CHANGES IN GROUND-WATER LEVELS AND GROUND-WATER BUDGETS, FROM PREDEVELOPMENT TO 1986, IN PARTS OF THE PASCO BASIN, WASHINGTON

By B.W. Drost, S.E. Cox, and K.M. Schurr

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

Multiply	By	To obtain
inch (in)	25.4	millimeter
inch per month (in/month)	25.4	millimeter per month
inches per year (in/yr)	25.4	millimeter per year
foot (ft)	0.3048	meter
foot per year (ft/yr)	0.3048	meter per year
square foot (ft^2)	0.0929	square meter
foot per day (ft/day)	0.0000035	meter per second
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
gallon (gal)	0.003785	cubic meter
gallon per day (gal/d)	0.003785	cubic meter per day
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per square foot per day [(ft^3/ft^2)d]	0.305	cubic meter per square meter per day

Temperature: To correct temperature given in this report in degrees Fahrenheit (°F) to degrees Celsius (°C), use the following equation: °C = 5/9(°F-32)

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.

Abbreviations:

BMID	Badger Mountain Irrigation District
CID	Columbia Irrigation District
Ecology	Washington State Department of Ecology
FCD	Franklin Conservation District
FCID	Franklin County Irrigation District
KID	Kennewick Irrigation District
RASA	Regional Aquifer-System Analysis (USGS program)
SCBID	South Columbia Basin Irrigation District
USACOE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

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ABSTRACT

Over the past 40 years, use of the Pasco Basin of south-central Washington has changed from rangeland and dryland farming to irrigated agriculture. Extensive irrigation, primarily with imported surface water, has transformed the area into one of the most productive agricultural lands in the United States. Irrigation has also caused water levels to rise several hundred feet over much of the irrigated area, resulting in large areas in which shallow water tables have created problems: waterlogged soils, landslides, and elevated concentration of nitrate in ground water. The annual flow through the ground-water system has increased seven-fold over predevelopment conditions. As of 1986, the flow through the ground-water system totaled nearly 400,000 acre-feet per year. The ground-water system has apparently reached equilibrium. Ground-water storage has increased by about 5,000,000 acre-feet from predevelopment conditions.

The changes in the ground-water system have resulted primarily from increased recharge from canal seepage and applied irrigation. These two factors account for nearly 85 percent of the increase in annual flow.

More efficient irrigation practices and increased use of liners in irrigation canals could significantly reduce recharge to the ground-water system and thereby lower water levels and decrease the problems caused by a shallow water table. However, reductions in recharge would result in increased pumping lifts and decreased ground-water availability. Recharge from canal seepage can dilute ground-water nitrate concentrations. Therefore, decreasing canal seepage could lead to significant increases in nitrate concentrations in ground water.

INTRODUCTION

The Pasco Basin (fig. 1) extends over approximately 2,000 mi^2 of south-central Washington. The basin has a diverse economy ranging from dryland and irrigated agriculture to the U.S. Department of Energy's Hanford Site. Over the past 40 years, much of the basin has been changing from rangeland and dryland farming into one of the major agricultural areas of the United States. Large volumes of water have been diverted from surface-water systems into this area for irrigation. There have also been large increases in ground-water pumping, primarily for irrigation.

A variety of problems have resulted, both directly and indirectly, from the increased irrigation in the basin. The use of surface water for irrigation has been linked to rises in ground-water levels in many areas (through percolation of surface water applied on crops and seepage from the distribution system). Ground-water levels have also risen because of higher surface-water levels, resulting from reservoirs formed by dams on the Columbia and Snake Rivers. Rising ground-water levels in some areas have resulted in septic system failures, damage to roads, and loss of agricultural land because of ponding. Rising ground-water levels have been identified as a cause of landslides along the Columbia River. Pumping of ground water has lowered water levels in some areas, causing concern over the future availability and cost of ground water for irrigation. Large concentrations of nitrate observed in water from some wells have been linked to application of fertilizers and (or) failure of septic systems. There also is concern that pesticides, which have been used in the area for many years, may have contaminated drinking water supplies, or may do so in the future.

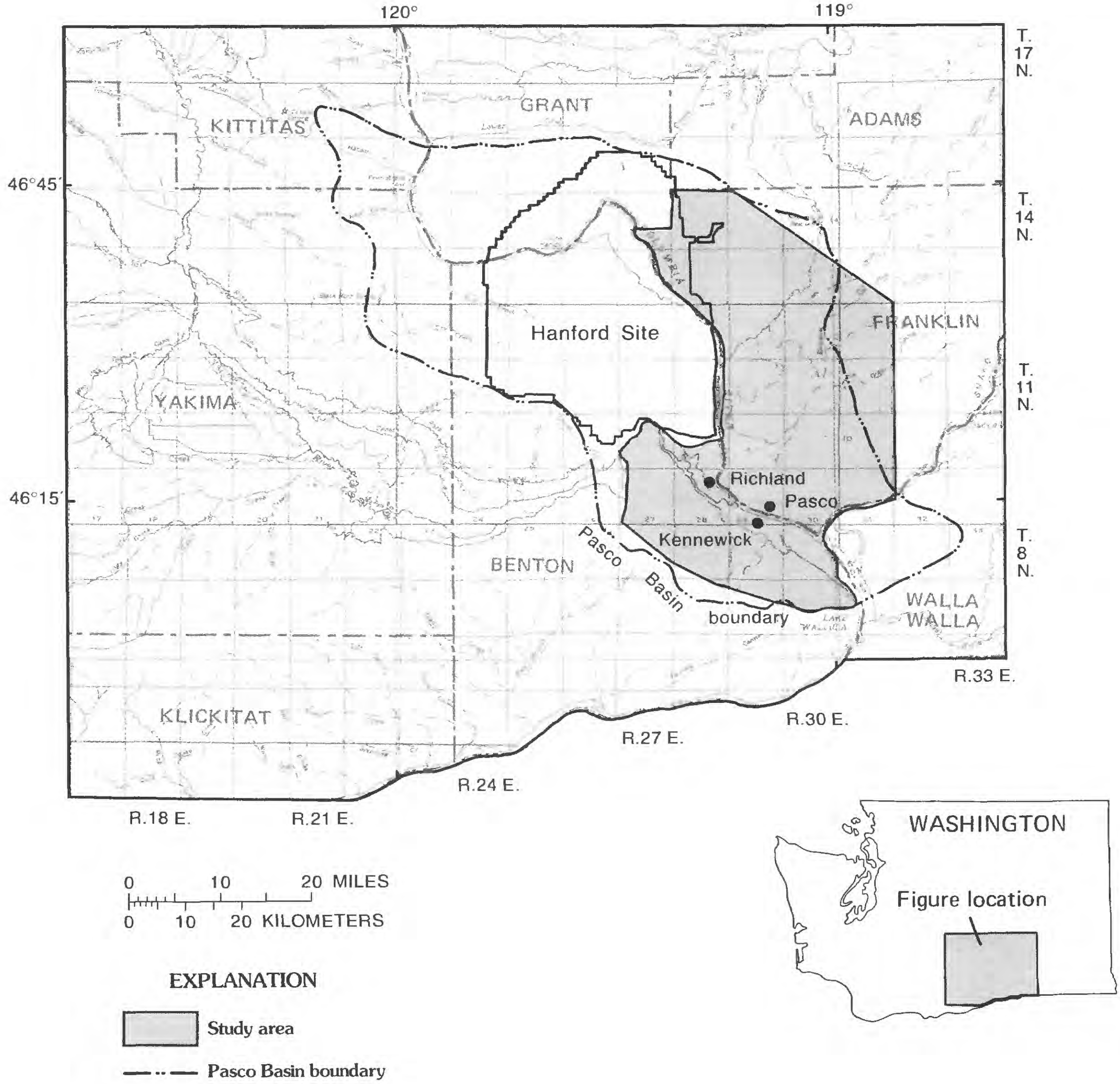


Figure 1.--Location of Pasco Basin and study area.

Rising ground-water levels have not come as a surprise in the Pasco Basin. Kocher and Strahorn (1919) concluded that some parts of Benton County would ultimately require drainage if significant amounts of irrigation water were ever applied. Mundorff and others (1952) pointed out that planned irrigation in Franklin County would eventually cause ground-water levels to be at or near land surface in much of the area and would probably lead to serious drainage problems.

Effective management of the ground-water system in the Pasco Basin requires knowledge of how each of the individual stresses (applied irrigation, canal seepage, pumping, and dams) influences the system, in terms of both water levels and water quality.

Purpose and Scope

The U.S. Geological Survey (USGS), in cooperation with the Washington State Department of Ecology (Ecology)[1], began a study in 1986 in parts of the Pasco Basin and adjacent areas (see study area, fig. 1) to determine

(1) The causes of changes in ground-water levels;

(2) The quality of the ground water, with emphasis on the distribution and probable sources of nitrate in the ground-water system;

(3) The possible presence of pesticides in ground water in selected areas of long-term pesticide application; and

(4) The important geohydrologic factors to be considered regarding management of the ground-water system.

This report contains the results of project efforts toward determination of the causes of ground-water level changes and identification of the geohydrologic factors to be considered regarding management of the ground-water system. All aspects of the project dealing with water quality are reported in Ebbert and others (1996). Two earlier reports (Drost and others, 1989a; and Drost and others, 1989b) contain basic data collected during the project.

[1] Ecology, in turn, reached a cooperative agreement for project funding and assistance with the following local agencies: Benton County, Franklin County, City of Kennewick, City of Pasco, City of Richland, City of West Richland, Columbia Irrigation District, and South Columbia Basin Irrigation District.

Description of the Study Area

The study area (fig. 2) encompasses nearly 900 mi^2 in Benton and Franklin Counties. The study area was delineated with the assistance of State and local agencies to include those areas in eastern Benton (not including the Hanford Site) and western Franklin Counties which have been, or may be, affected by changing water levels or elevated nitrate concentrations in ground water.

The study area lies almost entirely within the Pasco Basin, which is one of several basins in the Columbia Plateau province that are separated by anticlinal ridges. Altitudes range from about 340 ft to about 2,200 ft, with most of the study area at altitudes of less than 1,000 ft.

Many canyons, coulees, and scablands transect the study area. These features are the result of glacial-meltwater flooding during the Pleistocene. All present-day perennial and intermittent streams in the study area, including the Columbia and Snake Rivers, occupy channels with great relative sizes, indicating larger ancestral streams. These relict valleys have been only slightly modified by their present-day streams. Landslides and sand dunes are other features of the study area. Landslides, both active and inactive, are prominent along the White Bluffs of the Columbia River. Active and stabilized sand dunes cover large parts of Franklin County.

The climate of the study area is arid to semiarid. Mean annual precipitation ranges from 6 to 10 in. (figs. 2 and 3, and table 1) and occurs primarily in winter. Spring and summer precipitation is mainly in the form of local thunderstorms, whereas winter precipitation generally falls as light rain or snow. The mean annual temperature at Kennewick is about 57°F, with July the hottest month (mean monthly temperature of about 75°F) and January the coldest month (mean monthly temperature of about 31°F) (National Oceanic and Atmospheric Administration, 1974-87).

The 1986 population of the study area is about 125,000 (modified from Yates and Yates, 1987). About three-quarters of the population resides in the four largest cities (Kennewick, Pasco, Richland, and West Richland). The principal economic activities in the study area are food processing, agriculture, and manufacturing of chemical, metal, and nuclear products (Yates and Yates, 1987).

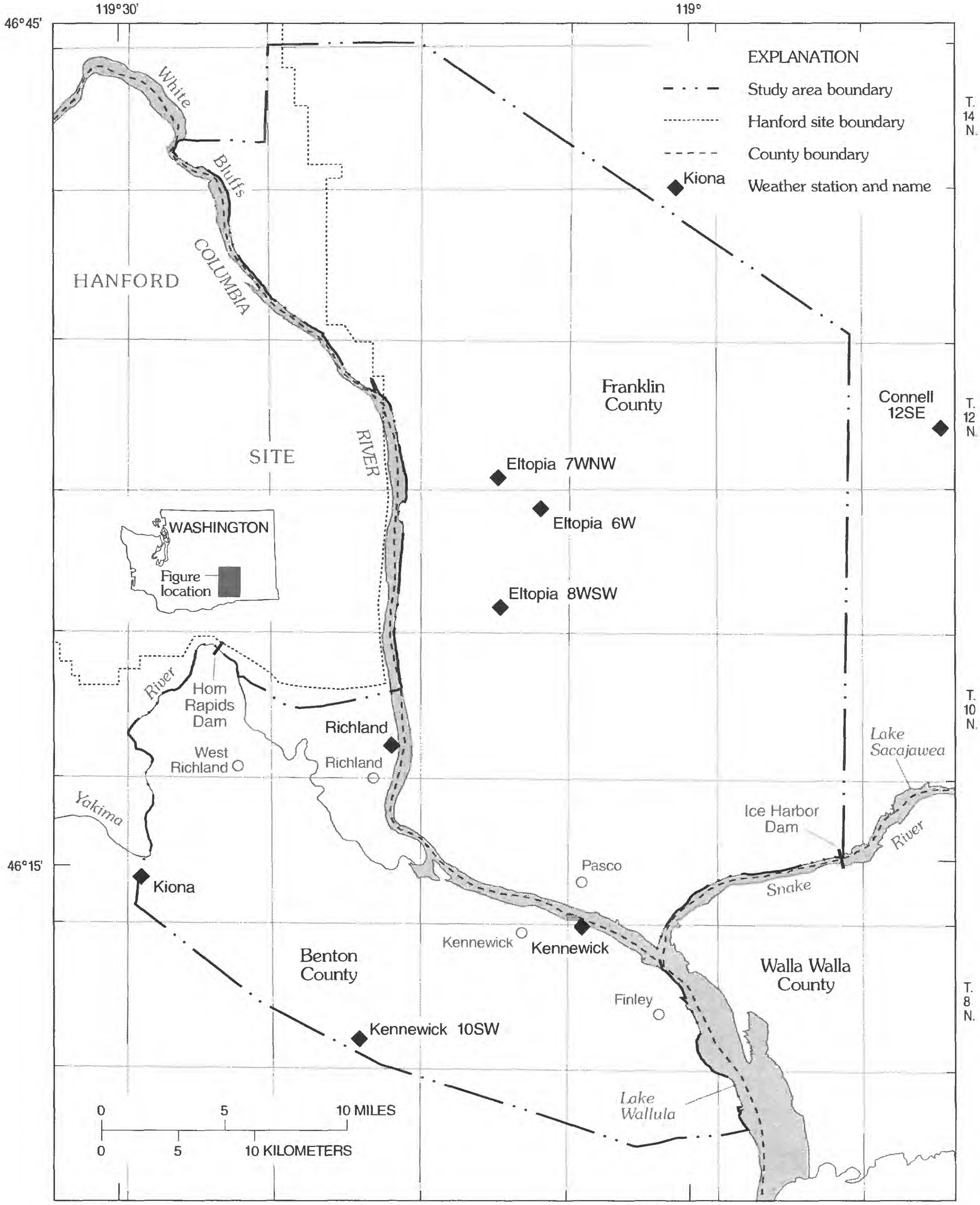


Figure 2.--Location of study area and weather stations.

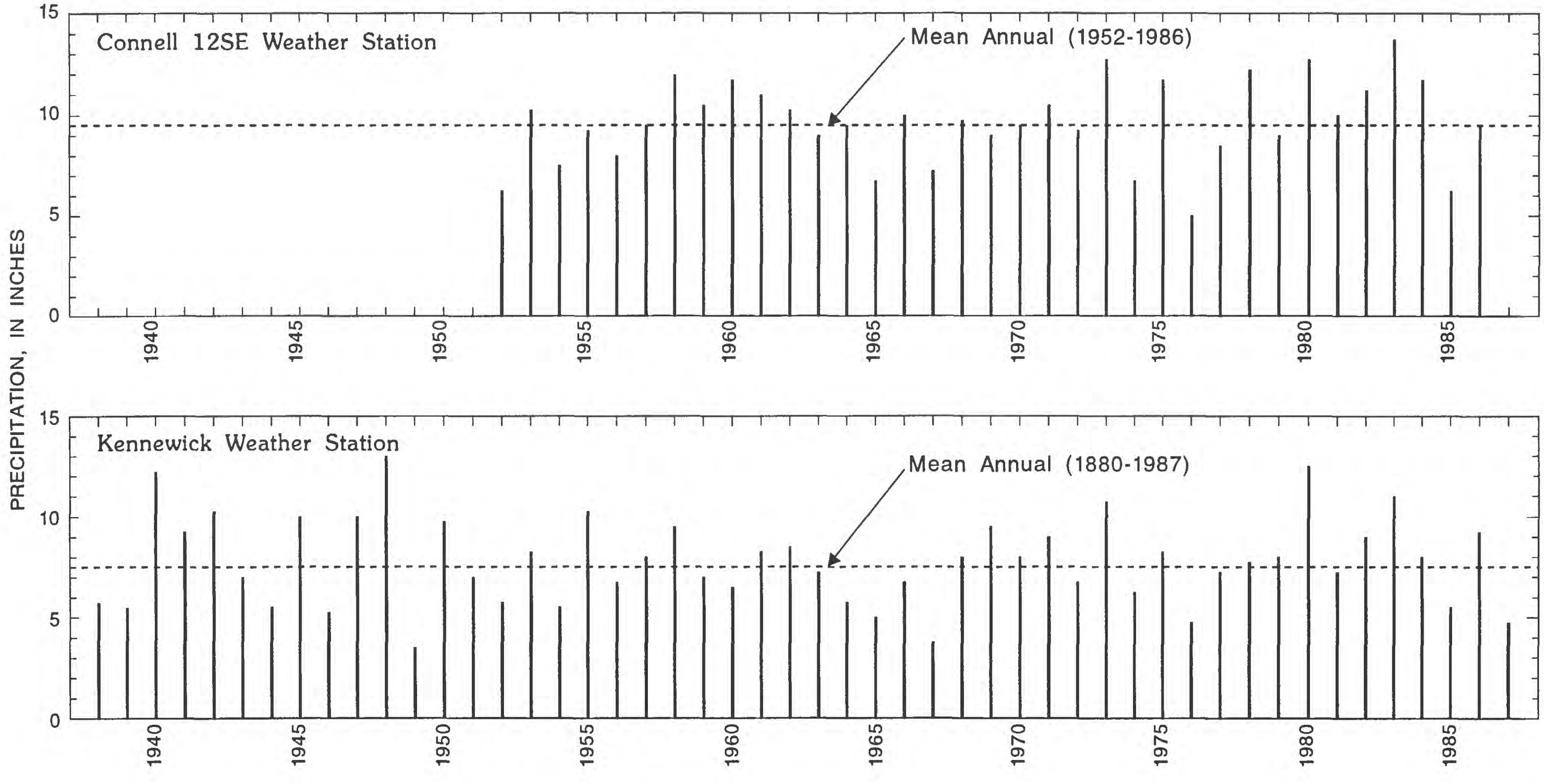


Figure 3.--Annual precipitation at Kennewick (1938-87) and Connell 12SE (1952-86) weather stations.

Many of the study area's residents work outside of the study area, primarily on the Hanford Site. Agriculture (crops, pasture, orchards, and vineyards) or undeveloped rangeland occupy 59 and 34 percent of the study area, respectively. Residential and urban uses account for about 3 percent of the study area; commercial and industrial about 2 percent; and rivers, streams, lakes, and wetlands about 2 percent. A generalized map of land use is shown on figure 4 (modified from U.S. Geological Survey, 1982).

Alfalfa, wheat, potatoes, and corn are the major crops in the study area, covering about 70 percent of the irrigated acres in 1986. Asparagus, fruits (apples, grapes, and cherries), pasture, and barley account for about 25 percent of the irrigated acres. The remaining 5 percent includes grass seed, carrots, peas, onions, oats, sorghums, cauliflower, and melons.

The dominant irrigation method uses sprinklers (center pivot, solid set, hand move, and wheel move), which are used on about 85 to 90 percent of the irrigated acreage (as of 1986). Most of the rest of the irrigated acreage is served by surface gravity systems. Less than 1 percent is served by drip irrigation.

Table 1.--*Precipitation at weather stations in the study area*

[Data from U.S. Weather Bureau, 1920-65; U.S. Department of Commerce, 1966-73; and National Oceanic and Atmospheric Administration, 1974-87]

Weather station name	Altitude (feet)	Period of record	Annual precipitation (inches) Minimum	Mean	Maximum
Connell 12SE	1,078	1952-86	5.17	9.46	13.62
Eltopia 6W	920	1955-57 1959-61	7.64	9.07	10.14
Eltopia 7WNW	895	1963-73	4.84	7.46	8.78
Eltopia 8WSW	700	1974-86	4.62	8.74	11.80
Kennewick[1]	390	1880-20 1922-87	3.78	7.52	12.90
Kennewick 10SW	1,500	1950-72	4.31	9.21	12.62
Kiona[2]	430	1907-37	5.59	8.16	11.28
Richland	373	1945-87	3.13	6.77	12.20

[1]Maximum and minimum values apply only to 1914-87.

[2]Maximum and minimum values apply only to 1914-37.

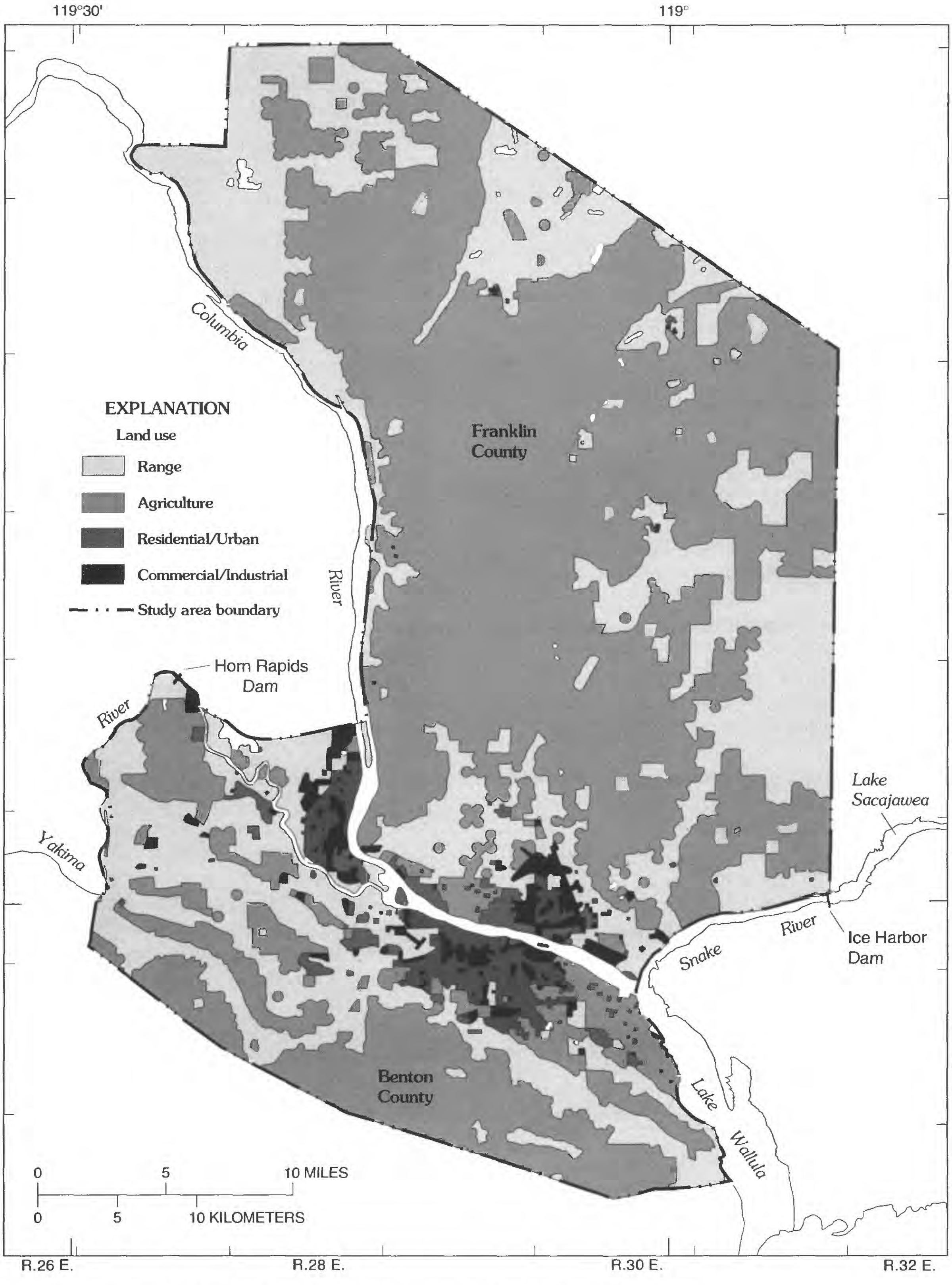


Figure 4.--Generalized land use in the study area (from Fegeas and others, 1983).

Acknowledgments

This study was done in cooperation with the Washington State Department of Ecology. Benton and Franklin Counties, the Cities of Kennewick, Pasco, Richland, and West Richland, the Columbia Irrigation District and the South Columbia Basin Irrigation District all took part in the study through a cooperative agreement with Ecology.

Michael Harris (Ecology) and Gary Karnofski (Benton Franklin Governmental Conference) provided much-needed lines of communication with the local agencies.

Swede Sunford and Timothy Mainwaring (CID), Merle Gibbens and Robert Hammond (SCBID), and Paul Chasco and Gary Weatherly of the Kennewick Irrigation District (KID) supplied data on their irrigation systems, allowed access to their canals for placement of gages, and assisted in canal-seepage tests.

John Holmes of the Franklin Conservation District contributed substantially to our investigations of applied irrigation water and subsequent ground-water recharge.

Daniel Hubbs of the Bureau of Reclamation and Michelle Zaro of the U.S. Army Corps of Engineers supplied information on observation wells and drains.

Karl Fecht of Westinghouse Hanford Corporation and Randall Brown (consulting geologist) provided informal reviews of the extent and thickness maps of the hydrologic units.

Numbering System for Wells and Springs

The location numbers used in this report give the location of wells and springs according to the official rectangular public-land survey (fig. 5). For example, in well number 09N/27E-12F02, the part preceeding the hyphen indicates the township and range (T.09 N., R.27 E.) north and east of the Willamette base line and meridian, respectively. The number following the hyphen indicates the section (sec. 12), and the letter (F) indicates the 40-acre subdivision of the section as shown on figure 5. The last two digits (02) are a sequence number used to distinguish wells in the same 40-acre tract. Thus, well 09N/27E-12F02 is in the SE1/4 of the NW1/4 of sec. 12, T.09 N., R.27 E. A "D" following the sequence number indicates a well which has undergone changes in construction (generally deepening). The number following the "D" is a sequence number to distinguish multiple construction changes in the same well. An "S" following the sequence number indicates that the site is a spring.

HISTORY OF WATER DEVELOPMENT

Significant development of the water resources of the study area began in the late 1880s. Earliest development was for grazing and dryland wheat farming, with minor ground-water withdrawals for individual domestic, stock, and small public supply uses. Through time, surface-water irrigation transformed the area into one of the major agricultural regions of the United States. Locations of the major development features discussed in this section are shown on figure 6. A summary of the history of water-resources development in the study area is contained in table 2.

The first significant irrigation began in 1893 when Horn Rapids Dam was built on the Yakima River and water was diverted by the Columbia Irrigation District (CID) to irrigate the area around Kennewick. Development of the CID (which is still in operation) was followed by the Richland Ditch (1904-43; supplying the Richland area from the Yakima River), the Pasco Reclamation Company (1909-17; supplying the Pasco area from the Snake River), and the Franklin County Irrigation District (FCID) (1922-present; supplying the Riverview area of Pasco from the Columbia River).

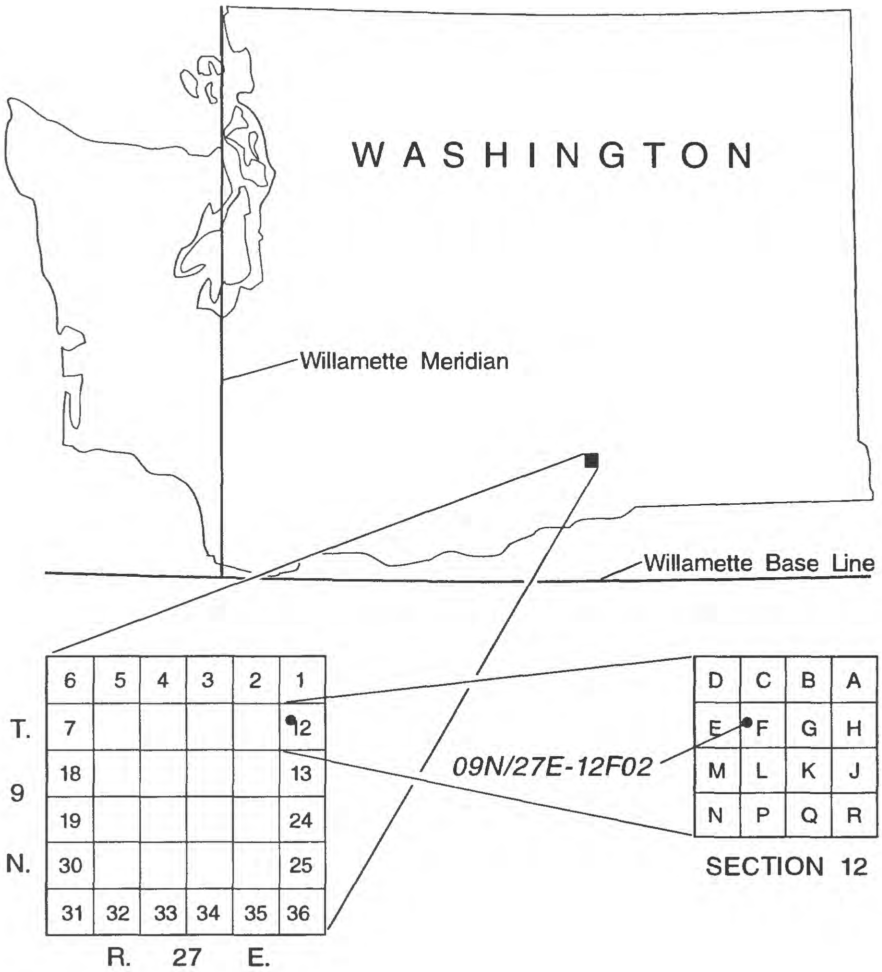


Figure 5.--Well- and spring-numbering system used in Washington.

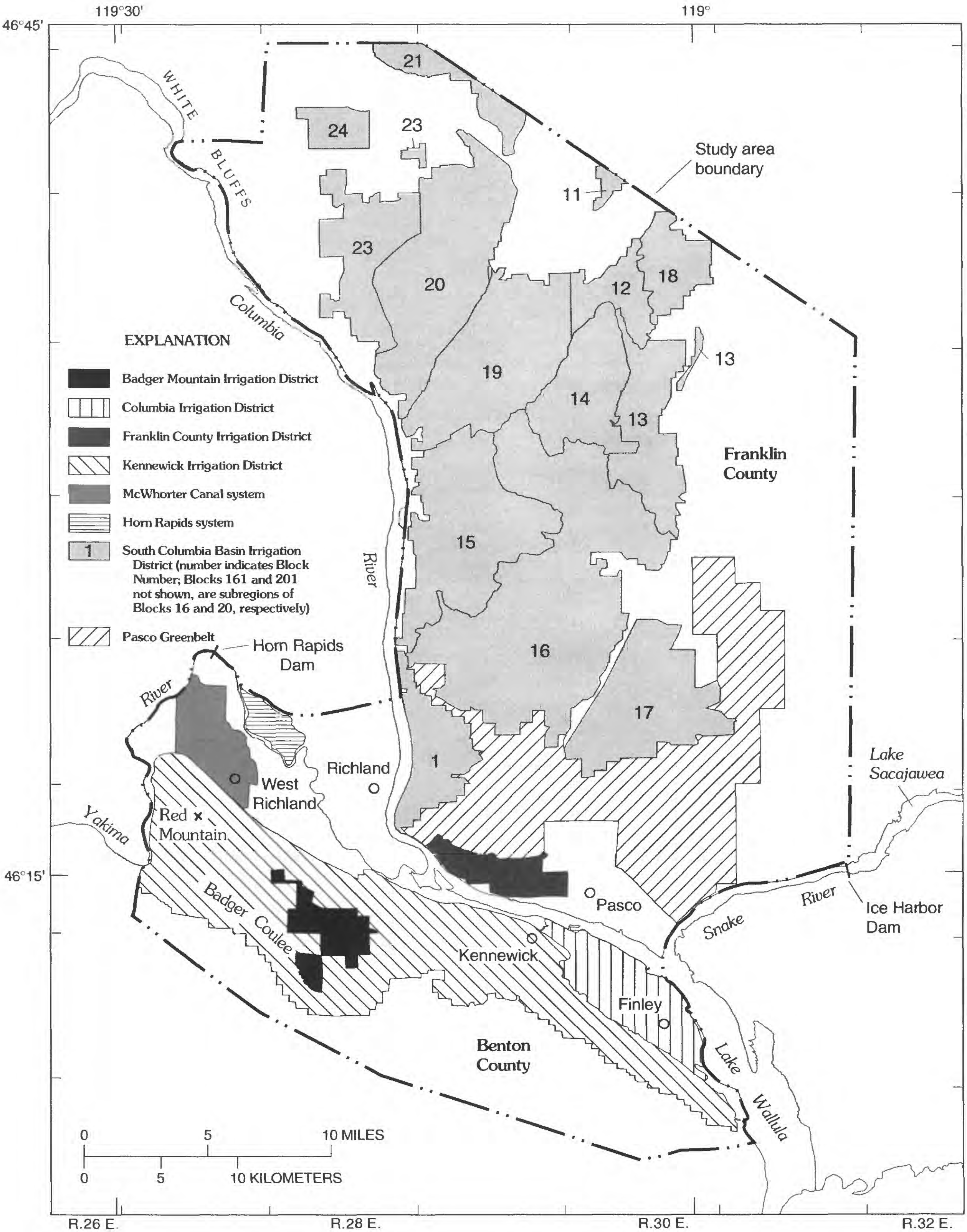


Figure 6.--Major features of water-resources development in the study area.

Table 2.--*Summary of history of water-resources development in the study area*

1893	- Columbia Irrigation District, first irrigation
1904	- Richland Ditch system, first irrigation
1909	- Pasco Reclamation Company, first irrigation
1922	- Franklin County Irrigation District, first irrigation
1943	- Richland water system began (wells and artificial-recharge basins)
1948	- Block 1 (SCBID), first irrigation
1953	- Start of filling of Scooteney Reservoir (Northeast of project area) - Block 11 (SCBID), first irrigation - Lake Wallula (McNary Dam) reached operating level
1954	- Scooteney Reservoir reached operating level - Esquatzel Coulee Wasteway began receiving irrigation wastewater - Blocks 12 and 15 (SCBID), first irrigation
1955	- Blocks 13 and 16 (SCBID), first irrigation
1956	- Block 19 (SCBID), first irrigation
1957	- Kennewick Irrigation District, first irrigation (from main canal off Yakima River) - Blocks 14 and 18 (SCBID), first irrigation
1959	- Block 20 (SCBID), first irrigation - Esquatzel Diversion Channel completed
1961	- Block 201 (SCBID), first irrigation
1962	- Lake Sacajawea (Ice Harbor Dam) formed
1963	- Block 23 (SCBID), first irrigation - Richland municipal water system converted to filtered Columbia River water (replacing wells and artificial-recharge system)
1964	- Block 17 (SCBID), first irrigation - Smith Canyon Wasteway began receiving irrigation wastewater from Eltopia Branch Canal - First buried drains installed in SCBID
1966	- Blocks 21 and 161 (SCBID) and Block 48 (immediately north or project area), first irrigation
1969	- Wahluke Branch Canal completed
1970	- McWhorter Canal system, first irrigation
1973	- Constructed reach of Esquatzel Coulee Wasteway at Eltopia completed - Pasco Green Belt, first significant irrigation with ground water
1975	- Red Mountain-Badger Mountain area, first significant irrigation with ground water
1976	- Esquatzel Coulee pumping plant constructed; to intercept wastewater flows that were becoming ground-water recharge in the Pasco area
1977	- Block 24 (SCBID), first irrigation
1978	- Badger Mountain Irrigation District, first irrigation
1979	- Constructed reach of Esquatzel Coulee Wasteway at Mesa completed
1985	- Red Mountain-Badger Mountain area, significant increase in irrigation with ground water

Creation of the Hanford Site (Federal reservation used to produce plutonium, fig. 1) in 1943 resulted in Richland changing from an agricultural community to a domestic and support community. The Richland Ditch (primarily agricultural use) was replaced by a system of wells and artificial-recharge basins (primarily domestic use). Water for artificial recharge was supplied at first from the Yakima River and later from the Columbia River. In 1963 a filtration plant using Columbia River water replaced most of the well and artificial-recharge system.

The Richland Ditch supplied water for lawn irrigation in Richland and for construction activities on the Hanford Site from 1943-57. In 1957 the system was sold to private interests, shortened, and renamed the Horn Rapids (or Barker) Ditch. Since 1957 the Horn Rapids Ditch system has supplied water for irrigation and for maintaining waterfowl habitats in several square miles of low-lying land along the Yakima River.

The most dramatic changes occurred when the Franklin County part of the study area began receiving irrigation water as part of the SCBID of the Columbia Basin Irrigation Project. SCBID irrigation began in 1948 in Block 1 and was still expanding in 1977 with the start of irrigation in Block 24. All SCBID irrigation water now comes from the Columbia River outside of the study area (Grand Coulee Dam). Block 1 received water pumped from the Columbia River near Pasco from 1948-54.

The formation of Lake Wallula behind McNary Dam (outside of the study area, about 33 mi down river) in 1953 backed up the Columbia, Snake and Yakima Rivers. Levees were constructed along reaches of the rivers to protect Kennewick, Pasco, and Richland from the resulting lake levels that were above the original land surface in many areas. Surface drains (trenches) and pumping stations were installed landward of the levees to collect ground- and surface-water flows and pump them into Lake Wallula. In 1962, the construction of Ice Harbor Dam on the Snake River created Lake Sacajawea. No levees or pumping stations were required as Lake Sacajawea extended up a narrow, deep canyon that had relatively little development. Lakes Wallula and Sacajawea contain about 1.45 million acre-ft and 356,000 acre-ft, respectively. The maximum increases in water-surface elevation caused by McNary and Ice Harbor Dams are about 85 ft and 103 ft, respectively.

Irrigation from the Kennewick Irrigation District (KID) main canal started in 1957 with water pumped from the Yakima River (from outside of the study area). This was the first use of irrigation water in Badger Coulee and some of the areas upslope of Kennewick and resulted in large areas changing from sage brush to agriculture. The McWhorter Canal (1970-present; supplying the West Richland area from the Yakima River) and the Badger Mountain Irrigation District (BMID) (1978-present; supplying the Badger Mountain area from the Yakima River) increased the irrigation acreage in the Benton County part of the study area.

Because the water table has risen to near the land surface in some areas, buried drains (perforated pipes) have been installed to stabilize the water table below the root zones of crops. The first buried drains were installed in 1964 in the SCBID. Drain installation continued in the SCBID through 1988.

Ground-water pumping for irrigation has become significant in recent years. In 1973, pumping began in what has become known as the Pasco Greenbelt north of Pasco. Less intense but locally important ground-water pumping for irrigation began in 1975 west and south of West Richland (Red Mountain-Badger Mountain area).

SURFACE-WATER IRRIGATION SYSTEMS

Surface-water irrigation systems account for most of the water used in the study area. These systems obtain water from the Columbia or Yakima Rivers (both within and outside of the study area), distribute it through canals or pipes, and dump the excess water (return flows and through flows) back into the rivers. The surface-water irrigation systems in Benton County are the BMID, the CID, the Horn Rapids Ditch system, the KID, and the McWhorter Canal system. In Franklin County the surface-water irrigation systems are the FCID and the SCBID.

Surface-water irrigation systems supply a major portion of the ground-water recharge in the study area, through deep percolation of applied irrigation water and seepage from the distribution systems. Understanding the ground-water flow system in the study area requires an understanding of the surface-water irrigation systems.

A surface-water-flow gaging network was established for this project to monitor all significant surface-water flows into and out of the study area. Inflow and outflow points were identified from topographic maps, air photos, field visits, and information supplied by personnel of the irrigation districts. In most cases, inflows are major irrigation canals and outflows are irrigation wasteways. Some outflows are a mixture of irrigation waste flows (return flows and through flows), storm runoff, and ground-water seepage. Some sites were chosen at intermediate locations between inflow and outflow points to determine the distribution of flow within the major irrigation systems.

The gaging network consisted of 39 gaging stations and 13 miscellaneous-measurement sites operated by the USGS (Drost and others, 1989a). The network also included sites operated by other agencies. Gages were operated to obtain at least one complete year of record at each site. However, not all gages were operated during identical periods. The first records were collected in February 1986, and all gages had a complete year of record by July 1987.

Using the surface-water flow records obtained from the network and information from the irrigation districts on the amount of water delivered to water users, it is possible to calculate water budgets for each of the irrigation systems. The completeness and accuracy of the calculated water budget for each system depend on the complexity of the system and the availability of data. Water budgets are presented in table 3.

According to Christopher (1981), ditchriders (irrigation personnel who control delivery rates) tend to deliver more water to users than is recorded. In their effort to keep the user adequately supplied, ditchriders generally set the delivery rates somewhat higher than that requested (and recorded as delivered). Christopher estimates that ditchriders deliver 10 to 25 percent more than is recorded. Staffs of the irrigation districts in the study area generally agree with Christopher's observation of over-delivery, but at lower estimated rates (5 to 10 percent). For those irrigation systems where ditchriders set and record individual deliveries, the delivery numbers in table 3 have been increased by 5 or 10 percent over those reported.

The BMID system pumps its water from the Yakima River near Richland (09N/28E-23K/Q). The distribution system is a network of pressurized pipes. Deliveries are recorded by flow meters. The system operated from about April 1 through October 15 and supplied water to about 930 acres in 1986 (on the basis of BMID records). Irrigated lands are about equal parts agricultural areas and domestic lawns. The BMID system has no wasteways, and essentially all water pumped from the Yakima River is eventually delivered to water users.

The CID system (fig. 7) obtains its water from the Yakima River at Horn Rapids Dam. The system also receives inflow from springs along the upland areas south of No. 3 Canal near Kennewick. The main distribution system is a network of open canals. Deliveries are not measured. The system generally operates from mid-March to mid-October, but in 1986 it did not begin operation until April 4 due to canal repairs. The CID system supplied water to about 5,200 acres in 1986 (based on examination of aerial photographs), with about 70 percent agricultural irrigation and about 30 percent domestic irrigation. The system dumps wastewater to the Columbia and Yakima Rivers and to the USACOE drain system near Finley.

The Horn Rapids Ditch system obtains its water by diversion from the Yakima River at Horn Rapids Dam. This system is a remnant of the Richland Ditch system that previously (1904-43) supplied the Richland area. The system now routes water through low-lying land next to the Yakima River to maintain wetland conditions for waterfowl. This system is relatively insignificant and is not included in table 3.

The KID system (fig. 8) obtains its water from the Yakima River near Prosser (outside of the study area). The system also receives a small amount of inflow from storm runoff, which was considered insignificant in calculating the water budget. The main distribution system is a network of open canals. Most deliveries are measured by daily readings of weirs at each major point of delivery. The KID system operates from mid-March to mid-October and supplied water to about 15,000 acres in 1986 (based on KID records). Water use is about 70 percent agricultural irrigation and about 30 percent domestic irrigation. The system dumps wastewater to the Columbia River and to wastewater ponds, the USACOE drain system, and Amon and Zintel Canyons.

Table 3.--*Water budgets of surface-water irrigation systems in the study area, March 1986 through February 1987*

[--, not measured;?, cannot be calculated due to absence of delivery data]

Irrigation system	Surface-water irrigation use (acre-feet) (all values rounded to two significant figures)				
	Inflow	Outflow	Net use[1]	Deliveries	Losses[2]
	Benton County, Wash.				
Badger Mountain Irrigation District	2,500	0	2,500	2,500	0
Columbia Irrigation District					
Entire System	[3]67,000	[4]>13,000	<54,000	--	?
Kennewick-Finley area[5]	[3]32,000	8,000	24,000	--	?
Kennewick Irrigation District	100,000	[6]28,000	72,000	[7]52,000	20,000
McWhorter Canal system	16,000	660	15,000	--	?
	Franklin County, Wash.				
Franklin County Irrigation District	20,000	890	19,000	--	?
South Columbia Basin Irrigation District	[8]960,000	[9]350,000	610,000	[10]480,000	130,000

[1]Inflow minus outflow.

[2]Net use minus deliveries.

[3]Includes 2,800 acre-feet of springflow into No. 3 Canal.

[4]There are significant unmeasured wastewater flows in the system.

[5]System below Grant Street gage (station number 12511020).

[6]Includes 19,000 acre-feet that are dumped to Amon Wasteway. Much of this flow is water that was passed through a hydraulic turbine to lift water to Amon Pump Lateral.

[7]Reported deliveries were increased by ten percent to account for ditchriders delivering more water than reported.

[8]There are numerous subsurface drains that empty into the canals. This inflow value does not include these drain flows.

[9]Includes 240,000 acre-feet that leave the study area to other parts of the South Columbia Basin Irrigation District (by Wahluke Branch Canal), and 110,000 acre-feet that are dumped to wasteways.

[10]Reported deliveries were increased by five percent to account for ditchriders delivering more water than reported, and were then decreased by ten percent to account for delivered water which is returned (unused and ungaged) to the delivery system. Does not include deliveries made from the wasteways.

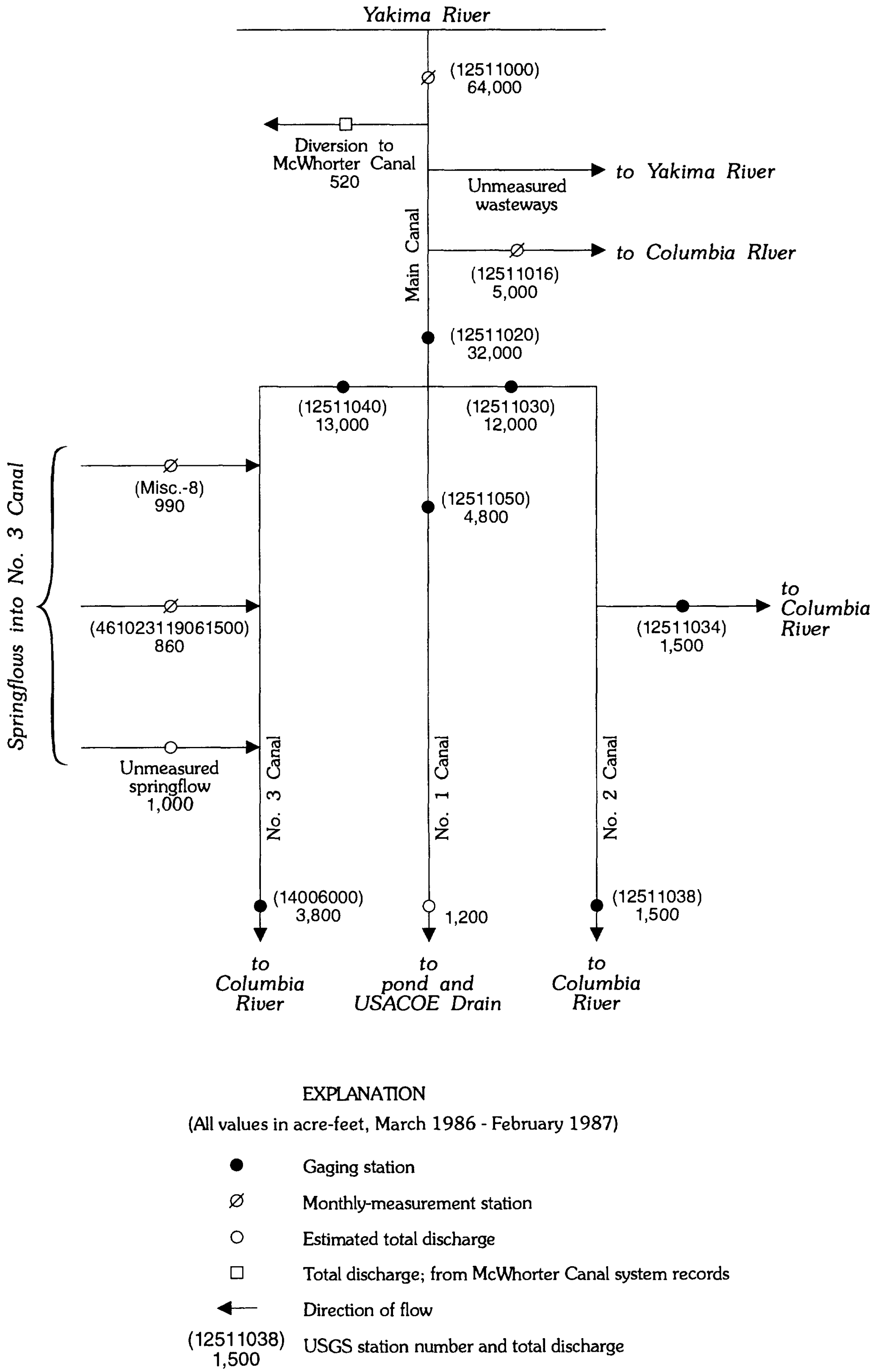


Figure 7.--Columbia Irrigation District.

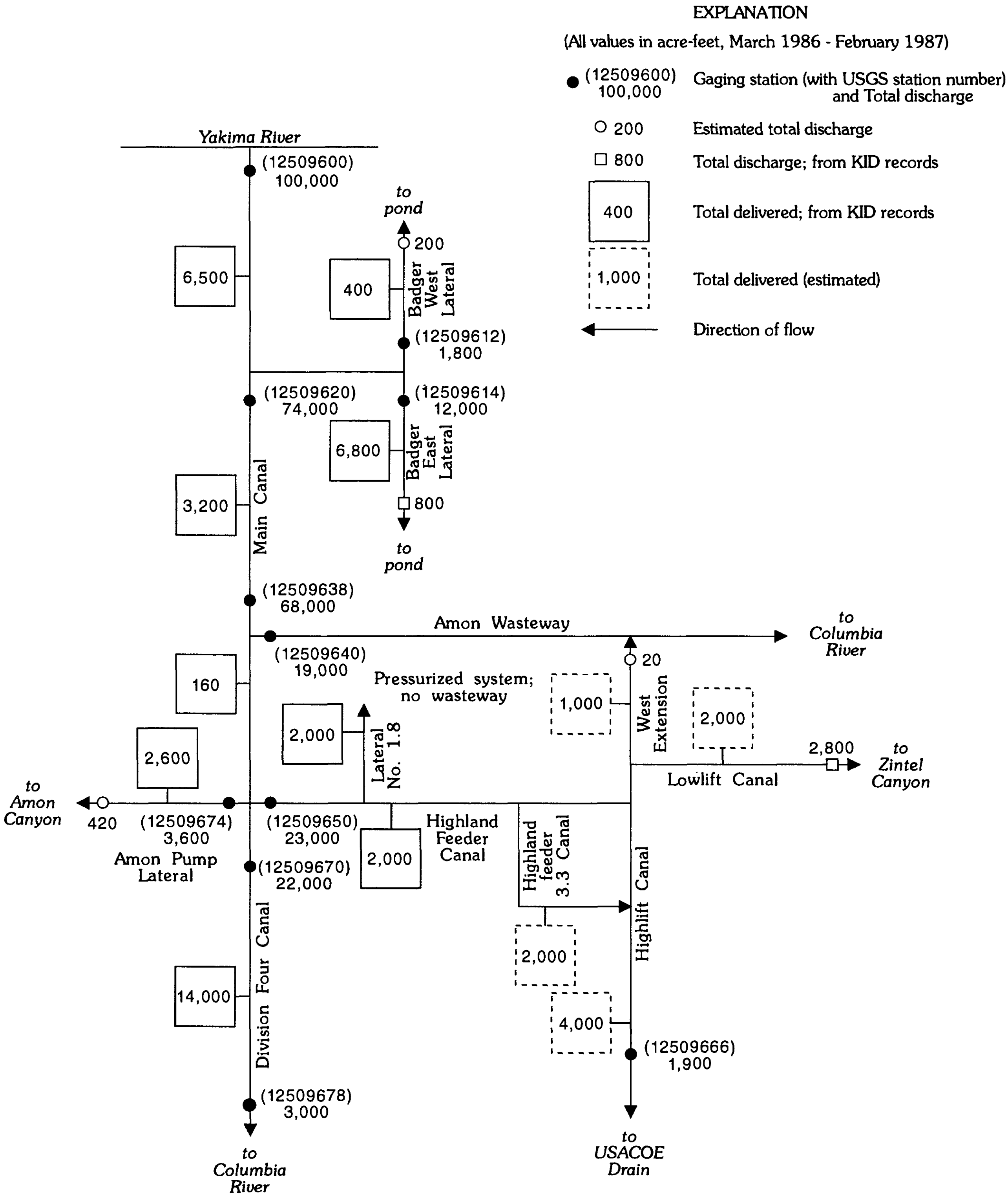


Figure 8.--Kennewick Irrigation District.

The McWhorter Canal system (fig. 9) obtains its water from the Yakima River upstream of Horn Rapids Dam (10N/27E-09K). The system also receives some water from the CID system which is diverted into Horn Rapids Canal (actually a large pond which is part of the McWhorter system). The distribution system is a set of open canals. The McWhorter system is unique in the study area in that the McWhorter Canal is essentially level, with direction of flow depending on which pumping station (Yakima River or Horn Rapids Canal) is in operation. Deliveries are not measured; the system is privately owned and supplies a single user. The system operates from late March to early October and supplied irrigation water to about 4,500 acres in 1986 (based on examination of aerial photographs). Irrigation water use is solely agricultural. The system dumps water to the Yakima River through a buried pipeline under the CID main canal. This pipeline reportedly is allowed to flow only during the non-irrigation season, and its flow apparently originates as ground-water seepage to Horn Rapids Canal.

The FCID system obtains its water from two locations on the Columbia River (09N/29E-18L and 09N/29E-27J). The distribution system consists of a single open canal. Deliveries are not measured. The system operates from mid-March to mid-October and supplied irrigation water to about 3,600 acres in 1986 (based on examination of aerial photographs). Water use is about 20 percent agricultural irrigation and about 80 percent domestic irrigation. The system dumps water to a wastewater pond (09N/29E-13N) at the end of the single canal.

The SCBID system (fig. 10) obtains its water from the Columbia River at Grand Coulee Dam (outside of the study area). By the time the water reaches the SCBID, it has passed through many miles of canals and has received large volumes of return flow. The distribution system is a vast network of open canals. The SCBID system is different from the other irrigation systems in the study area in that there are numerous internal flows into the canal system. These internal flows include surface drainage (return flows) and subsurface drainage (buried field drains). Deliveries are measured by daily readings of weirs at points of delivery. The system operates from mid-March to mid-October. Some of the system flows on a year-round basis due to inflows from subsurface drains. Water from the SCBID system was used to irrigate about 147,000 acres in the study area in 1986 (based on SCBID records). Essentially all water use is agricultural. The system dumps wastewater to the Columbia River through numerous wasteways. Some wastewater is dumped internally (for example, Smith Canyon and Esquatzel Coulee). Most of the flow at the downstream end of Esquatzel Coulee (just north of Pasco) is pumped into the Esquatzel Wasteway and routed to the Columbia River through the Esquatzel Diversion Channel.

HYDROGEOLOGY

Setting

The study area lies in the eastern half of the Pasco Basin, which is a structural and topographic low in south-central Washington. The Pasco Basin is underlain by three major stratigraphic units in which all significant ground water occurs. The stratigraphic units are, in ascending order: (1) the Yakima Basalt Subgroup; (2) the Ringold Formation; and (3) the informally named Hanford formation, hereafter referred to simply as the Hanford formation (table 4).

During the Tertiary, flood basalts flowed intermittently into the Pasco Basin, resulting in a total basalt thickness in excess of 15,000 ft. Between eruptions, particularly those producing the younger flows, minor amounts of sediment (Ellensburg Formation) were interbedded with the basalts. During later stages of the flood basalt volcanism, deformation took place in the form of northwest- to west-trending folds. The greatest degree of deformation was west of the study area and resulted in a series of folds known as the Yakima fold belt. The eastward extensions of these folds are seen in the study area as the Saddle Mountains in the north and Badger Mountain and neighboring structures in the south (fig. 1).

Folding and subsidence in the Late Cenozoic resulted in the deposition of fluvial sediments in the Pasco Basin by ancestral rivers flowing into and through the basin. These sediments formed the Ringold Formation (Pliocene), which consists of four textural units (basal Ringold Formation composed of sand and gravel; lower Ringold Formation composed of silt and clay; middle Ringold Formation, composed of sand, gravel and silt; and upper Ringold Formation composed of silt and sand). The middle and lower Ringold Formation facies appear to be complexly interfingered in the Richland area. In an ongoing study on the Hanford Site, the Ringold Formation has been divided into five lithofacies (Delaney and others, 1991). This work may ultimately yield a better definition of the Ringold Formation in the study area than is presently available. Total Ringold Formation thickness in the study area exceeds 600 ft in some places.

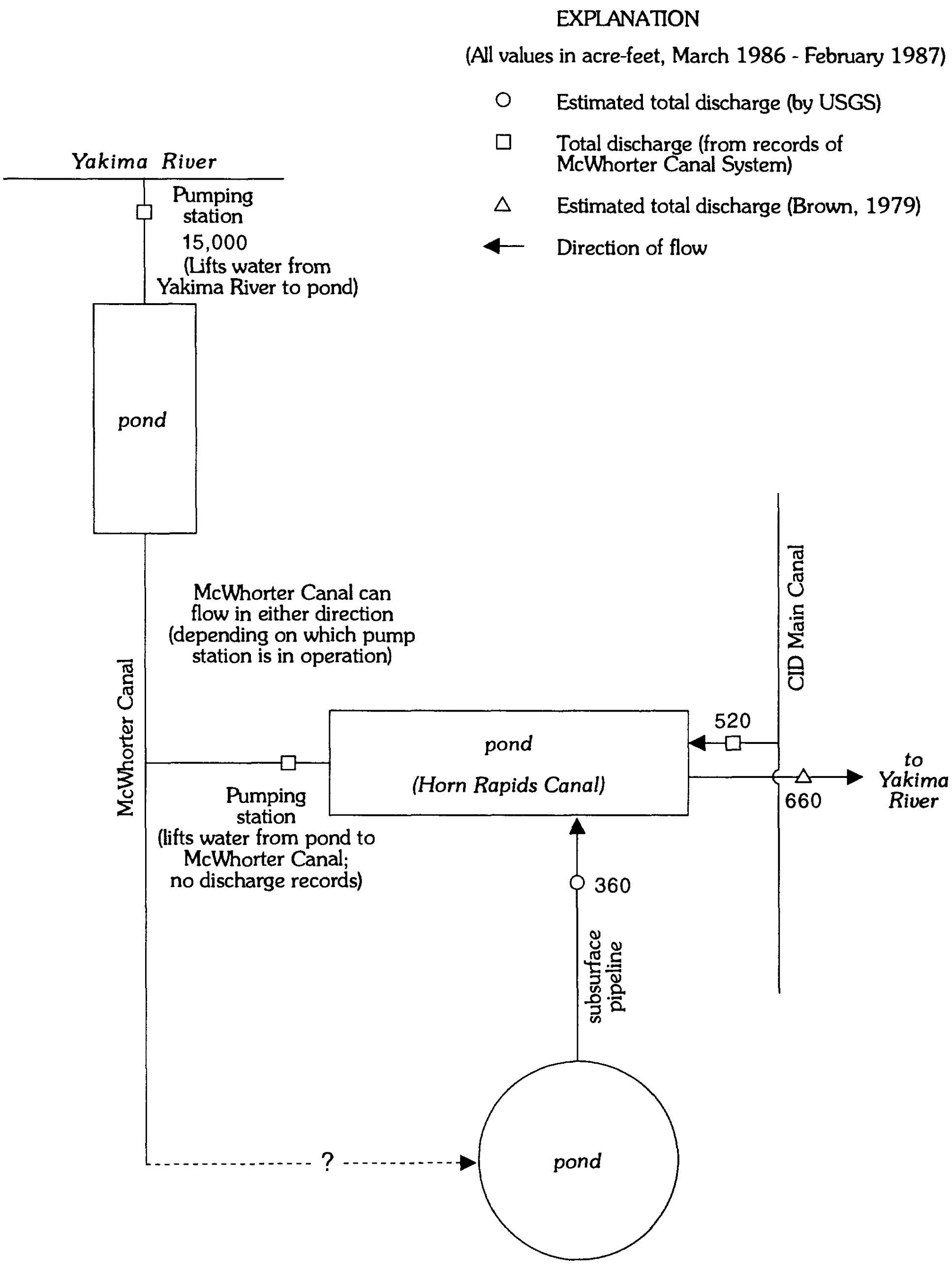
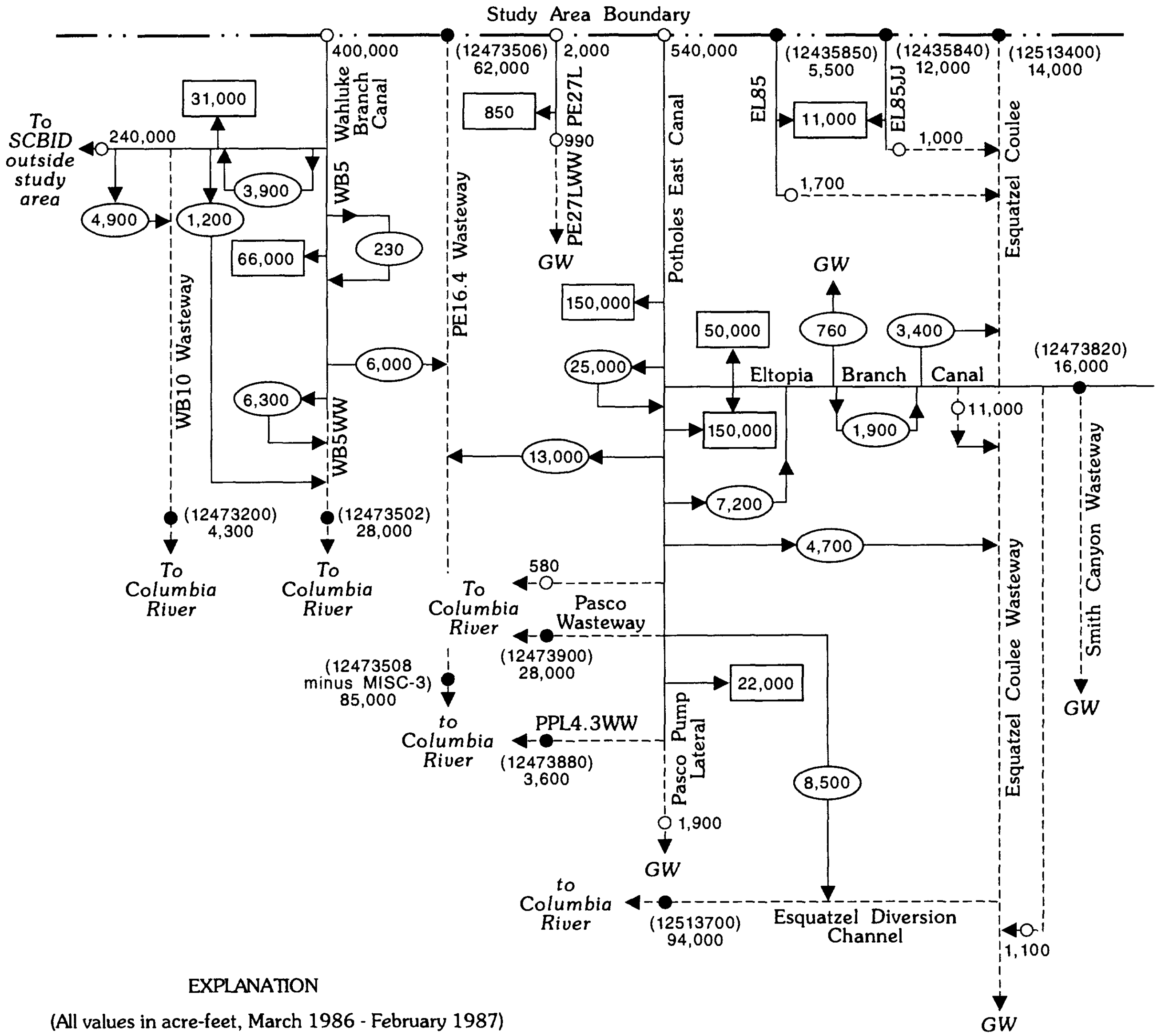


Figure 9.--McWhorter Canal system.



