consist primarily of sand and gravel, are the most productive and widespread aquifers in Idaho, Oregon, and Washington. These aquifers are prevalent along present and ancestral stream valleys and in lowlands that are associated with structural or erosional basins. These unconsolidated-deposit aquifers provide freshwater for most public-supply, domestic, commercial, and industrial purposes. They also are important sources of water for agricultural (primarily irrigation) purposes in many parts of Segment 7.

The unconsolidated deposits are mostly alluvial deposits, but in places, they consist of eolian, glacial, or volcanic deposits. Alluvial deposits consist primarily of well-sorted particles that range in size from clay to boulders. The finer particles—clay and silt—generally form confining units, whereas the coarser particles—primarily sand and gravel with some cobbles and boulders—form productive aquifers. Eolian deposits, or loess, consist chiefly of clay, silt, and fine sand. Although loess is well sorted, it does not form productive aquifers because it is fine grained, usually unsaturated, and commonly is only a veneer overlying other rocks. Glacial deposits consist chiefly of mixtures of particles that range in size from clay to boulders. These deposits can be either well sorted where they were deposited by glacial meltwater (glacial outwash) or unsorted where they were deposited at the margins of the ice (glacial till). Where these deposits are well sorted, they form productive aquifers. Volcanic deposits consist chiefly of ash and basaltic sand, particularly in southwestern Idaho and southeastern Oregon. These deposits, which commonly are interbedded with thin flows of basalt and welded tuff, generally have minimal permeability and do not form productive aquifers.

Typically, unconsolidated deposits along stream valleys consist chiefly of sand and gravel that form productive aquifers. The thickness of the deposits along present stream valleys commonly is less than 250 feet. Many of these aquifers are not shown in **figure 22** because of the scale of the map.

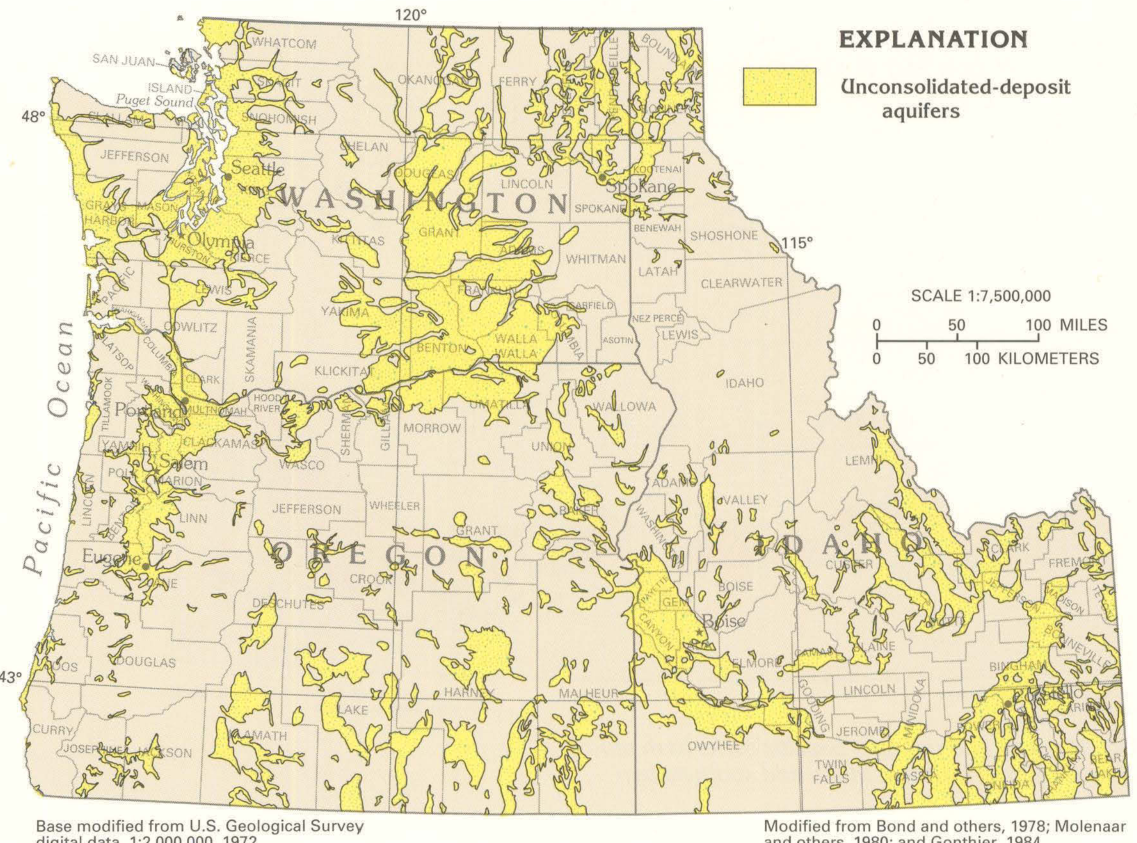


Figure 22. *Unconsolidated deposits of Holocene, Pleistocene, Pliocene, and Miocene age compose the most important and widely distributed aquifers in Segment 7.*

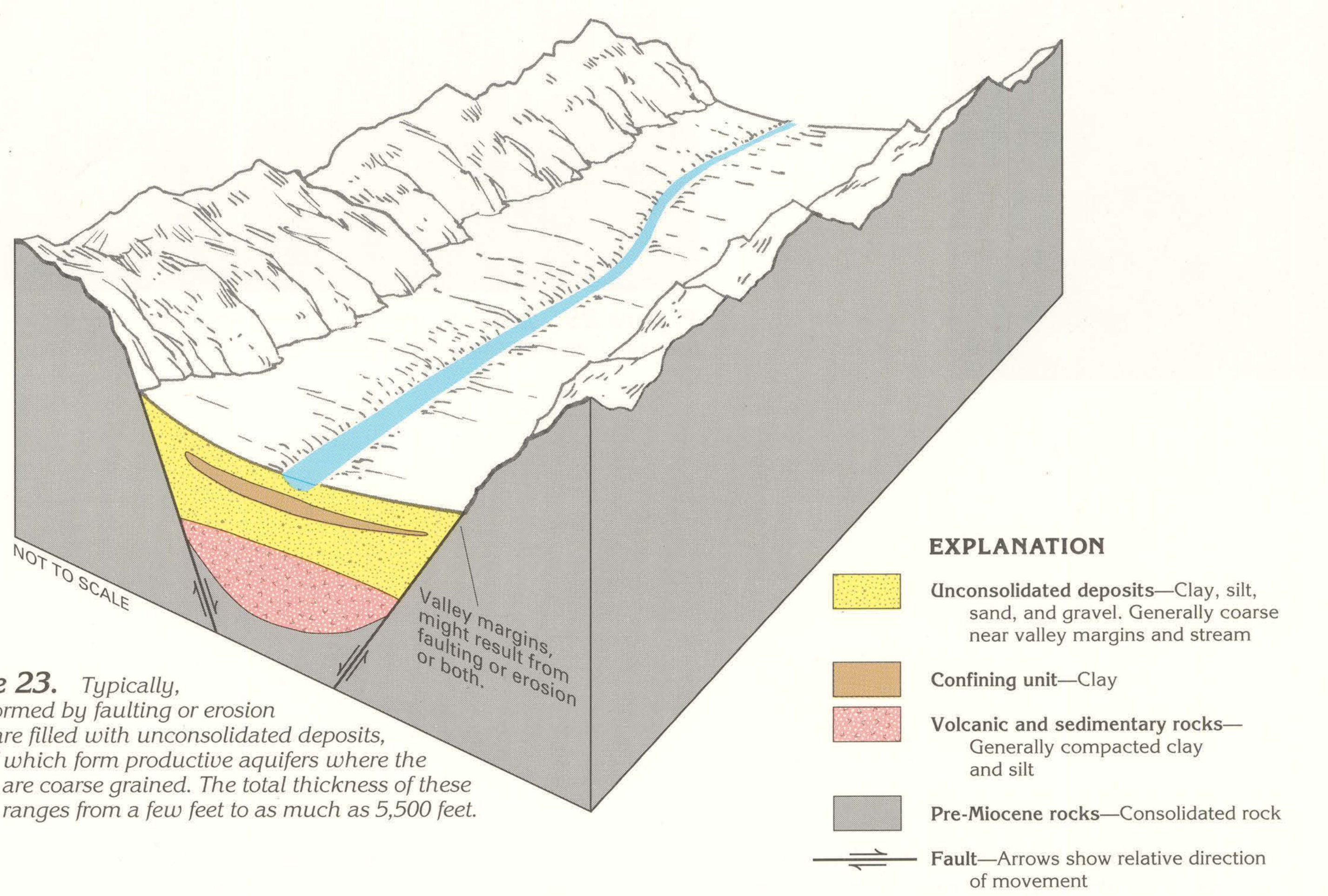


Figure 23. *Typically, basins formed by faulting or erosion or both are filled with unconsolidated deposits, many of which form productive aquifers where the deposits are coarse grained. The total thickness of these deposits ranges from a few feet to as much as 5,500 feet.*

Basins filled with unconsolidated deposits (**fig. 23**) were formed by faulting or erosion or both. Thick sequences of unconsolidated deposits that have variable permeability are common in these basins (**fig. 24**). In some basins, these deposits might be as much as 5,500 feet thick. Where thick sequences of these deposits are present, the uppermost 500 feet generally is the most permeable because the deposits are increasingly compacted with depth. The volume of water stored in the deposits and the permeability of the deposits depend primarily on the parent rock type. Basins in areas where the bedrock consists of volcanic, igneous, and metamorphic rocks typically contain extremely permeable aquifers that consist of coarse sand, gravel, and cobbles that were eroded from the parent rocks, whereas basins in areas where the bedrock consists of consolidated sedimentary rocks of marine origin, such as limestone, dolomite, and shale, typically contain much less permeable clay, silt, and fine sand that was eroded from the parent rocks. In both types of basins, the deposits typically are coarser grained near the margins of the basins and finer grained near the center of the basins.

Permeability of the unconsolidated deposits is variable; sand and gravel commonly yield from 20 to 2,000 gallons per minute to wells. Coarser deposits along major streams and deposits of glacial outwash yield from 500 to 2,500 gallons per minute to wells that penetrate from 50 to 150 feet of saturated deposits. Fine-grained deposits commonly yield from 1 to 100 gallons per minute depending on the percentage of clay. Unconsolidated deposits in closed basins in southeastern Oregon are typically fine grained and yield from 1 to 200 gallons per minute. Segmentwide, the specific capacity (the volume of water a well will yield per foot of drawdown in the well) of wells completed in unconsolidated deposits ranges from less than 5 to 1,000 gallons per minute per foot of drawdown. Public-supply wells completed in glacial outwash in Washington reportedly yield as much as 10,000 gallons per minute in the Puget Sound area and 19,000 gallons per minute in the Spokane Valley. The ability of this type of aquifer to yield water usually decreases with depth as the unconsolidated deposits become progressively finer grained and compacted. In some basins, however, the unconsolidated deposits might be underlain by volcanic rocks that are more permeable than the unconsolidated deposits.

The unconsolidated-deposit aquifers generally yield freshwater but locally yield saltwater, especially in south-central Oregon and in coastal areas. In south-central Oregon, the saltwater generally is the result of evaporation of surface and ground water in closed basins (**fig. 25**), which concentrates the dissolved constituents in the remaining water. In coastal areas, the saltwater is the result of induced movement of saltwater from the ocean or other saltwater bodies into the freshwater aquifers; this movement often is caused by large withdrawals from wells. Because saltwater is denser than freshwater, saltwater contamination is restricted to the basal part of the freshwater aquifers. Where such saltwater contamination has occurred, the adverse effects can be mitigated either by discontinuing withdrawals or by adjusting withdrawal depths or rates or both, so that, in effect, freshwater is "skimmed" from the top part of the aquifers.

Figure 24. *Thick, unconsolidated deposits of variable permeability are common in Segment 7. At this locality, extremely permeable sand and gravel underlie moderately permeable sand and clay and overlie minimally permeable clay (lakebeds).*

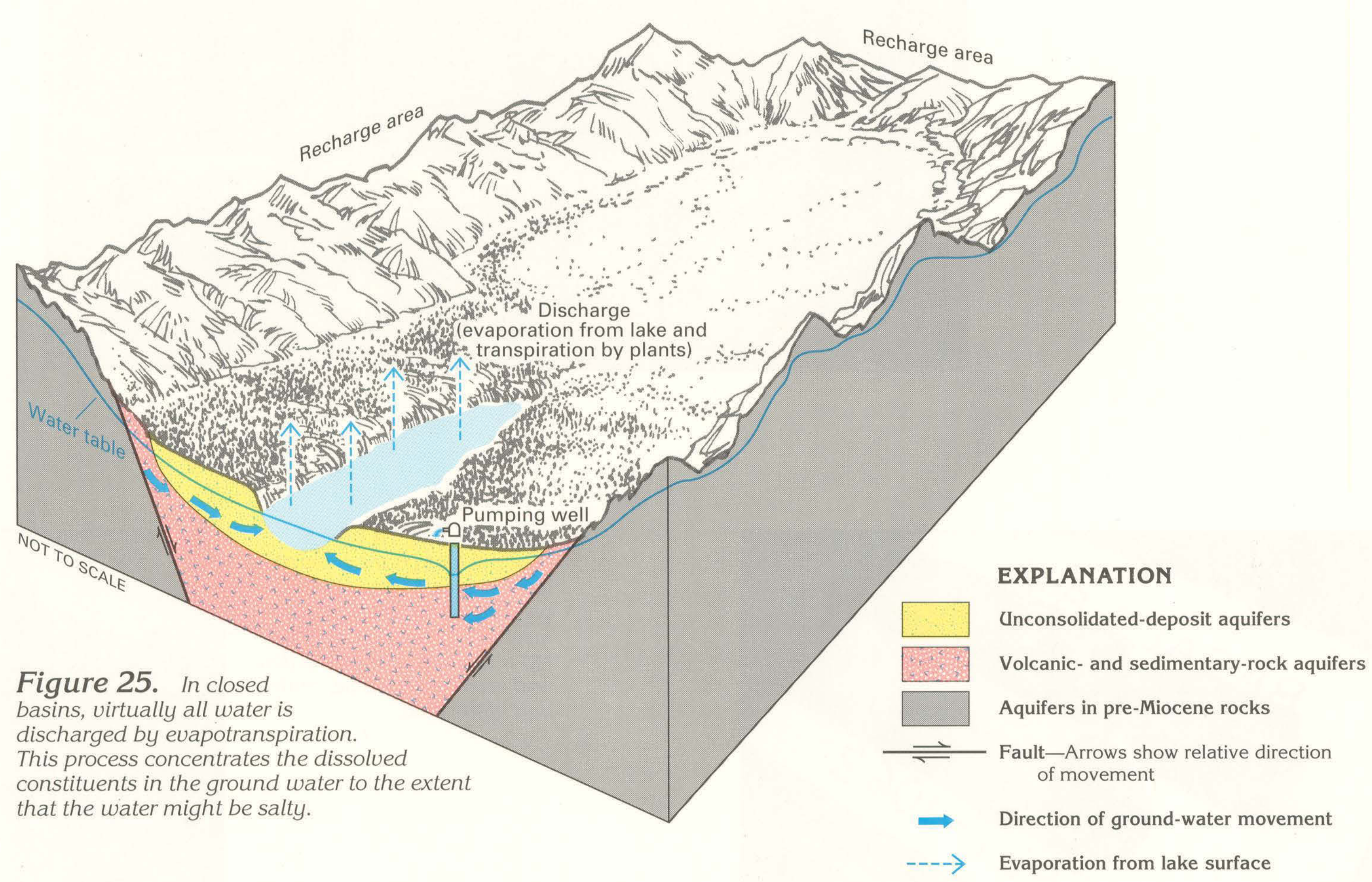


Figure 25. *In closed basins, virtually all water is discharged by evapotranspiration. This process concentrates the dissolved constituents in the ground water to the extent that the water might be salty.*

Pliocene and younger basaltic-rock aquifers

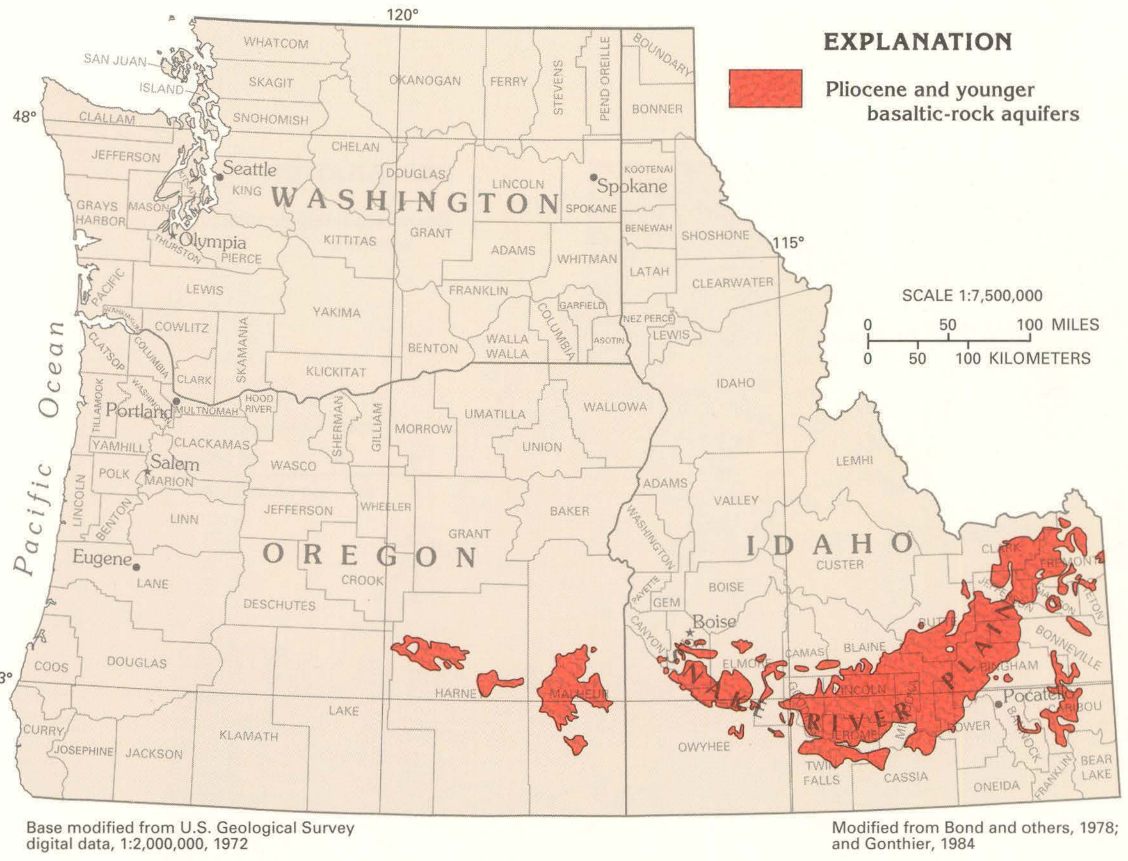


Figure 26. Pliocene and younger basaltic rocks form productive aquifers in parts of southern Idaho and southeastern Oregon.

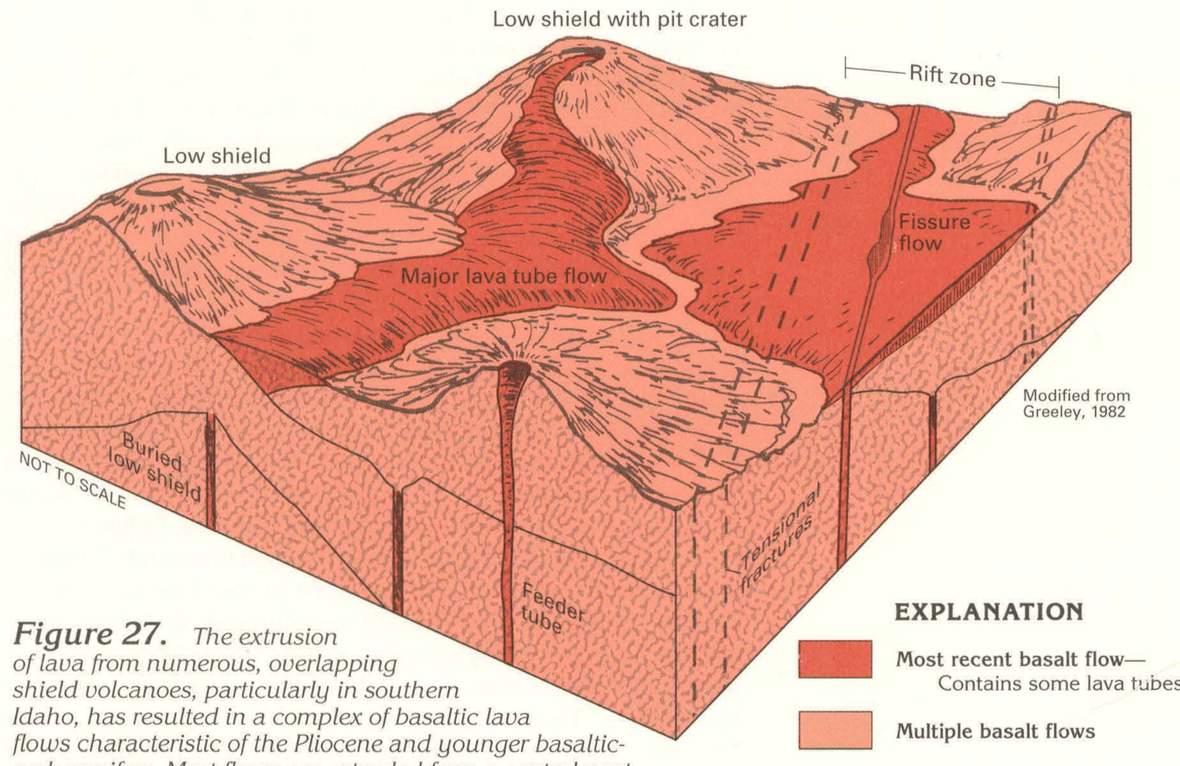


Figure 27. The extrusion of lava from numerous, overlapping shield volcanoes, particularly in southern Idaho, has resulted in a complex of basaltic lava flows characteristic of the Pliocene and younger basaltic-rock aquifers. Most flows are extruded from a central vent or fissure, and some are associated with large rift zones in the earth's crust.

PLIOCENE AND YOUNGER BASALTIC-ROCK AQUIFERS

Pliocene and younger basaltic-rock aquifers (**fig. 26**) consist primarily of thin, basaltic lava flows and beds of basaltic ash, cinders, and sand. The aquifers are most productive in the Snake River Plain of Idaho. These aquifers yield freshwater that is used mostly for agricultural (primarily irrigation) purposes.

Most of the Pliocene and younger basaltic rocks were extruded as lava flows from numerous vents and fissures concentrated along rift or major fault zones in the Snake River Plain. The lava flows spread for as much as about 50 miles from some vents and fissures. Overlapping shield volcanoes that formed around major vents extruded a complex of basaltic lava flows in some places (**fig. 27**). Thick soil, much of which is loess, covers the flows in many places. Where exposed at the land surface, the top of a flow typically is undulating and nearly barren of vegetation (**fig. 28**). The barrenness of such flows contrasts markedly with those covered by thick soil where agricultural development is intensive (**fig. 29**).

Figure 28. The undulating surface of the eastern Snake River Plain was formed primarily by basaltic lava flows that are, in many areas, mantled by wind-deposited soil that supports native grass and sagebrush. A shield volcano is shown on the horizon in the center of the photograph.

Figure 29. Barren basaltic lava flows contrast markedly with cultivated land developed in the thick soil that covers other flows.

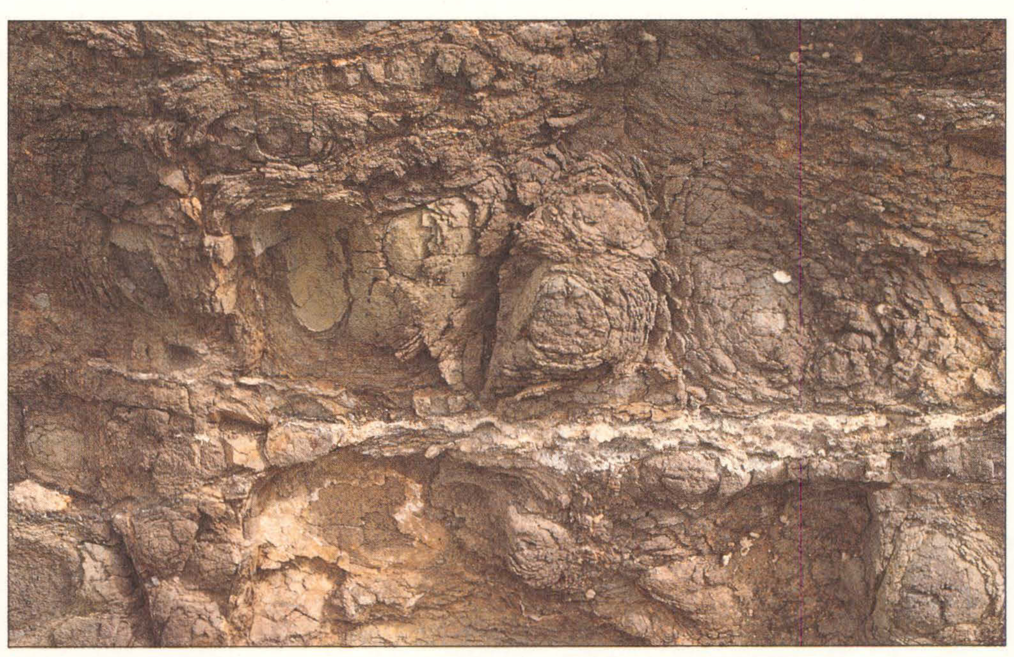


Figure 30. Pillow basalt formed when a basaltic lava flow entered water and cooled rapidly. As the ball-shaped pillows cooled and later were weathered, extensive interconnected open spaces developed in the flow.

The permeability of the Pliocene and younger basaltic rocks is dependent on several factors: (1) the cooling rate of the basaltic lava flows, (2) the thickness of the basaltic lava flows, and (3) the number and character of interflow zones (permeable zones at the tops and the bottoms of flows). The cooling rate was most rapid when flows entered water and formed pillow basalt (**fig. 30**). These flows have numerous interconnected open spaces at their tops and bottoms. Some of these flows have a fragmental texture similar to that of sand and gravel or of cobbles and boulders. Where flows did not enter water, cooling was slower, but the tops and the bottoms of the flows cooled much more rapidly than did their centers. Open spaces, such as vesicles (**fig. 31**), which are voids between rock fragments, and most importantly, fractures and joints between blocks of basalt, developed in the upper and lower zones of the flows (**fig. 32**) as the tops and the bottoms cooled while the centers continued to flow. In contrast, few open spaces developed in the centers of the flows where cooling was slowest (**figs. 31 and 32**). When entire flows cooled extremely slowly, few open spaces developed even in the upper and lower zones of the flows. These flows form dense zones within more permeable zones, and wells that penetrate these dense zones commonly yield little or no water (**fig. 33**).

The thickness of the individual flows is variable; the thickness of flows of Holocene and Pleistocene age averages about 25 feet, whereas that of Pliocene-age flows averages about 40 feet. The thinner the flows are, the greater the possibility for the transmission of some water through the centers of the flows and the greater the number of permeable interflow zones.

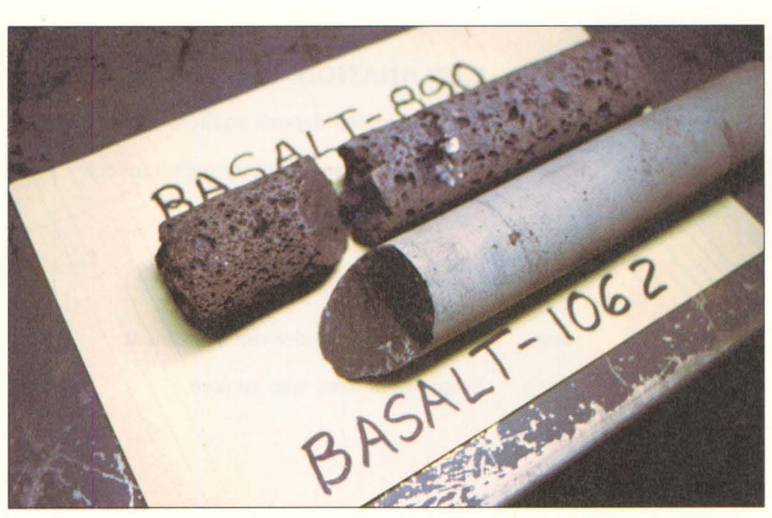
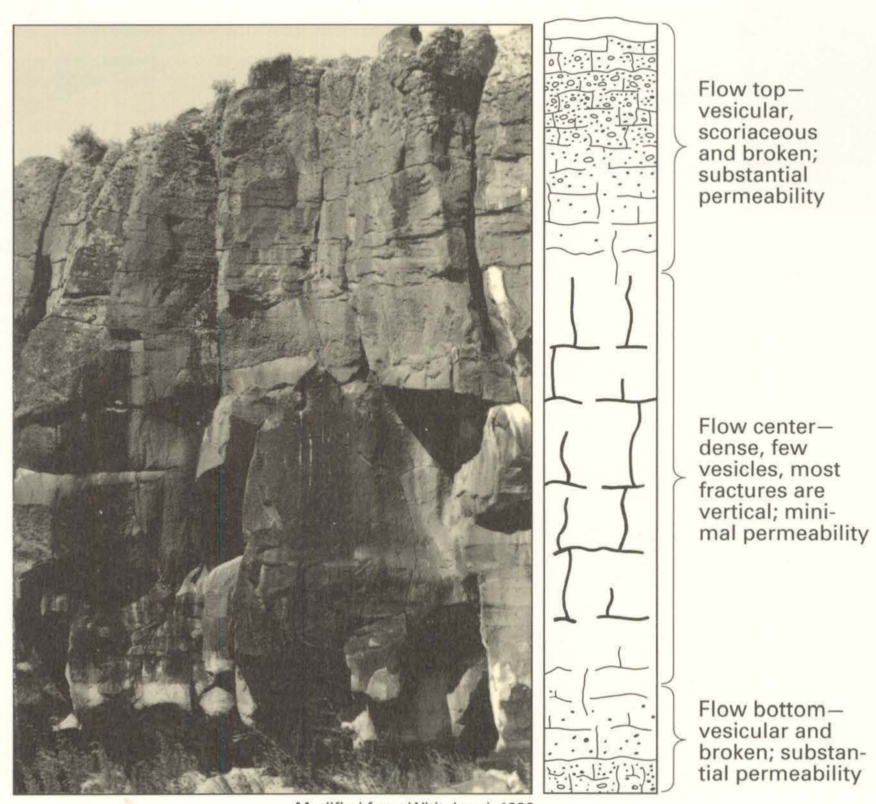


Figure 31. Core samples of basaltic rock from a test hole in Idaho show the differences between vesicular (top) and dense (bottom) basalt. The numbers are the depth below land surface, in feet, at which the core was collected.

Figure 32. A typical Pliocene and younger basaltic lava flow contains layers of varying permeability. Permeability is greatest near the top and the bottom of the flow and least in the dense, center part of the flow.



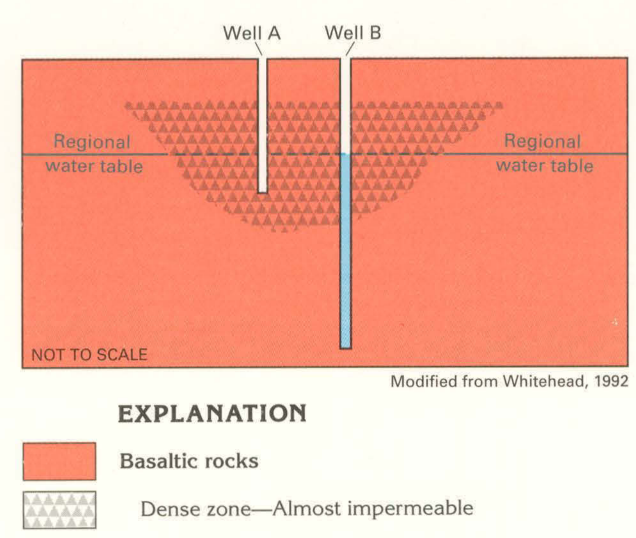


Figure 33. Dense zones of basalt might contain little or no water, even though deeper, less dense parts of the basalt, are saturated. Wells completed in dense zones (well A) will yield little or no water, even though they are completed below the regional water table shown by the dashed line. If a well is drilled deeper to penetrate saturated, permeable basalt (well B), then the water level in the well will rise to the level of the regional water table.

Figure 34. Layers of fine-grained, unconsolidated deposits between interflow zones form confining units that can create perched water-table conditions. The clay lakebed sediments shown here separate a fractured basalt from an overlying pillow basalt that cooled rapidly as it flowed into the lake.

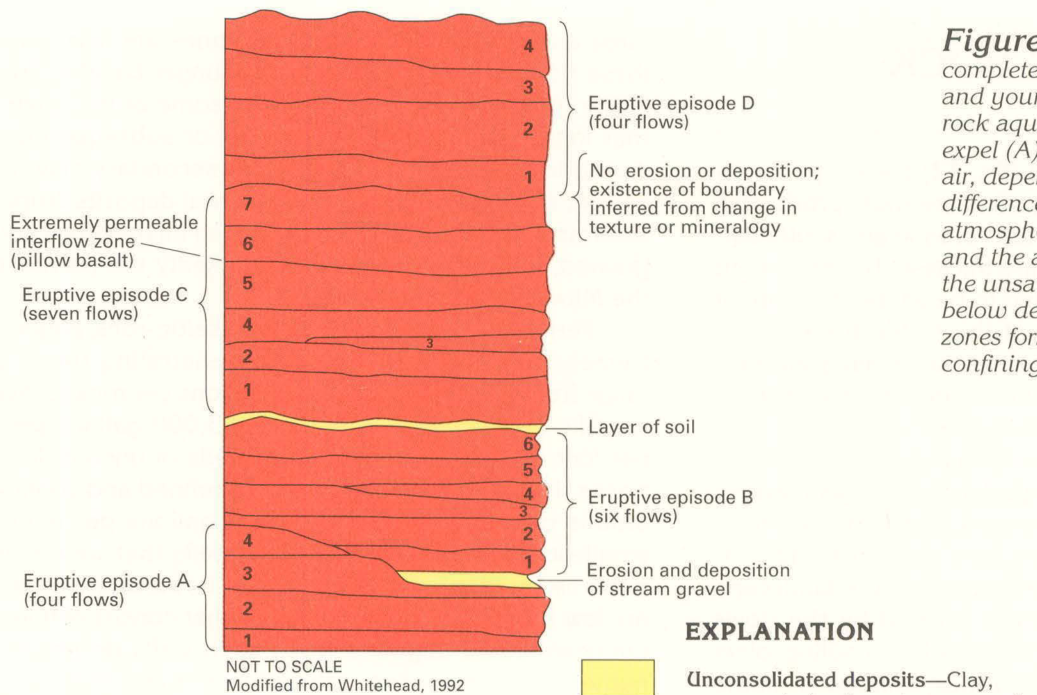
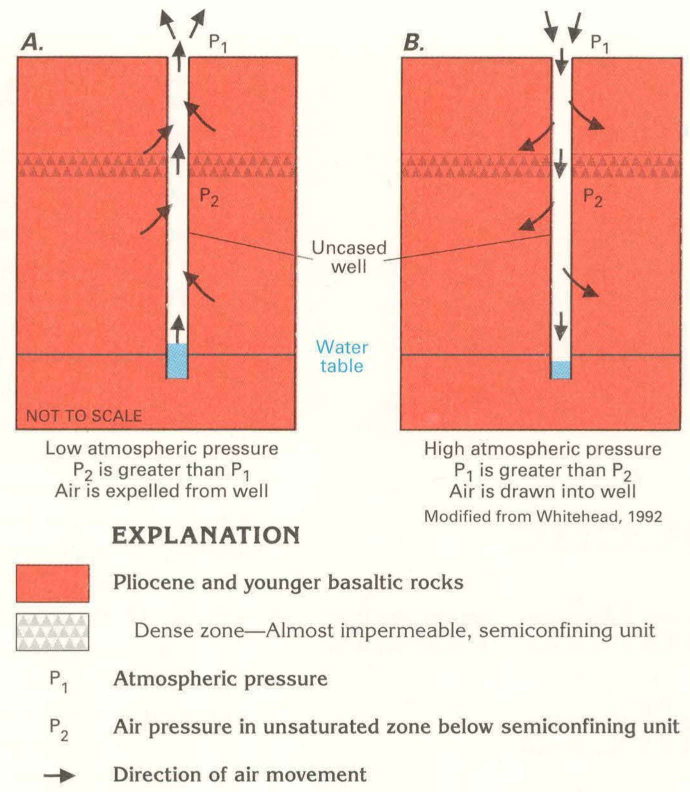


Figure 35. Sequences of thin basaltic lava flows provide multiple interflow zones that make these Pliocene and younger basaltic-rock aquifers extremely permeable.

Figure 36. Wells completed in Pliocene and younger basaltic-rock aquifers might expel (A) or draw in (B) air, depending on the difference between the atmospheric pressure and the air pressure in the unsaturated zone below dense basalt zones forming semiconfining units.



The interflow zones contain most of the interconnected open spaces in the basaltic rocks. In some places, the interflow zones are separated from each other by layers of unconsolidated deposits (**fig. 34**) that were emplaced during the time between flows or between eruptive episodes. Where the unconsolidated deposits are fine grained (soil or lakebed sediments), the deposits form confining units and can create perched water-table conditions. Where the unconsolidated deposits are coarse grained (stream gravel), the deposits enhance the permeability of the adjacent interflow zones.

The permeability of the Pliocene and younger basaltic rocks is greatest in areas that have sequences of flows that cooled rapidly, are thin, have numerous interflow zones, and have few interbedded layers of fine-grained unconsolidated deposits. Such an ideal sequence is shown in **figure 35**; this idealized sequence represents four eruptive episodes labeled A (oldest) through D (youngest). During each eruptive episode, as many as seven flows were extruded. After four flows were extruded during eruptive episode A, parts of flows 3 and 4 were eroded, and stream gravel was subsequently deposited on part of flow 3. This stream gravel forms a zone of substantial permeability. This gravel was subsequently covered by flow 1 of episode B. At the end of eruptive episode B, volcanic activity ceased long enough to allow soil to develop on flow 6. This soil forms a confining zone of minimal permeability. During episode C, flow 6 was extruded into water-forming pillow basalt; the resulting interflow zone between flows 5 and 6 is extremely permeable. In contrast to the zones between flows of episodes A and B or B and C, there is no evidence of either erosion and deposition or soil formation during the time between the extrusion of the last flow (flow 7) of episode C and the first flow (flow 1) of episode D; these episodes can be distinguished only by subtle textural or mineralogical changes in the respective flows.

The water level in some wells completed in Pliocene and younger basaltic-rock aquifers is affected by changes in atmospheric pressure where the overlying unsaturated zone in the Pliocene and younger basaltic rocks contains zones of dense basalt that function as semiconfining units (**fig. 36**). When the atmospheric pressure is less than the air pressure in the unsaturated zone below the semiconfining units, the water level in the wells will rise, and air might be expelled (**fig. 36**). Conversely, when the atmospheric pressure is greater than the air pressure in the unsaturated zone below the semiconfining units, the water level in the wells will decline, and air might be drawn in. Water levels in such wells might fluctuate several tenths of a foot in response to changes in atmospheric pressure (**fig. 37**). The exchange of air continues until equilibrium is reached between the atmospheric pressure and the air pressure in the unsaturated zone below the semiconfining units. If a person is standing adjacent to a well during a period of large differential, the force of the air being expelled or drawn in could be great enough to blow off the person's hat.

Wells completed in Pliocene and younger basaltic-rock aquifers commonly have specific-capacity values that range from 500 to 1,000 gallons per minute per foot of drawdown. In the Snake River Plain of Idaho, the transmissivity of these aquifers, which was estimated from aquifer tests and digital simulation of the upper 200 feet of the aquifers, ranges from about 100,000 to about 1 million feet squared per day. The estimated transmissivity for the entire thickness (about 4,000 feet) of these aquifers commonly ranges from about 10,000 to about 2,400,000 feet squared per day; the maximum estimated transmissivity is about 4 million feet squared per day.

Near the margins of their outcrop area, the Pliocene and younger basaltic-rock aquifers are underlain by unconsolidated-deposit, volcanic- and sedimentary-rock, and Miocene basaltic-rock aquifers and aquifers in pre-Miocene rocks. Most of the underlying aquifers are much less permeable than the Pliocene and younger basaltic-rock aquifers. The types of rocks or aquifers underlying the Pliocene and younger basaltic-rock aquifers in the central part of their outcrop area are unknown.

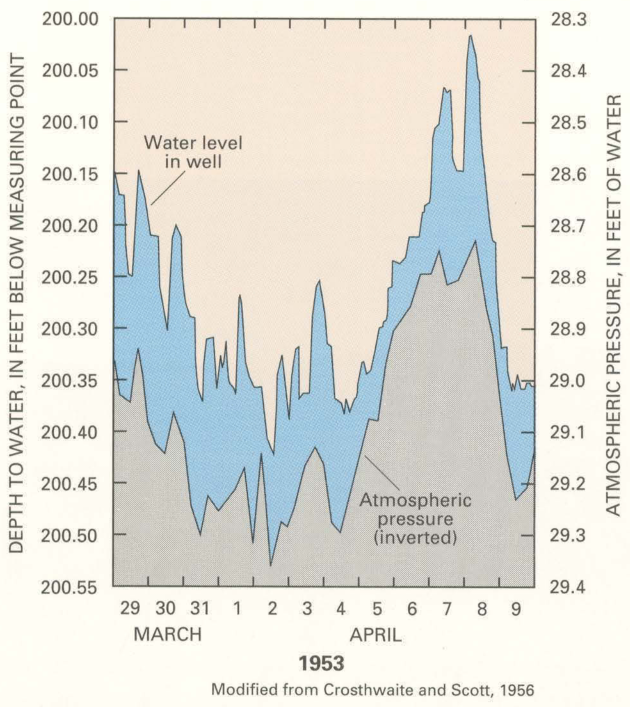


Figure 37. Atmospheric pressure changes inversely affect water levels in wells. Low pressure causes water levels to rise as much as several tenths of a foot. High pressure causes water levels to decline a similar distance.

VOLCANIC- AND SEDIMENTARY-ROCK AQUIFERS

Volcanic- and sedimentary-rock aquifers (**fig. 38**) consist of a variety of volcanic and sedimentary rocks. These aquifers are not as productive as the unconsolidated-deposit, Pliocene and younger basaltic-rock, or Miocene basaltic-rock aquifers. Volcanic- and sedimentary-rock aquifers generally yield freshwater but locally yield saltwater. About 30 percent of the fresh ground-water withdrawals are used for public-supply, about 20 percent are used for domestic and commercial, and about 50 percent are used for agricultural (primarily irrigation) purposes.

The volcanic rocks that compose the aquifers consist primarily of Pliocene and younger basaltic rocks on the eastern side of the Cascade Range in Oregon and Washington and silicic volcanic rocks in southern Idaho and southeastern Oregon; unconsolidated volcanic deposits included in the aquifers are ash and cinders. The sedimentary rocks that compose the aquifers consist primarily of semiconsolidated sand and gravel eroded mostly from volcanic rocks. In some places, the aquifers might consist of a single rock type; in other places, the aquifers might consist of several interbedded rock types.

The permeability of the various rocks that compose the aquifers is extremely variable. Interflow zones and faults in basaltic lava flows; fractures in tuffaceous, welded silicic volcanic rocks (**figs. 39 and 40**); and interstices in coarse ash, sand, and gravel mostly yield less than 100 gallons per minute of water to wells. Rarely, wells will yield several thousand gallons per minute. Where major faults are present, the rocks commonly contain geothermal water under confined conditions.

Silicic volcanic rocks in northeastern Idaho are extremely permeable in places, as indicated by the large springs that issue from these rocks (**fig. 41**). Specific-capacity values of wells completed in these rocks range from 1 to 2,000 gallons per minute per foot of drawdown but commonly are less than 400 gallons per minute per foot of drawdown. The known thickness of these rocks is about 3,000 feet.

The hydrogeologic characteristics of the volcanic- and sedimentary-rock aquifers are largely unknown in many places because they are in remote areas where the demand for ground water is small. Also, the subsurface extent of these aquifers is largely unknown because of limited outcrop areas where they are shown overlying older rocks or because they are too deep for wells to reach economically. However, in some areas, deep wells (500 to 2,000 feet) drilled chiefly for geothermal water, such as in Boise, Idaho, and in places along the southern margin of the Snake River Plain in southwestern Idaho, have penetrated these aquifers.