EXPLANATION

(All values in acre-feet, March 1986 - February 1987)

— · · —	Study area boundary
————	Canal
- - - - - - - -	Wasteway
◀————	Direction of flow
● (12473506) 62,000	Gaging station (with USGS station number) and Total discharge
○ 400,000	BUREC reported total discharge
[22,000]	Total delivered (BUREC records)
(8,500)	Total dumped to wasteways
GW	Indicates wastewater goes to pond, ditch, etc., which seeps to ground water

Figure 10.--The South Columbia Basin Irrigation District, within the study area.

Table 4.--*Relation of geologic units to hydrologic units in the study area*

Geologic Unit		Hydrologic unit: Type	Hydrologic unit: Name	Occurrence
Hanford formation		Confining bed	Touchet Beds	At land surface. Significant saturated thickness only in Badger Coulee.
Hanford formation		Aquifer (generally unconfined)	Pasco gravels	Generally at land surface. Overlain by Touchet Beds in Badger Coulee. Present primarily in southern part of study area.
Ringold Formation		Confining bed or unconfined aquifer	upper Ringold Formation	Generally at land surface. Present in northern and central part of study area.
Ringold Formation		Aquifer (generally confined)	middle Ringold Formation	Generally overlain by Pasco gravels or upper Ringold Formation. Present in central and southern parts of study area.
Ringold Formation		Confining bed or confined aquifer	lower Ringold Formation	Overlain by Pasco gravels, upper Ringold Formation, or middle Ringold Formation. Present primarily within a several-mile-wide zone along the Columbia River.
Ringold Formation		Confined aquifer	basal Ringold Formation	Overlain by lower Ringold Formation. Present only in small area along the Columbia River near Richland.
Yakima Basalt Subgroup	Saddle[1] Mountains Basalt	Series of aquifers (confined and unconfined) and confining beds	Saddle Mountains Basalt	At land surface or overlain by sediments. Present almost everywhere in study area.
Yakima Basalt Subgroup	Wanapum[2] Basalt	Series of aquifers (confined and unconfined) and confining beds	Wanapum Basalt	At depth. Almost everywhere overlain by Saddle Mountains Basalt. Present throughout study area.
Yakima Basalt Subgroup	Grande[3] Ronde Basalt	Series of confined aquifers and confining beds	Grande Ronde Basalt	At depth. Overlain by Wanapum Basalt. Present throughout study area

[1]Includes interbedded sediments and Mabton Member of Ellensburg Formation.

[2]Includes interbedded sediments and Vantage Member of Ellensburg Formation.

[3]Includes interbedded sediments.

Catastrophic proglacial flooding during the late Quaternary resulted in deposition of the Hanford formation in the Pasco Basin. The proglacial floodwaters cut into the basalts and Ringold Formation sediments and deposited over 200 ft of sediments in some parts of the study area. The Hanford formation has two textural facies (Pasco gravels, composed of sand or sand and gravel and Touchet Beds composed of silt and sand).

The generalized stratigraphy in the study area is shown on figure 11 and the surficial (or near surface) distribution of these units is shown on figure 12. The surficial geology shown on figure 12 is modified from Myers and Price (1979). Not shown are several surficial Pleistocene and Holocene units (generally less than 20 ft thick), including loess, sand dunes, landslide debris, and alluvium.

The altitude of the top of the Yakima Basalt Subgroup is shown on figure 13. The basin-like nature of the basalt surface can be seen on the figure, with top of basalt altitudes generally exceeding 700 ft and 1,000 ft along the southern and northern margins of the study area, respectively, and less than 200 ft along the Columbia River (where several hundred feet of sediments overlie the basalts). The contours on figure 13 are based on data from well logs summarized in table 25 (at end of report) and top of basalt maps by Brown (1979), Drost and Whiteman (1986), and Myers and Price (1979).

All of the stratigraphic units shown on figure 11 act as either aquifers or confining beds in at least some parts of the study area. The sediments above the basalt are separated into units primarily on the basis of their textures. From the Touchet Beds downward through the basal Ringold Formation, fine-grained and coarse-grained sediments alternate. The coarse-grained units (Pasco gravels, middle Ringold Formation, and basal Ringold Formation) are generally productive aquifers. The fine-grained units (Touchet Beds, upper Ringold Formation, and lower Ringold Formation) generally can produce small amounts of water (single-household supplies) in some locations, but they act primarily as confining beds.

The basalts and interbedded sediments form a complex series of aquifers and confining beds. Ground water in basalt occurs in joints, vesicles, fractures, and other localized features that result in permeable zones. The greatest permeabilities occur in the tops of basalt flows. Relatively high permeabilities occur in basal parts of basalt flows that are highly vesicular or fractured. These basalt flow tops and bases act as aquifers. The centers of most basalt flows are dense and have very low permeabilities. Basalt flow centers generally act as confining beds. However, basalt flow centers are different from most confining beds in that they usually have vertical jointing; vertical flow of ground water is therefore likelier than horizontal flow.

Interbedded sediments in the basalts act as aquifers where they are coarse-grained and as confining beds where they are fine-grained. The general ground-water flow in the basalts and interbedded sediments is shown on figure 14.

Table 4 lists the hydrologic units in the study area, with unit names that will be used in this report. Each of the basalt and interbedded sediment units is actually a series of aquifers and confining beds. These basalt and interbedded sediment units are composed of many basalt flows (about 19 flows in the Saddle Mountains Basalt, about 33 flows in the Wanapum Basalt, and about 111 flows in the Grande Ronde Basalt) and interbedded sediments (about 10 layers) and are simplified here into three main units.

Geometry of the Hydrologic Units

The extents and thicknesses of the hydrologic units listed in table 4 were interpreted from well data and the surficial geologic map shown on figure 12. The well data consist primarily of drillers' and geologists' logs (Bureau of Reclamation wells). Table 25 (at end of report) contains the identified units in 466 selected well logs in the study area. All wells listed in the table have been field checked to assure accurate locations.

The extent and thickness of the Touchet Beds in the study area are shown on figure 15. The Touchet Beds are generally at land surface. In a few places, primarily in northern Franklin County, the Touchet Beds are covered by thin sand dunes. The thicknesses are based on data from the well logs summarized in table 25. The Touchet Beds are less than 50 ft thick throughout most of the study area, with a maximum thickness of almost 200 ft in the center of Badger Coulee. The only area where a significant part of the total thickness of the Touchet Beds is saturated is in Badger Coulee.

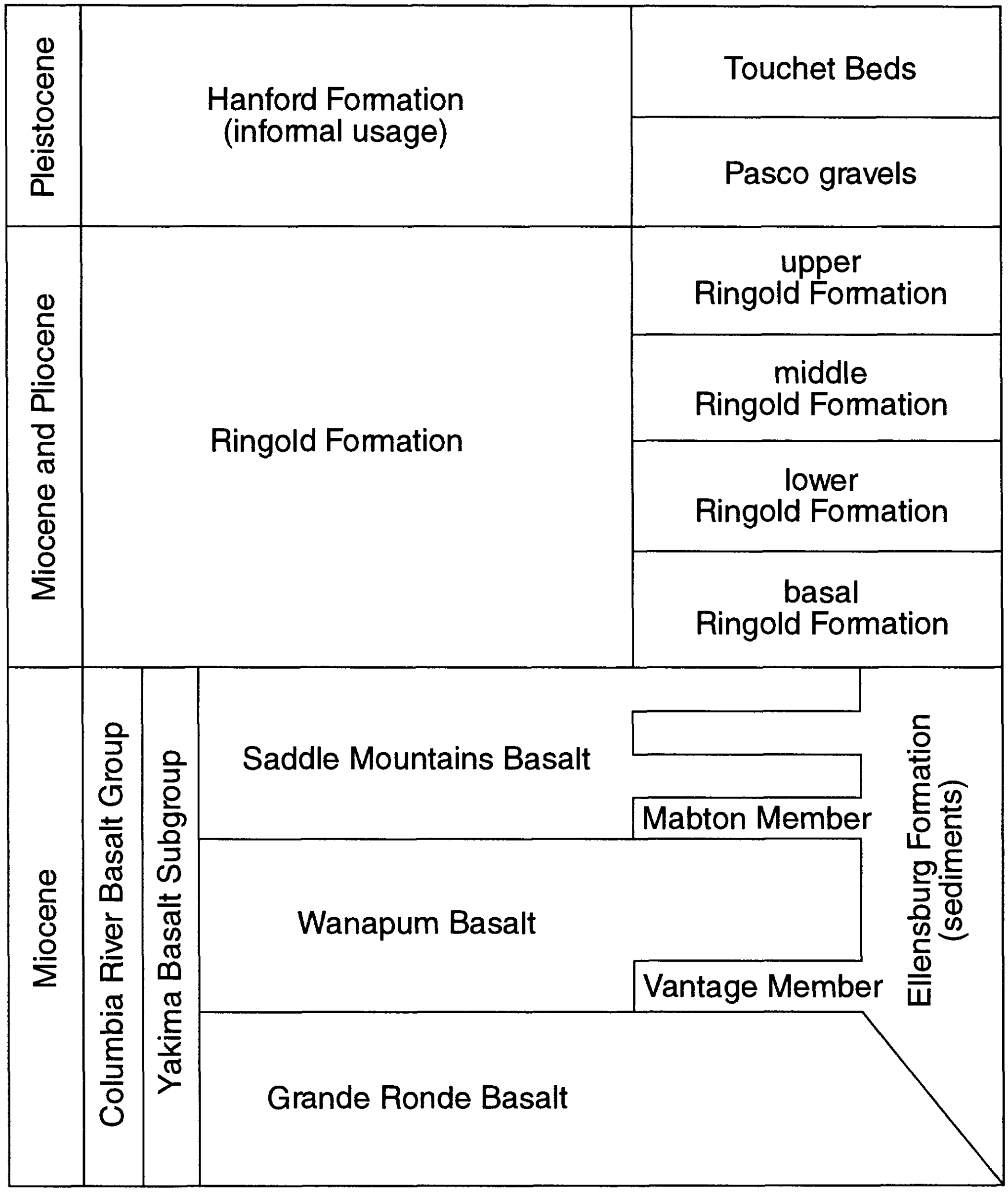


Figure 11.--Generalized stratigraphy of the Yakima Basalt Subgroup and suprabasalt sediments within the study area (modified from Myers and Price, 1979).

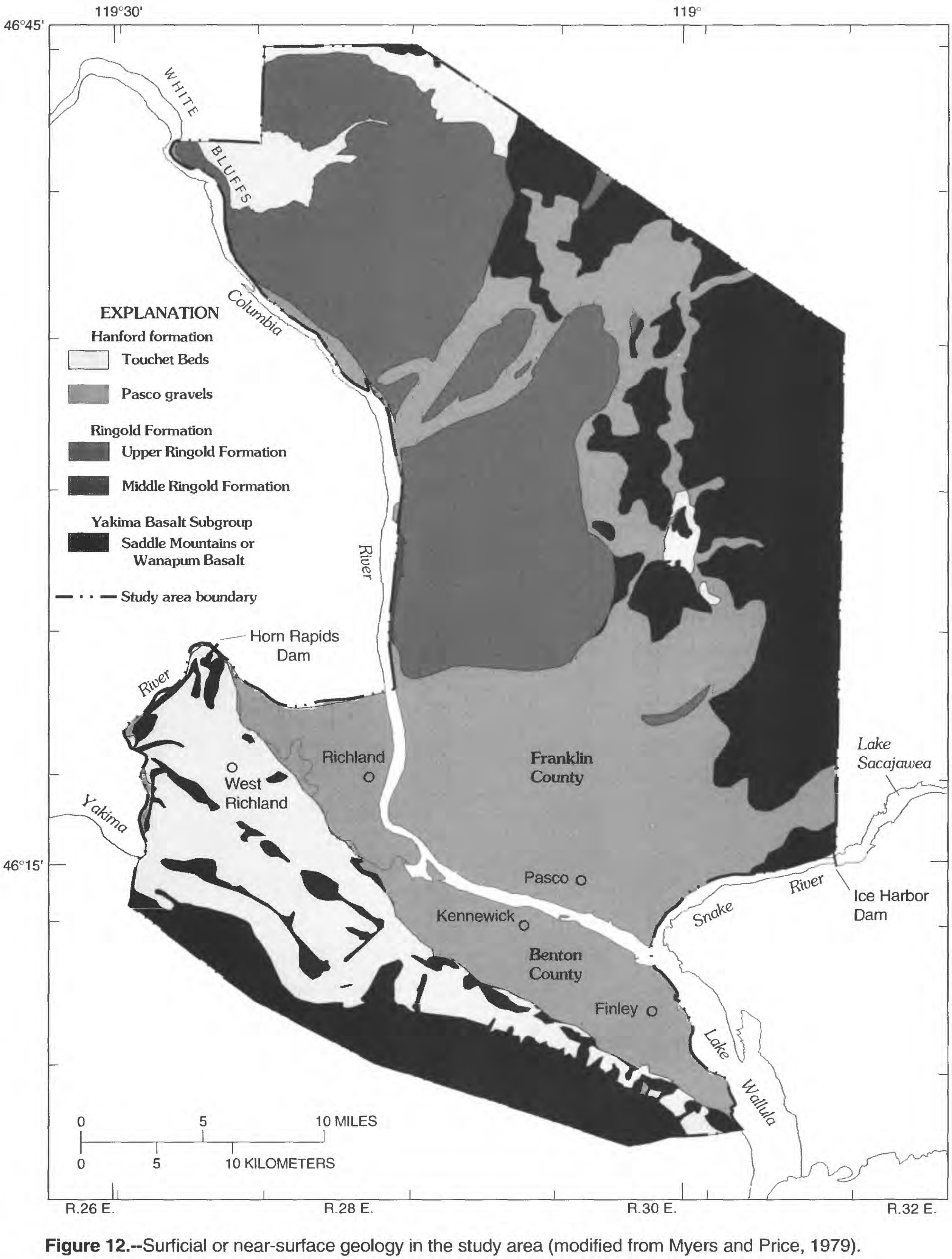


Figure 12.--Surficial or near-surface geology in the study area (modified from Myers and Price, 1979).

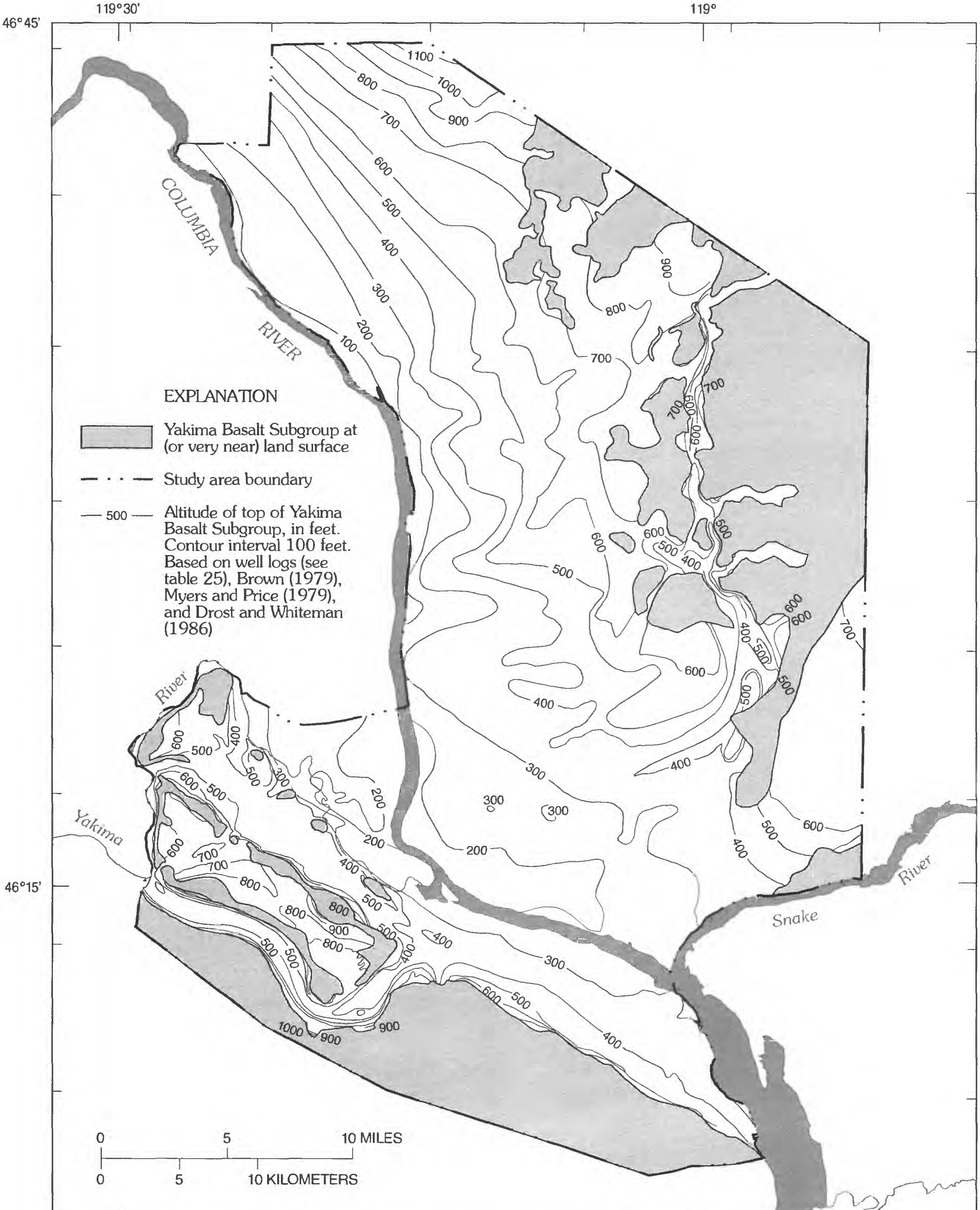


Figure 13.--Altitude of the top of the Yakima Basalt Subgroup in the study area.

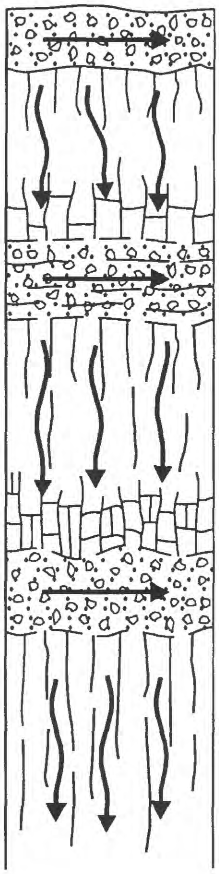


Figure 14.--General ground-water flow in the basalts and interbedded sediments in the study area.

The extent and thickness of the Pasco gravels in the study area are shown on figure 16. The Pasco gravels generally are at land surface, but are thinly covered locally by sand dunes or alluvium. The Touchet Beds overlie the Pasco gravels in Badger Coulee. The extent of the Pasco gravels is somewhat modified from Myers and Price (1979), with the major modification for southern Franklin County (northern half of T.10 N., R.29 E.). This area was designated as Ringold Formation at the land surface by Myers and Price, but well logs (table 25) indicate a thin (less than 50 ft) covering of fine-grained Pasco gravels. The Pasco gravels are from 50 to 150 ft thick throughout most of southern Franklin County, Badger Coulee, and the Kennewick area; maximum thickness is more than 200 ft. At least part of the total thickness of the Pasco gravels is saturated throughout most of its extent, with unsaturated areas near West Richland and in northern Franklin County.

The identification of the Pasco gravels from drillers' logs is extremely difficult in some parts of the study area. The gravels are difficult to distinguish from reworked middle Ringold Formation gravels or from gravels in gullies along the steep slopes of the Horse Heaven Hills. In Badger Coulee, all gravels underlying the Touchet Beds were designated as Pasco gravels, although they probably represent a complex mixture of Pasco gravels, middle Ringold Formation gravels, and gully gravels.

The extent and thickness of the upper Ringold Formation in the study area are shown on figure 17. The upper Ringold Formation generally is at land surface. Loess, Touchet Beds, Pasco gravels, and sand dunes cover the upper Ringold Formation in some places. The thicknesses are based on data from the well logs in table 25. The upper Ringold Formation is generally greater than 100 ft thick and reaches a maximum thickness of nearly 500 ft. At least part of the total thickness of the upper Ringold Formation is saturated throughout most of its extent in the study area.

The extent and thickness of the middle Ringold Formation in the study area are shown on figure 18. The middle Ringold Formation is almost exclusively at depth and generally is directly overlain by either the Pasco gravels or the upper Ringold Formation. The thicknesses on figure 18 are based on data from the well logs represented in table 25 and on a thickness map of the "Ringold Formation conglomerate" by Brown (1979). Brown's "Ringold Formation conglomerate" is equivalent in this report to the middle Ringold Formation. In the Richland area, there is a complex interfingering of middle and lower Ringold Formation facies. In this area, the contact between the units was designated at the first (highest altitude) occurrence of lower Ringold Formation type sediments. Maximum middle Ringold Formation thickness exceeds 200 ft, but average thickness is about 75 ft. The middle Ringold Formation is saturated throughout most of its extent in the study area.

The extent and thickness of the lower Ringold Formation in the study area are shown on figure 19. The lower Ringold Formation is exclusively at depth and is generally directly overlain by Pasco gravels, upper Ringold Formation, or middle Ringold Formation. The thicknesses on figure 19 are based on data from the well logs represented in table 25 and on a thickness map of the "Ringold Formation silts and clays" by Brown (1979). Brown's map represented the lower or upper Ringold

Formations, or a combination of the two units. In northern Franklin County, where the upper Ringold Formation directly overlies the lower Ringold Formation, it is difficult to determine the contact between the units (particularly from a driller's log). Therefore, the thicknesses of the upper Ringold Formation and lower Ringold Formation in this area are uncertain. The lower Ringold Formation has maximum thickness of more than 250 ft, but it is less than 100 ft thick in most of the study area. The lower Ringold Formation is saturated throughout its extent in the study area.

The extent and thickness of the basal Ringold Formation in the study area are shown on figure 20. The basal Ringold Formation is directly overlain by the lower Ringold Formation throughout the study area. The thicknesses on figure 20 are based on data from the well logs represented in table 25 and on a thickness map of the "Ringold Formation basal gravels" by Brown (1979). Brown's "Ringold Formation basal gravels" are equivalent in this report to the basal Ringold. With a maximum thickness of less than 20 ft, the basal Ringold Formation extent is limited in the study area. The basal Ringold Formation is saturated throughout its extent in the study area.

The extent and thickness of the Saddle Mountains Basalt in the study area is shown on figure 21. Present almost everywhere in the study area, the Saddle Mountains Basalt is at land surface in some places and buried beneath hundreds of feet of sediment in others. The thickness contours are from Drost and Whiteman (1986). Maximum thickness is greater than 800 ft; average thickness is about 400 ft. The thickness contours include all interbedded Ellensburg Formation sediments within the Saddle Mountains, but not the Mabton Member of the Ellensburg Formation, which is between the Saddle Mountains Basalt and the Wanapum Basalt. Figure 22 shows the extent and thickness of the Mabton Member. At least part of the total thickness of the Saddle Mountains Basalt is saturated throughout most of the study area.

The thickness of the Wanapum Basalt in the study area is shown on figure 23. The Wanapum Basalt is present everywhere in the study area and is overlain by the Saddle Mountains Basalt almost everywhere. The thickness contours on figure 23 are from Drost and Whiteman (1986). Maximum thickness is more than 1,000 ft, and throughout most of the study area the Wanapum Basalt is 800 ft thick or more. The thickness contours include all interbedded Ellensburg Formation sediments within the Wanapum Basalt plus the Vantage Member of the Ellensburg Formation, which is between the Wanapum Basalt and Grande Ronde Basalt. At least part of the total thickness of the Wanapum Basalt is saturated everywhere in the study area.

The thickness of the Grande Ronde Basalt in the study area is shown on figure 24. The Grande Ronde Basalt is present everywhere in the study area and is overlain by the Wanapum Basalt. The thickness contours on figure 24 were created by subtracting the thicknesses of the Saddle Mountains Basalt, Mabton Member of the Ellensburg Formation, and Wanapum Basalt from values on a map of total basalt thickness (Stephen P. Reidel, Westinghouse Hanford Company, written commun., 1989). The thickness contours include all interbedded sediments of the Ellensburg Formation. The Grande Ronde Basalt thickness in the study area ranges from about 6,000 to more than 15,000 ft. At least part of the total thickness of the Grande Ronde Basalt is saturated everywhere in the study area.

A series of sections of the hydrologic units is included in Ebbert and others (1996). These hydrogeologic sections also include the nitrate concentrations observed in wells tapping the units.

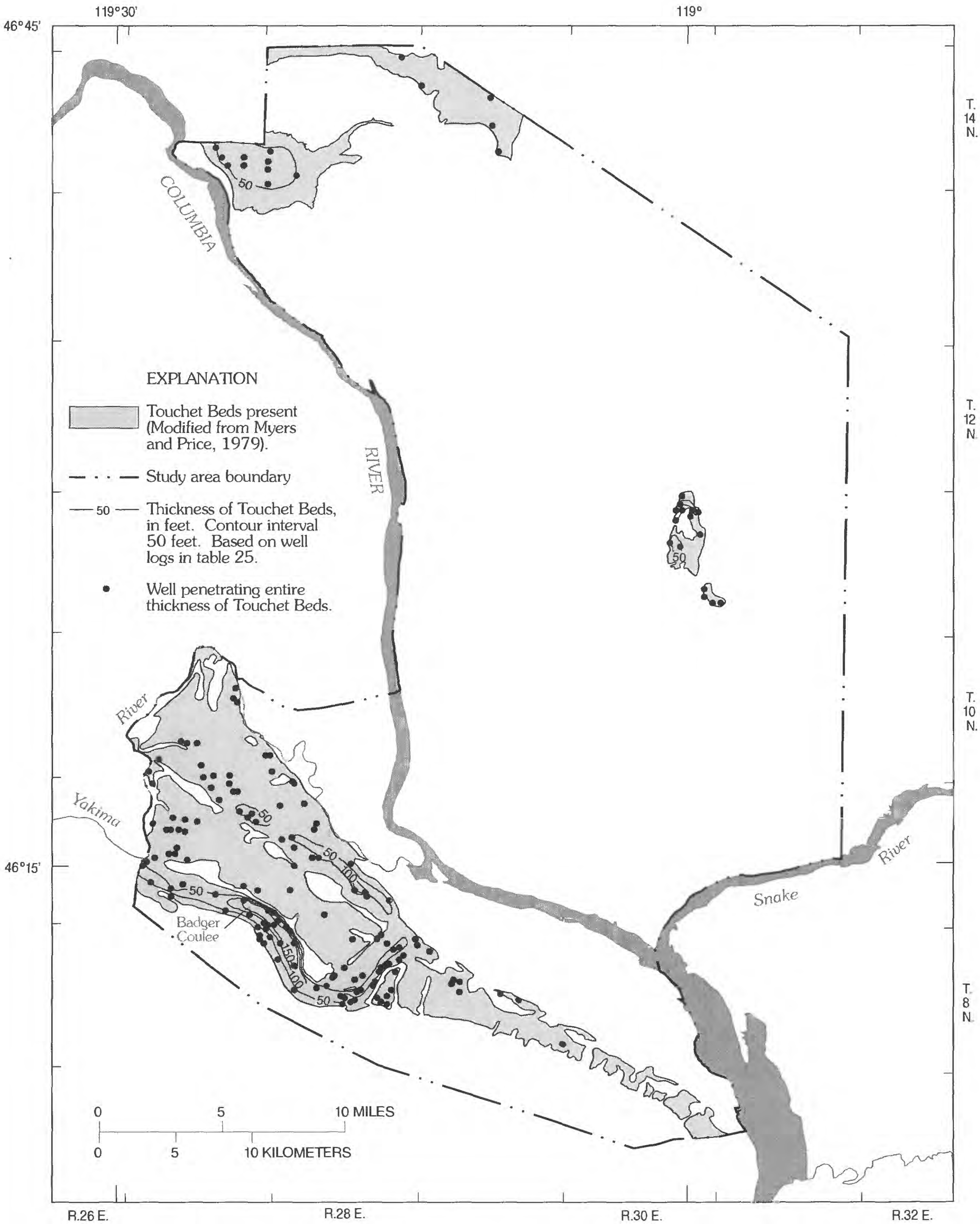


Figure 15.--Extent and thickness of Touchet Beds.

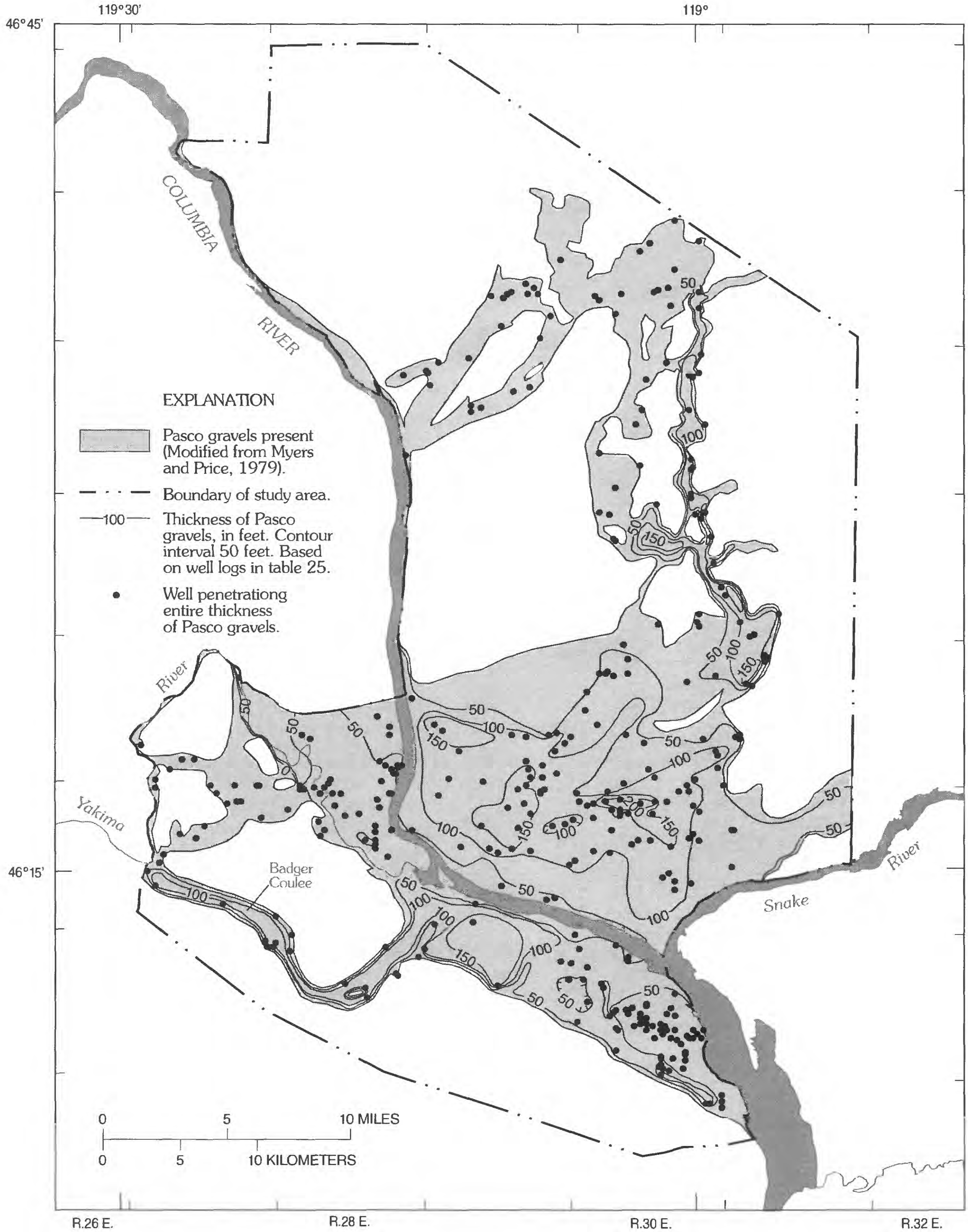


Figure 16.--Extent and thickness of Pasco gravels.

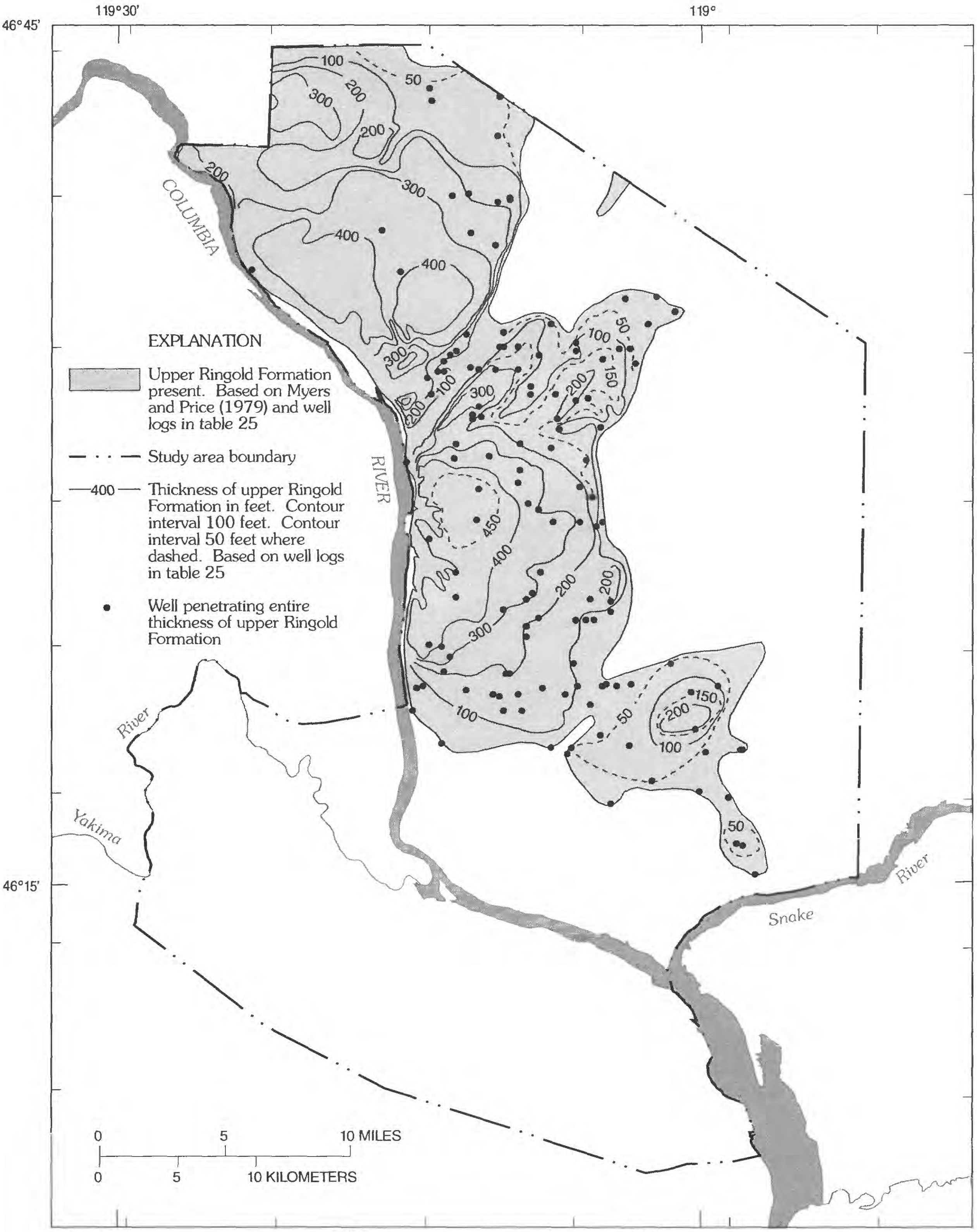


Figure 17.--Extent and thickness of the upper Ringold Formation.

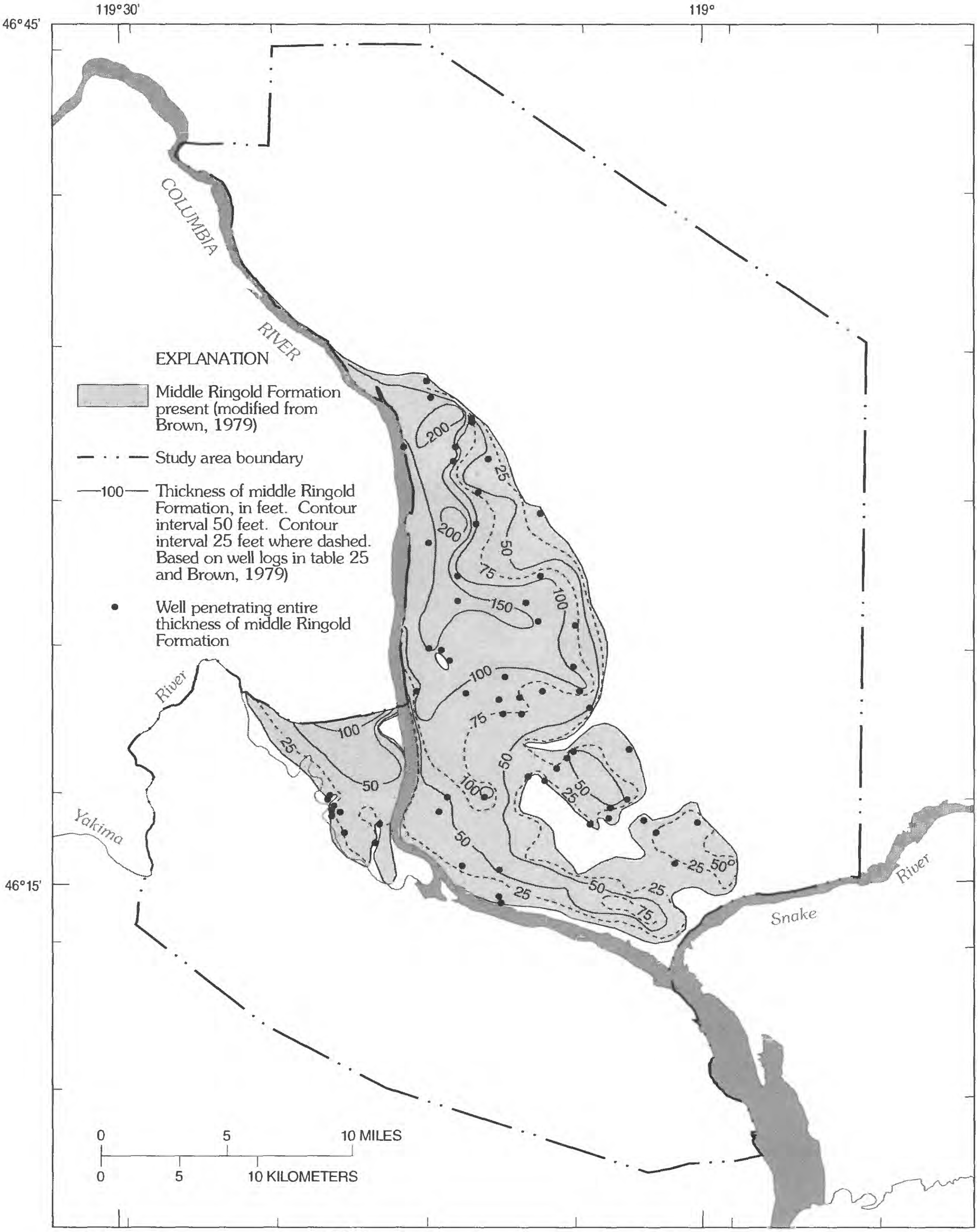


Figure 18.--Extent and thickness of the middle Ringold Formation.

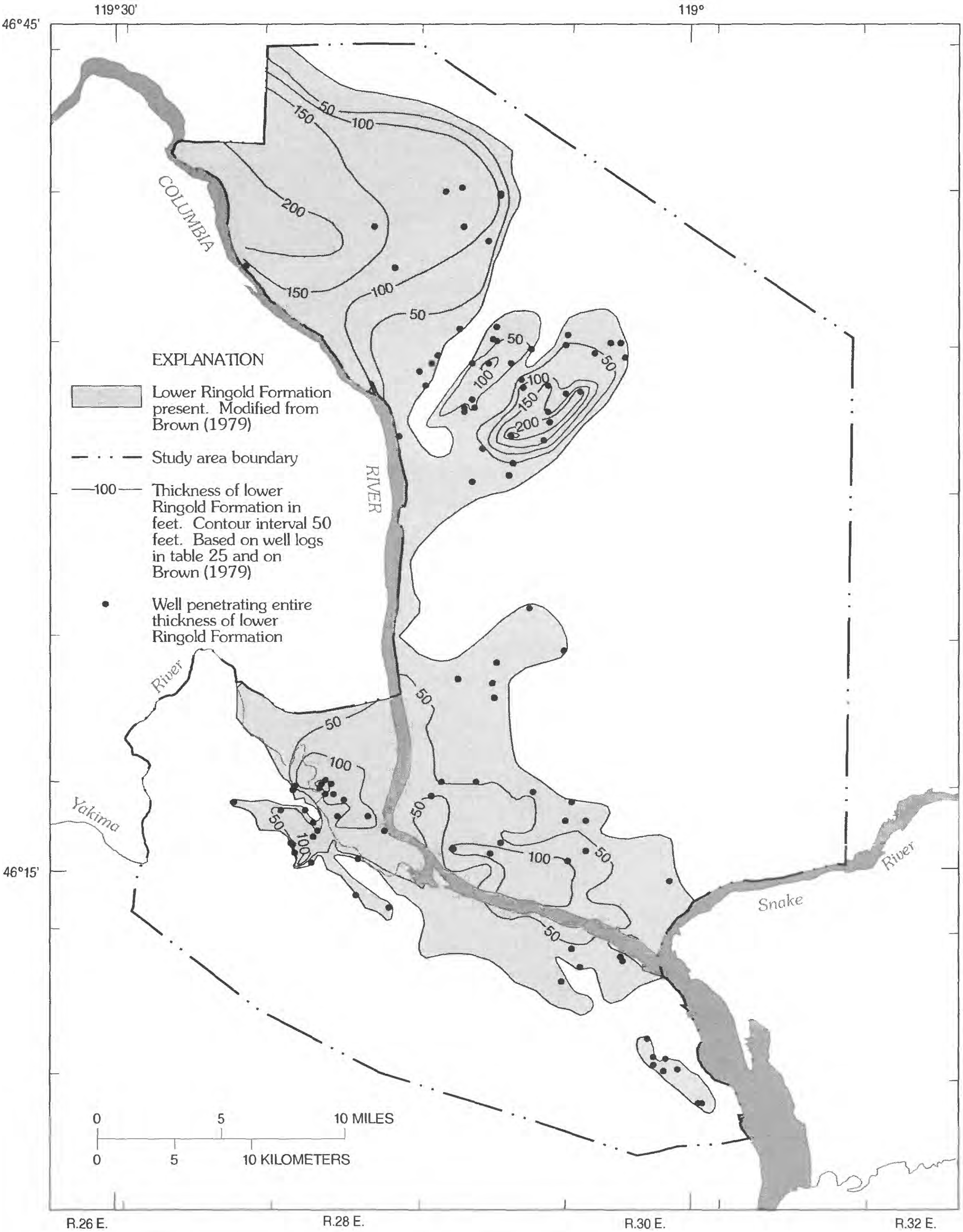


Figure 19.--Extent and thickness of the lower Ringold Formation.

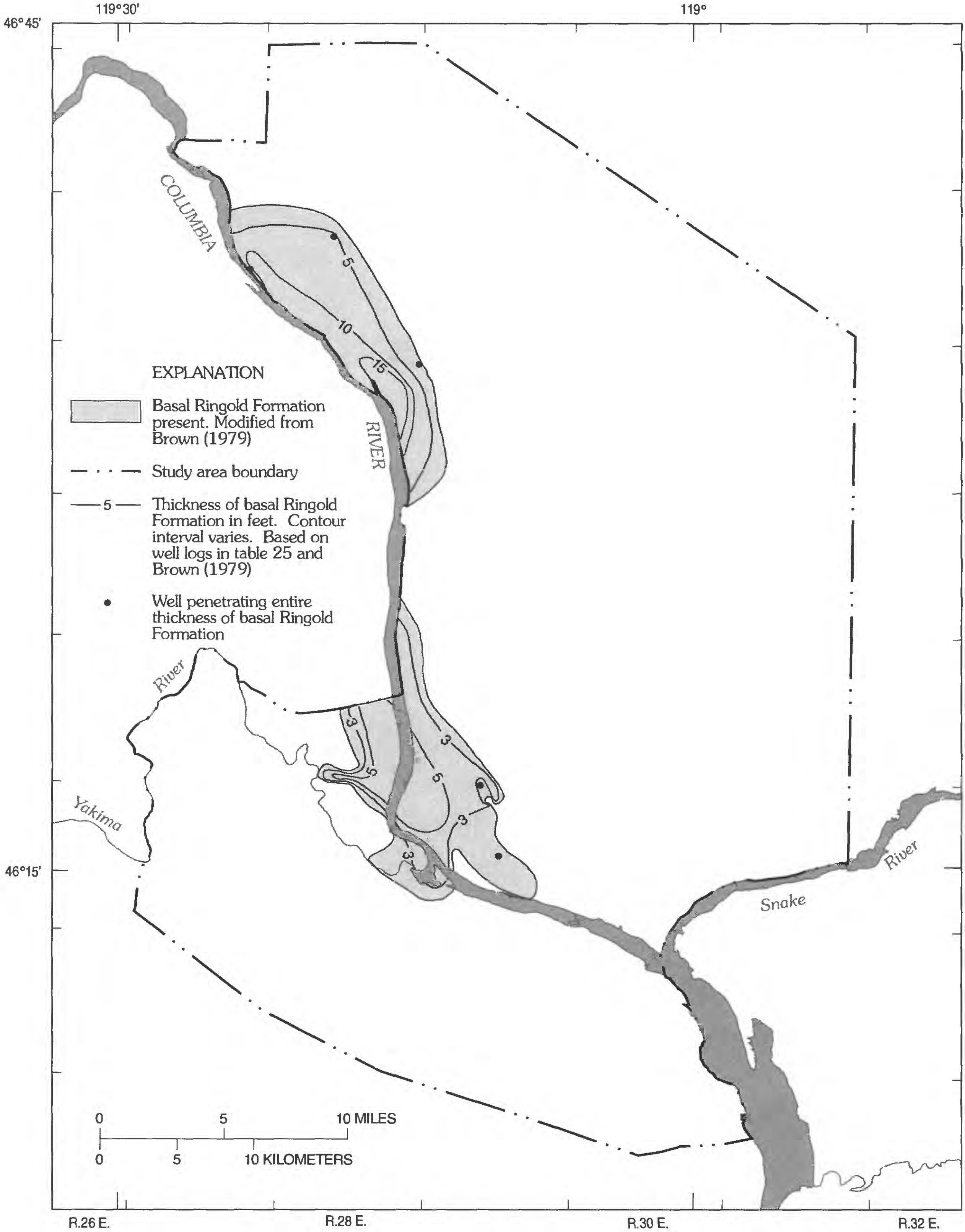


Figure 20.--Extent and thickness of basal Ringold Formation.

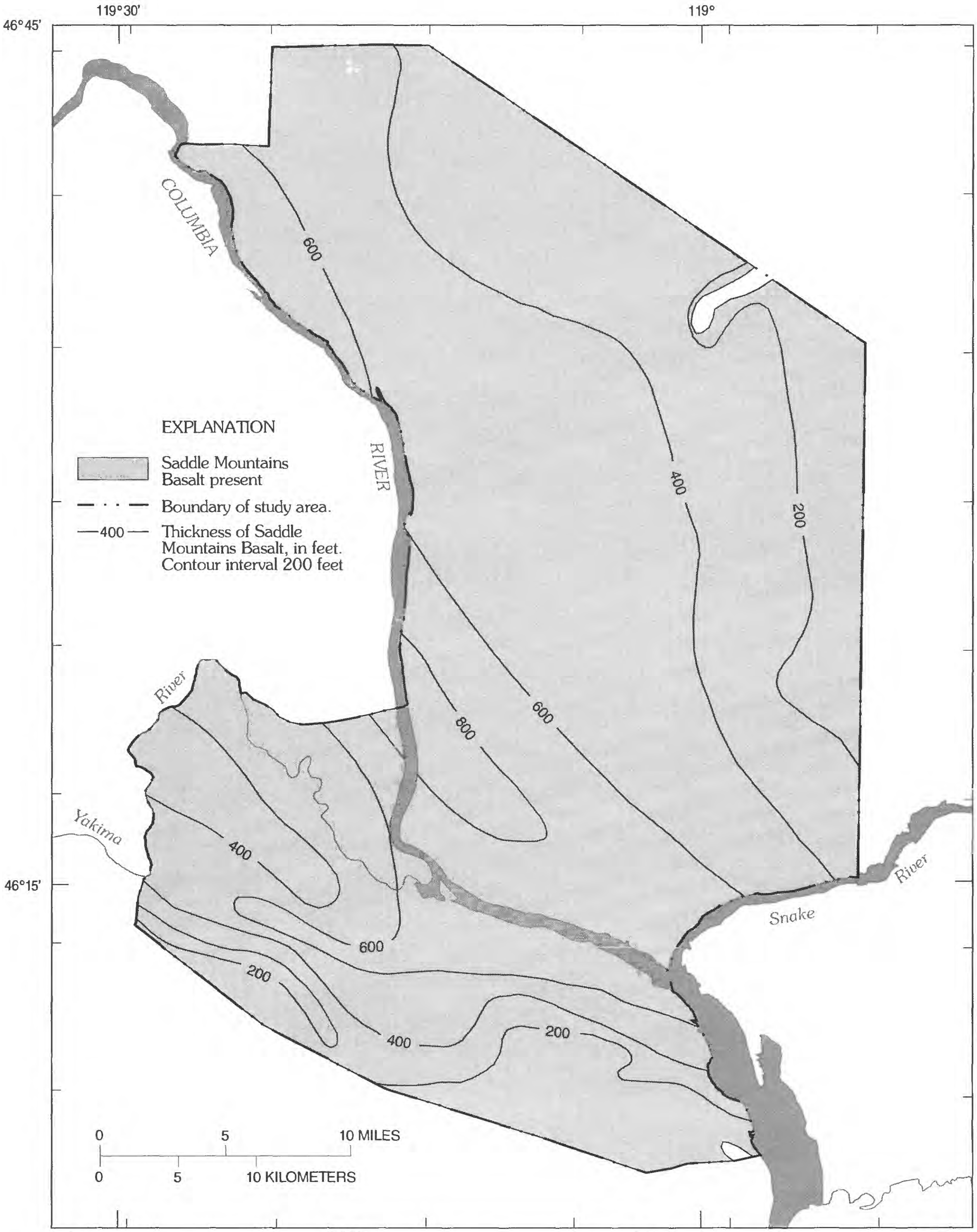


Figure 21.--Extent and thickness of the Saddle Mountains Basalt (from Drost and Whiteman, 1986).

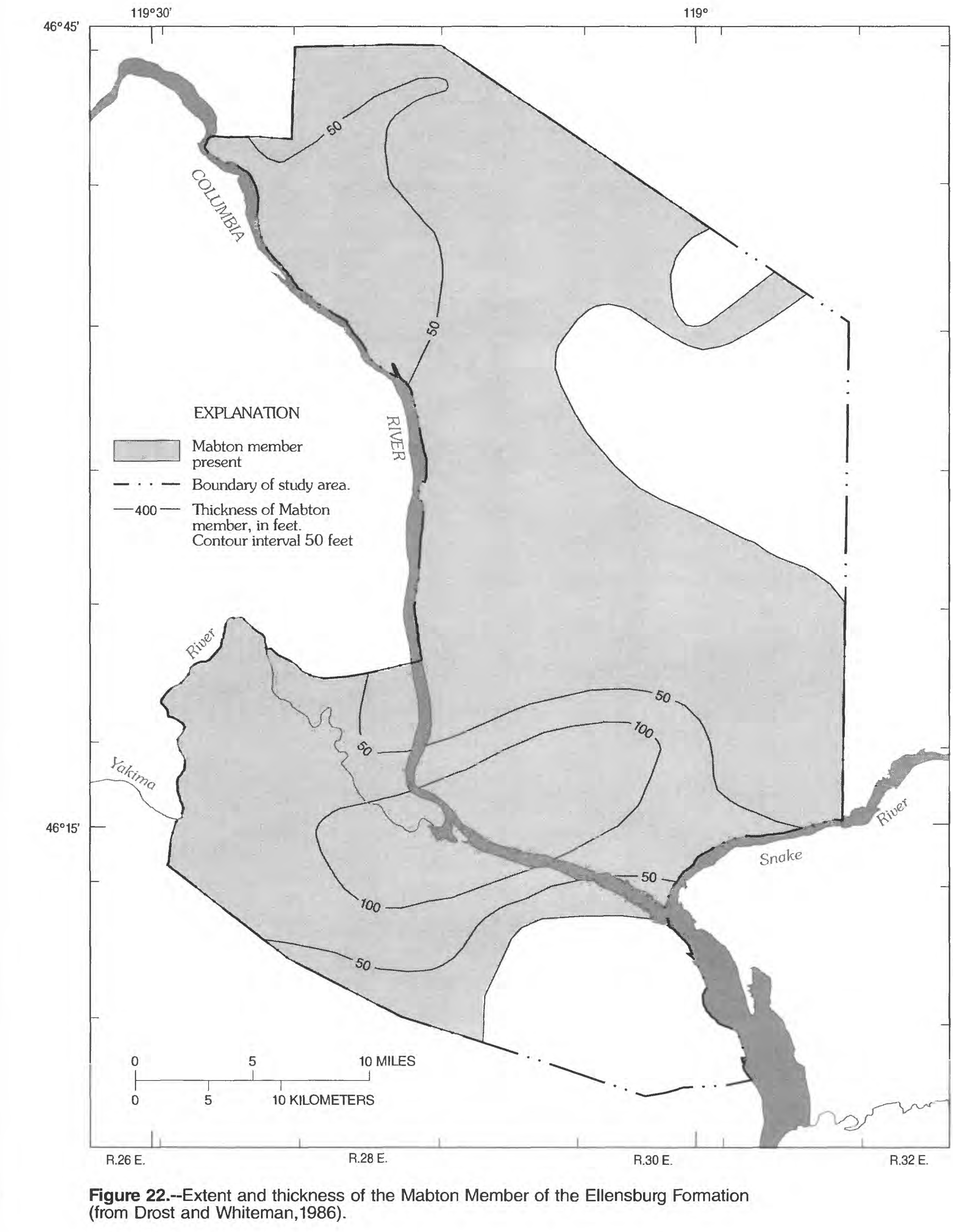


Figure 22.--Extent and thickness of the Mabton Member of the Ellensburg Formation (from Drost and Whiteman,1986).

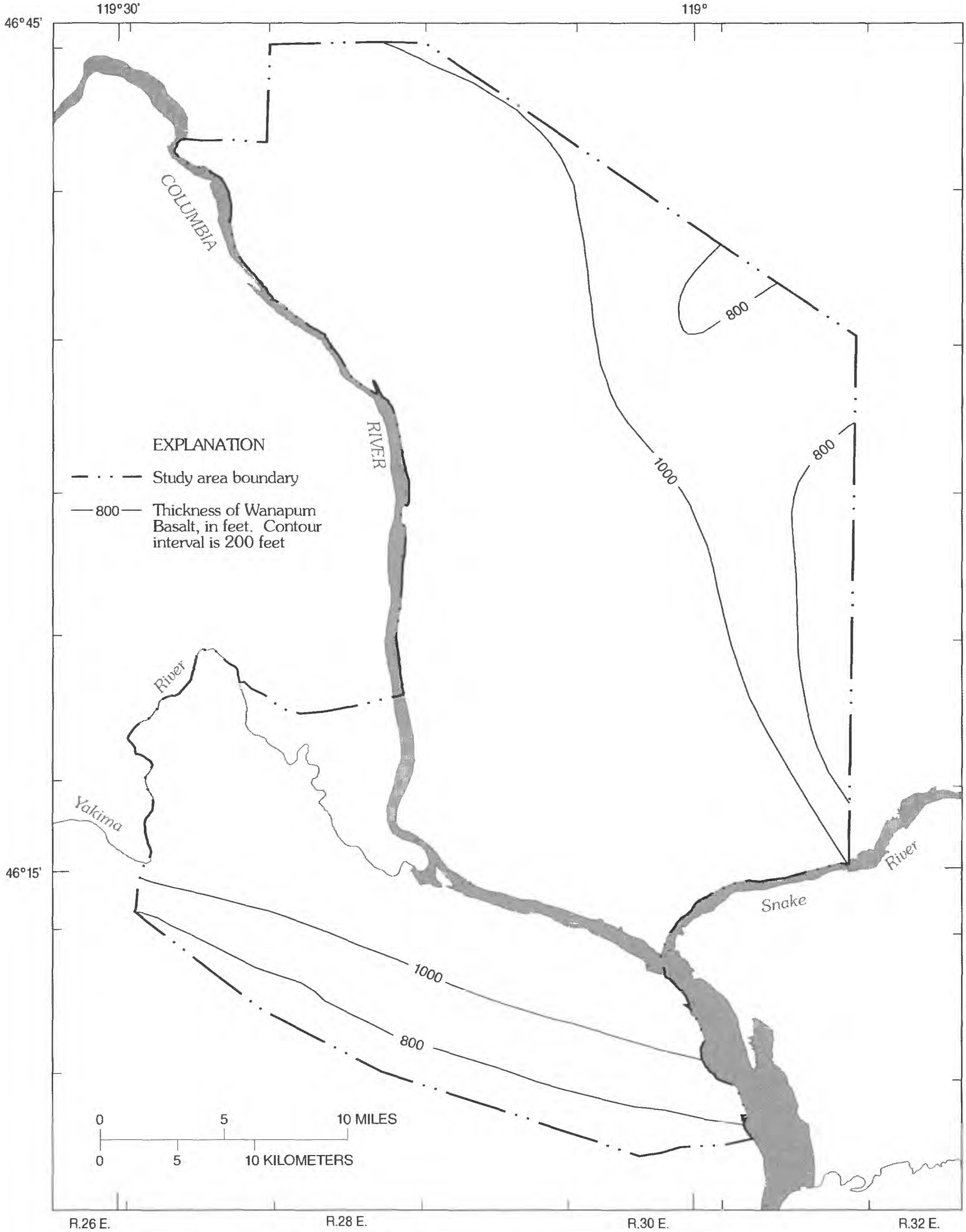


Figure 23.--Thickness of the Wanapum Basalt (from Drost and Whiteman, 1986).