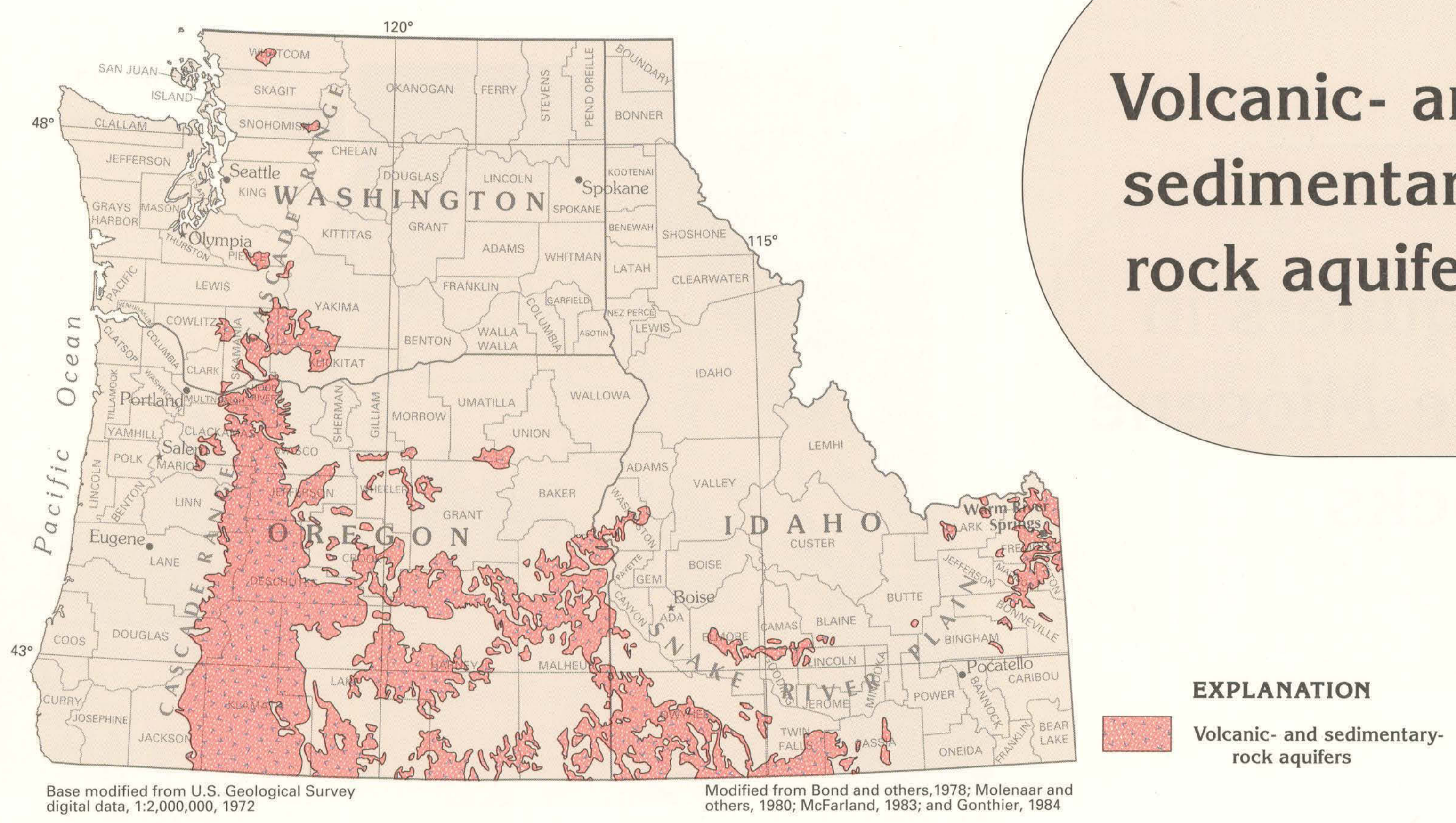


Figure 38. A variety of volcanic and sedimentary rocks of Holocene, Pleistocene, Pliocene, and Miocene age form productive aquifers in parts of southern Idaho, central and southeastern Oregon, and central Washington.

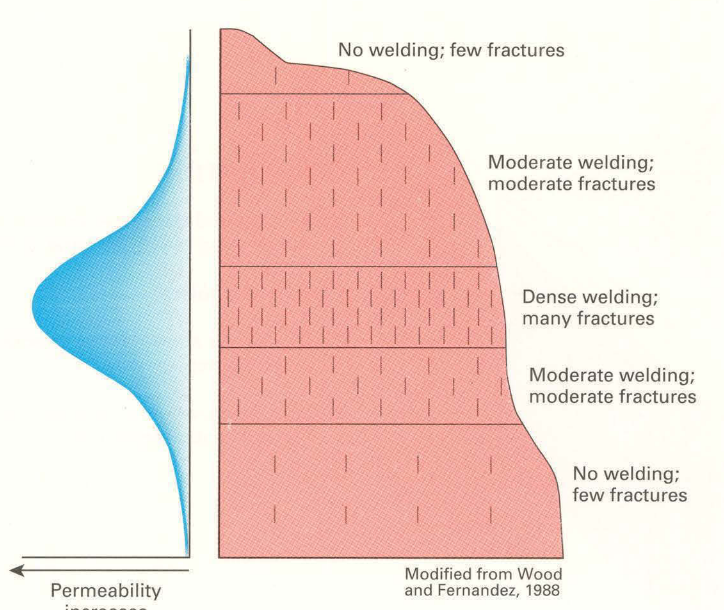
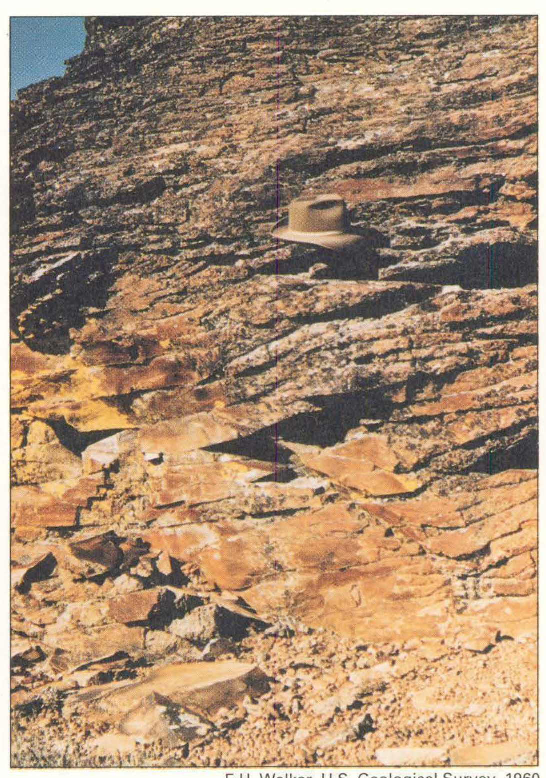


Figure 39. The density of fractures determines the permeability in tuffaceous silicic volcanic rocks that form many of the volcanic- and sedimentary-rock aquifers.



E.H. Walker, U.S. Geological Survey, 1960

Figure 40. Fractures in some silicic volcanic rocks provide conduits for water movement.

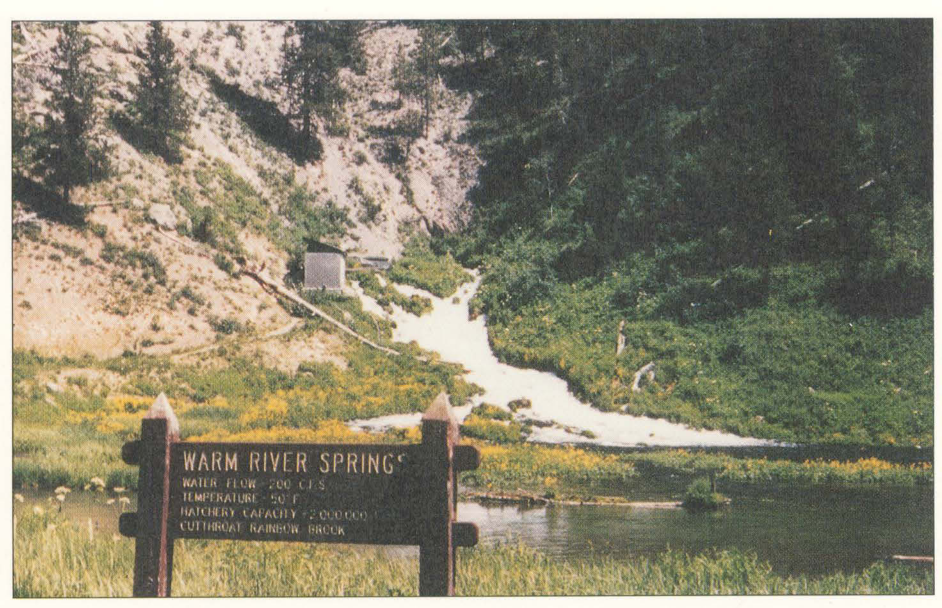


Figure 41. Some silicic volcanic rocks are extremely permeable, as indicated by the large springs that issue from the rocks.

Miocene basaltic-rock aquifers

MIOCENE BASALTIC-ROCK AQUIFERS

Miocene basaltic-rock aquifers (**fig. 42**) consist primarily of thick basaltic lava flows. The aquifers are most productive in the Columbia Plateau of northeastern Oregon and southeastern Washington where the aquifers are thickest. The maximum thickness of the aquifers is estimated to be as much as about 15,000 feet in the southern part of the Columbia Plateau. These aquifers generally yield freshwater but locally yield saltwater. Most of the fresh ground-water withdrawals are used for agricultural (primarily irrigation) purposes.

Miocene basaltic-rock aquifers consist primarily of flood-type basaltic lava flows that were extruded from major fissures; some flows extend along former lowlands for about 100 miles. Many of the flows have been folded into anticlines and synclines. Where these folded flows are exposed, the landscape is characterized by prominent ridges formed by the flows (**fig. 43**). Structural features in the flows include cooling joints (entablature and colonnade), rubble zones, and faults. Some of these structural features are shown in **figure 44**. Many structural features in these flows are similar to structural features in flows that compose most of the Pliocene and younger basaltic-rock aquifers. Open spaces along cooling joints and fractures and in rubble and interflow zones are less common in these flows than in Pliocene and younger basaltic lava flows. In the Miocene basaltic lava flows, some of the open spaces that initially formed during cooling or subsequently formed during folding have been filled with secondary clay minerals, calcite, silica, or unconsolidated alluvial deposits emplaced by streams or in lakes. Except where such fill materials are coarse grained, they tend to decrease markedly the permeability of the Miocene basaltic-rock aquifers.

Permeability of the Miocene basaltic-rock aquifers is extremely variable. Yields of wells penetrating these aquifers range from 1 to several thousand gallons per minute. Maximum specific-capacity values are about 3,000 gallons per minute per foot of drawdown. Some interbeds of unconsolidated deposits that contain water under unconfined and confined conditions can yield as much as 100 gallons per minute. The smallest yields are obtained from wells that were completed either in the dense, central parts of flows where open spaces are few (**fig. 45**) or in the interbeds that consist of fine-grained unconsolidated deposits when such wells do not penetrate numerous open spaces in the interval above their completion depth. The largest yields are obtained from wells that penetrate numerous open spaces. Generally, the more water-contributing interflow zones that are penetrated by a well, the greater the well yield that can be obtained.

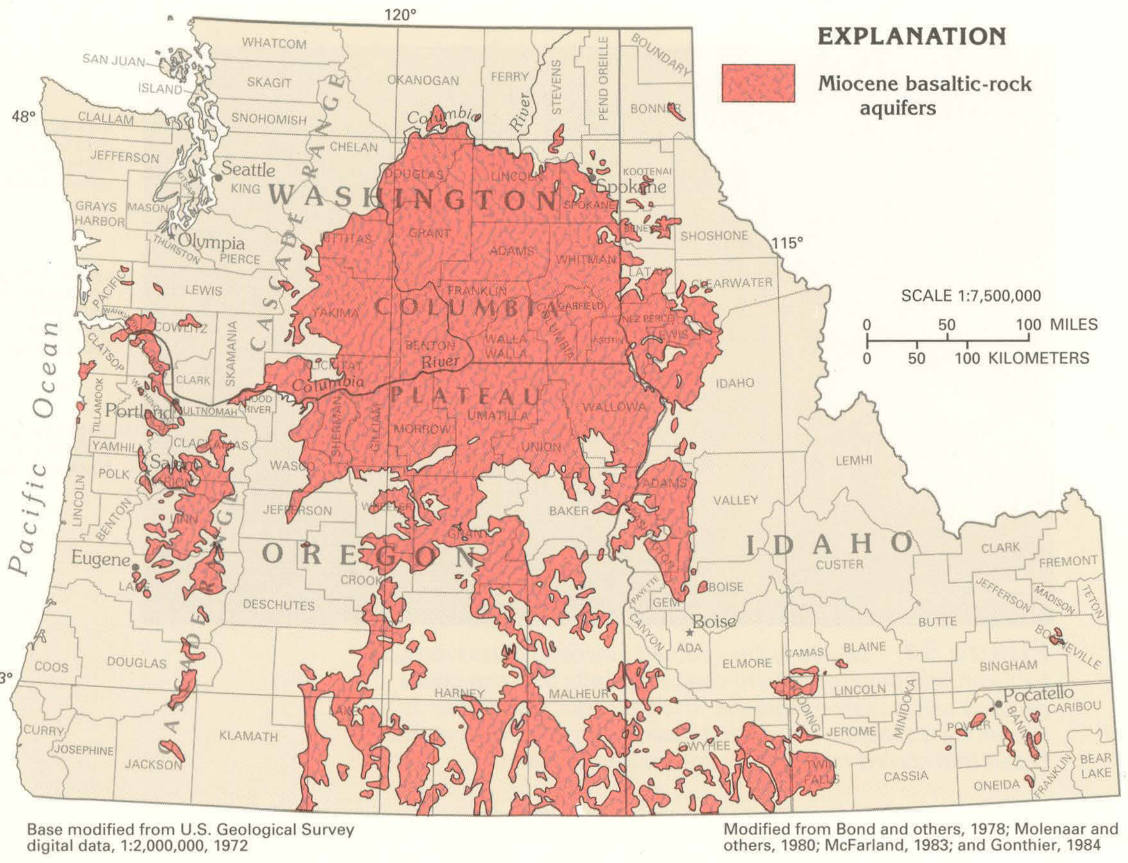


Figure 42. Miocene basaltic rocks form productive aquifers in parts of west-central and southern Idaho, eastern Oregon, southeastern Washington, and along the southern Cascade Range in Oregon and Washington. These rocks underlie Pliocene and younger rocks in much of the intervening areas between outcrops.

Figure 43. Miocene basaltic rocks form prominent ridges where the rocks have been extruded as thick flows along the Columbia River.

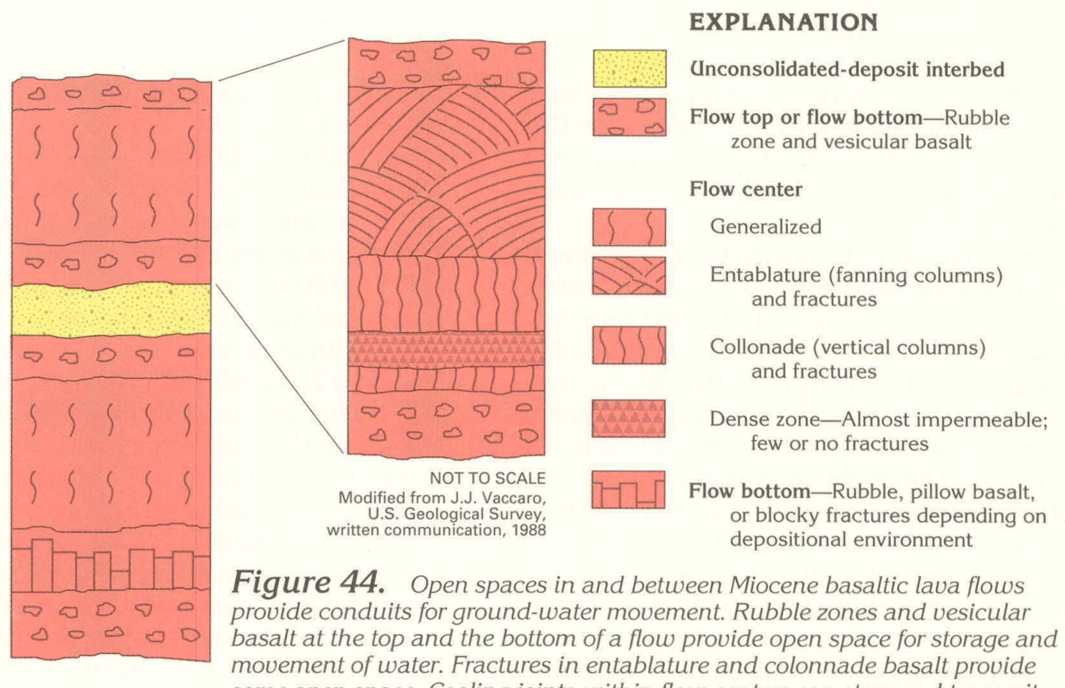


Figure 44. Open spaces in and between Miocene basaltic lava flows provide conduits for ground-water movement. Rubble zones and vesicular basalt at the top and the bottom of a flow provide open space for storage and movement of water. Fractures in entablature and colonnade basalt provide some open space. Cooling joints within flow centers can store and transmit water if they are connected to more permeable zones. The sediment interbed is permeable if coarse grained but can be a confining unit if fine grained.

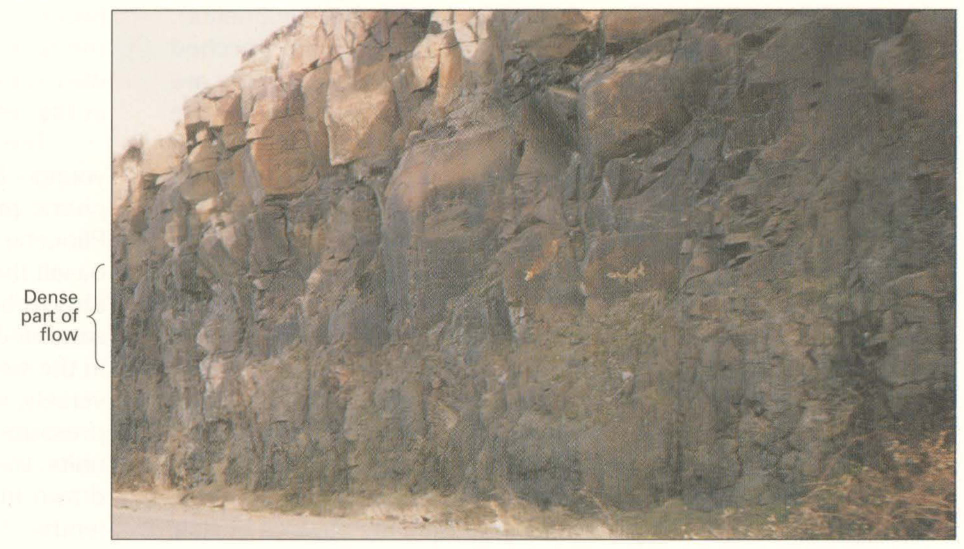


Figure 45. The central part of Miocene basaltic lava flows might be dense and contain few or no large open spaces. Yields of wells completed in dense basalt will be extremely small.

Aquifers in pre-Miocene rocks

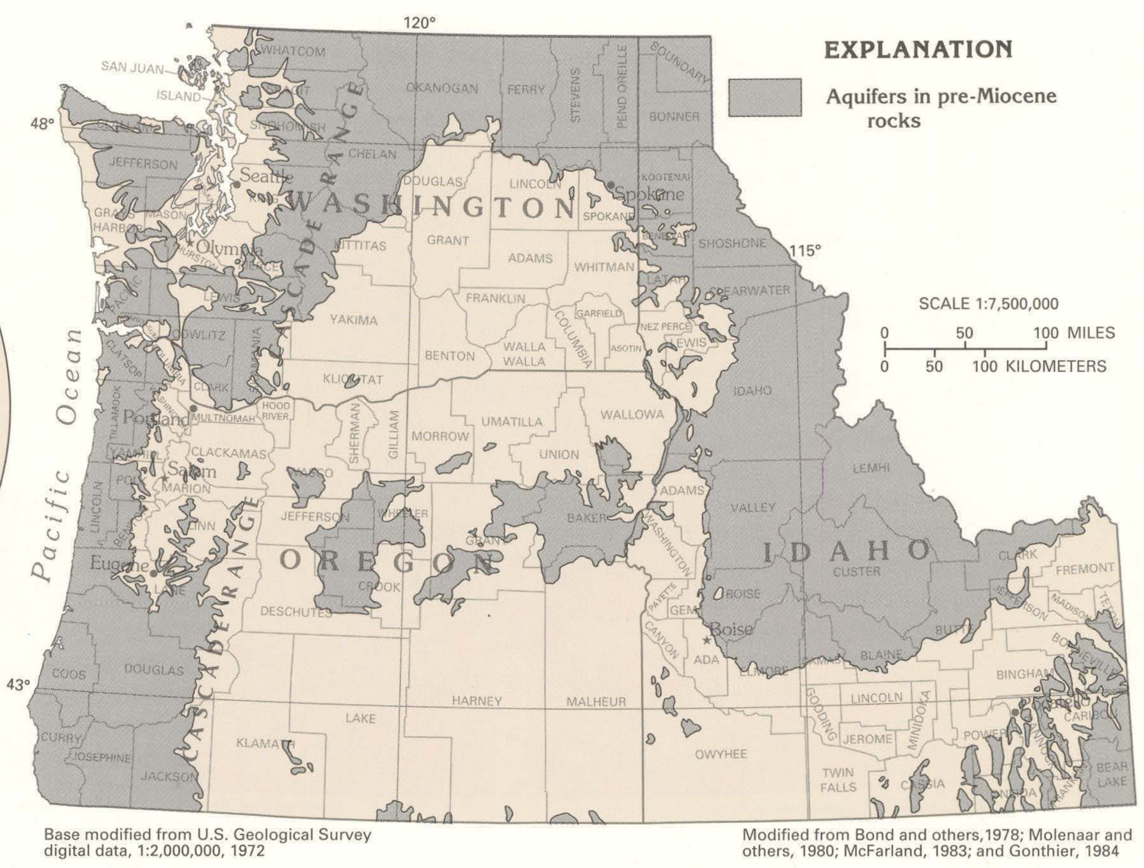


Figure 46. Aquifers in pre-Miocene rocks underlie extensive areas in Idaho, Oregon, and Washington, particularly in mountainous areas.

AQUIFERS IN PRE-MIOCENE ROCKS

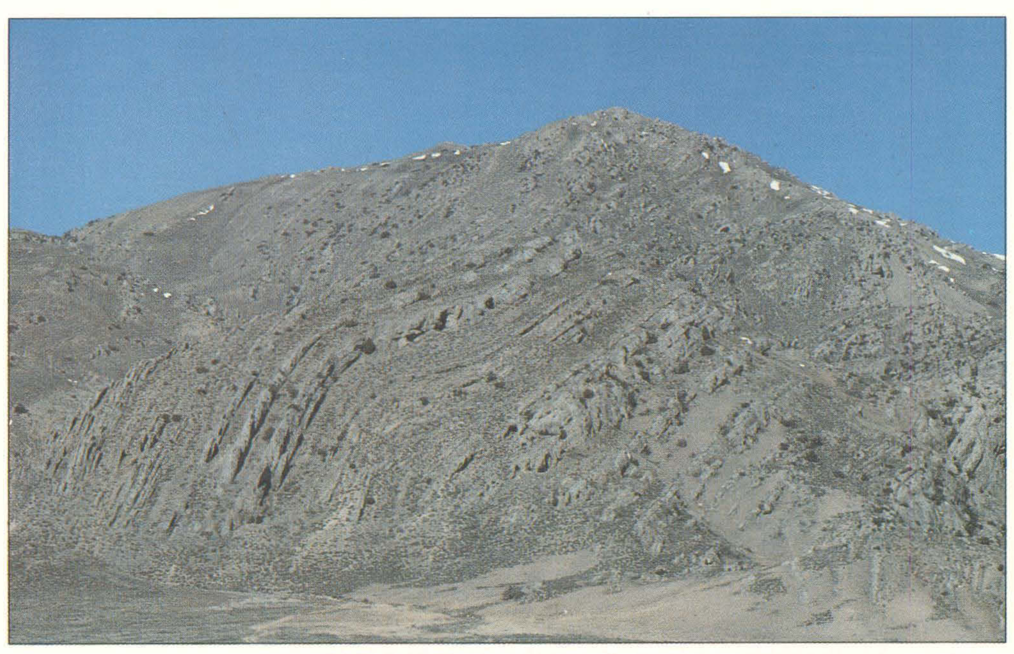
Aquifers in pre-Miocene rocks (**fig. 46**) consist of undifferentiated volcanic rocks, undifferentiated consolidated sedimentary rocks, and undifferentiated igneous and metamorphic rocks that are distributed throughout Segment 7, principally in the mountainous areas. In some places, the thickness of the volcanic rocks might be as much as about 5,000 feet and that of the consolidated sedimentary rocks might be as much as about 15,000 feet. The thickness of the igneous and metamorphic rocks is unknown. East of the Cascade Range, the aquifers in pre-Miocene rocks generally yield freshwater but locally yield saltwater. Within the Cascade Range and west of it, these aquifers commonly yield saltwater. Fresh ground-water withdrawals are used mostly for domestic and commercial purposes.

In the volcanic rocks, water is present primarily in joints and fractures as in the Pliocene and younger and the Miocene basaltic-rock aquifers. In the consolidated sedimentary rocks, water is present primarily in solution cavities and joints in carbonate rocks (**fig. 47**) and in fractures, faults, and intergranular pore spaces in clastic rocks, such as sandstone and conglomerate. In igneous and metamorphic rocks, water is present primarily in fractures, faults, and weathered zones that developed on exposed surfaces (**fig. 48**). The aquifers in all rock types generally yield only from 1 to 100 gallons per minute of water to wells. In all rock types, but especially in igneous and metamorphic rocks, yields of wells tend to decrease as depth increases and open spaces become fewer, smaller, or are filled with secondary minerals; for example, there generally are few open spaces in igneous and metamorphic rocks below a depth of about 300 to 400 feet.

In places, particularly in western Oregon and in Washington west of the Cascade Range, the consolidated sedimentary rocks are of marine origin. At depth, these rocks contain saltwater that can contaminate overlying freshwater aquifers. Locally, the saltwater can move upward through open spaces, particularly faults, and either mix with the freshwater in overlying aquifers or discharge to the land surface as springs. Such discharge can adversely affect the quality of water in the surficial aquifers that contain freshwater.

Saltwater contamination of freshwater aquifers also can occur in coastal areas if withdrawals from wells are sufficiently large to induce saltwater movement from the ocean or other saltwater bodies into the freshwater aquifers. Because saltwater is denser than freshwater, saltwater contamination generally is restricted to the basal part of the freshwater aquifers.

Figure 47. In outcrops, some carbonate rocks are folded and contorted; where present, solution cavities and fractures provide conduits for water movement.



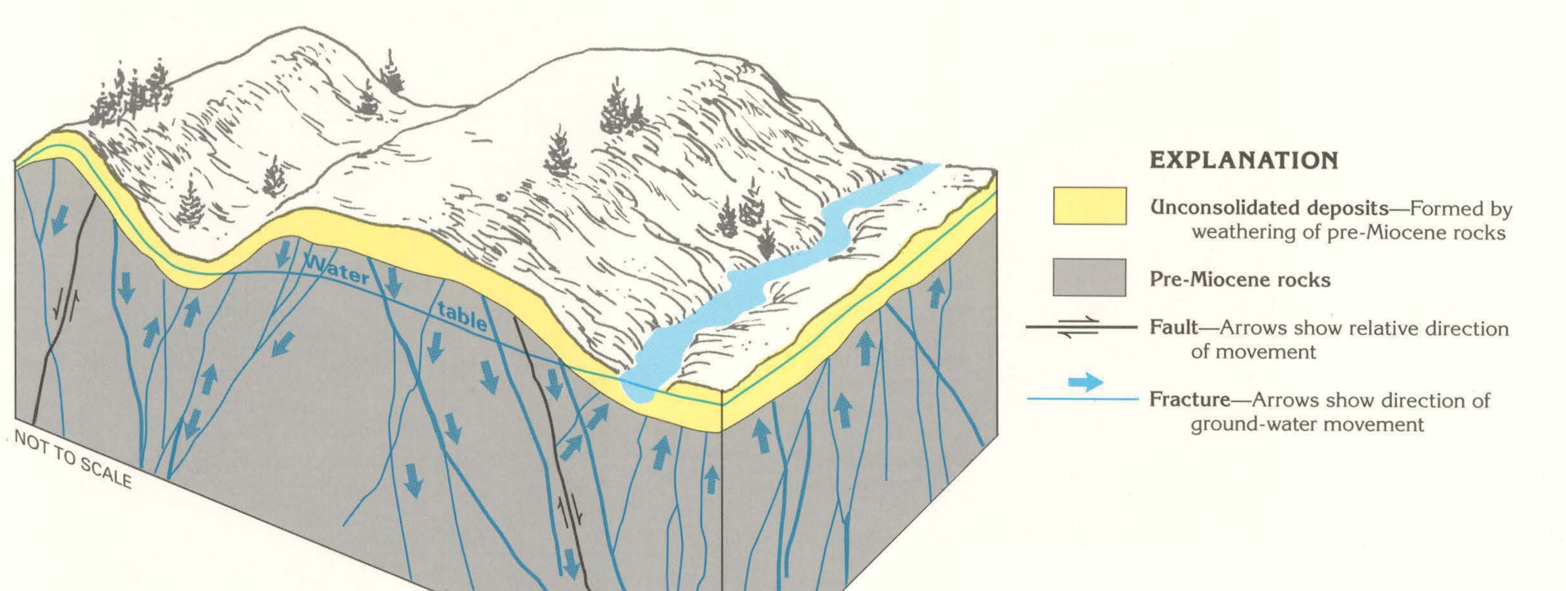


Figure 48. Fractures and faults in igneous and metamorphic rocks provide conduits for water movement.

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GREAT BASIN REGIONAL AQUIFER SYSTEM

Only small parts of the Great Basin regional aquifer system are present in southeastern Idaho and southeastern Oregon (**fig. 49**). In southeastern Idaho, the aquifer system consists primarily of unconsolidated-deposit aquifers (chiefly sand and gravel) that overlie volcanic- and sedimentary-rock aquifers (chiefly Pliocene and younger basaltic rocks) in basins, and aquifers in pre-Miocene rocks (chiefly carbonate rocks) that form mountain ranges between the basins (**figs. 50 and 51**); locally, Pliocene and younger and Miocene basaltic-rock aquifers are present along or near the northern margins of the aquifer system (**fig. 51**). Generally, there is an areally extensive confining unit between the unconsolidated-deposit aquifers and the underlying volcanic- and sedimentary-rock aquifers (**fig. 50**); local confining units are present in all the deposits and the rocks. In southeastern Oregon, the aquifer system consists primarily of volcanic- and sedimentary-rock and Miocene basaltic-rock aquifers; unconsolidated-deposit aquifers are present along the eastern margin of the easternmost area. Little is known about the aquifer system in the two areas of southeastern Oregon because these areas are sparsely populated, and ground-water use is minimal. For these reasons, subsequent discussions of the Great Basin regional aquifer system pertain primarily to southeastern Idaho, where development of the aquifer system for freshwater supplies has been extensive. In this report, aquifers that are present in unconsolidated deposits and in Pliocene and younger basaltic rocks in Bear Lake and Caribou Counties in Idaho are hydrologically similar to and are discussed with aquifers of the Great Basin regional aquifer system (**fig. 51**).

Recharge to the aquifer system is from precipitation, primarily snow falling on the mountain ranges. Snowmelt flows down the steep mountain fronts, and much of it either infiltrates unconsolidated deposits that form alluvial fans adjacent to many mountain fronts (**fig. 50**) or moves as overland runoff to small streams tributary to the principal stream that is present in each basin. Some snowmelt infiltrates Pliocene and younger basaltic-rock aquifers that are most common in Caribou County, Idaho, and some snowmelt infiltrates aquifers in the pre-Miocene rocks that form the mountain ranges. Tributary streams typically lose much of their flow by infiltration into the alluvial fans as the streams cross mountain-front slopes. Alternating fine- and coarse-grained layers in the alluvial fans result in perched water conditions in many places (**fig. 50**).

Water movement in the unconsolidated-deposit aquifers is primarily toward the principal stream flowing through each basin and toward wells completed in the aquifers (**fig. 50**); water movement in the Pliocene and younger basaltic-rock aquifers is similar to that in the unconsolidated-deposit aquifers. Because confined conditions are common in both types of aquifers, wells completed in the aquifers commonly flow at the land surface. Some water in the unconsolidated-deposit aquifers moves downward through confining units into the underlying volcanic- and sedimentary-rock aquifers (**fig. 50**). Water movement in the volcanic- and sedimentary-rock aquifers is primarily toward wells completed in the aquifers. Because of the confined conditions in these aquifers, the wells typically flow at the land surface. Virtually all water movement in aquifers in pre-Miocene rocks is toward the basins. Some of this water is discharged by large springs and sustains the flow in tributary streams.

Discharge from the aquifer system is primarily by evapotranspiration, inflow to streams, spring flow, and withdrawals from wells. Well yields range from about 1 to about 3,400 gallons per minute. Most wells are completed in either the unconsolidated-deposit or the Pliocene and younger basaltic-rock aquifers.

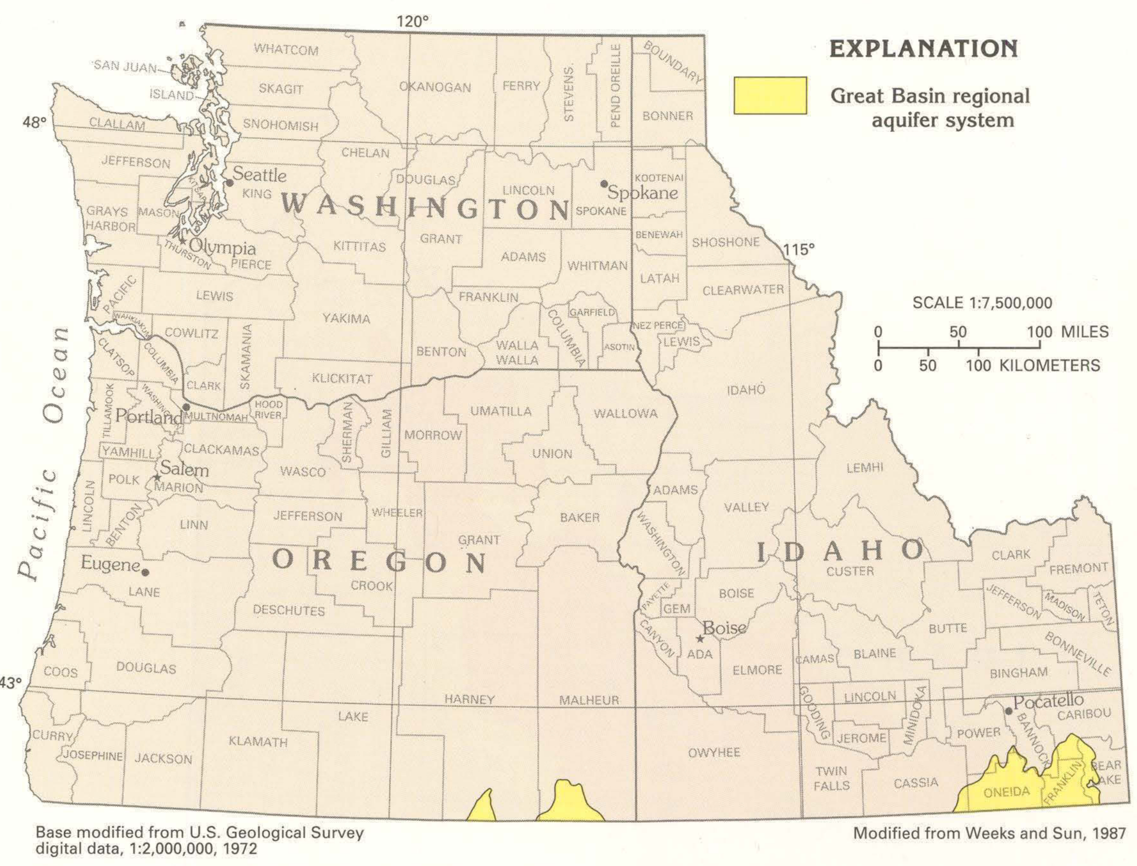


Figure 49. *The Great Basin regional aquifer system occupies only small areas in southeastern Idaho and southeastern Oregon.*

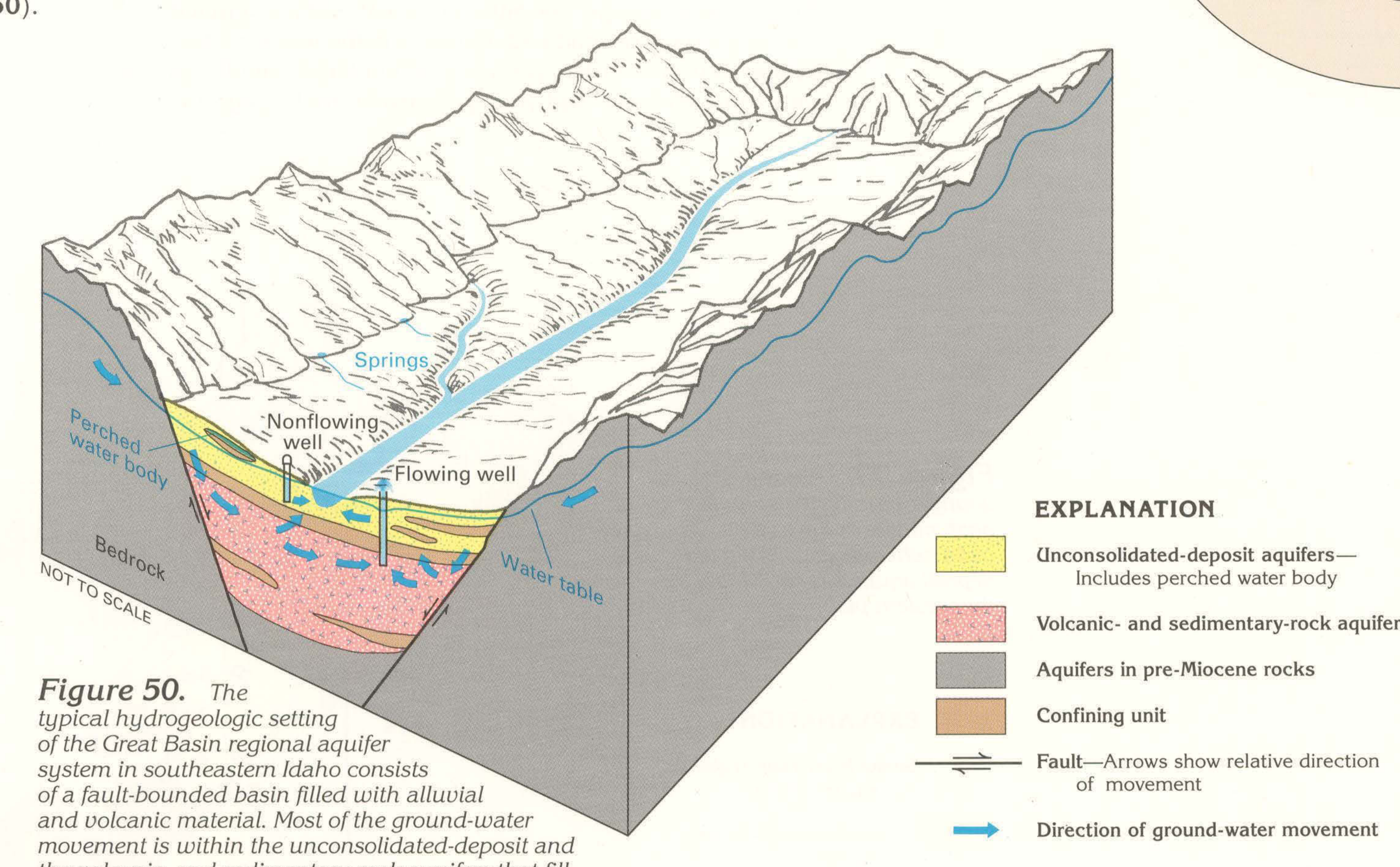


Figure 50. *The typical hydrogeologic setting of the Great Basin regional aquifer system in southeastern Idaho consists of a fault-bounded basin filled with alluvial and volcanic material. Most of the ground-water movement is within the unconsolidated-deposit and the volcanic- and sedimentary-rock aquifers that fill the basins.*

Development of the Great Basin regional aquifer system and equivalent aquifers within Segment 7 has been most extensive in parts of five counties in southeastern Idaho (**fig. 51**). A synopsis of some aspects of the ground-water system in the Great Basin regional aquifer system and equivalent aquifers in Idaho, by county, is presented below:

- **In Bear Lake County,** development is concentrated in the Bear River Valley. Most water is obtained from unconsolidated-deposit (most of the valley) and Pliocene and younger basaltic-rock (northern part of the valley) aquifers. Flowing wells are common; the depth to water in nonflowing wells is about 60 feet. Well yields range from about 10 to about 1,800 gallons per minute, and the water from all aquifers is fresh. Fresh ground-water withdrawals are used primarily for public-supply, domestic and commercial, agricultural (primarily irrigation and livestock watering), and industrial purposes.
- **In Caribou County,** development is concentrated in the Bear River Valley, Gem Valley, and the Soda Springs area. In the Bear River Valley, most water is obtained from unconsolidated-deposit aquifers. Flowing wells are common; the depth to water in nonflowing wells is about 60 feet. Well yields range from about 10 to about 1,800 gallons per minute. In Gem Valley, most water is obtained from Pliocene and younger basaltic-rock aquifers. The depth to water in wells ranges from about 10 to about 180 feet. Well yields range from about 30 to about 2,700 gallons per minute. In the Soda Springs area, most water is obtained from Pliocene and younger basaltic-rock aquifers. Flowing wells are common; the depth to water in nonflowing wells is about 265 feet. Well yields range from about 10 to about 3,400 gallons per minute, and the water from all aquifers is fresh. Fresh ground-water withdrawals are used primarily for public-supply, domestic and commercial, agricultural (primarily irrigation and livestock watering), and industrial purposes.
- **In Franklin County,** development is concentrated in the Bear River Valley and in the Preston area. In the Bear River Valley, most water is obtained from unconsolidated-deposit aquifers. Flowing wells are common; the depth to water in nonflowing wells is about 60 feet. Well yields range from about 10 to about 1,800 gallons per minute. In the Preston area, most water also is obtained from unconsolidated-deposit aquifers. Domestic wells generally are less than 200 feet deep, whereas large-capacity wells generally are from 200 to 500 feet deep. Flowing wells are common; the depth to water in nonflowing wells is about 120 feet. Well yields range from about 10 to about 2,500 gallons per minute, and the water is fresh. Fresh ground-water withdrawals are used primarily for public-supply, domestic and commercial, and agricultural (primarily irrigation and livestock watering) purposes.
- **In Oneida County,** development is concentrated in the Malad River Valley and the Curlew Valley. In the Malad River Valley, springs and seeps discharge large volumes of water from unconsolidated-deposit aquifers. About 300 flowing wells yield a total of about 8,000 gallons per minute, primarily from unconsolidated-deposit aquifers; the unconsolidated deposits are known to be as much as 1,200 feet thick in places. Wells generally are from about 200 to about 500 feet deep; the depth to water in nonflowing wells is about 100 feet. Well yields range from about 20 to about 2,000 gallons per minute. In Curlew Valley, most water is obtained from unconsolidated-deposit aquifers. Wells generally are from about 200 to about 840 feet deep. Well yields range from about 20 to about 2,500 gallons per minute, and the water from all aquifers is fresh. Fresh ground-water withdrawals are used primarily for public-supply, domestic and commercial, and agricultural (primarily irrigation and livestock watering) purposes.
- **In Power County,** development is concentrated in Arbon Valley. Most water is obtained from unconsolidated-deposit aquifers; unconsolidated deposits are known to be as much as about 3,000 feet thick in places. Flowing wells are common; the depth to water in nonflowing wells is about 50 feet. Well yields range from about 450 to about 3,400 gallons per minute, and the water is fresh. Fresh ground-water withdrawals are used primarily for public-supply, domestic and commercial, and agricultural (primarily irrigation and livestock watering) purposes.

Information pertaining to ground-water conditions in the Great Basin regional aquifer system and equivalent aquifers in Idaho is summarized by county in **table 1**.

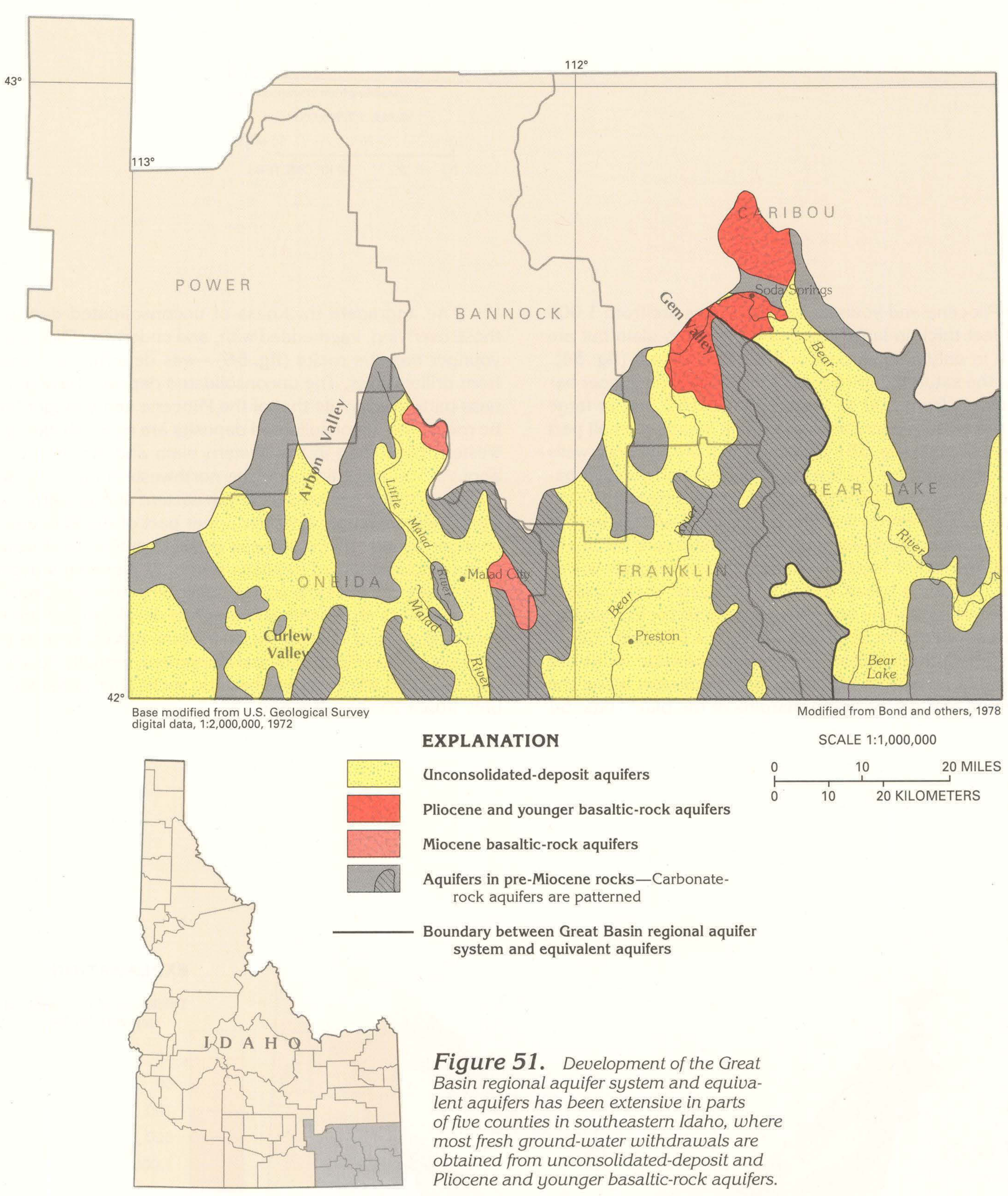


Figure 51. *Development of the Great Basin regional aquifer system and equivalent aquifers has been extensive in parts of five counties in southeastern Idaho, where most fresh ground-water withdrawals are obtained from unconsolidated-deposit and Pliocene and younger basaltic-rock aquifers.*

Table 1. *Ground-water conditions in the Great Basin regional aquifer system and equivalent aquifers in Idaho*

[Aquifer: Ud, unconsolidated deposits; Ybr, Pliocene and younger basaltic rocks; pM, pre-Miocene rocks. Water use: PS, public supply; DC, domestic and commercial; A, agricultural (primarily irrigation and livestock watering); I, industrial. Symbols: n.d., no data available; <, less than; >, greater than]

Location	Principal aquifer	Typical well depth (feet below land surface)	Depth to water (feet below land surface)	Range of well yields (gallons per minute)	Principal water use	Remarks
GREAT BASIN REGIONAL AQUIFER SYSTEM						
Franklin County	Ud, pM				PS, DC, A	
Bear River Valley		n.d.	Flowing–60	10–1,800		
Preston		<200–500	Flowing–120	<10–2,500		Domestic wells generally <200 feet deep.
Oneida County	Ud				ditto	
Curlew Valley		<200–840	n.d.	20–2,500		
Malad River Valley		<200–500	Flowing–100	20–2,000		Unconsolidated deposits 1,200 feet thick, in places.
Power County	ditto				ditto	
Arbon Valley		n.d.	Flowing–50	<450–3,400		Unconsolidated deposits 3,000 feet thick, in places.
EQUIVALENT AQUIFERS						
Bear Lake County	Ud, Ybr, pM				PS, DC, A, I	
Bear River Valley		n.d.	Flowing–60	10–1,800		Ybr is main aquifer in northern part of county.
Caribou County	Ud, Ybr				ditto	
Bear River Valley		n.d.	Flowing–60	10–1,800		Ud is main aquifer.
Gem Valley		n.d.	<10–180	30–2,700		Ybr is an important aquifer.
Soda Springs		n.d.	Flowing–265	10–3,400		ditto

SNAKE RIVER PLAIN REGIONAL AQUIFER SYSTEM

Snake River Plain regional aquifer system

The Snake River Plain regional aquifer system underlies a large, crescent-shaped lowland that extends from near the western boundary of Yellowstone National Park in eastern Idaho to the Idaho–Oregon border where the Snake River enters Hells Canyon (**fig. 52**). The northern and southern boundaries of the Snake River Plain generally coincide with the contact between unconsolidated deposits or Pliocene and younger basaltic rocks in the lowland and older rocks in adjacent highlands.

Early ground-water studies concentrated only on that part of the plain east of the Thousand Springs area and north of the Snake River, an area of about 9,600 square miles. A regional study, which was begun in 1979 by the U.S. Geological Survey, focused on the entire 15,600 square miles of the Snake River Plain. During 1980, about 3.1 million acres on the plain was irrigated—about 2 million acres with surface water, about 1 million acres with ground water, and about 100,000 acres with a combination of surface and ground water. About 5,300 wells provided ground water for irrigation.

Abrupt changes in hydrogeologic conditions along the Snake River between Salmon Falls Creek and King Hill, Idaho, make it feasible to discuss the regional aquifer system by area—the eastern and the western plains (**fig. 53**). In the eastern plain, the regional aquifer system consists primarily of Pliocene and younger basaltic rocks with some overlying and interbedded unconsolidated deposits; in the western plain, the aquifer system consists primarily of unconsolidated deposits with some Pliocene and younger basaltic rocks (**fig. 53**).

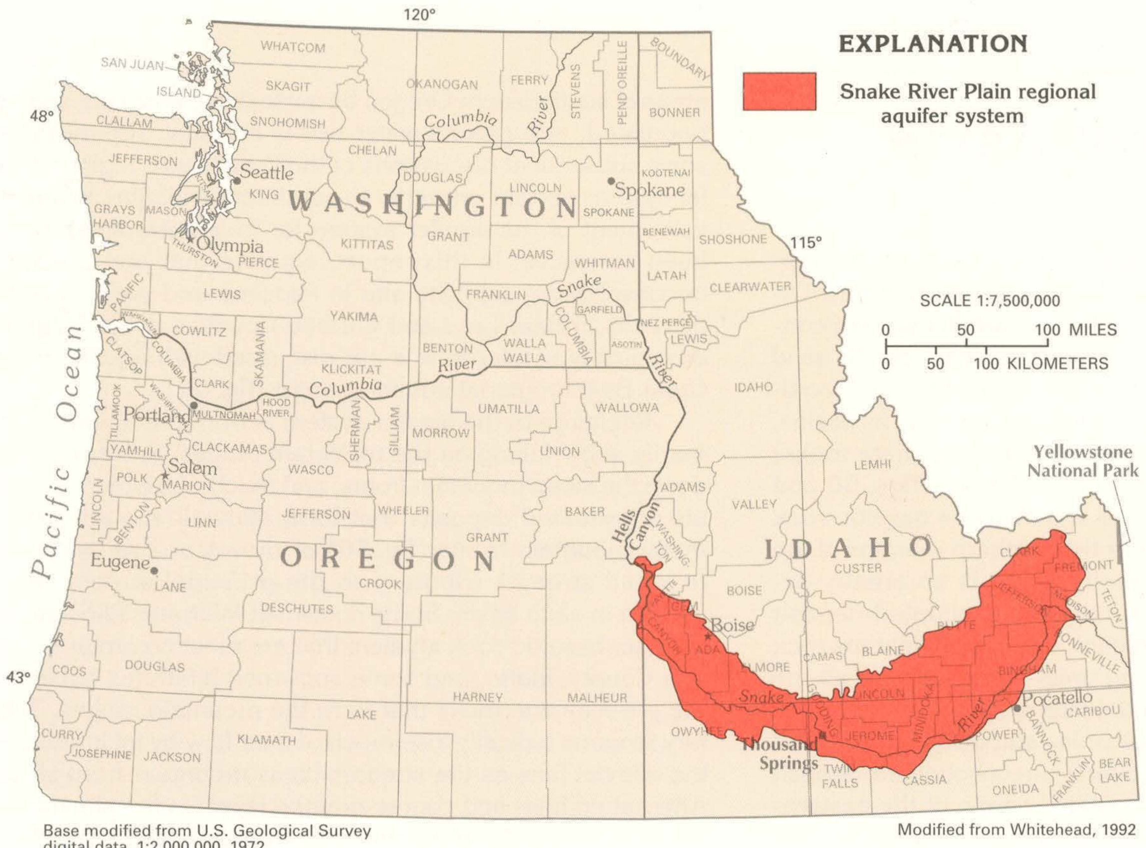
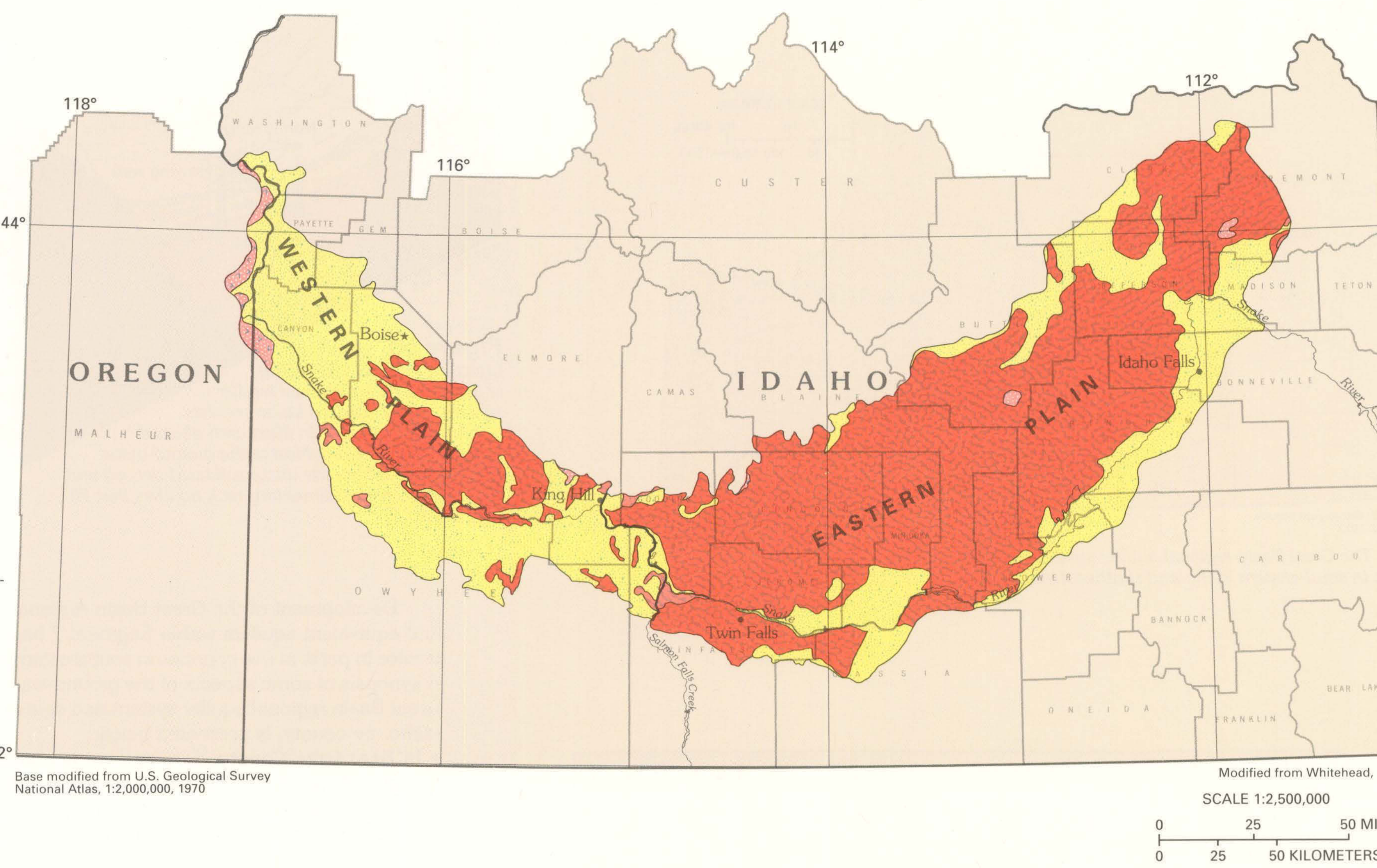


Figure 52. The Snake River Plain regional aquifer system underlies a large, crescent-shaped lowland in southern Idaho and a small part of east-central Oregon.

Figure 53. Pliocene and younger basaltic-rock aquifers predominate in the eastern plain, whereas unconsolidated-deposit aquifers predominate in the western plain.



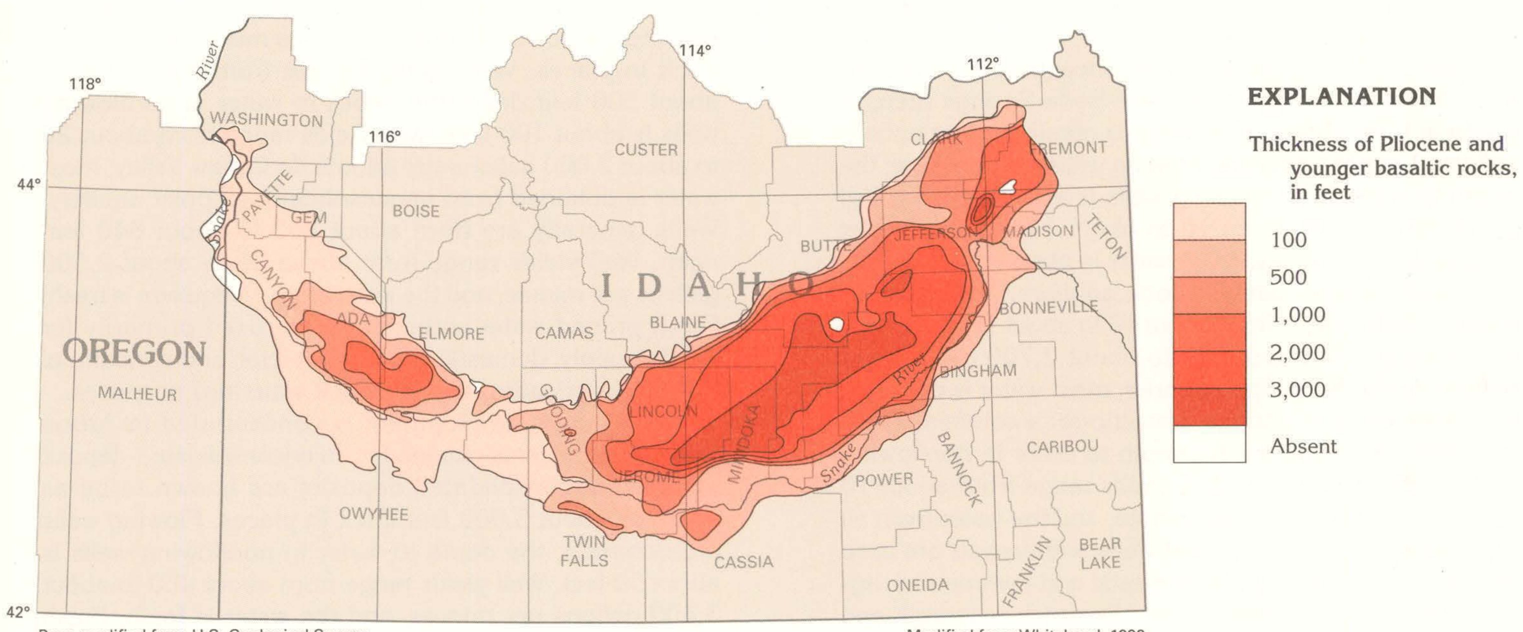


Figure 54. Pliocene and younger basaltic rocks are thickest near the central part of the eastern plain and are much thinner in the western plain.

The Pliocene and younger basaltic rocks are from 1,000 to 2,000 feet thick in large areas of the eastern plain but are that thick in only a small part of the western plain (**fig. 54**). Similarly, the saturated thickness of Pliocene and younger basaltic rocks is from 500 to greater than 1,000 feet in large areas of the eastern plain but is that thick in only a small part of the western plain (**fig. 55**). Because there are few deep wells in the eastern plain, the thickness of Pliocene and younger basaltic rocks in areas where these rocks range from 1,000 to more than 3,000 feet thick (**figs. 54 and 55**) was estimated by using electrical resistivity surveys (the maximum thickness estimated was 5,500 feet). Consequently, some older volcanic rocks (including basalt and silicic volcanic rocks) might be included with Pliocene and younger basaltic rocks, particularly in areas where the thickness exceeds 1,000 feet. This is also true where the Pliocene and younger basaltic rocks are shown as thin (less than 100 feet thick) or absent along the north-central and northeastern margins of the plain (**figs. 54 and 55**).

The aggregate thickness of unconsolidated deposits—those overlying, interbedded with, and underlying Pliocene and younger basaltic rocks (**fig. 56**)—was determined primarily from drillers' logs. The unconsolidated deposits have a thickness pattern opposite that of the Pliocene and younger basaltic rocks; the unconsolidated deposits are much thicker in the western plain than in the eastern plain and are as much as about 5,500 feet thick near the northwestern tip of the western plain. In the central part of the eastern and western plains, most wells penetrate only the upper part of the Pliocene and younger basaltic rocks. In these areas, therefore, the thickness of the unconsolidated deposits primarily represents deposits that overlie the Pliocene and younger basaltic rocks; much of this thickness represents soil that has developed on the Pliocene and younger basaltic rocks. In some places, such as parts of Craters of the Moon National Monument, virtually no soil has developed on the youngest basaltic rocks that were extruded only about 2,000 years ago.

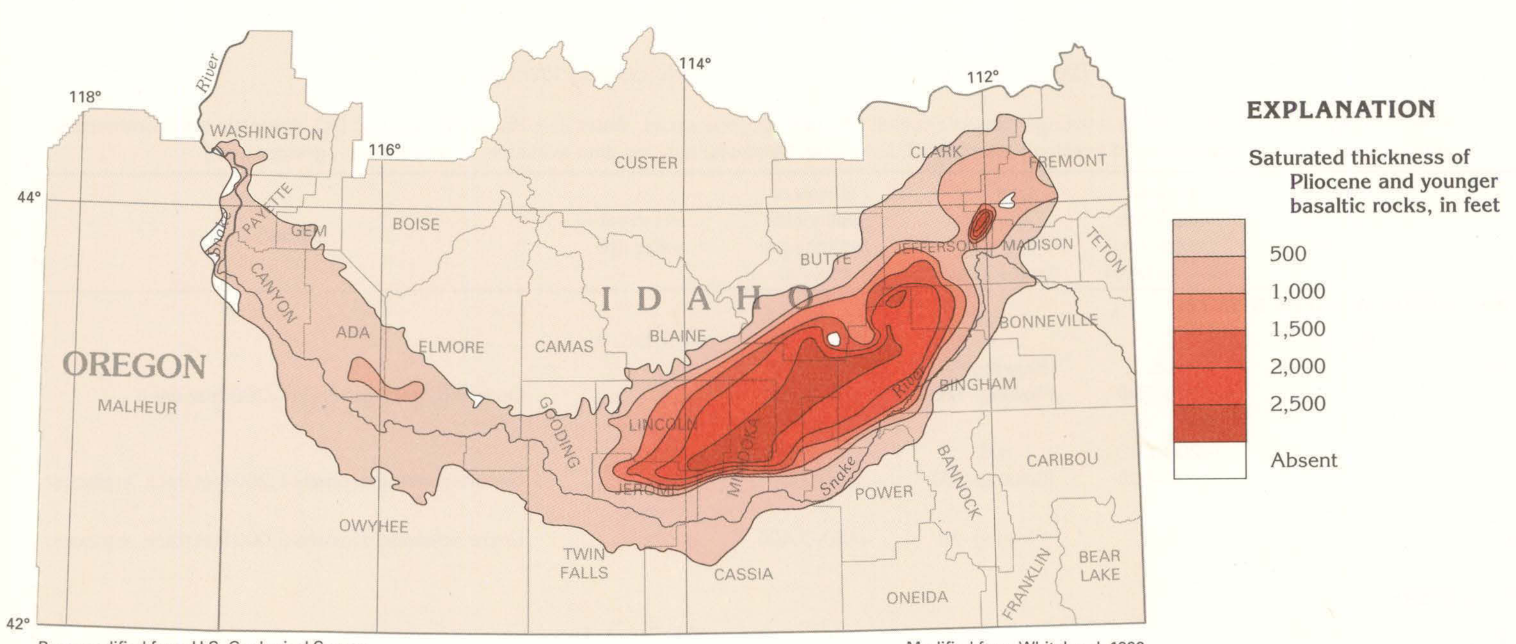


Figure 55. The saturated thickness of Pliocene and younger basaltic rocks is greatest near the central part of the eastern plain but is much less in the western plain.

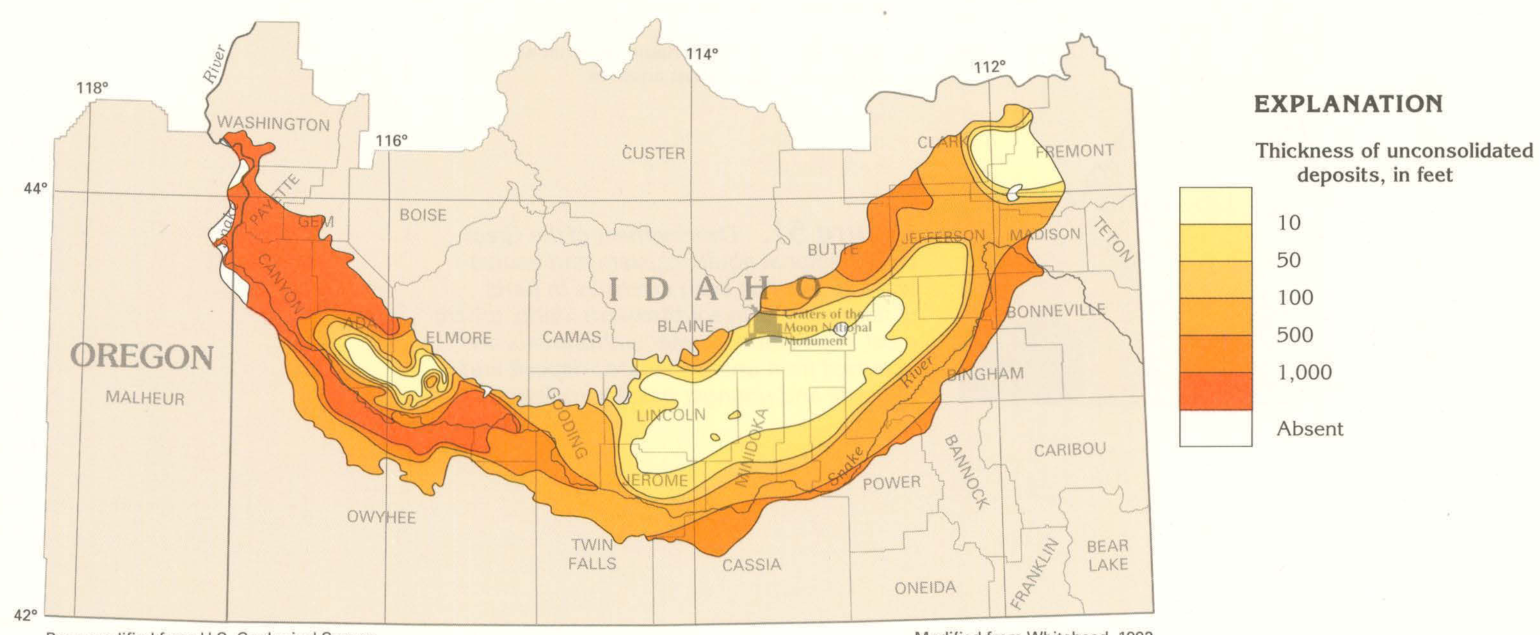


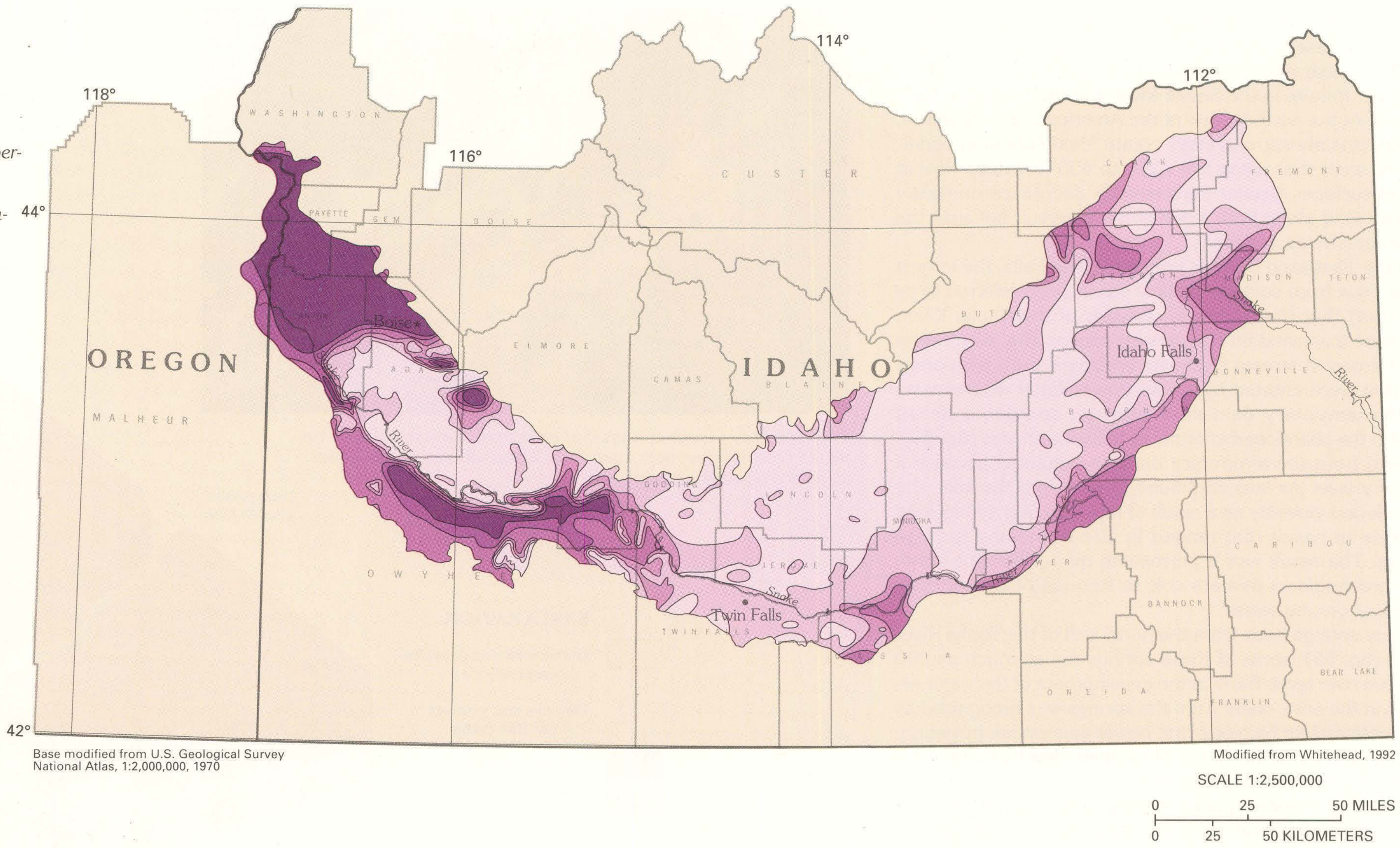
Figure 56. Unconsolidated deposits generally are thickest around the margins of the eastern plain and in the central and western parts of the western plain where Pliocene and younger basaltic rocks are absent.

Figure 57. The depth to the uppermost volcanic rock unit indicates the topography of the volcanic rock surface underlying the uppermost unconsolidated deposits.

EXPLANATION

Depth to uppermost volcanic-rock unit, in feet

- 10
- 50
- 100
- 500
- 1,000

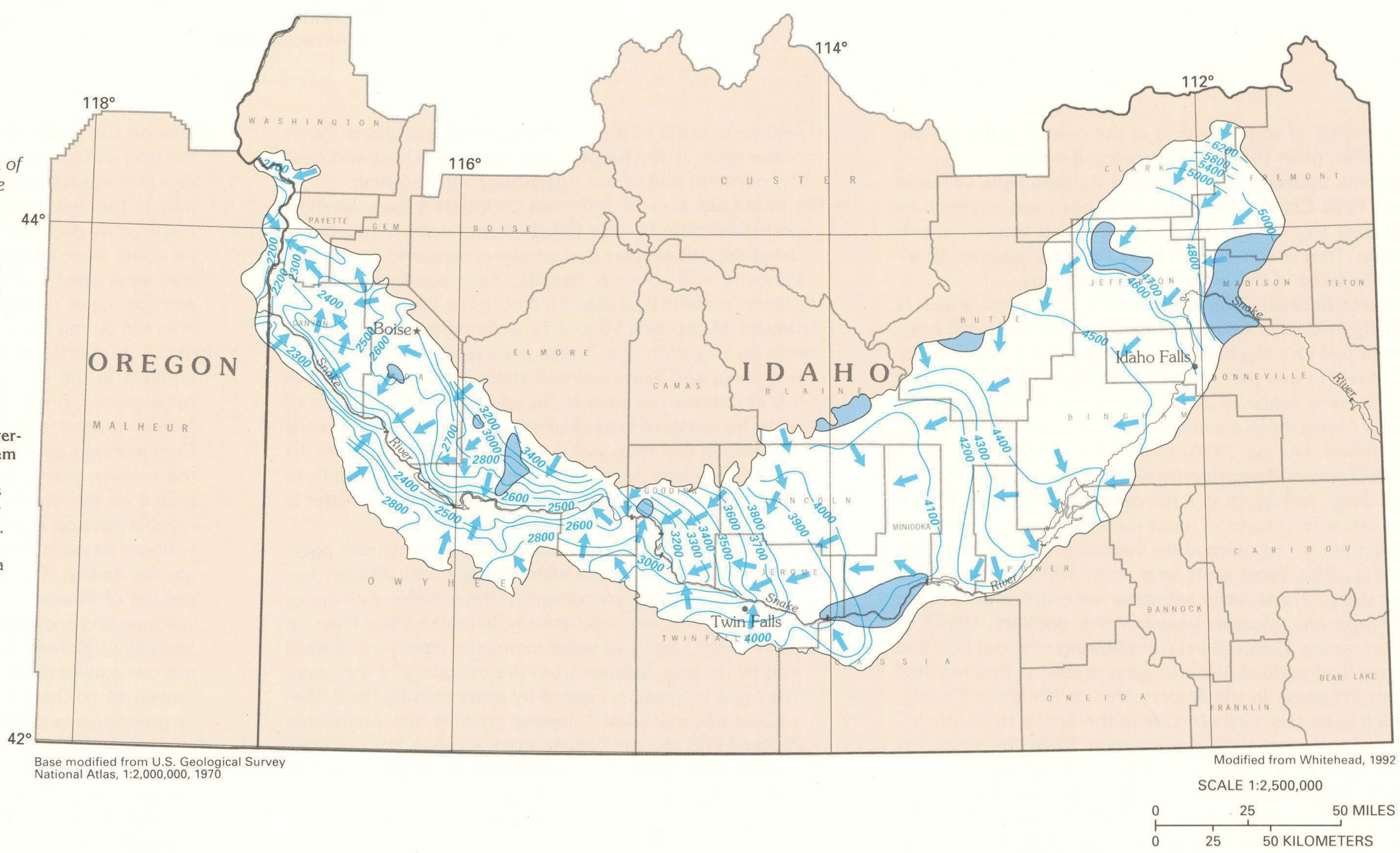


The topography of the volcanic rock surface underlying the uppermost unconsolidated deposits is indicated by **figure 57**, which shows the depth to the uppermost volcanic rocks. Pliocene and younger basaltic rocks are the shallowest volcanic rocks throughout much of the entire Snake River Plain. Miocene basaltic rocks and silicic volcanic rocks are the shallowest volcanic rocks, primarily near the margins of the eastern plain and in the southern and northwestern parts of the western plain. The canyonlike troughs in the volcanic rock surface in the western plain are the result of the complete erosion of near-surface, thin layers (generally less than 100 feet thick) of Pliocene and younger basaltic rocks that once overlaid thick sequences of unconsolidated deposits.

Figure 58. The general direction of ground-water movement in the Snake River Plain regional aquifer system is from east to west. Much of the discharge from the aquifer system is to the Snake River. Rocks of low permeability underlie areas of shallow local aquifers or perched water bodies.

EXPLANATION

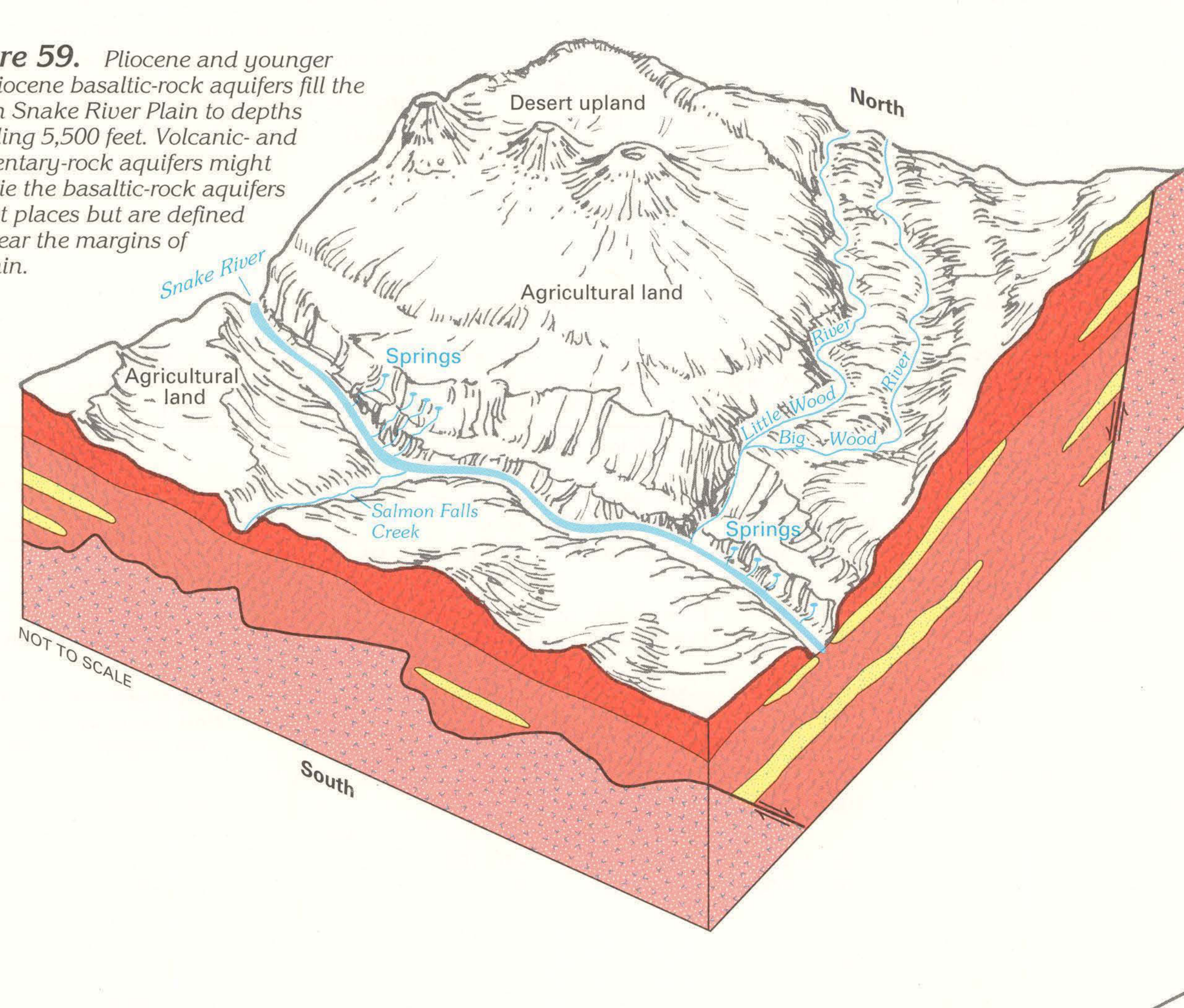
- Area where local aquifers or perched water bodies overlie the regional aquifer system
- 4000 Water-table contour—Shows altitude of regional water table during spring 1980. Contour interval, in feet, is variable. Datum is sea level
- Direction of ground-water movement



The configuration of the regional water table of the aquifer system (**fig. 58**) generally parallels the configuration of the land surface of the Snake River Plain; that is, the altitude of the water table is greatest in the extreme eastern part of the plain and is least in the Hells Canyon area along the Idaho–Oregon border. Upstream bending of the water-table contours where they cross the Snake River shows the places where the aquifer system is discharging to the river. The water-table contours shown in **figure 58** were based on water levels measured in about 1,600 wells during spring 1980. In a general way, the configuration of and the spacing between contours indicate changes in the geologic and hydrologic character of the aquifer system and show the direction of horizontal ground-water movement at the water table. The increasing space between contours generally indicates more permeable or thicker parts of the aquifer. Conversely, the narrowing space indicates less permeable or thinner parts of the aquifer. Hydraulic head must increase to move the same volume of water through the less permeable or thinner parts of the aquifer system. Estimates of the depth to the regional water table can be made by subtracting the altitude of a water-table contour at a given point from the altitude of the land surface at the same point.

Areas where shallow local aquifers or perched water bodies overlie the regional aquifer system are shown in **figure 58**. Water levels in these areas are higher than those in the regional aquifer system. Other such areas might exist but are too small to show in **figure 58**. These areas are underlain by rocks that have extremely low permeability.

Figure 59. Pliocene and younger and Miocene basaltic-rock aquifers fill the eastern Snake River Plain to depths exceeding 5,500 feet. Volcanic- and sedimentary-rock aquifers might underlie the basaltic-rock aquifers in most places but are defined only near the margins of the plain.



EXPLANATION

- Unconsolidated-deposit aquifers
- Pliocene and younger basaltic-rock aquifers
- Miocene basaltic-rock aquifers
- Volcanic- and sedimentary-rock aquifers
- Fault— Arrows show relative direction of movement

Eastern Plain

Multiple thin flows of Pliocene and younger basaltic rocks that are interbedded with unconsolidated deposits form the Snake River Plain regional aquifer system in the eastern plain. Pliocene and younger basaltic-rock aquifers predominate in the central part of the plain; unconsolidated-deposit aquifers predominate along the margins of the plain (**figs. 59 and 60**). Miocene basaltic-rock aquifers underlie the Pliocene and younger aquifers in part of the plain (**fig. 59**) but are used as a source of water only near the margins of the plain. In some places, silicic volcanic rocks of the volcanic- and sedimentary-rock aquifers underlie the Miocene basaltic-rock aquifers along the margins of the plain (**fig. 59**); in other places, aquifers in pre-Miocene rocks are along the plain's margins (**fig. 60**).

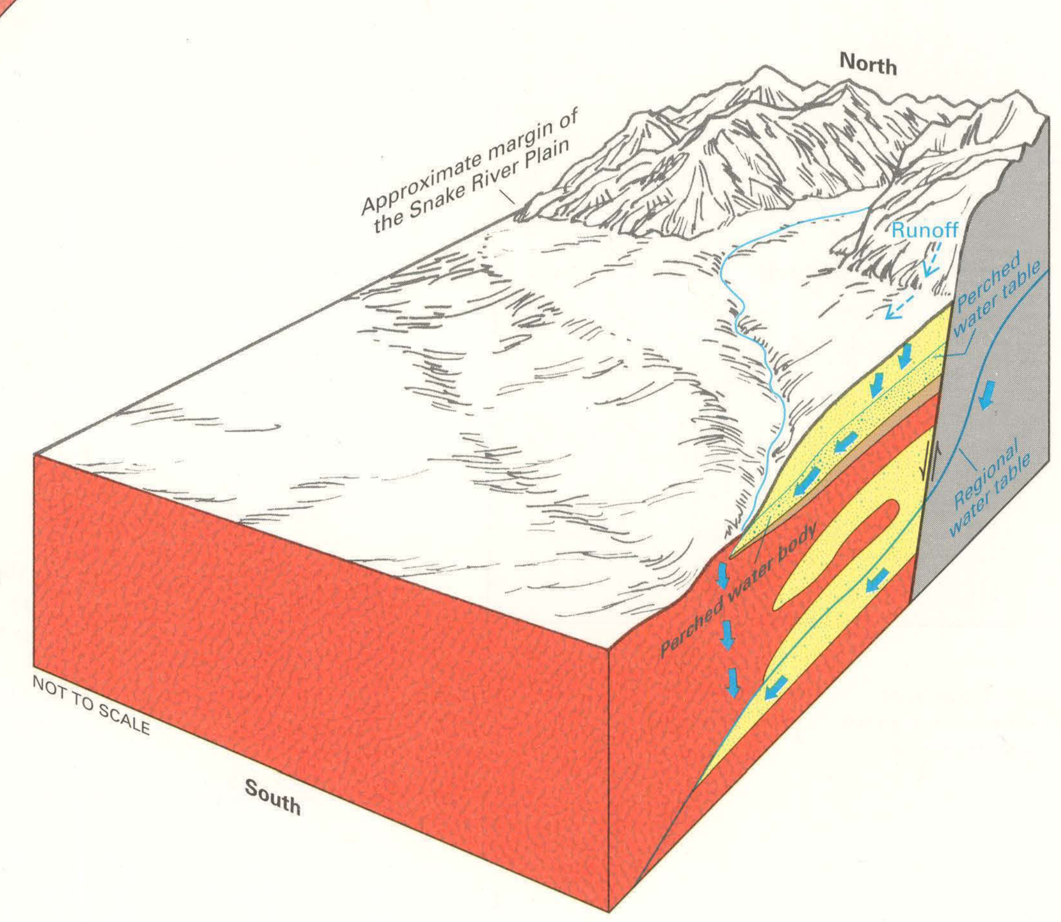


Figure 60. Unconsolidated-deposit aquifers are interbedded with Pliocene and younger basaltic-rock aquifers near the margins of the eastern Snake River Plain where perched water bodies commonly are present.

EXPLANATION

- **Unconsolidated-deposit aquifers**—Darker pattern shows perched water body
- Confining unit
- Pliocene and younger basaltic-rock aquifers
- Aquifers in pre-Miocene rocks
- Fault—Arrows show relative direction of movement
- Direction of ground-water movement
- Direction of surface-water runoff

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Eastern Plain—Continued

Generally, the regional aquifer system in the eastern plain is an unconfined system, although dense, unfractured basalt and interbedded clay layers cause semiconfined and confined conditions in places. Permeability of the Pliocene and younger basaltic-rock aquifers is extremely variable, as indicated by the considerable range in the size of openings present in outcrops (**fig. 61**). Individual basalt flows average about 25 feet in thickness; extremely permeable zones at the tops and the bottoms of flows range in thickness from less than 1 to about 10 feet. In places, permeable zones between flows or at the top of a flow might be filled with fine-grained unconsolidated deposits that decrease the permeability of the zones. The central parts of most Pliocene and younger flows are dense and almost impermeable. Wells completed in Pliocene and younger basaltic-rock aquifers generally penetrate numerous flows to obtain water from many permeable zones. Deeply buried flows of Miocene basaltic rocks typically are thicker and less permeable than flows of Pliocene and younger basaltic rocks.

Much of the recharge in the eastern plain originates as precipitation on the highlands adjacent to the plain, chiefly on the northern side. Precipitation falling on the plain itself accounts for less than 10 percent of the total recharge. Infiltration of surface water diverted from the Snake River for irrigation of land near the river accounts for about 67 percent of the total recharge. Rainfall and snowmelt on the plain infiltrate quickly to the water table because of many surface or near-surface openings (**fig. 61**) in Pliocene and younger basaltic rocks; similar openings at depth provide conduits for water movement.