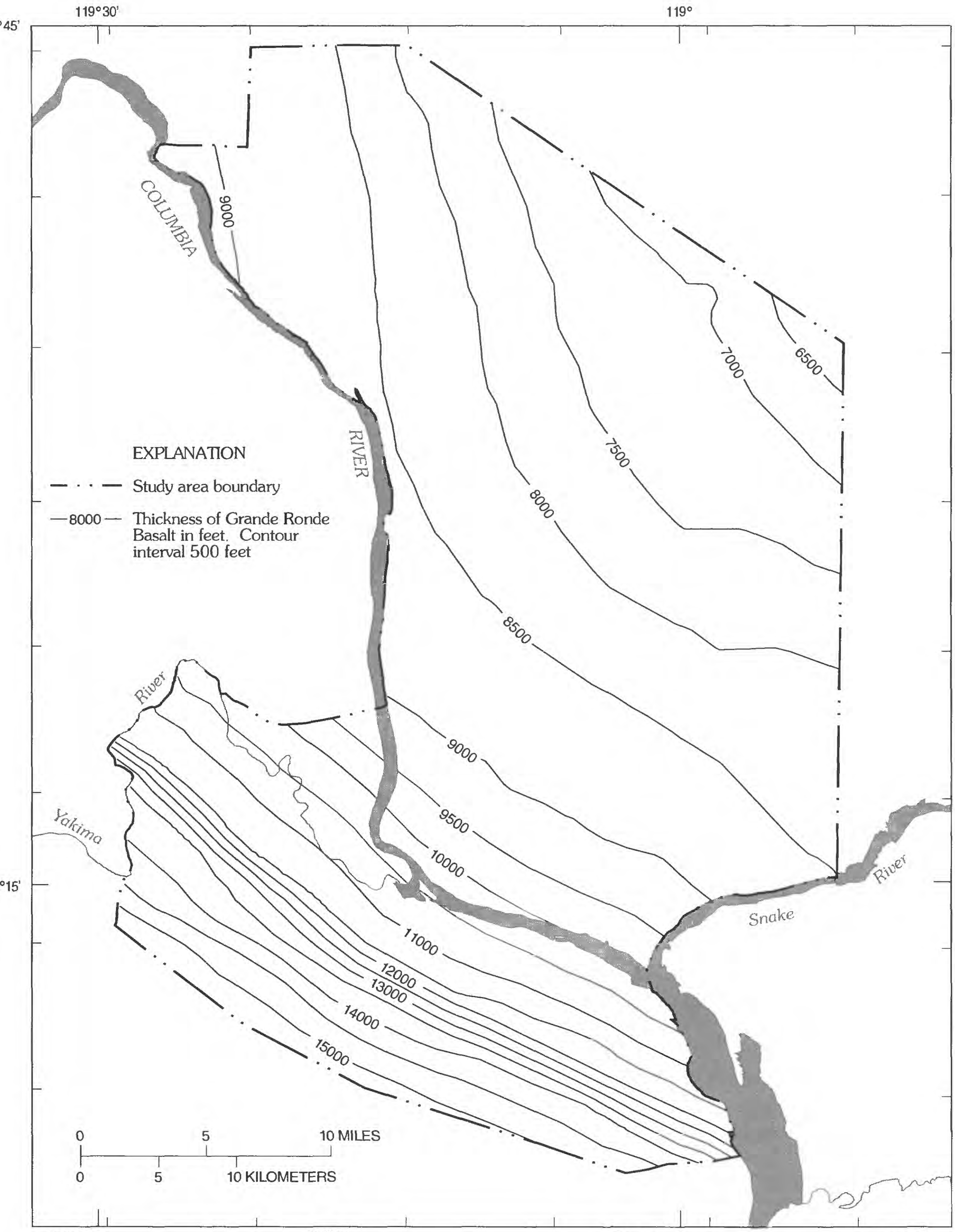


Figure 24.--Thickness of the Grande Ronde Basalt.

Hydraulic Characteristics of the Hydrologic Units

The abilities of water-bearing materials in an area to store and transmit water determine how the ground-water system operates. Knowledge of the hydraulic characteristics of the hydrologic units is necessary to evaluate how the ground-water flow system responds to stresses. These characteristics include horizontal and vertical hydraulic conductivities, and storage coefficient.

Horizontal Hydraulic Conductivity

Horizontal hydraulic conductivity is a measure of a hydrologic unit's ability to transmit water horizontally. Horizontal hydraulic conductivity is the volume of water that will move in unit time under a unit gradient through a unit area (measured at right angles to the direction of flow). It is in units of cubic feet per square feet per day, commonly simplified to feet per day.

Values of horizontal hydraulic conductivity were estimated from specific-capacity data with the Theis method for water-table units and the Brown method for artesian units (both in Bentall, 1963). The specific-capacity data were obtained from well records and generally represent short-term (about 4-hour) bailer tests conducted by well drillers at the time the wells were originally completed. The Theis and Brown methods actually calculate a transmissivity value. These transmissivity values were divided by the length of the open interval(s) in each well to estimate hydraulic conductivity. Table 5 and figure 25 show the estimates of horizontal hydraulic conductivity from specific-capacity data.

Horizontal hydraulic conductivity, as estimated from specific-capacity data, ranges over seven orders of magnitude (0.0073 to 73,000 ft/d). The individual sedimentary units above the basalt have conductivity ranges of two to three orders of magnitude. Horizontal hydraulic conductivity of the Saddle Mountains Basalt ranges over six orders of magnitude.

The estimated horizontal hydraulic conductivity values for the upper Ringold Formation and lower Ringold Formation are probably not representative of average conditions in these units. Wells generally are completed in these units where the units are unusually coarse-grained, and therefore specific-capacity tests are available only for the more permeable parts of the units. Three of the specific-capacity tests in the upper Ringold Formation represent fine-grained intervals (as reported by the drillers). The estimated horizontal hydraulic conductivities for these fine-grained intervals are 1.5, 2.7, and 11 ft/d. Two of the tests in the lower Ringold Formation also represent fine-grained intervals. The conductivity values for these intervals are 2.2 and 6.0 ft/d. These values for fine-grained intervals are probably more representative of average conditions in the upper and lower Ringold Formation than the remainder of the specific-capacity tests.

The extremely wide range of horizontal hydraulic conductivity values in the Saddle Mountains Basalt reflects the complex nature of the basalt flows in the study area. A specific-capacity test on a typical well open to the basalt will yield an estimated conductivity value that represents a composite of permeabilities (highly permeable basalt flow tops and bottoms, very poorly permeable basalt flow centers, and highly permeable fracture zones). The estimated conductivity for an individual well depends on the ratio of thickness of basalt flow tops and bottoms to thickness of basalt flow centers, as well as the number and size of fractures in the open interval of the well.

Injection, pulse, and swab tests conducted on the Hanford Site show the difference between basalt flow tops and basalt flow centers (Strait and Mercer, 1987). Strait and Mercer's transmissivity values in the Saddle Mountains Basalt and Wanapum Basalt were converted to horizontal hydraulic conductivity values by dividing by effective test interval. A total of 71 tests on basalt flow tops resulted in a range of horizontal hydraulic conductivity of 0.0003 to 50,000 ft/d (median of 35 ft/d). Tests on basalt flow centers (2 on Wanapum Basalt and 22 on Grande Ronde Basalt) yielded values of $5x10^{-9}$ to 0.001 ft/d (median of $2x10^{-7}$ ft/d).

The smaller range in horizontal hydraulic conductivity values shown for the Wanapum Basalt (as compared with the Saddle Mountains Basalt) is probably largely due to the smaller number of tests of the Wanapum Basalt. The difference may also be partly due to the difference in well types in these two basalt units. Many of the wells completed in the Saddle Mountains Basalt were drilled for domestic supplies and were completed when enough water was encountered for a single household; in some instances, only one poorly permeable basalt flow top was penetrated. Most of the Wanapum Basalt wells are used for irrigation and were drilled to sufficient depths to penetrate multiple basalt flow tops (at least one of which is highly permeable).

Table 5.--*Horizontal hydraulic conductivity values in the study area, estimated from specific-capacity data*

Hydrologic unit	Number of tests	Lateral hydraulic conductivity (feet per day)				
		Maximum	75th Percentile	Median	25th Percentile	Minimum
Pasco gravels	103	73,000	3,100	880	440	48
upper Ringold Formation	13	210	54	25	11	1.5
middle Ringold Formation	35	5,000	740	180	83	7.5
lower Ringold Formation	5	230	60	46	6.0	2.2
Saddle Mountains Basalt	87	3,200	36	2.3	.64	.0073
Wanapum Basalt	13	310	15	11	4.6	1.1

Although no aquifer test data are available for the study area, the horizontal hydraulic conductivity values estimated from specific-capacity data can be compared with values obtained from aquifer tests on the nearby Hanford Site. Twelve aquifer tests in the Pasco gravels yielded a median value of 1,250 ft/d (Myers and others, 1985). The median hydraulic-conductivity value from specific-capacity tests (table 5) is 880 ft/d. Six aquifer tests in the middle Ringold Formation on the Hanford Site yield a median value of 41 ft/d (Newcomb and others, 1972; Graham, 1981; and Meyers and others, 1985). This is significantly less than the median value (180 ft/d) obtained from 35 specific-capacity tests in the study area. However, recent work at the Hanford Site (Bergeron and others, 1986) estimates the average horizontal hydraulic conductivity of the middle Ringold to be about 200 to 250 ft/d. A single aquifer test at Hanford in the lower Ringold resulted in a calculated conductivity of 1 ft/d (Graham, 1981). This is less than any of the values estimated from the five specific-capacity tests in the study area, which ranged from 2.2 to 230 ft/d. However, the Hanford Site test may more accurately represent the average conditions in the lower Ringold than the specific-capacity tests, which tend to represent coarse-grained layers.

No specific-capacity data are available for the Touchet Beds, basal Ringold, or Grande Ronde Basalt in the study area. Two short-term recovery tests were conducted on shallow test holes completed in the Touchet Beds in Badger Coulee by Bureau of Reclamation and KID personnel. Analysis of the test data (using Bureau of Reclamation computation methods; Bureau of Reclamation, 1984) yielded horizontal hydraulic conductivities of 7.9 and 10.8 ft/d. The basal Ringold probably has conductivity values similar to the Middle Ringold. Bergeron and others (1986) estimate an average value of about 200 to 250 ft/d for a part of the Hanford Site.

Specific-capacity data for two wells in the Grande Ronde Basalt in the Pasco Basin (but not in the study area) yield conductivity values of 19 and 0.17 ft/d. Injection, pulse, and swab tests on the Hanford Site in the Grande Ronde Basalt give a conductivity range of 3×10^{-6} to 500 ft/d (72 tests; median of 0.1 ft/d) for basalt flow tops and 5×10^{-9} to 0.001 ft/d (22 tests, median of 2×10^{-7} ft/d) for basalt flow centers (Strait and Mercer, 1987).

Horizontal hydraulic conductivity probably varies areally in each of the hydrologic units. There is sufficient data only for the Pasco gravels, middle Ringold Formation, and Saddle Mountains Basalt to allow examination of areal distribution of conductivity. Relatively high conductivities are found in the Pasco gravels in the Pasco Greenbelt and Smith Canyon areas (25 tests; median = 1,600 ft/d) and Kennewick and Finley areas (46 tests; median = 1,200 ft/d). Low conductivities are found in the Pasco gravels in Badger Coulee (16 tests; median = 320 ft/d) and the Richland/West Richland area (11 tests; median = 670 ft/d).

The areal distribution of conductivities in the Pasco gravels may be somewhat misleading. As stated earlier, identification of the Pasco gravels in Badger Coulee is difficult, and some wells identified as open to the Pasco gravels may actually be tapping the middle Ringold Formation or other hydrologic units. The high conductivity values observed in the Pasco Greenbelt and Smith Canyon areas may be partly due to the fact that most wells completed in the Pasco gravels in this area are irrigation wells (usually with significant well development) and most wells completed in the Pasco Gravels elsewhere are used for single-household domestic supplies (usually with poor development).

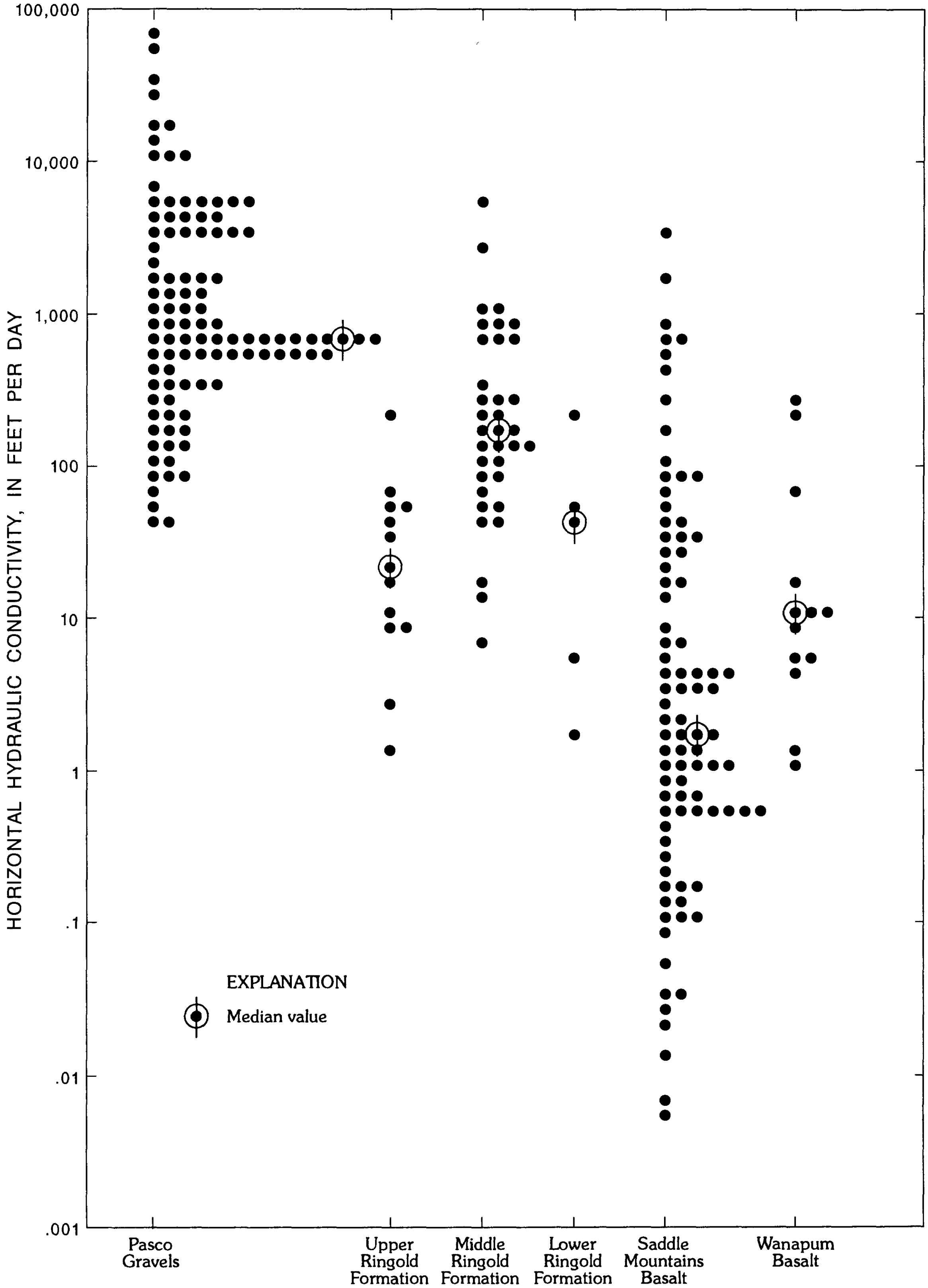


Figure 25.--Horizontal hydraulic conductivity estimated from specific-capacity tests in the study area.

The middle Ringold Formation appears to be more conductive in the Richland and West Richland areas (16 tests; median = 720 ft/d) than in Franklin County (18 tests; median = 110 ft/d). This difference may be partly due to the difficulty in distinguishing between the Pasco gravels and middle Ringold Formation in the Richland area. In some places, sediments identified as middle Ringold Formation may actually be middle Ringold Formation materials that were eroded and redeposited by the floods that deposited the Pasco gravels (Brown, 1979), resulting in greater conductivity.

The Saddle Mountains Basalt appears to have a definite areal distribution of horizontal hydraulic conductivity: relatively high values in Badger Coulee (7 tests; median = 53 ft/d) and the Richland and West Richland areas (8 tests; 32 ft/d), and relatively low values in the Kennewick and Finley areas (12 tests; median = 6.2 ft/d) and Franklin County (52 tests; median = 0.90 ft/d). However, great care must be exercised in the use of these data. As discussed earlier, horizontal hydraulic conductivity varies tremendously in the vertical direction, and therefore the distribution of open intervals in a well may be much more important than the areal distribution of wells in determining horizontal hydraulic conductivities.

Vertical Hydraulic Conductivity

Vertical hydraulic conductivity, an important control on the behavior of the ground-water system, is one of the most difficult characteristics to measure. Vertical hydraulic conductivity is a measure of a hydrologic unit's ability to transmit water vertically and is reported in the same units (feet per day) as horizontal hydraulic conductivity.

Seepage rates for unlined irrigation canals are generally reasonable estimates of vertical hydraulic conductivity. A later section, "Canal-Seepage Recharge", contains seepage rates for unlined canals in selected hydrologic units: Touchet beds, 0.4 ft/d; Pasco gravels, 0.7 ft/d; upper Ringold Formation, 0.4 ft/d; and Saddle Mountains Basalt, 0.3 ft/d. However, the seepage rate for unlined canals in the Pasco gravels is probably considerably less than the vertical hydraulic conductivity of this unit; sediment deposited in the canals has probably reduced the conductivity of the canal beds to much less than the vertical conductivity of the Pasco gravels.

Vertical hydraulic conductivity in the Saddle Mountain Basalt depends almost completely on the number and size of vertical fractures. Because it is doubtful that the basalts found in canal bottoms are representative of the basalts in general, vertical conductivity in the basalts is probably much less than that indicated by the canal seepage tests. Where canals occur in the basalts, the basalt (1) has been at or near the land surface for long periods of time (and therefore exposed to weathering), (2) is generally a basalt flow top which is much more conductive (both horizontally and vertically) than a basalt flow center, and (3) has probably been fractured during canal construction (by digging or blasting). On the other hand, sediment deposition in canals has probably filled some fractures in the basalts, leading to decreases in vertical conductivity.

The unlined canal seepage rates are reasonable estimates of vertical hydraulic conductivity for the Touchet Beds and upper Ringold Formation units. The materials in these units are of similar grain size to the material deposited in the canals, so the vertical hydraulic conductivities probably are unaffected by sediment deposition.

Vertical hydraulic conductivity can also be estimated in areas where ground water is rising to the surface. In the vicinity of well 08N/28E-22D05, in the Touchet Beds in Badger Coulee, the ground is marshy even during the driest times of the year. Therefore, the rate of vertical flow of ground water at this site must be greater than the maximum evapotranspiration rate during the year. Equation (1) can be used to estimate vertical hydraulic conductivity by substituting a pan evaporation rate of 7.25 in/month (0.02 ft/d) for Q_z ; unity for A ; 0.30 ft for $\Delta_z h$, the height of the ground-water head above land surface in the well; and 6.5 ft for b , the depth to the center of the open interval in the well. Solving the equation yields a value of 0.4 ft/d. This is a minimum value for vertical hydraulic conductivity of the Touchet Beds at this location, because Q_z is actually somewhat greater than the pan evaporation rate.

$$k_z = \frac{Q_z b}{A \Delta_z h} \quad , \qquad (1)$$

where

k_z = vertical hydraulic conductivity,
Q_z = rate of vertical flow,
b = distance over which head difference occurs,
A = area perpendicular to flow,
$\Delta_z h$ = head difference.

Storage Coefficient

Storage coefficient is a measure of a hydrologic unit's ability to store and release water. Storage coefficient is defined as the volume of water that a unit releases from or takes into storage per unit surface area per unit change in hydraulic head. The storage coefficient is in units of cubic feet per cubic feet or more commonly shown as dimensionless.

The magnitude of a storage coefficient depends on whether a unit is confined or unconfined. In confined units, the storage coefficient is related to the compressibility of water and of the solid framework and is therefore relatively small (generally less than $1x10^{-3}$). In unconfined units, the storage coefficient is essentially equal to the specific yield (the ratio of the volume of water yielded by gravity drainage to the volume of the unit) and is generally in the range of 0.1 to 0.3.

Aquifer tests in unconfined units in the Pasco Basin have resulted in calculated storage coefficient values of 0.11 for the middle Ringold Formation (CWC-HDR, Inc., 1988) and 0.15 to 0.20 for the Pasco gravels (Bierschenk, 1957; Newcomb and others, 1972; Tanaka and others, 1974; and Graham, 1981). Aquifer test data are not available for the other unconfined units, but on the basis of general grain sizes, storage coefficient values are probably about 0.08 for the Touchet Beds, 0.7 to 0.21 for the upper Ringold Formation, and 0.02 to 0.21 for the lower Ringold Formation (Johnson, 1966). For the unconfined basalt units, storage coefficients are probably in the range of 0.001 to 0.01 (Eddy, 1968).

Aquifer tests in confined parts of the sediments overlying the basalts in the Pasco Basin have yielded storage coefficient values of 0.03 to 0.07 for the Pasco gravels (Bierschenk, 1957; Newcomb and others, 1972; and Graham, 1981), $7x10^{-5}$ to 0.06 for the middle Ringold Formation (Bierschenk, 1957; Newcomb and others, 1972; and Graham, 1981), and 0.002 to 0.05 for the lower Ringold Formation (Graham, 1981). Some of these values are uncharacteristically high and probably reflect semiconfined conditions. No data are available for the basal Ringold Formation; it is probably similar to the middle Ringold Formation.

Aquifer tests in confined parts of the basalts have yielded storage coefficient values of $1.4x10^{-6}$ to $6x10^{-3}$ (La Sala and Doty, 1971; Tanaka and others, 1979; and Olson, 1989). Recent modeling studies of the basalts have resulted in calibrated storage coefficients of 0.01 to 0.0001 (Smoot and Ralston, 1987; and Davies-Smith and others, 1988).

Ground-Water Movement

The general direction of shallow ground-water flow can be inferred from figure 26, which shows the configuration of the water table for March 1986. Horizontal ground-water movement is generally perpendicular to the water-table contours. On a regional scale, most of the ground-water flow at the water table is directed toward the Columbia, Snake, and Yakima Rivers, the major areas of ground-water discharge in the study area. However, some flow at the water table is toward internal drains (for example, Esquatzel and Ringold Coulees). On a local scale, flow at the water table is frequently toward buried drains. Although the altitude of the water table varies seasonally, the general pattern of flow remains constant.

With increasing depth in the ground-water system, the influence of the drains decreases. Flow in the Saddle Mountains Basalt (fig. 27) is generally toward the rivers, but Esquatzel Coulee is an influence. Internal drains have little or no effect on flow in the Wanapum Basalt (fig. 28).

In addition to horizontal flow, there is also vertical flow in the ground-water system. Vertical flow occurs between aquifers through the confining beds. In most of the study area, vertical flow is downward. This can be seen by comparing the water table (fig. 26) with water levels in deeper aquifers (see Saddle Mountain Basalt (fig. 27) or Wanapum Basalt (fig. 28) water levels). Evidence of downward vertical flow can be seen in a set of nested piezometers just outside of the study area in Grant County. Figure 29 shows the construction, geology, and water levels for a set of three nested piezometers installed by the Bureau of Reclamation. The water levels on figure 29 show a decrease in head (water-level altitude) with depth, indicating downward flow. Vertical flow is upward only in very narrow bands along the major discharge areas: the Columbia, Snake, and Yakima Rivers.

Localized vertical flow within water-table aquifers occurs in areas with buried drains. Figure 30 shows idealized flow to a buried drain. Drains are generally installed at about 10 ft below land surface. In the nested piezometers A, B, and C on figure 30, the altitudes of the water levels in the piezometers increase with depth indicating an upward vertical flow. Nested piezometers D, E, and F show a different vertical gradient: downward from D to E and upward from F to E. The vertical gradient observed near a buried drain will depend on the placement of the piezometers in relation to the drain (both horizontally and vertically). Table 6 shows water-level altitudes for three sets of nested piezometers in areas of buried drains. The nested piezometers in 10N/29E-10N indicate upward flow in all cases. The other two sets of piezometers show a mixture of upward and downward flow.

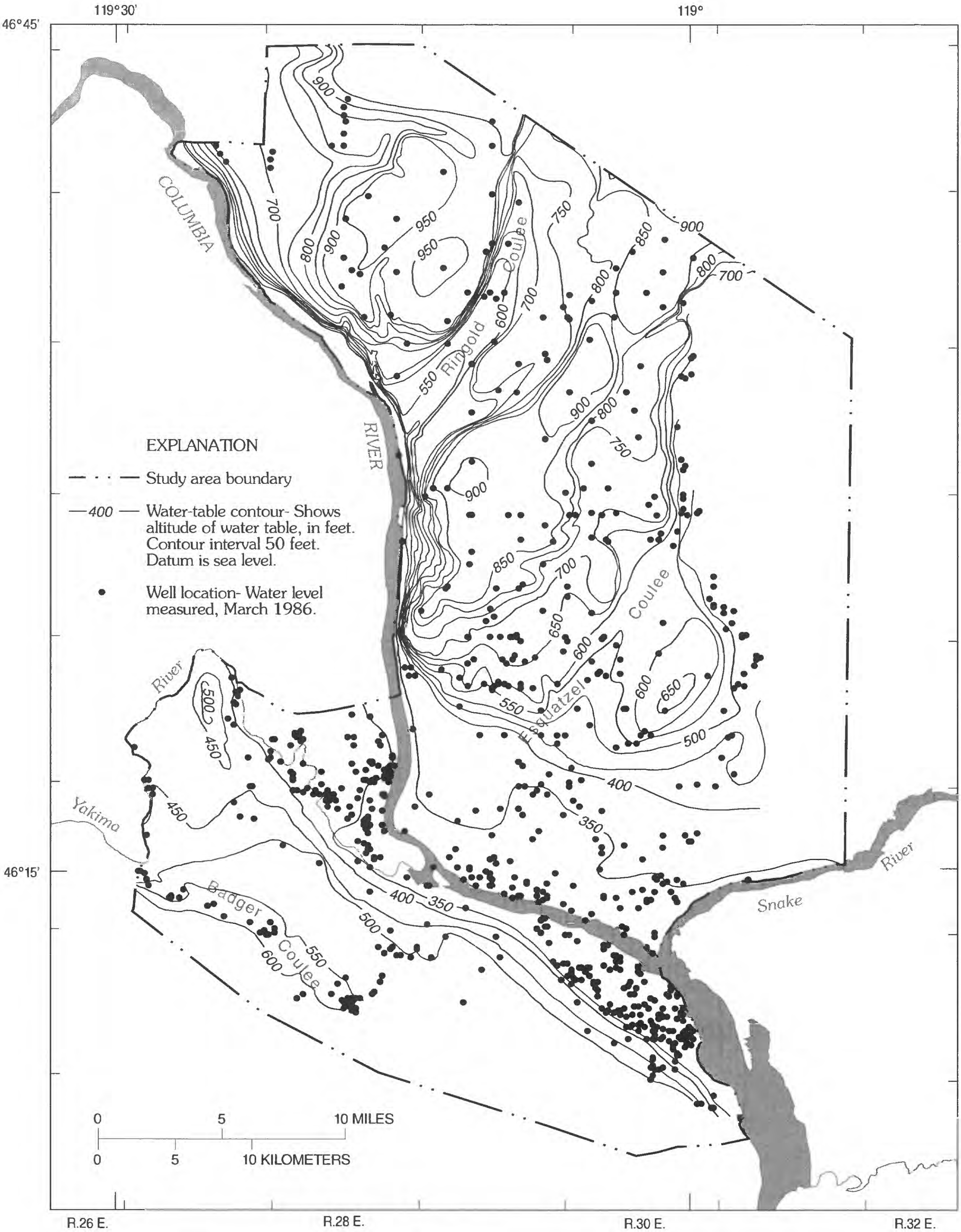


Figure 26.--Water-table altitude, March 1986.

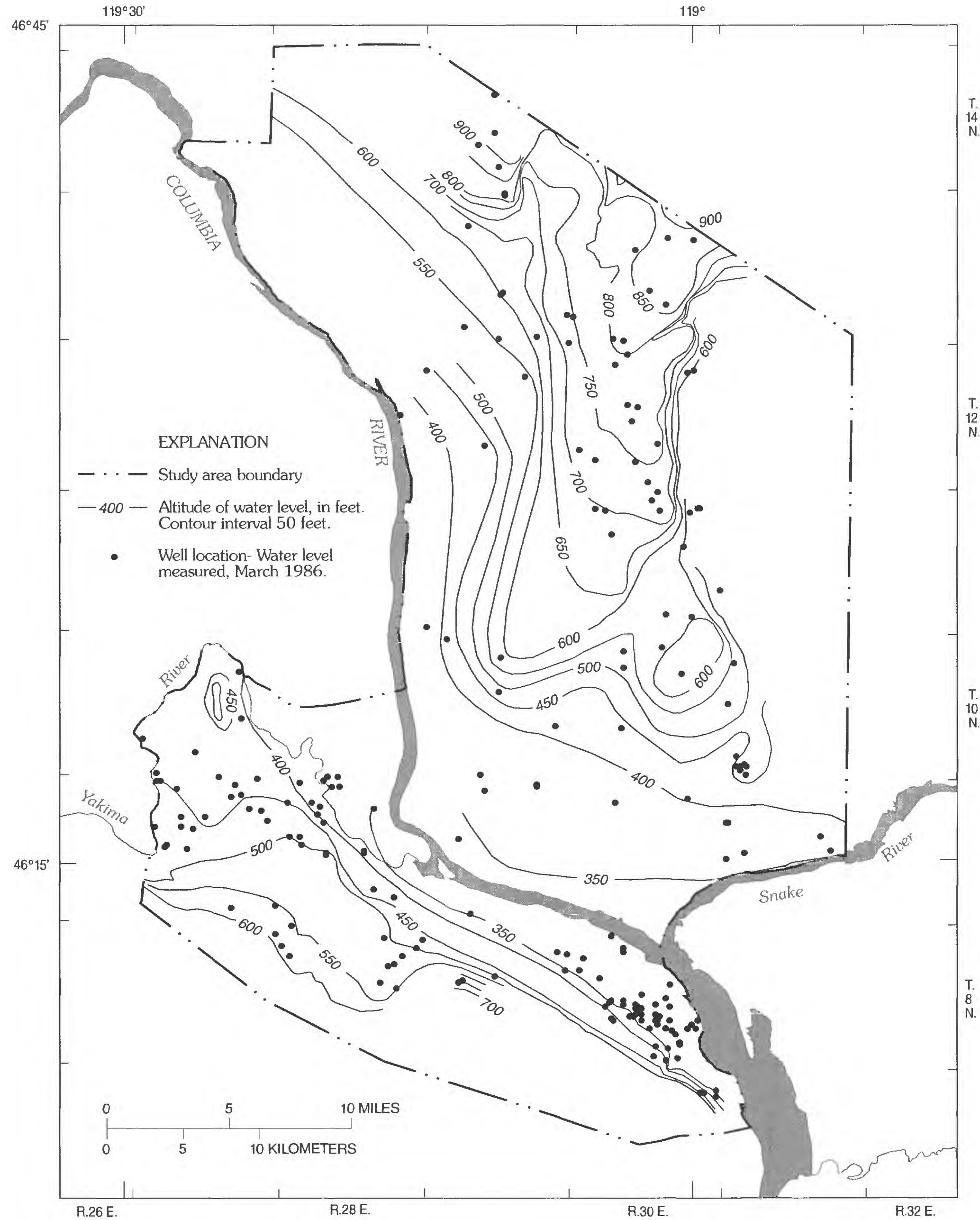


Figure 27.--Water-level altitudes in the Saddle Mountains Basalt, March 1986.

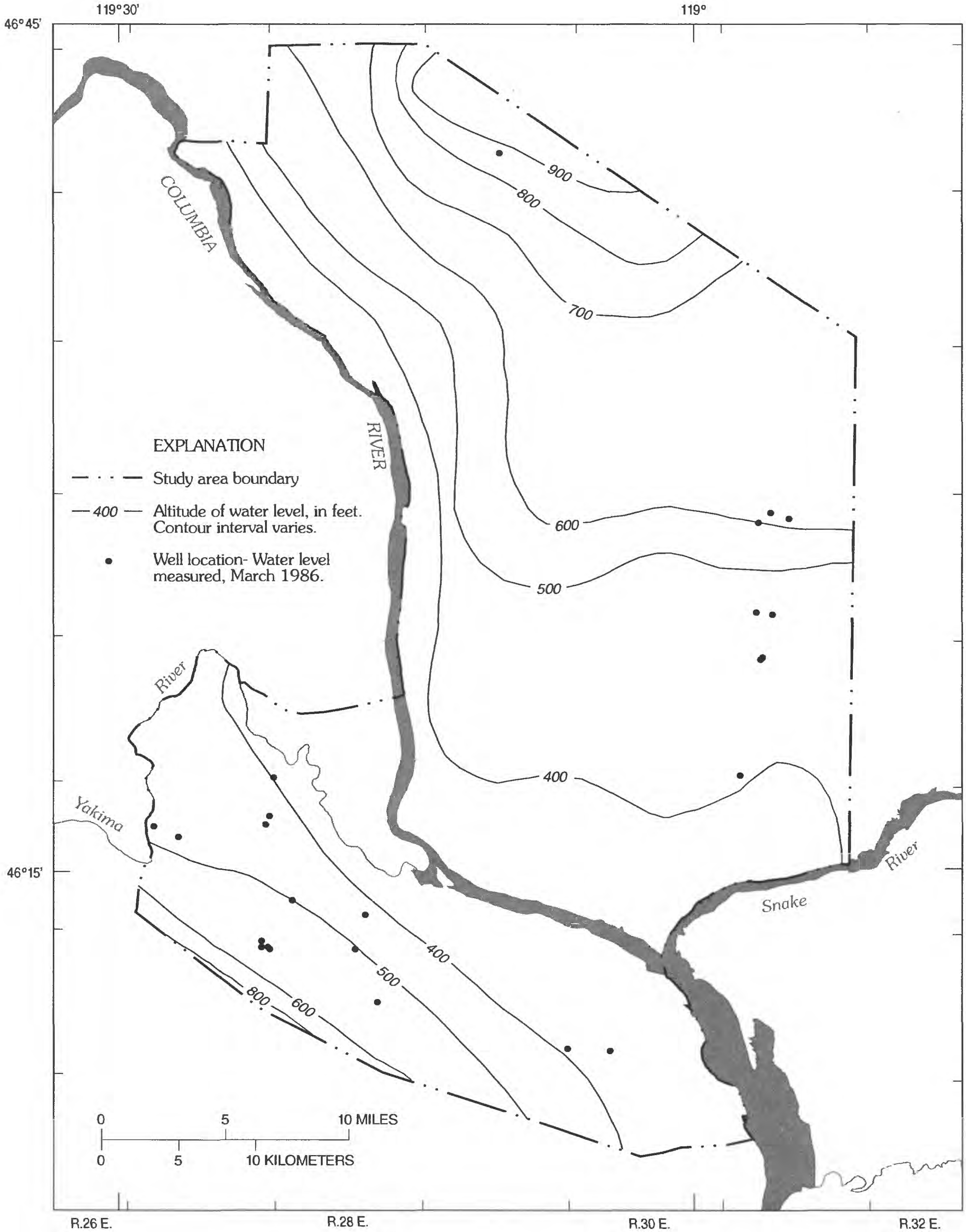


Figure 28.--Water-level altitudes in the Wanapum Basalt, March 1986 (Modified from Bauer, Vaccaro, and Lane, 1985).

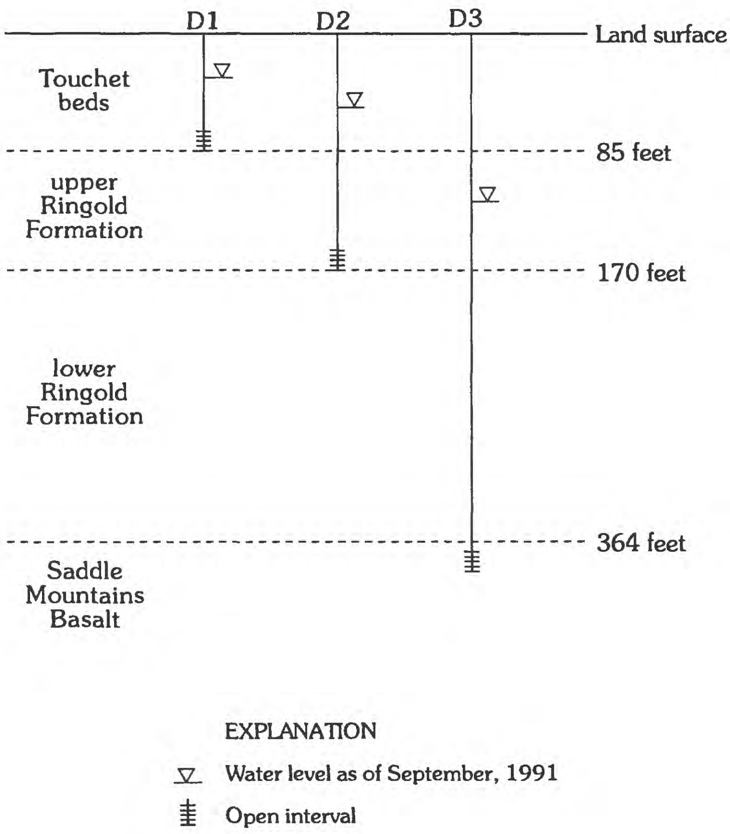


Figure 29.--September 1991 water levels in nested piezometers (14N/27E-03P01D1, -03P01D2, and -03P01D3), indicating downward vertical flow.

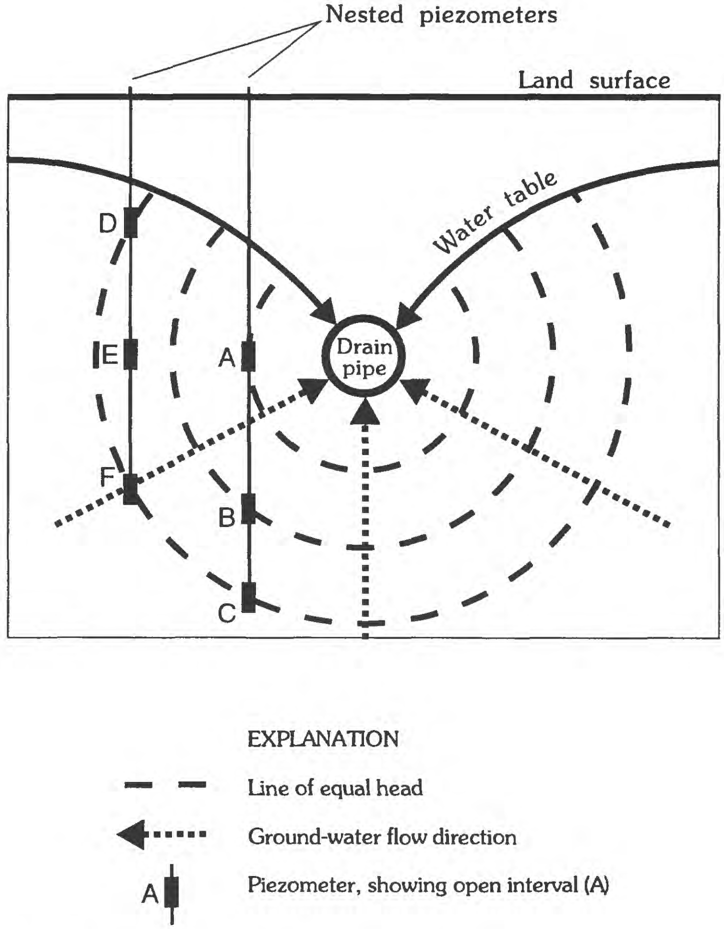


Figure 30.--Idealized flow to a buried drain.

Table 6.--*Water-level data from nested piezometers located near buried drains*

[--, not measured]

Local well number	Screened[1] interval	Water-level altitude, in feet above sea level					
		07-01-88	07-15-88	08-24-88	09-7-88	11-17-88	05-23-90
10N/29E-10N03	19.5 - 22.5	629.02	629.13	--	629.42	629.80	628.76
10N/29E-10N02	26 - 29	629.08	629.20	--	629.56	629.88	628.83
10N/29E-10N01	42 - 45	629.69	629.69	--	629.96	630.40	629.39
11N/29E-10C04	6 - 10	899.86	899.42	--	--	898.92	899.23
11N/29E-10C03	11 - 24	899.66	899.33	--	899.32	898.80	898.66
11N/29E-10C02	24 - 27	899.74	899.34	--	899.35	899.78	899.17
11N/29E-10C01	43 - 46	899.54	899.32	--	899.26	898.80	899.20
13N/28E-21J04	4 - 8	943.89	--	944.57	--	943.91	944.80
13N/28E-21J02	14 - 17	944.46	--	944.82	944.60	944.27	944.45
13N/28E-21J03	24 - 27	944.61	--	944.95	944.71	944.38	944.56
13N/28E-21J01	43 - 46	939.32	--	944.80	--	944.67	944.15

[1]In feet below land surface

Ground-Water Recharge

The ground-water system in the study area receives recharge from many sources. The natural sources are from deep percolation of precipitation, lateral inflow from adjacent areas, and infiltration from rivers. Man-made sources of ground-water recharge are deep percolation of applied irrigation water, seepage from canals, and artificial-recharge basins.

Precipitation Recharge

Because the study area has an arid to semiarid climate, ground-water recharge from deep percolation of precipitation under natural conditions is relatively small. A deep-percolation model, used in this study to estimate this recharge, was created for the Columbia Plateau as part of the Regional Aquifer-System Analysis Program of the U.S. Geological Survey (Bauer and Vaccaro, 1987). This model is based on daily precipitation and temperature records and includes the following recharge-related processes: snow accumulation and snow melt, interception of precipitation, surface runoff, evaporation from foliar cover, evaporation from unshaded bare soil, and plant transpiration. The model accounts for soil type, land use, plant growth stage, altitude, slope, and aspect. The deep-percolation model takes into account the above processes and factors and determines moisture excesses or deficits. The model computes soil-moisture budget on a daily basis, and if total soil-moisture exceeds the capacity of the soil, the excess water is assumed to be deep percolation.

The model was applied to the study area using a variable grid with cells ranging in size from 0.25 to 1.0 mi^2. Daily precipitation and temperature data for 1956-77 from all weather stations in the study area were used. The resulting calculated deep percolation rates (fig. 31) ranged from zero to 5 in/yr and averaged 0.45 in/yr. This calculated deep percolation rate is an average value for the period of record (1956-77). The major factors controlling deep percolation rates are land use and soil type. Generally, bare soils with low moisture-holding capacities yielded the greatest deep percolation rates. Calculated annual deep percolation from precipitation in the study area was 12,000 acre-ft for the non-irrigated areas and 28,000 acre-ft for the irrigated areas, yielding a total precipitation recharge of 40,000 acre-ft.

A time lag exists between deep percolation and actual ground-water recharge (when the deep percolation reaches the water table). This time lag may be tens or even hundreds of years where the water table is relatively deep. Pulses of deep percolation tend to approach a constant rate, the average pulse rate, at some depth (Bauer and Vaccaro, 1987). Therefore, the long-term average deep percolation rate is considered to be the best estimate of recharge for any particular year in the study area.

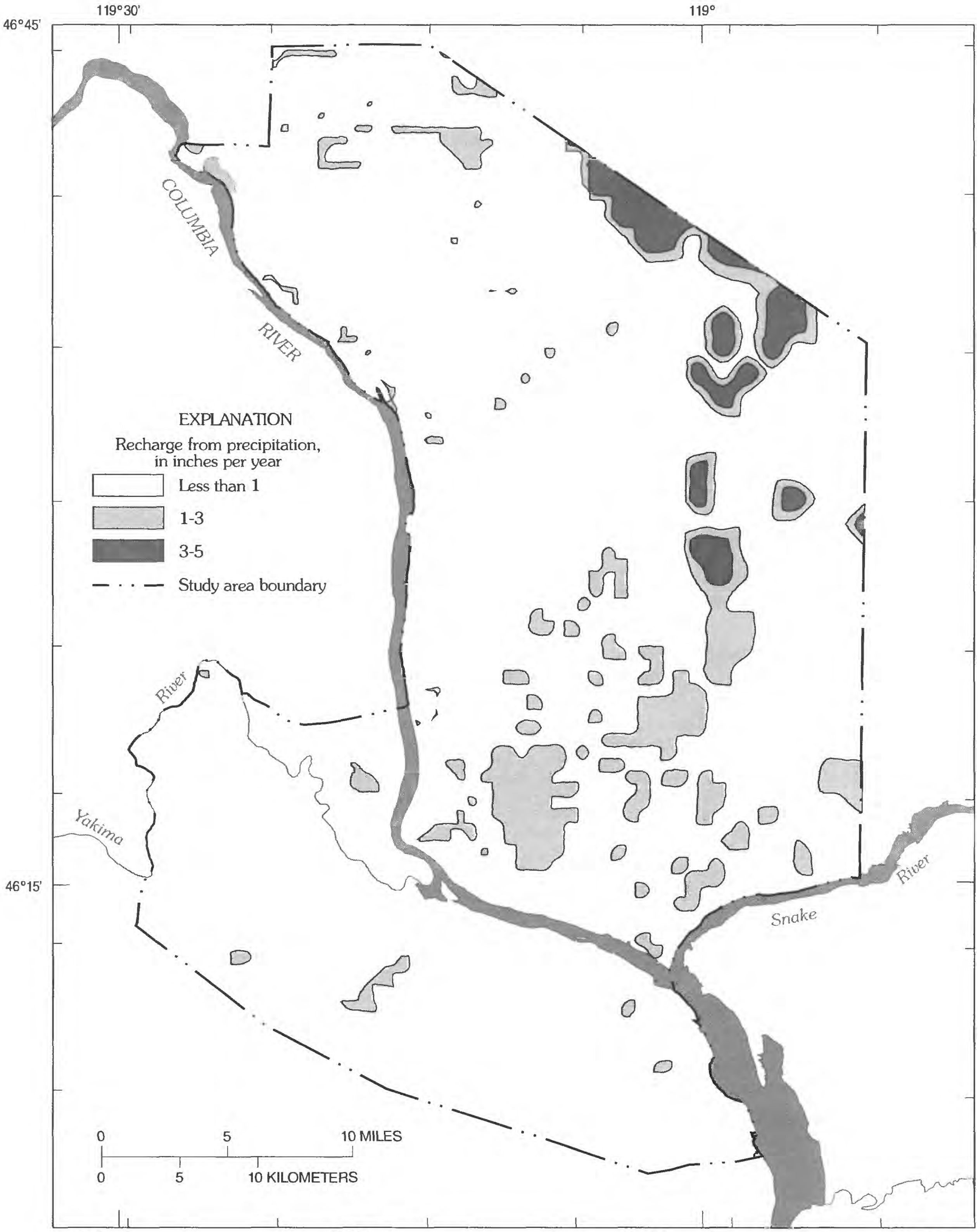


Figure 31.--Distribution of precipitation recharge.

River-Infiltration Recharge

Most of the river reaches in the study area are discharge areas for the ground-water system. However, several river reaches, such as parts of the Yakima River between Benton City and Richland and the Snake River near Ice Harbor Dam, act as recharge sources.

According to Brown (1979) and Lindberg and Bond (1979), the Yakima River downstream of Horn Rapids Dam serves as a recharge source, with water moving from the river through the shallow ground-water system to the southeast, through Richland and ultimately discharging to the Columbia River. Water-table contour maps by Brown (1979), Lindberg and Bond (1979), and this study (fig. 26) support this concept of recharge from the Yakima River. Ebbert and others, (1996) examined water-quality data and concluded that the ground water downgradient of the recharge area in question showed dissolved solids concentrations that were consistent with the Yakima River as a source. Brown (1979) also concluded that the Yakima River recharges the Saddle Mountains Basalt north of Benton City (near 10N/27E-32), where highly permeable sections of the basalt occur in the river bed. Although not conclusive, some evidence for this phenomenon can be seen in the 1986 water-level contours for the Saddle Mountains Basalt (fig. 27).

An estimate of river-infiltration recharge from the Yakima River can be made using Darcy's Law. Recharge from the river occurs as both horizontal flow (through the river bank) and vertical flow (through the river bed). Horizontal flow is calculated using horizontal hydraulic conductivity values, shoreline length, river depth, and horizontal hydraulic gradient values. Vertical flow is calculated using vertical hydraulic conductivity, shoreline length, one-half of river width (assuming symmetrical flow), and vertical hydraulic gradient.

Horizontal hydraulic conductivities can be taken from table 5 (median value for the Pasco gravels and the 75th percentile value for the Saddle Mountains Basalt). The 75th percentile is used for the Saddle Mountains Basalt because the basalt is believed to be highly permeable in this area (Brown, 1979). Vertical hydraulic conductivities are estimated as being one one-hundredth of the horizontal values. Using hydraulic gradients from figures 26 and 27, river widths from 7-1/2-minute topographic maps, and an estimated river depth of 5 ft, river-infiltration recharge of about 2,400 acre-ft/yr along a 9.2 mi reach of the Yakima River was estimated. This was calculated by dividing the recharging part of the river into five segments, each of which had the same geology, hydraulic gradient, and river width. The calculation also assumed that the hydraulic conductivity of the river bed and bank are not significantly different from the aquifer material, although the validity of this assumption is not proven.

Some recharge from the Snake River (Lake Sacajawea) apparently occurs immediately above Ice Harbor Dam. Water-table contours for 1986 (fig. 26) indicate that water flows from the Snake River into the shallow ground-water system of the study area. However, most of this recharge probably flows only a short distance through the ground-water system and then flows back to the Snake River downstream of Ice Harbor Dam.

Recharge occurs from Lake Wallula through the levees where the lake level is above the nearby land surface in the Kennewick, Finley, and Pasco areas. The water-table configuration (fig. 32) and water-quality data (Ebbert and others, 1996) indicate this recharge. However, most of this recharge is collected in the USACOE drain system and pumped back to Lake Wallula. Ignoring the river-infiltration recharge near Ice Harbor Dam and through the levees, the total river-infiltration recharge rate for the study area equals the estimated recharge from the Yakima River of 2,400 acre-ft/yr.

Applied-Irrigation Recharge

Some of the irrigation water applied to crops moves through the soil zone, becoming deep percolation and eventually recharging the ground-water system. To quantify this recharge source, it is necessary to know the area over which irrigation water is applied, the amount of irrigation water applied, and the percentage of this applied water that becomes deep percolation.

Irrigated areas in the study area were identified from aerial photographs. The photographs were 1:24,000-scale enlargements of 1:63,360-scale photography taken during the 1986 irrigation season by the Washinton State Department of Natural Resources. The parts of the study area that were irrigated during the 1986 irrigation season totaled 240,000 acres (fig. 33). The amount of irrigated acreage identified from aerial photographs is about 12 percent greater than that reported by the irrigation districts.

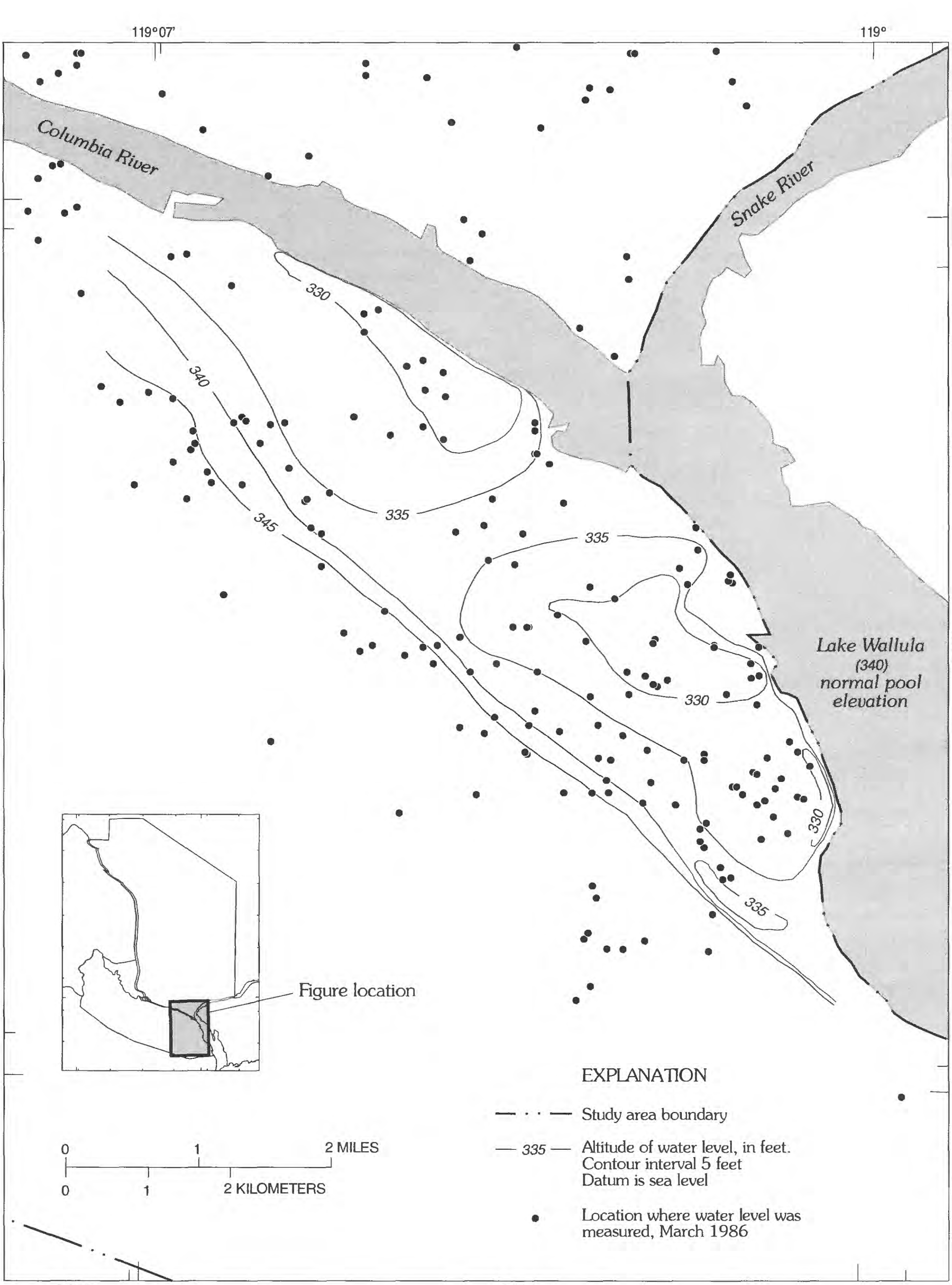


Figure 32.--Water-table altitude in the Kennewick-Finley area, March 1986.

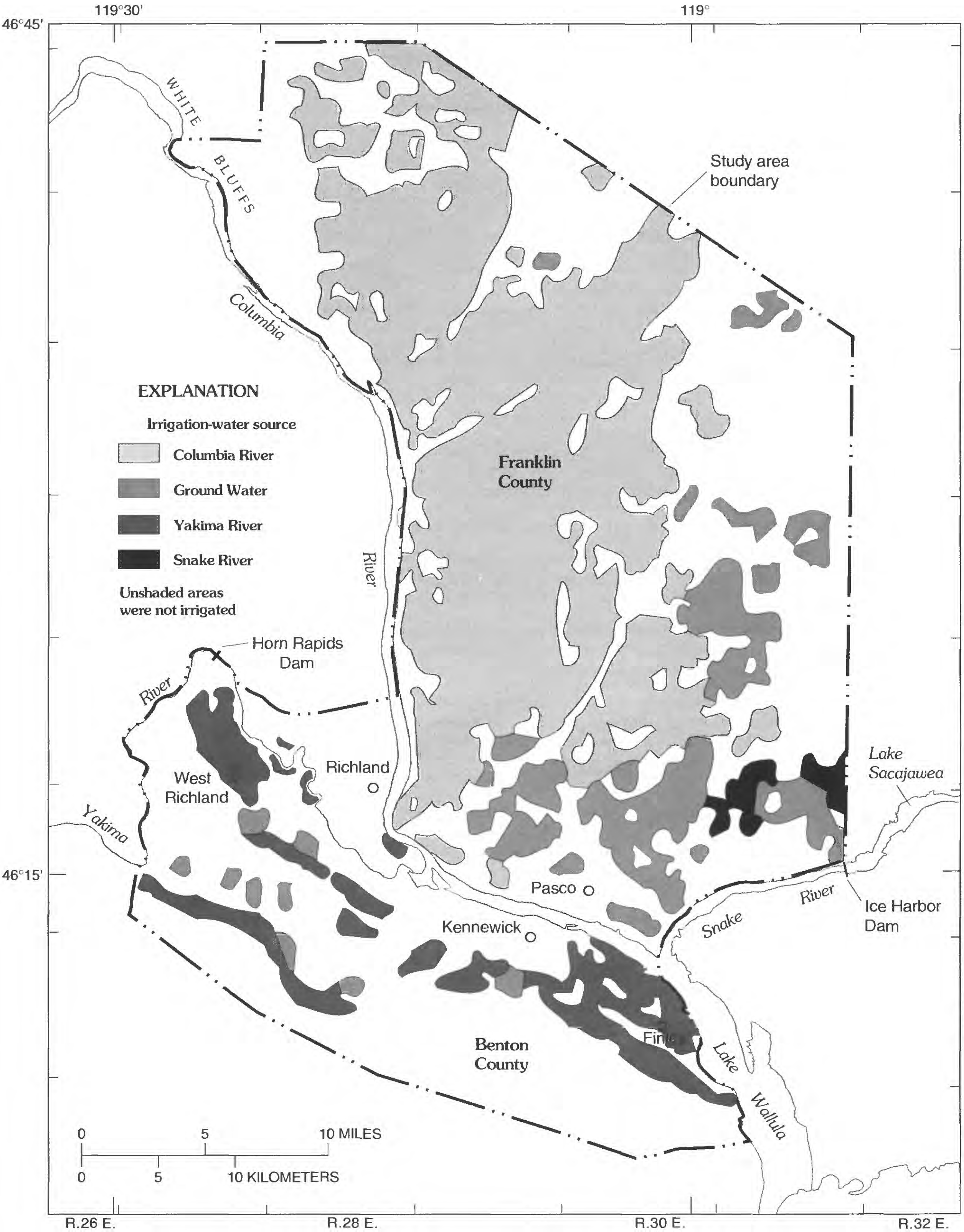


Figure 33.--Distribution and source of applied irrigation water during the 1986 irrigation season.

Estimates of applied irrigation water and the percentage of this applied water that becomes deep percolation were obtained from a study conducted by the Franklin Conservation District (FCD; John Holmes, written commun., 1987), in cooperation with the Benton Conservation District and Ecology.

In the FCD study, the study area was divided into three zones on the basis of similarities in climate and soil types (fig. 34). Application rates were determined in the FCD study by detailed field inventories of irrigation systems during the 1986 irrigation season. A representative sampling of irrigated acreage, obtained by random sampling, inventoried 7 percent of the total irrigated acreage. The field inventory included acreage irrigated, crop types, planting dates, dates of irrigation application, shutdown times, system hydraulics, and irrigation type. This information was used to determine the quantity and timing of each irrigation of each field throughout the irrigation season. Adjustments were made to account for runoff, wind drift, and evaporation of sprinkler-applied water before reaching the ground. The resulting application rates, therefore, are net rates: 41 in/yr in zone 1; 29 in/yr in zone 2; and 28 in/yr in zone 3.

These application rates are in general agreement with delivery rates calculated from irrigation system water budgets. Using the water budget information in table 3, delivery rates were calculated for each irrigation system for which delivery records are available (table 7). These delivery rates represent the total water delivered for irrigation. Net application rate equals the delivery rate minus the above-mentioned adjustments as well as other losses such as seepage and evaporation from irrigation ponds and other transmission losses from point of delivery to point of application.

The average rate of delivery to those irrigation districts with measured deliveries in zone 1 (as calculated from water-budget data) is 38 in/yr compared with the 41 in/yr of net application as calculated by the FCD method. There are several irrigation districts without measured deliveries in zone 1. These districts probably deliver greater amounts of water per acre than do those districts with measured deliveries (where consumers are charged by actual use rather than a flat fee per acre). Therefore, the average rate of delivery in zone 1 is probably greater than 38 in/yr.

The average rate of delivery in zones 2 and 3 (as calculated from SCBID water-budget data) is 35 in/yr (table 7). This compares with 28 to 29 in/yr of net application calculated by the FCD method.

The FCD study used U.S. Soil Conservation Service modeling techniques with local climate data and crop growth functions to determine crop water-use curves. Polynomial regression equations were developed for determining consumptive water use for each crop in each zone.

The difference between calculated net application and crop consumptive use was considered to be deep percolation. The resulting deep percolation (ground-water recharge) rates for zones 1, 2, and 3 were 7.9, 4.9, and 3.4 in/yr, respectively.

It was assumed that soil moisture was at maximum at the start of the irrigation season, from either winter precipitation or pre-irrigation (wetting of fields prior to planting); this assumption probably leads to slight overestimation of deep percolation. The areas of application (as determined from aerial photographs) and the rates of application of irrigation water (from the FCD study) were used to calculate the ground-water recharge from applied irrigation in the study area. The deep percolation rates for each zone (fig. 34) were used for the areas of applied irrigation (fig. 33), resulting in a calculated total groundwater recharge for the study area of 110,000 acre-ft/yr.