Much of the discharge from the eastern plain is through springs. Two major spring discharge areas are near the American Falls Reservoir and the Thousand Springs area near Twin Falls, Idaho. In the American Falls area, springs and flowing wells are common because permeable basalt, gravel, and sand units upstream grade into less permeable lakebeds in the vicinity of the reservoir. The result is a series of springs and seeps at or near river level that discharge about 1.1 million gallons per minute to the Snake River and the American Falls Reservoir. At the northern end of the American Falls Reservoir, lakebeds (mainly silt and clay) create ideal confining conditions and wells that range from 200 to 400 feet deep flow at the land surface. Aquifer permeability decreases markedly southwestward along both sides of the reservoir because the percentage of clay increases.

In the Thousand Springs area near Twin Falls, the largest springs issue from saturated pillow basalt (also referred to as pillow lava) that fills ancestral canyons of the Snake River, which were truncated by the present canyon (**fig. 62**). Pillow basalt formed in stream channels upstream from temporary dams that were created by basalt flows. Water downstream from the temporary dam drained away, and dense basalt formed in the abandoned channel as it filled with lava (**fig. 63**). Upstream from the temporary dam, the channel became a temporary lake. As lava continued to pour into the lake, the lava exploded violently as a result of rapid cooling and formed fragments of basalt that ranged in size from sand to huge boulders. The result was a permeable mix of basaltic sand, gravel, and boulders that are able to store and transmit large volumes of ground water.

Many springs issue from the north wall of the Snake River Canyon (**fig. 59**); some of these springs are as much as 200 feet above river level. Early in the development of the water resources in the area, water from the springs was recognized as having potential for hydroelectric power generation, irrigation, and aquaculture (fish farming). Since then, development of the springs has increased significantly.

Wells in the eastern plain withdraw large volumes of water primarily for agricultural (chiefly irrigation) purposes. Ground water in the eastern plain also is used for public-supply, domestic and commercial (including aquaculture), and industrial purposes.

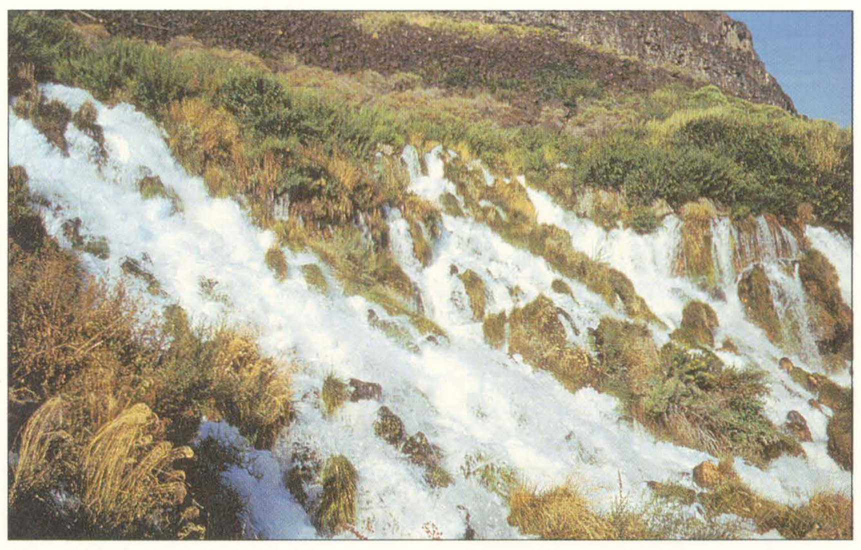

Figure 62. *Large springs that issue from the north wall of the Snake River Canyon near Twin Falls, Idaho, discharge thousands of gallons of water per minute.*

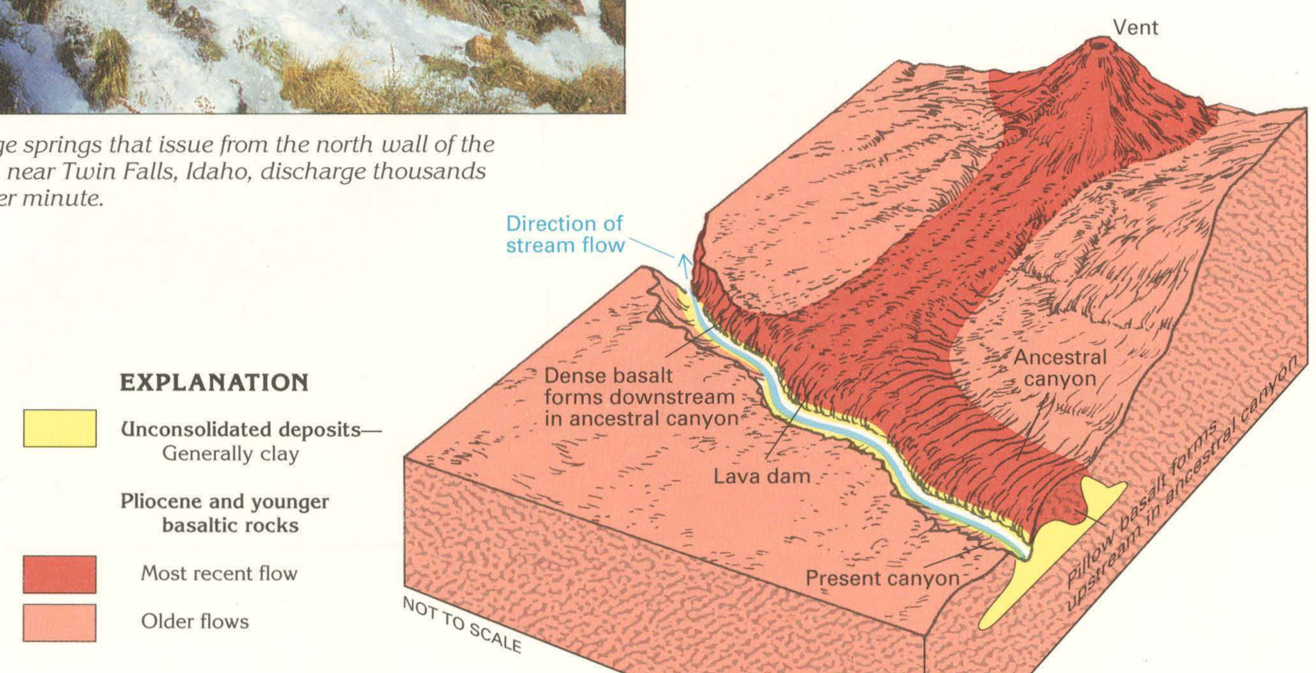

Figure 63. *Basaltic lava flows dammed and filled ancestral canyons of the Snake River in the eastern plain.*

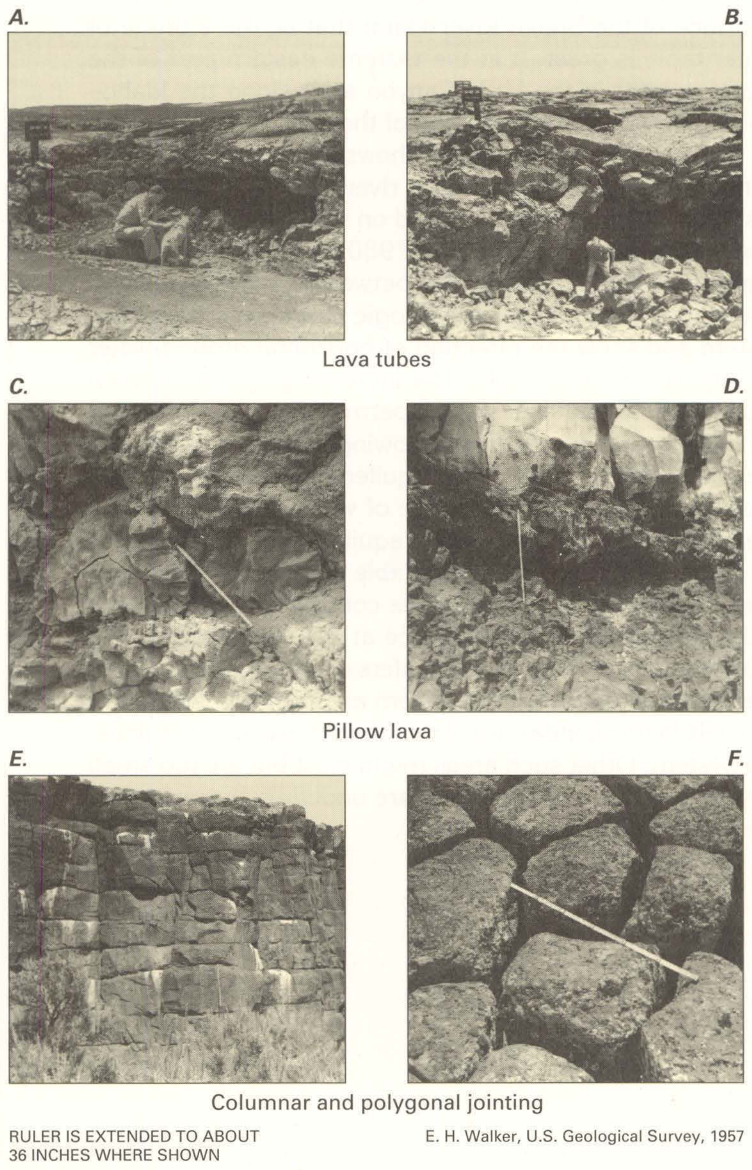

Figure 61. *Surficial features show the characteristic types of openings in the Pliocene and younger basaltic-rock aquifers. **A** and **B**, Undulating surface of a basalt flow with collapsed and partly collapsed lava tubes. **C**, Large boulders of pillow basalt formed when lava entered water and cooled quickly. **D**, Pillow basalt ranging from boulders to sand grain size. **E**, Side view of columnar basalt showing cooling joints. **F**, Top view of columnar basalt showing typical cooling joints. These openings provide easy access for water from recharge sources to enter the underlying aquifer.*

A synopsis of some aspects of the ground-water system in the eastern plain (**fig. 64**) is presented below:

- **In the area between Twin Falls and Salmon Falls Creek in Twin Falls County,** the water table has risen as much as 200 feet as a result of recharge from surface-water irrigation. Drains and tunnels have been constructed to alleviate some of the waterlogging problems.
- **In the area between Twin Falls and the Raft River, which is chiefly in Cassia County,** large tracts of land have been developed for irrigation with ground water. Declining water levels in this part of the Snake River Plain prompted the State of Idaho to designate several Critical Ground-Water Areas; these are areas where no additional wells can be drilled. During 1956, most wells withdrawing water from unconsolidated-deposit aquifers were from 50 to 500 feet deep, and depth to water ranged from flowing to 150 feet below land surface. Since then, many wells have been deepened to accommodate declining water levels, and during 1988, most wells were from 500 to about 1,500 feet deep. Some wells withdraw water from underlying Pliocene and younger basaltic-rock aquifers. Depth to water during 1988 ranged from flowing to about 500 feet below land surface. Waterlogging problems that resulted from irrigation in the Rupert area in Minidoka County, which is on the northern side of the Snake River, necessitated the construction of drains to lower the water levels in fine-grained unconsolidated-deposit aquifers.
- **In the Springfield area in Bingham County, which is at the northern end of the American Falls Reservoir,** layers of fine-grained unconsolidated deposits (lakebed sediments) composed chiefly of clay confine water in unconsolidated-deposit aquifers composed of interbedded sand and gravel. The sequence of clay layers and interbeds is as much as 750 feet thick.
- **Along the eastern side of the Snake River and near the river on the western side in the Fort Hall–Blackfoot area of Bannock and Bingham Counties,** unconsolidated-deposit aquifers that consist of coarse sand and gravel yield water to domestic and stock wells, but cinder zones in the underlying Pliocene and younger basaltic-rock aquifers yield water to most irrigation wells. The sand and gravel extends upstream along the Snake River channel to the junction of Henrys Fork and the Snake River in Madison County. In this reach, the Snake River loses a substantial volume of water to the underlying sand and gravel. Much of the water is discharged later from springs at and near the northern end of the American Falls Reservoir.
- **The Mud Lake area in Jefferson County** is a large, shallow basin underlain by clay (lakebed sediments), unconsolidated-deposit aquifers that consist of sand and gravel, and Pliocene and younger basaltic-rock aquifers. In most places, water is less than 50 feet below the land surface. Groups of between 10 and 12 wells pump water into canals for irrigation use. These wells range from 80 to 160 feet deep, and individual well yields range from 2,000 to 9,000 gallons per minute. In addition to the groups of wells, hundreds of individual irrigation and domestic wells are used in the area; yields of these wells range from 10 to 9,000 gallons per minute. Wells immediately south of Mud Lake are as deep as 400 feet, and depth to water is about 250 feet below land surface.
- **In Blaine and Butte Counties,** unconsolidated-deposit aquifers that are interlayered with Pliocene and younger basaltic-rock aquifers are present at the mouths of all drainage basins that are tributary to the Snake River Plain. In those areas, depth to water increases rapidly southward with increasing distance from the boundary of the plain. The rapid increase is caused by water moving from fine-grained unconsolidated-deposit aquifers into permeable Pliocene and younger basaltic-rock aquifers. For example, immediately south of Arco, wells as much as 1,000 feet deep are completed in Pliocene and younger basaltic-rock and interbedded unconsolidated-deposit aquifers; generally, depth to water is less than 500 feet below the land surface. A few miles farther south, deep wells penetrate only Pliocene and younger basaltic-rock aquifers; depth to water is as much as 1,000 feet below the land surface. Southwest of Craters of the Moon National Monument in Blaine County, depth to water is as much as 1,235 feet below land surface.
- **Much of the central plain,** which is primarily devoid of vegetation, consists of Pliocene and younger basaltic-rock aquifers, some of which are less than 2,000 years old. A thin, windblown soil cover supports sparse grass and sagebrush in places. The lack of economic opportunities, extensive areas of public land, and remoteness restrict ground-water development.
- **Areas on the Snake River Plain** where water can pond on the land surface are common because of the irregular surface that was formed by coalescing basalt flows. The problem of ponded water in irrigated and urban areas was resolved by drilling disposal wells through which the water could drain into an underlying permeable zone. Wells also were used to dispose of excess irrigation water and sewage. Laws restricting the use of disposal wells were enacted during the early 1970's.
- **Hydraulic properties of Pliocene and younger basaltic-rock aquifers in the eastern plain** are highly variable and, in most places, poorly defined. The most detailed subsurface investigations have been made at the Idaho National Engineering Laboratory (INEL) site in the central part of the eastern plain. A 10,000-foot exploratory hole was drilled on the site during the late 1970's. The most permeable section is the upper 1,200 feet in Pliocene and younger basaltic rocks of the Snake River Plain regional aquifer system. The next 1,100- and 7,700-foot sections consist of Miocene basaltic rocks and undifferentiated volcanic and sedimentary rocks, respectively, of low permeability. The hole bottomed in silicic volcanic rocks. Numerous aquifer tests have been made at the INEL site and elsewhere on the eastern plain to determine the hydraulic properties of the various rock types. Aquifer tests and computer simulation indicate that the transmissivity of the upper 200 feet of the Pliocene and younger basaltic-rock aquifers ranges from 104,000 to 1.8 million feet squared per day. Yields of wells completed in the Pliocene and younger basaltic-rock aquifers are among the largest in the Nation. Irrigation wells open to less than 100 feet of the aquifers yield as much as 7,000 gallons per minute with only a few feet of drawdown. Well yields that range from 2,000 to 3,000 gallons per minute are common. The Pliocene and younger basaltic-rock aquifers generally yield much more water than do the interbedded unconsolidated-deposit aquifers. In places where the Pliocene and younger basaltic-rock aquifers consist primarily of dense basalt, however, well yields are extremely small.

Information pertaining to ground-water conditions in the eastern plain is summarized by county in **table 2**.

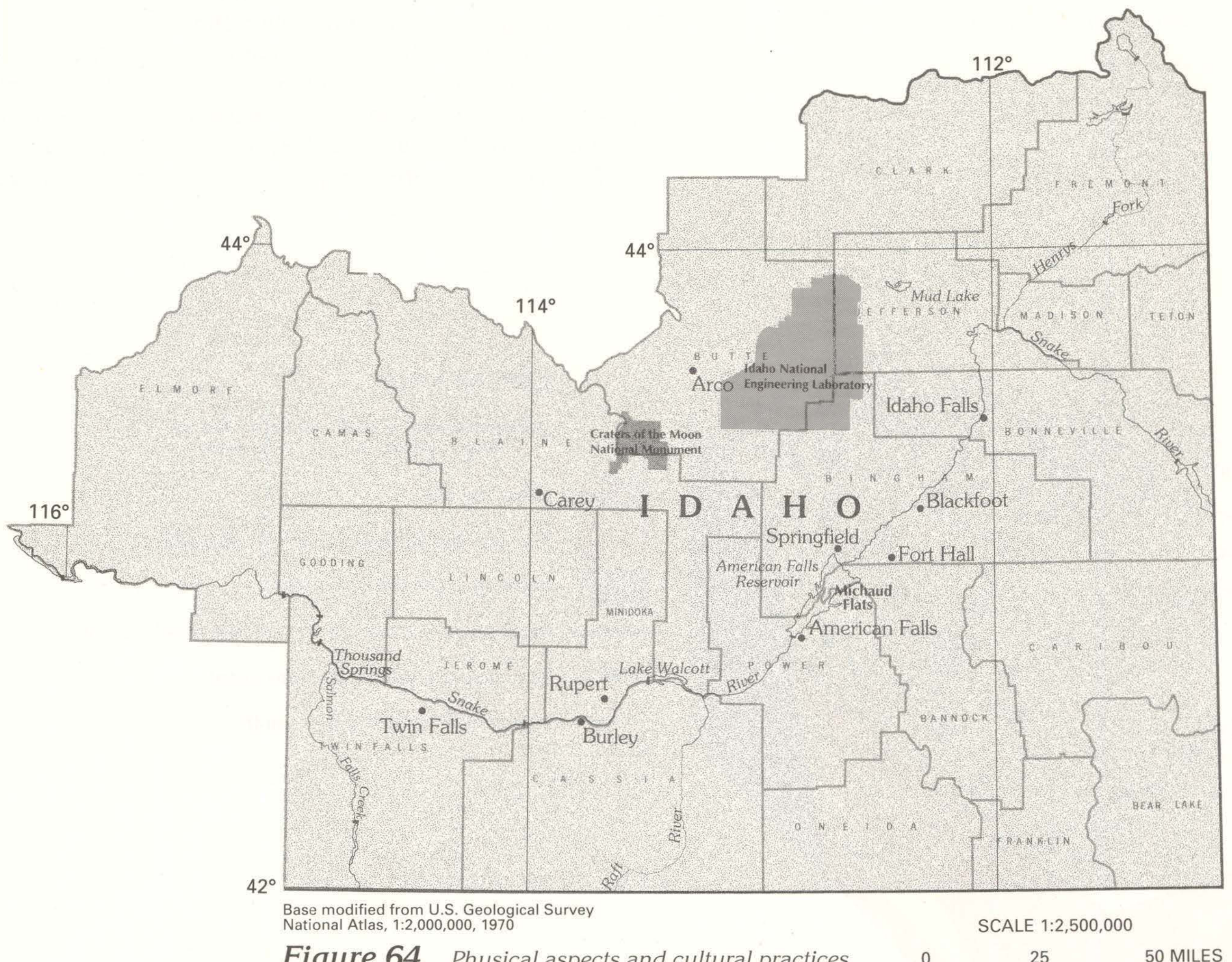

Figure 64. *Physical aspects and cultural practices affecting the ground-water flow system in the eastern plain of the Snake River Plain regional aquifer system are described for these locations.*

Table 2. *Ground-water conditions in the eastern Snake River Plain in Idaho*

[Aquifer: Ud, unconsolidated deposits; Ybr, Pliocene and younger basaltic rocks; Vsr, volcanic and sedimentary rocks; Obr, Miocene basaltic rocks. Water use: PS, public supply; DC, domestic and commercial; A, agricultural (primarily irrigation and livestock watering); I, industrial. Symbols: <, less than; >, greater than; INEL, Idaho National Engineering Laboratory]

Location	Principal aquifer	Typical well depth (feet below land surface)	Depth to water (feet below land surface)	Range of well yields (gallons per minute)	Principal water use	Remarks
Bannock County	Ud, Ybr	<50–>1,000	Flowing–>400	<10–>3,000	PS, DC, A, I	Ud is major aquifer.
Bingham County	ditto				ditto	
Fort Hall–Blackfoot area		<50–500	Flowing–200	<100–5,000		Ybr is major aquifer.
Springfield area		<50–>500	Flowing–200	<100–>3,600		Artesian wells common.
Blaine County	ditto				PS, DC, A	
Carey area		<50–>1,300	<50–1,235	<10–360		Deeper wells are east of Carey.
Lake Walcott area		100–>900	<100–>900	<10–>4,200		Most deeper wells are north of Lake Walcott near Craters of the Moon National Monument.
Bonneville County	Ud, Ybr, Vsr, Obr				PS, DC, A, I	
Snake River Valley		<100–>1,000	Flowing–500	<100–3,600		Large yields in places near Idaho Falls.
Butte County	Ud, Ybr				ditto	
Arco area		<50–>1,000	<10–>900	<10–100		
INEL		<100–10,000	<100–>700	<10–>7,000		Most wells <1,200 feet deep. Industrial use only at INEL.
Cassia County	Ud, Ybr, Vsr, Obr				ditto	Industrial use is for food processing.
Burley area		<100–>1,500	Flowing–500	<10–4,000		
Clark County	Ud, Ybr, Vsr	<100–>900	<100–>900	<100–2,250	DC, A	Chiefly agricultural use.
Fremont County	ditto	<100–>600	<100–>600	<10–5,000	ditto	ditto
Gooding County	Ud, Ybr	<100–>600	<20–>400	<10–1,800	PS, DC, A	
Jefferson County	ditto				PS, DC, A, I	Industrial wells at INEL.
Mud Lake area		<50–>1,000	Flowing–>500	10–9,000		
Snake River Valley		<100–<1,000	Flowing–<300	<10–100		
INEL		<300–>500	200–<500			
Jerome County	Ud, Ybr	100–>700	<100–<600	<10–3,300	PS, DC, A	
Lincoln County	ditto	<200–>600	150–>500	<10–2,700	ditto	
Madison County	Ud, Ybr, Vsr				ditto	
Snake River Valley		<50–>600	<10–>400	<20–5,100		
Minidoka County	Ud, Ybr	<100–>500	<50–>500	<10–>4,200	ditto	Ybr is major aquifer.
Power County	ditto				ditto	
Michaud Flats		<50–>800	<10–>600	<200–3,300		
Twin Falls County	Ud, Ybr, Vsr, Obr	<100–1,500	Flowing–>500	10–3,300	PS, DC, A, I	Geothermal water common near Snake River.

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Western Plain

In the western plain, the Snake River Plain regional aquifer system (**fig. 53**) consists chiefly of unconsolidated-deposit aquifers with some Pliocene and younger basaltic-rock aquifers (**fig. 65**). Pliocene and younger basaltic-rock aquifers are the major aquifers near Mountain Home in Elmore County, Idaho. Extremely productive unconsolidated-deposit aquifers that consist of sand and gravel predominate along the Boise River and the northern boundary of the western plain. The percentage of the sand and gravel generally decreases southward as distance from the source rocks—the highlands on the northern side of the plain—increases (**fig. 66**). Older fine-grained deposits of the unconsolidated-deposit aquifers predominate in the remainder of the western plain and yield only from 1 to 20 gallons per minute of water to wells. The water in these aquifers is generally under confined conditions. Discontinuous lenses of sand and gravel in the otherwise fine-grained deposits yield from 1 to 100 gallons per minute of water to wells. Permeable zones exist at depths of 5,500 feet below the land surface, but the most permeable zones are in the upper 500 feet (**fig. 67**). Estimated transmissivity of the upper 500 feet of the unconsolidated-deposit aquifers is generally less than 20,000 feet squared per day. Along the margins of the western plain, Miocene basaltic-rock and undifferentiated volcanic- and sedimentary-rock aquifers are present beneath the unconsolidated-deposit aquifers and are the principal sources of geothermal water.

Recharge to the western plain is chiefly from precipitation on the surrounding mountains and from infiltration of excess surface water used for irrigation on the lowlands. Discharge from the aquifer system is by spring flow, seeps, evapotranspiration, and withdrawals from wells.

On the western plain, water for public-supply, domestic and commercial, agricultural (primarily irrigation and livestock watering), and industrial purposes is provided by ground water. To obtain the needed volume, public-supply, irrigation, and industrial wells are usually deeper than domestic and commercial wells and wells used for livestock watering.

At Mountain Home, a local perched water body that is less than 100 feet thick in unconsolidated deposits supplies water to many domestic wells (**fig. 68**). A second perched water body of greater areal extent in Pliocene and younger basaltic rocks underlies the unconsolidated deposits. To the south and west of Mountain Home, the confining unit that underlies the second perched water body pinches out, and ground water moves downward through permeable Pliocene and younger basaltic rocks to the regional water table, which is more than 200 feet below the land surface. Total thickness of the Pliocene and younger basaltic-rock aquifer is generally less than 2,000 feet.

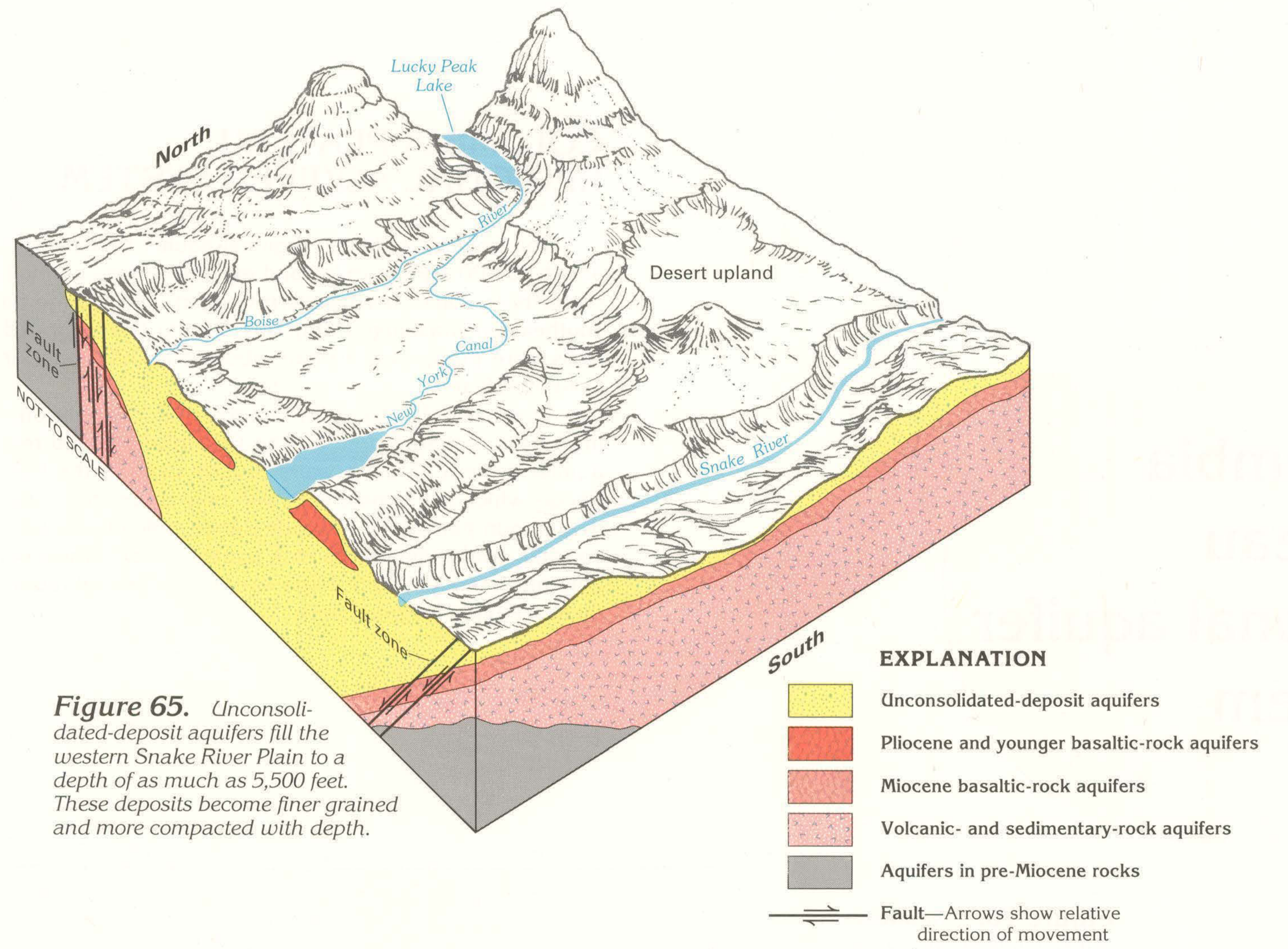


Figure 65. *Unconsolidated-deposit aquifers fill the western Snake River Plain to a depth of as much as 5,500 feet. These deposits become finer grained and more compacted with depth.*

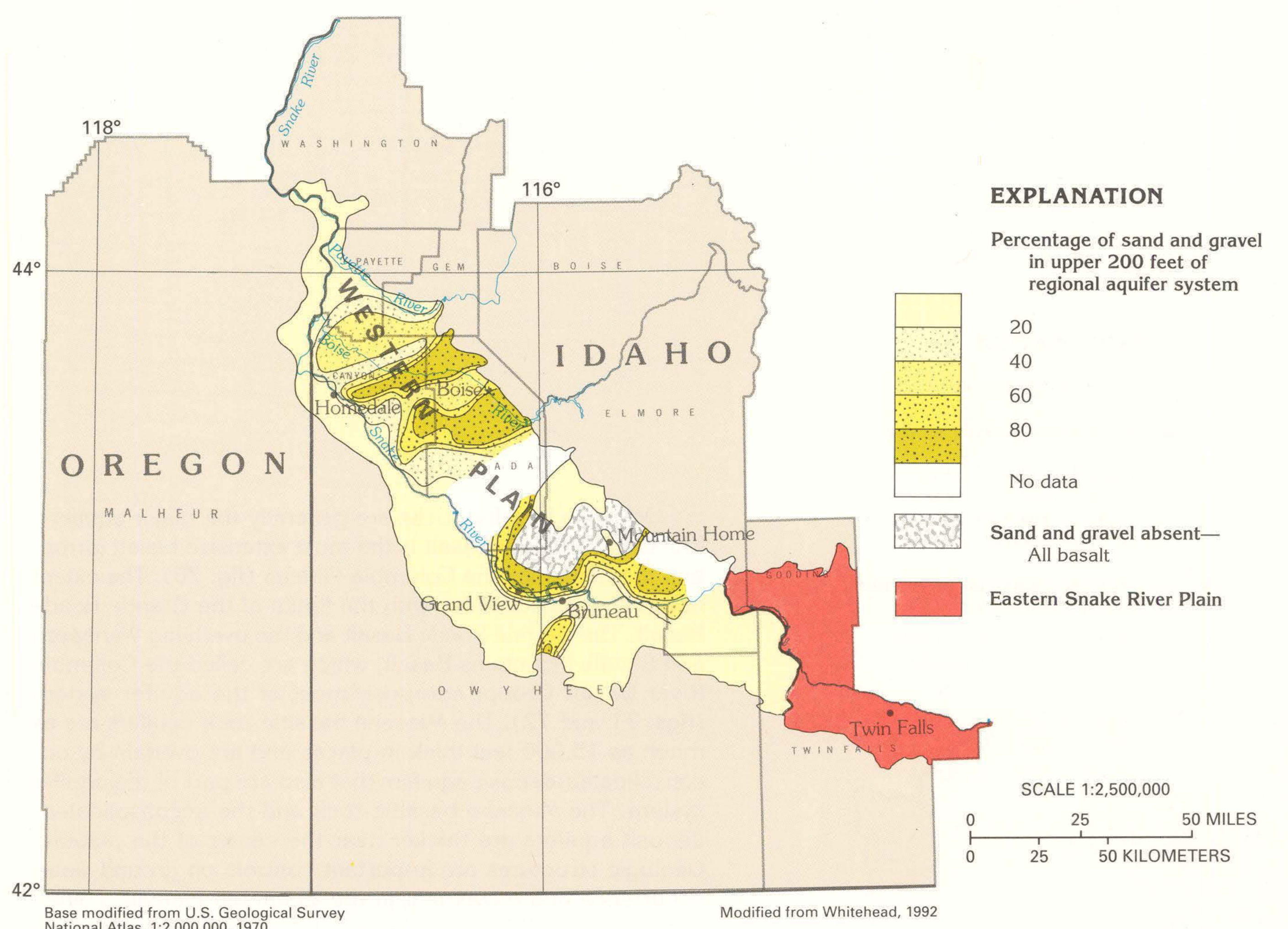


Figure 66. *The percentage of sand and gravel in the unconsolidated-deposit aquifers generally decreases southwestward toward the Snake River. The lobelike pattern of the areas where the percentage of sand and gravel exceeds 20 percent reflects ancestral drainage patterns by indicating the approximate course (along the center of the lobes) of streams that flowed across the plain from the adjacent highlands.*

A synopsis of some aspects of the ground-water system in the western plain (**fig. 66**) is presented below:

- **In Gem, Payette, and Washington Counties, Idaho,** the major stream valleys contain unconsolidated-deposit aquifers that consist of sand and gravel with varying proportions of clay. At the northwestern end of the western plain in Canyon, Gem, Payette, and Washington Counties, Idaho, and Malheur County, Oreg., the unconsolidated-deposit aquifers are finer grained than in the central part of the plain, and their permeability is low. Well yields typically range from 1 to 20 gallons per minute but are as much as 3,300 gallons per minute in places. Miocene basaltic-rock aquifers underlie the unconsolidated-deposit aquifers and, in places, supply from 1 to 20 gallons per minute of water to wells. Ground water is used mostly for some agricultural (primarily irrigation) and industrial purposes.
- **Typically, unconsolidated-deposit aquifers in northern Owyhee County, Idaho, adjacent to the Snake River** are fine grained. Therefore, some communities along the Snake River obtain their water supplies from wells north of the river in Canyon County, where unconsolidated-deposit aquifers are more permeable. Hydrogen sulfide and methane are emitted from some wells because of the organic debris in the fine-grained unconsolidated deposits. Along the southern side of the Snake River in Owyhee County, artesian wells drilled at land-surface altitudes of 2,700 feet or less usually produce free-flowing geothermal water from faulted volcanic- and sedimentary-rock aquifers. These aquifers locally are more than 2,000 feet thick, particularly in the Bruneau–Grand View area, where they are underlain by older volcanic-rock aquifers (chiefly basalt). These volcanic- and sedimentary-rock aquifers have low permeability except where they are intersected by faults. Wells that intersect major faults, most of which trend northwestward, typically have larger yields than those of wells in unfaulted areas. Some wells that once flowed have now ceased because of increased development of the volcanic- and sedimentary-rock aquifers. In the Bruneau–Grand View area, extensive ground-water development and water-level declines resulted in the State declaring this location a Ground-Water Management Area, which is an area where additional wells can be drilled only with permission if the State has determined that withdrawals from the proposed well will not lower the area's water level. Parts of southern Ada and western Elmore Counties, where most irrigation wells are completed in Pliocene and younger basaltic-rock aquifers, also have been declared Ground-Water Management Areas.

Information pertaining to ground-water conditions in the western plain is summarized by county in **table 3**.

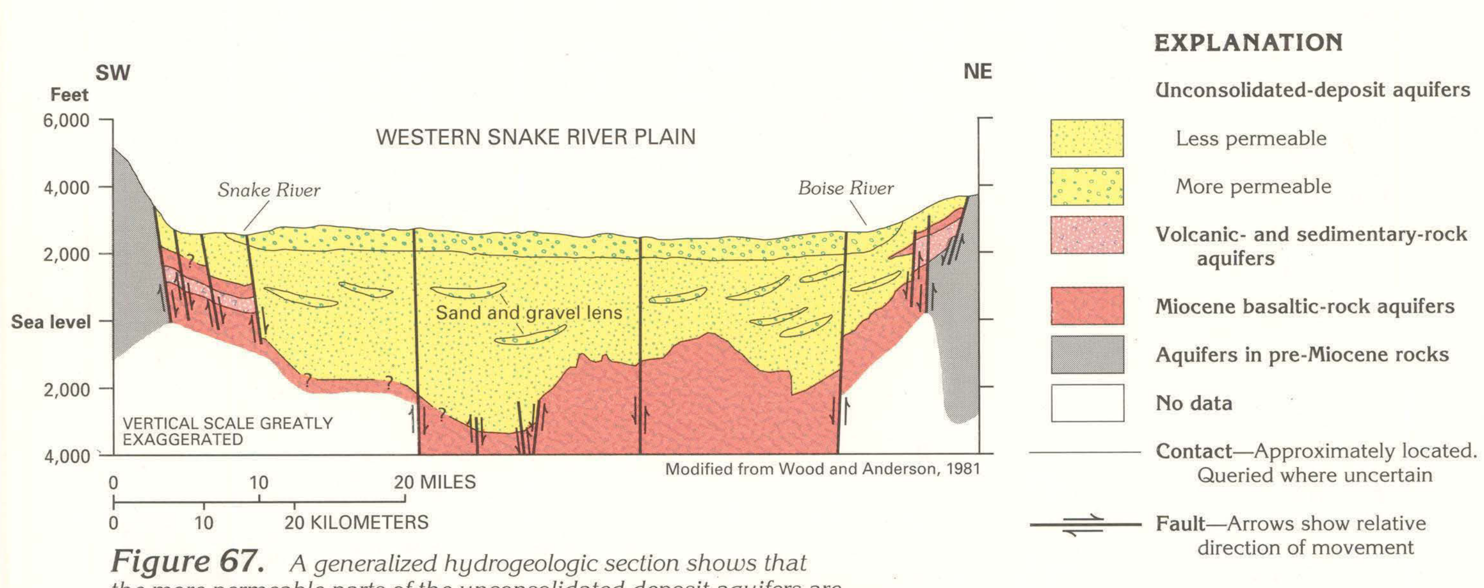


Figure 67. *A generalized hydrogeologic section shows that the more permeable parts of the unconsolidated-deposit aquifers are beds and lenses of sand and gravel. Miocene basaltic-rock aquifers that underlie the unconsolidated-deposit aquifers are known to be about 2,500 feet thick.*

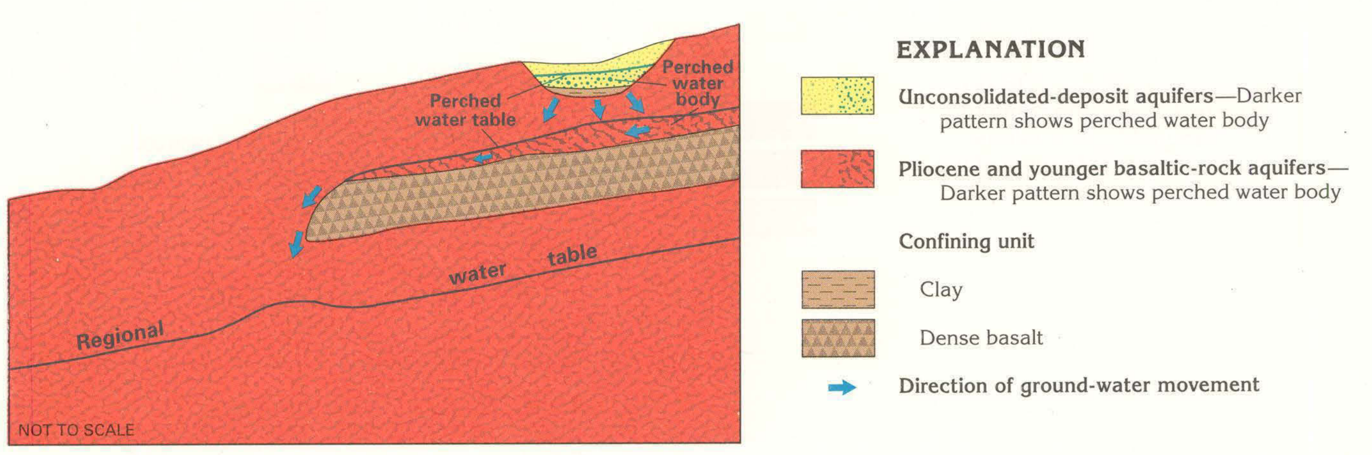


Figure 68. *Perched water cascades over the edge of confining units to move downward to the regional water table and recharge the regional aquifer system.*

Table 3. *Ground-water conditions in the western Snake River Plain*

[Aquifer: Ud, unconsolidated deposits; Ybr, Pliocene and younger basaltic rocks; Vsr, volcanic and sedimentary rocks; Obr, Miocene basaltic rocks. Water use: PS, public supply; DC, domestic and commercial; A, agricultural (primarily irrigation and livestock watering); I, industrial. Symbols: <, less than; >, greater than]

Location	Principal aquifer	Typical well depth (feet below land surface)	Depth to water (feet below land surface)	Range of well yields (gallons per minute)	Principal water use	Remarks
IDAHO						
Ada County	Ud, Ybr, Vsr				PS, DC, A, I	Vsr is aquifer for most geothermal wells.
Boise River Valley		<20–>1,100	Flowing–>600	<10–>3,800		Depth to water is greater on plateau in southern part of county.
Canyon County	Ud, Ybr				ditto	Industrial use is for food processing.
Boise River Valley		<20–>1,500	Flowing–>400	<10–3,000		
Elmore County	ditto				PS, DC, A	
Mountain Home area		<50–>1,500	>10–500	<10–5,000		
South of Snake River		400–>600	<200–400	<10–720		
Gem County	Ud				ditto	Most aquifers composed of fine-grained deposits. Small yields common.
Payette River Valley		<50–>200	Flowing–>100	<10–3,300		
Owyhee County	Ud, Ybr, Vsr, Obr				ditto	Most use is for DC and A.
Homedale to Grand View area		<50–2,000	Flowing–>405	<10–5,000		Geothermal water common.
Grand View to Bruneau area		<50–>3,000	Flowing–>200	<10–4,000		ditto
Area east of Bruneau		<150–>4,000	Flowing–>500	<10–>2,400		ditto
Payette County	Ud				ditto	Most aquifers composed of fine-grained deposits. Small yields common.
Payette River Valley		<100–600	<50–>200	<10–3,300		
Twin Falls County	Ud, Ybr, Vsr, Obr	<100–>1,500	Flowing–>400	<10–>800	PS, DC, A, I	Industrial use is for food processing. Geothermal water common near Snake River west of Twin Falls.
Washington County	Ud, Vsr, Obr	<50–>400	Flowing–>100	<10–100	PS, DC, A	Depth to water commonly less than 50 feet. Small yields common.
OREGON						
Malheur County	Ud	<50–1,300	<10–>500	<10–900	ditto	

Columbia Plateau regional aquifer system

COLUMBIA PLATEAU REGIONAL AQUIFER SYSTEM

The Columbia Plateau regional aquifer system occupies about 50,600 square miles and extends across a small part of northern Idaho, northeastern Oregon, and a large part of southeastern Washington (**fig. 69**). During 1984, about 3,500 wells were pumped to irrigate about 500,000 acres on the Columbia Plateau.

The Cascade Range in Oregon and Washington is an important recharge area for the Columbia Plateau regional aquifer system. Ground water is little used in the Cascade Range, which is a remote area with only sparse population. In the Oregon part of the Cascade Range, volcanic rocks of the volcanic- and sedimentary-rock aquifer are extremely permeable and readily accept large volumes of precipitation that recharge underlying aquifers.