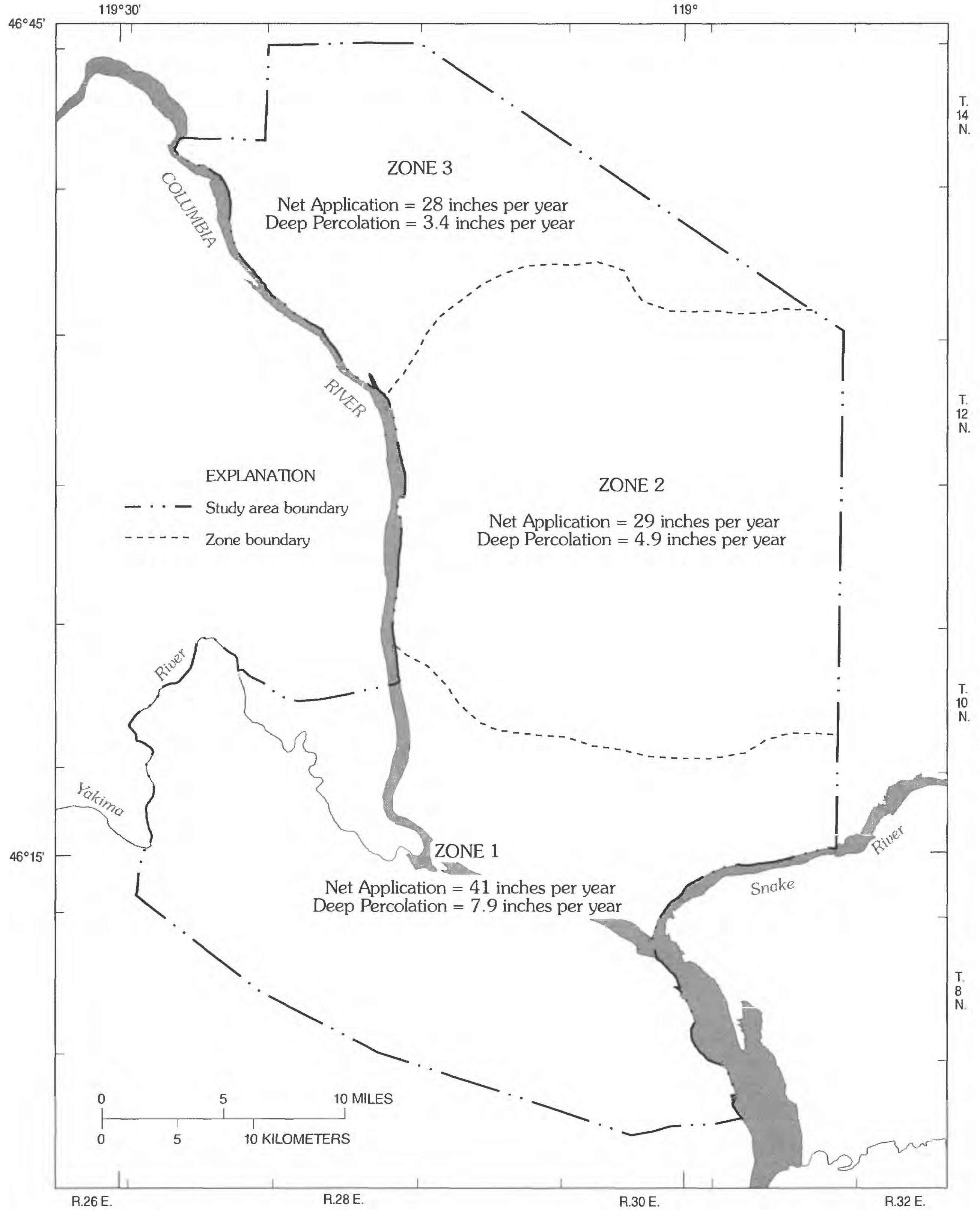


Figure 34.--Zones used in the Franklin Conservation District study of deep percolation of applied irrigation water during the 1986 irrigation season (John Holmes, Franklin Conservation District, written communication, 1987).

Table 7.--*Rates of delivery of irrigation water calculated from irrigation system water budgets*
[acre-ft/yr, acre feet per year; in/yr, inches per year]

Irrigation system[1]	Water delivered (acre-ft/yr)	Acres irrigated[2]	Delivery rate (in/yr)
	Zone 1		
Badger Mountain Irrigation District	2,500	720	42
Kennewick Irrigation District	52,000	17,000	37
McWhorter Canal system	[3]15,000	4,500	40
Zone 1 totals	69,500	22,220	38
	Zones 2 & 3		
South Columbia Basin Irrigation District	480,000	164,000	35

[1]Zones are from Franklin Conservation District (1989) (see figure 34).
[2]Used irrigated acres as identified from aerial photographs.
[3]Assumes all inflow to system is delivered to fields.

Canal-Seepage Recharge

The canal systems that distribute irrigation water in the study area are a source of ground-water recharge. Some of the water carried by the canals seeps through the canal beds. The rate of seepage depends on the nature of the geologic materials in and under the canal bed, the hydraulic gradient, and the cross-sectional area of seepage flow, as can be seen from the Darcy equation:

$$Q = k_z IA \quad , \qquad (2)$$

where

Q = rate of seepage (l^3/t),
k_z = effective hydraulic conductivity of the material in and under the canal bed (l/t),
I = hydraulic gradient (dimensionless),
A = cross-sectional area of seepage flow (l^2).

The value of k_z for any particular reach of canal reflects how the canal was constructed and maintained as well as the underlying natural geologic materials. Canals in the study area were constructed with no linings or with linings of plastic sheeting, concrete, or compacted earth. Maintenance of canals varies from almost none, allowing large buildups of fine-grained sediment along canal sides and bottoms (thus altering the original k_z), to annual reshaping of canal beds to remove sediment buildup. Underlying the canals are geologic materials from the Touchet Beds, Pasco gravels, upper Ringold Formation, and Saddle Mountains Basalt units.

The values of k_z also depend on the temperature of the water in the canal:

$$k_z = k\frac{\rho g}{\mu} \quad , \qquad (3)$$

where

k = hydraulic properties of the unconsolidated materials,
g = acceleration due to gravity,
ρ = fluid density,
μ = dynamic viscosity.

Because fluid density and dynamic viscosity are functions of temperature, variations in water temperature can affect the hydraulic conductivity of the canal bottom and therefore the rate of seepage. The range of water temperatures in the canal system during the irrigation season is probably between 5°C and 30°C. From equation (3), k_z at 5°C would be approximately one-half that at 30°C.

The water table under most canals is below the bottom of the canal. Therefore, flow beneath these canals is vertical, and the hydraulic gradient (I) is unity. In a few places in the study area, the water table is above the canal bottoms for part of the year. In these places, canal seepage decreases as the water table rises above the bottom of the canal. In rare instances, the water table will rise above the water level in the canal and ground water will discharge to the canal.

The cross-sectional area of seepage flow in a canal is referred to as the wetted perimeter (the bottom and parts of the sides of the canal that are below the water surface). Most canal systems are operated through a series of control structures so that the water levels in the canals are maintained relatively constant, regardless of the rate of flow in the canal. However, large buildups of aquatic vegetation can cause reductions in flow velocities, resulting in rises in water levels and increases in wetted perimeters. In those canals where vegetation is allowed to build up, there is a gradual increase in wetted perimeter over the course of the irrigation season.

Evidence of canal seepage can be seen in the cross sections and hydrographs on figures 35 and 36. These figures show the effect of canal seepage on the water table in two locations along the KID main canal in Badger Coulee. These are ideal locations to observe canal seepage because there are no other significant sources of ground-water recharge upgradient of the canal, and changes in the water table are therefore directly attributable to canal seepage. Changes in the water table near the canal closely follow the irrigation season, rising rapidly after the canal receives water in March and falling rapidly after the canal becomes dry in October. Changes in the water table are at a maximum near the canal and diminish with distance from the canal.

In order to estimate the amount of ground-water recharge from canal seepage in the study area, it is necessary to estimate seepage rates for over 1,300 mi of canals of various sizes (total wetted area of about 78 million ft^2, or about 1,800 acres) with various combinations of lining types and underlying hydrologic units. The approach used in this study was to measure seepage rates in a sufficient number of canals representing known combinations of factors so that relationships could be established among the factors and then applied to unmeasured canals.

Seepage rates were measured with two different methods: (1) inflow-outflow tests, in which the rate of flow in a canal was measured at two points and the decrease in flow rate between points was divided by the wetted surface to obtain the seepage rate; and (2) ponding tests, in which dams were placed at each end of a reach of canal and the rate of seepage (water-level drop) read from a staff gage.

The USGS conducted 35 inflow-outflow tests on 26 canal reaches at the end of the 1987 irrigation season. The results of these tests are shown in table 8. Seepage rates varied from 0.01 ft/d to as much as 1.3 ft/d (not including one canal with net ground-water inflow). The end of the irrigation season was chosen for the test period on the basis of practical considerations; it was the only period during which water was available in and not diverted from the canals.

The USGS conducted 31 ponding tests on five canal reaches in October 1987 and October 1988. Data were also obtained from 70 ponding tests conducted on four canal reaches by the SCBID as part of their maintenance operations in October 1987, and from 243 ponding tests conducted on 61 canal reaches by the Bureau of Reclamation from 1962-68. Seepage rates from ponding tests varied from 0.02 ft/d to 5.9 ft/d. Table 9 contains a summary of all the canal seepage tests.

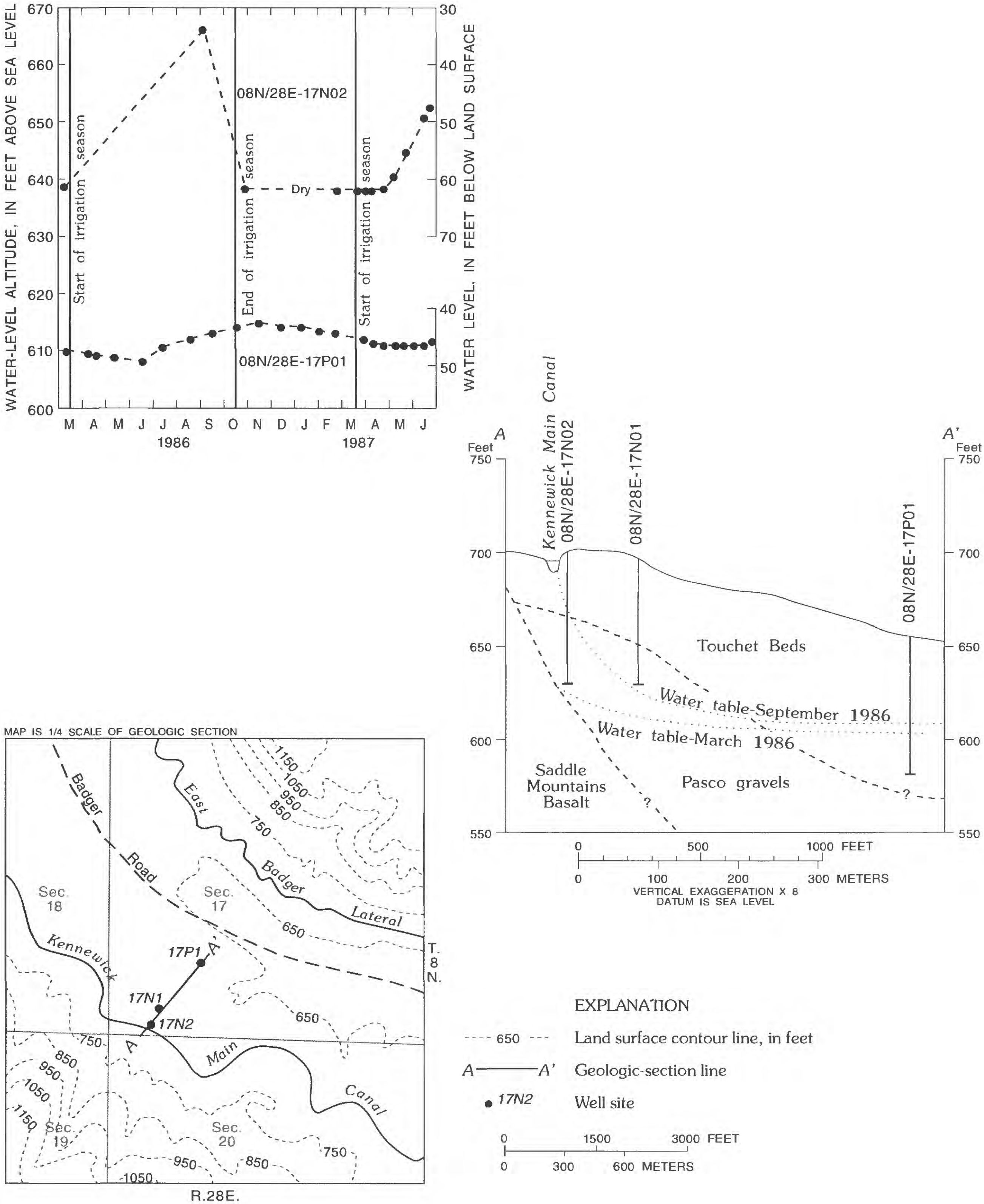


Figure 35.--Effect of canal seepage on the water table in central Badger Coulee, March 1986 through June 1987.

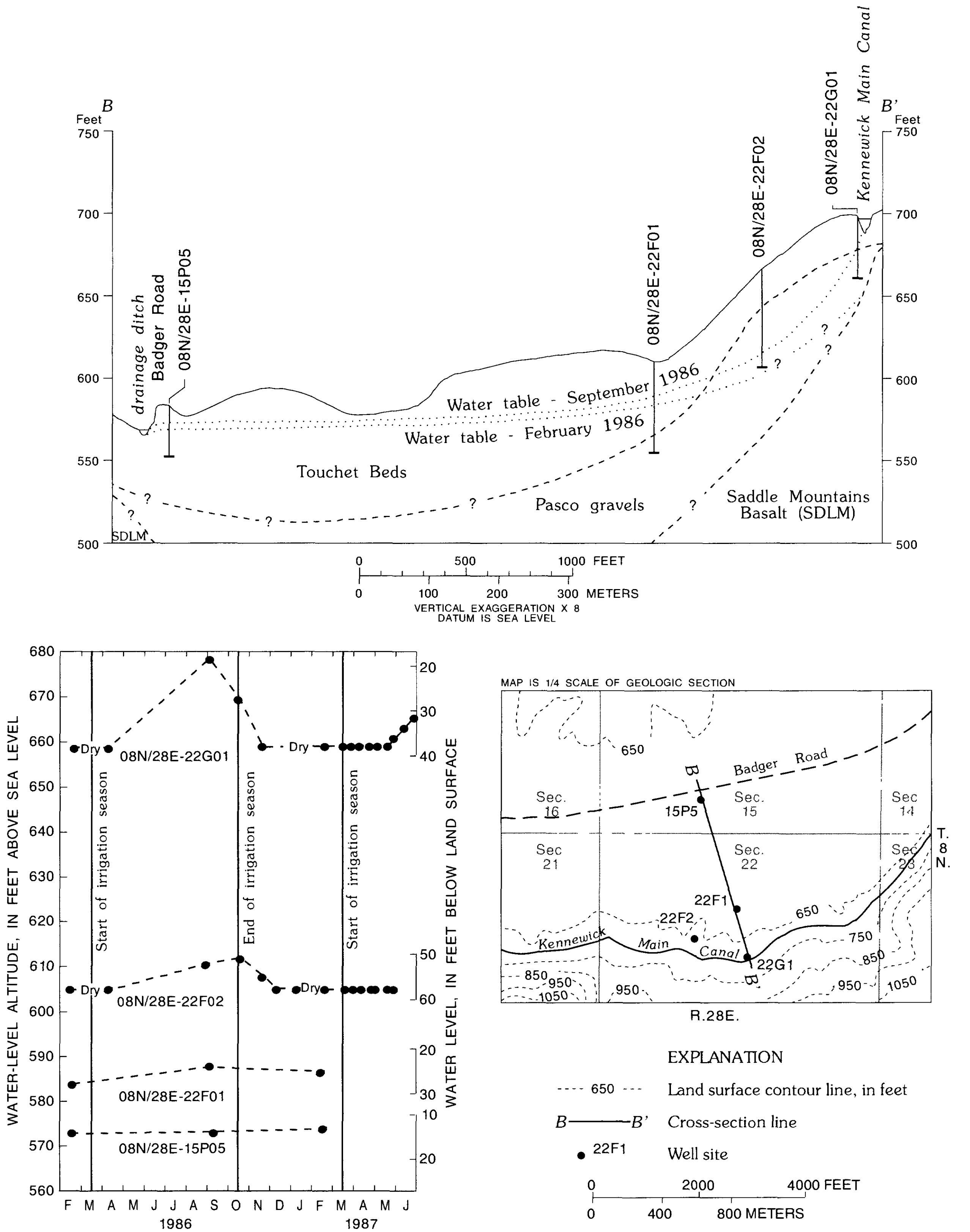


Figure 36.--Effect of canal seepage on the water table in eastern Badger Coulee, February 1986 through June 1987.

Table 8.--*Summary of U.S. Geological Survey canal-seepage tests by inflow-outflow method, October, 1987*

[ft^3/s; cubic foot per second; ft/d, cubic foot per day; E, compacted earth lining; C, concrete lining; P, PVC lining; U, unlined; DUNE, dune sand; TCHT, Touchet Beds; PSCO, Pasco gravels; UPRG, upper Ringold Formation; SDLM, Saddle Mountains Basalt]

Canal reach	Discharge (ft^3/s)[1] Up-stream	Discharge (ft^3/s)[1] Adjust-ment[2]	Discharge (ft^3/s)[1] Down-stream	Change in dis-charge[3] (ft^3/s)	Ave-rage wetted peri-meter (feet)	Length of reach (feet)	Canal lining type	Under-lying hydro-logic unit	Seepage rate (ft/d)
				Columbia Irrigation District					
Canal No. 1 #1	6.36	-0.07	5.21	-1.08	11.0	12,950	U[4]	PSCO	0.7
Canal No. 2 #1	23.2	-.08	22.1	-1.02	15.8	23,925	U+C[5]	PSCO	.2
				Kennewick Irrigation District					
Division 4 #1[6]	7.23	-.07	5.80	-1.36	18.7	26,300	U+C[7]	TCHT	.2
Division 4 #1[8]	7.14	-.07	5.95	-1.12	18.7	26,300	U+C[7]	TCHT	.2
Division 4 #2[6]	5.80	-.14	4.31	-1.35	18.8	25,650	U[9]	TCHT	.2
Division 4 #2[8]	5.95	-.14	4.29	-1.52	18.8	25,650	U[9]	TCHT	.3
Division 4 #3[6]	4.31	-.07	2.79	-1.45	13.4	24,050	U[10]	TCHT	.4
Division 4 #3[8]	4.29	-.07	2.78	-1.44	13.4	24,050	U[10]	TCHT	.4
East Badger #1	8.12	-.04	6.84	-1.24	11.0	24,800	U	TCHT	.4
East Badger #2	6.84	-.07	5.99	-.78	10.2	20,600	U[11]	TCHT	.3
East Badger #3	5.99	-.07	3.76	-2.16	8.8	25,600	U[12]	TCHT	.8
Main Canal #1+2[6]	113	-8.37	89.5	-15.13	33.	102,325	U+C[13]	TCHT+SDLM	.4
Main Canal #1[8]	112	-8.34	95.4	-8.26	33.	63,925	U+C	TCHT+SDLM	.3
Main Canal #2[8]	95.4	-.03	89.6	-5.77	32.	38,400	U+C	TCHT+SDLM	.4
				South Columbia Basin Irrigation District-Block 1					
PPL	7.79	-.18	7.57	-.04	7.8	13,102	C	PSCO	.3
				South Columbia Basin Irrigation District-Block 12					
PE35.8	7.70	-1.09	5.84	-.77	11.1	18,697	U[14]	SDLM	.3

Table 8.--*Summary of U.S. Geological Survey canal-seepage tests by inflow-outflow method, October, 1987--Continued*

Canal reach	Discharge (ft^3/s)[1] Up-stream	Adjust-ment[2]	Down-stream	Change in dis-charge (ft^3/s)[3]	Ave-rage wetted peri-meter (feet)	Length of reach (feet)	Canal lining type	Under-lying hydro-logic unit	Seepage rate (ft/d)
				South Columbia Basin Irrigation District-Block 13					
PE38.9 #1 [15]	8.98	-.48	7.15	-1.35	17.4	17,356	E+U	PSCO+SDLM	.4
PE38.9 #1 [16]	9.30	-.48	7.62	-1.20	17.6	16,956	E+U	PSCO+SDLM	.3
				South Columbia Basin Irrigation District-Block 15					
PE47J	7.58	-1.26	4.52	-1.80	12.9	37,000	U	UPRG	.3
				South Columbia Basin Irrigation District-Block 16					
EB8 #1	7.56	-.33	6.89	-.34	10.8	7,825	U[17]	SDLM	.3
EB8 #2	6.89	-.09	5.79	-1.01	8.2	8,425	U	PSCO	1.3
PE55[18]	9.39	-.83	7.39	-1.17	17.6	44,081	U	UPRG	.1
PE55[19]	11.3	-.83	8.22	-2.25	16.2	44,081	U	UPRG	.3
PE66 #1[16]	8.70	+.02	6.60	-2.12	17.4	21,487	U[20]	UPRG	.5
PE66 #1[21]	9.20	+.02	6.65	-2.57	17.6	21,487	U[20]	UPRG	.6
				South Columbia Basin Irrigation District-Block 17					
EBC	32.7	-.31	31.2	-1.19	17.4	47,808	E[22]	PSCO+UPRG	.1
EB15 #1	9.00	-.02	7.54	-1.44	12.0	23,375	E[23]	PSCO+DUNE	.4
				South Columbia Basin Irrigation District-Block 18					
EL85	13.7	-.12	12.0	-1.58	9.3	26,300	C+E+P+U	SDLM	.6

Table 8.--*Summary of U.S. Geological Survey canal-seepage tests by inflow-outflow method, October, 1987--Continued*

Canal reach	Discharge (ft^3/s)[1] Up-stream	Discharge (ft^3/s)[1] Adjust-ment[2]	Discharge (ft^3/s)[1] Down-stream	Change in dis-charge (ft^3/s)[3]	Ave-rage wetted peri-meter (feet)	Length of reach (feet)	Canal lining type	Under-lying hydro-logic unit	Seepage rate (ft/d)
				South Columbia Basin Irrigation District-Block 19					
PE41.2C #1	7.08	+.43	6.69	-.82	9.0	12,206	U+E[24]	UPRG+PSCO	.6
PE41.2C #2	6.69	+.02	6.97	+.26[25]	8.6	12,562	U+E	UPRG	+.2[25]
PE41.2D #1	6.44	-.01	5.72	-.71	6.2	10,521	C[26]	PSCO	.9
PE41.2D #2	5.72	-.02	5.00	-.70	6.0	11,011	C[26]	PSCO	.9
				South Columbia Basin Irrigation District-Block 20					
WB5G[27]									
				South Columbia Basin Irrigation District-Block 23					
WB10[21]	9.51	-.06	9.15	-.30	17.2	23,982	E	UPRG[28]	.06
WB10[18]	9.31	-.06	9.20	-.05	17.6	23,982	E	UPRG[28]	.01

[1]In most instances, the discharge at each site was measured two or more times. The discharge shown is the average of these measurements.

[2]The upstream discharge is adjusted for inflows and outflows that occur between sites. Inflows are generally drains or return flows to the canal, and outflows are leaks through turnout gates.

[3]Change in discharge is calculated by summing upstream discharge and adjustment and subtracting downstream discharge.

[4]Does not include 600 ft of concrete lining.

[5]Includes approximately 1,650 ft of badly broken concrete lining. Dense vegetative mat and heavy silting may have reduced leakage.

[6]Test of October 17, 1987.

[7]Does not include approximately 1,000 ft of PVC lining.

[8]Test of October 18, 1987.

[9]Does not include approximately 1,500 ft of siphons.

[10]Does not include approximately 1,350 ft of siphons.

Table 8.--*Summary of U.S. Geological Survey canal-seepage tests by inflow-outflow method, October, 1987--Continued*

Canal reach	Discharge (ft^3/s)[1] Up-stream	Discharge (ft^3/s)[1] Adjust-ment[2]	Discharge (ft^3/s)[1] Down-stream	Change in dis-charge (ft^3/s)[3]	Ave-rage wetted peri-meter (feet)	Length of reach (feet)	Canal lining type	Under-lying hydro-logic unit	Seepage rate (ft/d)

[11]Does not include approximately 1,000 ft of PVC lining nor approximately 700 ft of siphon.

[12]Does not include approximately 5,850 ft of PVC lining nor approximately 200 ft of siphons. Canal crosses numerous gullies in which canal was constructed in fill materials. These fill materials, or the possible occurrence of relatively highly permeable natural materials in the gullies, may be responsible for the relatively high leakage rate.

[13]Does not include approximately 6,600 ft of PVC lining.

[14]Does not include approximately 1700 ft of compacted earth lining and approximately 759 ft of concrete lining.

[15]Test of October 22, 1987.

[16]Test of October 23, 1987.

[17]There may be some clay lining.

[18]Test of October 25, 1987.

[19]Test of October 29,1987.

[20]Does not include approximately 843 ft of concrete chute and approximately 196 ft of concrete pipe.

[21]Test of October 24, 1987.

[22]Does not include approximately 2,000 ft of concrete lining.

[23]Does not include 50 ft of concrete lining.

[24]Does not include 254 ft of aqueduct nor approximately 200 ft of concrete lining.

[25]Canal receives net ground-water inflow.

[26]SCBID reports that concrete lining was poorly installed.

[27]Could not compute seepage; too many immeasurable inflow sources.

[28]May include (or be predominantly) loess.

Table 9.--*Summary of canal-seepage tests*

[ft^2; square foot; ft/d, foot per day; USGS, U.S.Geological Survey; Reclamation, Bureau of Reclamation; SCBID, South Columbia Basin Irrigation District; I, inflow-outflow tests; P, ponding tests; TCHT, Touchet Beds; PSCO, Pasco Gravels; UPRG, upper Ringold Formation; SDLM, Saddle Mountains Basalt; Y, value included in weighted average (table 11); N, value not included in weighted average (table 11); E, compacted earth lining; C, concrete lining; P, PVC lining; U, unlined]

Canal reach	Tests				Wetted area (ft^2)	Underlying hydrologic unit	Canal lining type	Average seepage rate (ft/d)
	Agency	Date	Type	Number				
				Columbia Irrigation District				
Canal No.1 #1	USGS	10-87	I	1	142,450	PSCO	U	0.7 Y
Canal No.2 #1	USGS	10-87	I	1	378,015	PSCO	U+C	.2 N
				Kennewick Irrigation District				
Division 4 #1	USGS	10-87	I	2	491,810	TCHT	U+C	.2 N
Division 4 #2	USGS	10-87	I	2	482,220	TCHT	U	.2 Y
Division 4 #3	USGS	10-87	I	2	322,270	TCHT	U	.4 Y
East Badger #1	USGS	10-87	I	1	272,800	TCHT	U	.4 Y
East Badger #2	USGS	10-87	I	1	210,120	TCHT	U	.3 Y
East Badger #3	USGS	10-87	I	1	225,280	TCHT	U	.8 Y
Main Canal #1+2	USGS	10-87	I	2	3,376,725	TCHT+SDLM	U+C	.4 N
				South Columbia Basin Irrigation District-Block 1				
PPL	USGS	10-87	I	1	102,196	PSCO	C	.03 N
PPL	USGS	10-88	I	1	145,450	PSCO	C	.07 Y
				South Columbia Basin Irrigation District-Block 11				
PE27 (64+04-238+55)	SCBID	10-87	P	31	87,435	UPRG	U	.6 Y
				South Columbia Basin Irrigation District-Block 12				
PE38.0(63+50-82+70)	SCBID	10-87	P	9	8,400	UPRG	U	.02[1] Y
PE35.8	USGS	10-87	I	1	207,537	SDLM	U	.3 Y
PE39 (21+00-26+00)	Reclamation	10-67	P	2	2,610	PSCO	U	1.0 Y
				South Columbia Basin Irrigation District-Block 13				
PE38.9	USGS	10-87	I	2	300,210	PSCO+SDLM	E+U	.4 N
PE38.9 (188+50-209+00)	Reclamation	11-65	P	2	48,002	SDLM	E	.5 Y
PE38.9P (00+37-06+80)	Reclamation	03-68	P	4	3,106	SDLM	E	.4 Y

Table 9.--*Summary of canal-seepage tests--Continued*

Canal reach	Tests: Agency	Tests: Date	Tests: Type	Tests: Number	Wetted area (ft^2)	Underlying hydrologic unit	Canal lining type	Average seepage rate (ft/d)	
				South Columbia Basin Irrigation District-Block 14					
PE38.9B (109+00-169+70)	Reclamation	10-63	P	4	93,435	UPRG	E	.1	Y
PE38.9B22 (01+15-15+38)	Reclamation	06-65	P	4	6,615	UPRG	U	5.9	Y
				South Columbia Basin Irrigation District-Block 15					
PE47 (01+62-136+84)	Reclamation	11-66	P	6	410,453	UPRG	U	0.3	Y
PE47AA (02+16-20+73)	Reclamation	10-67	P	4	13,184	UPRG	U	3.0	Y
PE47B (00+79-38+85)	Reclamation	11-67	P	10	39,306	UPRG	U	.7	Y
PE47J	USGS	10-87	I	1	477,300	UPRG	U	.3	Y
PE47J9 (0+41-54+25)	SCBID	10-87	P	6	53,840	UPRG	U	.4	Y
PE51 (32+30-71+70)	Reclamation	11-67	P	10	42,530	UPRG	U	.7	Y
PE51 (80+70-86+74)	Reclamation	11-67	P	1	3,889	UPRG	U	1.1	Y
PE51C (00+34-07+54)	Reclamation	11-65	P	2	3,650	UPRG	U	3.4	Y
PE64 (20+69-64+25)	Reclamation	11-65	P	5	44,333	UPRG	U	.3	Y
PE65 (41+45-70+50)	Reclamation	11-65	P	2	18,440	UPRG	U	.5	Y
PE65 (80+25-95+50)	Reclamation	11-68	P	3	13,092	UPRG	U	.3	Y
PE65B (00+66-06+70)	Reclamation	11-68	P	2	3,400	UPRG	U	.5	Y
				South Columbia Basin Irrigation District-Block 16					
EBC (254+03-287+03)	Reclamation	11-67	P	2	153,384	PSCO	U	.4	Y
EB8 #1	USGS	10-87	I	1	84,510	SDLM	U	.3	Y
EB8 #2	USGS	10-87	I	1	69,085	PSCO	U	1.3	Y
PCE (2490+00-2678+00)	Reclamation	11-65	P	4	860,369	UPRG	U	.3	Y
PE55	USGS	10-87	I	2	744,969	UPRG	U	.2	Y
PE55 (09+48-45+50)	Reclamation	11-65	P	2	76,608	UPRG	U	.4	N
PE55 (09+50-263+65)	SCBID	10-87	P	24	235,474	UPRG	U	.2	N
PE55D (15+11-42+04)	Reclamation	11-65	P	10	15,212	UPRG	U	.7	Y
PE59 (01+80-35+50)	Reclamation	11-65	P	6	38,576	UPRG	U	.9	Y
PE59.4	USGS	10-88	P	9	13,430	PSCO	U	.5	Y
PE59.4A (00+80-42+80)	Reclamation	11-65	P	5	43,890	UPRG	U	1.1	Y
PE59.4K (02+12-24+00)	Reclamation	11-65	P	1	17,219	PSCO	U	.4	Y
PE59.4K (24+42-45+90)	Reclamation	10-65	P	10	22,309	PSCO	U	.4	Y
PE66 #1	USGS	10-87	I	2	376,023	UPRG	U	.6	Y
				South Columbia Basin Irrigation District-Block 17					
EBC (850+50-1348+50)	USGS	10-87	I	2	831,859	PSCO+UPRG	E	.1	N
EBC (920+00-1012+40)	Reclamation	11-66	P	4	340,668	PSCO	E	.04[1]	Y
EB15 #1	USGS	10-87	I	1	280,500	PSCO[2]	E	.4	Y

Table 9.--*Summary of canal-seepage tests--Continued*

Canal reach	Tests				Wetted area (ft^2)	Underlying hydrologic unit	Canal lining type	Average seepage rate (ft/d)	
	Agency	Date	Type	Number					
	South Columbia Basin Irrigation District-Block 18								
EL85	USGS	10-87	I	1	244,590	SDLM	C+E+P+U	.6	N
EL85 (482+92-521+95)	Reclamation	10-65	P	2	131,692	UPRG	E+U	.08	N
EL85 (619+87-631+42)	Reclamation	11-65	P	2	26,058	UPRG	E	.1	Y
EL85 (632+38-676+50)	Reclamation	11-65	P	4	97,123	UPRG	U	0.3	Y
EL85BB (04+63-39+57)	Reclamation	10-65	P	4	49,591	UPRG	U	.3	Y
EL85FF (00+45-17+46)	Reclamation	10-65	P	5	10,547	UPRG+SDLM	U	.8	N
EL85JJ	USGS	10-88	P	4	9,000	SDLM	C	.1	Y
EL85JJ (109+07-128+23)	Reclamation	10-64	P	2	18,393	SDLM?	E+U	.3	N
EL85JJ (134+95-167+90)	Reclamation	10-64	P	14	32,094	SDLM?	U	.6	Y
EL85U (00+65-24+02)	Reclamation	10-64	P	4	25,965	UPRG	U	.3	Y
EL85X (23+86-29+85)	Reclamation	10-65	P	1	7,433	UPRG	E	.08	Y
EL85X (30+31-56+76)	Reclamation	10-65	P	6	21,995	UPRG	U	.3	Y
EL85X1 (01+24-14+27)	Reclamation	10-65	P	2	16,135	UPRG	E	.2	Y
EL85X1 (15+84-27+23)	Reclamation	10-65	P	3	8,056	SDLM?	U	.6	Y
	South Columbia Basin Irrigation District-Block 19								
PE41.2	USGS	10-88	P	7	7,200	SDLM	C	.3	Y
PE41.2 (79+45-98+10)	Reclamation	12-65	P	4	31,824	PSCO	C	.2	N
PE41.2 (79+46-104+80)	Reclamation	10-63	P	3	43,128	PSCO	C	.1	Y
PE41.2 (98+10-104+80)	Reclamation	12-68	P	7	11,591	PSCO	C	.4	N
PE41.2C #1	USGS	10-87	I	1	109,854	UPRG+PSCO	U+E	.6	N
PE41.2C #2	USGS	10-87	I	1	108,033	UPRG	U+E	+.2[3]	N
PE41.2C (183+57-253+30)	Reclamation	10-63	P	8	70,018	UPRG	U	.3	Y
PE41.2D #1	USGS	10-87	I	1	65,230	PSCO	C	.9	Y
PE41.2D #2	USGS	10-87	I	1	66,066	PSCO	C	.9	Y
PE46.2 (99+05-110+23)	Reclamation	11-65	P	2	18,066	UPRG	U	.4	Y
	South Columbia Basin Irrigation District-Block 20								
WB5 (246+25-260+75)	Reclamation	11-65	P	1	41,716	UPRG[4]	E	.02	Y
WB5 (260+75-279+50)	Reclamation	11-65	P	2	53,540	UPRG[4]	U	.3	Y
WB5 (281+55-303+89)	Reclamation	11-66	P	2	58,173	UPRG[4]	E	.03	Y
WB5 (305+10-351+19)	Reclamation	11-65	P	4	87,993	UPRG[4]	U	.8	N
WB5G (339+50-383+55)	Reclamation	12-63	P	3	69,828	UPRG	U	.6	Y
WB5G (383+82-428+95)	Reclamation	11-66	P	6	62,304	UPRG	U	.6	Y
WB5G5 (00+30-20+55)	Reclamation	11-65	P	6	15,636	UPRG	U	1.1	Y
WB5H (10+90-24+75)	Reclamation	11-66	P	4	11,680	UPRG	U	.6	Y
WB5H (25+37-30+00)	Reclamation	11-66	P	3	3,289	UPRG	E	.3	Y
WB5H (30+00-35+00)	Reclamation	11-66	P	2	3,520	UPRG[4]	U	1.2	N
WB5H (35+00-44+00)	Reclamation	11-66	P	4	5,996	UPRG[4]	E	.7	N
WB5H (44+00-52+77)	Reclamation	11-66	P	2	6,202	UPRG[4]	U	1.7	N

Table 9.--*Summary of canal-seepage tests--Continued*

Canal reach	Tests: Agency	Tests: Date	Tests: Type	Tests: Number	Wetted area (ft²)	Underlying hydrologic unit	Canal lining type	Average seepage rate (ft/d)
South Columbia Basin Irrigation District-Block 20--Continued								
WB5J (00+61-39+50)	Reclamation	11-66	P	4	54,889	UPRG[4]	U	.9 N
WB5J (00+61-72+55)	Reclamation	11-63	P	3	104,647	UPRG[4]	U	.5 N
WB5J1 (00+00-08+27)	Reclamation	11-65	P	2	5,947	UPRG[4]	U	.5 N
WB5K	USGS	10-88	P	6	61,866	UPRG[4]	E	.05 Y
WB5K (00+61-50+25)	Reclamation	11-65	P	2	59,440	UPRG[4]	E	.1 N
WB5L (00+00-18+35)	Reclamation	11-65	P	1	12,012	UPRG	E	.09 Y
WBC (333+50-479+50)	Reclamation	10-65	P	2	1,046,525	TCHT	U	.4 Y
South Columbia Basin Irrigation District-Block 23								
WB10	USGS	10-87	I	2	417,286	UPRG[4]	E	.04 Y
WB10B	USGS	10-88	P	5	9,788	UPRG[4]	E	.3 N
South Columbia Basin Irrigation District-Block 201								
WB10A (120+07-179+40)	Reclamation	10-67	P	5	108,807	UPRG[4]	U	.4 Y
WB10A (208+90-234+15)	Reclamation	10-64	P	7	58,318	UPRG[4]	U	.4 Y

[1]Possibly affected by ground-water inflow to canal.

[2]Includes about 9 percent dune sand.

[3]Positive seepage; net ground-water flow into canal.

[4]May include (or be predominantly) loess.

The canal seepage rates from table 9 were used to calculate weighted averages (based on the wetted area represented by each test) for each underlying hydrologic unit and canal lining type. Only those tests representing a single underlying hydrologic unit and a single canal lining type were used. Where several tests included overlapping canal reaches, the test representing the largest wetted area was used. Table 10 contains the weighted averages of canal-seepage rates.

There is one unexpected result in the weighted averages. The weighted average seepage rate for canals with compacted earth linings in the Saddle Mountains Basalt is greater than the value for unlined canals in the same unit. This may be due to the small number of tests available or it may actually reflect reasonable average values. Seepage rates in canals over basalt can be expected to vary widely, depending on the nature of the basalt. If a canal is cut into a basalt flow top or a highly fractured zone, or construction of the canal resulted in significant fracturing of the basalt, then the seepage rate presumably would be much greater than in a canal cut into a basalt flow interior or a poorly fractured zone. In the study area, those canals over basalt that have compacted earth linings (less than 1 percent of the total canal wetted area in the study area; see table 11) are the canals beneath which the basalt was presumed to be most permeable. Therefore, the compacted earth linings may have reduced seepage rates from extremely high values to values that are still in excess of the average for unlined canals over basalt.

To estimate total canal seepage in the study area, canal wetted perimeters, lining types, underlying hydrologic units, and seepage rates for the entire network of canals in the study area are required (fig. 37). Data on canal wetted perimeters and lining types were obtained largely from the files of the irrigation districts. These data were then overlain on a map of surficial geology (fig. 12). The areas represented by each underlying hydrologic unit and canal lining type are shown in table 11. The total wetted area of canals in the study area is nearly 1,800 acres.

There are some combinations of underlying hydrologic unit and canal lining type that were not tested and therefore do not match the seepage rates in table 10. However, these untested combinations account for only 8 percent of the total canal wetted area. A complete matrix of canal seepage rates for each type of underlying hydrogeologic unit and canal lining type (including estimates for untested combinations) is shown in table 12.

The appropriate rate of seepage was assigned to each canal reach on the basis of the actual seepage tests on each reach or on the matrix in table 12. This resulted in total canal seepage of 170,000 acre-ft/yr in the study area. The above calculated canal seepage compares favorably with the irrigation system water budgets shown in table 3. For the two largest irrigation systems in the study area, information was available to calculate complete water budgets. The KID and SCBID water budgets include a value for losses. This value includes canal seepage and evapotranspiration from canals. The calculated water budgets losses are 20,000 and 130,000 acre-ft/yr (KID and SCBID, respectively) compared with calculated canal seepages of 17,000 and 140,000 acre-ft/yr. Table 13 shows the calculated canal seepages for each irrigation district.

The canals identified on figure 37 and used to calculate total canal seepage are all those canals where the water table is known to be below the bottom of the canal and therefore where the hydraulic gradient is unity. All canal reaches where the water table may be above the canal bottom (a relatively small part of the total canal system) were removed from consideration for the seepage calculation. This may underestimate the total canal seepage.

Table 10.--*Weighted averages of canal-seepage tests by type of underlying hydrologic unit and type of canal lining*

[ft, foot; ft², square foot; ft/d, foot per day]

	Canal lining type					
	Unlined		Concrete		Compacted earth	
Underlying hydrologic unit	Wetted area (ft²)	Seepage rate (ft/d)	Wetted area (ft²)	Seepage rate (ft/d)	Wetted area (ft²)	Seepage rate (ft/d)
Touchet Beds	1,046,525	0.4				
	482,220	.2				
	322,270	.4				
	272,800	.4				
	225,280	.8				
	210,120	.3				
	Weighted average	.4				
Pasco gravels	153,384	.4	145,450	0.07	340,668	0.04
	142,450	.7	66,066	.9	280,500	.4
	69,085	1.3	65,230	.9		
	22,309	.4	43,128	.1		
	17,219	.4			Weighted average	.2
	13,430	.5				
	2,610	1.0	Weighted average	.4		
	Weighted average	.7				
upper Ringold Formation	860,369	.3	417,286	.04		
	744,969	.2	93,435	.1		
	477,300	.3	61,866	.05		
	410,453	.3	58,173	.03		
	376,023	.6	41,716	.02		
	108,807	.4	26,058	.1		
	97,123	.3	16,135	.2		
	87,435	.6	12,012	.09		
	70,018	.3	7,433	.08		
	69,828	.6	3,289	.3		
	62,304	.6				
	58,318	.4				
	53,840	.4	Weighted average	.05		
	53,540	.3				
	49,591	.3				

Table 10.--*Weighted averages of canal-seepage tests by type of underlying hydrologic unit and type of canal lining--Cont.*

Underlying hydrologic unit	Canal lining type: Unlined, Wetted Area (ft^2)	Unlined, Seepage Rate (ft/d)	Concrete, Wetted Area (ft^2)	Concrete, Seepage Rate (ft/d)	Compacted earth, Wetted Area (ft^2)	Compacted earth, Seepage rate (ft/d)
upper Ringold Formation (Continued)	44,333	.3				
	43,890	1.1				
	42,530	.7				
	39,306	.7				
	38,576	.9				
	25,965	.3				
	21,995	.3				
	18,440	.5				
	18,066	.4				
	15,636	1.1				
	15,212	.7				
	13,184	3.0				
	13,092	.3				
	11,680	.6				
	8,400	.02				
	6,615	5.9				
	3,889	1.1				
	3,650	3.4				
	3,400	.5				
	Weighted average	.4				
Saddle Mountains Basalt	207,537	.3	9,000	.1	48,002	.5
	84,510	.3	7,200	.3	3,106	.4
	32,094	.6	Weighted average	.2	Weighted average	.5
	8,056	.6				
	Weighted average	.3				

Table 11.--*Total wetted area of canals for each underlying hydrologic unit and canal lining type*

Underlying hydrologic unit	Wetted area (acres) — Canal lining type: Unlined	Concrete	Compacted earth	PVC	Other	Total
Touchet Beds	365	23	<1	8	0	396
Pasco gravels	252	189	44	0	23	508
upper Ringold Formation	530	50	123	0	20	723
Saddle Mountains Basalt	81	36	14	1	22	154
Totals	1,228	298	181	9	65	1,781

Table 12.--*Matrix of canal-seepage rates for types of underlying hydrologic units and canal linings*

[ft/d, foot per day; --, no occurrences]

Underlying hydrologic unit	Canal-seepage rates (ft/d) — Canal lining type: Unlined	Concrete	Compacted earth	PVC	Other
Touchet Beds	0.4	[1]0.2	[2]0.05	[3]0.007	--
Pasco gravels	.7	.4	.2	--	[4].4
upper Ringold Formation	.4	[1].2	.05	--	[4].2
Saddle Mountains Basalt	.3	.2	.5	[3].007	[4].2

[1]Assumed concrete lining reduced unlined rate by factor of 2.

[2]Assumed same rate as for upper Ringold Formation with compacted earth lining.

[3]Used rate from test in PVC-lined canal by Weimer (1987).

[4]Other includes miscellaneous lining types, generally variations on standard concrete. Assumed same rate as for concrete lining.

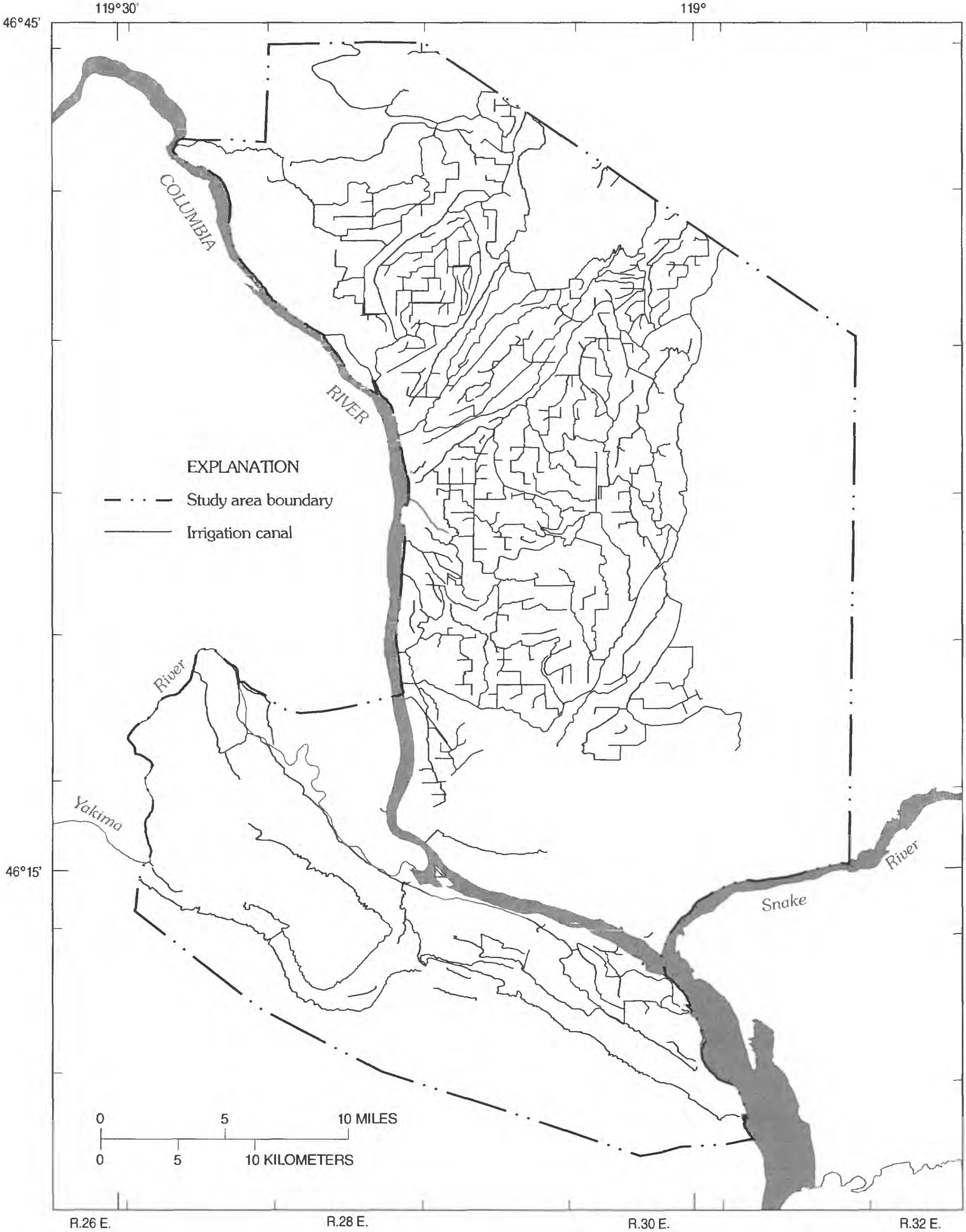


Figure 37.--Network of irrigation canals in the study area.

Table 13.--*Calculated canal seepage in irrigation districts, 1986*

[acre-ft/yr, acre foot per year; all values rounded to two significant figures]

Irrigation district	Calculated canal seepage, 1986 (acre-ft/yr)
Columbia Irrigation District	10,000
Horn Rapids Ditch system	1,700
Kennewick Irrigation District	17,000
McWhorter Canal system	940
Franklin County Irrigation District	870
South Columbia Basin Irrigation District	140,000
Total	170,000

Artificial-Recharge Basins

During the period 1943-63, the City of Richland's water supply was based on a system of artificial-recharge basins surrounded by wells. The system diverted water from the Yakima River to four recharge basins where the water seeped into the ground and was then pumped back out by shallow wells. In 1963, a water filtration plant was constructed on the Columbia River. From 1963 through 1988, the filtration plant was operated during March through December of each year and shut down for maintenance during January and February. During the shut-down period, the North Richland well field and artificial-recharge basin were used, and the other three recharge basins remained inoperative. Since 1988, the filtration plant has been used year round, with the North Richland well field and artificial-recharge basin used only as a back-up system.

An estimate of recharge from the North Richland Basin for the period March 1986 through February 1987 was obtained from City of Richland records (Scott Meyers, City of Richland, oral commun., 1989). Pumping records indicated that 2,618,600,000 gal (8,000 acre-ft) of water were pumped into the recharge basin. It was assumed that all of this water became ground-water recharge as there is essentially no evaporation during January and February.

Ground-Water Discharge

The ground-water system in the study area discharges its waters in five ways: to rivers, to springs and seepage faces, to evapotranspiration, to drains, and to wells. Discharge to rivers was the only significant ground-water discharge prior to development of the area's water resources.

Discharge to Rivers

The Columbia and lower Snake Rivers act as the ultimate ground-water discharge areas for most of the study area. The water table slopes directly toward the Columbia and lower Snake Rivers (fig. 26), indicating that these rivers are discharge locations. The deeper ground-water system (which is primarily in the basalt units) also discharges to the rivers, as can be seen from the water-level contours on figures 27 and 28. A water-level map for the Grande Ronde Basalt (Bauer and others, 1985) also indicates that ground water discharges to the rivers. The mean flows of the Columbia and lower Snake Rivers are more than 100,000 ft^3/s (72 million acre-ft/yr) and 50,000 ft^3/s (36 million acre-ft/yr), respectively (Williams and Pearson, 1985). Because ground-water discharge to the rivers is probably 100 ft^3/s (72,000 acre-ft/yr) or less, it is not possible to measure ground-water discharge by identifying downstream increases in river flow. Also, the rivers are in backwater conditions behind McNary Dam, further complicating any possible measurements of river flow. The operation of McNary Dam maintains a water-level altitude of about 335 to 340 ft in Lake Wallula (U.S. Army Corps. of Engineers, 1985); this is the base level of the ground-water flow system in most of the study area.

Estimates of ground-water discharge to rivers can be made using Darcy's Law as applied in the section on river-infiltration recharge. Median horizontal hydraulic conductivity values can be taken from table 5, and vertical hydraulic conductivities can be estimated as one one-hundredth of the lateral values (except for the Touchet Beds and Upper Ringold Formation, for which a value of 0.4 ft/d is a better estimate; see section on vertical hydraulic conductivity). Using hydraulic gradients from figures 26 and 27, river widths from 7-1/2--minute topographic maps, and estimated river depths from U.S. Army Corps. of Engineers (1977), ground-water discharge to rivers was estimated at about 63,000 acre-ft/yr along about 50 mi of the Columbia, Snake, and Yakima Rivers. This calculation was accomplished by dividing the discharging parts of the rivers into segments, each of which had constant geology, hydraulic gradient, river width, and river depth. The calculation also assumed that the hydraulic conductivity of the river beds and banks are not significantly different from the aquifer materials, although the validity of this assumption is not proven.

Discharge to Springs and Seepage Faces

One of the most obvious forms of ground-water discharge in the study area is springs and seepage faces, primarily along the White Bluffs of the Columbia River (fig. 38). Discharges along the White Bluffs range from slow seepage to impressive springs. Table 14 lists the measured discharges along the White Bluffs. Total measured discharge from the White Bluffs is about 68 ft^3/s (49,000 acre-ft/yr). This probably represents most, but not all, of the measurable discharge from the White Bluffs. There may be significant ground-water discharge through the jumbled materials in several landslides, which is not observable at land surface.

The seasonal nature of ground-water discharge from the White Bluffs can be seen on figure 39, which shows daily mean discharges in the vicinity of Ringold Springs for the period April 1986 through April 1987. The discharge from the Ringold Springs area reached a high of 99 ft^3/s in August 1986 and a low of 36 ft^3/s in March 1987.

There are large areas of the White Bluffs where ground-water seepage is slow and the major mechanism of discharge is actually evapotranspiration from these seepage faces. An estimate of ground-water evapotranspiration from the White Bluffs is possible if the assumption is made that the rate of ground-water evapotranspiration is equal to the difference between potential evapotranspiration and actual evapotranspiration. This difference is about 20 in/yr for the study area (Phillips, 1970). The area of ground-water evapotranspiration along the White Bluffs shown on figure 40 is about 3,000 acres. Multiplying the ground-water evapotranspiration rate by the area estimates ground-water evapotranspiration at 5,000 acre-ft/yr.

Table 14.--*Measured discharges from springs and seepage faces along the White Bluffs*
[ft^3/s, cubic feet per second]

Spring or seepage areas (map number, fig. 38)	Approximate mean annual discharge (ft^3/s)	Period of record	Remarks	Data source
Savage Island landslide (1)	0.7	4-83	Estimated flow from 330-acre area	Schuster and Hays (1984)
WB5 Wasteway springs[1] (2)	1.2	3-86 to 4-87	Collection of many springs	Drost and others (1989b)
Ringold Springs[2] (3)	64	4-86 to 3-87	Collection of many springs	Drost and others (1989b)
Baxter Springs (4)	1.3	3-86 to 2-87	Collection of springs	Drost and others (1989b)
Rankin Springs (5)	.4	3-86 to 2-87	Collection of springs	Drost and others (1989b)
Block 15 landslide (6)	.5	9-87 to 8-88	From 6,600 feet of bluff	Marratt (1988)

[1]Springs discharging to WB5 Wasteway. Estimated flow; based on difference between flow at U.S. Geological Survey Station no. 12473502 and Miscellaneous Site-2.

[2]Includes springflow gaged at Ringold Springs (U.S. Geological Survey Station no. 12473504) plus springflow to PE16.4 Wasteway (difference between flows gaged at U.S. Geological Survey Station no. 12473508 and Miscellaneous Site 3).

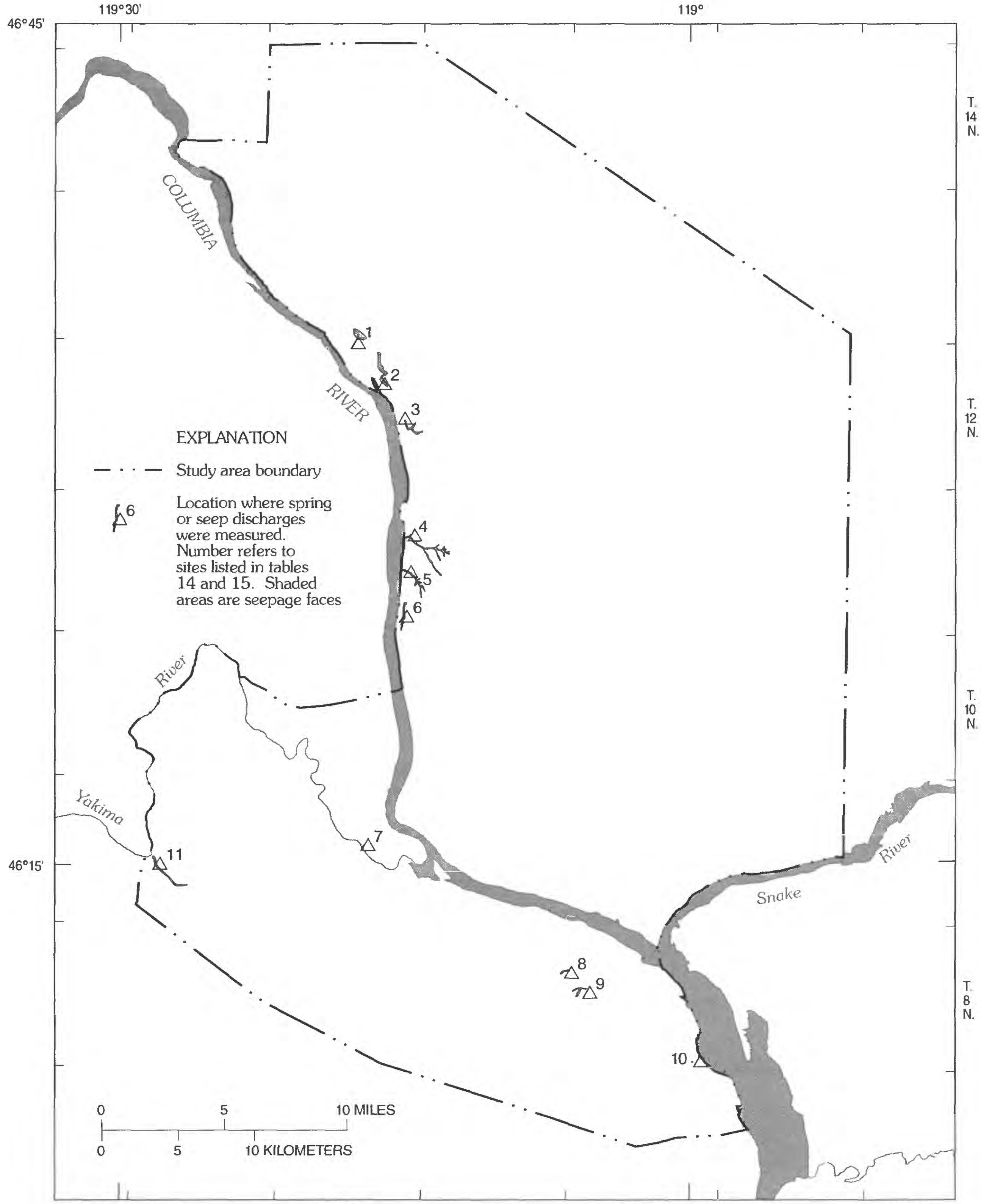


Figure 38.--Locations where discharges have been measured from springs or seepage faces.

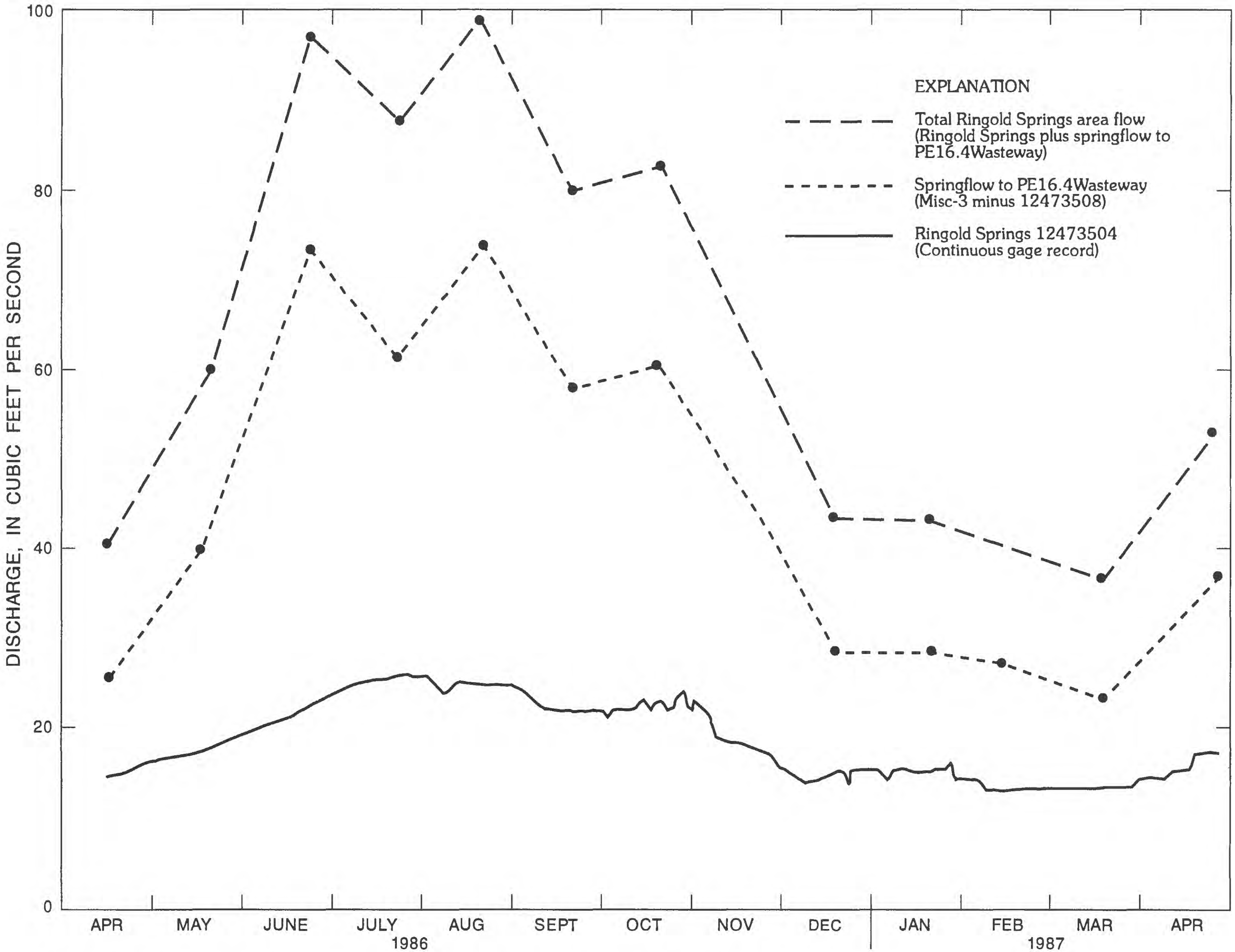


Figure 39.--Ground-water discharges in the vicinity of Ringold Springs, April 1986 through April 1987.

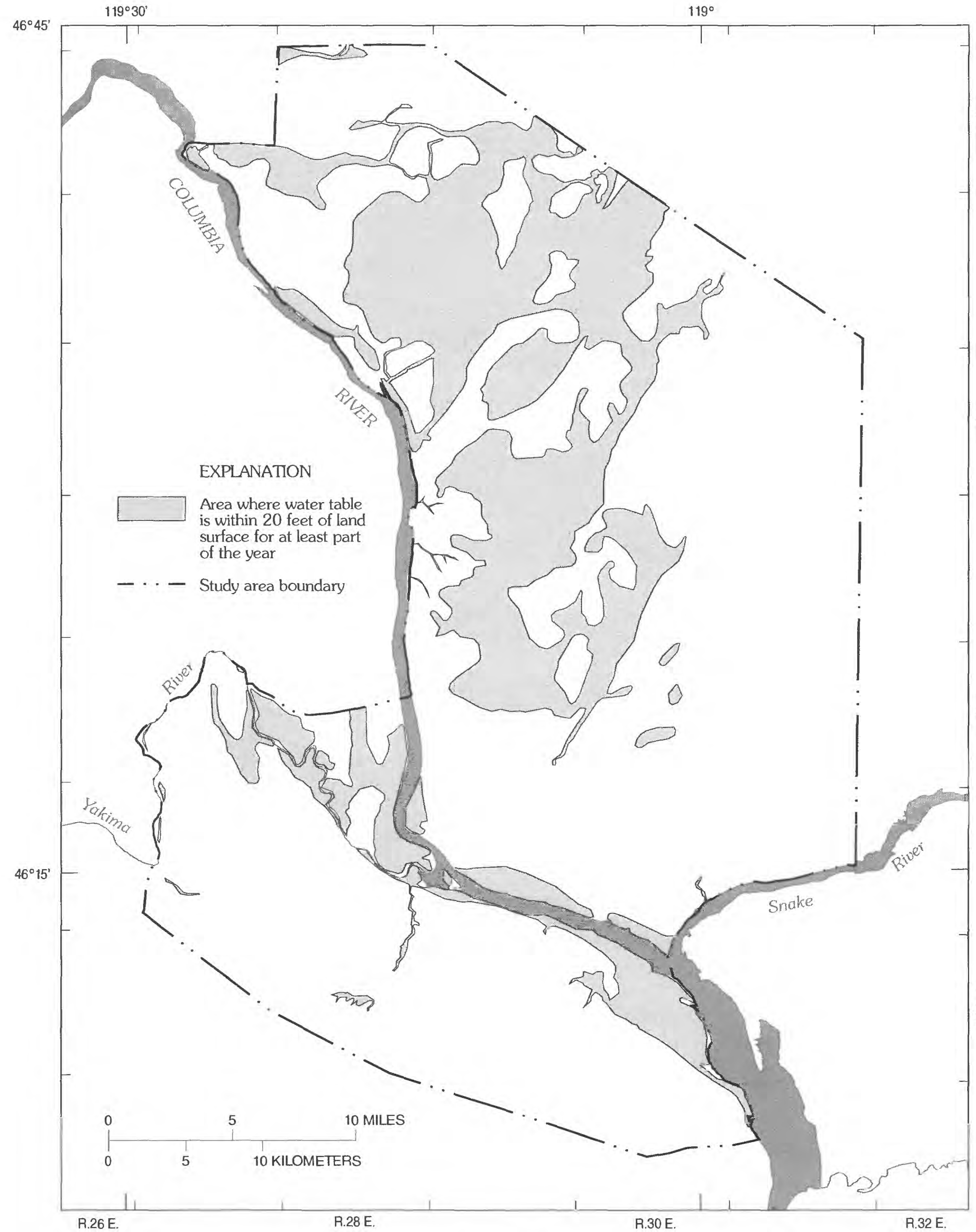


Figure 40.--Occurence of shallow ground water in the study area as of 1986.

Ground-water discharge from the White Bluffs has been identified as the major cause of the landslides that started in the late 1960s and early 1970s (Schuster and Hays, 1984; Marratt, 1988; and Bureau of Reclamation, 1976). The only significant springflows in the Franklin County part of the study area are from the White Bluffs.

The only other significant springflows in the study area are in Benton County, along the slopes south of Kennewick, along Interstate 182 near Richland, and at the west end of Badger Coulee (fig. 38). Springs with measured discharges are listed in table 15. All discharges in the table are from measurements taken during March 1986 to February 1987 (Drost and others, 1989b). The mean annual discharges are based on monthly measurements, except for that at the end of CID no. 3 Canal, which is based on continuous-stage records.

Most of the springflows along the slopes south of Kennewick discharge to CID no. 3 Canal. As can be seen in the discharge record for the end of the canal (Drost and others, 1989b), there is a non-irrigation season flow of about 4 ft^3/s (2,900 acre-ft/yr). This flow is essentially all springflow. The two tributaries to CID no. 3 Canal listed in table 15 represent part of this springflow.

The total of the measured ground-water discharges in table 15 is about 5.5 ft^3/s (4,000 acre-ft/yr) (the tributaries to Canal no. 3 are included in the 4.0 ft^3/s at the end of the canal). This probably represents most of the springflow in the Benton County part of the study area. Additional unmeasured springflows occur in Zintel Canyon (south of Kennewick), which discharge to Zintel Canyon Wasteway. Numerous other presumably insignificant springflows occur, including some that issue from the ground, travel short distances downslope, and re-enter the ground.

The total measured ground-water discharge through springs and seepage faces in the study area is about 73.5 ft^3/s (53,000 acre-ft/yr). Combining this discharge with the estimated ground-water evapotranspiration from the White Bluffs yields a total spring and seepage-face discharge of about 58,000 acre-ft/yr. This probably represents most of the spring and seepage-face discharge in the study area.

Discharge as Evapotranspiration

Ground-water evapotranspiration can take place in areas where the water table is shallow enough to be reached by plant roots. As can be seen on figure 40, there are large areas where the water table is shallow. Most of these shallow water-table areas are beneath irrigated fields, where applied irrigation water meets most of the potential evapotranspiration demand. Bare-soil evaporation can occur during fallow periods, but it is probably not significant in the study area.

The White Bluffs is the only significant non-irrigated area where the water table is shallow. An estimate of ground-water evapotranspiration (5,000 acre-ft/yr) from these areas is included in the section on discharge from springs and seepage faces.

Discharge to Drains

Drains are an important aspect of the ground-water system in the study area. Some drains are used to lower the water table in order to keep it below the crop root zone or to protect low-lying areas from flooding. Other drains serve to maintain the proper moisture-oxygen-salt balance necessary for irrigated agriculture. The study area has both open drains (open channels with exposed water surfaces) and buried drains (perforated pipes installed below land surface).

Some of the largest and most important open drains are the USACOE drains associated with McNary Dam and Lake Wallula. The construction of McNary Dam resulted in the impoundment of Lake Wallula, with an average water-level altitude of about 335 to 340 ft. This water level is above the land surface of much of the bordering land in the Kennewick, Pasco, and Richland areas.

As part of the McNary project, the USACOE designed and built a system of levees, drains, and pumping stations, with the goal of maintaining the pre-McNary Dam water table in the land bordering Lake Wallula (fig. 41). A cross section of a typical levee and drain is shown on figure 42. The water collected in the drains is routed to a series of pumping stations and lifted into Lake Wallula. Table 16 lists the total pumpage (March 1986 through February 1987) for these pumping stations.

Table 15.--*Measured discharges from springs in the Benton County part of the study area*

[ft^3/s, cubic foot per second; CID, Columbia Irrigation District]

Spring or seepage area (map number, fig. 38)	Approximate mean annual discharge (ft^3/s)	Tributary to	Remarks
Yakima River tributary at Interstate 182 near Richland (7)	1.1	Yakima River	Spring was created by excavation during construction of Interstate 182.
CID no. 3 Canal tributary at South Highlands at Kennewick (8)	1.4	CID no. 3 Canal	Represents area of seepage about 0.1 mi long.
CID no. 3 Canal tributary below private lake near Kennewick (9)	1.1	CID no. 3 Canal	Represents area of seepage about 0.2 mi long.
CID no. 3 Canal at end (10)	4.0	Columbia River	From mid-October to mid-March, discharge is essentially all springflow (includes flow from the above sites which are tributary to CID no. 3).
Yakima River tributary at Kiona (11)	0.4	Yakima River	Seepage from western end of Badger Coulee.

The water that collects in the USACOE drains is storm runoff and irrigation wastewater in addition to intercepted ground water. Storm runoff to these drains is probably insignificant. Irrigation wastewater contributes significantly to the USACOE drains from at least two sources: (1) KID Highlift Canal, which dumps to the drain that feeds pumping stations 15E and 15E-1 (about 1,900 acre-ft during March 1986 to February 1987; Drost and others, 1989a), and (2) CID No. 1 Canal, which dumps to the same drain (about 1,200 acre-ft during March 1986 to February 1987; estimated). Subtracting these two irrigation wastewater flows from the total pumping station pumpage yields a net pumpage of 53,000 acre-ft. This volume is the maximum ground-water discharge to the USACOE drains.

Buried drains consist of networks of perforated pipes in gravel envelopes. Most of the buried drains in the study area are those installed in the SCBID. A relatively insignificant number of buried drains have been installed by local landowners. As part of the SCBID operation, water levels are monitored in the irrigated areas. When the water table rises sufficiently to interfere with agriculture, drains are installed (where economically justified) to remove excess water and maintain the water table below the root zone of crops.

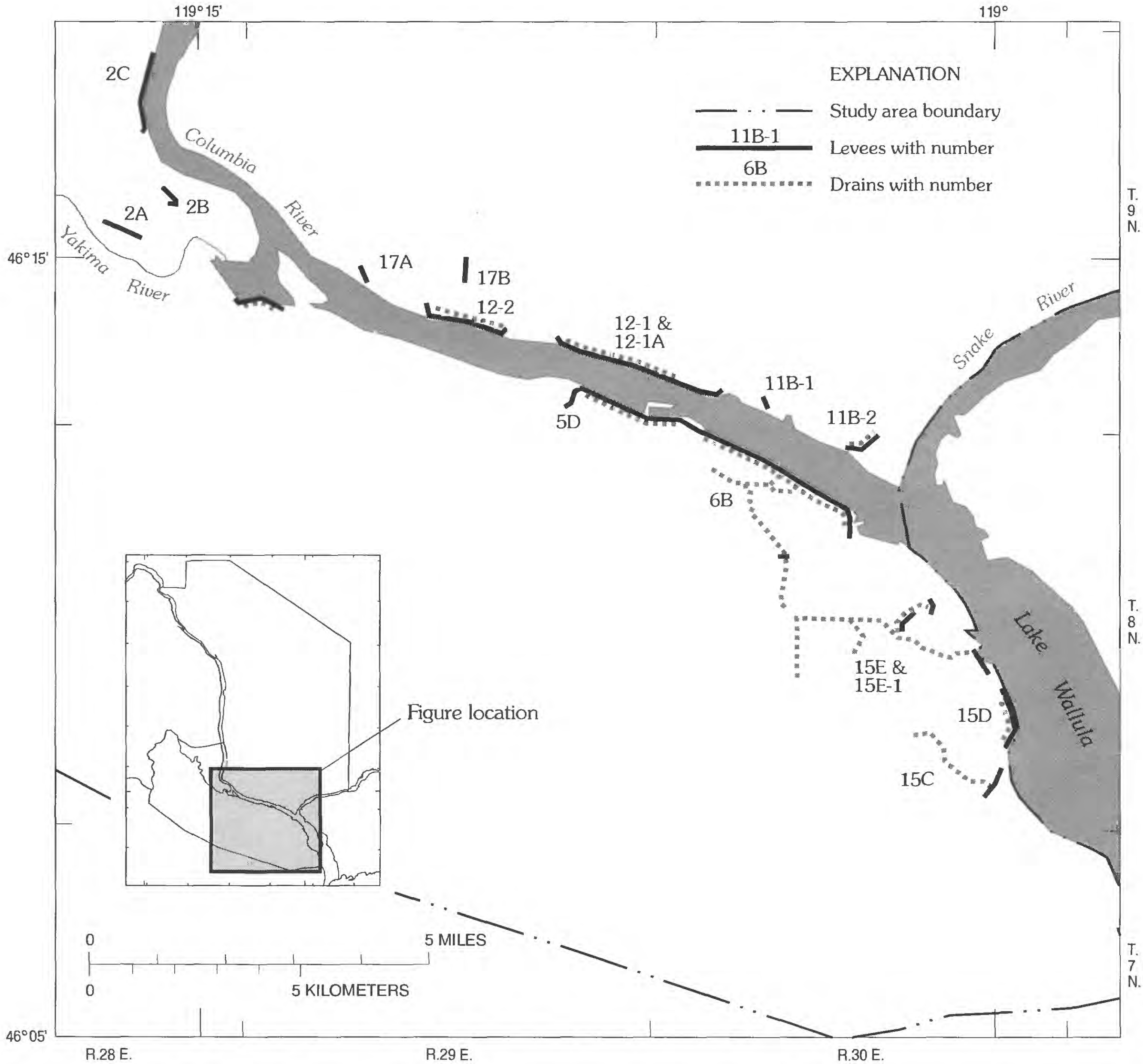


Figure 41.--Locations of US Army Corps of Engineers levees and drains.

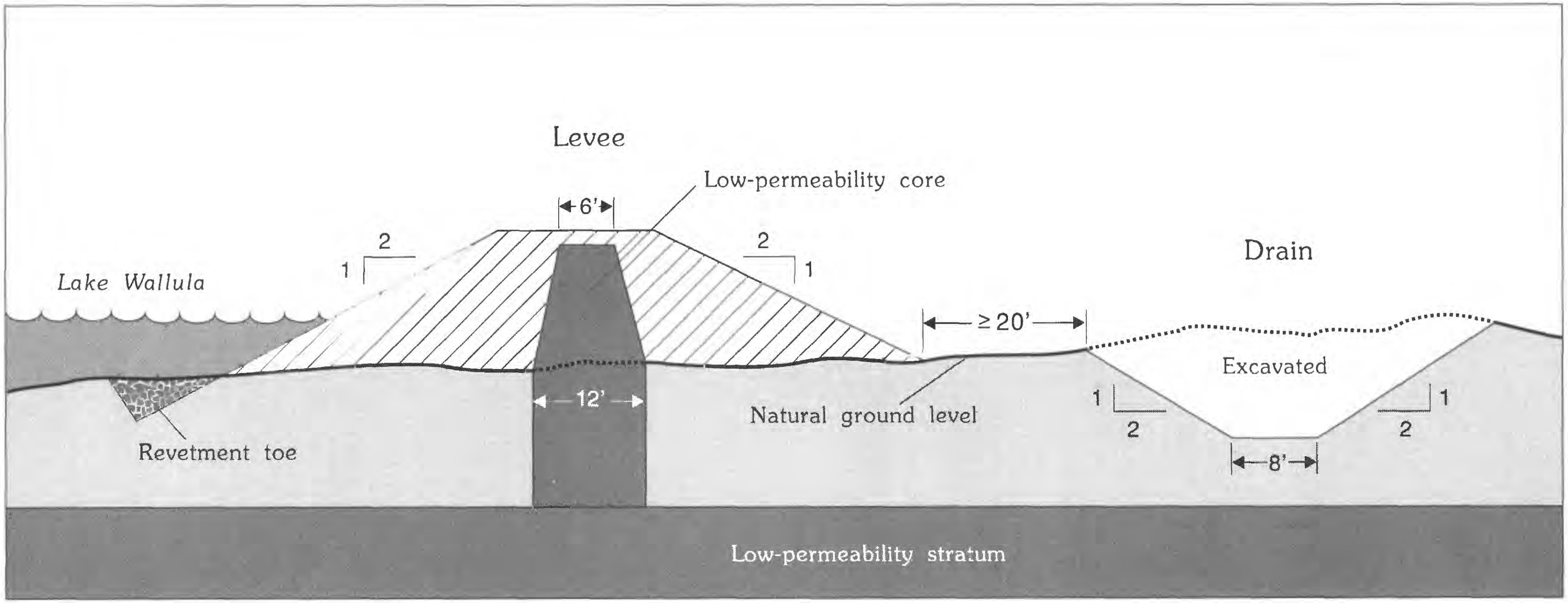


Figure 42.--Cross section of a typical US Army Corps of Engineers levee and drain system (Modified from US Army Corps of Engineers, 1974).

Table 16.--*Total pumpage from U.S. Army Corps of Engineers McNary Dam-Lake Wallula drains, March 1986 through February 1987*

Pumping station[1]	Location	Total pumpage[2] (acre-feet)
2B	09N/28E-13M	0
2C	09N/28E-11B	1,600
4A	09N/29E-30C	0
5D	09N/30E-31P	9,600
6B	08N/30E-04N	8,500
11-B2	08N/30E-03D	1,100
12-1 + 12-1A	09N/29E-31D	14,000
12-2	09N/29E-27K	6,400
15C	08N/30E-36E	1,300
15D	08N/30E-25C	3,900
15E + 15E-1	08N/30E-23H	9,900
	Total	56,000

[1]Pumping station number indicates the levee and drain system the pumping station is associated with (figure 41).

[2]From U.S. Army Corps of Engineers' records, except pumping station 11-B2, which is from Port of Pasco records; all values rounded to two significant figures.

In the part of the SCBID within the study area, construction of buried drains began in 1964 and continued through at least 1988, totalling about 936 mi of perforated pipe (figure 43). Table 17 lists the lengths of buried drain in each irrigation block in the SCBID. Figure 40 shows those areas where the water table is shallow, which totals about 140,000 acres and figure 44 shows the distribution of buried drains in the SCBID within the study area. Comparing figure 40 with fig. 44 shows that much of the shallow water-table area of SCBID contains buried drains.

The water collected by buried drains is discharged primarily to irrigation wasteways, with a few discharging directly to irrigation canals. Wasteways handle the excess flows from irrigation canals (tailwaters or operational wastes) and act as open drains for the ground-water system as well as accept flow from buried-drain systems. An estimate of ground-water discharge to buried drains and wasteways (open drains) can be obtained from water budgets for the major wasteway systems (table 18).

Table 17.--*Lengths of buried drains installed in irrigation blocks in the South Columbia Basin Irrigation District within the study area*

Block number	Miles of buried drain (through 1988)
11	4
12	18
13	13
14	39
15	174
16	239
17	21
18	4
19	78
20	146
21	7
23	120
[1]161	41
[2]201	32
Total	936

[1]Block 161 is a subdivision of Block 16.

[2]Block 301 is a subdivision of Block 20.

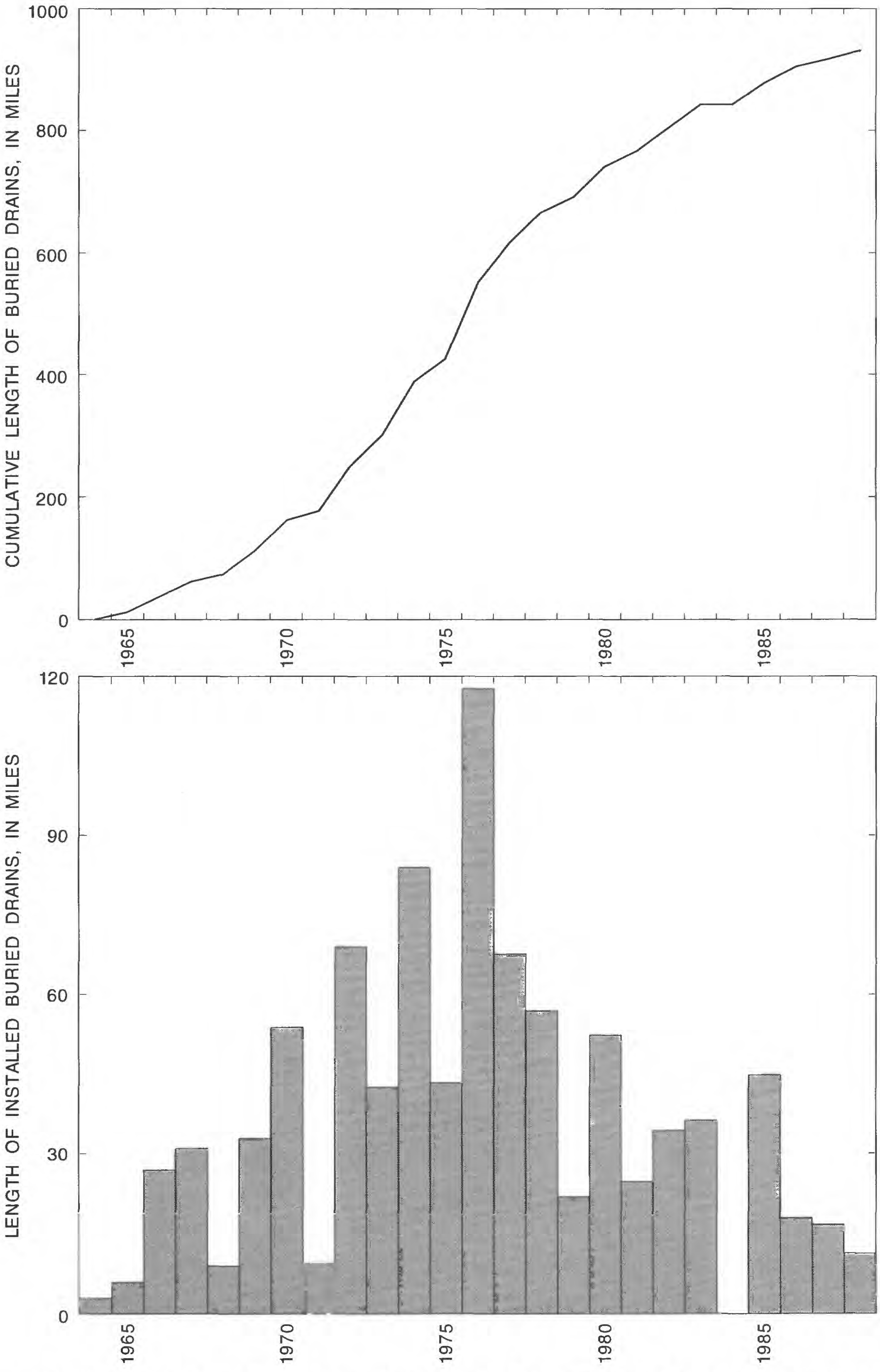


Figure 43.--History of buried-drain installation in the South Columbia Basin Irrigation District within the study area.

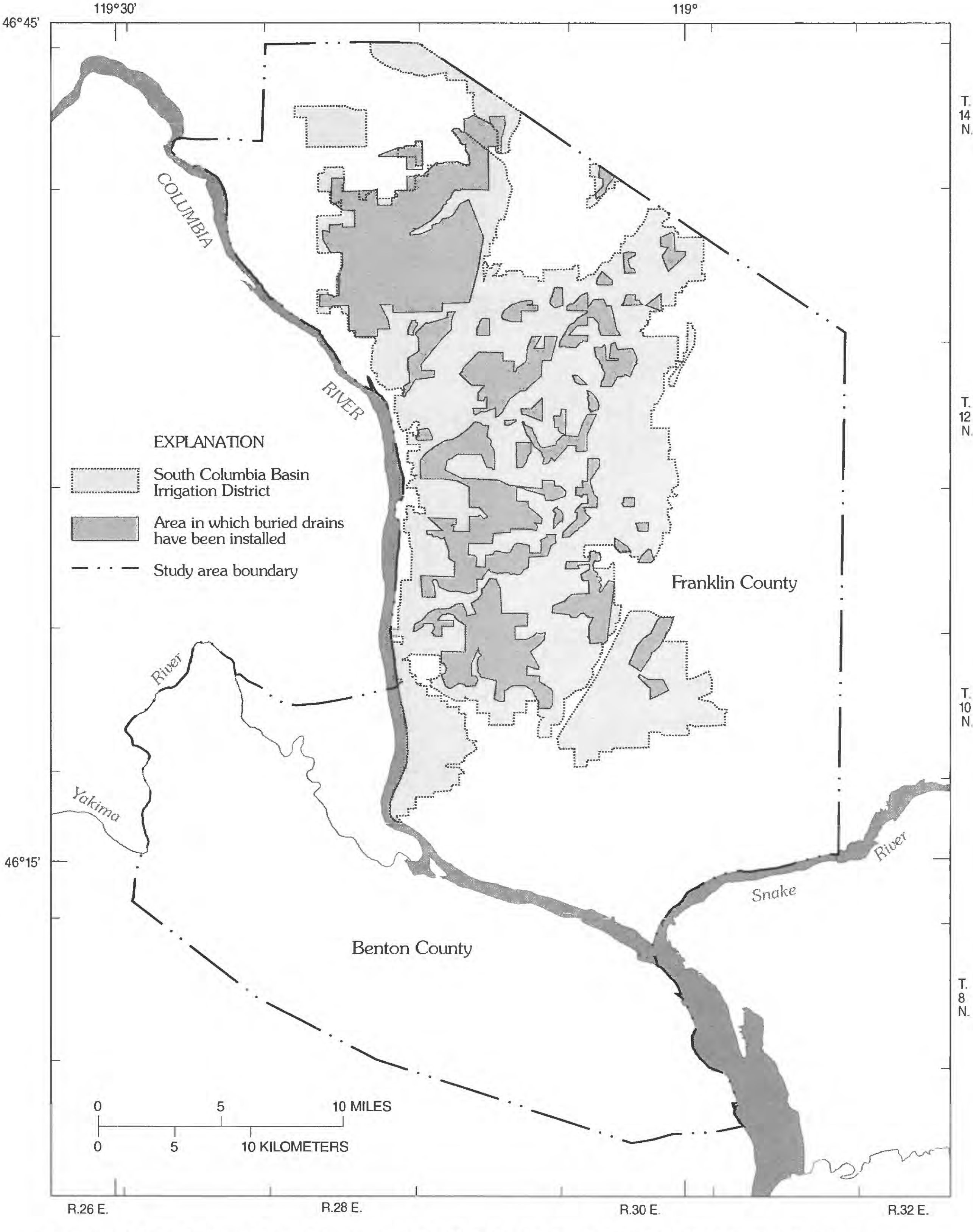


Figure 44.--Distribution of buried drains in the South Columbia Basin Irrigation District within the study area.

Table 18.--*Water budgets for the major wasteway systems, 1986*

[All values in acre-feet per year; NA, not applicable]

Wasteway	Inflow: At study area boundary	Inflow: From irrigation canals	Outflow	Outflow minus inflow
	South Columbia Basin Irrigation District			
Esquatzel Coulee Wasteway/Diversion Channel	[1]14,000	[2]32,000	[3]94,000	48,000
PE 16.4 Wasteway	[4]62,000	[5]19,000	[6]85,000	4,000
WB5 Wasteway	NA	[7]7,500	[8]28,000	20,000
	Kennewick Irrigation District			
Amon Wasteway	NA	[9]19,000	[10]23,000	4,000
			Total	76,000

[1]U.S. Geological Survey site 12513400.
[2]Total of 27 wasteways; discharges from Bureau of Reclamation records.
[3]U.S. Geological Survey site 12513700; some outflow passes Eltopia Diversion Channel pump and is not recorded in total.
[4]U.S. Geological Survey site 12473506.
[5]Total of 21 wasteways; discharges from Bureau of Reclamation records.
[6]U.S. Geological Survey site 12473508 minus springflow which occurs between this site and Miscellaneous-3 (Drost and others, 1989b).
[7]Total of 9 wasteways; discharges from Bureau of Reclamation records.
[8]U.S. Geological Survey site 12473502.
[9]U.S. Geological Survey site 12509640.
[10]U.S. Geological Survey site 12512150.

The differences between outflows and inflows to the wasteways shown in table 18 result primarily from ground-water discharge either directly to the wasteways or through buried-drain systems. The total calculated ground-water discharge to open and buried drains associated with the wasteways listed in table 18 is 76,000 acre-ft/yr. The wasteway systems in the table represent most of the drain flows in the study area, not including the USACOE drains discussed above. A few minor wasteway systems that receive drain flows are not included in the table because complete budget information is not available (for example, Zintel Canyon Wasteway in the KID system). Other wasteway systems were not included because they receive little or no drain flow (for example, Pasco Wasteway, PP4.3 Wasteway, and PE64 Wasteway No. 1, all in the SCBID system) or because they are primarily above the water table and act as recharge to the ground-water system (for example, Smith Canyon Wasteway and WB10 Wasteway, in the SCBID system).

The total ground-water discharge to drains equals the sum of agricultural drain flow (76,000 acre-ft/yr) and USACOE drain flow (53,000 acre-ft/yr). This total is about 130,000 acre-ft/yr.

Discharge to Wells

Significant amounts of water are pumped from the ground-water system in the study area. Ground water is used primarily for irrigation, but domestic and industrial uses are locally important. Of the several thousand wells in use, only a few percent are metered.

Ground water is used to irrigate about 41,000 acres (17 percent of the irrigated land) in the study area (fig. 33). The method of determining irrigated acreage and the rate of application of irrigation water is discussed in an earlier section of this report (Applied-Irrigation Recharge). The identification of the source of the irrigation water (ground water or surface water) was made using maps of the irrigation districts, water-well permits, and field checks. Total application of ground water for irrigation was about 120,000 acre-ft during the 1986 irrigation season.

Irrigation water was pumped primarily from the Pasco gravels, Saddle Mountains Basalt, and Wanapum Basalt hydrologic units. Determination of units tapped was made by matching irrigated areas with wells through water-well permits. Approximately 85 percent of the areas irrigated with ground water were successfully matched with wells. Where no match was found, the hydrologic unit tapped was based on data from surrounding wells. Table 19 lists the amounts of irrigation water pumped from each hydrologic unit, by type of use.

Ground water is the source of domestic water for about 28,000 people (22 percent of the total population) in the study area. About 4,700 acre-ft of ground water were used for domestic purposes from March 1, 1986, to February 28, 1987. Large public-supply systems (each serving 500 or more people) supplied water to nearly 9,000 people, accounting for approximately 1,900 acre-ft of water. Most of these large systems are metered. Small public-supply systems (less than 500 people each) and single-household wells supplied water to about 19,000 people. A reasonable estimate of water use by these small systems can be obtained by using a rate of 125 gal/d per person (Dion and Lum, 1977), or 2,800 acre-ft/yr for 19,000 people.

Table 19.--*Ground-water pumpage in the study area, March 1986 through February 1987*

[--, zero or insignificant]

	Ground water pumped (acre-feet) (all values rounded to two significant figures)				
			Domestic[1]		
Hydrologic unit	Irrigation	Industrial	Large systems	Small systems	Totals
Touchet Beds	--	--	--	--	--
Pasco gravels	75,000	4,400	1,100	1,400	82,000
upper Ringold Formation	--	--	--	--	--
middle Ringold Formation	5,400	--	140	140	5,700
lower Ringold Formation	140	--	72	140	350
basal Ringold Formation	--	--	--	--	--
Saddle Mountains Basalt	18,000	--	220	940	19,000
Wanapum Basalt	23,000	--	360	140	24,000
Grande Ronde Basalt	--	--	--	--	--
Totals	120,000	4,400	1,900	2,800	130,000

[1]Large systems supply water to 500 or more people; small systems supply water to less than 500 people.

Industrial use of ground water was about 4,400 acre-ft from March 1, 1986, to February 28, 1987 in the study area. This represents all three industrial users with water rights in excess of 0.1 ft^3/s (72.4 acre-ft/yr). Water-use numbers were supplied by the users and are a combination of metered and estimated values.

Total annual ground-water pumpage (March 1, 1986, to February 28, 1987) in the study area was about 130,000 acre-ft. The Pasco gravels (63 percent), Saddle Mountains Basalt (15 percent), and Wanapum Basalt (18 percent) hydrologic units supplied almost all of the ground water.

Seasonal Water-Level Changes

Within the study area, observed seasonal water-level fluctuations vary from barely measurable to as much as 160 ft. Seasonal water-level fluctuations reflect the non-constant nature of the recharge to and discharge from the ground-water system.

Seasonal water-level fluctuations in the Benton County part of the study area can be seen in hydrographs from five sites with continuous recorders (fig. 45) and in hydrographs from 56 wells that were measured monthly by the USGS (Appendix A).

Water levels in Benton County generally follow one of two seasonal trends. Water levels either reach a peak in August to December and a low in March to May, or reach a peak in February to April and a low in August to September. Those wells that peak in August to December are located where the major influence on the ground-water system is recharge either from canal seepage or applied irrigation. Where the peak water level occurs in February to April, the major influence is ground-water pumping.

Examples of these two different seasonal trends can be seen on figure 45. Well 08N/28E-22D03 is in Badger Coulee, an area mainly influenced by recharge from canal seepage and applied irrigation. The water level in this well was at a low in April and peaked in October. This trend closely follows the irrigation season which begins in mid-March and ends in mid-October. Water levels begin to rise shortly after water is introduced to the canals and applied to fields. Water levels peak after the irrigation season reaches its height (maximum application rate occurs in July to August). After irrigation ceases and the canals are dry (about mid-October), water levels steadily decline until after the start of the next irrigation season.

Well 08N/30E-35D01 (fig. 45) is in an area mainly influenced by ground-water pumping. The water level in this well was lowest in August and peaked in March. This trend closely follows the irrigation pumping season, which usually begins in March, reaches a maximum in July or August, and ends in October. Water levels begin to decline when pumping begins in March and continue downward through the irrigation pumping season. Water levels rise steadily after pumping decreases in September and ceases in October.

Table 20 contains summaries of the hydrographs of Benton County wells on figure 45 and in Appendix A. For each hydrograph, a dominant influence is identified, the feature of the hydrologic system that produces the observed seasonal trend. The primary dominant influences are pumping, canal seepage, and applied irrigation. Other identified influences are river stage and surface drains.

The general patterns of seasonal water-level fluctuations are summarized in table 21. Wells showing pumping as the dominant influence are generally open to basalt aquifers. Because they have much smaller hydraulic conductivities and storage coefficients than most of the unconsolidated aquifers, pumping effects are much more pronounced in the basalt aquifers.

Many of the wells influenced primarily by applied irrigation may also be influenced by canal seepage. Because the irrigated areas are traversed by numerous canals, it is difficult to separate the two influences.

Seasonal water-level fluctuations in the Franklin County part of the study area can be seen in hydrographs from 101 wells that were measured monthly or bimonthly (Appendixes A and B). The 20 Franklin County hydrographs in Appendix A were constructed from monthly measurements made by the USGS. The 81 hydrographs in Appendix B were constructed from bimonthly measurements made by the Bureau of Reclamation. Data for the five hydrographs on figure 46 were obtained from continuous recorders operated by the Bureau of Reclamation.

Water levels in Franklin County generally follow one of two seasonal trends. Water levels either reach a peak in August to November and a low in March to May, or reach a peak in February to April and a low in September to October. Those wells that peak in August to November are in locations where the major influence on the ground-water system is recharge from canal or wasteway seepage, or recharge from applied irrigation. Where the peak water level occurs in February to April the major influence is ground-water pumping.

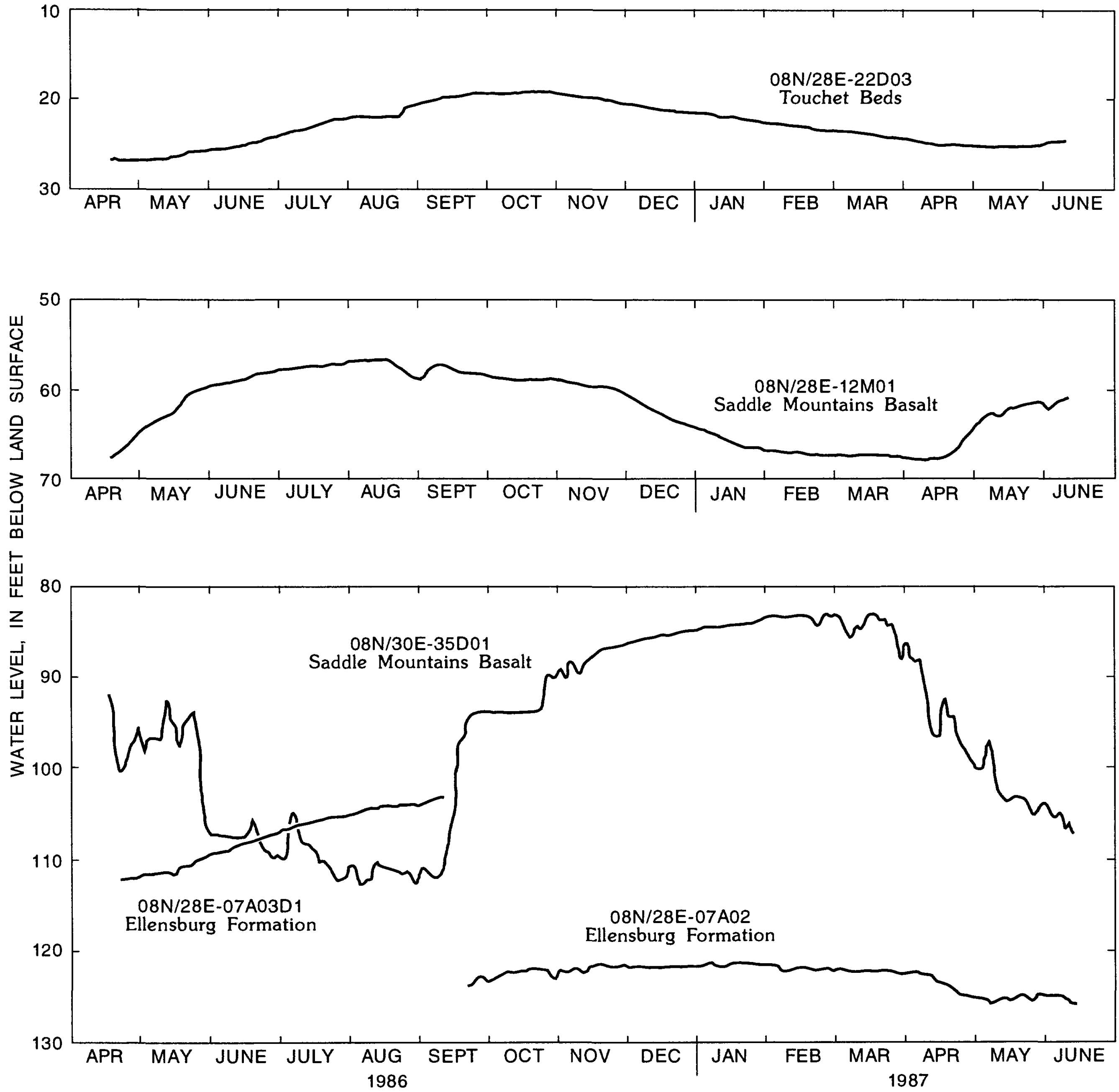


Figure 45.--Hydrographs of Benton County wells with continuous recorders, April 1986 through June 1987. Shows local well number and hydrologic unit tapped by the well.

Table 20.--*Seasonal trends in water levels in Benton County wells, February 1986 through April 1987*

[*, insufficient data or no distinct seasonal trend; TCHT, Touchet Beds; PSCO, Pasco gravels; MDRG, middle Ringold Formation; LRRG, lower Ringold Formation; BSRG, basal Ringold Formation; RGLD, undifferentiated Ringold Formation; ELBG, Ellensburg Formation (above basalt); SDLM, Saddle Mountains Basalt; WNPM, Wanapum Basalt; ?, dominant influence, uncertain; ?, water-level trend, month of peak or low water level uncertain]

Local well number	Hydro-logic unit	Dominant influence	Water-level trend		Seasonal change (feet)[1]
			Peak	Low	
07N/31E-07D01	SDLM	Pumping?	Feb.-Mar.?	Aug.	23
08N/27E-01J02	SDLM	Canal	Oct.	Apr.	6
08N/28E-06B01D2	SDLM	Pumping	*	*	*
08N/28E-06G01	ELBG	Pumping	Mar.?	Sept.?	>15
08N/28E-07A02/ -07A03D1	ELBG	Canal	Oct.	Apr.-May	*
08N/28E-07A03	ELBG	Canal	*	Apr.	*
08N/28E-11Q01	SDLM	Canal	Oct.	Mar.?	4
08N/28E-12M01	SDLM	Canal	Aug.	Apr.	11
08N/28E-15P01	PSCO	Pumping	Feb.-Mar.	Aug.-Sept.	3
08N/28E-17N02	PSCO	Canal	Sept.-Oct.?	*	>31
08N/28E-17P01	TCHT	Canal	Nov.	May	4
08N/28E-21A01	PSCO	Irrigation	Oct.-Nov.	Mar.?	1
08N/28E-22D03	TCHT	Irrigation	Oct.	Apr.	7
08N/28E-22D05	TCHT	Irrigation	Aug.	May	1
08N/28E-22F02	PSCO	Canal	Oct.	*	>6
08N/28E-22G01	PSCO	Canal	Sept.?	*	>20
08N/29E-05D01	PSCO	Irrigation	Nov.-Dec.	Apr.-May	1
08N/29E-13A01	SDLM	Irrigation	*	*	*
08N/29E-17L01	SDLM	Irrigation	*	*	*
08N/30E-05K01	PSCO	Irrigation+drain	Oct.	Apr.	1
08N/30E-05K02	PSCO	Irrigation+drain	Nov.	Apr.	1
08N/30E-07J02	PSCO	Irrigation	Sept.	Mar.-Apr.	4
08N/30E-15K01	PSCO	Drain	Apr.	June	3
08N/30E-22P01	PSCO	Irrigation	Aug.	Apr.	6
08N/30E-23A03	PSCO	River	*	*	*
08N/30E-25C01	SDLM	Drain	July	Feb.	<1
08N/30E-29A01	SDLM	Pumping?	Feb.	Aug.	19
08N/30E-29D01	PSCO	Canal	*	*	1
08N/30E-30N01	WNPM	Unstressed?	*	*	*
08N/30E-34Q01	PSCO	Canal	Nov.	*	1
08N/30E-35D01	SDLM	Pumping	Mar.	Aug.	30
09N/27E-01D01	SDLM	Pumping	*	*	1
09N/27E-08J02	SDLM	Pumping	*	*	>49
09N/27E-16B01	SDLM	Pumping	Mar.	Aug.	12

Table 20.--*Seasonal trends in water levels in Benton County wells, February 1986 through April 1987--Continued*

Local well number	Hydro-logic unit	Dominant influence	Water-level trend		Seasonal change (feet)[1]
			Peak	Low	
09N/27E-16D01	SDLM+WNPM	Pumping	Apr.	Aug.	34
09N/27E-19J01	PSCO	Irrigation+river	Nov.	Aug.	1
09N/27E-19K02	PSCO	Irrigation+river	*	July	>1
09N/27E-19P01	SDLM	Canal	Sept.-Oct.	May	6
09N/27E-35E01	SDLM	Canal	Nov.	Apr.-May	4
09N/28E-02G02	MDRG	River	June	Aug.	5
09N/28E-04C05	SDLM	Pumping	Feb.-Mar.	Aug.	160
09N/28E-04G03	MDRG	Pumping	Mar.-Apr.	Sept.	4
09N/28E-08C01	SDLM	Pumping	Feb.-Mar.	Sept.	8
09N/28E-15J01	PSCO	Pumping	*	Sept.	13
09N/28E-18L01	SDLM	Canal	Sept.	Apr.	6
09N/28E-21D01	SDLM	Pumping	Mar	*	2
09N/28E-22B01	SDLM	Pumping	Feb.-Mar.	Aug.	11
09N/28E-26M01	SDLM	Pumping	Mar.-Apr.	Sept.	7
09N/28E-30J01	WNPM	Pumping	Mar	Aug.-Sept.	60
09N/28E-31E02	SDLM	Pumping	Apr.	Sept.	6
09N/29E-33M01	SDLM	Irrigation	Aug.	Apr.	6
10N/27E-11L01	PSCO	Canal+river?	July	Feb.	6
10N/27E-11M02	SDLM	Pumping	Mar.	*	5
10N/27E-23L02	SDLM	Irrigation	Sept.-Oct.	May?	5
10N/27E-25R02	PSCO	Canal+river?	Aug.-Sept.	Mar.	6
10N/28E-18H01	SDLM	Pumping	*	*	3
10N/28E-19R01	MDRG	River	Dec.-Jan.	July	4
10N/28E-23E02	*	Irrigation	Aug.	Apr.-May	10
10N/28E-29C01	MDRG	River	Feb.	Aug.	7
10N/28E-35N03	MDRG	Irrigation+river	Sept.	Apr.	1

[1]The effects of long-term trends were removed prior to estimating seasonal changes.

Table 21.--*Summary of seasonal trends in water levels in Benton County wells, February 1986 through April 1987*

[--, not calculated]

Dominant influence[1]	Number of wells	Water-level trend		Magnitude of seasonal change (in feet)[2]				
		Peak	Low	Minimum	25th percentile	Median	75th percentile	Maximum
Pumping:								
All wells	21	Feb.-Apr.	Aug.-Sept.	1	4	12	23	160
Sediments	3	Feb.-Apr.	Aug.-Sept.	3	--	4	--	13
Basalts	18	Feb.-Apr.	Aug.-Sept.	1	5	12	28	160
Canal:								
All wells	14	Aug.-Nov.	Mar.-May	1	4	6	6	>31
Sediments	6	Sept.-Nov.	Mar.-May	1	--	5	--	>31
Basalts	8	Aug.-Nov.	Mar.-May	4	--	6	--	11
Applied irrigation:								
All wells	14	Aug.-Dec.	Mar.-May	1	1	2	6	10
Sediments	10	Aug.-Dec.	Mar.-May	1	1	1	4	10
Basalts	2	Aug.-Dec.	Apr.-May	5	--	--	--	6

[1]Sediments, all aquifers above basalts, except Ellensburg; Basalts, all basalt aquifers plus overlying Ellensburg.

[2]25th and 75th percentiles not calculated if number of wells is less than ten; median not calculated if number of wells is less than 3.

The hydrographs on figure 46 show little seasonal trend. These wells are all close to the Columbia River in areas where levees and drains maintain a nearly constant water table. There appears to be some correlation between the river stage at Pasco, shown on figure 47, and the water levels on figure 46.

Table 22 summarizes the hydrographs of Franklin County wells in Appendixes A and B. For each hydrograph, a dominant influence is identified. The primary dominant influences are pumping, canal and wasteway seepage, and applied irrigation. Other identified influences are river stage and surface drains.

The general patterns of seasonal fluctuation are summarized in table 23. Wells showing the greatest seasonal fluctuations are those tapping basalt aquifers in areas dominated by ground-water pumping. Many of the wells with applied irrigation identified as the dominant influence may also be greatly influenced by canal or wasteway seepage. Because the irrigated areas are traversed by many canals and wasteways, it is difficult to separate the two influences.

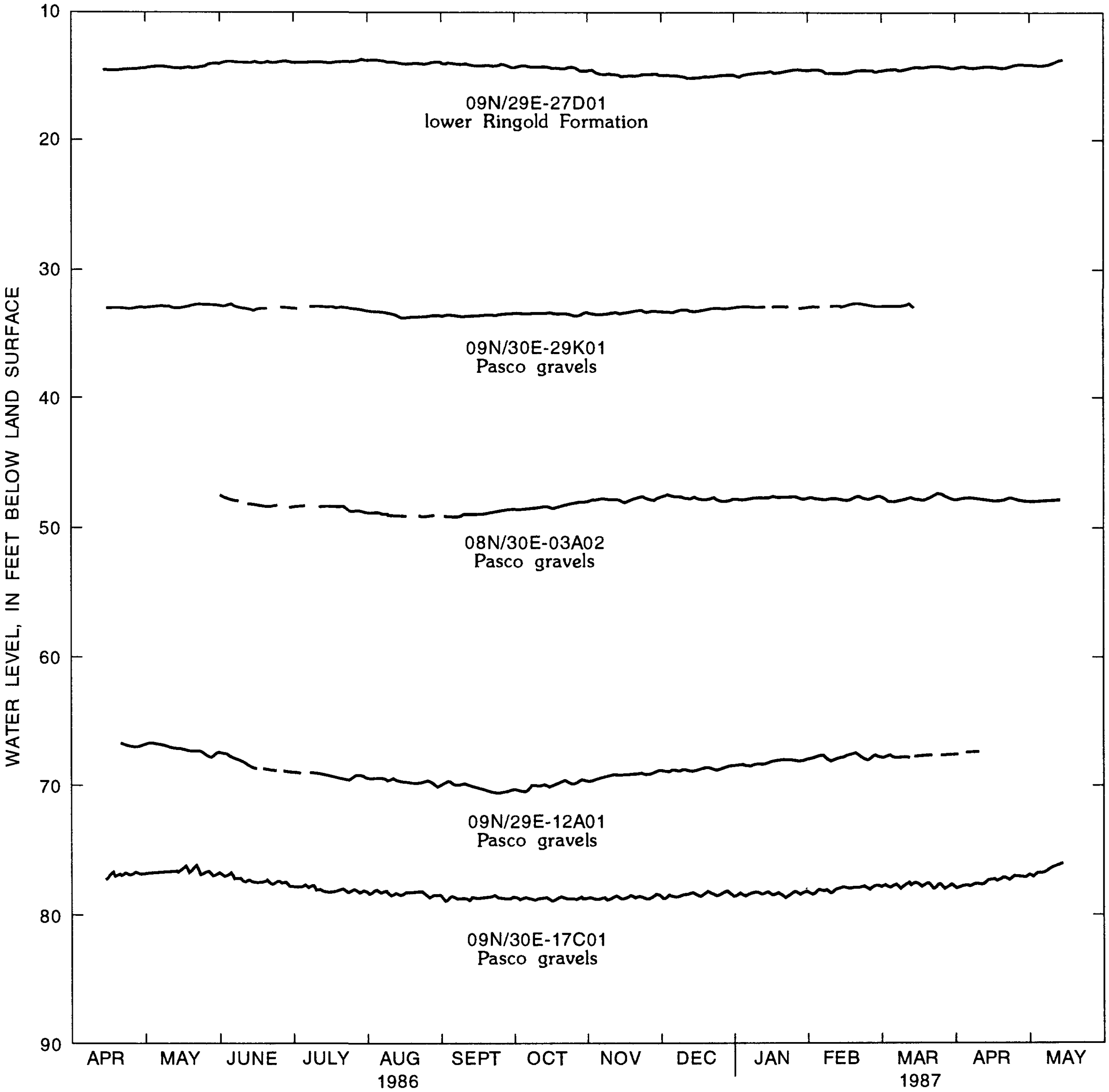


Figure 46.--Hydrographs of Franklin County wells with continuous recorders, April 1986 through May 1987. Shows local well number and hydrologic unit in which the well is completed.

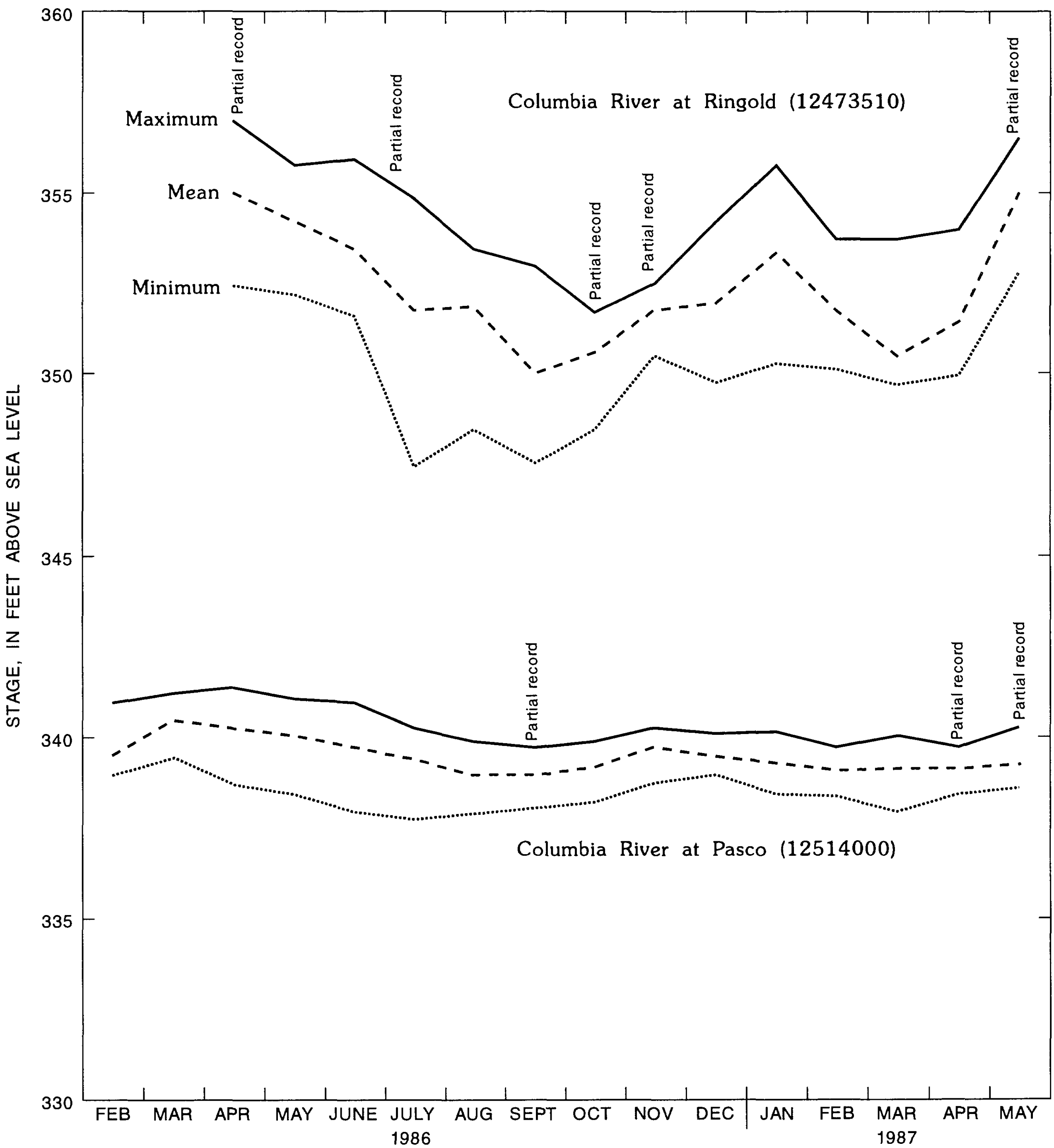


Figure 47.--Monthly maximum, mean, and minimum stages of Columbia River at Ringold and at Pasco, February 1986 through May 1987.

Table 22.--*Seasonal trends in water levels in Franklin County wells, April 1986 through May 1987*

[*, insufficient data or no distinct seasonal trend; ALVM, alluvium; DUNE, dune sands; TCHT, Touchet Beds; PSCO, Pasco gravels; PLUS, Palouse Formation; UPRG, upper Ringold Formation; MDRG, middle Ringold Formation; LRRG, lower Ringold Formation; BSRG, basal Ringold Formation; RGLD, undifferentiated Ringold Formation; SDLM, Saddle Mountains Basalt; WNPM, Wanapum Basalt; Dominant influence, ?, uncertain; Water-level trends, ?, month of peak or low-water level uncertain; Seasonal change, the effects of long-term trends were removed prior to estimating seasonal changes.]

Local well number	Dominant Aquifer	Influence	Water-level trend		Seasonal change (feet)
			Peak	Low	
08N/30E-03A01	PSCO	River+drain	Mar.-Apr.	July-Sept.	1
09N/29E-02G03	PSCO	Pumping	Mar.-Apr.?	*	6
09N/29E-06F01	PSCO	Irrigation	*	Apr.?	2
09N/29E-06G01	BSRG	Irrigation	*	*	1
09N/29E-09C01	PSCO	Pumping	*	*	<1
09N/29E-11D01	PSCO+LRRG	Pumping	Mar.	Sept.	5
09N/29E-15D01	PSCO	Pumping	Apr.	*	1
09N/29E-15N01	PSCO	Canal	Sept.	Mar.	1
09N/29E-17L01	SDLM	Pumping	Mar.	Sept.	10
09N/29E-25C03	PSCO	River?	May.	Jan.	2
09N/30E-02B01	PSCO+SDLM	Pumping	Mar.	Sept.	5
09N/30E-06D01	PSCO	Wasteway+pumping	Dec.	Aug.?	2
09N/30E-12P01	PSCO	Pumping	Mar.	Sept.	3
09N/30E-14D01	PSCO	Pumping	Apr.	Sept.-Oct.	5
09N/30E-14M01	PSCO+MDRG+ LRRG	Pumping	Apr.	Sept.-Oct.	5
09N/30E-14M02	MDRG	Pumping	Apr.	Sept.	5
09N/30E-16F01	PSCO+LRRG	Pumping	Apr.	Sept.	4
09N/30E-22K01	PSCO	Pumping	*	Sept.	3
09N/30E-23N01	PSCO+LRRG+ SDLM	Pumping	Mar.	Sept.	4
09N/30E-26A01	PSCO+SDLM	Pumping	Apr.	Sept.	3
09N/31E-06D01	PSCO+UPRG+ LRRG+SDLM	Pumping	Feb.	Sept.?	4
10N/28E-12F01	RGLD	Canal?	Oct.	May	4
10N/28E-12J01	MDRG	Canal?	Sept.-Oct.	May	7
10N/28E-12K01	LRRG	Canal?	Sept.-Oct.	May	4
10N/29E-03A01	UPRG	Irrigation	Sept.	Mar.-Apr.	3
10N/29E-05A01	UPRG	Irrigation	Sept.	*	>2
10N/29E-08R01	PSCO+UPRG	Irrigation	July-Aug.	Mar.	3
10N/29E-11N01	PSCO+UPRG	Canal	Aug.?	Mar.-Apr.	8
10N/29E-14R01	PSCO+UPRG	Irrigation	Aug.	Mar.	7
10N/29E-25A01	PSCO+UPRG+ MDRG+SDLM	Wasteway	Nov.	May	2
10N/29E-26A01	UPRG+SDLM	Canal	Sept.	Mar.	2

Table 22.--*Seasonal trends in water levels in Franklin County wells, April 1986 through May 1987--Continued*

Local well number	Dominant aquifer	Influence	Water-level trend Peak	Water-level trend Low	Seasonal change (feet)
10N/29E-27C01	DUNE+PSCO+ MDRG	Pumping	Mar.	Sept.-Oct.	1
10N/29E-28B01	PSCO	Irrigation	*	*	<1
10N/30E-03Q02	PSCO+UPRG	Canal	Oct.?	Apr.?	7
10N/30E-04E01	PSCO+SDLM	Wasteway	Oct.-Nov.	Mar.	4
10N/30E-05B01	DUNE+SDLM	Irrigation	Sept.-Oct.	Apr.?	1
10N/30E-05N01	PSCO	Irrigation	Sept.-Oct.	Mar.-Apr.	2
10N/30E-08F01	PSCO+SDLM	Wasteway	Nov.	Mar.-Apr.	3
10N/30E-18Q02	PSCO+SDLM	Wasteway	Oct.	Apr.	2
10N/30E-21N01	SDLM	Pumping	*	*	95
10N/30E-21R01	UPRG	Irrigation	Sept.-Oct.	Mar.-Apr.	2
10N/30E-33N04	MDRG	Pumping	*	*	16
10N/31E-30A03	PSCO+UPRG+ MDRG	Wasteway	Oct.-Nov.	Mar.	9
11N/28E-13C01	MDRG	River	*	Apr.?	5?
11N/28E-25R02	UPRG	Canal	Oct.?	Mar.-Apr.	3
11N/29E-05D01	UPRG	Canal	Aug.-Sept.	Mar.	5
11N/29E-07M01	MDRG	*	*	Mar.?	4
11N/29E-14R01	UPRG	Irrigation	Sept.?	Apr.?	1
11N/29E-16N01	UPRG	Canal	Sept.-Oct.	Mar.-Apr.	3
11N/29E-19R01	UPRG	Irrigation	*	Mar.-Apr.	2
11N/29E-24R01	UPRG	Irrigation	Sept.	Mar.	4
11N/29E-26D01	UPRG	Irrigation	Oct.-Nov.	May	2
11N/30E-01P01	PSCO	Pumping	Feb.?	Sept.	6
11N/30E-02B01	PSCO+SDLM	Wasteway	Nov.?	Apr.?	6
11N/30E-02H01	PSCO+SDLM	Wasteway	Nov.	Apr.?	5
11N/30E-02Q02	PSCO	Wasteway	Nov.?	Apr.?	6
11N/30E-03L01	SDLM	Canal	Sept.	Mar.-Apr.	11
11N/30E-06N01	UPRG	Canal	Sept.-Oct.	Mar.-Apr.	2
11N/30E-08N01	UPRG	Irrigation	Oct.-Nov.	May	4
11N/30E-11A02	PSCO+SDLM	Wasteway	Nov.?	Apr.?	6
11N/30E-12C01	SDLM	Pumping	Feb.?	Sept.	6
11N/30E-12C02	PSCO	Pumping	*	*	1
11N/30E-12C04	SDLM	Pumping	Feb.?	Sept.	5
11N/30E-32D01	UPRG	Canal	Sept.	Mar.	5
11N/30E-35J01	SDLM	Pumping	*	*	63
11N/31E-32A01D1	SDLM+WNPM	Pumping	Mar.?	*	12

Table 22.--*Seasonal trends in water levels in Franklin County wells, April 1986 through May 1987--Continued*

Local well number	Dominant aquifer	Influence	Water-level trend		Seasonal change (feet)
			Peak	Low	
12N/28E-11J01	UPRG	Irrigation	Oct.?	May	1
12N/29E-01A01	SDLM	Pumping	*	*	5?
12N/29E-01E01	UPRG	Irrigation	*	*	<1
12N/29E-03R01	UPRG	Irrigation	*	*	2
12N/29E-15A01	PSCO	Irrigation	Sept.?	Apr.?	2
12N/29E-15D01	UPRG	Irrigation	Sept.?	Apr.?	3
12N/29E-25D01	UPRG	Irrigation	Sept.?	Mar.-Apr.	5
12N/29E-28F01	SDLM	Pumping	Mar.?	Sept.?	5
12N/30E-01M03	PSCO+SDLM	Wasteway	Nov.?	*	<1
12N/30E-11G01	PSCO+SDLM	Wasteway	Sept.?	Mar.?	10
12N/30E-11H01	PSCO+SDLM	Wasteway	Sept.?	Mar.?	7
12N/30E-18D01	UPRG	Canal	Sept.-Oct.	Mar.-Apr.	8
12N/30E-23G01	PSCO	Wasteway	Sept.	Mar.	4
12N/30E-26Q01	PSCO+SDLM	Wasteway	Sept.-Oct.	Mar.-Apr.	3
12N/30E-30R01	DUNE+SDLM	Irrigation	*	*	1
12N/30E-35A01	PSCO	Wasteway	Sept.	Mar.-Apr.	3
12N/30E-35H01	PSCO+SDLM	Wasteway	Sept.-Oct.	Mar.	2
13N/28E-03A01	PLUS+UPRG	Canal	Sept.	Mar.	4
13N/28E-03N01	PLUS+UPRG	Irrigation	Sept.	Mar.	3
13N/28E-14B01	UPRG	Canal	Sept.?	Mar.	11
13N/28E-16J01	UPRG	Irrigation	*	*	*
13N/28E-22B01	PLUS+UPRG	Canal	*	Mar.	5
13N/29E-03C01	SDLM	Pumping	*	*	22
13N/29E-04A02	PSCO	Canal	Aug.-Sept.	Mar.	4
13N/30E-16G01D2	SDLM	Canal	Sept.-Oct.	Mar.-Apr.	14
13N/30E-30H01	PSCO+UPRG	Canal	Sept.	Mar.	6
14N/27E-26E01	DUNE+TCHT+UPRG	Wasteway	*	Mar.	1
14N/27E-26M01	TCHT+UPRG	Wasteway	*	*	<1
14N/27E-27A01	TCHT+UPRG	Wasteway	Nov.	Mar.?	<1
14N/28E-30D01	TCHT	Wasteway	Sept.?	Mar.?	<1
14N/28E-30M01	ALVM+TCHT	Wasteway	*	*	<1
14N/28E-30N01	ALVM+TCHT+UPRG	Wasteway	*	*	<1
14N/29E-09B02	SDLM+WNPM	Canal	*	May?	8
14N/29E-21A01	TCHT+UPRG	Irrigation	*	*	<1
14N/29E-28A01	UPRG	Canal	Sept.	Mar.-Apr.	9

Table 23.--*Summary of seasonal trends in water levels in Franklin County wells, April 1986 through May 1987*
[--, not calculated if number of wells is less than ten]

Dominant influence[1]	Number of wells	Water-level trend		Magnitude of seasonal change (in feet)				
		Peak	Low	Minimum	25th percentile	Median	75th percentile	Maximum
Pumping:								
All wells	27	Feb.-Apr.	Sept.-Oct.	<1	3	5	6	95
Sediments	18	Feb.-Apr.	Sept.-Oct.	<1	2	4	5	16
Basalts	9	Feb.-Mar.	Sept.	5	--	10	--	95
Canal:								
All wells	19	Aug.-Oct.	Mar.-May	1	3	5	8	14
Sediments	16	Aug.-Oct.	Mar.-Apr.	1	3	5	7	11
Basalts	3	Sept.-Oct.	Mar.-May	8	--	11	--	14
Applied irrigation[2]								
Sediments	25	Aug.-Nov.	Mar.-May	<1	1	2	3	7
Wasteway[2]								
Sediments	22	Sept.-Nov.	Mar.-May	<1	<1	3	6	10

[1]Sediments, all aquifers above basalts (except Ellensburg Formation) and wells open to both sediments and basalts; Basalts, all basalt aquifers plus overlying Ellensburg Formation.