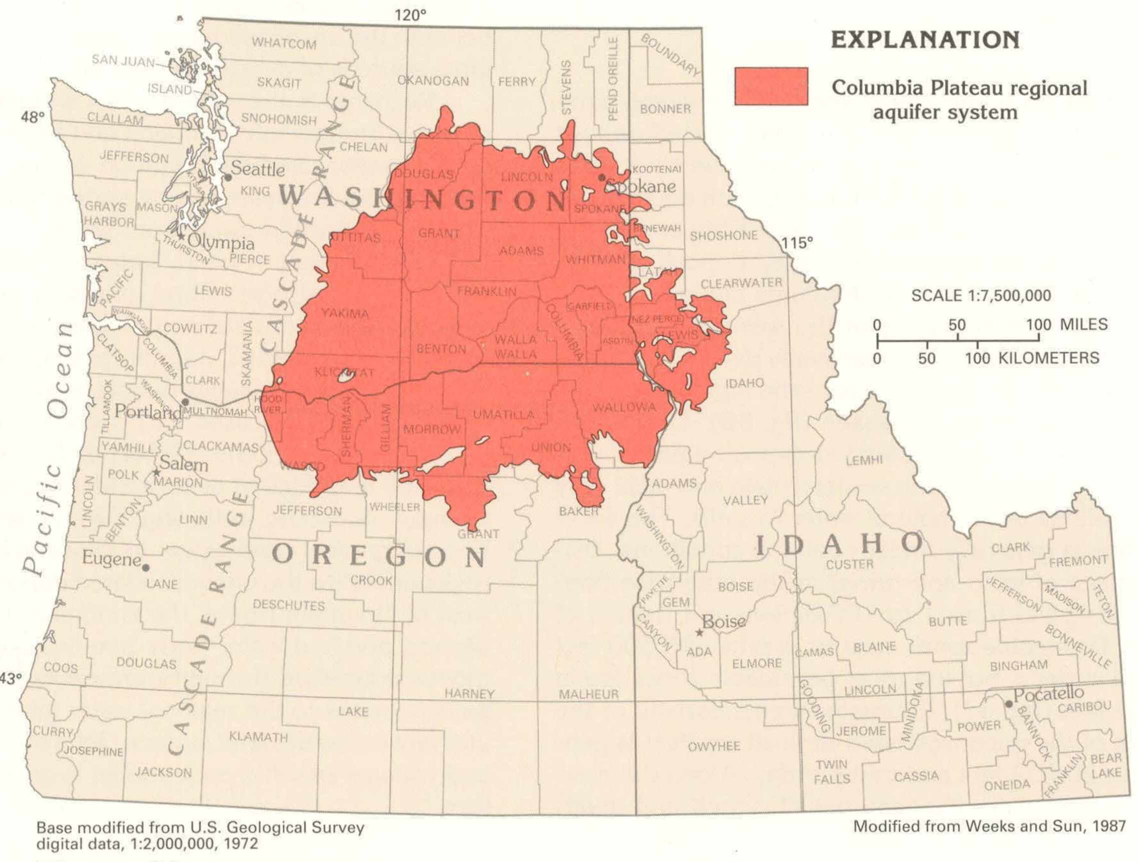
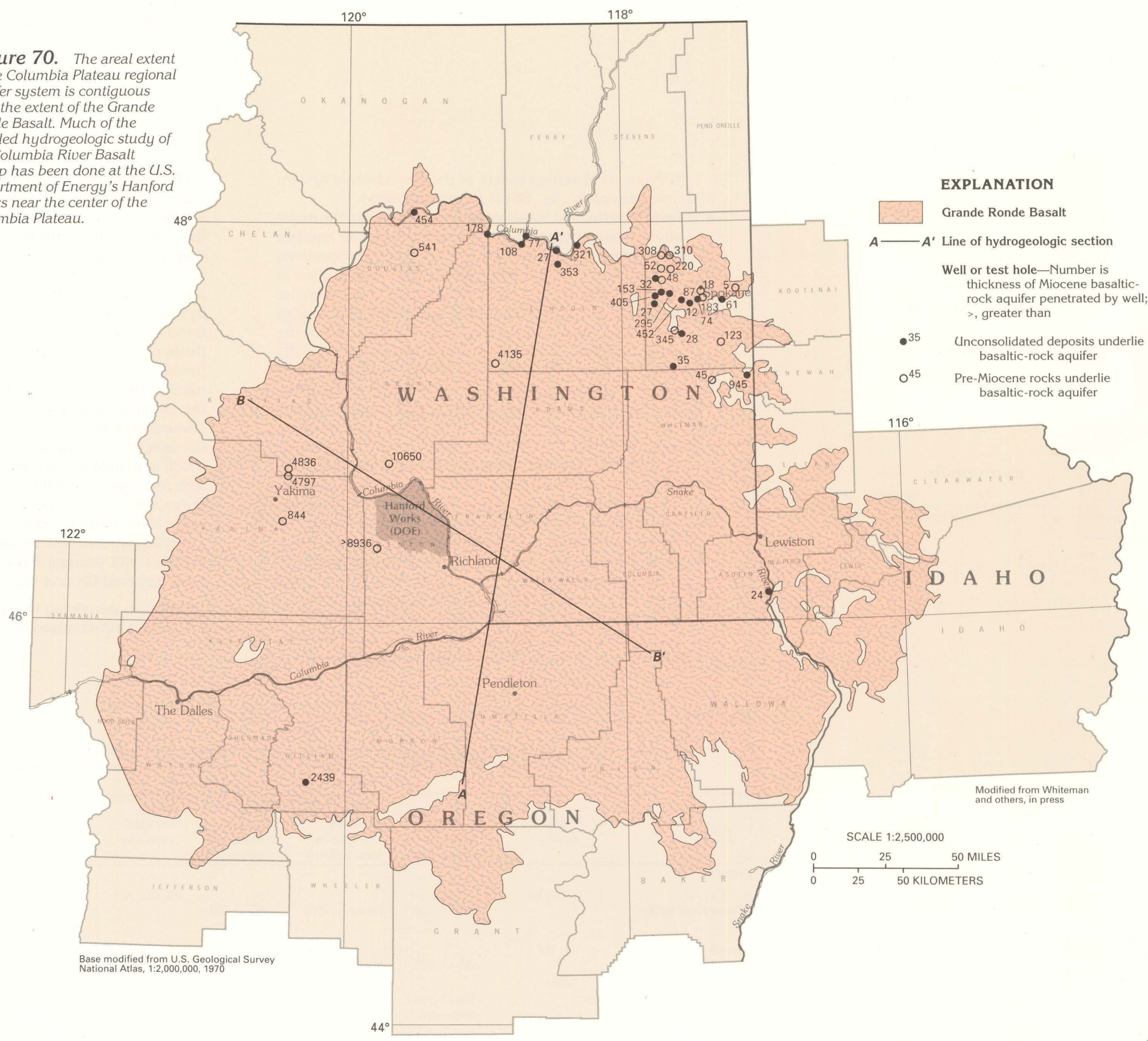


Figure 69. The Columbia Plateau is a large, approximately circular plateau underlain primarily by Miocene basaltic rocks.

Figure 70. The areal extent of the Columbia Plateau regional aquifer system is contiguous with the extent of the Grande Ronde Basalt. Much of the detailed hydrogeologic study of the Columbia River Basalt Group has been done at the U.S. Department of Energy's Hanford Works near the center of the Columbia Plateau.



Miocene basaltic rocks are generally the major aquifers. The Grande Ronde Basalt is the most extensive basalt formation that underlies the Columbia Plateau (**fig. 70**). The extent of the plateau coincides with the limits of the Grande Ronde Basalt. The Grande Ronde Basalt and the overlying Wanapum and Saddle Mountains Basalt, which are called the Columbia River Basalt Group, compose most of the aquifer system (**figs. 71 and 72**). The Miocene basaltic-rock aquifers are as much as 15,000 feet thick in places and are overlain by unconsolidated-deposit aquifers that also are part of the aquifer system. The Miocene basaltic-rock and the unconsolidated-deposit aquifers are thicker near the center of the plateau. Geologic structures are important controls on ground-water occurrence and movement in the Columbia Plateau. Folded and subsequently eroded layers of rock crop out in upland areas where water enters the aquifer system; the water then moves downgradient along permeable zones. In places, tight folds or faults or both and gently dipping layers of rock sloping opposite to the direction of ground-water movement can impede the movement of ground water. The general movement of water in the aquifer system is from recharge areas near the edges of the plateau toward regional drains, such as the Columbia River (**fig. 73**).

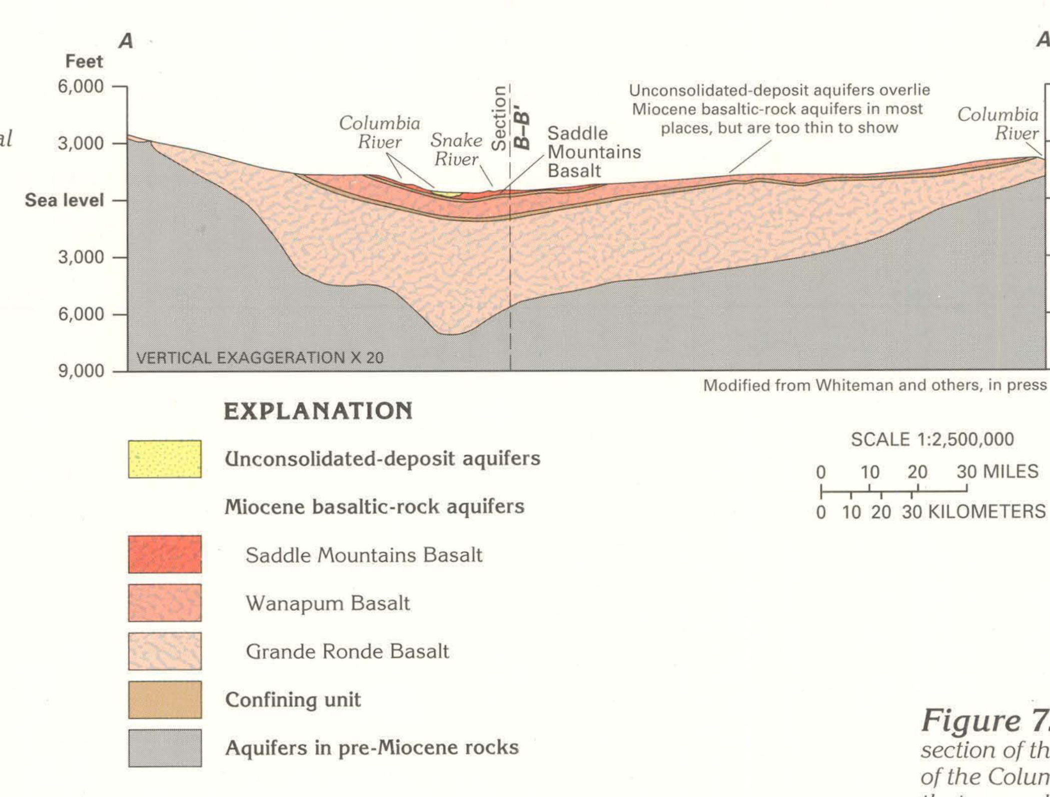


Figure 71. Unconsolidated-deposit aquifers thin markedly away from the central part of the Columbia Plateau and are thin throughout much of the plateau. The line of the section is shown in figure 70.

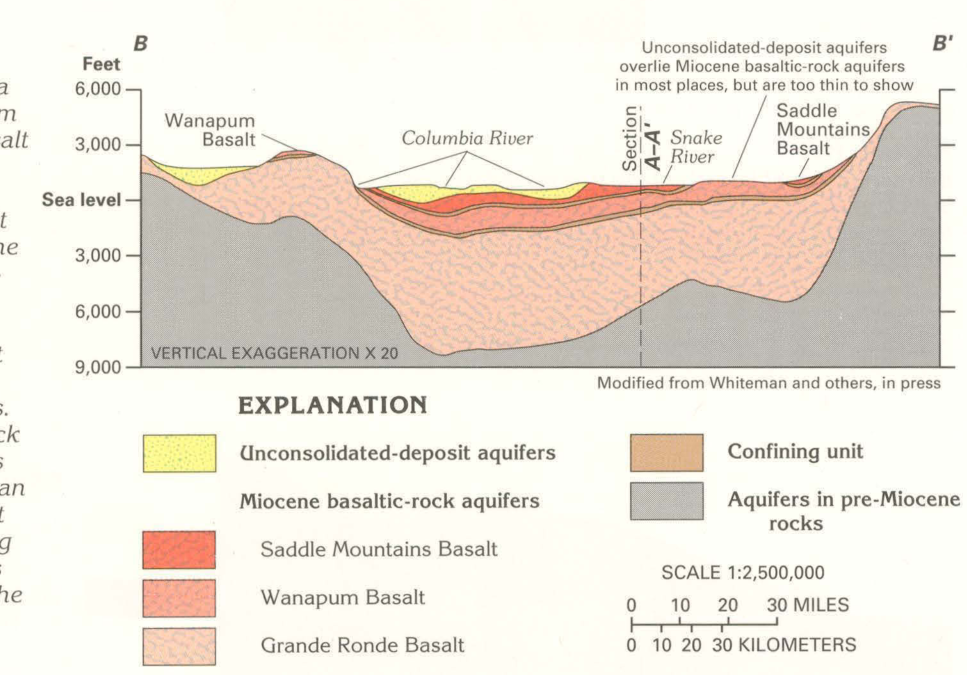


Figure 72. The Columbia Plateau regional aquifer system consists primarily of three basalt formations separated by confining units. Unconsolidated deposits that overlie the basalt formations also are a part of the aquifer system. The unconsolidated-deposit aquifers are a principal source of water for many wells and locally might be more permeable than the Miocene basaltic-rock aquifers. Collectively, however, the thick Miocene basaltic-rock aquifers generally yield more water than do the unconsolidated-deposit aquifers. Locally, the confining units can yield small volumes of water to wells. The line of the section is shown in figure 70.

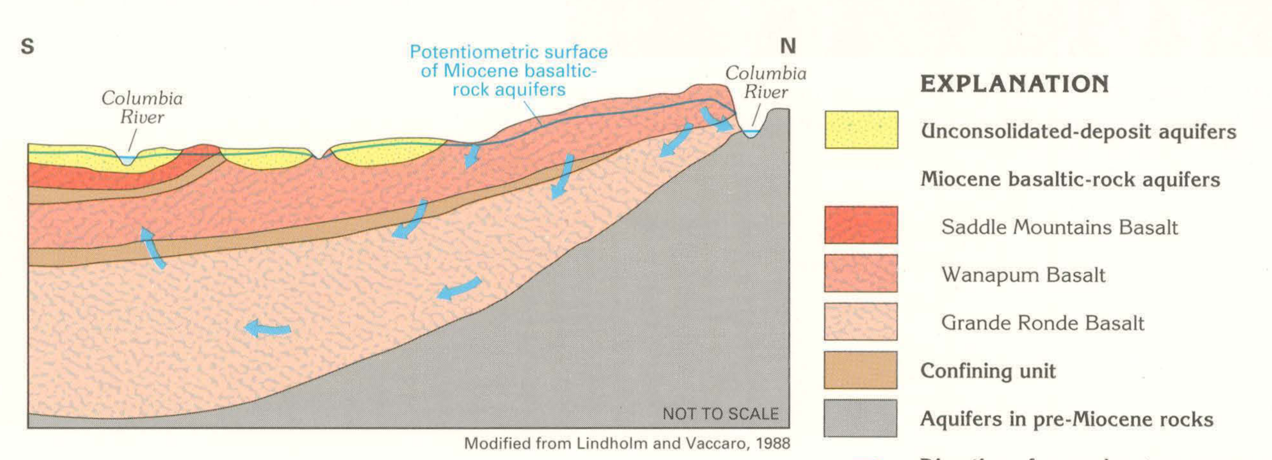


Figure 73. A generalized section of the northwestern part of the Columbia Plateau shows that ground-water flow through the Miocene basaltic-rock aquifers generally is toward the Columbia River from recharge areas near the boundaries of the plateau. Ground water moves through the confining units that separate the aquifers but at a slower rate than through the aquifers.

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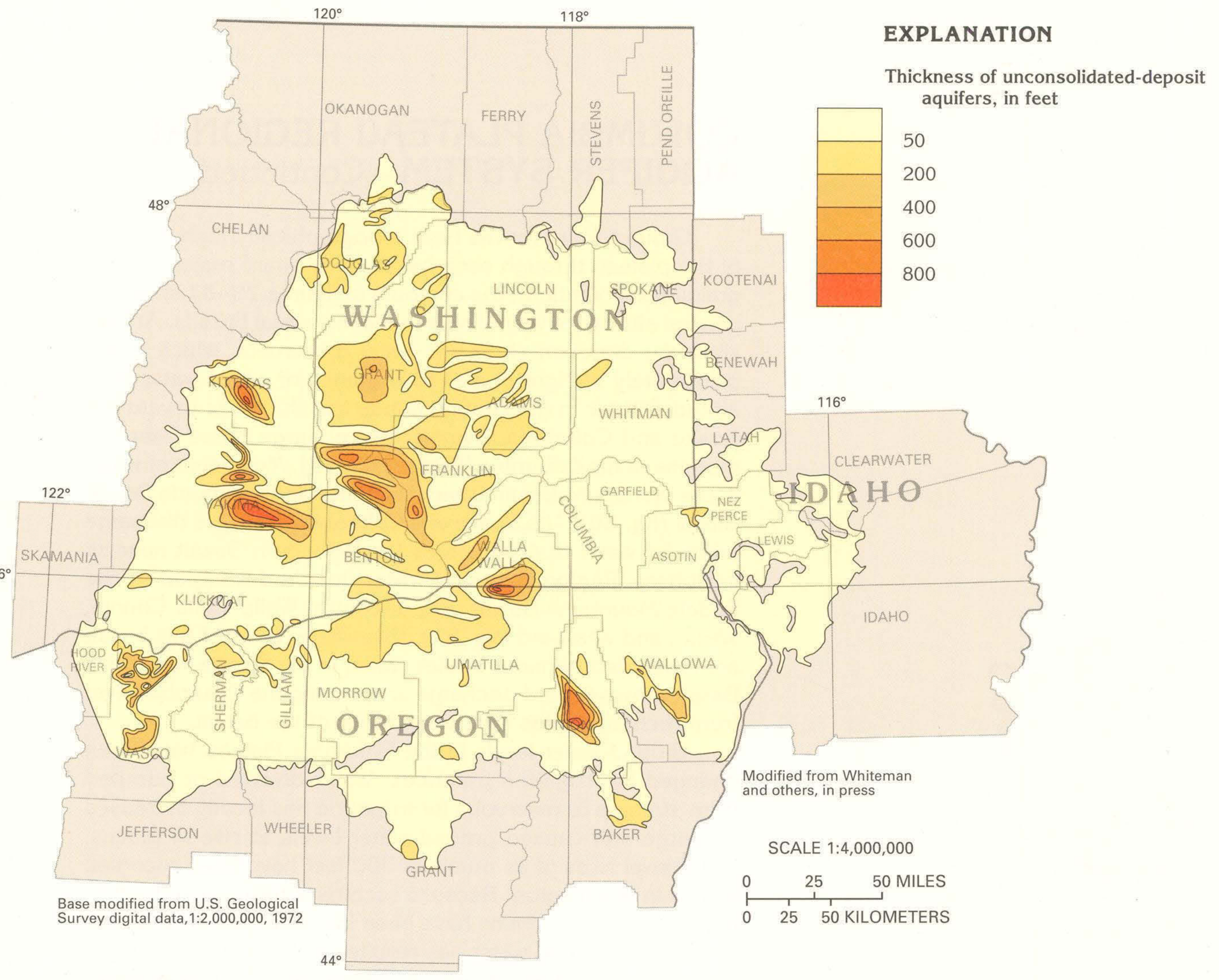


Figure 74. *In places, the thickness of unconsolidated-deposit aquifers exceeds 800 feet and can be as much as 2,000 feet. The unconsolidated deposits generally are not saturated where they are less than 50 feet thick, especially in the eastern half of the Columbia Plateau where the materials consist mostly of loess.*

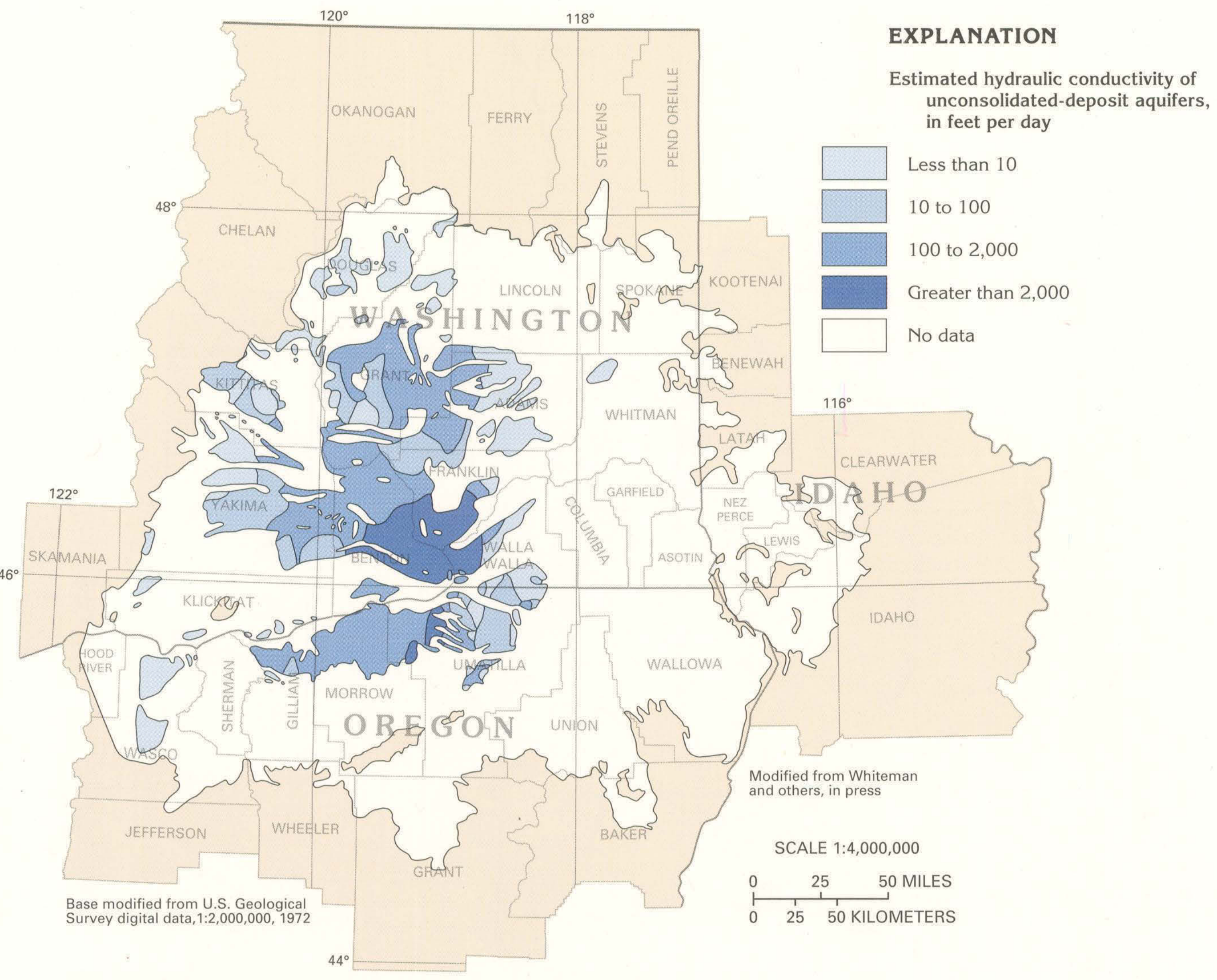


Figure 75. *The estimated hydraulic conductivity of the unconsolidated-deposit aquifers varies considerably. Hydraulic conductivity multiplied by the thickness of the aquifers equals the transmissivity of the aquifers. The estimated transmissivity of the unconsolidated-deposit aquifers ranges from 40 to 300,000 feet squared per day with a median of 12,000 feet squared per day.*

In places, unconsolidated-deposit aquifers are more important aquifers than are the Miocene basaltic-rock aquifers. The thickness of the unconsolidated-deposit aquifers exceeds 200 feet in many areas (**fig. 74**) and is locally more than 800 feet (as much as 2,000 feet in places). The estimated hydraulic conductivity of these aquifers (**fig. 75**) is extremely variable but is large enough in places so that the aquifers are productive, especially where they are thick.

Individual basalt flows in the Columbia River Basalt Group range from a few tens of feet to about 300 feet in thickness and average about 100 feet. Some thick flows that are exposed in canyons and road cuts display extensive fracture patterns owing to differential rates of cooling. The tops and the bottoms of flows typically are permeable because of rubble zones, vesicles, and fractures. Some of these open spaces, however, are filled with clay minerals that decrease permeability. The central parts of most flows are dense and almost impermeable. Openings that have been caused by minor vertical cooling fractures might provide some permeability in the central part of the flows.

Wells that are deep enough to penetrate several interflow zones in the Miocene basaltic-rock aquifers can yield large volumes of water; however, wells commonly need to be drilled several hundred feet deeper than the top of the saturated zone to obtain a desired yield. Expected yields of Miocene basaltic-rock aquifers are about 1.5 gallons per minute for each foot of saturated material penetrated. Unconsolidated-deposit aquifers (chiefly glacial outwash) yield as much as 0.5 gallon per minute for each foot of saturated material penetrated.

On the basis of rock geochemical differences and sedimentary interbeds, the Columbia River Basalt Group sequence has been divided, from oldest to youngest, into three main units: the Grande Ronde Basalt, the Wanapum Basalt, and the Saddle Mountains Basalt. The Grande Ronde Basalt, which is the thickest, contains as many as 131 flows; the Wanapum Basalt, as many as 33 flows; and the Saddle Mountains Basalt, as many as 14 flows. Interbeds separate the three basalt formations (**figs. 71 and 72**). Interbedded unconsolidated deposits are more prevalent near the eastern margin of the plateau (**fig. 76**). In the east-central parts of the plateau, the basalt sequence is relatively free of interbedded unconsolidated deposits, except for the interbed that separates the Wanapum Basalt and the Grande Ronde Basalt. This interbed is present throughout much of the plateau. In most places, the interbeds are confining units. The bedrock that underlies the Columbia River Basalt Group consists of pre-Miocene igneous, metamorphic, and consolidated sedimentary rocks.

The extent of the Grande Ronde Basalt is shown in **figure 70**. Its thickness is known at only a few places, mostly near the edges of the plateau.

The Wanapum Basalt, which extends over almost as much area as the Grande Ronde Basalt, is much thinner (**fig. 77**). In a few places, the Wanapum Basalt is more than 1,000 feet thick.

The Saddle Mountains Basalt is much thinner and extends over a much smaller area than either the Wanapum or the Grande Ronde Basalts (**fig. 78**). In a few small areas, the Saddle Mountains Basalt is more than 800 feet thick.

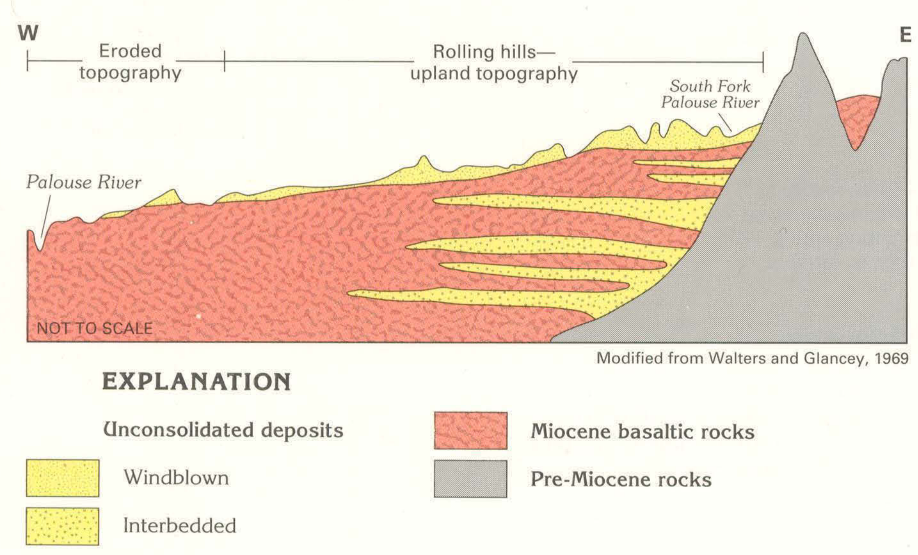


Figure 76. *A generalized section near the eastern margin of the Columbia Plateau shows that the Miocene basaltic rocks contain numerous interbeds of unconsolidated deposits.*

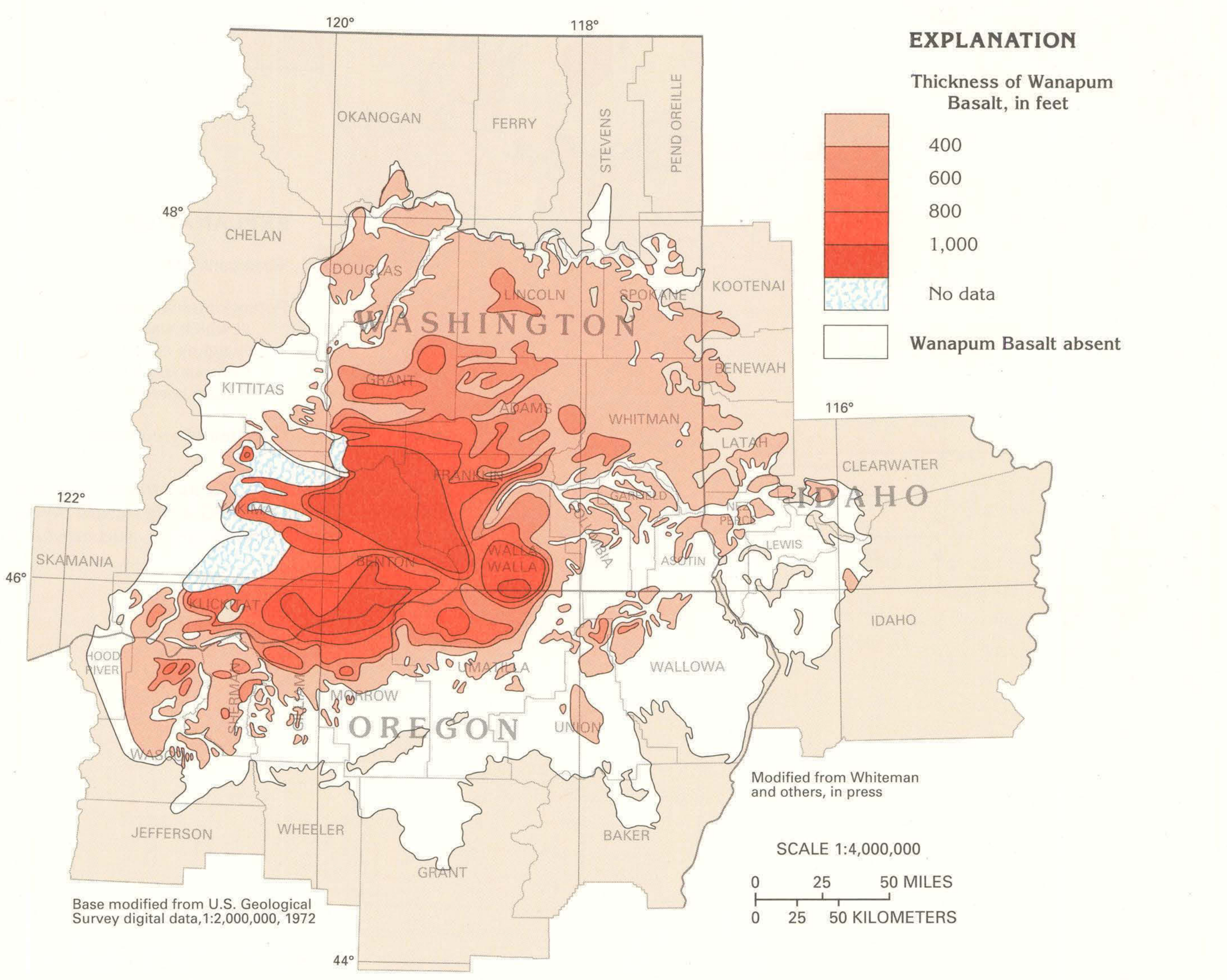


Figure 77. *The Wanapum Basalt is thickest in the central part of the Columbia Plateau.*

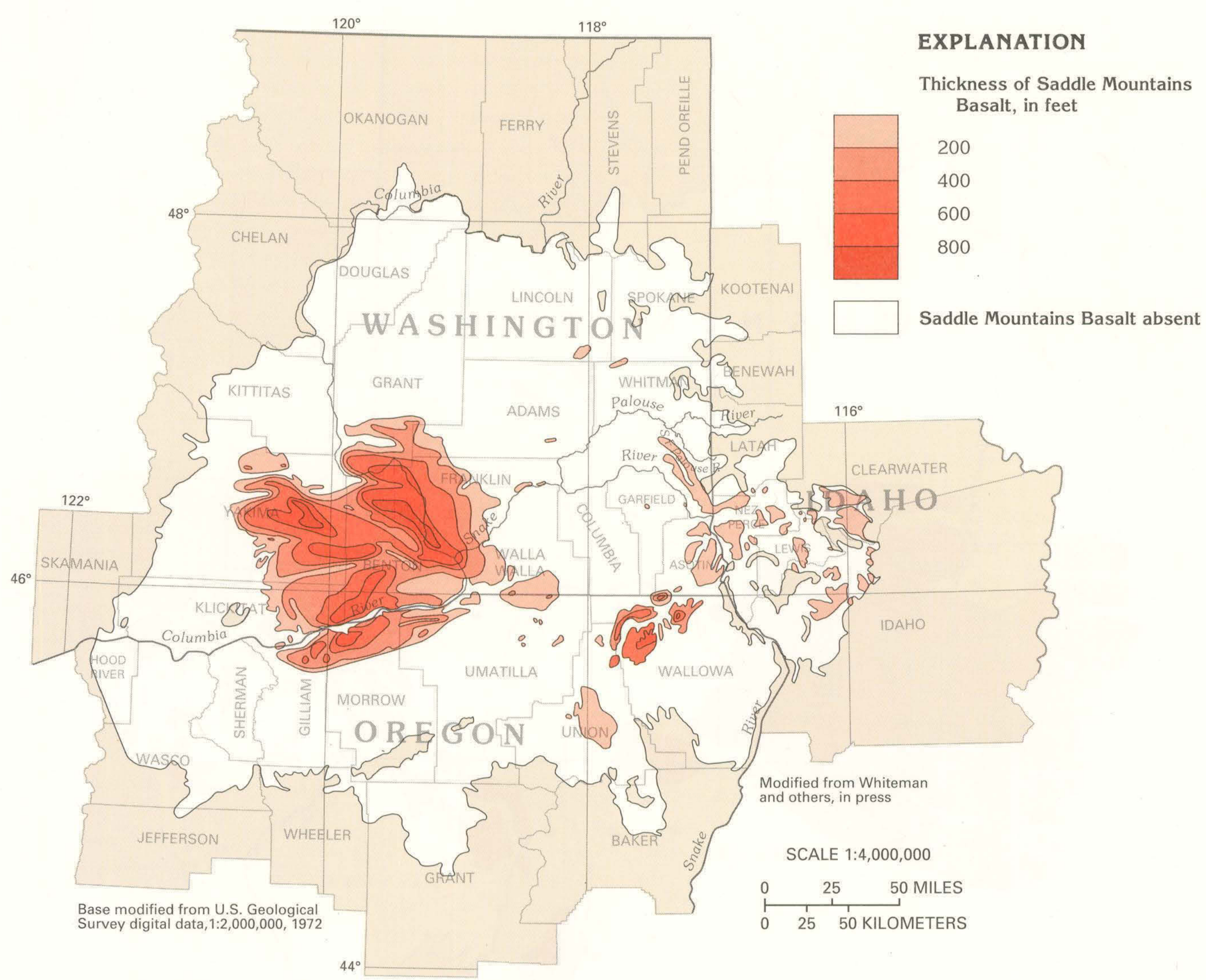
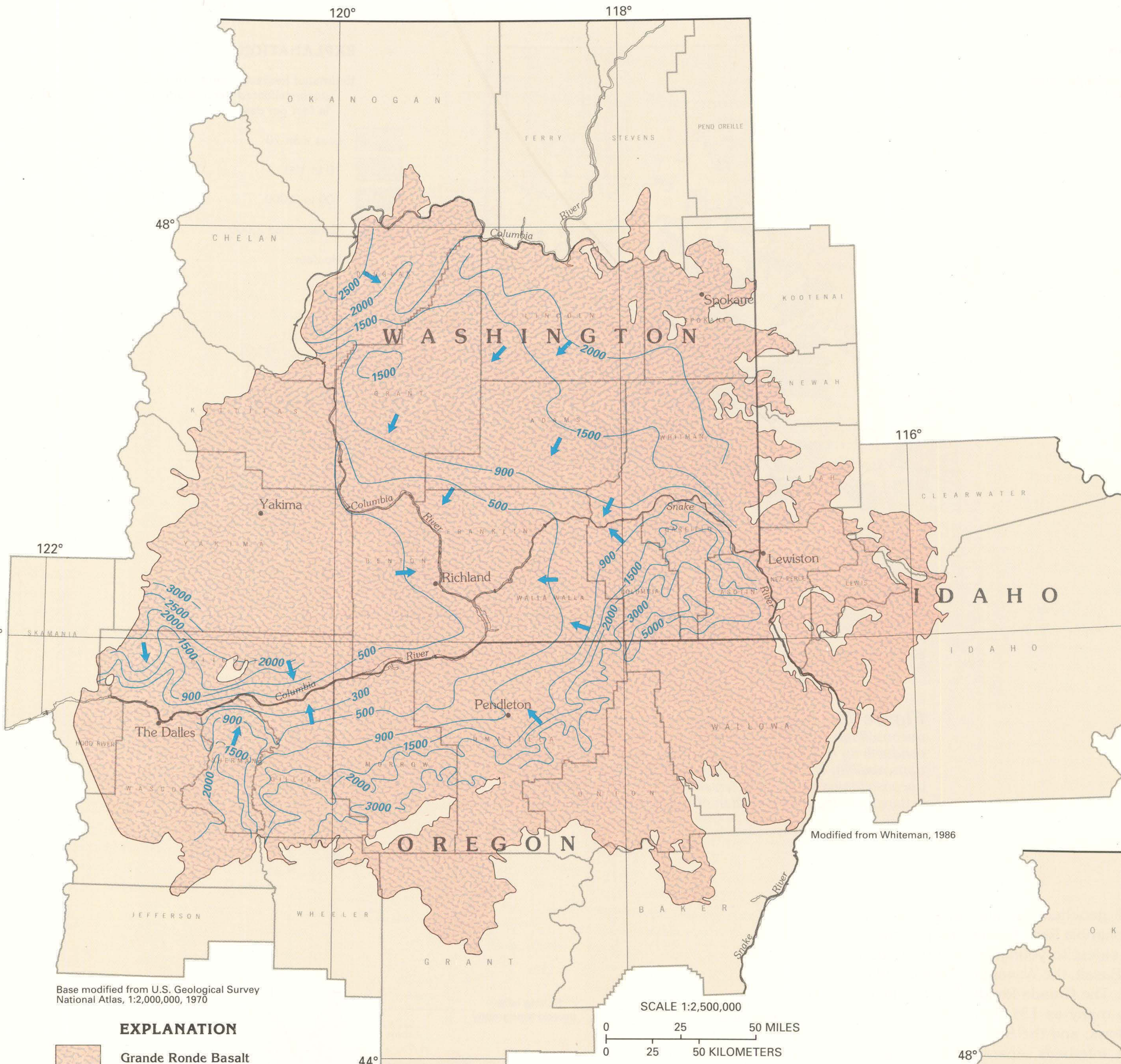


Figure 78. *The extent and thickness of the Saddle Mountains Basalt are considerably less than those of the Wanapum and Grande Ronde Basalts.*

COLUMBIA PLATEAU REGIONAL AQUIFER SYSTEM—Continued

Ground water moves from topographically high margins of the plateau through each basalt unit toward major surface drainages. Potentiometric contours in **figures 79–81** show the general altitude of water levels in the individual basalts. Arrows show the direction of ground-water movement, which is approximately at right angles to the lines of equal water-level altitude. Water in the Grande Ronde Basalt moves toward the Snake and Columbia Rivers from recharge areas near the margins of the Columbia Plateau (**fig. 79**). Movement of water in the Wanapum Basalt is similar to that in the Grande Ronde Basalt (**fig. 80**). The Snake and Columbia Rivers are discharge areas for water that recharges the Wanapum Basalt near its periphery. Regional ground-water flow is developed in the Saddle Mountains Basalt only in central Walla Walla County, Wash., and westward (**fig. 81**). Elsewhere, flows of this basalt are local, discontinuous bodies. Water in the Saddle Mountains Basalt moves toward discharge areas along the Columbia River from recharge areas near boundaries of the basalt.

Ground-water levels in the Columbia Plateau have been changed by irrigation practices. Water diverted or pumped from streams or reservoirs for irrigation has locally increased recharge and caused ground-water levels to rise in places. Water-level rises of as much as 300 feet have been recorded locally in Washington. Because such rises have caused water-logging in places, drains have been installed. Conversely, irrigation with ground water has resulted in local water-level declines of as much as 300 feet in Oregon and 150 feet in Washington.