[2]No wells completed in basalt.

LONG-TERM CHANGES IN GROUND-WATER LEVELS

The development of the water resources in the study area has resulted in dramatic changes in ground-water levels. Figure 48 shows an approximation of the predevelopment water table and figure 26 shows the water table as of March 1986. In parts of the study area (particularly where development began in the late 1800s or early 1900s), no predevelopment water-table data are available. Where no predevelopment water-level data are available, the earliest pre-1950 data were used. The rise in the water table from predevelopment to March 1986 is depicted on figure 49.

The history of water-level changes in the study area is shown through 107 long-term hydrographs (plate 1), summarized in table 24. In the table each hydrograph is separated into periods of constant rates of water-level change. The indicated trends in the table are estimated to the nearest 0.5 ft/yr.

The most recent water-level data (1986-91) indicate that most of the study area has reached a state of dynamic equilibrium. Eighty-nine of the wells in table 24 have sufficient record to determine water-level trends through at least 1987. Of these, 59 indicate equilibrium conditions, 22 indicate rising water levels, and 8 indicate declining water levels (fig. 50).

The only area experiencing significant declines in water levels is the Red Mountain-Badger Mountain area. Water-level declines of 0.5 to 2.5 ft/yr were occurring in the Saddle Mountains and Wanapum Basalts in the Red Mountain-Badger Mountain area as of 1987-88. In parts of the Smith Canyon area and nearby parts of the Pasco Greenbelt, water-level declines of 0.5 to 4.5 ft/yr were occurring in the Pasco gravels and Saddle Mountains Basalt as of 1988. More recent water-level data (1988-91) indicate that the declines in the Smith Canyon area have apparently halted.

The areas experiencing recent significant rises in water levels are most of the KID, the White Bluffs area in northwest Franklin County, the Smith Canyon area and nearby parts of the Pasco Greenbelt, and parts of the SCBID. Water-level rises of 1 to 3 ft/yr were occurring in the KID in the central and eastern parts of Badger Coulee as of 1987-89. In the Badger East and Division Four parts of the KID, water-level rises of 0.5 to 1 ft/yr were occurring as of 1987-88. The water-level rises in the KID were observed in hydrographs of wells tapping the Pasco gravels and Saddle Mountains Basalt. Similar rises were probably also occurring in the overlying Touchet Beds, although no long-term hydrographs are available for this unit.

In the White Bluffs area, particularly where wasteways and wastewater ponds are located, water levels were rising as of 1991 at a rate of 0.5 ft/yr. These rises were occurring in the Touchet Beds and upper Ringold Formation.

As of 1991, water levels were rising 0.5 to 1 ft/yr in the Pasco gravels and Saddle Mountains Basalt in the Smith Canyon area and nearby parts of the Pasco Greenbelt. Water-levels were declining in these areas until 1988.

Hydrographs of wells in Blocks 16, 17, and 23 of the SCBID indicate a mixture of equilibrium conditions and rising water levels as of 1987. In Block 16, all of the wells tapping the shallow water-table unit (upper Ringold Formation or Pasco gravels) were at equilibrium, while some of the deeper wells tapping confined units (middle Ringold Formation or Saddle Mountains Basalt) were experiencing water-level rises of 1 to 2.5 ft/yr. In Block 17, one of the two hydrographs of wells tapping the shallow water-table unit (upper Ringold Formation) indicates a water-level rise of 1.5 ft/yr, while the other shallow-well hydrograph and the single hydrograph of a well tapping the deeper confined unit (Saddle Mountains Basalt) were at equilibrium. In Block 23, all of the hydrographs are from wells tapping the shallow, water-table unit (upper Ringold Formation). Three of the four hydrographs in Block 23 indicate equilibrium conditions as of 1987, and the fourth indicates a rise of 0.5 ft/yr.

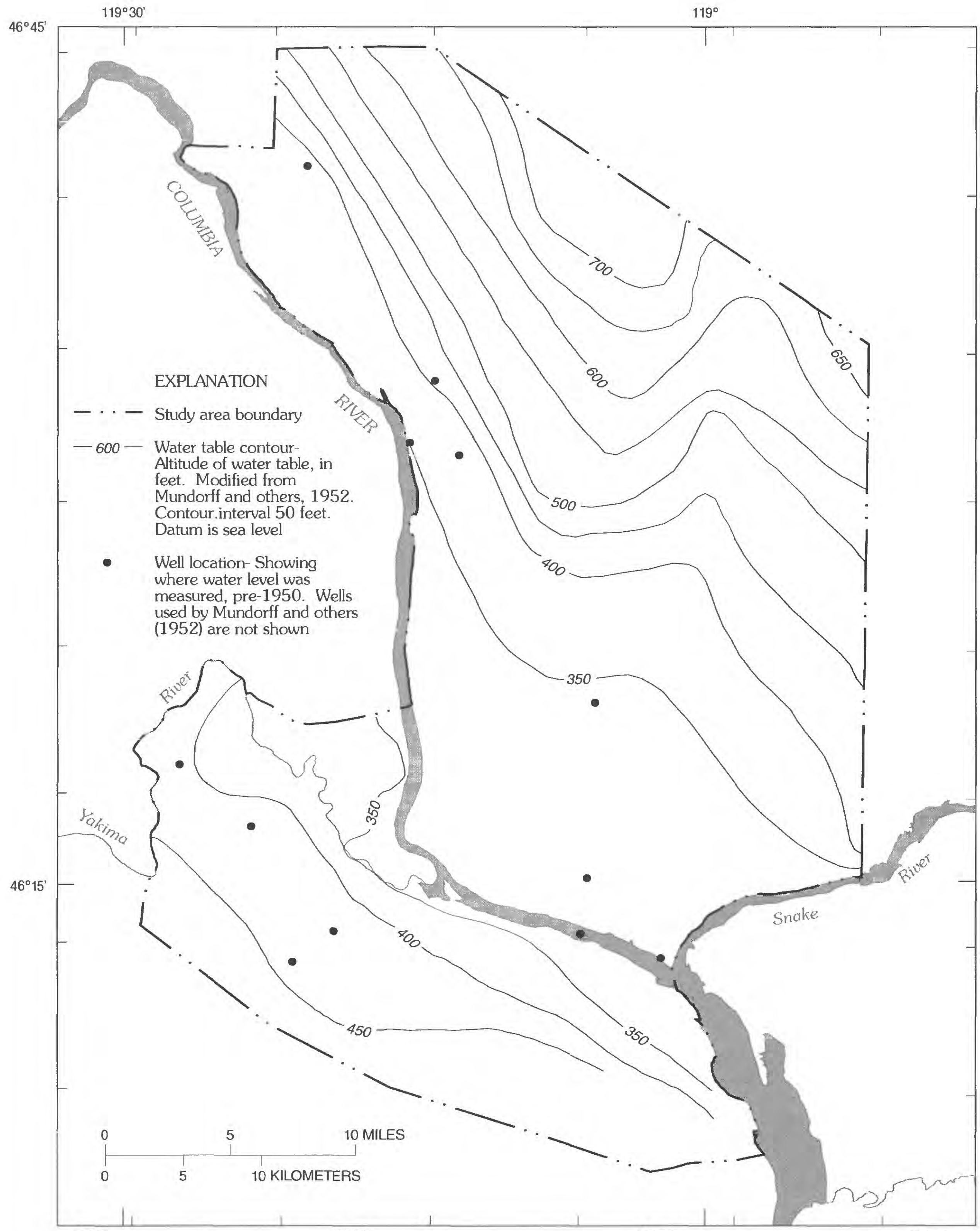


Figure 48.--Approximation of predevelopment water-table altitude in the study area.

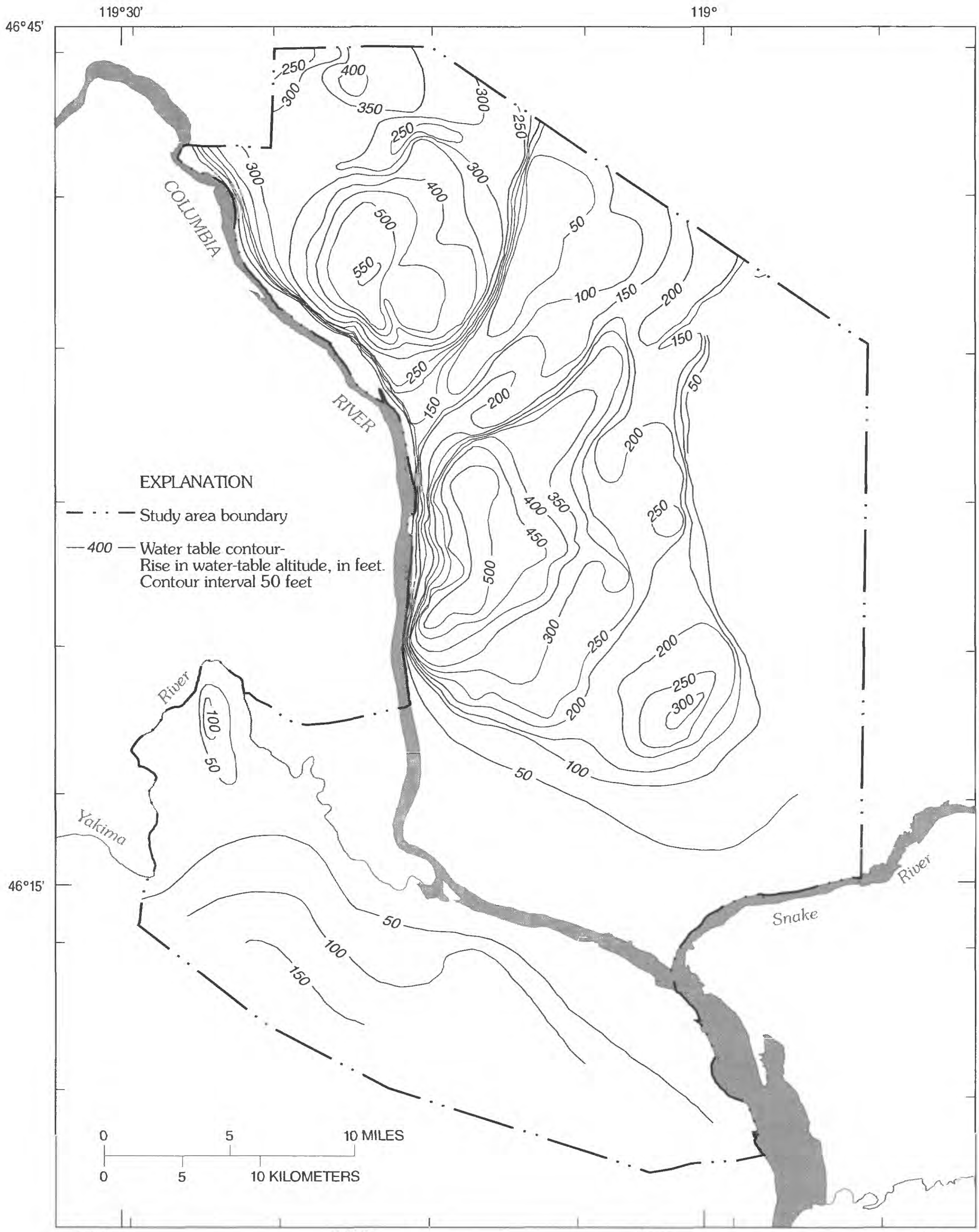


Figure 49.--Rise in the water-table altitude in the study area, predevelopment through March 1986.

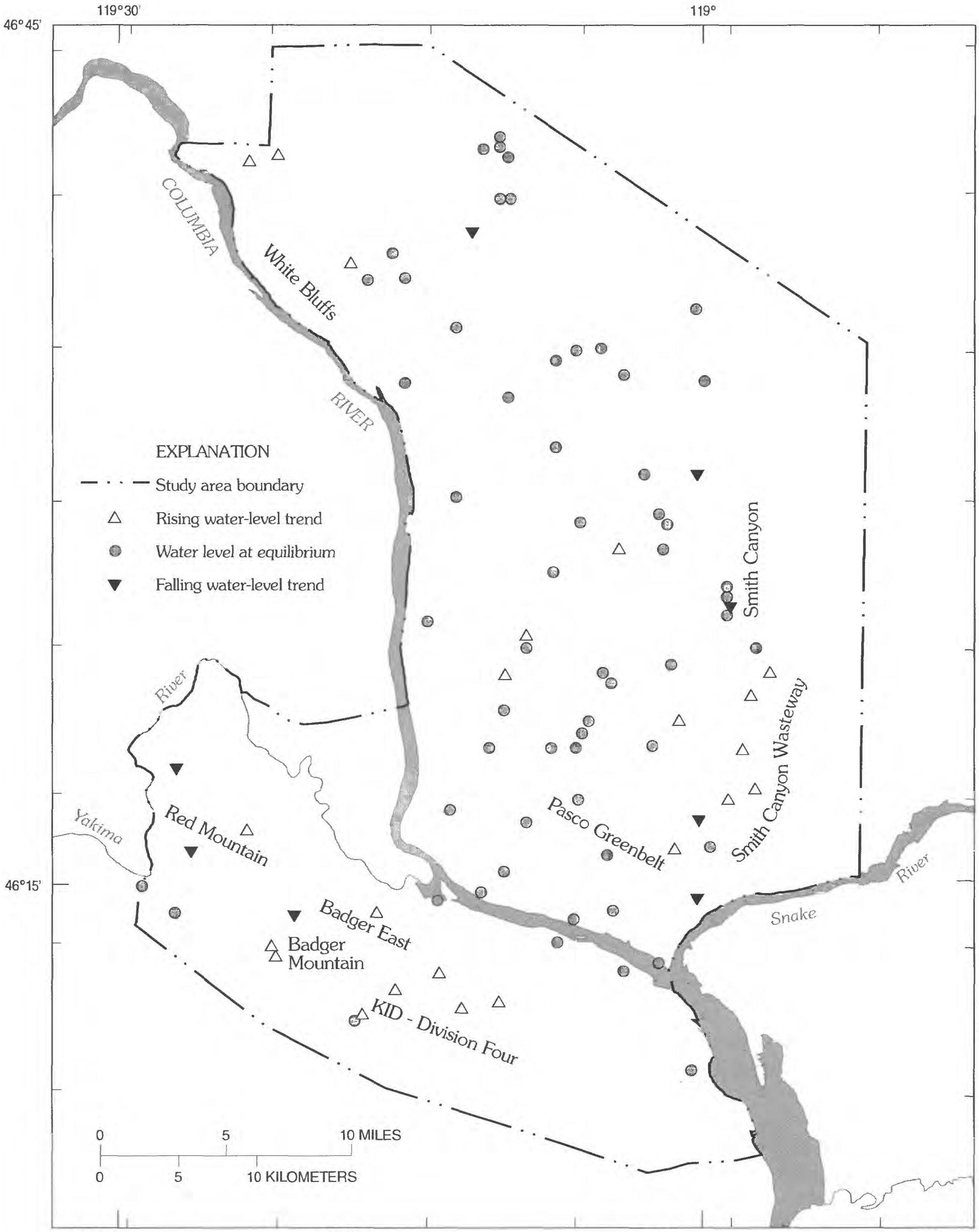


Figure 50.--Status of water levels as of 1987.

GROUND-WATER BUDGETS

Ground-water budgets have been calculated for both predevelopment and 1986 conditions in the study area. Some of the individual components of these budgets are best estimates based on incomplete data. However, the water budgets reveal significant insight into the present dynamics of the ground-water system and how the system has changed with time.

Conditions in 1986

Under 1986 conditions, the ground-water budget of the study area is expressed as:

$$GW_{in} + R = D + \Delta S \quad , \qquad (4)$$

where

GW_{in} = ground-water inflow to the study area,
R = recharge,
D = discharge,
ΔS = change in ground-water storage.

Recharge to the ground-water system occurs from precipitation, river infiltration, applied irrigation, canal seepage, and artificial-recharge basins. Discharge from the ground-water system occurs as flow to rivers, drains, springs, and seepage faces, as evapotranspiration, and by pumping from wells. A more detailed representation of the ground-water budget in the study area is

$$GW_{in} + R_{ppt} + R_{irr} + R_{can} + R_{art} = D_{riv} + D_{dra} + D_{spr} + D_{ppg} + \Delta S \qquad (5)$$

where

R_{ppt} = precipitation recharge,
R_{riv} = river-infiltration recharge,
R_{irr} = irrigation recharge,
R_{can} = canal-seepage recharge,
R_{art} = artificial-recharge basin recharge,
D_{riv} = discharge to rivers,
D_{dra} = discharge to drains,
D_{spr} = discharge to springs and seepage faces,
D_{ppg} = pumping from wells,
ΔS = change in ground-water storage.

The configuration of the water table (fig. 26) and water levels in the deeper aquifers (Wanapum Basalt (fig. 28) and Grande Ronde Basalt (Bauer and others, 1985)) indicate those areas where ground water flows into the study area. The only significant inflows occur along the northern and northeastern boundaries of the study area in Franklin County. The southern boundary coincides with the crest of the Horse Heaven Hills (plate 1), which is a ground-water divide. The southeastern boundary and most of the western boundary are composed of the Snake and Columbia Rivers, which are the discharge areas for ground-water flows on each side of the rivers. Ground water could flow into the project area along the part of the southwestern boundary represented by the Yakima River; however, the available water-level data indicate that this flow is probably small.

Ground-water inflow can be estimated using Darcy's Law. Hydraulic gradients can be obtained from the water-table and water-level maps, aquifer thicknesses from Drost and Whiteman (1986), and horizontal hydraulic conductivities (median values) from table 5 for all units except the Grande Ronde Basalt. For the Grande Ronde Basalt, a median hydraulic conductivity of 4.9 ft/d and a saturated thickness of 2,000 ft were used (Hansen and others, 1992). The resulting estimate of total ground-water inflow to the study area is 61,000 acre-ft/yr.

Substituting the estimated values for each of the factors into equation 5 yields the following (all values in thousands of acre-ft/yr)

$$GW_{in} + R_{ppt} + R_{irr} + R_{can} + R_{art} = D_{riv} + D_{dra} + D_{spr} + D_{ppg} + \Delta S$$

$$61 + 40 + 2.4 + 110 + 170 + 8 = 63 + 130 + 57 + 130 + \Delta S$$

$$390 = 380 + \Delta S \qquad (6)$$

The result indicates that ground-water storage (ΔS) is increasing by about 10,000 acre-ft/yr. The ground-water system is apparently near equilibrium. Recent water-level trends (see section on long-term water-level changes) support a conclusion of approximate equilibrium in regard to the overall water-level conditions in the study area. However, many of the numbers in the water budget are estimates whose accuracies are unknown.

Predevelopment Conditions

Under predevelopment conditions, the ground-water budget of the study area can be represented by

$$GW_{in} + R = D \quad . \tag{7}$$

The ground-water system was presumably in equilibrium in predevelopment times; therefore, no storage-change factor is needed in the equation.

In predevelopment times, the only recharge to the ground-water system was from precipitation and river infiltration, and the only discharge was flow to the rivers. Therefore, a more detailed representation of the predevelopment ground-water budget of the study area is

$$GW_{in} + R_{ppt} + R_{riv} = D_{riv} \quad . \tag{8}$$

The configuration of the predevelopment water table (fig. 48) indicates the areas where ground water flowed into the study area. The only significant inflows occurred along the northern and northeastern boundaries of the study area in Franklin County. Although there are no predevelopment water-level maps for the deeper aquifers, the available data indicate that the areas of ground-water inflow in the deeper aquifers were probably similar to the areas of inflow in the water-table aquifer. Predevelopment ground-water inflow was estimated using Darcy's Law. Hydraulic gradients were obtained from the predevelopment water-table map (fig. 48) (and estimated from data for the deeper aquifers), aquifer thicknesses from Drost and Whiteman (1986), and horizontal hydraulic conductivities (median values) from table 5. For the Grande Ronde Basalt, a median hydraulic conductivity value of 4.9 ft/d and a saturated thickness of 2,000 ft were used (Hansen and others, 1992). The resulting estimated predevelopment ground-water inflow to the study area is 32,000 acre-ft/yr.

Predevelopment ground-water recharge from precipitation can be calculated by the RASA recharge model (see section on precipitation recharge). This model calculation results in an estimated recharge of 21,000 acre-ft/yr, which is about one-half of the rate that occurs under present development. This difference is due to the soil moisture supplied by irrigation. Under undeveloped conditions, most of the fall and winter precipitation replenishes the soil moisture. Under developed conditions, the fall and winter precipitation falls on soils that are mostly saturated, and much of the precipitation becomes recharge.

The predevelopment water-table map indicates that the Yakima River was probably the only river that recharged the ground-water system in predevelopment times. From near Benton City to about Horn Rapids, water from the Yakima River probably infiltrated to highly permeable basalts of the Saddle Mountains Basalt. From Horn Rapids to near Richland, water from the Yakima River probably infiltrated to the Pasco gravels.

An estimate of river-infiltration recharge from the Yakima River can be made using Darcy's Law. Lateral hydraulic conductivities can be taken from table 5 (median value for the Pasco gravels and the 75th percentile for the Saddle Mountains Basalt). The 75th percentile is used for the Saddle Mountains Basalt because the basalt is believed to be highly permeable in this area (Brown, 1979). Vertical hydraulic conductivities are estimated at one one-hundredth of the horizontal values. Using hydraulic gradients from the predevelopment water-table map (fig. 48), river widths from 7-1/2-minute quadrangle maps, and an estimated river depth of 5 ft, predevelopment river-infiltration recharge was estimated at about 3,100 acre-ft/yr along a 19.1 mi reach of the Yakima River. This was calculated by dividing the recharging part of the river into 11 segments, each of which had constant geology, hydraulic gradient, and river width.

Substituting the estimated values for each of the factors into equation 8 yields the following (all values in thousands of acre-ft/yr):

$$GW_{in} + R_{ppt} + R_{riv} = D_{riv}$$

$$32 + 21 + 3.1 = D_{riv} = 56 \quad . \tag{9}$$

CAUSES OF CHANGES IN GROUND-WATER BUDGETS AND LEVELS

The ground-water budget of the study area changed dramatically from predevelopment time to 1986. The annual flow through the ground-water system increased about seven-fold, from 56,000 acre-ft/yr to 390,000 acre-ft/yr.

In response to this increased flow, the ground-water system adjusted. Increased storage of water in the ground (with associated higher water levels) and a greater rate of discharge from the ground-water system were the primary adjustments. From equations 6 and 9, recharge increased through time (both in amount and types), resulting in increases in discharge (both in amount and types). As of 1986, the ground-water system appeared to be near dynamic equilibrium; the evidence suggests that there is no ongoing change in storage. However, between predevelopment time and 1986, large changes in ground-water storage and associated ground-water levels occurred.

An estimate of the total change in storage can be obtained using the change in the water table from predevelopment to 1986 (fig. 49) and the storage coefficients of each of the aquifers. Multiplying the area between water-level change contours by the average water-level change and again by the storage coefficient of the appropriate aquifer material, yields a change in storage for that area. Repeating this procedure for the entire study area results in an estimated total increase in storage of about 5,000,000 acre-ft. During the period of development (approximately 1950-86), the average annual increase in storage has been approximately 140,000 acre-ft.

As can be seen from the ground-water budgets, recharge from canal seepage and applied irrigation account for about 85 percent of the increase in flow in the ground-water system from predevelopment to 1986. These two factors were primarily responsible for the change in storage and rise in water levels in the study area.

The change in ground-water flow from predevelopment to 1986 was probably not a linear progression. The total recharge from applied irrigation undoubtedly increased as irrigated acreage increased, but the recharge per acre probably decreased as irrigators became more efficient (for example, changing from rill irrigation to sprinklers). Recharge from canal seepage certainly increased as more canals were added to the irrigation systems, but the recharge per square foot of canal bed decreased as more of the canals were lined. These changes in the major components of the ground-water system through time make it difficult to identify precisely how much of the change in water levels is attributable to each factor. However, it is apparent that canal seepage and applied irrigation are responsible for the vast majority of the change in water levels.

GEOHYDROLOGIC FACTORS TO BE CONSIDERED REGARDING MANAGEMENT OF WATER RESOURCES

The greatest problems that confront water managers in the study area are shallow water tables and large concentrations of nitrate in the ground water. As has been shown in this report, the primary cause of shallow ground water is excess recharge from canal seepage and applied irrigation. The sources of nitrate in the study area's ground water are discussed by Ebbert and others (1996).

Measures have been taken in much of the study area to address the problem of shallow ground water. Drain systems have been installed to maintain the water table at some desired depth (generally below the root zone of crops), and many more miles of drains might be needed in the future to lower water tables in parts of the study area. However, the installation of drains deals only with the effects, not the causes. Reducing excess recharge could reduce the area affected by shallow ground water and would reduce the need for drain systems.

A guide for irrigators has been prepared by the Franklin Conservation District (1989) which shows how the proper timing and amount of irrigation can result in much less recharge to the ground-water system with no loss in agricultural productivity. This guide also indicates the water-quality advantages of decreasing applied irrigation recharge.

Excessive recharge from canal seepage can be reduced by lining canals. Approximately 69 percent of the irrigation canals in the study area are unlined (table 11), and seepage from unlined canals occurs at nearly 60 times the rate from lined canals (table 12).

Undesirable effects of reducing recharge and lowering water levels include increased pumping lifts and decreased ground-water availability. Throughout much of the study area, domestic water supplies are obtained from shallow wells, and in some locations significant amounts of irrigation and industrial water supplies are obtained from the shallow ground-water system. A significant reduction in ground-water recharge could adversely affect these water uses.

In the case of reducing canal seepage, a significant undesirable consequence is possible. The recharge from canal seepage acts as a diluting factor in regard to ground-water nitrate concentrations (Ebbert and others, 1996). Decreasing canal seepage could lead to greater nitrate concentrations in the study area's ground water. Ebbert and others (1996) includes a detailed explanation of the relationship between canal seepage and nitrate concentrations in the study area's ground water.

SUMMARY

Over the past 40 years, use of the Pasco Basin of south-central Washington has changed from rangeland and dryland farming to irrigated agriculture. Extensive irrigation, primarily with imported surface water, has transformed the area into one of the most productive agricultural lands in the United States. Irrigation has also caused water levels to rise several hundred feet over much of the irrigated area, resulting in large areas in which shallow water tables have created problems: waterlogged soils, landslides, and elevated concentration of nitrate in ground water.

The annual flow through the ground-water system has increased seven-fold over predevelopment conditions: from a predevelopment rate of about 56,000 acre-feet per year to about 390,000 acre-feet per year by 1986. The ground-water system has apparently reached equilibrium. Ground-water storage has increased by about 5,000,000 acre-feet from predevelopment conditions.

The major changes in the ground-water system have been the result of increased recharge from canal seepage and applied irrigation. Together they account for about 85 percent of the total increase in flow through the ground-water system. More efficient irrigation practices and increased use of liners in irrigation canals could significantly reduce the recharge to the ground-water system. This in turn would lead to a lower water table and decrease the need for drain systems. However, decreased canal seepage would probably lead to increases in nitrate concentrations in ground water.

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Table 24.--*Summaries of long-term hydrographs*

[ft/yr; feet per year; ?, unknown or accuracy of value given uncertain]

Hydrologic unit:

C	= Confined;	RGLD	= undifferentiated Ringold Formation;
D	= Dry;	SDLM	= Saddle Mountains Basalt;
U	= Unconfined;	TCHT	= Touchet Beds;
LRRG	= lower Ringold Formation;	UPRG	= upper Ringold Formation;
MDRG	= middle Ringold Formation;	WNPM	= Wanapum Basalt
PSCO	= Pasco gravels;		

Well use: H = domestic; I = irrigation; N = industrial; O = observation; S = stock; U = unused

Open interval: Values shown indicate shallowest and deepest points at which well is open to the aquifer. Well is not necessarily open to entire interval indicated. Values shown as "@" indicate open-ended casing at the value given.

Feature: The element of the hydrologic system assumed most significant in the area of the well during the time period of interest. Locations of features are shown on plate 1 or figures 6 or 50.

Columbia River-CID	=	In Columbia Irrigation District and near the Columbia River
Columbia River-FCID	=	In Franklin County Irrigation District and near the Columbia River
Dryland farming	=	In area of dryland farming
Esquatzel Coulee	=	In Esquatzel Coulee upstream of the Esquatzel Coulee Wasteway
Esquatzel Coulee WW	=	In the part of Esquatzel Coulee containing the Esquatzel Coulee Wasteway
KID-Badger Coulee	=	In Badger Coulee within the Kennewick Irrigation District
KID-Badger East	=	Downgradient of Badger East Lateral, outside of Badger Coulee
KID-Division Four	=	In Division Four area of Kennewick Irrigation District (Division Four is area downstream of the Amon Pump Station)
Lake Wallula-CID	=	In Columbia Irrigation District and near Lake Wallula
Lake Wallula-FCID	=	In Franklin County Irrigation District and near Lake Wallula
Pasco Greenbelt	=	Area of significant irrigation pumping to the south and southeast of South Columbia Basin Irrigation District
Red Mtn.-Badger Mtn.	=	General area of significant irrigation pumping, extending from near Red Mountain to Badger Mountain
SCBID-Block #	=	In indicated Block in South Columbia Basin Irrigation District
SCBID-Dryland farming	=	In area of dryland farming, downgradient of South Columbia Basin Irrigation District
SCBID-FCID	=	In Franklin County Irrigation District, downgradient of South Columbia Basin Irrigation District
Smith Canyon	=	In Smith Canyon upstream of the Smith Canyon Wasteway
Smith Canyon WW	=	In Smith Canyon downstream of the Smith Canyon Wasteway
White Bluffs-WB10WW	=	In the area above the White Bluffs in northwest Franklin County, where no irrigation takes place, but where irrigation wasteways and wastewater ponds are located
Yakima River	=	Near Yakima River

Period of record: *, discontinuous record. Intervals in which there are no water-level measurements for at least one calendar year.

Rate of change of water level: +, rising; -, declining; 0, at equilibrium

Table 24.--*Summaries of long-term hydrographs--Continued*

Local well number	Hydrologic unit	Well use	Open interval (feet below land surface)	Feature	Period of record used to compute rate of change of water level	Rate of change of water level (ft/yr)
08N/28E-06M01	SDLM-C?	H	? - 265	KID-Badger Coulee	1972-89*	+3
08N/28E-11R01	SDLM-U	H	28 - 320	KID-Badger Coulee	1977-84*	+8
	--do--			--do--	1984-87*	+1.5
08N/28E-15P01	PSCO-U/C	H	103 - 108	KID-Badger Coulee	1977-88*	+2
08N/28E-22D07	PSCO-C	H	? - 156	KID-Badger Coulee	1967-86*	+3.5
	--do--			--do--	1986-89	0?
08N/29E-07B01	PSCO-U	H	@154	KID-Division Four	1976-88*	+1
08N/29E-15Q01	SDLM-U, WNPM-C	U	92 - 760	KID-Division Four	1977-84*	+8
	--do--			--do--	1984-85	+3
08N/29E-16H01	SDLM-C, WNPM-C	H	? - 388	KID-Division Four	1978-86*	+3
	--do--			--do--	1986-87	+0.5
08N/29E-17L01	SDLM-U	H	112 - 352	KID-Division Four	1974-88*	+1
08N/30E-03L01	PSCO-U	O	? - 38	Columbia River	1946-53*	+.5
	--do--			Lake Wallula	1953-54	+12
	--do--			--do--	1954-57	+1
	--do--			--do--	1957-87	0
08N/30E-08A01	PSCO-U	O	? - 9	Columbia River-CID	1946-52	0
	--do--			--do--	1952-53	-2
	--do--			Lake Wallula-CID	1953-87*	0
08N/30E-26Q03	PSCO-U	O	? - 15	Lake Wallula-CID	1947-87*	0
09N/27E-11H01	SDLM-C	I	70 - 104	KID-Badger East	1968-88*	+.5
09N/27E-16B01	SDLM-U	H	285 - 290	Red Mtn.-Badger Mtn.	1977-84*	-2.5
	--do--			--do--	1984-87*	-.5
	--do--			--do--	1987-88	-2?
09N/27E-19G01	PSCO-C	I	@ 27	Yakima River	1940-51	0
	--do--			--do--	1951-52	-4
	--do--			--do--	1952-57	0
	--do--			KID-Badger Coulee	1957-62	+1
09N/27E-19K01	PSCO-C, SDLM-C	H	110 - 143	KID-Badger Coulee	1979-87*	0
09N/27E-29J03	PSCO-U	H	96 - 98	KID-Badger Coulee	1979-87*	0

Table 24.--*Summaries of long-term hydrographs--Continued*

Local well number	Hydrologic unit	Well use	Open interval (feet below land surface)	Feature	Period of record used to compute rate of change of water level	Rate of change of water level (ft/yr)
09N/27E-36R02	PSCO-U/C	U	@153	KID-Badger Coulee	1978-86*	+5
	PSCO-C			--do--	1986-88	+1
09N/28E-20B01	SDLM-U, WNPM-C	I	? - 446	KID-Badger East	1960-84*	+3
09N/28E-26M01	SDLM-U/C	H	102 - 272	KID-Badger East	1972-87*	+1
09N/28E-30J01	WNPM-C	I	686 - 800	Red Mtn.-Badger Mtn.	1978-87*	-2.5
09N/29E-06J01	RGLD?-C?	H	? - 207	SCBID-Block 1	1960-68*	+.5
	--do--			--do--	1968-87*	0?
09N/29E-11D01	PSCO-U, LRRG-C	O	20 - 207	SCBID-Dryland frmg	1954-73*	+.5
	--do--			Pasco Greenbelt	1973-76	0
	--do--			--do--	1976-77	-2
	--do--			--do--	1977-88*	0
09N/29E-15N01	PSCO-U	O	64 - 79	SCBID-FCID	1955-74*	+.5
	--do--			--do--	1974-78	-1
	--do--			--do--	1978-91	0
09N/29E-21P01	PSCO-U	O	? - 33	Columbia River-FCID	1950-53	0
	--do--			Lake Wallula-FCID	1953-54	+5
	--do--			--do--	1954-87	0
09N/29E-25D01	PSCO-U	U	@ 45	Columbia River-FCID	1940-52*	0
	--do--			Lake Wallula-FCID	1952-56	+1.5
	--do--			--do--	1956-60	0
09N/29E-25R01	PSCO-U	O	? - 27	Columbia River-FCID	1950-53	0
	--do--			Lake Wallula-FCID	1953-54	+2
	--do--			--do--	1954-87	0
09N/29E-30C01	PSCO-U	O	? - 12	Lake Wallula-CID	1954-87*	0
09N/29E-36P01	PSCO-U	O	? - 24	Columbia River-CID	1950-53	-1.5
	--do--			Lake Wallula-CID	1953-63	0
	--do--			--do--	1963-64	-1.5
	--do--			--do--	1964-73	0
	--do--			--do--	1973-75	-1
	--do--			--do--	1975-87*	0
09N/30E-02R01	SDLM-C	H	178 - 211	SCBID-Dryland frmg	1962-84*	+2
	--do--			Pasco Greenbelt	1984-88	-1?

Table 24.--*Summaries of long-term hydrographs--Continued*

Local well number	Hydrologic unit	Well use	Open interval (feet below land surface)	Feature	Period of record used to compute rate of change of water level	Rate of change of water level (ft/yr)
09N/30E-06D01	PSCO-U	O	20 - 105	Esquatzel Coulee WW	1954-74*	+1.5
	--do--			Pasco Greenbelt	1974-77	-2.5
	--do--			--do--	1977-91	0
09N/30E-12P01	PSCO-U	O	20 - 100	Smith Canyon WW	1954-75*	+3
	--do--			--do--	1975-78	-4
	--do--			--do--	1978-85	0
	--do--			--do--	1985-89	-1.5
	--do--			--do--	1989-91	0
09N/30E-14D01	PSCO-U	O	20 - 180	SCBID-Dryland frmg	1954-75*	+3
	--do--			Pasco Greenbelt	1975-78	-3.5
	--do--			--do--	1978-81	0
	--do--			--do--	1981-86*	-.5
	--do--			--do--	1986-89	-1.5
	--do--			--do--	1989-91	+.5
09N/30E-17C01	PSCO-U	O	82 - 97	Esquatzel Coulee WW	1956-62	0
	--do--			--do--	1962-73	+1
	--do--			Pasco Greenbelt	1973-77	-1
	--do--			--do--	1977-86	0
	--do--			--do--	1986-89	-1
	--do--			--do--	1989-91	0?
09N/30E-18J01	SDLM-C	U	227 -1,033	Dryland farming	1942-54	0?
	--do--			Esquatzel Coulee WW	1954-68*	+1
	--do--			Pasco Greenbelt	1968-85*	0
09N/30E-26A01	PSCO-U, SDLM-C	O	20 - 68	Smith Canyon WW	1954-74*	+1.5
	--do--			--do--	1974-78	-1.5
	--do--			--do--	1978-86*	0
	--do--			--do--	1986-91	-.5
09N/30E-26K01	PSCO-U	O	70 - 85	SCBID-Dryland frmg	1955-70*	+1
	--do--			--do--	1970-76	0
	--do--			Pasco Greenbelt	1976-78	-1.5
	--do--			--do--	1978-85	0
09N/30E-29K01	PSCO-U	O	45 - 59	Esquatzel Coulee WW	1956-61	0
	--do--			--do--	1961-72	+.5
	--do--			--do--	1972-91	0
09N/31E-04N01	SDLM-U	H	? - 343	SCBID-Dryland frmg	1958-71*	+2
	--do--			--do--	1971-81	0

Table 24.--*Summaries of long-term hydrographs--Continued*

Local well number	Hydrologic unit	Well use	Open interval (feet below land surface)	Feature	Period of record used to compute rate of change of water level	Rate of change of water level (ft/yr)
09N/31E-06D01	PSCO-D/U, UPRG-U/C, LRRG-U/C, SDLM-C	O	20 - 120	Smith Canyon WW	1954-75*	+4
	PSCO-U, UPRG-C, LRRG-C, SDLM-C			--do--	1975-78	-3.5
	--do--			--do--	1978-83	0?
	--do--			--do--	1983-84	+1
	--do--			--do--	1984-88*	-1.5
	--do--			--do--	1988-91	+.5
10N/27E-29R02	SDLM-U	H	244 - 330	Red Mtn.-Badger Mtn.	1979-87*	-1
10N/29E-02D01	UPRG-U	H	69 - 102	SCBID-Block 16	1960-68*	+3.5
	--do--			--do--	1968-73*	+7.5
	--do--			--do--	1973-78*	+.5
	--do--			--do--	1978-84*	0
10N/29E-03A01	UPRG-U	O	0 - 50	SCBID-Block 16	1969-74	+8.5
	--do--			--do--	1974-79	0
	--do--			--do--	1979-80	-2
	--do--			--do--	1980-87	0
10N/29E-10D01	SDLM-U	H	291 - 618	SCBID-Block 16	1953-58*	+1.5
	SDLM-U/C			--do--	1958-85*	+7
	SDLM-C			--do--	1985-87	+2.5
10N/29E-15M01	SDLM-U/C	H	195 - 350	SCBID-Block 16	1959-60	+54
	SDLM-C			--do--	1960-85*	+3
	--do--			--do--	1985-87	0
10N/29E-25A01	UPRG-D/U, MDRG-U/C, SDLM-C	O	20 - 136	Esquatzel Coulee WW	1954-58*	+1
	PSCO-D/U,UPRG-U/C, MDRG-C,SDLM-C			--do--	1958-68*	+8.5
	PSCO-U,UPRG-C, MDRG-C,SDLM-C			--do--	1968-91*	0?
10N/29E-26A01	UPRG-D/U, SDLM-U/C	O	20 - 76	SCBID-Dryland frmg	1954-63*	+.5
	UPRG-U, SDLM-C			--do--	1963-68*	0
	--do--			Pasco Greenbelt	1968-81	+1.5
	--do--			--do--	1981-87	0
	--do--			--do--	1987-89	-.5
	--do--			--do--	1989-91	0

Table 24.--*Summaries of long-term hydrographs--Continued*

Local well number	Hydrologic unit	Well use	Open interval (feet below land surface)	Feature	Period of record used to compute rate of change of water level	Rate of change of water level (ft/yr)
10N/29E-28B01	PSCO-U	O	20 - 172	SCBID-Block 1	1956-73*	+.5
	--do--			--do--	1973-91	0
10N/30E-03J01	SDLM-U/C	H	70 - 230	SCBID-Block 17	1965-85*	+7
	SDLM-C			--do--	1985-87	0
10N/30E-05N01	PSCO-U	O	0 - 50	SCBID-Block 16	1954-56	+7.5
	--do--			--do--	1956-91	0
10N/30E-08F01	PSCO-U,SDLM-C	O	20 - 64	Esquatzel Coulee WW	1954-68*	+2.5
	--do--			--do--	1968-91*	0
10N/30E-14N01	UPRG-U	O	5 - 50	SCBID-Block 17	1985-87	+5.5
	--do--			--do--	1987-90	+2
	--do--			--do--	1990-91	+1.5
10N/30E-18Q02	PSCO-?,SDLM-?	O	20 - 89	Esquatzel Coulee WW	1954-68*	+5.5
	PSCO-U,SDLM-C			--do--	1968-91	0
10N/30E-19E01	SDLM-U	N	? - 395	Esquatzel Coulee WW	1956-70*	+2.5
	--do--			--do--	1970-73	-1
	--do--			--do--	1973-77	+4
	--do--			--do--	1977-86*	+.5
	--do--			--do--	1986-87	0?
10N/30E-21R01	UPRG-U	O	0 - 50	SCBID-Block 17	1969-70	+17
	--do--			--do--	1970-74	+4
	--do--			--do--	1974-88	+1
	--do--			--do--	1988-91	0
10N/31E-05C01	PSCO-U	I	115 - 135	Smith Canyon	1977-85	-.5
	--do--			--do--	1985-88	-3
	--do--			--do--	1988-91	0?
10N/31E-08P02	PSCO-U	O	? - 183	Smith Canyon	1977-85	-.5
	--do--			--do--	1985-88	-4
	--do--			--do--	1988-91	+.5?
10N/31E-09D01	SDLM-U/C,WNPM-C	H	160 - 310	Smith Canyon	1959-63*	+32
	SDLM-C,WNPM-C			--do--	1963-87*	+1

Table 24.--*Summaries of long-term hydrographs--Continued*

Local well number	Hydrologic unit	Well use	Open interval (feet below land surface)	Feature	Period of record used to compute rate of change of water level	Rate of change of water level (ft/yr)
10N/31E-30A03	PSCO-U,UPRG-C, MDRG-C	O	48 - 128	Smith Canyon WW	1969-71	+6
	--do--			--do--	1971-74	0
	--do--			--do--	1974-78	-3
	--do--			--do--	1978-82	0
	--do--			--do--	1982-88*	-1.5
	--do--			--do--	1988-91	+1
10N/31E-32L02	SDLM-U	H	310 - 350	Smith Canyon WW	1979-83*	+7
	--do--			--do--	1983-87*	+4.5
11N/28E-25R02	UPRG-U	O	0 - 50	SCBID-Block 15	1969-82*	+3
	--do--			--do--	1982-85	-1.5
	--do--			--do--	1985-91	0?
11N/29E-05D01	UPRG-U	O	0 - 50	SCBID-Block 15	1965-67	+8.5
	--do--			--do--	1967-91	0
11N/29E-14R01	UPRG-U	O	0 - 50	SCBID-Block 16	1968-69	+27
	--do--			--do--	1969-73	+1
	--do--			--do--	1973-84	0
	--do--			--do--	1984-90	-.5
	--do--			--do--	1990-91	0
11N/29E-34J02	MDRG-U/C	H	@211	SCBID-Block 16	1975-80	+14.5
	MDRG-C			--do--	1980-84	+5.5
	---do---			--do--	1984-86	+4
	---do---			--do--	1986-88	+2
11N/30E-03L01	SDLM-U	H	45 - 105	SCBID-Block 13	1959-63*	+2.5
	--do--			--do--	1963-68*	+.5
	--do--			--do--	1968-87*	0?
11N/30E-06B01	SDLM-C	H	142 - 196	SCBID-Block 16	1960-63*	+6.5
	--do--			--do--	1963-73*	+1
	--do--			--do--	1973-78*	-.5
	--do--			--do--	1978-84*	+1
11N/30E-06N01	UPRG-U	O	0 - 50	SCBID-Block 16	1959-60	+23
	--do--			--do--	1960-62	+5.5
	--do--			--do--	1962-65	+1.5
	--do--			--do--	1965-68	0
	--do--			--do--	1968-72	-1

Table 24.--*Summaries of long-term hydrographs--Continued*

Local well number	Hydrologic unit	Well use	Open interval (feet below land surface)	Feature	Period of record used to compute rate of change of water level	Rate of change of water level (ft/yr)
11N/30E-06N01	UPRG-U			SCBID-Block 16	1972-76	0
	--do--			--do--	1976-83	-.5
	--do--			--do--	1983-91	0
11N/30E-10B01	SDLM-U	H	20 - 115	SCBID-Block 16	1958-60*	+13
	--do--			--do--	1960-63*	+2.5
	--do--			--do--	1963-83*	+.5
	--do--			--do--	1983-87*	0?
11N/30E-15C01	PSCO-U	H	@ 94	SCBID-Block 16	1960-63*	+2
	--do--			--do--	1963-83*	+.5
	--do--			--do--	1983-87*	0?
11N/30E-17B01	SDLM-U/C	H	26 - 100	SCBID-Block 16	1960-63*	+6
	SDLM-C			--do--	1963-68*	+.5
	---do---			--do--	1968-83*	0?
	---do---			--do--	1983-87*	+1?
11N/30E-25J01	PSCO-U	I	117 - 132	Smith Canyon	1976-87	-1
	--do--			--do--	1987-91	0?
11N/31E-19M01	PSCO-U	O	? - 155	Smith Canyon	1978-85	+1
	--do--			--do--	1985-88	-4.5
	--do--			--do--	1988-91	0?
11N/31E-19N01	PSCO-U	I	147 - 167	Smith Canyon	1978-88	-2
	--do--			--do--	1988-91	0?
11N/31E-27A01	SDLM-U,WNPM-C	S	? ->235	Dryland farming	1968-78*	0?
	--do--			--do--	1978-83*	-.5?
11N/31E-30E01	SDLM-U,WNPM-C	I	150 - 410	Smith Canyon	1978-85	-.5
	--do--			--do--	1985-87	-3
12N/28E-11J01	UPRG-U	O	0 - 51	SCBID-Block 20	1973-76	+4
	--do--			--do--	1976-78	+1
	--do--			--do--	1978-91	0
12N/29E-01A01	SDLM-U	H	128 - 313	SCBID-Block 19	1963-78*	+1.5
	--do--			--do--	1978-83*	0
	--do--			--do--	1983-84	+1.5
	--do--			--do--	1984-88	0?

Table 24.--*Summaries of long-term hydrographs--Continued*

Local well number	Hydrologic unit	Well use	Open interval (feet below land surface)	Feature	Period of record used to compute rate of change of water level	Rate of change of water level (ft/yr)
12N/29E-01E01	UPRG-U	O	6 - 50	SCBID-Block 19	1962-63	+8
	--do--			--do--	1963-67	+2
	--do--			--do--	1967-69	+8
	--do--			--do--	1969-73	0
	--do--			--do--	1973-74	+9
	--do--			--do--	1974-82	+.5
	--do--			--do--	1982-86	-1
	--do--			--do--	1986-91	0?
12N/29E-15D01	UPRG-U	O	4 - 50	SCBID-Block 19	1968-69	+12
	--do--			--do--	1969-74	+2
	--do--			--do--	1974-91	0
12N/29E-25D01	UPRG-U	O	6 - 50	SCBID-Block 14	1959-60	+10
	--do--			--do--	1960-67	+2.5
	--do--			--do--	1967-83	0
	--do--			--do--	1983-87	-1
	--do--			--do--	1987-91	0?
12N/30E-04D01	SDLM-U	H	63 - 290	SCBID-Block 14	1959-68*	+6.5
	SDLM-U/C			--do--	1968-73*	+1.5
	SDLM-C			--do--	1973-83*	0
	--do--			--do--	1983-86*	+1.5
12N/30E-08A01	SDLM-?	U	? - 392	SCBID-Block 14	1960-63*	+27
	--do--			--do--	1963-68*	+7.5
	--do--			--do--	1968-73*	+1.5
	--do--			--do--	1973-86*	+.5
	--do--			--do--	1986-87	0
12N/30E-12E01	SDLM-C	S	120 - 121	Dryland farming	1940-56*	0?
	--do--			Esquatzel Coulee WW	1956-70	+1
	--do--			--do--	1970-73	-3.5
	--do--			--do--	1973-80	0
	--do--			--do--	1980-81	-2?
	--do--			--do--	1981-88	0
12N/30E-19A01	SDLM-U	H	48 - 137	SCBID-Block 14	1960-63*	+7.5
	SDLM-U/C			--do--	1963-73*	+4.5
	SDLM-C			--do--	1973-83*	+.5
	--do--			--do--	1983-84	0?

Table 24.--*Summaries of long-term hydrographs--Continued*

Local well number	Hydrologic unit	Well use	Open interval (feet below land surface)	Feature	Period of record used to compute rate of change of water level	Rate of change of water level (ft/yr)
12N/30E-33B01	SDLM-U	H	20 - 374	SCBID-Block 13	1958-68*	+2.5
	--do--			--do--	1968-88*	0
12N/30E-35A01	PSCO-U	O	20 - 100	Esquatzel Coulee WW	1954-58*	+4.5
	--do--			--do--	1958-70*	+1
	--do--			--do--	1970-73	-1.5
	--do--			--do--	1973-84	0
	--do--			--do--	1984-91	-.5
13N/28E-14B01	UPRG-U	O	5 - 50	SCBID-Block 23	1966-73	+5
	--do--			--do--	1973-79	0
	--do--			--do--	1979-80	+9
	--do--			--do--	1980-91	0
13N/28E-16J01	UPRG-U	O	6 - 50	SCBID-Block 23	1983-85	+14.5
	--do--			--do--	1985-86	+4.5
	--do--			--do--	1986-88	+2
	--do--			--do--	1988-91	+.5
13N/28E-22B01	UPRG-U/C	O	5 - 50	SCBID-Block 23	1967-69	+11.5
	--do--			--do--	1969-71	+7
	--do--			--do--	1971-72	+2
	--do--			--do--	1972-91	0
13N/28E-24D01	UPRG-U	O	0 - 50	SCBID-Block 20	1961-62	+42
	--do--			--do--	1962-65	+.5
	--do--			--do--	1965-68	0
	--do--			--do--	1968-69	-2
	--do--			--do--	1969-91	0
13N/28E-28A01	UPRG-U	O	5 - 50	SCBID-Block 23	1976-80	+7
	--do--			--do--	1980-81	-10
	--do--			--do--	1981-83	-2.5
	--do--			--do--	1983-85	+14
	--do--			--do--	1985-86	0
13N/29E-03C01	SDLM-C	H	259 - 260	SCBID-Block 20	1962-73*	+3.5
	--do--			--do--	1973-83*	+9.5
	--do--			--do--	1983-86*	+2.5
	--do--			--do--	1986-87	0
13N/29E-04A02	PSCO-U	O	@ 50	SCBID-Block 20	1965-67	0
	--do--			--do--	1967-75	+2.5
	--do--			--do--	1975-78	+.5
	--do--			--do--	1978-91	0

Table 24.--*Summaries of long-term hydrographs--Continued*

Local well number	Hydrologic unit	Well use	Open interval (feet below land surface)	Feature	Period of record used to compute rate of change of water level	Rate of change of water level (ft/yr)
13N/29E-08H01	SDLM-U/C	I	412 - 453	SCBID-Block 20	1964-83*	+3?
	SDLM-C			--do--	1983-86	-4.5
	--do--			--do--	1986-87	-.5?
13N/29E-24R01	SDLM-?	U	? - 228	Dryland farming	1940-50*	0
	--do--			SCBID-Dryland frmg	1950-54*	+2
	--do--			SCBID-BlockS 12+19	1954-57	+33.5
	--do--			--do--	1957-63*	0
13N/29E-28B02	SDLM-C	H	? -540?	SCBID-Block 20	1951-68*	+1.5
13N/29E-32D01	UPRG-U	O	0 - 50	SCBID-Block 20	1962-66	+7
	--do--			--do--	1966-91	0
13N/30E-25C01	SDLM-C	U	115 - 200	Esquatzel Coulee WW	1953-58*	+3.5
	--do--			--do--	1958-63*	+2
13N/30E-26G01	PSCO-U	U	? - 37	Esquatzel Coulee	1940-50	0
	--do--			--do--	1950-53	-1.5
	--do--			Esquatzel Coulee WW	1953-60	+4
	--do--			--do--	1960-87*	0
13N/30E-27J01	SDLM-C	H	@ 56	SCBID-Block 18	1960-63*	+2.5
	--do--			--do--	1963-83*	+.5
	--do--			--do--	1983-86*	0.?
13N/30E-28R02	UPRG-D/U, SDLM-U/C	O	0 - 35	SCBID-Block 12	1960-73*	+2.5
	UPRG-U, SDLM-C,			--do--	1973-83	+.5?
13N/30E-31R01	UPRG-U	O	5 - 51	SCBID-Block 14	1962-70	+4
	--do--			--do--	1970-80	0
	--do--			--do--	1980-83	-2
	--do--			--do--	1983-89	0
14N/27E-26J01	TCHT-U/C, UPRG-U/C	O	0 - 116	White Bluffs-WB10WW	1971-72	+16
	TCHT-U, UPRG-C			--do--	1972-74	+3
	--do--			--do--	1974-77	+11.5
	--do--			--do--	1977-84	+3
	--do--			--do--	1984-88	+1
	--do--			--do--	1988-91	+.5

Table 24.--*Summaries of long-term hydrographs--Continued*

Local well number	Hydrologic unit	Well use	Open interval (feet below land surface)	Feature	Period of record used to compute rate of change of water level	Rate of change of water level (ft/yr)
14N/28E-30D01	TCHT-D/U	O	0 - 54	White Bluffs-WB10WW	1969-70	+22
	TCHT-U			--do--	1970-73	0
	--do--			--do--	1973-75	+8.5
	--do--			--do--	1975-79	0
	--do--			--do--	1979-80	+4
	--do--			--do--	1980-86	0
	--do--			--do--	1986-91	+.5
14N/29E-21J01	SDLM-U	H	132 - 260	SCBID-Block 201	1962-68*	+17
	SDLM-U/C			--do--	1968-78*	+5
	SDLM-C			--do--	1978-83*	+.5
	--do--			--do--	1983-84	+6
	--do--			--do--	1984-88	0
14N/29E-27E01	WNPM-C	H	435 - 498	SCBID-Block 20	1958-68	+7.5
	--do--			--do--	1968-75	+11.5
	--do--			--do--	1975-82	+4
	--do--			--do--	1982-84	+1
	--do--			--do--	1984-88	0
14N/29E-28A01	UPRG-U	O	0 - 50	SCBID-Block 20	1975-81	+5
	--do--			--do--	1981-90	+.5
	--do--			--do--	1990-91	0?
14N/29E-28C01	SDLM-U/C	H	161 - 343	SCBID-Block 20	1962-78*	+9.5
	SDLM-C			--do--	1978-83*	+2
	--do--			--do--	1983-86*	+.5
	--do--			--do--	1986-88	0

Table 25.--*Depths to top of hydrologic units in selected wells in the study area*

EXPLANATION

[NP, unit not present; UK, presence of unit and (or) top of unit unknown; ?, unit present but depth uncertain; --, well does not penetrate to stratigraphic position where unit may or may not be present]

Altitude: Altitudes were assigned from topographic maps (1:24,000-scale; with 10- or 20-foot contour intervals) and are generally accurate to within 10 feet. In steep terrain, or where the precise location of the well is in doubt, the error may be as great as 40 feet. Some wells were checked with altimeters (accurate to within 5 feet), and some (primarily Bureau of Reclamation wells) had been surveyed (accurate to within 1 foot) for earlier projects.

Hole depth: Total depth penetrated during drilling; does not necessarily reflect finished depth of well

Depth to top of hydrologic unit--Unit codes:

TCHT	=	Touchet Beds;
PSCO	=	Pasco gravels;
RGLD	=	Ringold Formation (undifferentiated);
UPRG	=	upper Ringold Formation;
MDRG	=	middle Ringold Formation;
LRRG	=	lower Ringold Formation;
BSRG	=	basal Ringold Formation;
ELBG	=	Ellensburg Formation (only where above basalt sequence);
SDLM	=	Saddle Mountains Basalt;
MBTN	=	Mabton member of Ellensburg Formation;
WNPM	=	Wanapum Basalt;
VNTG	=	Vantage Member of Ellensburg Formation;
GDRD	=	Grand Ronde Basalt

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Lati-tude	Longi-tude	Alti-tude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
07N/30E-01P02	460637	1190012	550	178	NP	0	90	NP	NP	90	NP	NP	95	--	--	--	--
07N/30E-01P03	460637	1190008	543	200	NP	0	?	NP	NP	?	NP	NP	115	--	--	--	--
07N/30E-01Q02	460637	1185956	510	175	NP	0	100	NP	NP	100	NP	NP	106	--	--	--	--
07N/31E-06M01	460653	1185919	400	165	NP	0	NP	NP	NP	NP	NP	NP	26	--	--	--	--"
07N/31E-06N01	460641	1185920	400	250	NP	0	NP	NP	NP	NP	NP	NP	25	--	--	--	--
07N/31E-07D01	460628	1185922	480	220	NP	0	NP	NP	NP	NP	NP	NP	5	--	--	--	--
08N/27E-01A02	461240	1192214	674	170	0	70	--	--	--	--	--	--	--	--	--	--	--
08N/27E-01A03	461243	1192212	668	140	0	70	--	--	--	--	--	--	--	--	--	--	--
08N/27E-01B01	461244	1192235	688	160	0	54	--	--	--	--	--	--	--	--	--	--	--
08N/27E-01G01	461227	1192238	781	600	0	36	NP	NP	NP	NP	NP	NP	123	302	352	--	--
08N/27E-01J02	461224	1192210	692	205	0	40	NP	NP	NP	NP	NP	NP	150	--	--	--	--
08N/27E-01K01	461216	1192235	769	510	0	35	NP	NP	NP	NP	NP	NP	152	260	360	--	--
08N/27E-01R01	461213	1192217	707	328	0	30	NP	NP	NP	NP	NP	NP	106	241	319	--	--
08N/28E-01R01	461213	1191433	517	75	0	7	--	--	--	--	--	--	--	--	--	--	--
08N/28E-01R03	461208	1191430	550	180	0	15	NP	NP	NP	NP	NP	NP	140	--	--	--	--
08N/28E-02K03	461219	1191623	600	415	0	NP	NP	NP	NP	NP	NP	NP	22	--	--	--	--
08N/28E-02P01	461213	1191629	574	125	0	18	NP	NP	NP	NP	NP	NP	25	--	--	--	--
08N/28E-02R01	461210	1191556	535	89	0	20	--	--	--	--	--	--	--	--	--	--	--
08N/28E-02R02	461214	1191549	542	65	0	38	--	--	--	--	--	--	--	--	--	--	--
08N/28E-02R03	461210	1191557	535	77	0	39	--	--	--	--	--	--	--	--	--	--	--
08N/28E-03P01	461211	1191750	822	633	0	NP	NP	NP	NP	NP	NP	NP	38	501	630	--	--
08N/28E-06B01D2	461240	1192117	711	330	0	96	NP	NP	NP	NP	NP	NP	130	--	--	--	--
08N/28E-06D01	461244	1192150	683	193	0	171	--	--	--	--	--	--	--	--	--	--	--
08N/28E-06G01	461230	1192110	706	332	0	NP	NP	NP	NP	NP	NP	185	329	--	--	--	--
08N/28E-07A02	461207	1192102	699	204	0	NP	NP	NP	NP	NP	NP	192	--	--	--	--	--
08N/28E-07A03D1	461154	1192102	691	233	0	NP	NP	NP	NP	NP	NP	188	--	--	--	--	--
08N/28E-07B01	461205	1192125	680	432	0	158	NP	NP	NP	NP	NP	NP	208	247	308	--	--
08N/28E-07M01	461138	1192148	728	440	0	NP	NP	NP	NP	NP	NP	NP	22	156	223	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Lati-tude	Longi-tude	Alti-tude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
08N/28E-07P01	461127	1192137	710	435	0	NP	NP	NP	NP	NP	NP	NP	17	132	200	--	--
08N/28E-08D01	461206	1192049	707	250	0	NP	NP	NP	NP	NP	NP	189	249	--	--	--	--
08N/28E-08N01	461127	1192047	675	229	0	NP	NP	NP	NP	NP	NP	188	225	--	--	--	--
08N/28E-11B01	461200	1191613	565	142	0	?	NP	NP	NP	NP	NP	NP	142	--	--	--	--
08N/28E-11Q01	461114	1191618	577	120	0	NP	NP	NP	NP	NP	NP	NP	10	--	--	--	--
08N/28E-11R01	461118	1191603	610	320	0	5	22	NP	NP	22	NP	NP	28	--	--	--	--
08N/28E-11R02	461113	1191555	700	402	NP	0	NP	NP	NP	NP	NP	NP	5	--	--	--	--
08N/28E-12B02	461153	1191452	567	105	NP	30	NP	NP	NP	NP	NP	NP	45	--	--	--	--
08N/28E-12C03	461155	1191523	611	120	0	57	--	--	--	--	--	--	--	--	--	--	--
08N/28E-12D02	461155	1191534	602	142	0	61	--	--	--	--	--	--	--	--	--	--	--
08N/28E-12F01	461139	1191511	625	115	0	NP	NP	NP	NP	NP	NP	NP	27	--	--	--	--
08N/28E-12M01	461133	1191532	583	358	0	NP	NP	NP	NP	NP	NP	NP	15	--	--	--	--
08N/28E-12N01	461113	1191530	755	540	0	NP	NP	NP	NP	NP	NP	NP	15	--	--	--	--
08N/28E-14C01	461059	1191628	604	150	0	50	--	--	--	--	--	--	--	--	--	--	--
08N/28E-14C02	461102	1191626	598	147	0	60	--	--	--	--	--	--	--	--	--	--	--
08N/28E-14L01	461037	1191641	615	190	0	NP	NP	NP	NP	NP	NP	NP	2	--	--	--	--
08N/28E-14M03	461036	1191647	580	160	0	NP	NP	NP	NP	NP	NP	NP	1	--	--	--	--
08N/28E-14R02	461026	1191554	930	518	0	NP	NP	NP	NP	NP	NP	NP	15	516	--	--	--
08N/28E-15A01	461059	1191710	618	170	0	37	--	--	--	--	--	--	--	--	--	--	--
08N/28E-15D01	461108	1191811	628	174	0	10	--	--	--	--	--	--	--	--	--	--	--
08N/28E-15G01D1	461047	1191737	648	235	0	32	225	NP	NP	225	--	--	--	--	--	--	--
08N/28E-15N03	461024	1191808	578	20	0	--	--	--	--	--	--	--	--	--	--	--	--
08N/28E-15P01	461027	1191741	587	108	0	71	--	--	--	--	--	--	--	--	--	--	--
08N/28E-15P02	461027	1191754	574	18	0	--	--	--	--	--	--	--	--	--	--	--	--
08N/28E-15P03	461020	1191757	576	18	0	--	--	--	--	--	--	--	--	--	--	--	--
08N/28E-15P04	461024	1191746	591	57	0	--	--	--	--	--	--	--	--	--	--	--	--
08N/28E-15P05	461023	1191749	586	32	0	--	--	--	--	--	--	--	--	--	--	--	--
08N/28E-15P07	461027	1191742	587	116	0	78	--	--	--	--	--	--	--	--	--	--	--
08N/28E-15Q01	461025	1191725	575	193	0	66	NP	NP	NP	NP	NP	NP	188	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Latitude	Longitude	Altitude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
08N/28E-16G01	461055	1191838	673	110	0	11	NP	NP	NP	NP	NP	NP	106	--	--	--	--
08N/28E-16G02	461049	1191851	688	144	0	19	--	--	--	--	--	--	--	--	--	--	--
08N/28E-16L01	461035	1191858	614	60	0	26	--	--	--	--	--	--	--	--	--	--	--
08N/28E-16M01	461034	1191929	625	145	0	60	--	--	--	--	--	--	--	--	--	--	--
08N/28E-16R01	461022	1191827	612	120	0	100	--	--	--	--	--	--	--	--	--	--	--
08N/28E-17N01	461025	1192038	699	70	0	50	--	--	--	--	--	--	--	--	--	--	--
08N/28E-17N02	461024	1192039	701	70	0	36	--	--	--	--	--	--	--	--	--	--	--
08N/28E-17P01	461034	1192024	651	70	0	--	--	--	--	--	--	--	--	--	--	--	--
08N/28E-21A01	461019	1191819	603	135	0	40	--	--	--	--	--	--	--	--	--	--	--
08N/28E-21H01	461002	1191818	668	125	0	50	--	--	--	--	--	--	--	--	--	--	--
08N/28E-22C01	461014	1191753	597	18	0	--	--	--	--	--	--	--	--	--	--	--	--
08N/28E-22D01	461018	1191817	612	126	0	50	--	--	--	--	--	--	--	--	--	--	--
08N/28E-22D03	461009	1191808	602	35	0	--	--	--	--	--	--	--	--	--	--	--	--
08N/28E-22D04	461011	1191805	603	17	0	--	--	--	--	--	--	--	--	--	--	--	--
08N/28E-22D05	461013	1191809	588	13	0	--	--	--	--	--	--	--	--	--	--	--	--
08N/28E-22F01	461006	1191740	614	57	0	46	--	--	--	--	--	--	--	--	--	--	--
08N/28E-22F02	461000	1191753	662	60	0	22	--	--	--	--	--	--	--	--	--	--	--
08N/28E-23A01	461015	1191605	970	754	0	NP	NP	NP	NP	NP	NP	NP	21	481	552	--	--
08N/28E-23C01	461009	1191625	987	825	0	NP	NP	NP	NP	NP	NP	NP	27	550	--	--	--
08N/28E-23C02	461016	1191638	960	600	0	NP	NP	NP	NP	NP	NP	NP	14	460	553	--	--
08N/28E-23G01	461003	1191609	1,009	707	0	NP	NP	NP	NP	NP	NP	NP	20	441	460	--	--
08N/28E-23M01	460944	1191659	1,195	1,174	NP	NP	NP	NP	NP	NP	NP	NP	3	630	675	--	--
08N/28E-23P01	460934	1191629	1,112	385	NP	NP	NP	NP	NP	NP	NP	NP	10	--	--	--	--
08N/29E-01F02	461221	1190745	410	93	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/29E-05D01	461235	1191301	560	90	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/29E-07B01	461152	1191349	614	154	0	60	--	--	--	--	--	--	--	--	--	--	--
08N/29E-10C01	461150	1191012	554	95	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/29E-12B01	461142	1190732	388	64	NP	0	NP	NP	NP	NP	NP	NP	52	--	--	--	--
08N/29E-12G01	461135	1190720	387	61	NP	0	--	--	--	--	--	--	--	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Lati-tude	Longi-tude	Alti-tude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
08N/29E-12H01	461139	1190704	380	125	NP	0	NP	NP	NP	NP	NP	NP	59	--	--	--	--
08N/29E-13A01	461101	1190711	430	160	NP	0	43	NP	NP	43	NP	NP	70	--	--	--	--
08N/29E-15Q01	461020	1191006	715	760	0	NP	NP	NP	NP	NP	NP	NP	29	NP	?	--	--
08N/29E-16H01	461050	1191048	709	388	NP	0	178	NP	NP	178	NP	NP	180	360	380	--	--
08N/29E-17G01D1	461043	1191237	765	430	0	NP	NP	NP	NP	NP	NP	NP	17	--	--	--	--
08N/29E-17G02	461040	1191230	759	245	0	NP	NP	NP	NP	NP	NP	NP	8	--	--	--	--
08N/29E-17G03	461040	1191224	760	460	0	NP	NP	NP	NP	NP	NP	NP	25	--	--	--	--
08N/29E-17K01D1	461027	1191221	855	1,000	0	NP	NP	NP	NP	NP	NP	NP	3	355	357	--	--
08N/29E-17L01	461037	1191242	812	354	0	NP	NP	NP	NP	NP	NP	NP	1	--	--	--	--
08N/29E-32B01	460825	1191239	1,147	787	NP	NP	NP	NP	NP	NP	NP	NP	50	--	--	--	--
08N/30E-03A01	461242	1190218	390	65	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-03A02	461242	1190218	393	64	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-04B01	461239	1190352	355	43	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-04N02	461156	1190418	339	25	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-05J01	461217	1190446	340	125	NP	0	NP	NP	NP	NP	NP	NP	99	--	--	--	--
08N/30E-05K01	461215	1190455	345	36	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-05K02	461208	1190455	346	32	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-06D03	461237	1190652	348	87	NP	0	28	NP	NP	28	--	--	--	--	--	--	--
08N/30E-06L01	461208	1190637	368	535	NP	0	61	NP	NP	61	NP	NP	104	--	--	--	--
08N/30E-06L02	461208	1190635	368	555	NP	0	60	NP	NP	60	NP	NP	96	--	--	--	--
08N/30E-07E02	461137	1190649	380	55	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-07G02	461128	1190612	376	105	NP	0	62	NP	NP	62	NP	NP	74	--	--	--	--
08N/30E-07G03	461129	1190604	371	39	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-07G04	461130	1190607	375	66	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-07J02	461127	1190549	365	45	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-07L01	461119	1190635	368	40	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-07L02	461124	1190636	381	48	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-07L03	461116	1190637	372	48	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-07N02	461111	1190648	380	55	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-07P02	461103	1190624	361	43	NP	0	NP	NP	NP	NP	NP	NP	39	--	--	--	--
08N/30E-07Q04	461102	1190606	362	38	NP	0	--	--	--	--	--	--	--	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Lati-tude	Longi-tude	Alti-tude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
08N/30E-08A01	461153	1190428	337	9	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-08E01	461128	1190541	362	75	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-08G01	461132	1190459	355	70	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-09C01	461141	1190404	343	182	NP	0	38	NP	NP	38	NP	NP	79	--	--	--	--
08N/30E-09C02D1	461151	1190406	335	102	NP	0	38	NP	NP	38	NP	NP	69	--	--	--	--
08N/30E-09E01	461128	1190417	357	33	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-09L02	461123	1190405	350	44	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-10M03	461114	1190301	362	49	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-14C01	461049	1190131	365	50	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-14L01	461022	1190136	342	8	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-14L02	461025	1190135	347	15	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-14M01	461032	1190141	357	160	NP	0	NP	NP	NP	NP	NP	NP	49	--	--	--	--
08N/30E-15K01	461023	1190234	351	34	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-15N01	461010	1190310	338	245	NP	0	NP	NP	NP	NP	NP	NP	29	--	--	--	--
08N/30E-15P01	461011	1190253	339	11	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-16B03	461048	1190338	357	34	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-16F01	461045	1190356	358	50	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-16K01	461034	1190336	347	13	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-17C01	461100	1190513	421	107	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-17D02	461056	1190532	400	61	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-17D03	461057	1190526	425	99	NP	0	9	UK	UK	UK	UK	--	--	--	--	--	--
08N/30E-17D04	461056	1190527	422	97	NP	0	97	NP	NP	97	--	--	--	--	--	--	--
08N/30E-17F05	461043	1190517	423	100	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-17F06	461045	1190523	408	155	NP	0	NP	NP	NP	NP	NP	NP	82	--	--	--	--
08N/30E-17L01	461029	1190516	380	51	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-17R01	461011	1190438	355	40	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-19M01	460932	1190642	570	330	NP	0	NP	NP	NP	NP	NP	NP	85	NP	295	--	--
08N/30E-20A01	460956	1190444	361	155	NP	0	NP	NP	NP	NP	NP	NP	39	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Lati-tude	Longi-tude	Alti-tude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
08N/30E-20G01	460944	1190505	450	325	NP	0	NP	NP	NP	NP	NP	NP	107	--	--	--	--
08N/30E-20G02D1	460954	1190452	358	180	NP	0	NP	NP	NP	NP	NP	NP	32	--	--	--	--
08N/30E-20R01	460918	1190446	466	350	NP	0	NP	NP	NP	NP	NP	NP	60	--	--	--	--
08N/30E-21C01	460957	1190406	360	28	NP	0	NP	NP	NP	NP	NP	NP	28	--	--	--	--
08N/30E-21C03	460957	1190406	361	35	NP	0	NP	NP	NP	NP	NP	NP	35	--	--	--	--
08N/30E-21C04	461001	1190352	350	28	NP	0	NP	NP	NP	NP	NP	NP	28	--	--	--	--
08N/30E-21D02	460956	1190414	365	31	NP	0	NP	NP	NP	NP	NP	NP	31	--	--	--	--
08N/30E-21F02	460949	1190407	361	161	NP	0	NP	NP	NP	NP	NP	NP	20	--	--	--	--
08N/30E-21H02	460950	1190329	348	125	NP	0	NP	NP	NP	NP	NP	NP	29	--	--	--	--
08N/30E-21J01	460935	1190317	361	250	NP	0	NP	NP	NP	NP	NP	NP	29	--	--	--	--
08N/30E-21J02	460939	1190329	360	240	NP	0	NP	NP	NP	NP	NP	NP	30	--	--	--	--
08N/30E-21Q02	460923	1190350	375	125	NP	0	NP	NP	NP	NP	NP	NP	10	--	--	--	--
08N/30E-21R01	460928	1190329	362	122	NP	0	NP	NP	NP	NP	NP	NP	17	--	--	--	--
08N/30E-22D04	461005	1190310	340	26	NP	0	NP	NP	NP	NP	NP	NP	26	--	--	--	--
08N/30E-22H02	460948	1190211	340	28	NP	0	NP	NP	NP	NP	NP	NP	28	--	--	--	--
08N/30E-22J02	460939	1190210	345	30	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-22K01	460937	1190232	344	17	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-22M01	460938	1190312	352	225	NP	0	NP	NP	NP	NP	NP	NP	22	--	--	--	--
08N/30E-22M02	460931	1190305	361	29	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-22N02	460925	1190309	361	153	NP	0	NP	NP	NP	NP	NP	NP	30	--	--	--	--
08N/30E-22P01	460923	1190250	365	35	NP	0	NP	NP	NP	NP	NP	NP	35	--	--	--	--
08N/30E-22Q02	460926	1190227	349	52	NP	0	NP	NP	NP	NP	NP	NP	31	--	--	--	--
08N/30E-22R03	460915	1190207	350	530	NP	0	NP	NP	NP	NP	NP	NP	32	NP	523	--	--
08N/30E-22R04	460922	1190212	352	52	NP	0	NP	NP	NP	NP	NP	NP	25	--	--	--	--
08N/30E-23D01	461002	1190154	355	105	NP	0	NP	NP	NP	NP	NP	NP	26	--	--	--	--
08N/30E-23D02	461001	1190156	345	20	NP	0	NP	NP	NP	NP	NP	NP	19	--	--	--	--
08N/30E-23E02	460943	1190154	345	19	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-23E03	460945	1190146	343	50	NP	0	NP	NP	NP	NP	NP	NP	33	--	--	--	--
08N/30E-23G01	460940	1190110	342	21	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-23H01	460948	1190051	336	26	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-23H02	460947	1190056	335	26	NP	0	--	--	--	--	--	--	--	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Lati-tude	Longi-tude	Alti-tude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
08N/30E-23N01	460916	1190157	350	30	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-23N02	460914	1190142	350	228	NP	0	NP	NP	NP	NP	NP	NP	38	--	--	--	--
08N/30E-23P01	460915	1190123	350	32	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-23R01	460914	1190045	340	30	NP	0	NP	NP	NP	NP	NP	NP	30	--	--	--	--
08N/30E-24N03	460917	1190027	350	30	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-25C01	460911	1190019	345	30	NP	0	NP	NP	NP	NP	NP	NP	29	--	--	--	--
08N/30E-25D01	460905	1190036	350	40	NP	0	NP	NP	NP	NP	NP	NP	35	--	--	--	--
08N/30E-25D02	460901	1190040	341	16	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-25E02	460858	1190026	345	35	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-25F01	460857	1190022	345	110	NP	0	NP	NP	NP	NP	NP	NP	34	--	--	--	--
08N/30E-26B01	460901	1190105	351	37	NP	0	NP	NP	NP	NP	NP	NP	37	--	--	--	--
08N/30E-26B02	460901	1190103	351	37	NP	0	NP	NP	NP	NP	NP	NP	37	--	--	--	--
08N/30E-26C01	460912	1190123	348	34	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-26C02	460912	1190135	351	36	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-26D01	460902	1190155	350	14	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-26E01	460853	1190139	351	45	NP	0	NP	NP	NP	NP	NP	NP	25	--	--	--	--
08N/30E-26F01	460855	1190133	352	36	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-26H01	460858	1190059	350	37	NP	0	NP	NP	NP	NP	NP	NP	37	--	--	--	--
08N/30E-26H02	460856	1190046	348	35	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-26H03	460857	1190050	348	298	NP	0	NP	NP	NP	NP	NP	NP	37	--	--	--	--
08N/30E-26H04	460854	1190050	350	38	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-26L03	460843	1190124	348	165	NP	0	NP	NP	NP	NP	NP	NP	19	--	--	--	--
08N/30E-26L04	460846	1190121	347	17	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-26Q01	460822	1190110	344	85	NP	0	NP	NP	NP	NP	NP	NP	14	--	--	--	--
08N/30E-26Q02	460827	1190112	345	100	NP	0	NP	NP	NP	NP	NP	NP	16	--	--	--	--
08N/30E-26Q03	460823	1190105	343	15	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-27B01	460903	1190222	360	125	NP	0	NP	NP	NP	NP	NP	NP	23	--	--	--	--
08N/30E-27B02	460911	1190219	358	124	NP	0	NP	NP	NP	NP	NP	NP	27	--	--	--	--
08N/30E-27B03	460912	1190227	363	141	NP	0	NP	NP	NP	NP	NP	NP	37	--	--	--	--
08N/30E-27D01	460913	1190310	360	160	NP	0	NP	NP	NP	NP	NP	NP	9	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Latitude	Longitude	Altitude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
08N/30E-27D02	460914	1190312	360	181	NP	0	NP	NP	NP	NP	NP	NP	12	--	--	--	--
08N/30E-27F01	460857	1190247	365	125	NP	0	3	NP	NP	3	NP	NP	8	--	--	--	--
08N/30E-27H01	460855	1190158	351	215	NP	0	NP	NP	NP	NP	NP	NP	18	--	--	--	--
08N/30E-27H02	460854	1190159	348	14	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-29A01	460913	1190439	462	215	NP	0	NP	NP	NP	NP	NP	NP	70	--	--	--	--
08N/30E-29D01	460916	1190544	549	120	0	41	--	--	--	--	--	--	--	--	--	--	--
08N/30E-29R01	460830	1190446	610	380	NP	0	NP	NP	NP	NP	NP	NP	20	200	220	--	--
08N/30E-30N01	460834	1190657	854	575	0	NP	NP	NP	NP	NP	NP	NP	52	135	155	--	--
08N/30E-34B01D1	460813	1190226	454	59	NP	0	NP	NP	NP	NP	NP	NP	56	--	--	--	--
08N/30E-34B02	460818	1190229	450	56	NP	0	41	NP	NP	41	NP	NP	54	--	--	--	--
08N/30E-34G01	460756	1190233	510	105	NP	0	NP	NP	NP	NP	NP	NP	87	--	--	--	--
08N/30E-34G02D1	460758	1190231	490	71	NP	0	52	NP	NP	52	NP	NP	62	--	--	--	--
08N/30E-34J01	460747	1190200	477	260	NP	0	68	NP	NP	68	NP	NP	75	--	--	--	--
08N/30E-34J02	460752	1190209	480	81	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-34K01	460752	1190219	490	65	NP	0	NP	NP	NP	NP	NP	NP	64	--	--	--	--
08N/30E-34Q01	460730	1190236	639	155	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-34Q02	460736	1190228	583	165	0	18	NP	NP	NP	NP	NP	NP	163	--	--	--	--
08N/30E-35D01	460811	1190149	425	225	NP	0	35	NP	NP	35	NP	NP	45	--	--	--	--
08N/30E-35E02	460756	1190156	450	50	NP	0	--	--	--	--	--	--	--	--	--	--	--
08N/30E-35G02	460807	1190116	380	35	NP	0	24	NP	NP	24	--	--	--	--	--	--	--
08N/30E-35K01	460752	1190117	423	177	NP	0	25	NP	NP	25	NP	NP	50	--	--	--	--
09N/27E-01D01	461758	1192304	465	80	NP	0	NP	NP	NP	NP	NP	NP	55	--	--	--	--
09N/27E-01D02D1	461758	1192300	461	165	NP	0	NP	NP	NP	NP	NP	NP	40	--	--	--	--
09N/27E-02D02	461800	1192413	543	300	0	11	NP	NP	NP	NP	NP	NP	39	--	--	--	--
09N/27E-02D03D1	461802	1192413	541	375	0	?	NP	NP	NP	NP	NP	NP	50	300	370	--	--
09N/27E-02E01	461746	1192415	535	273	0	NP	NP	NP	NP	NP	NP	NP	23	--	--	--	--
09N/27E-02L01	461724	1192357	535	120	0	3	45	NP	NP	45	NP	NP	75	--	--	--	--
09N/27E-02L02	461724	1192407	530	285	0	30	NP	NP	NP	NP	NP	NP	60	--	--	--	--
09N/27E-03B01	461801	1192506	518	275	0	NP	NP	NP	NP	NP	NP	NP	3	--	--	--	--
09N/27E-03D01	461759	1192527	590	330	0	3	NP	NP	NP	NP	NP	NP	50	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Latitude	Longitude	Altitude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
09N/27E-03F02	461740	1192508	600	400	0	64	NP	NP	NP	NP	NP	NP	69	--	--	--	--
09N/27E-03G01	461742	1192456	540	260	0	?	NP	NP	NP	NP	NP	NP	20	--	--	--	--
09N/27E-03R02	461719	1192438	570	280	0	28	NP	NP	NP	NP	NP	NP	105	--	--	--	--
09N/27E-03R03	461716	1192436	559	320	0	NP	NP	NP	NP	NP	NP	NP	3	--	--	--	--
09N/27E-05D01D1	461752	1192806	510	150	0	25	NP	NP	NP	NP	NP	NP	?	--	--	--	--
09N/27E-06A01	461755	1192821	455	104	NP	6	46	NP	NP	46	NP	NP	65	--	--	--	--
09N/27E-07B01	461659	1192843	460	28	NP	6	NP	NP	NP	NP	NP	NP	21	--	--	--	--
09N/27E-07D01	461711	1192919	590	360	0	NP	NP	NP	NP	NP	NP	NP	38	--	--	--	--
09N/27E-07P02	461621	1192900	466	42	NP	?	NP	NP	NP	NP	NP	NP	40	--	--	--	--
09N/27E-08J02	461637	1192701	693	561	0	?	60	NP	NP	60	NP	NP	75	--	--	--	--
09N/27E-08N01	461631	1192809	569	638	0	NP	NP	NP	NP	NP	NP	NP	19	530	610	--	--
09N/27E-09J01	461635	1192551	730	446	0	NP	NP	NP	NP	NP	NP	NP	134	--	--	--	--
09N/27E-09L01	461631	1192623	688	447	0	NP	NP	NP	NP	NP	NP	NP	25	--	--	--	--
09N/27E-09R01	461630	1192547	679	325	0	9	NP	NP	NP	NP	NP	NP	14	--	--	--	--
09N/27E-11H01	461653	1192333	510	104	0	NP	NP	NP	NP	NP	NP	NP	70	--	--	--	--
09N/27E-11H02D1	461653	1192332	510	240	0	NP	NP	NP	NP	NP	NP	NP	80	--	--	--	--
09N/27E-12F02	461647	1192252	559	180	0	65	NP	NP	NP	NP	NP	NP	90	--	--	--	--
09N/27E-12P01	461630	1192256	530	402	0	NP	NP	NP	NP	NP	NP	NP	66	330	--	--	--
09N/27E-12Q01	461627	1192237	539	438	0	NP	NP	NP	NP	NP	NP	NP	86	350	--	--	--
09N/27E-16B01	461611	1192624	685	290	0	NP	NP	NP	NP	NP	NP	NP	6	--	--	--	--
09N/27E-16B02	461607	1192612	670	323	0	18	NP	NP	NP	NP	NP	NP	50	--	--	--	--
09N/27E-16D01	461610	1192653	688	760	0	NP	NP	NP	NP	NP	NP	NP	4	590	688	--	--
09N/27E-17A01	461615	1192706	685	445	0	15	NP	NP	NP	NP	NP	NP	70	--	--	--	--
09N/27E-17P01	461532	1192751	630	252	0	25	NP	NP	NP	NP	NP	NP	148	--	--	--	--
09N/27E-17P02	461534	1192746	645	324	0	NP	NP	NP	NP	NP	NP	NP	30	--	--	--	--
09N/27E-18A01	461613	1192822	480	115	NP	NP	NP	NP	NP	NP	NP	NP	15	--	--	--	--
09N/27E-19G01	461511	1192856	500	27	19	22	--	--	--	--	--	--	--	--	--	--	--
09N/27E-19H01	461513	1192832	461	40	NP	15	--	--	--	--	--	--	--	--	--	--	--
09N/27E-19J01	461453	1192830	539	115	0	24	--	--	--	--	--	--	--	--	--	--	--
09N/27E-19J02	461454	1192840	548	110	0	60	--	--	--	--	--	--	--	--	--	--	--
09N/27E-19K01	461454	1192847	548	143	0	68	NP	NP	NP	NP	NP	NP	115	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Latitude	Longitude	Altitude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
09N/27E-19K02	461454	1192846	540	108	0	70	--	--	--	--	--	--	--	--	--	--	--
09N/27E-19P01	461440	1192910	720	438	0	NP	155	NP	NP	155	NP	NP	179	--	--	--	--
09N/27E-20E01	461513	1192805	575	138	0	30	NP	NP	NP	NP	NP	NP	70	--	--	--	--
09N/27E-21C01	461524	1192644	725	405	0	NP	NP	NP	NP	NP	NP	NP	8	--	--	--	--
09N/27E-23N01D1	461438	1192423	940	1,230	0	NP	NP	NP	NP	NP	NP	NP	32	553	634	--	--
09N/27E-25E01	461409	1192317	864	1,098	0	NP	NP	NP	NP	NP	NP	NP	18	790	872	--	--
09N/27E-27R01	461348	1192455	603	145	0	58	NP	NP	NP	NP	NP	NP	143	--	--	--	--
09N/27E-28F01	461415	1192632	590	137	0	29	--	--	--	--	--	--	--	--	--	--	--
09N/27E-29D01	461427	1192819	652	185	0	65	NP	NP	NP	NP	NP	NP	168	--	--	--	--
09N/27E-29J01	461405	1192711	552	75	0	17	--	--	--	--	--	--	--	--	--	--	--
09N/27E-29J02	461400	1192716	580	100	0	60	--	--	--	--	--	--	--	--	--	--	--
09N/27E-29J03	461358	1192712	588	100	0	52	--	--	--	--	--	--	--	--	--	--	--
09N/27E-29J04	461401	1192713	570	89	0	75	--	--	--	--	--	--	--	--	--	--	--
09N/27E-35E01	461319	1192424	665	165	0	NP	NP	NP	NP	NP	NP	NP	70	--	--	--	--
09N/27E-36D01	461339	1192320	667	238	0	156	--	--	--	--	--	--	--	--	--	--	--
09N/27E-36D02	461339	1192320	667	238	0	156	--	--	--	--	--	--	--	--	--	--	--
09N/27E-36H01	461322	1192210	679	400	0	180	NP	NP	NP	NP	NP	NP	220	--	--	--	--
09N/27E-36M01	461308	1192305	655	150	0	92	--	--	--	--	--	--	--	--	--	--	--
09N/27E-36P01	461259	1192248	655	202	0	?	--	--	--	--	--	--	--	--	--	--	--
09N/27E-36R02	461249	1192218	661	164	0	105	--	--	--	--	--	--	--	--	--	--	--
09N/28E-02G01	461741	1191619	359	40	NP	0	10	NP	10	--	--	--	--	--	--	--	--
09N/28E-02G02	461738	1191610	360	80	NP	1	38	NP	38	--	--	--	--	--	--	--	--
09N/28E-02G04	461736	1191610	360	23	NP	1	--	--	--	--	--	--	--	--	--	--	--
09N/28E-02M01D1	461733	1191658	381	40	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/28E-02M02	461728	1191655	378	90	NP	0	50	NP	50	--	--	--	--	--	--	--	--
09N/28E-02N01D1	461710	1191646	362	148	NP	0	40	NP	40	70	--	--	--	--	--	--	--
09N/28E-03G01	461747	1191723	387	65	NP	0	?	NP	?	--	--	--	--	--	--	--	--
09N/28E-03P01	461716	1191756	405	120	NP	0	?	NP	?	80	--	--	--	--	--	--	--
09N/28E-04C04	461750	1191908	371	>88	NP	NP	30	NP	30	40	--	--	--	--	--	--	--
09N/28E-04C05	461801	1191856	370	200	NP	NP	34	NP	NP	34	NP	NP	180	--	--	--	--
09N/28E-04D03	461802	1191928	370	190	NP	0	12	NP	12	25	NP	NP	180	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Lati-tude	Longi-tude	Alti-tude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
09N/28E-04E01	461742	1191914	371	193	NP	11	14	NP	14	39	NP	NP	179	--	--	--	--
09N/28E-04G01	461739	1191849	365	314	NP	9	12	NP	12	48	NP	NP	178	--	--	--	--
09N/28E-04G03	461740	1191849	365	52	NP	0	11	NP	11	--	--	--	--	--	--	--	--
09N/28E-04J02	461727	1191821	383	230	NP	0	?	NP	?	63	NP	NP	195	--	--	--	--
09N/28E-04P01D1	461716	1191906	361	100	NP	2	12	NP	12	--	--	--	--	--	--	--	--
09N/28E-05A01D1	461754	1191935	370	220	NP	10	25	NP	NP	25	NP	NP	169	--	--	--	--
09N/28E-05B01	461752	1192007	375	95	NP	0	24	NP	NP	24	--	--	--	--	--	--	--
09N/28E-05E01	461749	1192039	419	73	NP	0	40	NP	NP	40	--	--	--	--	--	--	--
09N/28E-05F01	461744	1192020	390	43	NP	10	--	--	--	--	--	--	--	--	--	--	--
09N/28E-05F02	461744	1192020	390	46	NP	4	--	--	--	--	--	--	--	--	--	--	--
09N/28E-05G01	461741	1191950	365	107	NP	7	19	NP	NP	19	--	--	--	--	--	--	--
09N/28E-05H01	461742	1191932	361	93	NP	NP	15	NP	NP	15	--	--	--	--	--	--	--
09N/28E-06A01	461800	1192051	410	250	0	26	76	NP	76	93	NP	NP	176	--	--	--	--
09N/28E-06A02	461751	1192054	455	90	0	28	63	NP	NP	63	NP	NP	73	--	--	--	--
09N/28E-07C01	461705	1192134	643	540	0	3	58	58	NP	99	NP	NP	164	--	--	--	--
09N/28E-08B01	461658	1191951	628	354	NP	NP	NP	NP	NP	NP	NP	NP	0	--	--	--	--
09N/28E-08C01	461706	1192018	525	204	0	NP	20	NP	NP	20	NP	NP	50	--	--	--	--
09N/28E-08K01	461638	1191955	606	325	NP	0	85	NP	NP	85	NP	NP	148	--	--	--	--
09N/28E-08R01	461623	1191937	542	260	0	22	65	NP	NP	65	NP	NP	110	--	--	--	--
09N/28E-10F01	461656	1191749	405	68	NP	0	39	NP	39	--	--	--	--	--	--	--	--
09N/28E-10H04	461648	1191703	357	129	NP	0	?	NP	?	36	--	--	--	--	--	--	--
09N/28E-10J04	461631	1191703	358	62	NP	0	33	NP	33	51	--	--	--	--	--	--	--
09N/28E-11E01	461652	1191701	358	135	NP	NP	3	NP	NP	3	NP	NP	130	--	--	--	--
09N/28E-11Q01	461624	1191611	354	155	NP	18	26	26	NP	48	NP	NP	138	--	--	--	--
09N/28E-12P01	461621	1191510	370	135	NP	0	53	NP	NP	53	--	--	--	--	--	--	--
09N/28E-14P01	461527	1191626	355	46	NP	0	46	NP	46	--	--	--	--	--	--	--	--
09N/28E-15A01D1	461616	1191703	358	75	NP	31	58	NP	NP	58	--	--	--	--	--	--	--
09N/28E-15G01	461600	1191732	415	95	NP	0	55	NP	55	--	--	--	--	--	--	--	--
09N/28E-15H06D1	461552	1191703	359	70	NP	0	65	NP	NP	65	--	--	--	--	--	--	--
09N/28E-15H07D1	461601	1191703	359	67	NP	30	61	NP	NP	61	--	--	--	--	--	--	--
09N/28E-15J01	461543	1191704	359	72	NP	28	70	NP	NP	70	--	--	--	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Latitude	Longitude	Altitude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
09N/28E-17A01	461611	1191950	550	1,105	0	20	50	NP	NP	50	NP	NP	107	395	451	--	--
09N/28E-17N01	461535	1192047	597	270	0	NP	20	NP	NP	20	NP	NP	72	--	--	--	--
09N/28E-17Q01	461530	1191956	575	365	UK	UK	UK	UK	UK	UK	UK	UK	80	--	--	--	--
09N/28E-18H01	461553	1192055	552	308	0	NP	60	NP	NP	60	NP	NP	108	--	--	--	--
09N/28E-18H02	461555	1192100	560	253	0	NP	42	NP	NP	42	NP	NP	100	--	--	--	--
09N/28E-18L01	461550	1192127	583	101	0	NP	NP	NP	NP	NP	NP	NP	7	--	--	--	--
09N/28E-19J01	461456	1192100	856	542	0	NP	NP	NP	NP	NP	NP	NP	2	505	--	--	--
09N/28E-20A01	461514	1191933	569	102	0	NP	NP	NP	NP	NP	NP	NP	75	--	--	--	--
09N/28E-20B01	461515	1191958	611	446	0	NP	55	NP	NP	55	NP	NP	122	394	430	--	--
09N/28E-21D01	461516	1191930	558	240	0	60	NP	NP	NP	NP	NP	NP	70	--	--	--	--
09N/28E-22B01	461515	1191731	430	172	0	?	NP	NP	NP	NP	NP	NP	40	--	--	--	--
09N/28E-22B02	461522	1191736	385	225	NP	NP	0	NP	NP	0	NP	NP	26	--	--	--	--
09N/28E-22F01D1	461459	1191756	520	210	0	30	NP	NP	NP	NP	NP	NP	70	--	--	--	--
09N/28E-23C01	461523	1191641	356	60	NP	15	--	--	--	--	--	--	--	--	--	--	--
09N/28E-26M01	461359	1191700	533	272	0	NP	NP	NP	NP	NP	NP	NP	98	--	--	--	--
09N/28E-26R01D1	461339	1191601	497	281	0	NP	50	NP	NP	50	NP	NP	70	--	--	--	--
09N/28E-27D01	461427	1191801	575	274	NP	0	?	22	NP	?	NP	NP	103	--	--	--	--
09N/28E-27K01	461402	1191738	620	525	0	NP	130	NP	NP	130	NP	NP	168	--	--	--	--
09N/28E-27R01	461347	1191704	578	297	0	NP	12	12	NP	?	NP	NP	122	--	--	--	--
09N/28E-30J01	461356	1192106	812	800	0	NP	NP	NP	NP	NP	NP	NP	29	565	660	--	--
09N/28E-31E02	461323	1192207	683	265	0	NP	NP	NP	NP	NP	NP	NP	75	--	--	--	--
09N/28E-31M01	461308	1192201	675	181	0	130	--	--	--	--	--	--	--	--	--	--	--
09N/28E-31N01D1	461253	1192152	678	215	0	175	--	--	--	--	--	--	--	--	--	--	--
09N/28E-31P01D1	461254	1192145	675	225	0	118	--	--	--	--	--	--	--	--	--	--	--
09N/28E-33M01	461310	1191924	848	535	0	NP	NP	NP	NP	NP	NP	NP	58	--	--	--	--
09N/28E-34H01	461326	1191718	751	905	UK	UK	UK	UK	UK	UK	UK	UK	244	325	366	--	--
09N/29E-02A01	461759	1190808	450	128	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-02A02	461749	1190823	452	133	NP	0	132	NP	132	--	--	--	--	--	--	--	--
09N/29E-02C04	461757	1190855	470	135	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-02D03	461757	1190916	460	160	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-02G02D1	461742	1190836	460	493	NP	4	152	NP	NP	152	NP	NP	198	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Lati- tude	Longi- tude	Alti- tude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
09N/29E-02G03	461739	1190836	460	118	NP	0	NP	NP	NP	NP	NP	NP	8	--	--	--	--
09N/29E-02G04	461742	1190836	460	145	NP	3	--	--	--	--	--	--	--	--	--	--	--
09N/29E-02G06	461737	1190831	458	133	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-03A01	461748	1190941	500	235	NP	0	219	NP	NP	219	--	--	--	--	--	--	--
09N/29E-03P01	461708	1191012	520	172	NP	0	156	NP	156	--	--	--	--	--	--	--	--
09N/29E-04D01	461800	1191150	525	241	NP	0	?	NP	?	210	--	--	--	--	--	--	--
09N/29E-04K01D1	461729	1191115	520	235	NP	0	?	?	103	?	NP	NP	182	--	--	--	--
09N/29E-06F01	461740	1191351	482	160	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-06G01	461736	1191349	480	231	NP	0	132	NP	132	162	224	--	--	--	--	--	--
09N/29E-09C01	461703	1191128	514	160	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-09L01	461629	1191135	502	201	NP	0	158	NP	158	--	--	--	--	--	--	--	--
09N/29E-10B01	461703	1190948	515	200	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-10R01	461627	1190943	510	200	NP	0	185	NP	NP	185	--	--	--	--	--	--	--
09N/29E-11D01	461708	1190924	479	207	NP	0	180	NP	NP	180	--	--	--	--	--	--	--
09N/29E-11D02	461656	1190906	480	159	NP	0	157	NP	157	--	--	--	--	--	--	--	--
09N/29E-12A01	461656	1190656	415	106	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-15D01	461614	1191041	512	183	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-15N01	461523	1191032	402	79	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-16R01	461533	1191044	445	301	NP	0	138	NP	138	188	296	NP	297	--	--	--	--
09N/29E-17L01	461545	1191240	390	260	NP	0	60	NP	60	109	NP	NP	230	--	--	--	--
09N/29E-21P01	461442	1191140	358	33	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-21R01D1	461440	1191047	361	90	NP	?	31	NP	31	48	--	--	--	--	--	--	--
09N/29E-22D01	461512	1191029	395	86	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-22M02	461449	1191043	353	35	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-23J02	461448	1190829	385	58	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-23N02	461443	1190928	346	24	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-23P01	461432	1190903	358	28	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-23P02	461433	1190852	358	42	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-24B01	461522	1190732	400	77	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-25C01	461429	1190745	374	51	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-25C03	461429	1190751	370	51	NP	0	--	--	--	--	--	--	--	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Latitude	Longitude	Altitude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
09N/29E-25D01	461428	1190811	368	45	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-25L03	461401	1190752	347	26	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-25L04	461356	1190752	348	50	NP	0	49	NP	NP	49	--	--	--	--	--	--	--
09N/29E-25N01	461349	1190814	353	30	NP	0	29	NP	NP	29	--	--	--	--	--	--	--
09N/29E-25R01	461345	1190700	349	27	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-26B01	461429	1190850	358	33	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-26J02	461400	1190823	355	40	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-26L02	461400	1190910	361	35	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-27A01	461419	1190938	366	40	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-27D01	461425	1191037	356	40	NP	0	5	NP	5	16	--	--	--	--	--	--	--
09N/29E-27D02	461425	1191044	359	29	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-30B01	461421	1191353	354	9	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-30C01	461423	1191356	354	12	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-30C02	461426	1191400	353	12	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-31L01	461302	1191402	545	100	0	82	NP	NP	NP	NP	NP	NP	95	--	--	--	--
09N/29E-33M01	461305	1191202	508	292	NP	0	NP	NP	NP	NP	NP	NP	178	--	--	--	--
09N/29E-35R01	461254	1190819	365	33	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-36E01	461314	1190800	348	24	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-36E02	461313	1190805	347	27	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-36M01	461308	1190813	351	17	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-36N02	461254	1190757	362	41	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-36N03	461254	1190758	362	21	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/29E-36P01	461256	1190750	351	24	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-02B01	461755	1190100	508	154	NP	20	NP	NP	NP	NP	NP	NP	151	--	--	--	--
09N/30E-02R01	461712	1190041	515	211	NP	37	145	NP	145	NP	NP	NP	177	--	--	--	--
09N/30E-06D01	461755	1190643	440	105	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-06L01	461727	1190630	432	93	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-06Q01D1	461711	1190608	435	153	NP	0	101	NP	101	152	--	--	--	--	--	--	--
09N/30E-08A02	461704	1190429	543	600	NP	0	NP	NP	NP	NP	NP	NP	222	--	--	--	--
09N/30E-08B02D1	461703	1190457	475	158	NP	0	130	NP	130	--	--	--	--	--	--	--	--
09N/30E-08H01	461650	1190430	448	171	NP	0	NP	NP	NP	NP	NP	NP	160	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Lati- tude	Longi- tude	Alti- tude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
09N/30E-12P01	461616	1190008	431	100	NP	10	--	--	--	--	--	--	--	--	--	--	--
09N/30E-13E02	461556	1190028	443	89	NP	15	87	NP	87	--	--	--	--	--	--	--	--
09N/30E-14A02	461612	1190044	495	158	NP	38	136	NP	136	--	--	--	--	--	--	--	--
09N/30E-14D01	461611	1190153	496	180	NP	10	--	--	--	--	--	--	--	--	--	--	--
09N/30E-14M01	461546	1190155	483	225	NP	18	176	NP	176	197	--	--	--	--	--	--	--
09N/30E-14M02	461545	1190155	482	190	NP	4	142	NP	142	190	--	--	--	--	--	--	--
09N/30E-16F01	461549	1190352	405	134	NP	0	110	NP	NP	110	--	--	--	--	--	--	--
09N/30E-16F02	461547	1190351	406	122	NP	0	119	NP	NP	119	--	--	--	--	--	--	--
09N/30E-17C01	461601	1190518	424	97	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-17K01D1	461545	1190501	428	105	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-17Q01	461532	1190458	425	109	NP	0	90	NP	90	--	--	--	--	--	--	--	--
09N/30E-18J01	461538	1190554	405	1033	NP	0	140	NP	NP	140	NP	NP	220	933	--	--	--
09N/30E-19D01	461515	1190645	399	246	NP	0	118	NP	NP	118	NP	NP	212	--	--	--	--
09N/30E-20D01	461513	1190540	420	0	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-20F01	461455	1190518	420	1030	NP	0	?	NP	?	NP	NP	NP	200	940	--	--	--
09N/30E-20L01	461458	1190505	430	105	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-22K01	461439	1190216	420	138	NP	0	138	NP	138	--	--	--	--	--	--	--	--
09N/30E-22R01	461433	1190210	422	145	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-23M02	461446	1190157	475	157	NP	8	151	NP	151	--	--	--	--	--	--	--	--
09N/30E-23N01	461430	1190138	440	164	NP	0	158	NP	NP	158	NP	NP	160	--	--	--	--
09N/30E-26A01	461425	1190049	364	68	NP	0	NP	NP	NP	NP	NP	NP	65	--	--	--	--
09N/30E-26D01	461425	1190156	413	94	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-26F01	461409	1190126	422	137	NP	8	--	--	--	--	--	--	--	--	--	--	--
09N/30E-26K01	461356	1190116	406	85	NP	10	--	--	--	--	--	--	--	--	--	--	--
09N/30E-26Q01	461346	1190107	398	81	NP	10	--	--	--	--	--	--	--	--	--	--	--
09N/30E-27E01	461412	1190258	420	112	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-27F01	461405	1190250	420	120	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-27H01	461407	1190216	415	95	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-27H02	461407	1190218	420	120	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-27K01	461352	1190230	425	121	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-27L01	461352	1190242	420	121	NP	0	--	--	--	--	--	--	--	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Lati-tude	Longi-tude	Alti-tude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
09N/30E-12P01	461616	1190008	431	100	NP	10	--	--	--	--	--	--	--	--	--	--	--
09N/30E-13E02	461556	1190028	443	89	NP	15	87	NP	87	--	--	--	--	--	--	--	--
09N/30E-14A02	461612	1190044	495	158	NP	38	136	NP	136	--	--	--	--	--	--	--	--
09N/30E-14D01	461611	1190153	496	180	NP	10	--	--	--	--	--	--	--	--	--	--	--
09N/30E-14M01	461546	1190155	483	225	NP	18	176	NP	176	197	--	--	--	--	--	--	--
09N/30E-14M02	461545	1190155	482	190	NP	4	142	NP	142	190	--	--	--	--	--	--	--
09N/30E-16F01	461549	1190352	405	134	NP	0	110	NP	NP	110	--	--	--	--	--	--	--
09N/30E-16F02	461547	1190351	406	122	NP	0	119	NP	NP	119	--	--	--	--	--	--	--
09N/30E-17C01	461601	1190518	424	97	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-17K01D1	461545	1190501	428	105	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-17Q01	461532	1190458	425	109	NP	0	90	NP	90	--	--	--	--	--	--	--	--
09N/30E-18J01	461538	1190554	405	1033	NP	0	140	NP	NP	140	NP	NP	220	933	--	--	--
09N/30E-19D01	461515	1190645	399	246	NP	0	118	NP	NP	118	NP	NP	212	--	--	--	--
09N/30E-20D01	461513	1190540	420	0	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-20F01	461455	1190518	420	1030	NP	0	?	NP	?	NP	NP	NP	200	940	--	--	--
09N/30E-20L01	461458	1190505	430	105	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-22K01	461439	1190216	420	138	NP	0	138	NP	138	--	--	--	--	--	--	--	--
09N/30E-22R01	461433	1190210	422	145	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-23M02	461446	1190157	475	157	NP	8	151	NP	151	--	--	--	--	--	--	--	--
09N/30E-23N01	461430	1190138	440	164	NP	0	158	NP	NP	158	NP	NP	160	--	--	--	--
09N/30E-26A01	461425	1190049	364	68	NP	0	NP	NP	NP	NP	NP	NP	65	--	--	--	--
09N/30E-26D01	461425	1190156	413	94	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-26F01	461409	1190126	422	137	NP	8	--	--	--	--	--	--	--	--	--	--	--
09N/30E-26K01	461356	1190116	406	85	NP	10	--	--	--	--	--	--	--	--	--	--	--
09N/30E-26Q01	461346	1190107	398	81	NP	10	--	--	--	--	--	--	--	--	--	--	--
09N/30E-27E01	461412	1190258	420	112	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-27F01	461405	1190250	420	120	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-27H01	461407	1190216	415	95	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-27H02	461407	1190218	420	120	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-27K01	461352	1190230	425	121	NP	0	--	--	--	--	--	--	--	--	--	--	--
09N/30E-27L01	461352	1190242	420	121	NP	0	--	--	--	--	--	--	--	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Lati-tude	Longi-tude	Alti-tude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
10N/27E-30F01	461927	1192859	520	260	0	15	NP	NP	NP	NP	NP	NP	85	--	--	--	--
10N/27E-32F01	461841	1192747	635	355	0	NP	NP	NP	NP	NP	NP	NP	7	--	--	--	--
10N/27E-32F02	461841	1192745	635	315	NP	NP	NP	NP	NP	NP	NP	NP	0	--	--	--	--
10N/27E-32G01	461835	1192734	750	420	NP	0	NP	NP	NP	NP	NP	NP	60	--	--	--	--
10N/27E-32N01	461811	1192817	510	187	0	6	NP	NP	NP	NP	NP	NP	27	--	--	--	--
10N/27E-33B01	461854	1192622	575	250	0	3	NP	NP	NP	NP	NP	NP	8	--	--	--	--
10N/27E-33D01	461856	1192659	590	372	0	3	NP	NP	NP	NP	NP	NP	31	--	--	--	--
10N/27E-36J01	461817	1192158	450	585	0	NP	NP	NP	NP	NP	NP	NP	61	352	383	--	--
10N/28E-12F01	462210	1191508	495	196	NP	0	50	UK	UK	UK	UK	--	--	--	--	--	--
10N/28E-12J01	462152	1191435	495	179	NP	NP	0	0	60	--	--	--	--	--	--	--	--
10N/28E-12K01	462150	1191451	501	203	NP	NP	0	0	78	155	--	--	--	--	--	--	--
10N/28E-13L01	462103	1191505	470	200	NP	0	78	78	81	--	--	--	--	--	--	--	--
10N/28E-17B01D1	462118	1191958	458	228	NP	5	?	NP	?	180	--	--	221	--	--	--	--
10N/28E-19R01	461948	1192044	385	35	NP	7	18	NP	18	--		--	--	--	--	--	--
10N/28E-23E01	462025	1191653	398	100	NP	0	82	NP	NP	82	--	--	--	--	--	--	--
10N/28E-23L01	462004	1191620	407	134	NP	0	128	NP	NP	128	--	--	--	--	--	--	--
10N/28E-23P03	461953	1191627	390	87	NP	0	82	NP	NP	82	--	--	--	--	--	--	--
10N/28E-26B01	461945	1191615	378	60	NP	0	55	NP	55	--	--	--	--	--	--	--	--
10N/28E-26C02	461934	1191628	367	62	NP	0	57	NP	NP	57	--	--	--	--	--	--	--
10N/28E-29C01	461939	1192022	383	38	NP	5	21	NP	21	--	--	--	--	--	--	--	--
10N/28E-29D02	461933	1192028	382	30	NP	14	--	--	--	--	--	--	--	--	--	--	--
10N/28E-29D03	461942	1192039	382	30	NP	18	--	--	--	--	--	--	--	--	--	--	--
10N/28E-31C01	461852	1192132	382	65	NP	?	53	NP	NP	53	--	--	--	--	--	--	--
10N/28E-32C01	461847	1192024	372	81	NP	16	--	--	--	--	--	--	--	--	--	--	--
10N/28E-33N01	461812	1191917	380	202	NP	3	46	NP	46	67	NP	NP	182	--	--	--	--
10N/28E-34R02	461811	1191714	363	12	NP	0	--	--	--	--	--	--	--	--	--	--	--
10N/28E-35A04	461842	1191553	372	36	NP	0	14	NP	14	--	--	--	--	--	--	--	--
10N/28E-35C03	461842	1191630	375	50	NP	0	18	NP	18	--	--	--	--	--	--	--	--
10N/28E-35D04	461850	1191649	405	86	NP	0	52	NP	52	--	--	--	--	--	--	--	--
10N/28E-35G02	461834	1191611	370	48	NP	0	16	NP	16	--	--	--	--	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Latitude	Longitude	Altitude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
10N/28E-35H09	461838	1191555	350	44	NP	0	18	NP	18	--	--	--	--	--	--	--	--
10N/28E-35J02	461824	1191601	370	44	NP	0	13	NP	13	--	--	--	--	--	--	--	--
10N/28E-35K04	461823	1191604	371	50	NP	0	24	NP	24	--	--	--	--	--	--	--	--
10N/28E-35K05	461817	1191609	360	60	NP	0	--	--	--	--	--	--	--	--	--	--	--
10N/28E-35K06	461818	1191610	355	20	NP	0	--	--	--	--	--	--	--	--	--	--	--
10N/28E-35N03	461805	1191644	363	37	NP	0	25	NP	25	--	--	--	--	--	--	--	--
10N/28E-35R01	461807	1191600	375	59	NP	0	--	--	--	--	--	--	--	--	--	--	--
10N/28E-35R02	461806	1191559	365	39	NP	0	--	--	--	--	--	--	--	--	--	--	--
10N/28E-36D01	461841	1191540	359	53	NP	7	49	NP	49	--	--	--	--	--	--	--	--
10N/29E-01A01	462314	1190650	662	51	NP	NP	0	0	--	--	--	--	--	--	--	--	--
10N/29E-01J01	462242	1190655	668	200	NP	NP	0	0	82	162	190	NP	195	--	--	--	--
10N/29E-02D01	462305	1190910	700	102	NP	NP	0	0	--	--	--	--	--	--	--	--	--
10N/29E-02Q01	462227	1190837	675	386	NP	NP	0	0	NP	?	NP	NP	298	--	--	--	--
10N/29E-02Q02	462231	1190825	660	68	NP	NP	0	0	--	--	--	--	--	--	--	--	--
10N/29E-03A01	462313	1190921	692	50	NP	NP	0	0	--	--	--	--	--	--	--	--	--
10N/29E-03P01	462225	1191006	682	75	NP	NP	0	0	--	--	--	--	--	--	--	--	--
10N/29E-03R01	462225	1190934	682	102	NP	NP	0	0	--	--	--	--	--	--	--	--	--
10N/29E-03R02	462233	1190925	685	114	NP	NP	0	0	--	--	--	--	--	--	--	--	--
10N/29E-04N01	462225	1191133	689	110	NP	NP	0	0	--	--	--	--	--	--	--	--	--
10N/29E-05A01	462313	1191151	721	50	NP	NP	0	0	--	--	--	--	--	--	--	--	--
10N/29E-06H01	462256	1191312	794	470	NP	NP	0	0	330	NP	NP	NP	466	--	--	--	--
10N/29E-06Q01	462225	1191330	700	480	NP	NP	0	0	NP	NP	NP	NP	240	--	--	--	--
10N/29E-08C01	462221	1191227	685	70	NP	NP	0	0	--	--	--	--	--	--	--	--	--
10N/29E-08K01	462145	1191225	641	463	NP	0	45	45	196	291	NP	NP	297	--	--	--	--
10N/29E-08K02	462147	1191220	641	125	NP	0	?	?	--	--	--	--	--	--	--	--	--
10N/29E-08R01	462130	1191150	620	50	NP	0	35	35	--	--	--	--	--	--	--	--	--
10N/29E-09Q01	462136	1191102	575	149	NP	0	?	?	140	--	--	--	--	--	--	--	--
10N/29E-09R01	462133	1191041	616	388	NP	0	33	33	136	242	NP	NP	249	--	--	--	--
10N/29E-10B01	462218	1190951	685	55	NP	NP	0	0	--	--	--	--	--	--	--	--	--
10N/29E-10C01	462218	1191007	686	397	NP	NP	0	0	NP	NP	NP	NP	207	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Lati-tude	Longi-tude	Alti-tude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
10N/29E-10D01	462218	1191025	685	618	NP	NP	0	0	195	281	NP	NP	290	--	--	--	--
10N/29E-10N01	462138	1191017	649	55	NP	0	33	33	--	--	--	--	--	--	--	--	--
10N/29E-10N02	462137	1191017	648	29	NP	0	--	--	--	--	--	--	--	--	--	--	--
10N/29E-10N03	462136	1191017	648	22	NP	0	--	--	--	--	--	--	--	--	--	--	--
10N/29E-10Q01	462135	1190943	658	370	NP	0	21	21	180	NP	NP	NP	253	--	--	--	--
10N/29E-10Q02	462132	1190957	652	168	NP	0	35	35	--	--	--	--	--	--	--	--	--
10N/29E-11C01	462220	1190855	680	57	NP	NP	0	0	--	--	--	--	--	--	--	--	--
10N/29E-11K01	462150	1190831	650	397	NP	NP	0	0	172	NP	NP	NP	246	--	--	--	--
10N/29E-11N01	462135	1190909	653	50	NP	0	30	30	--	--	--	--	--	--	--	--	--
10N/29E-11N02	462135	1190911	666	92	NP	0	?	?	--	--	--	--	--	--	--	--	--
10N/29E-12Q01	462134	1190718	630	126	NP	0	?	?	119	--	--	--	--	--	--	--	--
10N/29E-14D01	462126	1190909	652	58	NP	0	21	21	--	--	--	--	--	--	--	--	--
10N/29E-14R01	462038	1190805	603	50	NP	0	25	25	--	--	--	--	--	--	--	--	--
10N/29E-15D01	462128	1191033	615	40	NP	NP	0	0	--	--	--	--	--	--	--	--	--
10N/29E-15J01	462059	1190931	617	373	NP	0	12	12	152	NP	NP	NP	237	--	--	--	--
10N/29E-15M01	462102	1191031	567	352	NP	0	?	?	109	188	NP	NP	195	--	--	--	--
10N/29E-16A01	462127	1191037	610	144	NP	0	129	NP	129	--	--	--	--	--	--	--	--
10N/29E-16A02	462121	1191038	608	104	NP	0	90	NP	90	--	--	--	--	--	--	--	--
10N/29E-17J01	462055	1191154	536	400	UK	UK	UK	UK	UK	UK	UK	UK	209	--	--	--	--
10N/29E-19L01	462006	1191357	502	225	NP	0	195	NP	195	--	--	--	--	--	--	--	--
10N/29E-19Q01	461953	1191335	495	238	NP	0	185	185	210	--	--	--	--	--	--	--	--
10N/29E-21A01	462036	1191036	509	50	NP	0	--	--	--	--	--	--	--	--	--	--	--
10N/29E-24P01	461947	1190739	525	285	NP	0	NP	NP	NP	NP	NP	NP	100	--	--	--	--
10N/29E-25A01	461944	1190654	498	136	NP	0	70	70	120	NP	NP	NP	130	--	--	--	--
10N/29E-25B01	461944	1190718	493	90	NP	0	--	--	--	--	--	--	--	--	--	--	--
10N/29E-25G01	461929	1190714	480	131	NP	0	25	25	53	NP	NP	NP	128	--	--	--	--
10N/29E-26A01	461944	1190806	496	76	NP	0	15	15	NP	NP	NP	NP	71	--	--	--	--
10N/29E-26D01	461943	1190918	505	274	NP	0	NP	NP	NP	NP	NP	NP	149	--	--	--	--
10N/29E-27C01	461944	1191001	483	205	NP	30	150	NP	150	--	--	--	--	--	--	--	--
10N/29E-28B01	461944	1191115	504	172	NP	0	--	--	--	--	--	--	--	--	--	--	--
10N/29E-29L01	461913	1191241	520	218	NP	0	144	NP	144	--	--	--	--	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Lati- tude	Longi- tude	Alti- tude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
10N/29E-31R01	461808	1191318	512	315	NP	0	120	NP	120	181	NP	NP	219	--	--	--	--
10N/29E-33P01	461806	1191129	520	325	NP	0	125	NP	125	232	260	NP	261	--	--	--	--
10N/29E-34C01	461852	1191000	454	120	NP	8	--	--	--	--	--	--	--	--	--	--	--
10N/29E-35D01	461850	1190917	450	141	NP	0	105	NP	105	NP	NP	NP	141	--	--	--	--
10N/29E-35E01	461833	1190911	450	165	NP	0	157	157	NP	NP	NP	NP	162	--	--	--	--
10N/29E-35H01	461840	1190825	450	144	NP	0	110	NP	110	NP	NP	NP	144	--	--	--	--
10N/29E-35P01	461813	1190902	460	180	NP	0	163	NP	163	179	--	--	--	--	--	--	--
10N/30E-03J01	462238	1190159	640	230	NP	NP	11	11	NP	NP	NP	NP	67	--	--	--	--
10N/30E-03Q02	462236	1190201	641	51	NP	0	10	10	--	--	--	--	--	--	--	--	--
10N/30E-04E01	462257	1190412	555	30	NP	10	NP	NP	NP	NP	NP	NP	28	--	--	--	--
10N/30E-04N01	462227	1190403	590	121	NP	0	NP	NP	NP	NP	NP	NP	58	--	--	--	--
10N/30E-05B01	462314	1190449	590	27	NP	NP	NP	NP	NP	NP	NP	NP	22	--	--	--	--
10N/30E-05N01	462221	1190526	553	51	NP	0	--	--	--	--	--	--	--	--	--	--	--
10N/30E-07J02	462144	1190542	548	28	NP	0	--	--	--	--	--	--	--	--	--	--	--
10N/30E-07M01	462150	1190640	607	314	NP	0	?	?	70	NP	NP	NP	188	--	--	--	--
10N/30E-08F01	462200	1190505	538	64	NP	0	NP	NP	NP	NP	NP	NP	60	--	--	--	--
10N/30E-08K01	462150	1190445	567	90	NP	0	55	55	NP	NP	NP	NP	85	--	--	--	--
10N/30E-08M01	462155	1190512	527	53	NP	0	26	26	NP	NP	NP	NP	46	--	--	--	--
10N/30E-08M02	462154	1190527	546	76	NP	0	45	45	NP	NP	NP	NP	70	--	--	--	--
10N/30E-09M01	462155	1190401	580	180	NP	0	75	75	NP	NP	NP	NP	90	--	--	--	--
10N/30E-11Q01	462139	1190058	720	286	NP	0	30	30	NP	NP	NP	NP	160	--	--	--	--
10N/30E-14N01	462038	1190141	713	51	NP	0	6	6	--	--	--	--	--	--	--	--	--
10N/30E-16A01	462128	1190259	654	51	NP	0	19	19	--	--	--	--	--	--	--	--	--
10N/30E-16P01D1	462041	1190347	653	111	NP	0	--	--	--	--	--	--	--	--	--	--	--
10N/30E-18G01	462114	1190605	547	716	NP	0	50	50	75	NP	NP	NP	135	--	--	--	--
10N/30E-18Q02	462040	1190611	500	89	NP	0	NP	NP	NP	NP	NP	NP	84	--	--	--	--
10N/30E-19E01	462013	1190632	493	395	UK	UK	UK	UK	UK	UK	UK	UK	87	--	--	--	--
10N/30E-19J01	462008	1190534	551	122	NP	0	62	62	103	--	--	--	--	--	--	--	--
10N/30E-20C01	462036	1190454	565	51	NP	0	--	--	--	--	--	--	--	--	--	--	--
10N/30E-21N01	461945	1190408	611	366	NP	0	99	99	192	195	NP	NP	208	--	--	--	--
10N/30E-21R01	461946	1190300	604	51	NP	NP	0	0	--	--	--	--	--	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Lati-tude	Longi-tude	Alti-tude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
10N/30E-22N01	461952	1190249	613	17	NP	0	--	--	--	--	--	--	--	--	--	--	--
10N/30E-23H02	462021	1190042	678	641	NP	NP	0	0	NP	?	NP	NP	248	565	568	--	--
10N/30E-23H03	462021	1190042	678	400	NP	NP	0	0	NP	225	NP	NP	251	--	--	--	--
10N/30E-25D01	461933	1190011	545	208	NP	20	45	45	NP	84	NP	NP	103	--	--	--	--
10N/30E-27C01	461946	1190230	594	17	NP	0	--	--	--	--	--	--	--	--	--	--	--
10N/30E-28G01	461925	1190335	577	17	NP	0	--	--	--	--	--	--	--	--	--	--	--
10N/30E-29H01	461920	1190415	562	51	NP	0	20	20	--	--	--	--	--	--	--	--	--
10N/30E-30A01	461944	1190531	548	51	NP	0	--	--	--	--	--	--	--	--	--	--	--
10N/30E-30E01	461920	1190648	502	51	NP	0	--	--	--	--	--	--	--	--	--	--	--
10N/30E-33G01	461836	1190334	550	471	UK	UK	UK	UK	UK	UK	UK	UK	154	--	--	--	--
10N/30E-33H01	461830	1190300	548	156	NP	16	85	85	NP	NP	NP	NP	151	--	--	--	--
10N/30E-33N04	461801	1190414	549	229	NP	92	181	NP	181	NP	NP	NP	229	--	--	--	--
10N/30E-35R01	461807	1190036	515	147	NP	37	129	129	142	NP	NP	NP	146	--	--	--	--
10N/31E-04N02D1	462233	1185700	536	545	NP	18	NP	NP	NP	NP	NP	NP	74	NP	?	--	--
10N/31E-05D01	462313	1185757	559	53	NP	10	NP	NP	NP	NP	NP	NP	49	--	--	--	--
10N/31E-07E01	462158	1185911	722	533	NP	0	?	?	NP	NP	NP	NP	264	NP	517	--	--
10N/31E-08A02	462209	1185705	563	147	NP	6	--	--	--	--	--	--	--	--	--	--	--
10N/31E-08E01	462201	1185815	592	400	UK	UK	UK	UK	UK	UK	UK	UK	78	--	--	--	--
10N/31E-08K02	462155	1185736	590	140	NP	19	--	--	--	--	--	--	--	--	--	--	--
10N/31E-09D01	462219	1185701	535	310	NP	60	NP	NP	NP	NP	NP	NP	136	282	285	--	--
10N/31E-17B01	462128	1185741	583	84	NP	12	NP	NP	NP	NP	NP	NP	79	--	--	--	--
10N/31E-19B01	462037	1185839	575	105	NP	NP	NP	NP	NP	NP	NP	NP	17	--	--	--	--
10N/31E-29D01	461944	1185818	493	103	NP	50	NP	NP	NP	NP	NP	NP	97	--	--	--	--
10N/31E-30A01	461936	1185820	483	121	4	11	97	97	112	NP	NP	NP	120	--	--	--	--
10N/31E-30A02	461935	1185820	483	137	5	12	102	102	111	NP	NP	NP	123	--	--	--	--
10N/31E-30A03	461937	1185827	508	129	6	23	106	106	107	--	--	--	--	--	--	--	--
10N/31E-32L01	461820	1185742	565	305	NP	NP	NP	NP	NP	NP	NP	NP	10	--	--	--	--
10N/31E-32L02	461815	1185750	540	350	NP	NP	NP	NP	NP	NP	NP	NP	9	--	--	--	--
10N/31E-32L03	461824	1185747	538	290	NP	NP	NP	NP	NP	NP	NP	NP	20	--	--	--	--
10N/31E-32M01	461822	1185812	523	165	NP	NP	NP	NP	NP	NP	NP	NP	16	--	--	--	--
y10N/31E-32M02	461815	1185803	518	400	NP	NP	NP	NP	NP	NP	NP	NP	14	371	384	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Latitude	Longitude	Altitude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
10N/31E-32M03	461819	1185802	520	310	NP	NP	NP	NP	NP	NP	NP	NP	18	--	--	--	--
10N/31E-32N03	461811	1185801	520	295	NP	NP	NP	NP	NP	NP	NP	NP	19	--	--	--	--
10N/31E-32P03	461810	1185758	530	360	NP	NP	NP	NP	NP	NP	NP	NP	17	--	--	--	--
10N/31E-32P04	461802	1185743	592	320	NP	25	NP	NP	NP	NP	NP	NP	31	--	--	--	--
10N/31E-34K01	461816	1185458	795	600	NP	NP	9	UK	UK	UK	UK	NP	210	NP	510	--	--
11N/28E-13C01	462640	1191510	418	140	NP	NP	0	NP	0	--	--	--	--	--	--	--	--
11N/28E-13C02	462639	1191510	418	105	NP	NP	0	NP	0	--	--	--	--	--	--	--	--
11N/28E-13C03	462637	1191511	383	288	NP	NP	0	NP	0	?	--	--	--	--	--	--	--
11N/28E-25R02	462409	1191419	859	50	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-01A01	462822	1190650	840	40	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-02L01	462803	1190837	927	459	NP	NP	0	0	295	NP	NP	NP	300	--	--	--	--
11N/29E-03H01	462813	1190908	913	552	NP	NP	0	0	NP	NP	NP	NP	388	--	--	--	--
11N/29E-05D01	462830	1191254	917	50	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-05R01	462740	1191150	924	1000	NP	NP	0	0	492	NP	NP	NP	572	--	--	--	--
11N/29E-05R02	462736	1191142	923	105	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-06C01	462832	1191337	908	66	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-07M01	462704	1191413	895	600	NP	NP	0	0	460	590	--	--	--	--	--	--	--
11N/29E-10C01	462734	1190945	908	50	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-10C02	462735	1190945	907	27	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-10C03	462733	1190945	907	14	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-10C04	462736	1190945	908	10	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-11A01	462736	1190754	920	433	NP	NP	0	0	NP	NP	NP	NP	362	--	--	--	--
11N/29E-12E01	462712	1190752	918	105	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-13C01	462639	1190728	880	30	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-14D01	462641	1190909	911	50	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-14R01	462552	1190758	781	50	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-16N01	462551	1191142	911	50	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-17N01	462554	1191249	889	565	NP	NP	0	0	400	NP	NP	NP	475	--	--	--	--
11N/29E-19R01	462500	1191302	874	50	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-20N01	462501	1191251	885	936	NP	NP	0	0	417	NP	NP	NP	612	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Lati- tude	Longi- tude	Alti- tude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
11N/29E-20N02	462502	1191252	885	77	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-23C01	462550	1190836	787	519	NP	NP	0	0	255	NP	NP	NP	330	--	--	--	--
11N/29E-23N01	462507	1190857	865	329	NP	NP	0	0	322	--	--	--	--	--	--	--	--
11N/29E-23N02	462507	1190901	865	99	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-24R01	462500	1190646	685	50	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-25N02	462408	1190758	694	51	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-25R01	462410	1190650	660	454	NP	NP	0	0	114	NP	NP	NP	204	--	--	--	--
11N/29E-26D01	462457	1190912	830	50	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-26P01	462415	1190842	707	426	NP	NP	0	0	201	304	NP	NP	309	--	--	--	--
11N/29E-27A01	462457	1190919	840	500	NP	NP	0	0	310	NP	NP	NP	450	--	--	--	--
11N/29E-27D01	462457	1191021	870	45	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-27M01	462432	1191026	801	461	NP	NP	0	0	310	--	--	--	--	--	--	--	--
11N/29E-28R01	462414	1191040	795	87	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-28R02	462414	1191040	795	87	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-31N01	462321	1191415	851	746	NP	NP	0	0	420	NP	NP	NP	580	--	--	--	--
11N/29E-31Q01D4	462317	1191337	862	920	NP	NP	0	0	400	NP	NP	NP	540	--	--	--	--
11N/29E-32R01	462315	1191151	718	371	NP	NP	0	0	237	NP	NP	NP	365	--	--	--	--
11N/29E-33G01	462351	1191054	742	47	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-34A01	462359	1190919	701	339	NP	NP	0	0	178	--	--	--	--	--	--	--	--
11N/29E-34D01	462405	1191026	760	72	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-34D02	462359	1191028	760	78	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-34J01	462337	1190922	689	106	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-34J02	462339	1190920	692	211	NP	NP	0	0	171	--	--	--	--	--	--	--	--
11N/29E-34P01	462315	1191014	695	150	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-34R01	462316	1190934	690	109	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/29E-34R02	462316	1190937	690	160	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/30E-01P01	462743	1185950	626	195	NP	16	--	--	--	--	--	--	--	--	--	--	--
11N/30E-02B01	462818	1190046	597	138	NP	25	NP	NP	NP	NP	NP	NP	128	--	--	--	--
11N/30E-02H01	462806	1190042	595	170	0	45	NP	NP	NP	NP	NP	NP	161	--	--	--	--
11N/30E-02J01	462752	1190040	597	102	0	52	--	--	--	--	--	--	--	--	--	--	--
11N/30E-02Q02	462737	1190047	591	133	53	81	--	--	--	--	--	--	--	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Latitude	Longitude	Altitude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
11N/30E-02R01	462747	1190040	595	130	0	42	--	--	--	--	--	--	--	--	--	--	--
11N/30E-02R02	462747	1190041	594	114	0	40	--	--	--	--	--	--	--	--	--	--	--
11N/30E-03G01	462814	1190212	798	113	NP	NP	NP	NP	NP	NP	NP	NP	0	--	--	--	--
11N/30E-03L01	462754	1190233	765	105	NP	0	NP	NP	NP	NP	NP	NP	35	--	--	--	--
11N/30E-05B01	462830	1190438	753	109	NP	0	NP	NP	NP	NP	NP	NP	27	--	--	--	--
11N/30E-05N01	462737	1190524	708	57	NP	0	15	15	NP	NP	NP	NP	50	--	--	--	--
11N/30E-05N02	462737	1190524	708	79	NP	0	15	15	NP	NP	NP	NP	53	--	--	--	--
11N/30E-06B01	462830	1190553	780	196	NP	NP	0	0	NP	NP	NP	NP	142	--	--	--	--
11N/30E-06N01	462736	1190636	851	50	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/30E-07A01	462725	1190546	750	200	NP	NP	0	0	NP	NP	NP	NP	106	--	--	--	--
11N/30E-07D01D1	462736	1190632	848	591	NP	NP	0	0	NP	NP	NP	NP	281	--	--	--	--
11N/30E-08C01	462734	1190454	708	52	NP	0	NP	NP	NP	NP	NP	NP	4	--	--	--	--
11N/30E-08N01	462644	1190526	747	50	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/30E-10B01	462734	1190208	765	115	NP	0	NP	NP	NP	NP	NP	NP	5	--	--	--	--
11N/30E-10G01	462716	1190205	766	246	NP	0	NP	NP	NP	NP	NP	NP	10	--	--	--	--
11N/30E-11A01	462727	1190029	665	290	NP	NP	NP	NP	NP	NP	NP	NP	0	--	--	--	--
11N/30E-11A02	462735	1190034	590	104	0	75	NP	NP	NP	NP	NP	NP	96	--	--	--	--
11N/30E-11B02	462731	1190048	588	118	20	55	--	--	--	--	--	--	--	--	--	--	--
11N/30E-11C01	462735	1190119	700	614	0	NP	NP	NP	NP	NP	NP	NP	38	NP	412	--	--
11N/30E-11G01	462722	1190102	589	392	0	NP	NP	NP	NP	NP	NP	NP	18	--	--	--	--
11N/30E-11G02	462723	1190052	589	42	NP	NP	NP	NP	NP	NP	NP	NP	33	--	--	--	--
11N/30E-12C01	462736	1190002	623	229	0	74	NP	NP	NP	NP	NP	NP	222	--	--	--	--
11N/30E-12C02	462736	1185955	624	177	0	70	--	--	--	--	--	--	--	--	--	--	--
11N/30E-12C03	462736	1185958	623	75	0	68	--	--	--	--	--	--	--	--	--	--	--
11N/30E-12C04	462736	1190007	621	203	0	41	NP	NP	NP	NP	NP	NP	196	--	--	--	--
11N/30E-12D01	462731	1190015	625	410	0	NP	NP	NP	NP	NP	NP	NP	9	NP	?	--	--
11N/30E-12D03	462724	1190015	633	215	0	11	NP	NP	NP	NP	NP	NP	NP	207	--	--	--
11N/30E-13B01	462644	1185942	606	217	0	16	NP	NP	NP	NP	NP	NP	214	--	--	--	--
11N/30E-14F01	462630	1190117	583	196	0	80	--	--	--	--	--	--	--	--	--	--	--
11N/30E-14F02	462625	1190123	580	162	?	80	--	--	--	--	--	--	--	--	--	--	--
11N/30E-14K01	462615	1190054	575	265	0	NP	NP	NP	NP	NP	NP	NP	76	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Latitude	Longitude	Altitude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
11N/30E-15B01	462643	1190202	733	163	NP	0	--	--	--	--	--	--	--	--	--	--	--
11N/30E-15C01	462642	1190225	690	94	NP	0	--	--	--	--	--	--	--	--	--	--	--
11N/30E-15D01	462642	1190257	720	191	NP	0	--	--	--	--	--	--	--	--	--	--	--
11N/30E-17B01	462643	1190440	675	100	NP	0	NP	NP	NP	NP	NP	NP	25	--	--	--	--
11N/30E-17B02	462637	1190435	655	30	NP	0	27	27	--	--	--	--	--	--	--	--	--
11N/30E-21R01	462502	1190301	566	345	NP	NP	NP	NP	NP	NP	NP	NP	30	--	--	--	--
11N/30E-24B01	462549	1185935	605	315	NP	0	NP	NP	NP	NP	NP	NP	90	--	--	--	--
11N/30E-25H01	462435	1185926	615	133	8	50	--	--	--	--	--	--	--	--	--	--	--
11N/30E-29C01	462450	1190501	818	220	NP	NP	?	NP	?	--	--	--	--	--	--	--	--
11N/30E-29C02	462450	1190501	818	251	NP	NP	0	0	200	NP	NP	NP	225	--	--	--	--
11N/30E-29L01	462430	1190457	788	312	NP	NP	0	0	NP	NP	NP	NP	176	--	--	--	--
11N/30E-30B01	462454	1190600	714	531	NP	NP	0	0	NP	NP	NP	NP	280	--	--	--	--
11N/30E-30P01	462413	1190617	666	101	NP	NP	0	0	70	--	--	--	--	--	--	--	--
11N/30E-30Q01	462413	1190551	680	326	NP	NP	0	0	NP	NP	NP	NP	86	--	--	--	--
11N/30E-32D01	462406	1190526	667	51	NP	NP	0	0	--	--	--	--	--	--	--	--	--
11N/30E-34H01	462345	1190151	602	105	NP	NP	NP	NP	NP	NP	NP	NP	0	--	--	--	--
11N/30E-34L01	462339	1190224	626	526	NP	7	NP	NP	NP	NP	NP	NP	15	--	--	--	--
11N/30E-35J01	462341	1190029	720	487	NP	13	NP	NP	NP	NP	NP	NP	42	--	--	--	--
11N/30E-35J02	462341	1190031	705	205	NP	NP	NP	NP	NP	NP	NP	NP	15	--	--	--	--
11N/30E-36M01	462336	1190024	720	237	NP	10	NP	NP	NP	NP	NP	NP	40	--	--	--	--
11N/31E-04P01	462737	1185625	850	1310	NP	NP	NP	NP	NP	NP	NP	NP	35	NP	352	NP	?
11N/31E-15G01	462621	1185449	661	460	NP	NP	NP	NP	NP	NP	NP	NP	30	NP	?	--	--
11N/31E-29N01	462407	1185810	615	162	NP	12	--	--	--	--	--	--	--	--	--	--	--
11N/31E-30D01	462458	1185909	602	184	NP	7	140	140	160	NP	NP	NP	180	--	--	--	--
11N/31E-30E01	462438	1185900	586	410	NP	20	NP	NP	NP	NP	NP	NP	144	326	329	--	--
11N/31E-31H01	462343	1185817	560	122	NP	25	NP	NP	NP	NP	NP	NP	122	--	--	--	--
11N/31E-32E01	462342	1185812	565	142	NP	20	--	--	--	--	--	--	--	--	--	--	--
11N/31E-33B01D1	462357	1185617	605	700	NP	35	NP	NP	NP	NP	NP	NP	135	345	367	--	--
12N/28E-11J01	463230	1191527	667	51	NP	0	28	28	--	--	--	--	--	--	--	--	--
12N/28E-12H01	463234	1191411	620	450	NP	0	30	30	NP	?	NP	NP	297	--	--	--	--
12N/28E-12H02	463241	1191420	611	321	NP	0	6	6	215	230	274	NP	276	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Lati-tude	Longi-tude	Alti-tude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
12N/28E-24N01	463023	1191528	396	755	NP	NP	18	NP	18	161	NP	NP	205	NP	720	--	--
12N/28E-25M01	462943	1191522	380	95	NP	8	50	50	57	--	--	--	--	--	--	--	--
12N/28E-25R01	462930	1191413	860	50	NP	NP	0	0	--	--	--	--	--	--	--	--	--
12N/28E-36Q02	462837	1191449	766	122	NP	NP	0	0	--	--	--	--	--	--	--	--	--
12N/28E-36Q03	462841	1191439	880	126	NP	NP	0	0	--	--	--	--	--	--	--	--	--
12N/28E-36Q04	462840	1191438	878	269	NP	NP	0	0	--	--	--	--	--	--	--	--	--
12N/28E-36Q05	462839	1191446	856	207	NP	NP	0	0	--	--	--	--	--	--	--	--	--
12N/28E-36Q06	462839	1191446	856	59	NP	NP	0	0	--	--	--	--	--	--	--	--	--
12N/29E-01A01	463337	1190645	880	313	NP	NP	0	0	NP	77	NP	NP	128	--	--	--	--
12N/29E-01E01	463319	1190750	733	50	NP	NP	0	0	--	--	--	--	--	--	--	--	--
12N/29E-01G01	463318	1190657	884	482	NP	NP	0	0	NP	?	NP	NP	190	--	--	--	--
12N/29E-02F01	463326	1190835	808	274	NP	NP	0	0	NP	105	NP	NP	184	--	--	--	--
12N/29E-02R01	463258	1190804	790	300	NP	NP	0	0	NP	?	NP	NP	155	--	--	--	--
12N/29E-03F01	463320	1190952	851	401	NP	NP	0	0	NP	?	NP	NP	395	--	--	--	--
12N/29E-03Q01	463256	1190937	822	317	NP	NP	0	0	NP	198	NP	NP	258	--	--	--	--
12N/29E-03R01	463256	1190908	740	50	NP	NP	0	0	--	--	--	--	--	--	--	--	--
12N/29E-04N01	463258	1191138	640	170	NP	NP	0	0	NP	84	NP	NP	126	--	--	--	--
12N/29E-04Q01	463258	1191047	856	463	NP	NP	0	0	NP	182	NP	NP	298	--	--	--	--
12N/29E-05D01	463339	1191252	610	181	NP	NP	0	0	NP	NP	NP	NP	154	--	--	--	--
12N/29E-05Q01	463304	1191206	580	191	NP	0	68	68	NP	NP	NP	NP	85	--	--	--	--
12N/29E-06H01	463329	1191306	604	225	NP	NP	0	0	NP	NP	NP	NP	160	--	--	--	--
12N/29E-06K01	463315	1191325	598	237	NP	NP	0	0	NP	80	NP	NP	165	--	--	--	--
12N/29E-07B01	463255	1191327	580	305	NP	NP	0	0	NP	NP	NP	NP	161	--	--	--	--
12N/29E-07C01	463256	1191344	604	260	NP	0	41	41	NP	110	NP	NP	201	--	--	--	--
12N/29E-07N01	463208	1191406	588	465	NP	0	19	19	190	215	258	NP	266	--	--	--	--
12N/29E-11M01	463222	1190905	715	212	NP	NP	0	0	NP	95	NP	NP	164	--	--	--	--
12N/29E-11N01	463204	1190902	746	300	NP	0	10	10	NP	70	NP	NP	186	--	--	--	--
12N/29E-12N01	463207	1190745	935	430	NP	NP	0	0	NP	165	NP	NP	328	--	--	--	--
12N/29E-12R01	463202	1190645	960	563	NP	NP	0	0	NP	?	NP	NP	337	--	--	--	--
12N/29E-13A01	463153	1190646	957	480	NP	NP	0	0	NP	225	NP	NP	326	--	--	--	--
12N/29E-13N01	463112	1190743	950	627	NP	NP	0	0	NP	237	NP	NP	357	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Lati-tude	Longi-tude	Alti-tude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
12N/29E-15A01	463155	1190916	745	50	NP	0	--	--	--	--	--	--	--	--	--	--	--
12N/29E-15C01	463158	1190950	689	260	NP	0	11	11	NP	?	NP	NP	161	--	--	--	--
12N/29E-15D01	463200	1191017	717	50	NP	NP	0	0	--	--	--	--	--	--	--	--	--
12N/29E-16N01	463111	1191135	671	50	NP	0	40	40	--	--	--	--	--	--	--	--	--
12N/29E-16N02	463120	1191133	685	368	NP	0	12	12	NP	196	NP	NP	282	--	--	--	--
12N/29E-17H01	463140	1191141	818	440	NP	NP	0	0	NP	355	NP	NP	400	--	--	--	--
12N/29E-17K01	463124	1191203	790	478	NP	0	125	125	340	350	NP	NP	400	--	--	--	--
12N/29E-17Q01	463113	1191202	694	544	NP	0	40	40	262	297	NP	NP	315	--	--	--	--
12N/29E-20N01	463021	1191250	860	540	NP	NP	0	0	296	NP	NP	NP	380	--	--	--	--
12N/29E-21E01	463046	1191133	849	240	NP	NP	0	0	--	--	--	--	--	--	--	--	--
12N/29E-21E02	463048	1191135	828	200	NP	NP	0	0	--	--	--	--	--	--	--	--	--
12N/29E-21M01	463038	1191126	879	282	NP	NP	0	0	--	--	--	--	--	--	--	--	--
12N/29E-22Q01	463022	1190937	916	450	NP	NP	0	0	NP	170	NP	NP	425	--	--	--	--
12N/29E-23A01	463101	1190757	948	456	NP	NP	0	0	NP	?	NP	NP	370	--	--	--	--
12N/29E-24E01	463052	1190737	954	468	NP	NP	0	0	NP	100	NP	NP	340	--	--	--	--
12N/29E-24R01	463025	1190642	925	360	NP	NP	0	0	NP	?	NP	NP	254	--	--	--	--
12N/29E-25D01	463016	1190749	927	50	NP	NP	0	0	--	--	--	--	--	--	--	--	--
12N/29E-26A02	463012	1190757	922	1,090	NP	NP	0	0	NP	160	NP	NP	325	NP	?	--	--
12N/29E-28F01	462955	1191110	914	700	NP	NP	0	0	360	405	NP	NP	450	--	--	--	--
12N/29E-30J01	462953	1191256	884	934	NP	NP	0	0	350	NP	NP	NP	549	--	--	--	--
12N/29E-32R01	462845	1191141	916	932	NP	NP	0	0	480	514	NP	NP	523	--	--	--	--
12N/29E-33D01	462926	1191138	912	50	NP	NP	0	0	--	--	--	--	--	--	--	--	--
12N/29E-34B01D1	462924	1190933	920	997	NP	NP	0	0	NP	340	NP	NP	390	899	901	--	--
12N/29E-34K01	462859	1190943	909	971	NP	NP	0	0	NP	390	NP	NP	416	962	964	--	--
12N/30E-01M01	463307	1190016	677	86	NP	10	NP	NP	NP	NP	NP	NP	80	--	--	--	--
12N/30E-01M02	463310	1190012	669	119	NP	21	NP	NP	NP	NP	NP	NP	110	--	--	--	--
12N/30E-01M03	463311	1190007	671	65	NP	0	NP	NP	NP	NP	NP	NP	54	--	--	--	--
12N/30E-03P01	463257	1190222	782	290	UK	UK	UK	UK	UK	UK	UK	UK	30	--	--	--	--
12N/30E-03R01	463254	1190158	800	240	NP	0	NP	NP	NP	NP	NP	NP	45	--	--	--	--
12N/30E-04D01	463338	1190357	880	290	NP	NP	0	0	NP	55	NP	NP	60	--	--	--	--
12N/30E-04L01	463308	1190343	878	250	NP	NP	0	0	NP	19	NP	NP	55	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Latitude	Longitude	Altitude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
12N/30E-04R01	463300	1190257	780	325	NP	NP	NP	NP	NP	NP	NP	NP	0	NP	280	--	--
12N/30E-05B01	463341	1190428	920	457	NP	NP	0	0	NP	135	NP	NP	141	--	--	--	--
12N/30E-05E01	463320	1190520	966	451	NP	NP	0	0	NP	178	NP	NP	245	--	--	--	--
12N/30E-07B01	463247	1190558	964	500	NP	0	15	15	NP	?	NP	NP	345	--	--	--	--
12N/30E-09J01	463223	1190257	779	186	NP	0	NP	NP	NP	NP	NP	NP	3	--	--	--	--
12N/30E-11G01	463227	1190048	675	158	NP	1	NP	NP	NP	NP	NP	NP	151	--	--	--	--
12N/30E-11H01	463226	1190036	667	105	NP	6	NP	NP	NP	NP	NP	NP	95	--	--	--	--
12N/30E-12E01	463231	1190015	679	121	NP	0	NP	NP	NP	NP	NP	NP	120	--	--	--	--
12N/30E-14Q01	463116	1190049	640	171	NP	42	NP	NP	NP	NP	NP	NP	163	--	--	--	--
12N/30E-15B01	463151	1190201	820	210	NP	NP	0	0	NP	NP	NP	NP	20	--	--	--	--
12N/30E-16Q01	463117	1190315	810	56	NP	0	NP	NP	NP	NP	NP	NP	11	--	--	--	--
12N/30E-17B01	463154	1190431	950	502	NP	NP	0	0	NP	?	NP	NP	253	--	--	--	--
12N/30E-18C01	463155	1190605	965	600	NP	NP	0	0	NP	122	NP	NP	343	--	--	--	--
12N/30E-18D01	463156	1190634	962	50	NP	NP	0	0	--	--	--	--	--	--	--	--	--
12N/30E-18R01	463114	1190532	970	519	NP	NP	0	0	NP	?	NP	NP	260	--	--	--	--
12N/30E-19A01	463055	1190526	816	137	NP	NP	0	0	NP	NP	NP	NP	34	--	--	--	--
12N/30E-21G01	463044	1190330	809	211	NP	0	NP	NP	NP	NP	NP	NP	15	--	--	--	--
12N/30E-23G01	463040	1190059	626	128	NP	40	--	--	--	--	--	--	--	--	--	--	--
12N/30E-24F01	463042	1190000	735	405	NP	0	NP	NP	NP	NP	NP	NP	90	--	--	--	--
12N/30E-26Q01	462930	1190049	609	136	NP	14	NP	NP	NP	NP	NP	NP	126	--	--	--	--
12N/30E-27G01	462955	1190211	792	215	NP	0	8	8	NP	NP	NP	NP	30	--	--	--	--
12N/30E-30H01	462946	1190528	742	492	NP	0	NP	NP	NP	NP	NP	NP	10	--	--	--	--
12N/30E-30L01	462946	1190616	845	219	NP	NP	0	0	NP	NP	NP	NP	168	--	--	--	--
12N/30E-30R01	462922	1190526	726	20	NP	NP	NP	NP	NP	NP	NP	NP	10	--	--	--	--
12N/30E-31M01	462850	1190633	860	335	NP	NP	0	0	NP	NP	NP	NP	207	--	--	--	--
12N/30E-33B01	462916	1190319	790	374	NP	0	NP	NP	NP	NP	NP	NP	20	--	--	--	--
12N/30E-34A01	462920	1190152	790	117	NP	0	NP	NP	NP	NP	NP	NP	2	--	--	--	--
12N/30E-34J01	462850	1190150	755	276	0	24	NP	NP	NP	NP	NP	NP	87	--	--	--	--
12N/30E-34N01	462832	1190241	792	328	NP	0	NP	NP	NP	NP	NP	NP	8	--	--	--	--
12N/30E-35A01	462915	1190037	618	108	NP	0	NP	NP	NP	NP	NP	NP	103	--	--	--	--
12N/30E-35H01	462907	1190040	608	131	NP	36	NP	NP	NP	NP	NP	NP	118	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Latitude	Longitude	Altitude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
12N/31E-10M01	463222	1185534	1,058	961	NP	NP	NP	NP	NP	NP	NP	NP	118	NP	?	--	--
13N/27E-14R02	463626	1192315	410	607	NP	NP	48	48	NP	194	303	NP	314	--	--	--	--
13N/28E-03A01	463855	1191654	993	50	NP	NP	14	14	--	--	--	--	--	--	--	--	--
13N/28E-03N01	463806	1191809	967	51	NP	NP	15	15	--	--	--	--	--	--	--	--	--
13N/28E-09L01	463729	1191852	941	810	NP	NP	?	?	NP	?	675	NP	682	--	--	--	--
13N/28E-11E01	463751	1191636	974	727	NP	NP	27	27	NP	375	NP	NP	554	--	--	--	--
13N/28E-13N01	463622	1191536	952	1,119	NP	NP	12	12	NP	410	NP	NP	558	977	1028	--	--
13N/28E-14B01	463705	1191606	974	50	NP	NP	4	4	--	--	--	--	--	--	--	--	--
13N/28E-16J01	463645	1191813	938	51	NP	NP	4	4	--	--	--	--	--	--	--	--	--
13N/28E-21J01	463543	1191822	951	50	NP	NP	7	7	--	--	--	--	--	--	--	--	--
13N/28E-21J02	463544	1191822	951	17	NP	NP	7	7	--	--	--	--	--	--	--	--	--
13N/28E-21J03	463545	1191822	951	27	NP	NP	7	7	--	--	--	--	--	--	--	--	--
13N/28E-21J04	463542	1191822	951	8	NP	NP	7	7	--	--	--	--	--	--	--	--	--
13N/28E-22B01	463609	1191723	963	51	NP	NP	7	7	--	--	--	--	--	--	--	--	--
13N/28E-24D01	463613	1191527	950	51	NP	NP	0	0	--	--	--	--	--	--	--	--	--
13N/28E-26R01	463442	1191548	940	51	NP	NP	10	10	--	--	--	--	--	--	--	--	--
13N/28E-27Q01	463437	1191710	928	50	NP	NP	14	14	--	--	--	--	--	--	--	--	--
13N/28E-28A01	463526	1191827	948	50	NP	NP	5	5	--	--	--	--	--	--	--	--	--
13N/29E-03C01	463858	1191006	947	260	NP	NP	0	0	NP	163	NP	NP	259	--	--	--	--
13N/29E-03C02	463855	1191006	945	608	NP	NP	0	0	NP	168	NP	NP	262	--	--	--	--
13N/29E-04A01	463850	1191044	945	294	NP	0	60	60	NP	178	--	--	--	--	--	--	--
13N/29E-04A02	463856	1191034	936	51	NP	0	--	--	--	--	--	--	--	--	--	--	--
13N/29E-06A01	463853	1191306	1,038	590	NP	NP	0	UK	UK	UK	UK	NP	450	--	--	--	--
13N/29E-08H01	463747	1191202	995	453	NP	NP	10	10	NP	260	NP	NP	405	--	--	--	--
13N/29E-09R01	463720	1191048	946	358	NP	0	25	25	NP	260	NP	NP	328	--	--	--	--
13N/29E-10N02	463714	1191031	947	51	NP	0	40	40	--	--	--	--	--	--	--	--	--
13N/29E-12L01	463739	1190725	762	225	NP	NP	NP	NP	NP	NP	NP	NP	0	--	--	--	--
13N/29E-13K01	463636	1190722	765	702	NP	0	NP	NP	NP	NP	NP	NP	9	398	401	--	--
13N/29E-16D01	463709	1191144	1,008	1,043	UK	UK	UK	UK	UK	UK	UK	UK	442	NP	1030	--	--
13N/29E-16H01	463658	1191049	945	104	NP	0	21	21	--	--	--	--	--	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Lati-tude	Longi-tude	Alti-tude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
13N/29E-20D01	463620	1191302	992	51	NP	NP	13	13	--	--	--	--	--	--	--	--	--
13N/29E-20N01	463532	1191255	982	900	UK	UK	UK	UK	UK	UK	UK	UK	520	--	--	--	--
13N/29E-22P01	463529	1190954	629	13	NP	0	NP	NP	NP	NP	NP	NP	7	--	--	--	--
13N/29E-23M01	463544	1190910	695	310	NP	0	12	12	NP	NP	NP	NP	42	--	--	--	--
13N/29E-23P01	463538	1190843	725	747	NP	0	NP	NP	NP	NP	NP	NP	15	NP	383	--	--
13N/29E-26B01	463526	1190834	738	175	NP	0	NP	NP	NP	NP	NP	NP	19	--	--	--	--
13N/29E-26D01	463524	1190904	716	362	NP	0	NP	NP	NP	NP	NP	NP	18	--	--	--	--
13N/29E-27C01	463523	1191011	621	279	NP	0	NP	NP	NP	NP	NP	NP	18	--	--	--	--
13N/29E-27D01	463518	1191019	605	75	NP	0	NP	NP	NP	NP	NP	NP	21	--	--	--	--
13N/29E-28A01	463528	1191038	585	25	NP	0	--	--	--	--	--	--	--	--	--	--	--
13N/29E-28B01D1	463521	1191056	579	100	NP	0	NP	NP	NP	NP	NP	NP	34	--	--	--	--
13N/29E-28B02	463521	1191056	579	540	NP	0	NP	NP	NP	NP	NP	NP	34	--	--	--	--
13N/29E-30Q01D1	463437	1191328	952	900	NP	NP	25	25	NP	?	NP	NP	?	--	--	--	--
13N/29E-31R01	463349	1191315	904	535	UK	UK	UK	UK	UK	UK	UK	UK	477	--	--	--	--
13N/29E-32D01	463428	1191251	950	51	NP	NP	0	0	--	--	--	--	--	--	--	--	--
13N/29E-32G01	463411	1191215	625	264	NP	NP	0	0	NP	123	NP	NP	143	--	--	--	--
13N/29E-33R01	463347	1191037	693	208	NP	NP	0	0	NP	76	NP	NP	82	--	--	--	--
13N/29E-34E01	463415	1191024	676	149	NP	0	32	32	NP	69	NP	NP	105	--	--	--	--
13N/29E-34N01	463345	1191024	718	182	NP	NP	0	0	NP	102	NP	NP	118	--	--	--	--
13N/29E-35A01	463432	1190800	770	396	NP	NP	0	0	NP	NP	NP	NP	75	--	--	--	--
13N/29E-35D01	463434	1190910	760	373	NP	NP	0	0	NP	?	NP	NP	118	--	--	--	--
13N/29E-35Q01	463347	1190826	815	330	NP	0	7	7	NP	?	NP	NP	191	--	--	--	--
13N/29E-36D01	463436	1190757	770	50	NP	0	10	10	--	--	--	--	--	--	--	--	--
13N/29E-36D02	463430	1190754	766	360	NP	0	?	?	NP	NP	NP	NP	50	--	--	--	--
13N/30E-11D01	463800	1190126	948	269	NP	0	NP	NP	NP	NP	NP	NP	5	--	--	--	--
13N/30E-11H01	463751	1190025	947	350	NP	NP	NP	NP	NP	NP	NP	NP	0	NP	?	--	--
13N/30E-12N01	463715	1190014	974	280	NP	0	NP	NP	NP	NP	NP	NP	5	--	--	--	--
13N/30E-15D01	463710	1190244	915	200	NP	0	NP	NP	NP	NP	NP	NP	15	--	--	--	--
13N/30E-16G01D2	463656	1190318	900	160	NP	0	NP	NP	NP	NP	NP	NP	24	--	--	--	--
13N/30E-22N01	463529	1190236	910	154	NP	0	22	22	NP	NP	NP	NP	29	--	--	--	--
y13N/30E-22P01	463532	1190220	904	361	NP	0	NP	NP	NP	NP	NP	NP	18	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Latitude	Longitude	Altitude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
13N/30E-22R01	463536	1190148	939	364	NP	0	NP	NP	NP	NP	NP	NP	16	--	--	--	--
13N/30E-23D01	463617	1190131	936	220	NP	0	NP	NP	NP	NP	NP	NP	3	--	--	--	--
13N/30E-25C01	463520	1185953	680	200	NP	NP	NP	NP	NP	NP	NP	NP	115	--	--	--	--
13N/30E-25D01	463527	1190015	678	142	NP	51	NP	NP	NP	NP	NP	NP	142	--	--	--	--
13N/30E-25M04	463454	1190016	675	62	NP	45	NP	NP	NP	NP	NP	NP	60	--	--	--	--
13N/30E-26G01	463505	1190040	674	37	NP	0	--	--	--	--	--	--	--	--	--	--	--
13N/30E-26G04	463503	1190039	674	30	NP	27	--	--	--	--	--	--	--	--	--	--	--
13N/30E-27J01	463458	1190140	875	56	NP	0	5	5	NP	NP	NP	NP	50	--	--	--	--
13N/30E-28D01	463528	1190406	891	50	NP	0	32	32	--	--	--	--	--	--	--	--	--
13N/30E-29A01	463524	1190413	888	540	NP	0	43	43	NP	NP	NP	NP	65	NP	?	--	--
13N/30E-29Q01	463441	1190435	904	245	NP	0	21	21	NP	?	NP	NP	113	--	--	--	--
13N/30E-30A01	463519	1190534	772	350	NP	0	NP	NP	NP	NP	NP	NP	16	--	--	--	--
13N/30E-30H01	463509	1190525	856	50	NP	0	30	30	--	--	--	--	--	--	--	--	--
13N/30E-31D01	463433	1190635	755	50	NP	NP	0	0	NP	?	NP	NP	43	--	--	--	--
13N/30E-31N01	463356	1190641	890	235	NP	NP	0	0	NP	100	NP	NP	130	--	--	--	--
13N/30E-31R01	463346	1190532	956	51	NP	NP	0	0	--	--	--	--	--	--	--	--	--
13N/30E-32A02	463436	1190417	883	50	NP	0	16	16	--	--	--	--	--	--	--	--	--
13N/30E-33A01	463433	1190300	894	538	NP	NP	0	0	NP	NP	NP	NP	20	NP	?	--	--
13N/31E-27C01	463520	1185440	921	270	NP	0	NP	NP	NP	NP	NP	NP	4	NP	80	--	--
13N/31E-34K01	463407	1185434	1,046	445	NP	0	NP	NP	NP	NP	NP	NP	90	NP	?	--	--
14N/27E-26E01	464025	1192434	680	80	10	NP	72	72	--	--	--	--	--	--	--	--	--
14N/27E-26J01	464015	1192321	721	116	0	NP	111	111	--	--	--	--	--	--	--	--	--
14N/27E-26M01	464009	1192417	675	96	0	NP	87	87	--	--	--	--	--	--	--	--	--
14N/27E-26R01	463959	1192322	730	112	0	NP	107	107	--	--	--	--	--	--	--	--	--
14N/27E-27A01	464041	1192452	683	70	0	NP	48	48	--	--	--	--	--	--	--	--	--
14N/28E-01F01	464354	1191508	1,149	30	0	NP	NP	NP	NP	NP	NP	NP	27	--	--	--	--
14N/28E-16A01	464221	1191811	967	36	0	NP	10	10	--	--	--	--	--	--	--	--	--
14N/28E-28C01	464042	1191847	838	20	0	NP	17	17	--	--	--	--	--	--	--	--	--
14N/28E-29B01	464034	1191953	829	666	NP	NP	0	0	NP	?	NP	NP	498	--	--	--	--
14N/28E-30D01	464029	1192155	737	60	0	NP	55	55	--	--	--	--	--	--	--	--	--
14N/28E-30M01	464012	1192200	733	91	18	NP	85	85	--	--	--	--	--	--	--	--	--