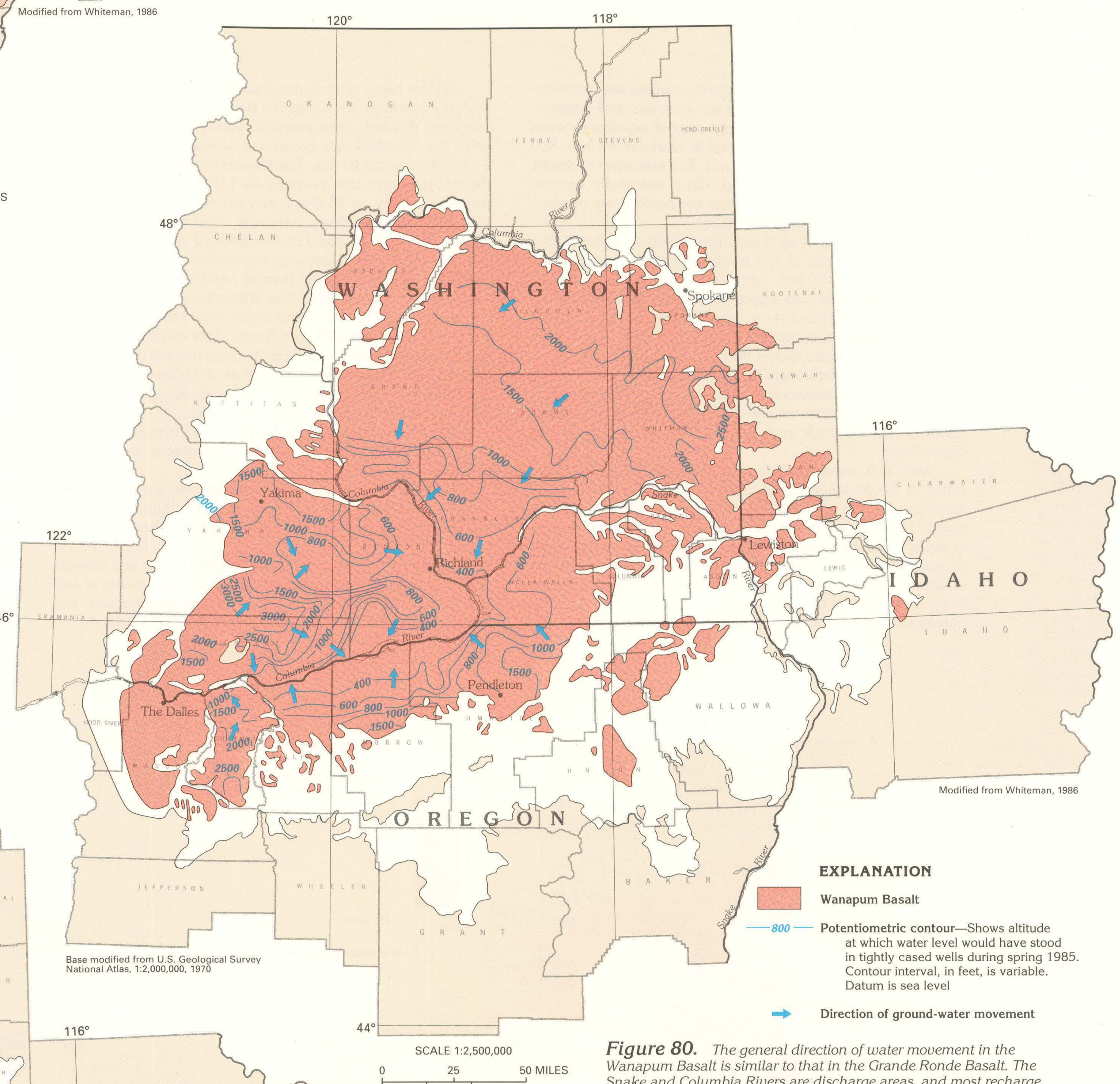
EXPLANATION

Grande Ronde Basalt

900 — **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells during spring 1985. Contour interval, in feet, is variable. Datum is sea level

Direction of ground-water movement

Figure 79. *Potentiometric contours show that the general direction of water movement in the Grande Ronde Basalt is from recharge areas near the boundary of the Columbia Plateau regional aquifer system toward the Snake and Columbia Rivers.*



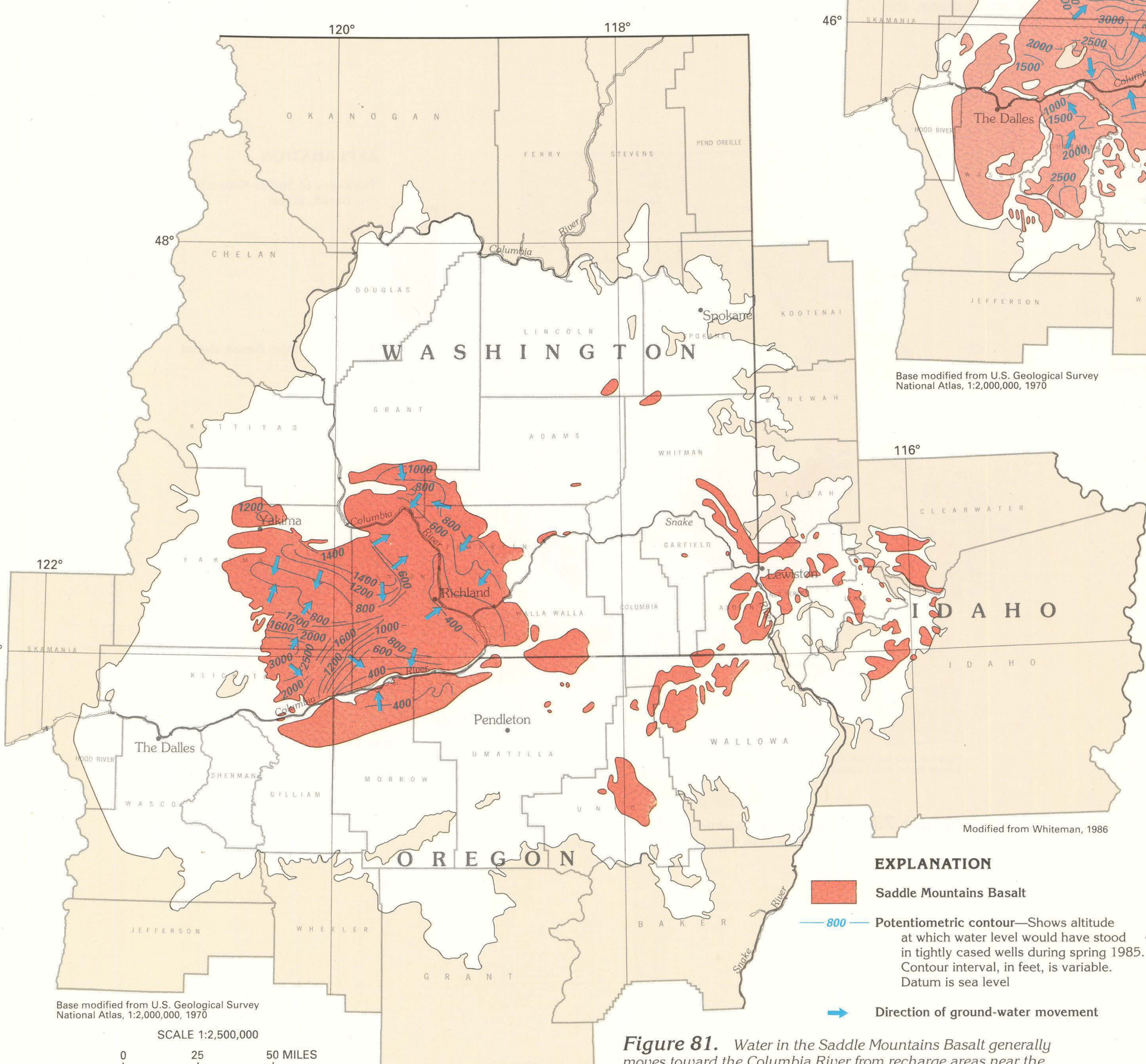
EXPLANATION

Wanapum Basalt

800 — **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells during spring 1985. Contour interval, in feet, is variable. Datum is sea level

Direction of ground-water movement

Figure 80. *The general direction of water movement in the Wanapum Basalt is similar to that in the Grande Ronde Basalt. The Snake and Columbia Rivers are discharge areas, and most recharge is near the boundary of the basalt.*



EXPLANATION

Saddle Mountains Basalt

800 — **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells during spring 1985. Contour interval, in feet, is variable. Datum is sea level

Direction of ground-water movement

Figure 81. *Water in the Saddle Mountains Basalt generally moves toward the Columbia River from recharge areas near the boundary of the basalt in the central part of the Columbia Plateau.*

A synopsis of some aspects of the ground-water system in the Columbia Plateau area (**fig. 82**) is presented below:

- **The principal unconsolidated-deposit aquifer in Spokane County, Wash.,** is composed of glacial outwash filling a preglacial valley. The deposits are coarse sand and gravel that are as much as 880 feet thick. Yields of as much as 5,000 gallons per minute have been obtained from some wells north of Spokane, Wash.; one well reportedly yielded 19,000 gallons per minute. Near the junction of Chemokane Creek and Spokane River, clay is mixed with the sand and gravel, and well yields range from 100 to 500 gallons per minute. Southwest of Spokane, the Miocene basaltic rocks constitute important aquifers.
- **In Latah County, Idaho, and Whitman County, Wash.,** Miocene basaltic-rock aquifers supply water for Moscow, Idaho, and Pullman, Wash. Some wells that are as much as 1,400 feet deep yield as much as 1,500 gallons per minute. Many of the wells flowed initially, but extensive pumping since the early 1920's has caused the hydraulic head to decline, and these wells no longer flow. Some wells near the town of Colfax, Wash., and in other parts of the area, however, still flow; about 6 miles northeast of Colfax, a 106-foot-deep municipal well flowed 1,550 gallons per minute when drilled in 1927. Since then, the hydraulic head in this area has declined, and the flow rate of the well has decreased substantially.
- **Near Odessa and Lind in Lincoln and Adams Counties, Wash.,** ground water is used extensively for irrigation. Wells completed in the Miocene basaltic-rock aquifers yield from 150 to 3,800 gallons per minute, except near basin margins where the basalt thins and well yields are smaller.
- **In the Quincy Basin in Grant County, Wash.,** unconsolidated deposits that are as much as 1,000 feet thick yield as much as 3,200 gallons per minute to wells for public-supply, domestic and commercial, and agricultural (primarily irrigation) purposes. Miocene basaltic rocks that underlie the unconsolidated deposits yield as much as 4,800 gallons per minute. Unconsolidated-deposit aquifers (primarily sand and gravel) along the Columbia River in the southern part of Grant County yield as much as 1,800 gallons per minute to wells.
- **Near Pasco in Franklin County, Wash.,** unconsolidated-deposit aquifers yield as much as 3,900 gallons per minute to wells where the aquifers are mostly sand. Commonly, however, well yields are much less where the clay content is greater.
- **In the Ellensburg Basin in Kittitas County, Wash.,** unconsolidated deposits that are as much as 1,000 feet thick yield as much as 3,200 gallons per minute to wells for public-supply, domestic and commercial, and agricultural (primarily irrigation) purposes. Miocene basaltic rocks that underlie the unconsolidated deposits yield as much as 4,800 gallons per minute.

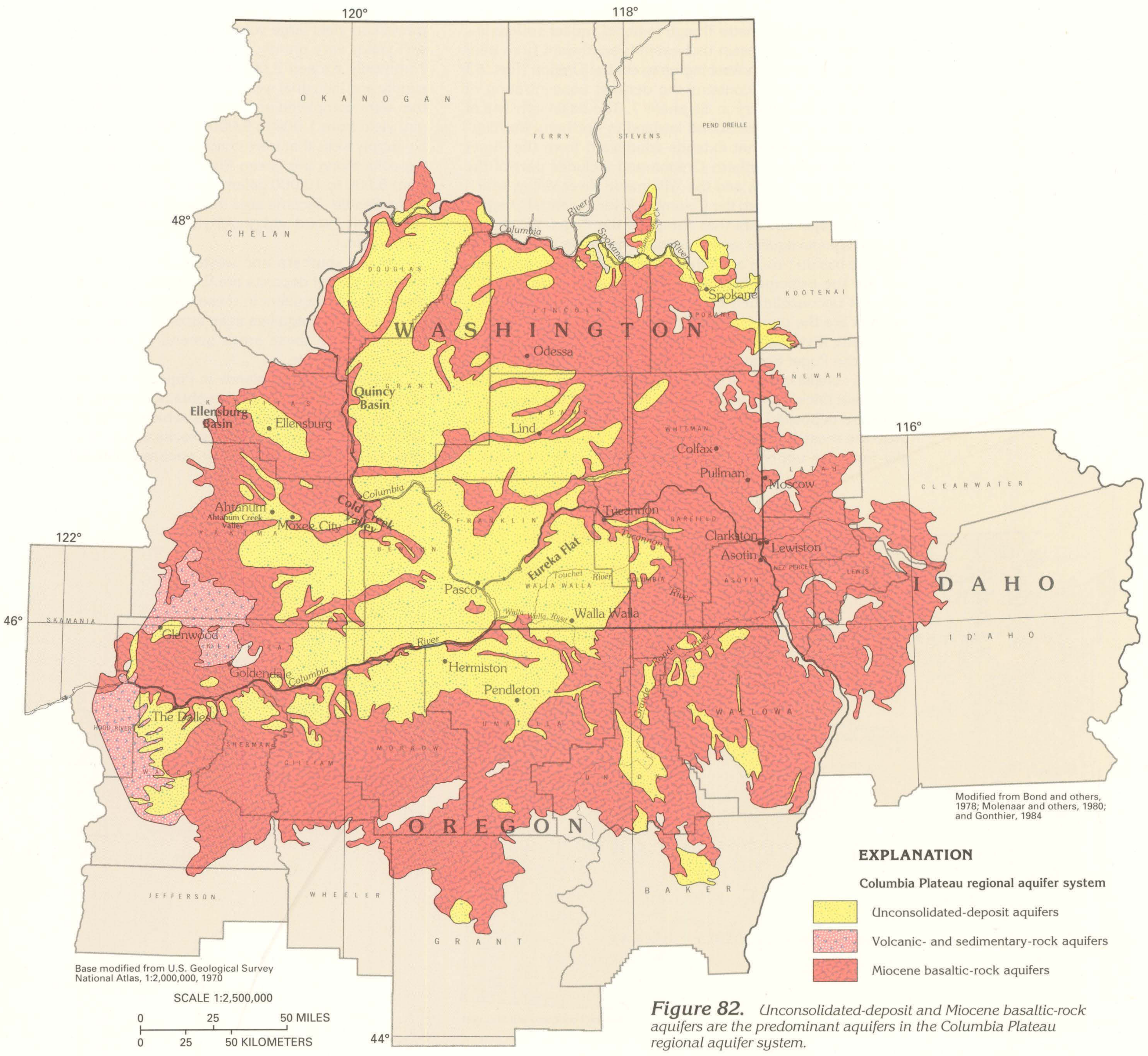


Figure 82. *Unconsolidated-deposit and Miocene basaltic-rock aquifers are the predominant aquifers in the Columbia Plateau regional aquifer system.*

- **In Yakima County, Wash.,** unconsolidated-deposit aquifers that are greater than 800 feet thick and that underlie Miocene basaltic-rock aquifers provide water for public-supply, domestic and commercial, agricultural (primarily irrigation), and industrial purposes. In Ahtanum Creek Valley, a 2,760-foot-deep artesian well flowed 2,000 gallons per minute when drilled years ago. Near Moxee City, wells that range from 900 to 1,320 feet deep yield from 200 to 875 gallons per minute.
- **Artesian wells are common in parts of Kittitas and Yakima Counties, Wash.** Flows from 600- to 1,300-foot-deep wells that are completed in Miocene basaltic-rock aquifers range from 300 to about 2,000 gallons per minute. Such flows are not obtained everywhere because the permeability of the aquifers varies greatly.
- **In Klickitat County, near Glenwood, Wash.,** wells that are less than 160 feet deep and that are completed in unconsolidated deposits yield as much as 500 gallons per minute. Near Goldendale, in the same county, some wells that range from 100 to 1,100 feet deep and that are completed in Miocene basaltic rocks yield as much as 1,500 gallons per minute.
- **In the southern part of Benton County and the eastern part of Klickitat County, Wash.,** unconsolidated deposits and Miocene basaltic rocks are aquifers; the Miocene basaltic rocks are the major aquifers. Several irrigation wells that range from 200 to 1,000 feet deep have artesian flows of 2,000 to 4,000 gallons per minute. Near the Columbia River in Benton County, yields of 50 to 1,000 gallons per minute are obtained from 30- to 50-foot-deep wells that are completed in unconsolidated deposits. Elsewhere, yields of 10 to 200 gallons per minute are common from 150- to 1,100-foot-deep wells that are completed in Miocene basaltic rocks.
- **In Columbia and Walla Walla Counties, Wash.,** unconsolidated deposits as much as 800 feet deep fill basins such as the Walla Walla River Valley. In the vicinity of the city of Walla Walla, these deposits (primarily sand and gravel) yield as much as 1,000 gallons per minute to wells. Unconsolidated-deposit aquifers along the Touchet and the Tucannon Rivers are much less productive, but yields might be adequate for domestic use and local irrigation supplies. The unconsolidated deposits are underlain by Miocene basaltic rocks. Wells that were completed at depths of 100 to 2,000 feet in the Miocene basaltic rocks are used for public-supply, agricultural (primarily irrigation), and industrial purposes; yields range from 30 to 3,000 gallons per minute. When drilled in 1945, some wells flowed; since then, however, flows have decreased greatly or have ceased. Depth to water beneath Eureka Flat ranges from 500 to 1,000 feet below land surface, and well yields are commonly less than 15 gallons per minute.
- **Aquifers in the eastern part of the Columbia Plateau in Idaho** generally are discontinuous and isolated. Demand for ground water usually is limited to domestic and commercial or small public supplies in lowland areas. Wells in Nez Perce County, Idaho, yield from 1 to 2,000 gallons per minute of water, although small yields are more common. The most intensive ground-water development in Nez Perce County, Idaho, and Asotin County, Wash., is near the towns of Lewiston, Idaho, and Asotin and Clarkston, Wash. Wells withdraw water for public-supply, domestic and commercial, agricultural, and industrial purposes. Water-resource development in the remainder of the area is sparse because of rugged topography and small population.
- **Ground-water development is extensive in much of the area from near The Dalles, Oreg., eastward to Pendleton, Oreg.,** where unconsolidated deposits (primarily sand and gravel) and Miocene basaltic rocks are aquifers. The sand and gravel is as much as 600 feet thick. Rapid water-level declines in The Dalles area prompted the State of Oregon to designate it a Critical Ground-Water Area during 1959. Intensive pumping of artesian aquifers for irrigation near Pendleton has resulted in hydraulic head declines of 2 to 5 feet per year since 1966.
- **Unconsolidated deposits fill the broad Grande Ronde Valley in Union County, Oreg.,** to depths of as much as 2,000 feet. Typically, the deposits are fine grained near the center of the valley and coarser near the valley margins. The deposits are underlain by basalt.

Information pertaining to ground-water conditions in the Columbia Plateau is summarized by county in **table 4**.

Table 4. *Ground-water conditions in the Columbia Plateau*

[Aquifer: Ud, unconsolidated deposits; Vsr, volcanic and sedimentary rocks; Obr, Miocene basaltic rocks. Water use: PS, public supply; DC, domestic and commercial; A, agricultural (primarily irrigation and livestock watering); I, industrial. Symbols: n.d., no data available; <, less than; >, greater than]

Location	Principal aquifer	Typical well depth (feet below land surface)	Depth to water (feet below land surface)	Range of well yields (gallons per minute)	Principal water use	Remarks
IDAHO						
Benewah County	Ud, Obr	<50->200	<10-50	1-500	PS, DC	
Clearwater County	ditto	n.d.	n.d.	1-500	DC, A, I	
Idaho County	ditto	<100->700	<10-300	<20-2,000	PS, DC, A	Small yields common.
Kootenai County	ditto	<200-480	<100->470	1->2,000	ditto	
Latah County	ditto	<100-1,400	<10->250	<100->1,520	ditto	
Lewis County	ditto	n.d.	n.d.	1-500	ditto	
Nez Perce County	ditto	<100->700	<10-300	1-2,000	PS, DC, A, I	ditto
WASHINGTON						
Adams County	Ud, Obr	<50-4,715	<10->790	150-3,800	PS, DC, A, I	Large withdrawals in Lind area.
Asotin County	ditto	<100-1,340	<15->855	n.d.	PS, DC, A	
Benton County	ditto	<50-4,821	Flowing->550	10-4,000	PS, DC, A, I	
Chelan County	ditto	52-4,903	<15-<50	n.d.	DC, A	
Columbia County	ditto	50-2,000	Flowing-620	30-3,000	PS, DC, A, I	Obr is most productive aquifer in Tucannon area.
Douglas County	ditto	<100-1,315	<5-603	n.d.	PS, DC, A	
Franklin County	ditto	<50-1,615	<5-568	25-3,900	PS, DC, A, I	Small yields common.
Garfield County	ditto	<100-997	<5-404	n.d.	ditto	
Grant County	ditto	<20-6,980	Flowing-650	<500-4,800	PS, DC, A	Yields of as much as 4,800 gallons per minute reported from Ud.
Kittitas County	ditto	<100-1,300	Flowing->400	<500-4,800	ditto	Large yields common in Ellensburg area.
Klickitat County	Ud, Vsr, Obr	<20-1,474	Flowing->682	10-4,000	PS, DC, A	
Lincoln County	Ud, Obr	<50-4,682	Flowing-597	150-3,800	PS, DC, A, I	Obr is most productive aquifer in Odessa area.
Spokane County	ditto	<50-2,134	<5-606	<100-5,000	ditto	One well reportedly yielded 19,000 gallons per minute.
Walla Walla County	ditto	<50-2,728	Flowing-1,000	15-3,000	ditto	Artesian wells common.
Whitman County	ditto	50-1,400	Flowing-688	<100->1,550	ditto	Obr supplies Pullman area.
Yakima County	Ud, Vsr, Obr	<50-2,760	Flowing-755	<100-2,000	ditto	Artesian wells common in Cold Creek Valley.
OREGON						
Gilliam County	Ud, Obr	125-1,320	Flowing->29	n.d.	PS, DC, A, I	Obr is most productive aquifer.
Grant County	ditto	n.d.	n.d.	<20	DC, A	
Hood River County	Ud, Vsr, Obr	n.d.	n.d.	<10-500	PS, DC, A	
Jefferson County	Ud, Obr	n.d.	n.d.	<20	DC, A	
Morrow County	ditto	<100-1,270	Flowing-705	<20-2,000	PS, DC, A, I	
Sherman County	ditto	125-710	Flowing->455	<20-2,000	ditto	ditto
Umatilla County	ditto				ditto	
Hermiston area		190-625	20->500	n.d.		
Pendleton area		100-700	Flowing->500	n.d.		
Union County	ditto	10-2,000	Flowing->240	>2,000	ditto	Ud thickest in Grande Ronde Valley.
Wallowa County	ditto	<50-1,160	Flowing-298	n.d.	ditto	
Wasco County	Ud, Vsr, Obr	<100-1,060	Flowing->420	<20-2,000	ditto	The Dalles area is a Critical Ground-Water Area.

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Puget–Willamette Trough regional aquifer system

PUGET–WILLAMETTE TROUGH REGIONAL AQUIFER SYSTEM

The Puget–Willamette Trough regional aquifer system underlies an elongated basin that extends southward from near the Canadian border in Washington to central Oregon (**figs. 83 and 84**). This basin contains the densest concentration of population and industry in Segment 7. The basin consists of three areas—the Puget Sound lowland in northern Washington, a central area that extends southward from the Puget Sound lowland to northern Oregon and includes part of the Columbia River Valley, and the Willamette River Valley, which extends southward from the Columbia River to central Oregon.

The major aquifers that compose the Puget–Willamette Trough regional aquifer system are unconsolidated-deposit and Miocene basaltic-rock aquifers. Unconsolidated-deposit aquifers are the principal aquifers in the Puget Sound lowland, whereas unconsolidated-deposit and Miocene basaltic-rock aquifers are the principal aquifers in the central area and the Willamette River Valley.

In the Puget Sound lowland, the unconsolidated-deposit aquifers consist chiefly of glacial deposits that are as much as 3,000 feet thick near Seattle, Wash. (**fig. 85**). Sand and gravel that were deposited during the last period of glaciation compose the most productive aquifers in the lowland and generally form the upper 200 to 300 feet of the unconsolidated deposits (**fig. 85**). At depth, sand and gravel deposits typically are discontinuous lenses that can be present as much as 2,000 feet below the land surface. Although usually much less permeable at depth because of compaction, lenses of sand and gravel can yield large volumes of water to wells. Even though well yields vary greatly, yields from sand and gravel aquifers commonly exceed 2,000 gallons per minute. Some public-supply and industrial wells in the Tacoma, Wash. area (**fig. 84**), that were completed in shallow sand and gravel of glacial origin, yield from 1,000 to 9,000 gallons per minute. Other public-supply wells that were completed in coarse-grained alluvial deposits along the Green River in King County, Wash., yield from 8,000 to 10,000 gallons per minute. Some artesian wells in the Seattle–Tacoma area that were completed in deeply buried lenses of sand and gravel yield from 150 to 1,700 gallons per minute.

In the southern and western parts of the Puget Sound lowland, glacial deposits are fine grained, and the unconsolidated-deposit aquifers in these areas are much less productive than similar aquifers near Tacoma. Public-supply and irrigation wells in these areas generally yield from 50 to 750 gallons per minute.

Residents of the islands in Puget Sound rely on ground-water supplies that have been obtained from unconsolidated-deposit and underlying aquifers, which are primarily in fractured consolidated sedimentary rocks of pre-Miocene age that yield little water. In places, the unconsolidated-deposit aquifers yield only small volumes of water, and wells are constructed to penetrate several aquifers to obtain adequate supplies of water (**fig. 86**).

Although numerous wells withdraw water from the unconsolidated-deposit aquifers in the Puget Sound lowland, only a small percentage of the total discharge from the aquifers is withdrawn by wells. Most ground water discharges from springs and seeps to streams that drain the lowland. Large springs discharge from 1,000 to 20,000 gallons per minute from some unconsolidated deposits that consist of glacial-outwash gravel. Some of these springs are sources of water for public supply; for example, the principal source of water for Olympia, Wash. (**fig. 84**), is a large spring that yields from 6,750 to 11,000 gallons per minute.

In the central area (**fig. 84**), natural discharge from unconsolidated-deposit and Miocene basaltic-rock aquifers is mostly toward the Columbia River. In this area, large volumes of water are withdrawn by wells in and near the Columbia River Valley. Large-diameter (as much as 36 inches) public-supply and industrial wells in Vancouver, Wash. (**fig. 84**), near the Columbia River yield as much as 4,500 gallons per minute from unconsolidated-deposit aquifers. Yields of 100 to 1,000 gallons per minute, however, are more common. Smaller diameter wells in the Vancouver area yield from 100 to 500 gallons per minute. Three springs that have a combined discharge of about 2,100 gallons per minute are used to supplement the public supply of Vancouver.

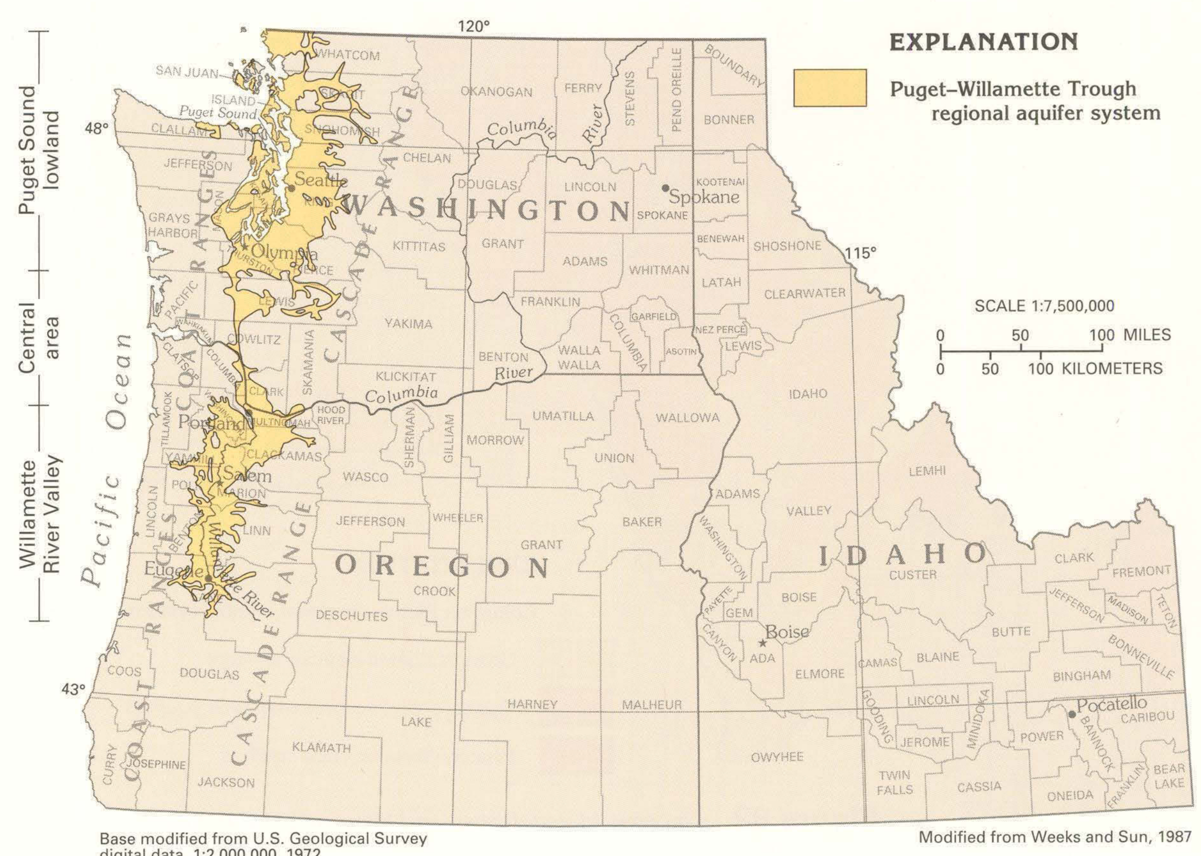

Figure 83. *The Puget–Willamette Trough is the lowland between the Cascade and Coast Ranges in Washington and Oregon. The trough contains the Puget Sound lowland in Washington and the Willamette River Valley in Oregon.*

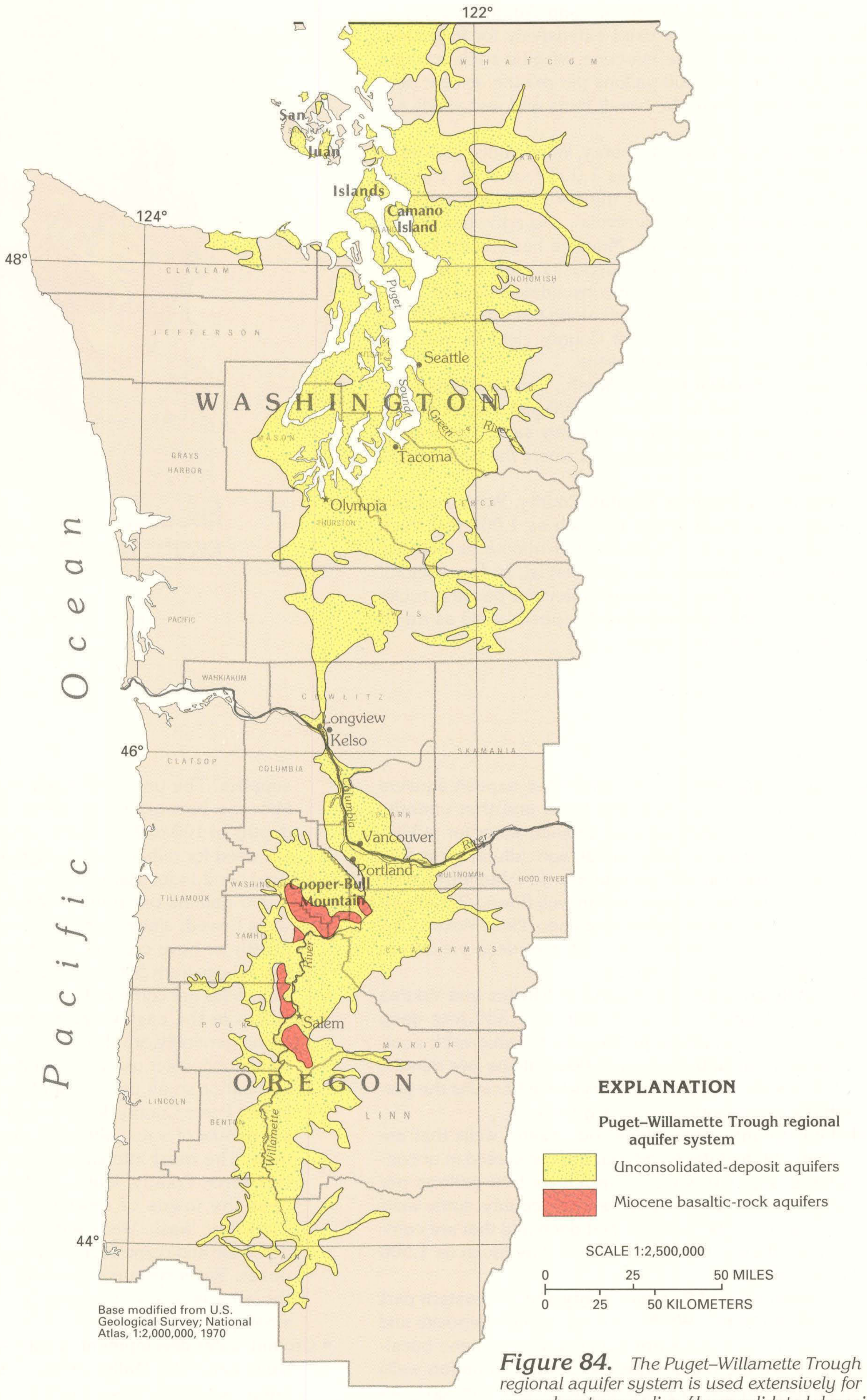

Figure 84. *The Puget–Willamette Trough regional aquifer system is used extensively for ground-water supplies. Unconsolidated-deposit aquifers predominate.*

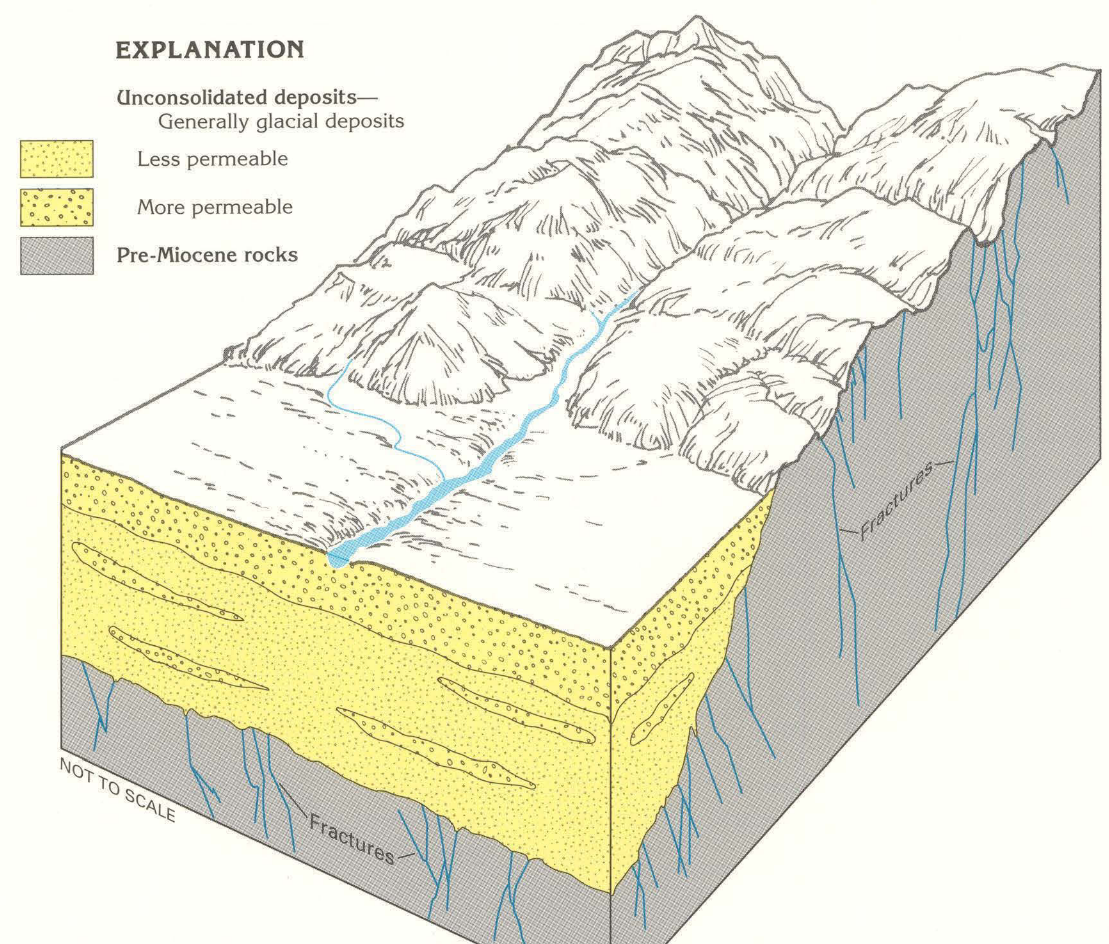

Figure 85. *The Puget Sound lowland is underlain by unconsolidated deposits that are as much as 3,000 feet thick near Seattle, Wash. The deposits become finer grained and more compacted as depth increases.*

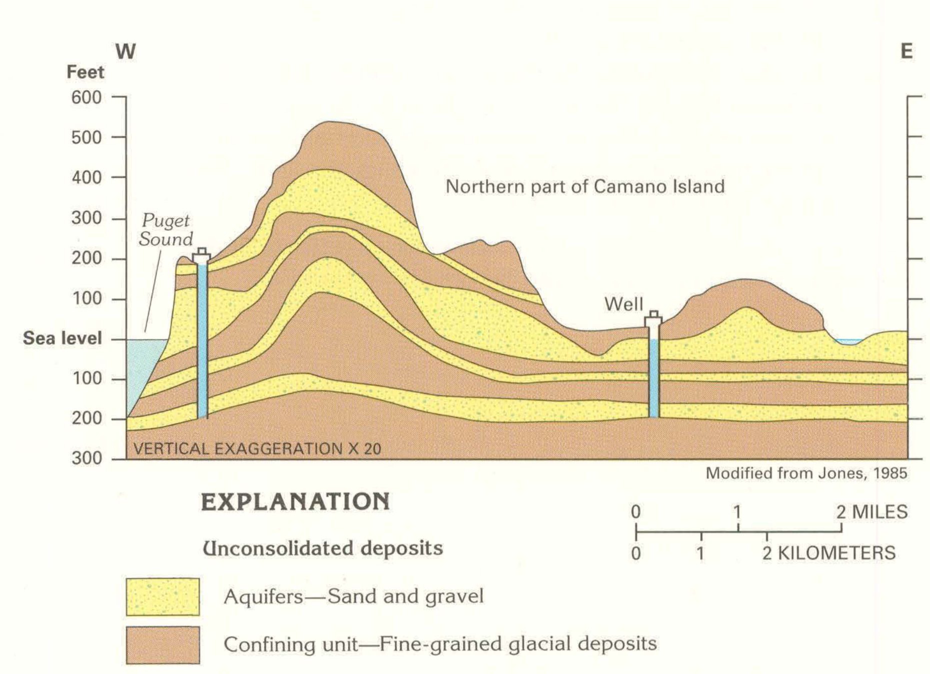

Figure 86. *On the islands, such as Camano Island in Puget Sound, the underlying unconsolidated-deposit aquifers yield only small volumes of water. This generalized section shows that wells might be constructed to penetrate as many as four aquifers to obtain adequate yields.*

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Along the Columbia River Valley and in the Willamette River Valley in Oregon, unconsolidated-deposit and Miocene basaltic-rock aquifers are the principal aquifers. Near Portland, Oreg., unconsolidated deposits are greater than 800 feet thick (**fig. 87**). Sand and gravel within these deposits (**fig. 88**) yield large volumes of water to wells. Some 36-inch-diameter wells, which supply water for Portland, yield as much as 10,000 gallons per minute from unconsolidated-deposit aquifers. Other public-supply and industrial wells completed in these aquifers commonly yield from 100 to 1,500 gallons per minute. Miocene basaltic-rock aquifers in the Portland area are about 1,500 feet thick. Yields from these aquifers range from less than 10 to 1,000 gallons per minute.

In the Willamette River Valley, unconsolidated deposits along the axis of the valley thin gradually to a thickness of about 200 feet near Salem, Oreg. (**fig. 87**). South of Salem, the unconsolidated deposits thin rapidly southward and toward the margins of the valley; these deposits generally are less than 100 feet thick (**fig. 87**). On the western side of the Willamette River Valley in this area, wells deeper than 100 feet usually penetrate consolidated pre-Miocene sedimentary rocks that yield saltwater. Miocene basaltic-rock aquifers that underlie the unconsolidated deposits in the eastern side of the valley are the most productive aquifers.

A synopsis of some aspects of the ground-water system in the Puget–Willamette Trough area (**fig. 84**) is presented below:

- **In the San Juan Islands, San Juan County, Wash.**, unconsolidated-deposit aquifers are thin and discontinuous. Because most of these deposits are fine grained, yields of wells completed in the deposits are barely adequate for domestic and commercial and agricultural (primarily livestock watering) supplies. The underlying pre-Miocene rocks also yield little water. On some islands, several aquifers might need to be penetrated by a well to obtain adequate supplies of ground water. Intrusion of saltwater into freshwater aquifers can be a problem.
- **Because water levels have declined substantially in the Cooper–Bull Mountain area on the western side of the Willamette River Valley in Washington County, Oreg.**, the State has designated this as a Critical Ground-Water Area.
- **Because water levels have declined substantially in the Salem Heights area east of Salem on the eastern side of the Willamette River Valley in Marion County, Oreg.**, the State has designated this as a Ground-Water Management Area.

Information pertaining to ground-water conditions in the Puget–Willamette Trough is summarized by county in **table 5**.

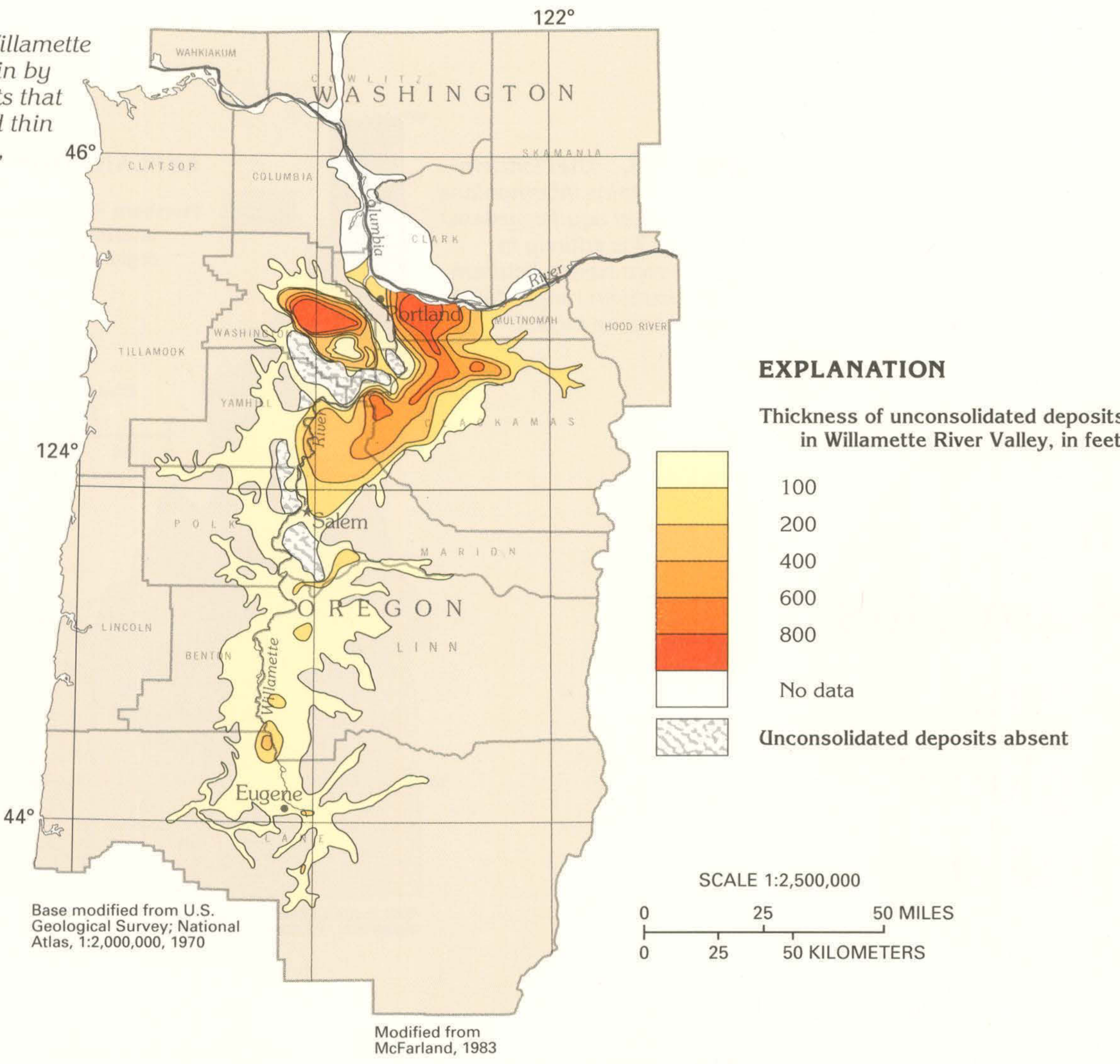


Figure 87. *The Willamette River Valley is underlain by unconsolidated deposits that thicken northward and thin southward from Salem, Oregon.*

Table 5. *Ground-water conditions in the Puget–Willamette Trough*

[Aquifer: Ud, unconsolidated deposits; Vsr, volcanic and sedimentary rocks; Obr, Miocene basaltic rocks; pM, pre-Miocene rocks. Water use: PS, public supply; DC, domestic and commercial; A, agricultural (primarily irrigation and livestock watering); I, industrial. Symbols: n.d., no data available; <, less than; >, greater than]

Location	Principal aquifer	Typical well depth (feet below land surface)	Depth to water (feet below land surface)	Range of well yields (gallons per minute)	Principal water use	Remarks
WASHINGTON						
Clallam County	Ud	50–100	n.d.	5–300	PS, DC, A	
Clark County	ditto	50–300	n.d.	10–4,500	PS, DC, A, I	Large yields from Ud in Vancouver area.
Cowlitz County	Ud, Obr	n.d.	n.d.	<10–1,000	ditto	Withdrawals chiefly in Longview–Kelso area.
Island County	Ud	n.d.	n.d.	50–500	ditto	
Jefferson County	Ud, pM	n.d.	n.d.	<5–25	ditto	
King County	Ud				ditto	
Green River Valley		n.d.	n.d.	150–1,700		Artesian wells common.
North Fork Green River Valley		n.d.	n.d.	<200–10,000		Larger yields from public-supply wells.
Kitsap County	ditto	130–1,100	n.d.	<5–1,000	ditto	Artesian wells common.
Lewis County	Ud, pM	<100–>500	n.d.	<50–4,500	ditto	Larger yields near Columbia River. Flowing wells common.
Mason County	ditto	<100–>1,100	n.d.	<2–>1,000	ditto	Flowing wells common.
Pierce County	Ud	n.d.	n.d.	<200–10,000	ditto	Larger yields from public-supply wells. Flowing wells common.
San Juan County	Ud, pM	n.d.	n.d.	<5–>100	PS, DC, A	
Skagit County	ditto	n.d.	n.d.	<5–>1,000	ditto	
Snohomish County	Ud	n.d.	n.d.	<5–>1,000	ditto	
Thurston County	ditto	50–300	n.d.	10–>5,000	PS, DC, A, I	Larger yields from public-supply wells. Flowing wells common.
Whatcom County	ditto	<50	n.d.	5–500	PS, DC, A	
OREGON						
Benton County	Ud	60–150	10–35	<500–1,000	PS, DC, A, I	
Clackamas County	Ud, Obr	25–>700	10–190	<100–>1,000	ditto	Ud thicker in northern part of Willamette Valley.
Columbia County	ditto	n.d.	n.d.	1–500	PS, DC, A	
Lane County	Ud, Vsr, Obr	75–200	<10–25	n.d.	PS, DC, A, I	Eastern side of valley is more permeable.
Linn County	ditto	30–175	10–70	n.d.	ditto	ditto
Marion County	ditto				ditto	
Salem Heights		n.d.	n.d.	n.d.		Ground-Water Management Area.
Northern Willamette Valley		25–>270	10–55	<300–>2,000		
Multnomah County	ditto				ditto	
Portland area		n.d.	n.d.	10–10,000		
Northern Willamette Valley		25–>700	10–190	n.d.		
Polk County	Ud	60–150	10–315	<500–1,000	ditto	Saltwater common from deeper wells.
Washington County	Ud, Obr				ditto	
Cooper–Bull Mountain area		n.d.	n.d.	n.d.		Critical Ground-Water Area.
Northern Willamette Valley		25–>700	10–190	n.d.		
Yamhill County	ditto	65–220	n.d.	500–800	ditto	In northern Willamette Valley, Obr is less productive.

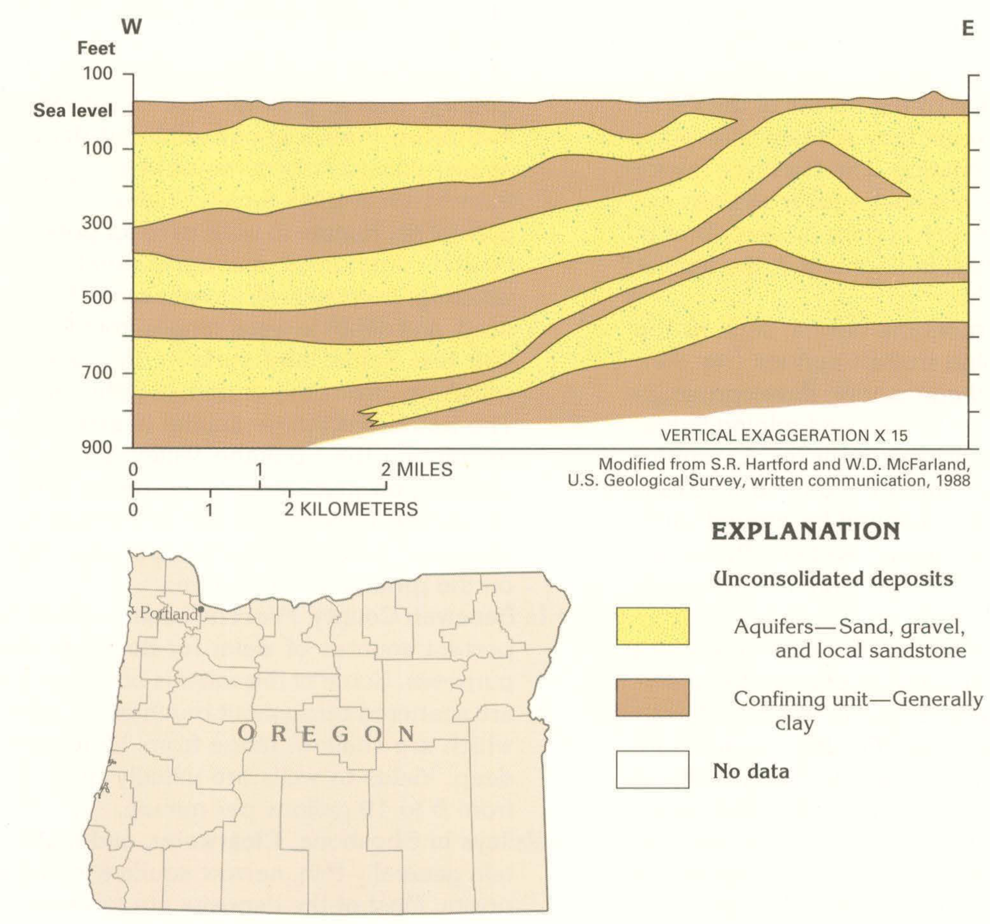


Figure 88. *East of Portland, Oreg., permeable unconsolidated deposits that consist chiefly of sand and gravel form aquifers that are interlayered with confining units that consist chiefly of unconsolidated deposits of clay.*

Northern Rocky Mountains intermontane basins regional aquifer system

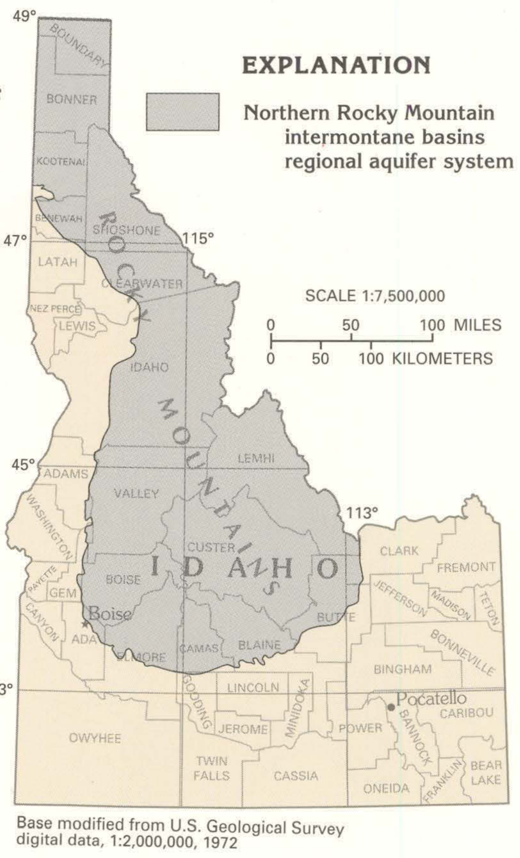


Figure 89. The Northern Rocky Mountains intermontane basins regional aquifer system in Segment 7 is entirely in Idaho. Narrow basins between rugged mountain ranges typify the intermontane basins.

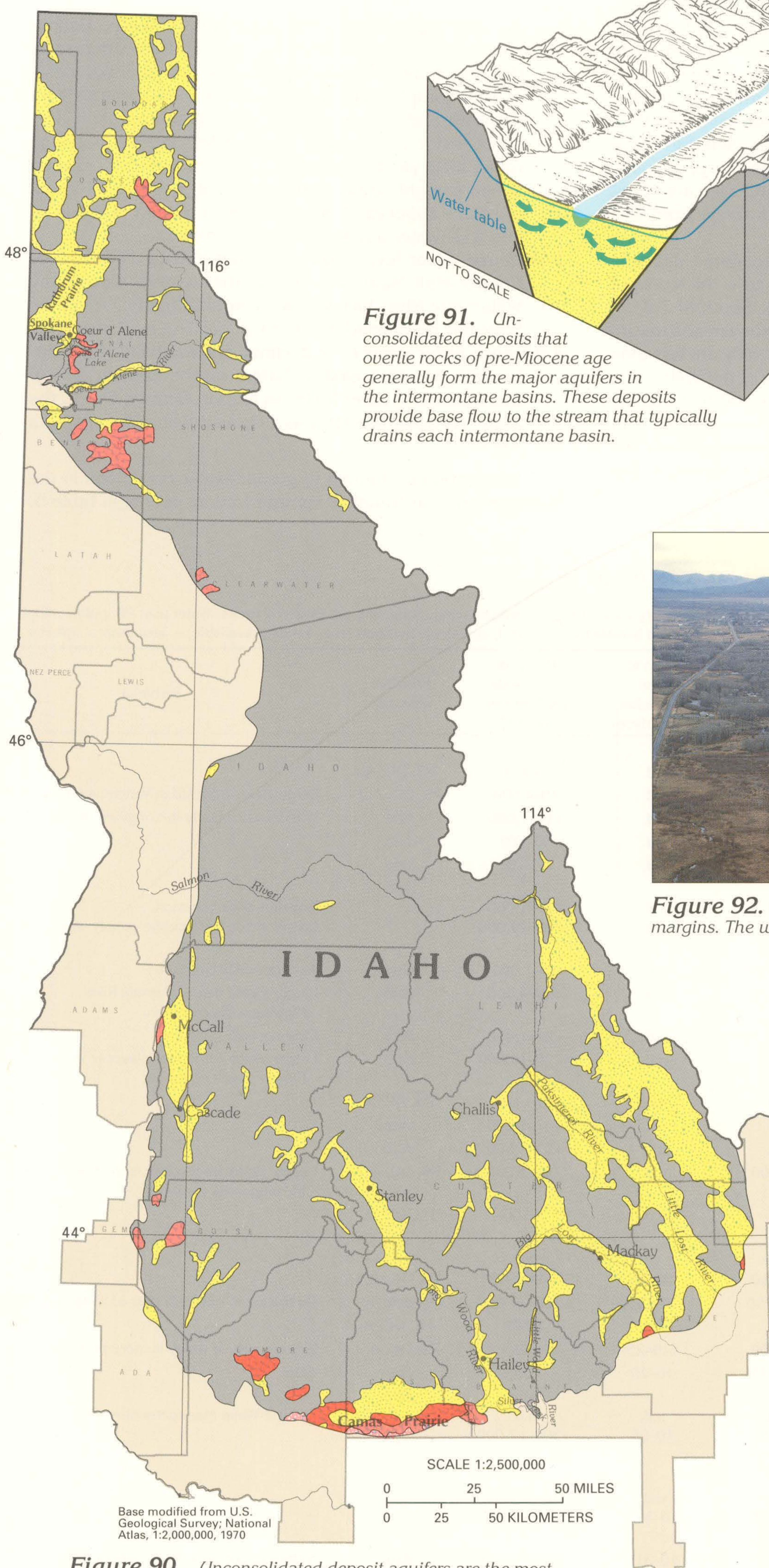


Figure 90. Unconsolidated-deposit aquifers are the most important aquifers in the Northern Rocky Mountains intermontane basins regional aquifer system. Aquifers in pre-Miocene rocks are important for domestic and stock use.

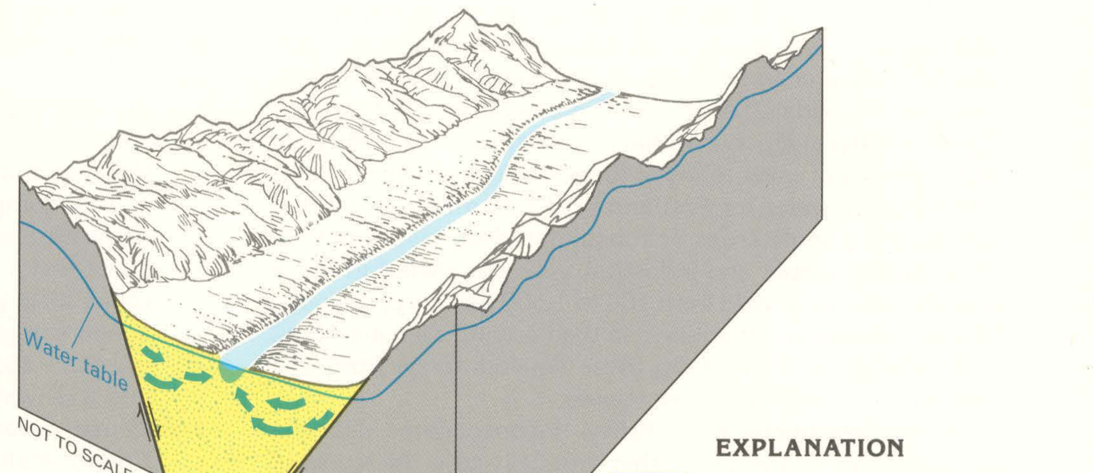


Figure 91. Unconsolidated deposits that overlie rocks of pre-Miocene age generally form the major aquifers in the intermontane basins. These deposits provide base flow to the stream that typically drains each intermontane basin.

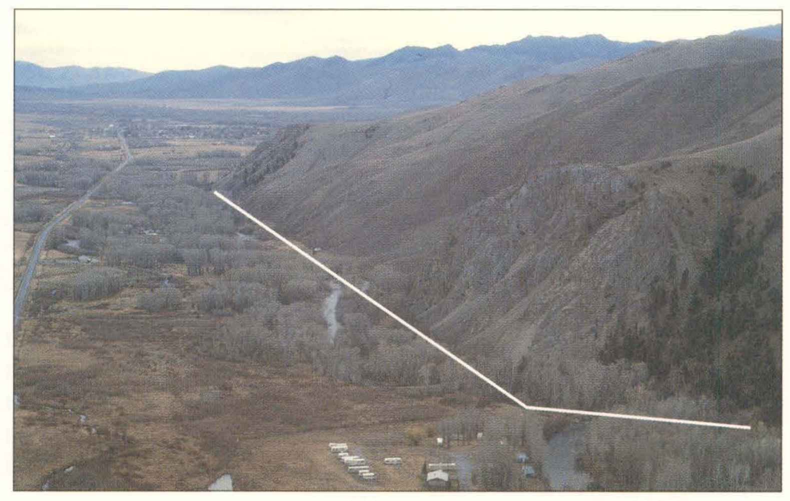


Figure 92. Many intermontane basins have faulted valley margins. The white line indicates a fault.

NORTHERN ROCKY MOUNTAINS INTERMONTANE BASINS REGIONAL AQUIFER SYSTEM

The basins that compose the Northern Rocky Mountains intermontane basins regional aquifer system (**fig. 89**) are geologically and hydrologically similar to the basins of the Great Basin regional aquifer system, except they are typically much narrower and receive more precipitation. The Northern Rocky Mountains intermontane basins regional aquifer system extends into Montana; that part of the system is described in Segment 8 (Chapter I) of this Atlas. In Segment 7, the aquifer system is located entirely in Idaho.

Although some of the intermontane basins, such as the Big Lost River basin in Custer and Butte Counties (**fig. 90**), have been developed for irrigated agriculture, development in most of the basins is related to the lumber and mining industries, recreational activities, and livestock raising. Except for lowland areas, a large part of each intermontane basin is rugged, uninhabited public land where demand for ground water is small. Ground water in these basins is used chiefly for domestic and commercial, and agricultural (primarily livestock watering) purposes.

Unconsolidated-deposit aquifers are the most important aquifers in the intermontane basins, but in places, the underlying Pliocene and younger basaltic rocks or Miocene basaltic rocks compose important aquifers (**fig. 90**). In addition, aquifers in pre-Miocene rocks yield water to many wells or springs for domestic and commercial purposes. Unconsolidated deposits in the basin lowlands range from clay and fine sand to coarse sand and gravel. Where increasing proportions of clay are intermixed with the coarse-grained deposits, permeability is decreased. Faulted valley margins might affect ground-water movement (**figs. 91 and 92**). Depth to the water table ranges from a few feet below land surface in the lowlands near streams to several hundred feet below land surface in alluvial fans close to the mountain fronts.

A synopsis of some aspects of the ground-water system in selected Northern Rocky Mountains intermontane basins (**fig. 90**) is presented below:

- **Unconsolidated-deposit aquifers in Boundary and Bonner Counties** yield small volumes of water to wells for public-supply, domestic and commercial, and agricultural (primarily livestock watering) purposes. The unconsolidated deposits are chiefly fine grained, or, if coarse grained, they contain a matrix of clay. In Boundary County, most wells range from 10 to 200 feet deep. Depth to water ranges from flowing to more than 100 feet below land surface. In Kootenai County, wells completed in unconsolidated deposits in the Coeur d'Alene River Valley can yield as much as 3,000 gallons per minute. The thickness of the deposits ranges from a few feet near the Kootenai–Shoshone County boundary to more than 400 feet at the mouth of the Coeur d'Alene River where it enters Coeur d'Alene Lake. In places, Miocene basaltic rock that underlies the unconsolidated deposits will yield small to moderate volumes of water to wells for domestic and commercial and agricultural (primarily livestock watering) purposes.
- **In the southern part of Bonner County and in Kootenai County,** coarse-grained glacial outwash composes the Rathdrum Prairie unconsolidated-deposit aquifer. The aquifer consists of coarse sand and gravel that are more than 510 feet thick locally. Yields are as much as 3,000 gallons per minute to wells used for public-supply, domestic and commercial, and agricultural (primarily livestock watering) purposes. Most wells range from 100 to 500 feet deep, and depth to water ranges from flowing to more than 400 feet below land surface. In places, some water is withdrawn from the underlying Miocene basaltic rocks. The Rathdrum Prairie aquifer is extremely important for recharging the Spokane Valley aquifer in northeastern Washington just west of the Idaho–Washington border. During the summer months, recreational activities attract thousands of tourists to the area and intensify demands on the ground-water system.
- **In Benewah County,** Miocene basaltic-rock aquifers are important sources of water for domestic and commercial purposes. Some of the water is obtained from springs that are scattered throughout much of the county. Most wells, which are shallow, range from 15 to less than 100 feet deep. Yields to wells are usually quite small and range from 5 to 15 gallons per minute.
- **Valleys in Shoshone, Clearwater, and Idaho Counties** contain generally thin, narrow aquifers in unconsolidated deposits. Most of the deposits are too small to show at the scale of **figure 90**. These aquifers yield water to wells chiefly for public-supply and domestic and commercial purposes; some of the water might be used for agricultural (primarily livestock watering) purposes, but if so, the amount is extremely small. Aquifers in pre-Miocene rocks also are used for water supply in many places. Because much of each county is uninhabited, demand for ground water is small.
- **Valley County contains the recreation-oriented towns of Cascade and McCall,** which experience large population increases and subsequent increases in ground-water demand during the summer. Unconsolidated-deposit aquifers yield water to wells for public-supply, domestic and commercial, and agricultural (primarily livestock watering) purposes; most agricultural water needs, however, are met by using surface-water sources.
  The unconsolidated deposits consist of fine- to coarse-grained rocks, which are chiefly of glacial origin; their permeability is extremely variable. Yields to wells range from 1 to 500 gallons per minute. In places, aquifers in Miocene basaltic or pre-Miocene rocks yield water for domestic and commercial purposes.
- **Lemhi and Custer Counties** contain large, wide valleys filled with unconsolidated deposits to unknown depths. Except for those deposits in or near stream channels, most deposits contain a large percentage of clay or silt, and permeability is generally low. Some deposits in or near streams yield as much as 3,850 gallons per minute to wells. Elsewhere, the yields are much lower. Some water is withdrawn from aquifers in pre-Miocene rocks. The water withdrawn is used for public-supply, domestic and commercial, and agricultural purposes. Wells range in depth from less than 10 to more than 500 feet. Depth to water ranges from flowing to more than 500 feet below land surface. Wells in the lowlands are shallowest, and those on alluvial fans near the valley margins are generally deepest. The Stanley area in southwestern Custer County experiences an extremely large increase in population during the summer owing to recreational activities that also increase demands on the area's ground-water system.
  In the Big Lost River Valley and the Challis area, ground water is used for public-supply, domestic and commercial, and agricultural (primarily irrigation and livestock watering) purposes. Much of Custer and Lemhi Counties is uninhabited and extremely rugged.
- **In Boise County,** most ground water is withdrawn for public-supply, domestic and commercial, and agricultural (primarily livestock watering) purposes. Although unconsolidated-deposit aquifers are the most important, aquifers in Miocene basaltic and pre-Miocene rocks are used locally. Yields to wells are usually small, but some wells in unconsolidated deposits yield as much as 500 gallons per minute. Ground water in Elmore County is withdrawn from unconsolidated-deposit and Pliocene and younger basaltic-rock aquifers, and aquifers in pre-Miocene rocks for domestic and commercial and agricultural (primarily livestock watering) purposes. In the western part of Camas Prairie, ground water is used for agricultural (primarily irrigation) purposes.
- **Camas County** contains a large, wide valley filled with unconsolidated deposits that are as much as 1,125 feet thick. The unconsolidated deposits and Pliocene and younger basaltic rocks yield water to wells for public-supply, domestic and commercial, and agricultural (primarily irrigation) purposes. Most ground water in the county is used for agricultural (primarily irrigation) purposes. Wells range from less than 50 to as much as 1,125 feet deep; however, many wells in Camas Prairie are less than 50 feet deep. Depth to water ranges from flowing to about 200 feet below land surface. Most shallow wells are completed in unconfined aquifers and deeper wells are completed in confined aquifers. Yields of wells in the county are variable and range from less than 100 to 2,000 gallons per minute.
- **In Blaine County,** ground water is withdrawn from unconsolidated-deposit aquifers in the Hailey area for public-supply, domestic and commercial, and agricultural (primarily irrigation and livestock watering) purposes. The unconsolidated deposits were emplaced as alternating layers of fine- and coarse-grained material. Confined aquifers are common in the southern end of the Big Wood River Valley and the Silver Creek area. Wells that range from 30 to more than 500 feet deep yield from less than 10 to more than 5,000 gallons per minute. Depth to water ranges from flowing to 150 feet below land surface. Most deeper wells flow at the land surface. In the Little Wood River Valley, there are only a few wells, and depth to water in these wells ranges from less than 10 to 130 feet below the land surface. Blaine County contains uninhabited, topographically rugged areas where there are no demands on the ground-water system.
- **Unconsolidated deposits fill the Big Lost River Valley in Butte and Custer Counties** to as much as 5,500 feet deep. The uppermost 500 feet of the deposits is the most permeable. Unconsolidated-deposit aquifers yield water to wells for most public-supply, domestic and commercial, and agricultural purposes. However, aquifers in pre-Miocene rocks provide small volumes of water to wells. Well depths range from less than 10 to more than 500 feet. Depth to water ranges from flowing to more than 500 feet below land surface. Yields of wells range from less than 10 to more than 2,800 gallons per minute. The permeability of the unconsolidated-deposit aquifers is variable. Confined aquifers are present locally. The Big Lost River Valley is an important recharge source for the eastern Snake River Plain aquifer system. The Little Lost River Valley is similar to the Big Lost River Valley, except that it receives less annual recharge to underlying aquifers. Because the Little Lost River Valley is sparsely populated, most water is used for agricultural purposes. Depth to water ranges from less than 10 to 280 feet below land surface. Yields of wells range from 10 to 2,500 gallons per minute. Butte and Custer Counties contain uninhabited, topographically rugged areas where there are no demands on the ground-water system.
- **In Clark County,** the large area of unconsolidated deposits is virtually unused. Although the ground-water potential might be good, little is known of ground-water conditions in this part of Clark County. The area is sparsely populated.

Information pertaining to ground-water conditions in the Northern Rocky Mountains intermontane basins is summarized by county in **table 6**.

Table 6. *Ground-water conditions in the Northern Rocky Mountains intermontane basins in Idaho*

[Aquifer: Ud, unconsolidated deposits; Ybr, Pliocene and younger basaltic rocks; Obr, Miocene basaltic rocks; pM, pre-Miocene rocks. Water use: PS, public supply; DC, domestic and commercial; A, agricultural (primarily irrigation and livestock watering); I, industrial. Symbols: n.d., no data available; <, less than; >, greater than]

Location	Principal aquifer	Typical well depth (feet below land surface)	Depth to water (feet below land surface)	Range of well yields (gallons per minute)	Principal water use	Remarks
Benewah County	Ud, Obr, pM	15–<100	n.d.	5–15	PS, DC, A	Many springs used for water supply.
Blaine County	Ud, Ybr				PS, DC, A, I	
Big Wood River Valley–Silver Creek area		30–>500	Flowing–150	<10–>5,000		Flowing wells common.
Little Wood River Valley		n.d.	<10–130	n.d.		
Boise County	Ud, Obr, pM	n.d.	n.d.	1–500	PS, DC, A	
Bonner County	Ud, Obr	n.d.	n.d.	1–1,500	ditto	
Boundary County	Ud	10–200	Flowing–>100	n.d.	ditto	Unconsolidated deposits chiefly fine grained.
Butte County	Ud, pM				ditto	
Big Lost River Valley		<10–>500	Flowing–>500	<10–2,800		Unconsolidated deposits 5,500 feet thick near Mackay.
Little Lost River Valley		n.d.	<10–280	10–2,500		
Camas County	Ud, Ybr	<50–1,125	Flowing–200	<100–2,000	ditto	Unconsolidated deposits as much as 1,125 feet thick in places. Deeper wells usually artesian.
Clark County	Ud	n.d.	n.d.	n.d.	DC, A	Ground water not yet developed.
Clearwater County	Ud, Obr, pM	n.d.	n.d.	1–500	ditto	
Custer County	Ud, pM				PS, DC, A	
Big Lost River Valley		<10–>500	Flowing–>500	<10–2,800		Unconsolidated deposits 5,500 feet thick southeast of Mackay.
Challis area		n.d.	Flowing–120	<20–200		
Pahsimeroi River Valley		n.d.	<10–175	50–3,850		Unconsolidated deposits 3,000 feet thick in central part of valley.
Elmore County	Ud, Ybr, pM	n.d.	n.d.	1–20	DC, A	
Idaho County	Ud, pM	n.d.	n.d.	1–500	ditto	
Kootenai County	Ud, Obr, pM				PS, DC, A	
Coeur d'Alene River Valley		n.d.	Flowing–200	5–3,000		Unconsolidated deposits >400 feet thick in places.
Rathdrum Prairie		100–500	Flowing–>400	>1,500		Unconsolidated deposits >500 feet thick in places.
Lemhi County	Ud, pM	n.d.	<5–80	>2,240	ditto	
Shoshone County	Ud, Obr, pM	n.d.	n.d.	1–20	ditto	
Valley County	ditto	n.d.	n.d.	1–500	ditto	

OTHER AREAS OF SUBSTANTIAL GROUND-WATER DEVELOPMENT

Segment 7 contains areas of substantial ground-water development that are not included in any of the regional aquifer systems. Therefore, this section gives a brief overview of ground-water conditions in those areas by State and county. Those counties that are extremely rugged topographically or lack ground-water development are not mentioned in the following discussion.

IDAHO

Counties in Idaho (**fig. 93**) that contain areas of substantial ground-water development include Adams and Washington in western Idaho; Twin Falls and Cassia in south-central Idaho; Power, Bannock, Bingham, Bonneville, and Caribou in southeastern Idaho; and Clark, Fremont, and Teton in eastern Idaho. Wells withdraw water from unconsolidated deposits, Pliocene and younger basaltic rocks, volcanic and sedimentary rocks, Miocene basaltic rocks, and pre-Miocene rocks. In each county, the water is used for one or more of the following purposes: public-supply, domestic and commercial, agricultural, and industrial.

A synopsis of some aspects of the ground-water system in selected areas of ground-water development in Idaho (**fig. 93**) is presented below:

- **In Adams County,** most ground-water development is in the southern part of the county. Water is withdrawn by shallow wells that are usually less than 100 feet deep in unconsolidated-deposit aquifers near streams. Yields are usually less than 100 gallons per minute. Deeper wells completed in Miocene basaltic-rock aquifers are the largest yielding wells in the county. Yields of as much as 600 gallons per minute from these aquifers have been reported. The volcanic and sedimentary rocks are mostly silt and clay and are not known to be aquifers here, except where they contain scattered lenses of sand and gravel. The water is used for domestic and commercial and agricultural purposes. Depth to water ranges from flowing to more than 200 feet below land surface.
- **Unconsolidated deposits in Washington County** contain a significant percentage of silt and clay. Except for lenses of sand and gravel, the permeability of these deposits is generally low; the permeability of the volcanic and sedimentary rocks is low for the same reasons. Yields of wells in the unconsolidated-deposit aquifers and the volcanic- and sedimentary-rock aquifers are generally less than 10 gallons per minute. In contrast, Miocene basaltic-rock aquifers yield as much as 1,835 gallons per minute to wells. Most wells range from less than 20 to more than 960 feet deep. Depth to water ranges from flowing to 80 feet below land surface. The water is used for public-supply, domestic and commercial, and agricultural purposes. Geothermal water is common in places.
- **Most ground water in Twin Falls County** is withdrawn from Miocene basaltic-rock aquifers and volcanic- and sedimentary-rock aquifers. The unconsolidated deposits contain a large percentage of clay, and permeability is low. Wells range from less than 300 to as much as 2,525 feet deep. Water levels range from flowing to about 80 feet below land surface. Some wells might yield as much as 2,800 gallons per minute. Water is used for public-supply, domestic and commercial, and agricultural purposes. Geothermal water from deep wells and some springs is common in places.

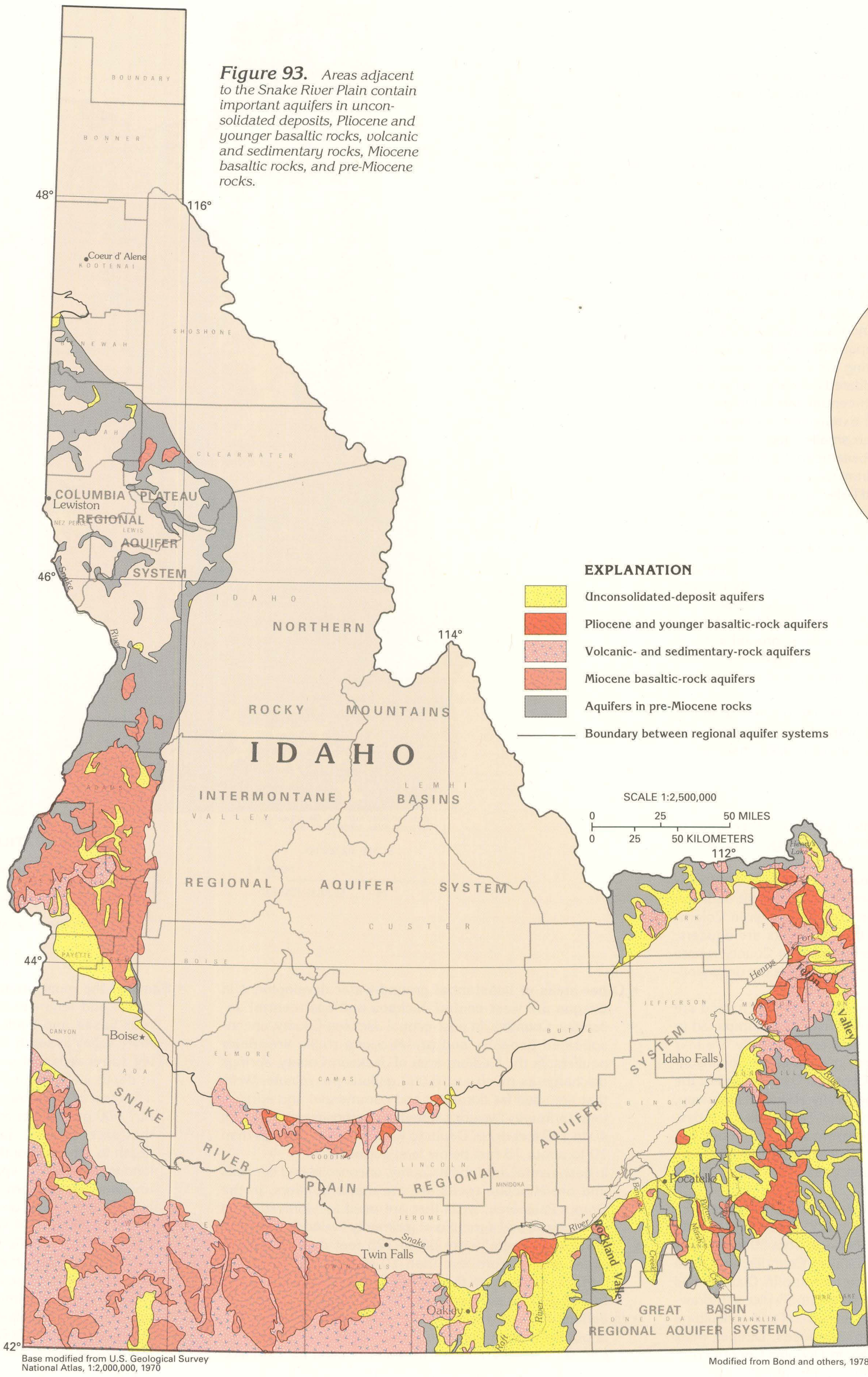


Figure 93. *Areas adjacent to the Snake River Plain contain important aquifers in unconsolidated deposits, Pliocene and younger basaltic rocks, volcanic and sedimentary rocks, Miocene basaltic rocks, and pre-Miocene rocks.*

Other areas of substantial ground-water development

- **Wells in Cassia County** produce large quantities of water, as much as 3,000 gallons per minute, from unconsolidated-deposit and Pliocene and younger basaltic-rock aquifers in the northern part of the Raft River Valley. In the rest of the valley to the south, the permeability of the unconsolidated deposits is variable but overall is low. Parts of the county near Oakley were designated as Critical Ground-Water Areas by the State in the early 1960's. Depth to water ranges from flowing to more than 500 feet below land surface. The central part of the Raft River Valley has been studied in detail for its geothermal potential. A large quantity (about 50,000 gallons per minute) of ground water is estimated to flow out of the valley at its north end to recharge the eastern Snake River Plain regional aquifer system. Water in the county is used for public-supply, domestic and commercial, and agricultural purposes.
- **Rockland Valley and Bannock Creek Valley in Power County** are areas where ground water is used primarily for agricultural purposes and, to a small extent, for domestic and commercial purposes. Depth to water ranges from flowing to more than 600 feet below land surface. Yields of wells completed in unconsolidated-deposit aquifers range from less than 20 to more than 500 gallons per minute; smaller yields are more common. Miocene basaltic rocks are aquifers at the north end of Rockland Valley.
- **In Bannock and Caribou Counties,** ground water is used for public-supply, domestic and commercial, agricultural, and industrial purposes; the industrial use is related to mining activities and food processing. Unconsolidated deposits and Pliocene and younger and Miocene basaltic rocks are aquifers. The unconsolidated deposits are typically fine grained and, except for flood-plain deposits that consist of layers of sand and gravel, permeability is low. The Pliocene and younger basaltic rocks are extremely permeable. Depth to water ranges from flowing to more than 200 feet below land surface. Yields of wells range from less than 20 to 3,500 gallons per minute in Caribou County and 5,000 gallons per minute in Bannock County.
- **Ground water is used in Bingham and Bonneville Counties** for domestic and commercial and agricultural purposes. Most development is near the Snake River in areas of unconsolidated deposits or in upland areas in Pliocene and younger basaltic or volcanic and sedimentary rocks. Depth to water ranges from flowing to more than 100 feet below land surface. Yields are typically low; however, one well that was completed in unconsolidated deposits and basaltic rocks in Bonneville County was reported to yield as much as 1,800 gallons per minute.
- **In Madison County,** Pliocene and younger basaltic-rock and volcanic- and sedimentary-rock aquifers yield small amounts of water to wells in upland areas. However, most ground-water development is near the Snake River where wells are completed in unconsolidated deposits. Yields range from less than 10 to 75 gallons per minute. The water is used for domestic and commercial and agricultural (primarily livestock watering) purposes.
- **The Teton Valley in Teton County** is a broad, alluvium-filled valley that has substantial agricultural development. Coarse-grained unconsolidated deposits on the east side of the valley yield far more water to wells than do the fine-grained deposits on the west side. Some wells yield as much as 800 gallons per minute. Most of the water used for public-supply, domestic and commercial, and agricultural purposes is withdrawn by wells completed in unconsolidated-deposit aquifers and, in part, from wells completed in Pliocene and younger basaltic-rock aquifers at the northern end of the valley. Depth to water ranges from less than 5 to more than 100 feet below land surface and increases near the valley margins.
- **In Fremont County,** most of the demand for ground water is near Henrys Fork. Aquifers in unconsolidated deposits, Pliocene and younger basaltic rocks, and volcanic and sedimentary rocks yield from less than 5 to more than 800 gallons per minute to wells that are about 10 to more than 400 feet deep. The water is used for public-supply, domestic and commercial, and agricultural (primarily livestock watering) purposes. Demand on the ground-water resources is small during the winter, but thousands of visitors during the summer put a great demand on the ground-water resources.
  The unconsolidated deposits are as much as 3,600 feet thick along the eastern side of Henrys Lake. The volcanic and sedimentary rocks, which are typically not very permeable in other areas, are extremely permeable here. As much as 90,000 gallons per minute is discharged from some groups of springs in these rocks.
- **In Clark County,** most ground water is used for agricultural purposes. Volcanic and sedimentary rocks that underlie the unconsolidated deposits are the major aquifers. Well depths range from less than 100 to more than 500 feet.

Information pertaining to ground-water conditions in other areas of substantial ground-water development in Idaho is summarized by county in **table 7**.

Table 7. *Ground-water conditions in other areas of substantial ground-water use in Idaho*

[Aquifer: Ud, unconsolidated deposits; Ybr, Pliocene younger basaltic rocks; Vsr, volcanic and sedimentary rocks; Obr, Miocene basaltic rocks; pM, pre-Miocene rocks. Water use: PS, public supply; DC, domestic and commercial; A, agricultural (primarily irrigation and livestock watering); I, industrial. Symbols: n.d., no data available; <, less than; >, greater than]

Location	Principal aquifer	Typical well depth (feet below land surface)	Depth to water (feet below land surface)	Range of well yields (gallons per minute)	Principal water use	Remarks
Adams County	Ud, Obr	<20–>600	Flowing–>200	<10–600	PS, DC, A	Obr is most productive aquifer.
Bannock County	Ud, Ybr, Obr	n.d.	Flowing–>200	<20–5,000	PS, DC, A, I	Withdrawals chiefly in Portneuf River Valley and Marsh Creek Valley.
Bingham County	Ud, Ybr, Vsr	<20–>700	Flowing–>100	1–20	DC, A	
Bonneville County	Ud, Ybr, Vsr, Obr	n.d.	Flowing–>100	<20–1,800	ditto	
Caribou County	Ud, Ybr, Obr	n.d.	Flowing–200	40–3,500	PS, DC, A, I	
Cassia County	Ud, Ybr, Vsr	<200–>1,800	Flowing–>500	<10–3,000	PS, DC, A	Critical Ground-Water Area near Oakley.
Clark County	Ud, Vsr	<100–>500	n.d.	n.d.	DC, A	
Fremont County	Ud, Ybr, Vsr	<10–>400	<5–25	<5–>800	PS, DC, A	Sediments 3,600 feet thick near Henrys Lake.
Madison County	ditto	<100–>500	Flowing–500	<10–75	ditto	
Owyhee County	Ud, Vsr, Obr	200–>1,400	<200–>1,200	n.d.	DC, A	Yields generally small; permeability decreases eastward.
Power County	Ud, Ybr, Vsr	<100–>600	Flowing–>600	<20–>500	PS, DC, A	Large withdrawals in Rockland Valley.
Teton County	Ud, Vsr, pM	n.d.	<5–>100	<50–800	ditto	Larger yields on eastern side of Teton Valley.
Twin Falls County	Ud, Vsr, Obr	<300–2,525	Flowing–>80	<20–2,800	ditto	Geothermal water common in places.
Washington County	ditto	<20–>960	Flowing–80	<10–1,835	ditto	ditto

OREGON

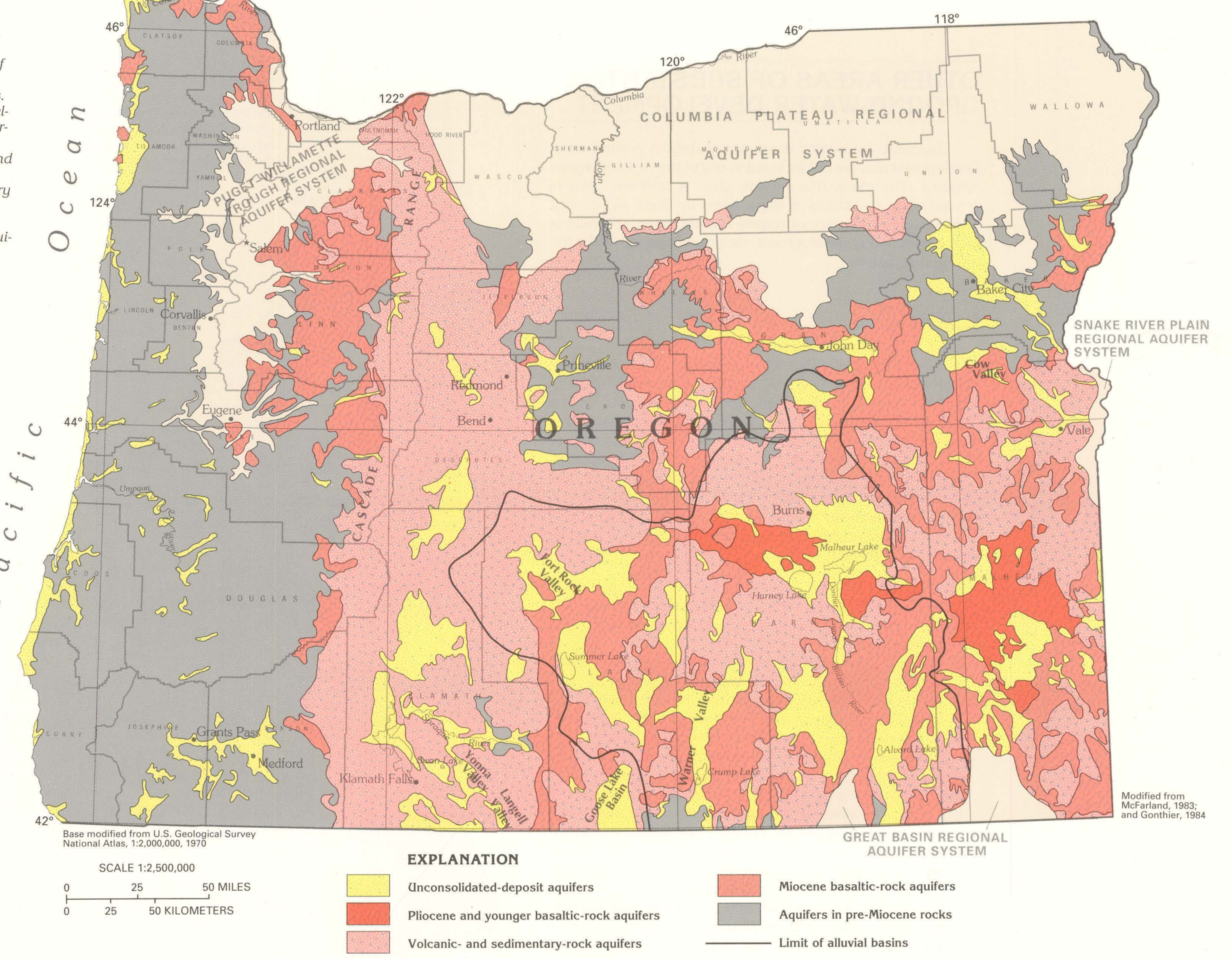
A substantial amount of ground-water development occurs throughout Oregon in areas that are not included as part of the regional aquifer systems (**fig. 94**).

Counties west of the Cascade Range are, for the most part, topographically rugged and have little or no ground-water development. However, unconsolidated deposits in stream valleys provide substantial quantities of water to wells for public-supply, domestic and commercial, agricultural, and industrial purposes. Miocene basaltic rocks are aquifers in Clatsop, Lane, Linn, and Marion Counties. Volcanic and sedimentary rocks along the crest of the Cascade Range are extremely permeable and transmit recharge from rainfall and snowmelt to underlying aquifers. There are only a few wells along the crest of the Cascade Range. Along the Oregon coast, virtually all communities obtain water from unconsolidated-deposit aquifers. An exception is along the Umpqua River Valley in Douglas County, where aquifers in underlying pre-Miocene rocks supply some water to wells. Unconsolidated deposits and volcanic and sedimentary rocks in the north-central part of Oregon east of the Cascade Range are used extensively as aquifers in Deschutes County and, to a much smaller degree, in Crook and Jefferson Counties. Miocene basaltic rocks are important aquifers in places in Crook and Grant Counties. In south-central Oregon, chiefly in Klamath and Lake Counties, the volcanic and sedimentary rocks are extremely permeable in places, and large quantities of water are withdrawn by wells for public-supply, domestic and commercial, agricultural, and industrial purposes. Underlying Miocene basaltic rocks are important aquifers in places. Klamath Falls in Klamath County has developed geothermal water in volcanic- and sedimentary rock aquifers into a system for heating homes and public buildings.

In Baker, Harney, and Malheur Counties, ground water is withdrawn by wells completed in unconsolidated deposits, Pliocene and younger basaltic rocks, volcanic and sedimentary rocks, and Miocene basaltic rocks.

The alluvial basins, chiefly in Lake and Harney Counties, are closed basins from which no water flows. All water that leaves the closed basins does so only as evapotranspiration.

Figure 94. Much of Oregon is outside of the regional aquifer systems. Most ground-water development is in areas underlain by unconsolidated deposits, but Pliocene and younger basaltic rocks, volcanic and sedimentary rocks, Miocene basaltic rocks, and pre-Miocene rocks are productive aquifers in places.



A synopsis of the ground-water system in other areas of substantial ground-water development in Oregon (**fig. 94**) is presented below:

- **Along and near the Oregon coast,** virtually all communities obtain water from unconsolidated-deposit aquifers. Two exceptions are along the Columbia River in Columbia County, where Miocene basaltic rocks are aquifers, and along the Umpqua River in Douglas County, where aquifers in pre-Miocene rocks that underlie the unconsolidated deposits supply some water to wells.

  In Lane and Lincoln Counties, dune and beach sand are major aquifers. Most wells that have been completed in the unconsolidated-deposit aquifers generally are less than 150 feet deep. The deepest wells in the unconsolidated-deposit aquifers are in Coos and Curry Counties; the shallowest wells, which are generally about 10 feet deep, are predominantly in Clatsop and Tillamook Counties. Depth to water in wells ranges from less than 5 feet below land surface in Lane and Lincoln Counties to 110 feet below land surface in the deep wells in Coos and Curry Counties.

  The unconsolidated-deposit aquifers are productive. Well yields generally range from 50 to 250 gallons per minute in Coos, Curry, and Douglas Counties; from 50 to 700 gallons per minute in Lane and Lincoln Counties; and from 300 to about 2,000 gallons per minute in Clatsop and Tillamook Counties. Most fresh ground-water withdrawals are used for domestic and commercial and agricultural (primarily livestock watering) purposes. Deeper wells along the Umpqua River Valley in Douglas County commonly yield saltwater. The potential for saltwater intrusion into freshwater aquifers exists along the entire coast.

- **Other areas of substantial ground-water development in Oregon are west-central Jackson and east-central Josephine Counties.** In west-central Jackson County, unconsolidated deposits and pre-Miocene rocks are major aquifers. In the Medford area of Jackson County, springs discharge as much as 18,000 gallons per minute. Wells that are used for domestic and commercial and agricultural (primarily livestock watering) purposes generally are 40 to 145 feet deep. Depth to water ranges from less than 10 to about 15 feet below land surface.

  In east-central Josephine County, unconsolidated deposits and pre-Miocene rocks are the major aquifers. In the Grants Pass area, wells that are used for domestic and commercial and agricultural (primarily livestock watering) purposes generally are 60 to 125 feet deep. Depth to water ranges from less than 10 to 50 feet below land surface. Yields from these wells range from less than 50 to 200 gallons per minute.

- **In Jefferson County in north-central Oregon,** ground water is obtained from unconsolidated deposits and volcanic and sedimentary rocks. The water is used for domestic and commercial and agricultural purposes. Well yields are generally small.

- **Some of the most productive aquifers in Oregon** are volcanic- and sedimentary-rock aquifers that consist of porous basalt and cinders and that underlie the Sprague River Valley in south-central Klamath County. In this valley, some wells that generally range from 100 to 700 feet in depth yield about 3,500 gallons per minute with only a few feet of drawdown. Artesian wells might flow at a rate of 1,000 gallons per minute and can be pumped at rates that exceed 2,000 gallons per minute. The maximum depth to water in nonflowing wells is about 65 feet below land surface. Large springs also are present in the valley and discharge from 39,000 to 135,000 gallons per minute, depending on the volume of recharge.

  South of Sprague River Valley, Swan Lake, Yonna, and Langell Valleys are filled with fine-grained unconsolidated deposits that yield little water, but the underlying volcanic- and sedimentary-rock aquifers yield large quantities of water to wells; maximum well yields in Swan Lake Valley are about 2,850 gallons per minute, and those in Yonna Valley are about 3,000 gallons per minute. Well depth in the valleys varies—from 180 to 860 feet in Swan Lake Valley, from 100 to 600 feet in Yonna Valley, and from 210 to 990 feet in Langell Valley; however, depth to water in the wells is similar—from 15 to 120 feet below land surface in Swan Lake Valley, from 10 to 110 feet below land surface in Yonna Valley, and from 15 to 150 feet below land surface in Langell Valley. Fresh ground-water withdrawals in all four valleys are used mostly for agricultural (primarily irrigation and livestock watering) purposes. In the Klamath Falls area, wells that are as much as 2,000 feet deep yield geothermal water from volcanic- and sedimentary-rock aquifers. As many as 500 wells supply geothermal water for heating homes and public buildings in Klamath Falls. Well yields in the Klamath Falls area generally range from 100 to 3,000 gallons per minute.

- **In southwestern Lake County, Goose Lake Basin** is filled with unconsolidated deposits, some of which contain organic debris. Decay of the organic debris results in ground water that contains large concentrations of iron, hydrogen sulfide, and methane. However, most wells that generally are from 110 to 810 feet deep are completed in the underlying volcanic- and sedimentary-rock aquifers and do not contain large concentrations of iron, hydrogen sulfide, and methane. Some of these deeper wells yield geothermal water.

- **The upper John Day River Valley in Grant County in north-central Oregon** is long and narrow (less than 1 mile wide) and is bordered by steep rock walls. Unconsolidated deposits that fill the valley are coarse and extremely permeable. Near the town of John Day, the Miocene basaltic rocks that underlie the unconsolidated deposits are much less permeable. The water is used for domestic and commercial and agricultural purposes.

- **Near Bend in Deschutes County,** ground water is obtained from volcanic and sedimentary rocks that consist of basalt flows, cinders, ash, and pumice. Depth to water normally exceeds 500 feet below land surface; domestic wells generally are not drilled to this depth. Northwestward from Bend toward Redmond, depth to water decreases and ranges from 200 to 300 feet below land surface, which slopes northward. Well yields of as much as 500 gallons per minute are common near Redmond.

- **In Baker City, Baker County,** the water table ranges from less than 10 to 50 feet below land surface. Shallow wells yield water from unconsolidated-deposit aquifers; deeper wells yield water from Miocene basaltic-rock aquifers for public-supply, domestic and commercial, and agricultural purposes. The wells range in depth from about 10 to more than 650 feet.

- **Cow Valley in northern Malheur County** is a small upland basin that was declared a Critical Ground-Water Area during 1959. Wells in the valley yield water from unconsolidated deposits (primarily sand and gravel) and from Miocene basaltic rocks that are at various depths; for example, some wells that are less than 500 feet deep are completed in basaltic rocks, whereas nearby wells that are as much as 1,000 feet deep might be completed in sand and gravel. The water is used mostly for agricultural purposes. Unconsolidated deposits in the Vale area southeast of Cow Valley are the primary source of ground water that is used for public-supply, domestic and commercial, and agricultural purposes. Well depths range from 200 to more than 600 feet. Depth to water ranges from about 5 feet to 220 feet below land surface.

- **In south-central Oregon,** alluvial basins, which are characterized by semiarid environments, are underlain primarily by unconsolidated-deposit, Pliocene and younger basaltic-rock, volcanic- and sedimentary-rock, and Miocene basaltic-rock aquifers and occupy most of Harney and Lake Counties. Most recharge to aquifers originates from winter snowfall or summer rainstorms, and most discharge is by evapotranspiration and, in developed areas, by ground-water withdrawals. Typically, the alluvial basins are closed; that is, virtually all surface water and ground water that enters the basins flows or discharges into lakes, ponds, or marshes that occupy the centers of the basins where the water is evaporated or transpired by plants. Dissolved minerals in the surface and the ground water are concentrated by evaporation, which results in saltwater lakes, ponds, and marshes, and salty ground water at shallow depths in the ponding areas. Some minerals precipitate from solution and form deposits on the land surface.

- **Several communities in Harney and Lake Counties** obtain their water supply from streams that are sustained by spring flow; for example, flow in the Donner Und Blitzen River, which is sustained by generally constant discharge from several large springs, provides a dependable water supply for Burns in Harney County. In northern Harney County, unconsolidated-deposit aquifers, which consist of sand and gravel, are the major source of water; Miocene basaltic-rock aquifers also provide some water. Well depths generally range from 15 to 300 feet. Depth to water generally is from 10 to 90 feet below land surface. Fresh ground water is used for public-supply, domestic and commercial, and agricultural (primarily livestock watering), purposes. Salty ground water is present near Harney and Malheur Lakes. In southern Harney County, unconsolidated deposits and volcanic and sedimentary rocks are major aquifers. Depth to water generally is from 15 to 100 feet below land surface. Fresh ground water is used for the same purposes as in northern Harney County. In southern Harney County, salty ground water is present near Alvord Lake and in much of the basin northeast of the lake.

- **In Lake County,** unconsolidated deposits and volcanic and sedimentary rocks are major aquifers. Well yields might be as much as 2,000 gallons per minute. In Fort Rock Valley (northwestern Lake County), well depths generally range from 50 to 700 feet. Depth to water generally is 15 to 55 feet below land surface. In the Goose Lake Basin, well depths exceed 800 feet. Depth to water can be more than 500 feet below land surface. In Warner Valley (southeastern Lake County), well depths generally range from 80 to 375 feet. Some of the deeper wells, which are completed in volcanic- and sedimentary-rock aquifers, are geothermal and flow at land surface. Depth to water in nonflowing wells in Warner Valley generally is about 20 feet below land surface. Fresh ground water in Lake County is used for public-supply, domestic and commercial, and agricultural (primarily irrigation and livestock watering) purposes. Salty ground water is present near Crump and Summer Lakes.

Information pertaining to ground-water conditions in other areas of substantial ground-water development in Oregon is summarized by county in **table 8**.

Table 8. *Ground-water conditions in other areas of substantial ground-water use in Oregon*

[Aquifer: Ud, unconsolidated deposits; Ybr, Pliocene and younger basaltic rocks; Vsr, volcanic and sedimentary rocks; Obr, Miocene basaltic rocks; pM, pre-Miocene rocks. Water use: PS, public supply; DC, domestic and commercial; A, agricultural (primarily irrigation and livestock watering); I, industrial. Symbols: n.d., no data available; <, less than; >, greater than]

Location	Principal aquifer	Typical well depth (feet below land surface)	Depth to water (feet below land surface)	Range of well yields (gallons per minute)	Principal water use	Remarks
Baker County	Ud, Obr	<10–>650	<10–50	n.d.	PS, DC, A	Most wells in Baker City area.
Clackamas County	ditto	n.d.	n.d.	1–20	DC, A	
Clatsop County	Ud	10–100	<10–50	300–2,000	ditto	
Columbia County	Ud, Obr	n.d.	n.d.	1–500	PS, DC, A	
Coos County	Ud	20–150	10–110	50–250	DC, A	
Crook County	Ud, Vsr, Obr	45–250	20–60	>500	PS, DC, A	Ud is major aquifer in Prineville area.
Curry County	Ud	20–150	10–110	50–250	DC, A	
Deschutes County	Ud, Vsr, Obr				PS, DC, A, I	
Bend		>500	>500	n.d.		
Redmond		n.d.	200–300	500		
Douglas County	Ud, pM	80–120	<10–25	50–250	PS, DC, A	Saltwater is common from deeper wells in Umpqua River Valley.
Grant County	Ud, Obr	n.d.	n.d.	n.d.	ditto	Ud is major aquifer in John Day River Valley.
Harney County	Ud, Ybr, Vsr, Obr				ditto	
Northern		15–300	10–90	n.d.		Sand and gravel are major aquifers.
Southern		n.d.	15–100	n.d.		
Jackson County	Ud, pM	40–145	<10–15	n.d.	DC, A	Near Medford, some springs discharge as much as 18,000 gallons per minute.
Jefferson County	Ud, Vsr	n.d.	n.d.	1–20	ditto	
Josephine County	Ud, pM	60–125	<10–50	<50–200	DC, A	Numerous wells in Grants Pass area.
Klamath County	Ud, Vsr				PS, DC, A, I	
Klamath Falls		<100–2,000	n.d.	100–3,000		Geothermal and flowing wells common.
Langell Valley		210–990	15–150	n.d.		
Sprague River Valley		110–700	Flowing–65	>3,500		Vsr underlying Ud is most permeable. Some springs discharge as much as 135,000 gallons per minute.
Swan Lake Valley		180–860	15–120	n.d.–2,850		Vsr underlying Ud is most permeable.
Yonna Valley		100–600	10–110	n.d.–3,000		ditto
Lake County	ditto				PS, DC, A	
Fort Rock Valley		50–700	15–55	<100–2,000		
Goose Lake Basin		110–810	5–>500	<100–2,000		Geothermal wells common.
Warner Valley		80–375	Flowing–20	<100–2,000		ditto
Lane County	Ud, Vsr, Obr	<150	<5–25	50–700	DC, A	Dune and beach sand are important aquifers.
Lincoln County	Ud	<150	<5–25	50–700	ditto	ditto
Linn County	Ud, Vsr, Obr	n.d.	n.d.	1–20	ditto	
Malheur County	Ud, Ybr, Vsr, Obr				PS, DC, A	
Cow Valley		<200–1,000	<30–>100	1–2,000		Critical Ground-Water Area.
Vale area		200–>600	5–220	1–100		
Marion County	Ud, Vsr, Obr	n.d.	n.d.	1–20	DC, A	
Tillamook County	Ud	10–100	<10–50	300–2,000	PS, DC, A	

WASHINGTON

Other areas of substantial ground-water development in Washington that are not in the regional aquifer systems include Ferry, Okanogan, Pend Oreille, and Stevens Counties in northeastern Washington (**fig. 95**); Chelan and Kittitas Counties in central Washington; Clallam, Grays Harbor, Jefferson, and Pacific Counties along the Washington coast; and Wahkiakum County along the Columbia River near the Washington coast. Unconsolidated deposits are the most important aquifers. They provide water for public-supply, domestic and commercial, agricultural, and industrial purposes.

Much of each of the above counties is topographically rugged, and ground-water development is in the valleys or terraces. Aquifers in Miocene basaltic and pre-Miocene rocks locally yield small quantities of water to wells.

A synopsis of some aspects of the ground-water system in selected areas of substantial ground-water development in Washington (**fig. 95**) is presented below:

- **The river valleys in Ferry, Pend Oreille, and Stevens Counties** are filled with alluvium and glacial deposits that compose the unconsolidated-deposit aquifers. Ground water is used for domestic and commercial and agricultural purposes. Most wells, which range from less than 100 to 200 feet deep, yield from 50 to 250 gallons per minute. A few deeper wells yield from 250 to as much as 1,700 gallons per minute. An artesian municipal well for Colville in Stevens County yields as much as 1,700 gallons per minute.
- **Glacial deposits of sand and gravel as much as several hundred feet thick are major aquifers in the Okanogan River Valley in Okanogan County.** The greatest use of ground water is for agricultural (irrigation and livestock watering) purposes, but some is used for public-supply and domestic and commercial purposes. Wells that are less than 60 feet deep yield from less than 10 to 1,000 gallons per minute in most places.
- **In Chelan and Kittitas Counties,** unconsolidated deposits are major aquifers; some deposits are as much as 100 feet thick. Most wells, which range from 30 to 100 feet deep, withdraw water for public-supply, domestic and commercial, and agricultural (primarily livestock watering) purposes. Yields to wells range from 10 to 1,000 gallons per minute.
- **Along the Washington coast,** virtually all wells yield water from unconsolidated-deposit aquifers. In Clallam, Grays Harbor, and Jefferson Counties, the depth of wells, which generally ranges from 50 to 100 feet, is similar, as is the yield, which ranges from 25 to 300 gallons per minute. In Pacific County, wells tend to be deeper (100 to 500 feet) and yield more water (50 to 2,000 gallons per minute). Artesian wells are common. Dune and beach sand are aquifers in places. In all four counties, the principal uses of fresh ground-water withdrawals are for public-supply, domestic and commercial, and agricultural (primarily irrigation and livestock watering) purposes; fresh ground-water withdrawals also are used for industrial purposes in Pacific County. As along the Oregon coast, the potential for saltwater intrusion into freshwater aquifers exists.
- **Along the Columbia River in Wahkiakum County,** wells produce water from unconsolidated-deposit aquifers in the lowlands and from Miocene basaltic-rock aquifers in the uplands. Wells completed in the unconsolidated deposits yield from 25 to 250 gallons per minute. Wells completed in the Miocene basaltic rocks yield from 50 to 500 gallons per minute. Most freshwater withdrawn is used for domestic and commercial and agricultural (primarily livestock watering) purposes.

Information pertaining to ground-water conditions in other areas of substantial ground-water development in Washington is summarized by county in **table 9**.

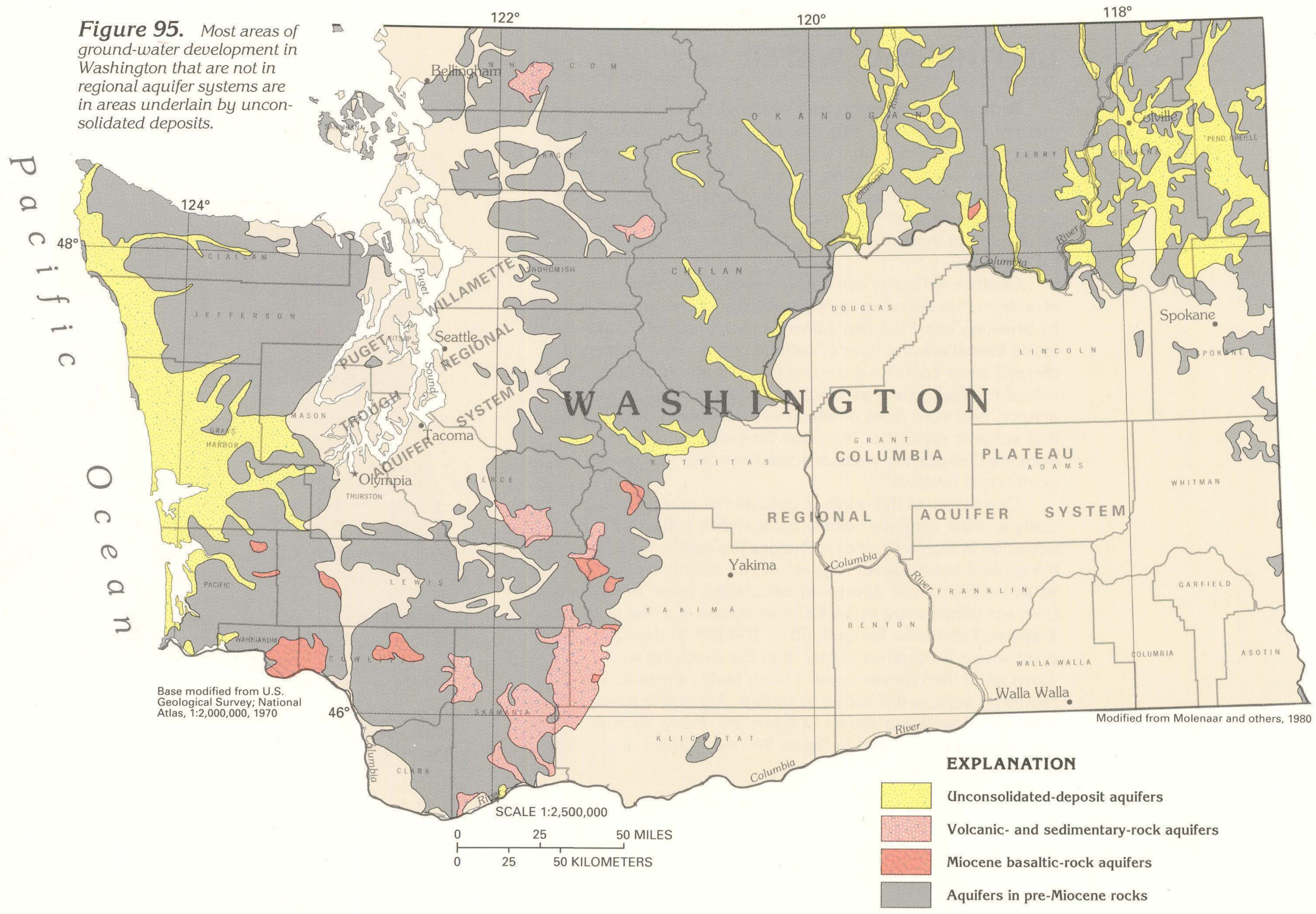


Figure 95. Most areas of ground-water development in Washington that are not in regional aquifer systems are in areas underlain by unconsolidated deposits.

Table 9. *Ground-water conditions in other areas of substantial ground-water use in Washington*

[Aquifer: Ud, unconsolidated deposits; Obr, Pliocene basaltic rocks; pM, pre-Miocene rocks. Water use: PS, public supply; DC, domestic and commercial; A, agricultural (primarily irrigation and livestock watering); I, industrial. Symbols: n.d., no data available; <, less than; >, greater than]

Location	Principal aquifer	Typical well depth (feet below land surface)	Depth to water (feet below land surface)	Range of well yields (gallons per minute)	Principal water use	Remarks
Chelan County	Ud	30–100	n.d.	10–1,000	PS, DC, A	Sediments as much as 100 feet thick.
Clallam County	Ud, pM	50–100	n.d.	25–300	ditto	Flowing wells common.
Clark County	Ud	50–300	n.d.	<100–4,500	PS, DC, A, I	Larger yields are from public-supply or industrial wells.
Cowlitz County	ditto	n.d.	n.d.	<5–3,000	ditto	ditto
Ferry County	Ud, pM	10–200	n.d.	50–>1,000	PS, DC, A	Flowing wells in places.
Grays Harbor County	Ud	50–100	n.d.	25–300	ditto	Flowing wells common.
Jefferson County	Ud, pM	<50–100	n.d.	25–300	ditto	ditto
Kittitas County	ditto	n.d.	n.d.	10–1,000	ditto	
Okanogan County	ditto	10–100	n.d.	<10–1,000	ditto	Sediments greater than 200 feet thick in places.
Pacific County	ditto	100–500	n.d.	<10–2,000	ditto	Flowing wells common.
Pend Oreille County	ditto	10–300	n.d.	50–250	ditto	Ud generally has medium to high permeability.
Stevens County	ditto	<100–>200	n.d.	<5–1,700	PS, DC, A, I	Flowing wells in places.
Wahkiakum County	Ud, Obr, pM	n.d.	n.d.	<25–500	PS, DC, A	Obr is most productive aquifer.

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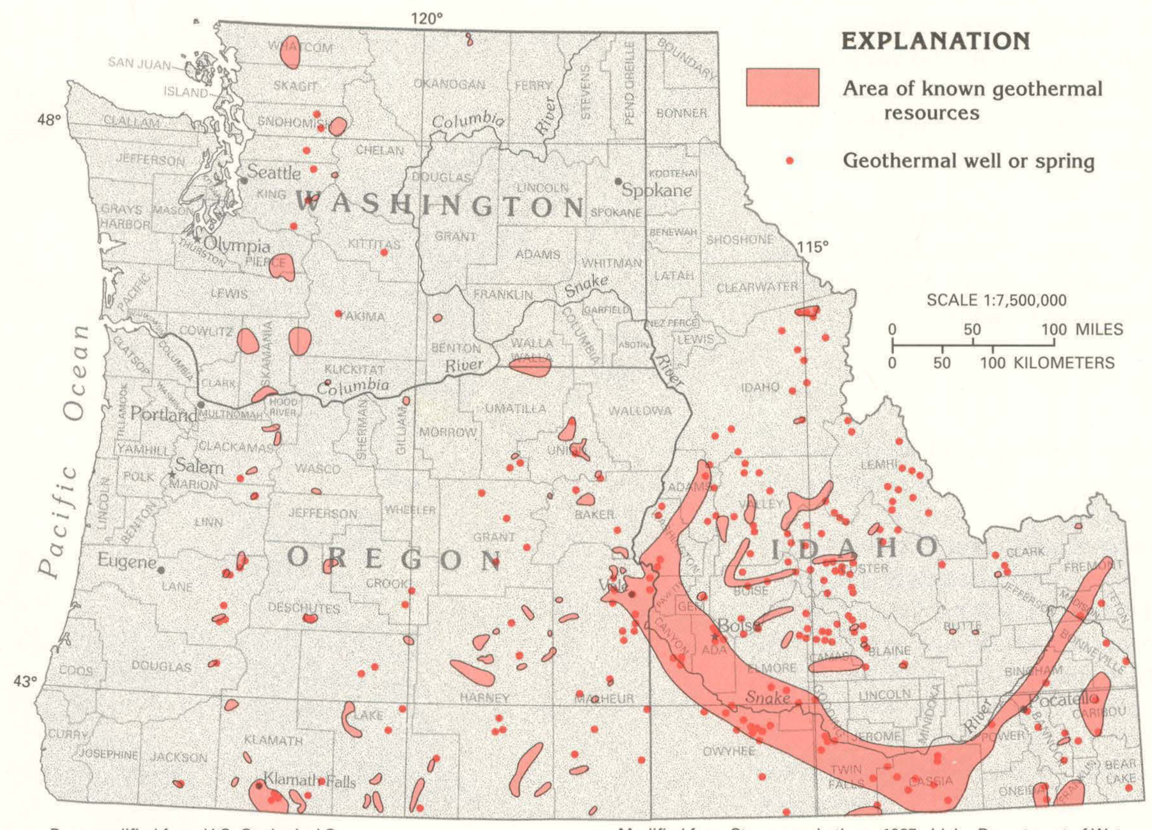
GEOTHERMAL WATER

Parts of Idaho, Oregon, and Washington have known geothermal resources (**fig. 96**) that are particularly valuable in Boise, Idaho, and Klamath Falls, Oreg., where the resource has been used for space heating since the late 1890's. The temperature of geothermal water is appreciably higher than the local mean annual air temperature. In Idaho, geothermal water can be so hot that it needs to be cooled before it can be used for irrigation.

Geothermal water can contain excessive concentrations of sodium that decrease the permeability of fine-grained soils by breaking apart the clay minerals in the soil, which results in the formation of a layer of caliche or hardpan. Some geothermal water contains excessive concentrations of other dissolved minerals, such as calcium, sulfate, chloride, fluoride, arsenic, and iron, most of which were dissolved from the silicic volcanic rocks that compose the geothermal reservoir or from the fine-grained unconsolidated deposits that overlie the geothermal reservoir.

One theory of the origin of geothermal water, which generally is under confined conditions, is shown in **figure 97**. Precipitation in highland areas recharges the aquifer system, and the ground water moves to great depth, mainly along faults. At some depth, the downward-circulating water is warmed (average temperature in the Earth increases at a rate of about 1 degree Fahrenheit for each 60 to 100 feet of depth) to the point where it becomes lighter than the overlying water. The warm water then moves upward along faults, where it is intercepted by wells, or discharges to springs. Areas with successful geothermal wells are shown in **figure 96**. Many, such as the well shown being drilled in **figure 98**, were drilled at sites of geothermal springs.

Geothermal water



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1972

Modified from Stearns and others, 1937; Idaho Department of Water Resources, 1980; Washington Department of Natural Resources, 1981; and Oregon Department of Geology and Mineral Industries, 1982

Figure 96. Most areas of known geothermal resources are small and scattered throughout Segment 7, except for the large area along the Snake River in Idaho.

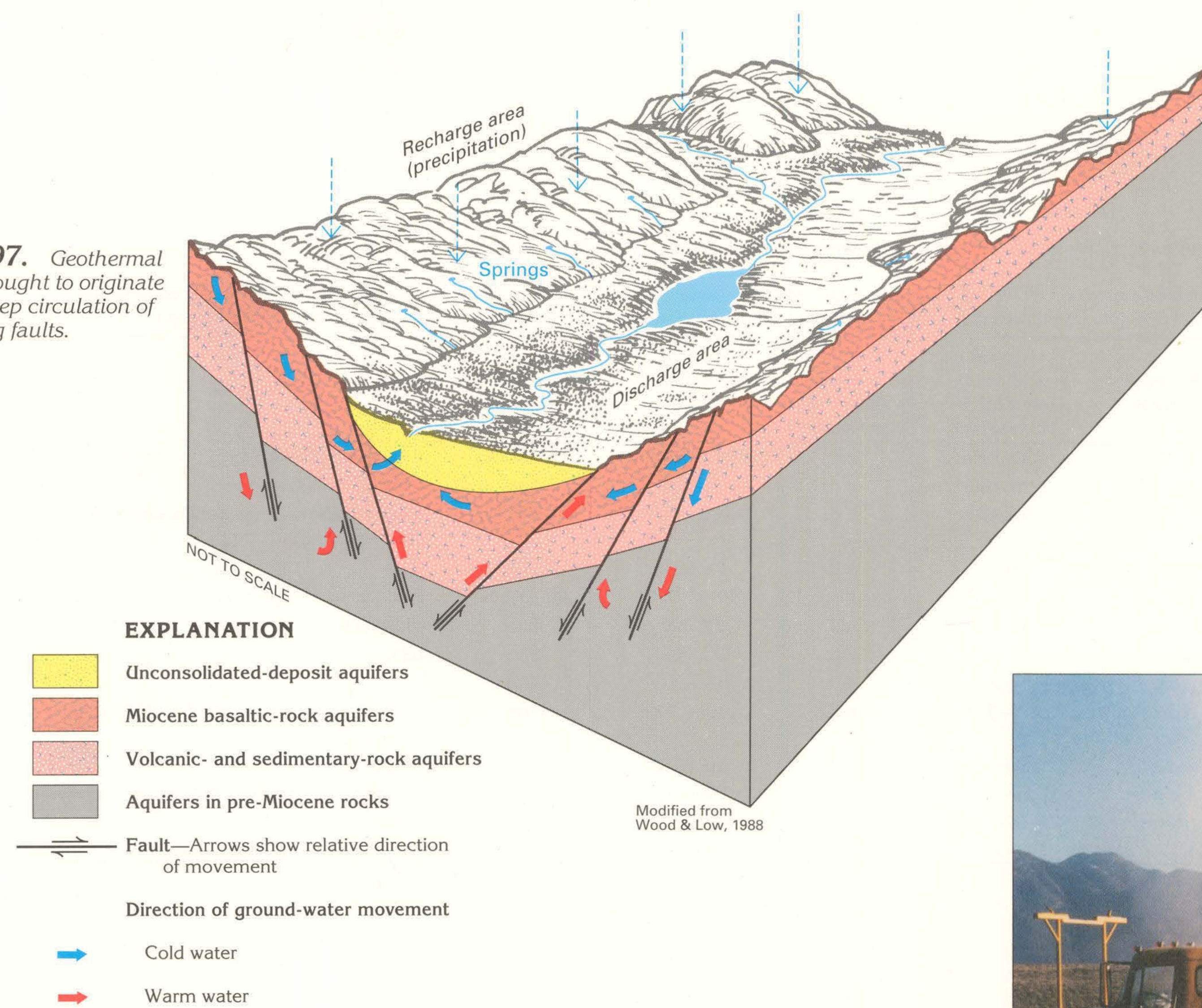


Figure 97. Geothermal water is thought to originate from the deep circulation of water along faults.

E.G. Crosthwaite, U.S. Geological Survey, 1975

Figure 98. Drilling geothermal wells is hot, dangerous work.

Figure 99. Tongs are needed to hold sample bottles at some geothermal wells. Water temperature is as much as 225 degrees Fahrenheit in places.

During the 1970's, considerable attention was given to developing additional geothermal resources in Idaho and Oregon. As a result, water-level measuring and water-sampling programs were initiated to monitor hydraulic-head changes in the aquifers and geothermal-water quality. A typical technique for sampling geothermal wells is to hold the sampling device with tongs to avoid being scalded by the hot water (**fig. 99**). A geothermal well near Vale in Malheur County, Oreg., produced water with a temperature of 225 degrees Fahrenheit.

Most of the geothermal systems developed are used for space heating, food processing, and aquaculture. Some geothermal wells yield small quantities of methane, which is used in a few places in Idaho for cooking and heating.

The volume of water in geothermal systems is small relative to that in cold-water systems. For this reason, reinjecting water withdrawn from geothermal systems into the aquifer can decrease pressure loss and alleviate water-level declines.

GROUND-WATER PROBLEMS

Long-term declines in ground-water levels are probably the most important ground-water problem in Idaho, Oregon, and Washington. In some places within Segment 7, long-term declines in ground-water levels have been intensified by free-flowing artesian wells that decrease the hydraulic pressure in aquifers and remove water from storage in the aquifers. Many of these wells discharge thousands of gallons of water per minute and are not constructed to shut off flow as required by State law. Where water levels have declined substantially, State water agencies have attempted to alleviate the problem by designating Critical Ground-Water Areas or Ground-Water Management Areas (**fig. 100**). In either type of area, further development is allowed only where withdrawals from new wells will not interfere with those from existing wells (**fig. 101**). Most long-term water-level declines are in volcanic- and sedimentary-rock aquifers in the arid and semiarid parts of Idaho, Oregon, and Washington. Some Ground-Water Management Areas in Oregon and Washington were so designated to alleviate and control water-quality problems.

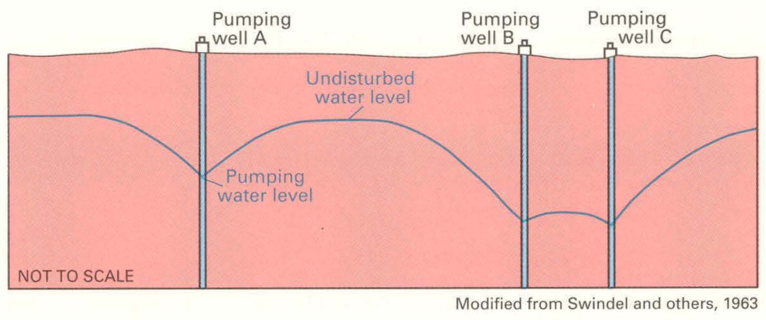


Figure 101. *Well interference can be avoided by careful design and spacing of wells. Of the three pumped wells, well A is properly spaced in relation to wells B and C. The cones of depression around wells B and C overlap and cause increased drawdown or decreased yield or both.*

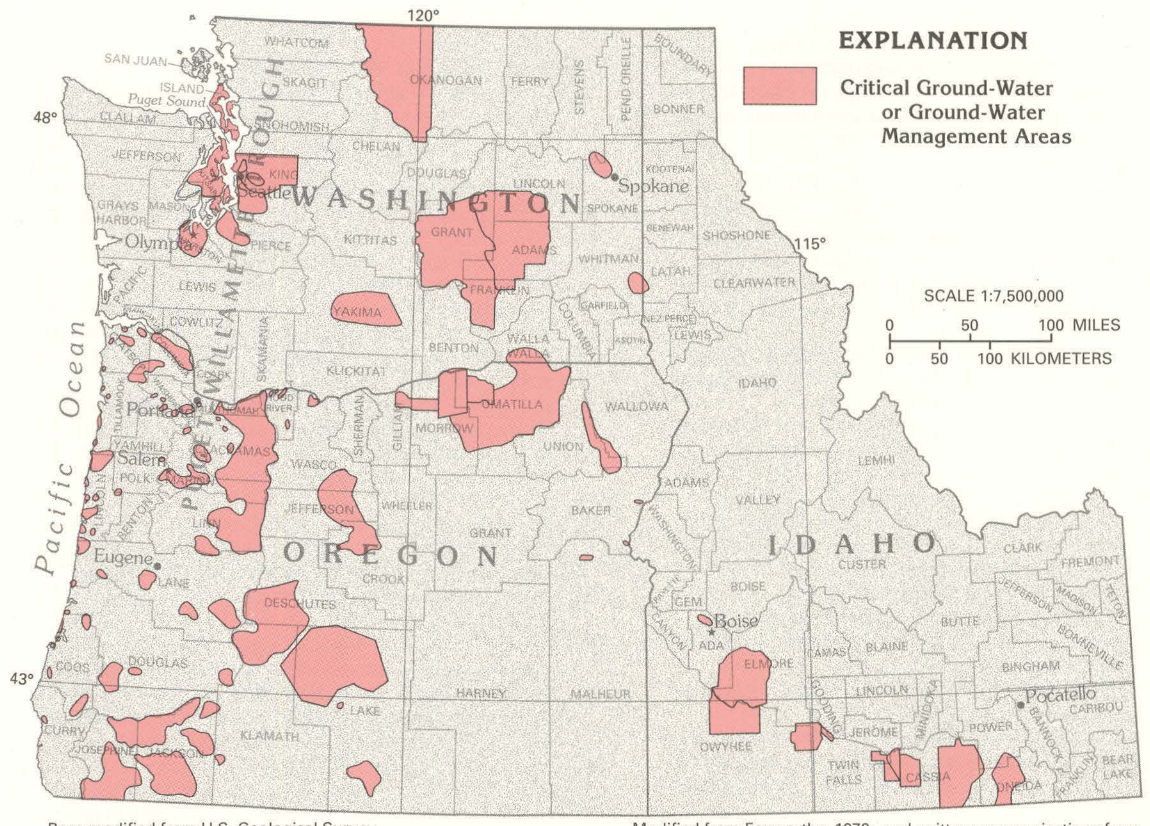


Figure 100. *Areas with significant or potentially significant ground-water problems are classified as Critical Ground-Water Areas or Ground-Water Management Areas subject to State regulations.*

Ground-water quality problems in Segment 7 include the fluctuation of the freshwater-saltwater interface beneath the land surface on the islands in Puget Sound (**fig. 102**), the intrusion of saltwater into freshwater aquifers in the Puget-Willamette Trough (**fig. 103**), the intrusion of saltwater into freshwater aquifers in coastal areas of Oregon and Washington (**fig. 104**), and the contamination of freshwater aquifers by geothermal water in Idaho and Oregon. Locally, freshwater aquifers have been contaminated by human activities in some parts of Segment 7.

Where permeable zones, such as the sand and gravel lenses in unconsolidated-deposit aquifers that underlie the islands in Puget Sound, are hydraulically connected to the Sound, movement of saltwater into the aquifers is naturally prevented by a column of freshwater (**fig. 102**). Because freshwater is lighter than saltwater, a column of freshwater that is 41 feet high is necessary to balance a column of saltwater that is 40 feet high. The result is that for each foot of freshwater above sea level, there is a column of freshwater about 40 feet thick below sea level. Lowering the freshwater column by decreasing precipitation or by increasing ground-water withdrawals or both results in saltwater rising to a higher altitude. Such a condition is shown by the position of the late summer interface (**fig. 102**), which corresponds to a time when the water table is lower. As the water table rises in response to precipitation in the spring, the freshwater column becomes higher, and the saltwater interface is simultaneously lowered. Incomplete flushing of the saltwater during this lowering could create a zone of brackish water in the aquifer. A similar situation is applicable in the coastal areas of Oregon and Washington.

In the Puget–Willamette Trough, particularly south of the Puget Sound lowland, saltwater can intrude into freshwater aquifers under a variety of conditions (**fig. 103**). The conditions that are illustrated in **figure 103*A*** and ***B*** can be intensified by the installation of wells within or near the zone of mixing, as illustrated in **figure 103*C***. The intrusion of saltwater can be minimized by careful monitoring of (1) well construction by installing shallow wells that skim the uppermost freshwater and (2) the magnitude and timing of ground-water withdrawals by allowing maximum withdrawals only during periods of maximum recharge.

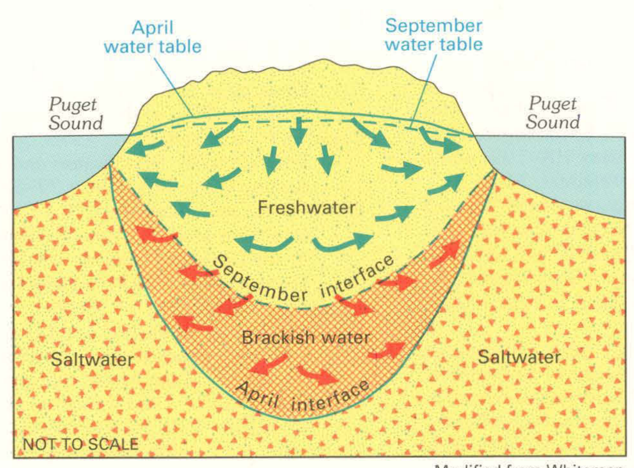
In coastal areas of Oregon and Washington, hydrologic conditions (**fig. 104**) are similar to those on the islands in Puget Sound (**fig. 102**). In the coastal areas, the extent of saltwater intrusion is determined primarily by the magnitude of ground-water withdrawals. As in the Puget–Willamette Trough, intrusion of saltwater into coastal areas can be minimized by careful design and placement of wells and careful monitoring of the magnitude and timing of ground-water withdrawals.

Excessive concentrations of certain dissolved minerals in geothermal water pose water-quality problems. The most common of these minerals are dissolved fluoride, arsenic, and iron. Concentrations of dissolved fluoride in excess of 4 milligrams per liter can cause mottling of teeth, especially children's, and can cause bones to become brittle. Dissolved iron is not detrimental to human health, but concentrations in excess of 200 micrograms per liter can cause staining of kitchen and bathroom fixtures and can cause clogging of well-screen openings and pumps. Concentrations of dissolved arsenic in excess of 30 micrograms per liter are toxic to humans.

Although generally of local extent, degradation of ground-water quality by human activities is more widespread and of greater consequence than are the naturally occurring water-quality problems. Ground water underlying the irrigated areas can contain greater-than-background concentrations of dissolved minerals because of increased salts, which are caused by evaporation of applied irrigation water. Large concentrations of chloride, nitrate, sulfate, and residue from fertilizers and pesticides applied to the land might reach the water table as irrigation water percolates downward. Ground water at and in the vicinity of abandoned and active landfills and other hazardous waste sites might be degraded by leachates that originated in the disposed material. Methane in explosive concentrations also might be entering the ground-water system at such sites. Chemicals in return water that is used for cooling and heating are potential contaminants of ground water. In addition, return-water temperature might differ substantially from the temperature of the water in the aquifer and cause adverse chemical reactions in the aquifer. Many wells are subject to intermittent contamination problems because of improper sealing around the well casing at the land surface.

Another local ground-water problem is waterlogging. Waterlogging has developed in some areas because of excess application of irrigation water obtained from surface-water sources. In other areas, natural waterlogging problems have been intensified by irrigation practices.

Figure 102. *The position of the saltwater-freshwater interface in unconsolidated-deposit aquifers under the surface of the islands in Puget Sound fluctuates seasonally. The interface is deeper during periods of greater-than-normal precipitation, such as early spring.*



EXPLANATION

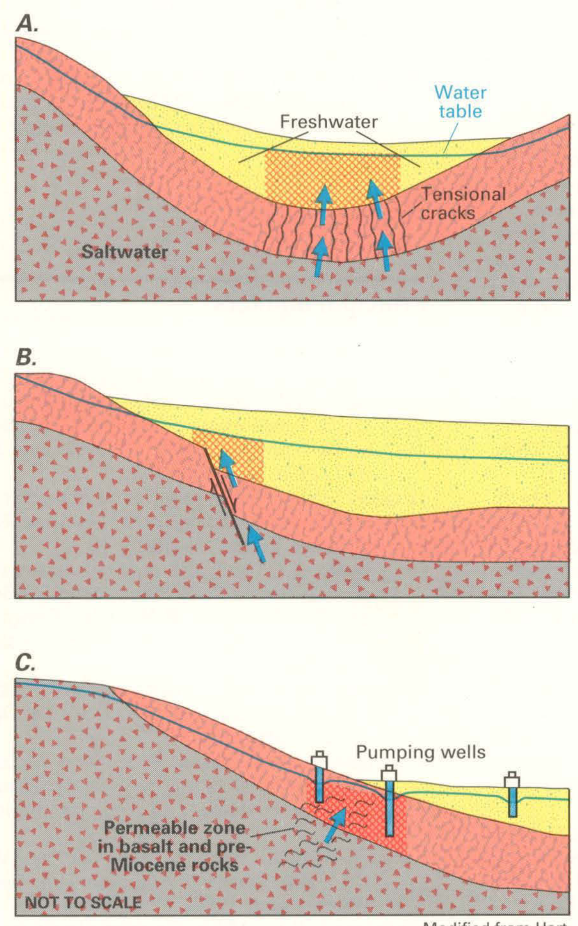
Unconsolidated-deposit aquifers

Direction of ground-water movement

Freshwater

Brackish water

Figure 103. *A water-quality problem typical of the Puget–Willamette Trough, particularly south of the Puget Sound lowland, is the intrusion of saltwater into Miocene basaltic-rock and unconsolidated-deposit aquifers from sedimentary-rock aquifers in underlying pre-Miocene rocks. **A**, Upward movement of saltwater through tensional cracks that developed during the formation of a syncline in Miocene basaltic-rock aquifers. **B**, Upward movement of saltwater along a fault that developed in Miocene basaltic-rock aquifers. **C**, Upward movement of saltwater through interconnected permeable zones in the aquifers is induced by ground-water withdrawals.*



EXPLANATION

Unconsolidated-deposit aquifers

Miocene basaltic-rock aquifers

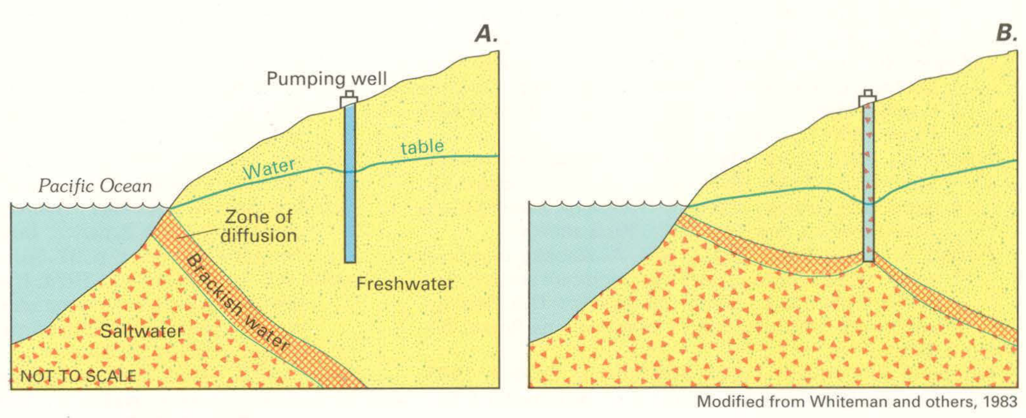
Aquifers in pre-Miocene rocks

Mixing freshwater and saltwater

Fault—Arrows show relative direction of movement

Direction of ground-water movement

Figure 104. *In coastal areas of Oregon and Washington, saltwater intrusion into freshwater aquifers can result from large withdrawals by wells. **A**, Diagram of a well completed in an unconfined, near-shore, unconsolidated-deposit aquifer under normal conditions of hydraulic equilibrium. No saltwater intrusion has taken place. **B**, Diagram of the same well under conditions of large ground-water withdrawals. Saltwater has intruded into the freshwater aquifer and has reached the well.*



EXPLANATION

Unconsolidated-deposit aquifers

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