Table 25.--*Depth to top of hydrologic units in selected wells in the study area--Continued*

Local well number	Latitude	Longitude	Altitude (feet)	Hole depth (feet)	Depth to top of hydrologic unit (feet)												
					TCHT	PSCO	RGLD	UPRG	MDRG	LLRG	BSRG	ELBG	SDLM	MBTN	WNPM	VNTG	GDRD
14N/28E-30N01	463957	1192201	736	99	22	NP	94	94	--	--	--	--	--	--	--	--	--
14N/28E-31E01	463925	1192204	736	106	0	NP	101	101	--	--	--	--	--	--	--	--	--
14N/28E-32D01	463943	1192040	739	53	0	NP	48	48	--	--	--	--	--	--	--	--	--
14N/29E-05A01	464412	1191157	1,100	305	0	28	33	33	136	NP	NP	NP	163	--	--	--	--
14N/29E-05M01	464342	1191258	1,212	550	NP	NP	NP	NP	NP	NP	NP	NP	7	246	280	--	--
14N/29E-07M01	464251	1191407	1,060	827	0	NP	17	17	NP	NP	NP	NP	105	387	440	--	--
14N/29E-08A01	464318	1191205	1,160	423	0	NP	18	18	NP	NP	NP	NP	114	NP	?	--	--
14N/29E-09A01	464321	1191048	1,265	863	NP	NP	0	0	NP	NP	NP	NP	30	240	253	--	--
14N/29E-09B01	464322	1191058	1,270	860	NP	NP	0	0	NP	NP	NP	NP	30	240	253	--	--
14N/29E-09B02	464316	1191052	1,268	725	NP	NP	0	0	NP	NP	NP	NP	60	NP	561	--	--
14N/29E-09R01	464231	1191035	1,055	360	0	NP	25	25	NP	NP	NP	NP	88	326	350	--	--
14N/29E-14C01	464219	1190841	1,006	350	NP	NP	NP	NP	NP	NP	NP	NP	46	254	274	--	--
14N/29E-19Q01	464043	1191322	1,088	420	NP	NP	?	?	NP	?	NP	NP	275	--	--	--	--
14N/29E-20L01D1	464110	1191227	890	870	NP	NP	0	UK	UK	UK	UK	NP	?	NP	?	--	--
14N/29E-20M02D1	464107	1191302	860	920	NP	NP	0	UK	UK	UK	UK	NP	?	NP	?	--	--
14N/29E-21A01	464135	1191033	1,012	51	0	NP	35	35	--	--	--	--	--	--	--	--	--
14N/29E-21J01	464108	1191038	938	260	NP	NP	0	0	NP	NP	NP	NP	52	--	--	--	--
14N/29E-27E01	464025	1191014	947	498	0	NP	19	19	NP	?	NP	NP	119	302	342	--	--
14N/29E-28A01	464044	1191033	926	51	NP	NP	0	0	--	--	--	--	--	--	--	--	--
14N/29E-28C01	464041	1191125	915	343	NP	NP	0	0	NP	?	NP	NP	161	--	--	--	--
14N/29E-32N01	463904	1191300	1,051	596	NP	NP	18	18	NP	290	NP	NP	400	--	--	--	--
14N/29E-32Q01	463910	1191209	960	330	NP	NP	0	0	NP	150	NP	NP	300	--	--	--	--

APPENDIX A

Hydrographs of wells measured monthly by the U.S. Geological Survey, February 1986 through April 1987

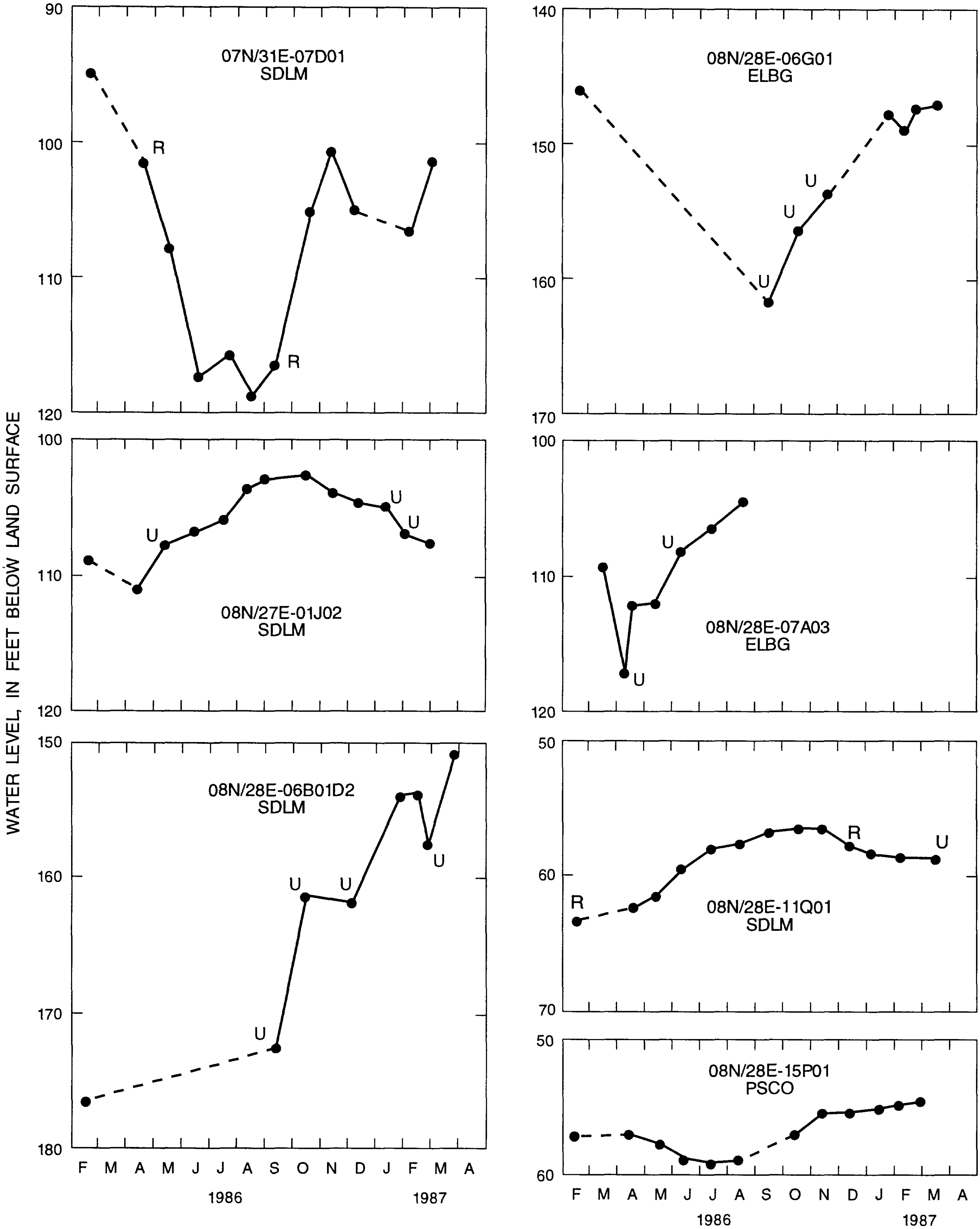
EXPLANATION

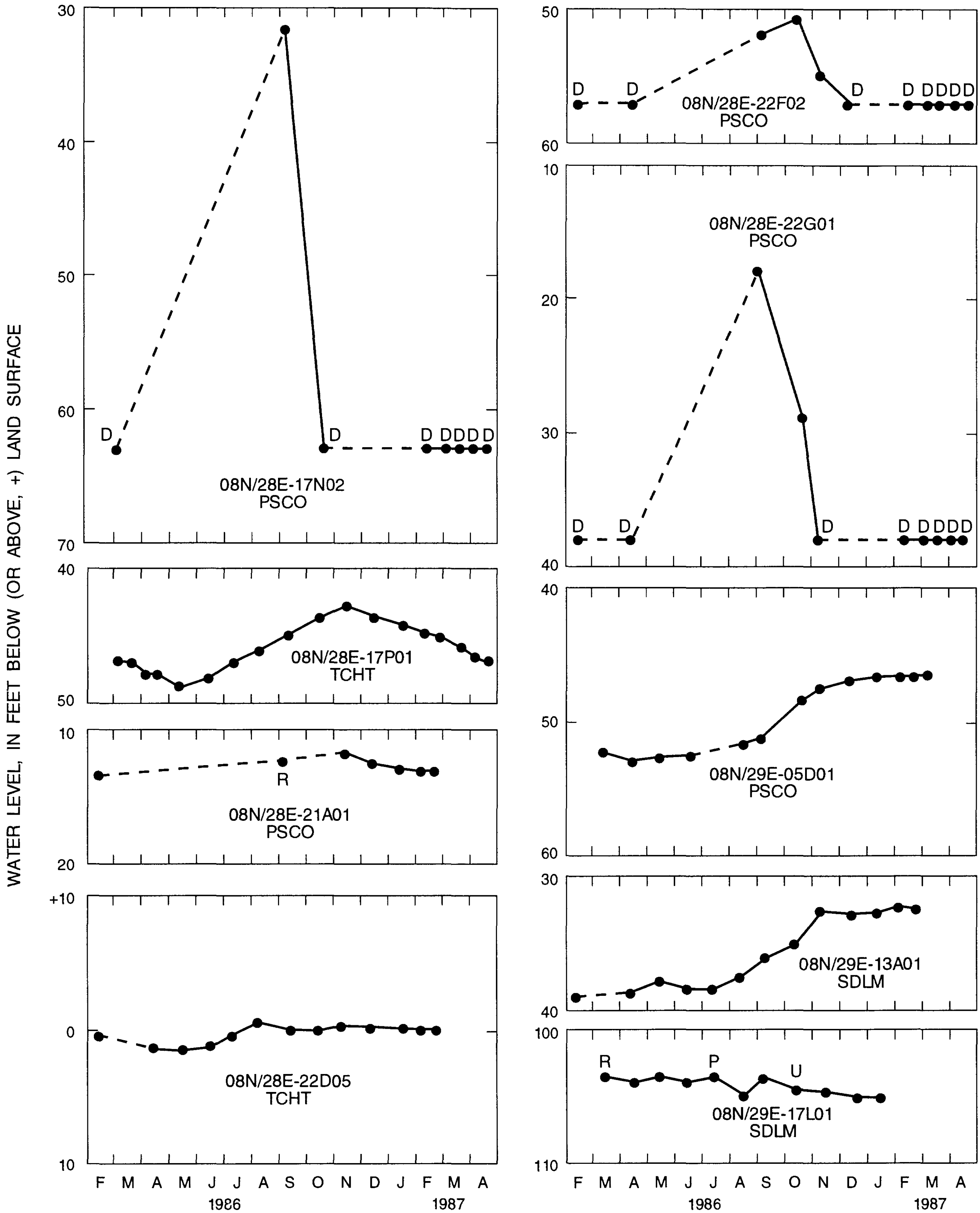
Aquifer:

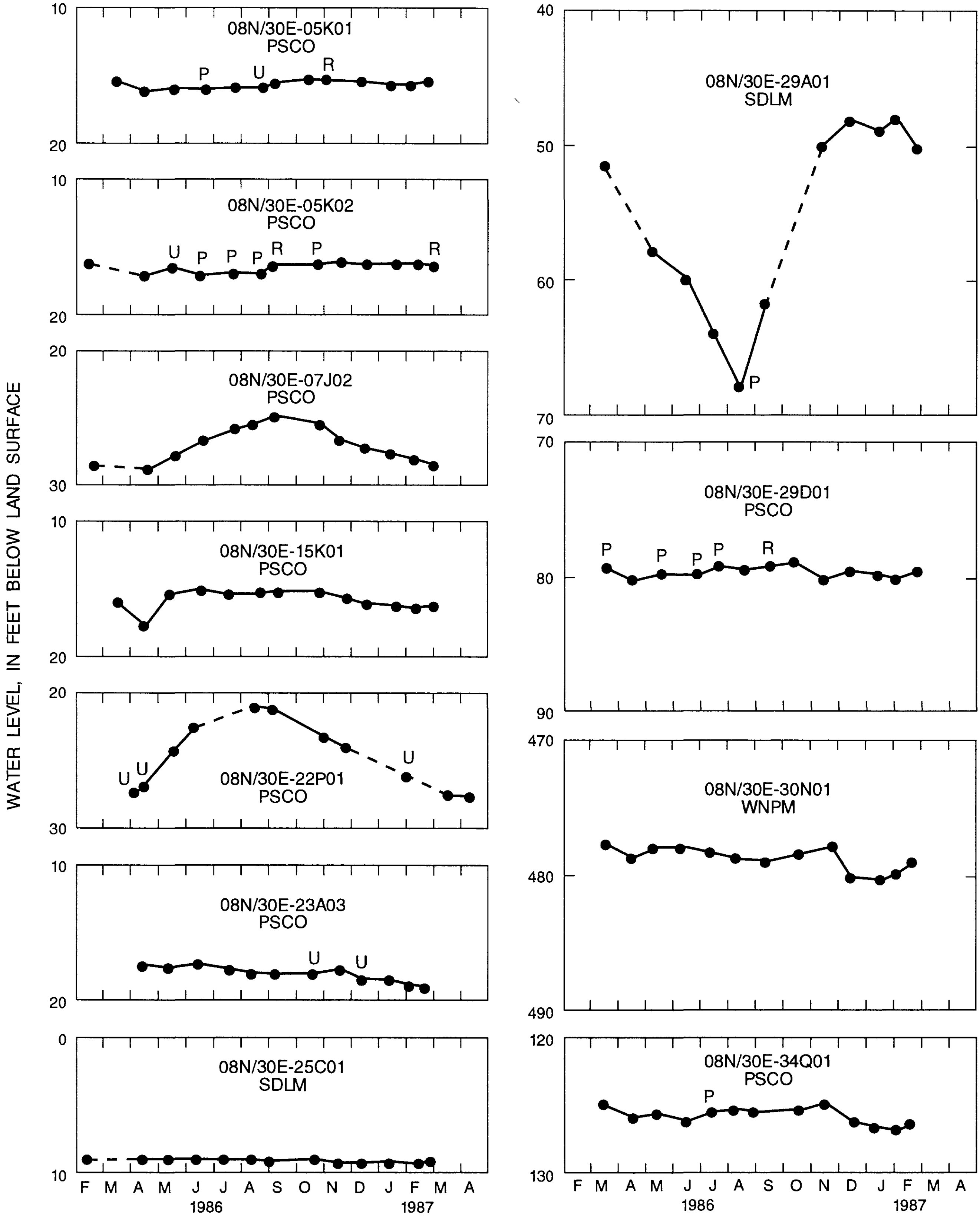
TCHT	=	Touchet Beds
PSCO	=	Pasco gravels
MDRG	=	middle Ringold Formation
BSRG	=	basal Ringold Formation
RGLD	=	undifferentiated Ringold Formation
ELBG	=	Ellensburg Formation (above basalt)
SDLM	=	Saddle Mountains Basalt
WNPM	=	Wanapum Basalt

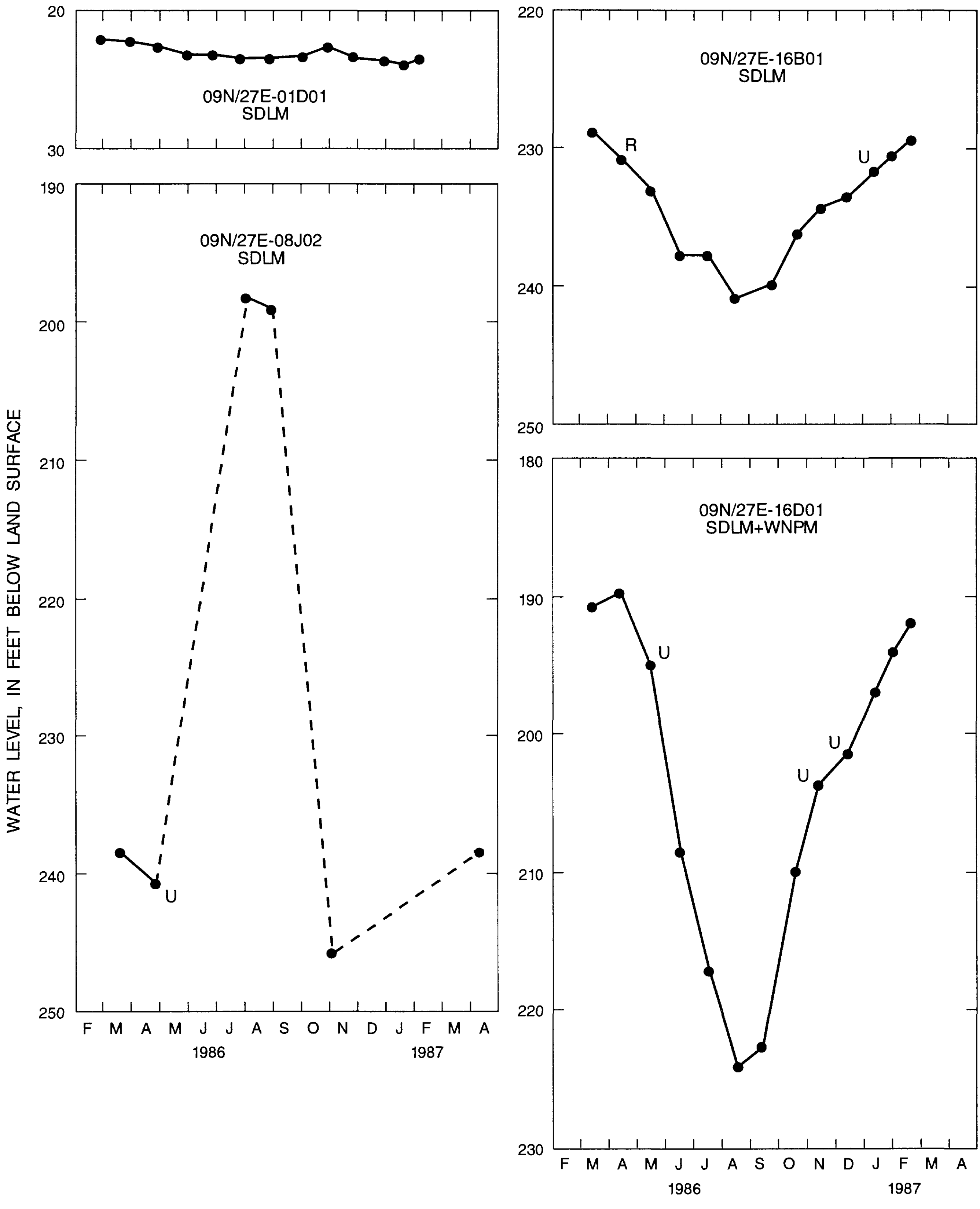
Water-level status:

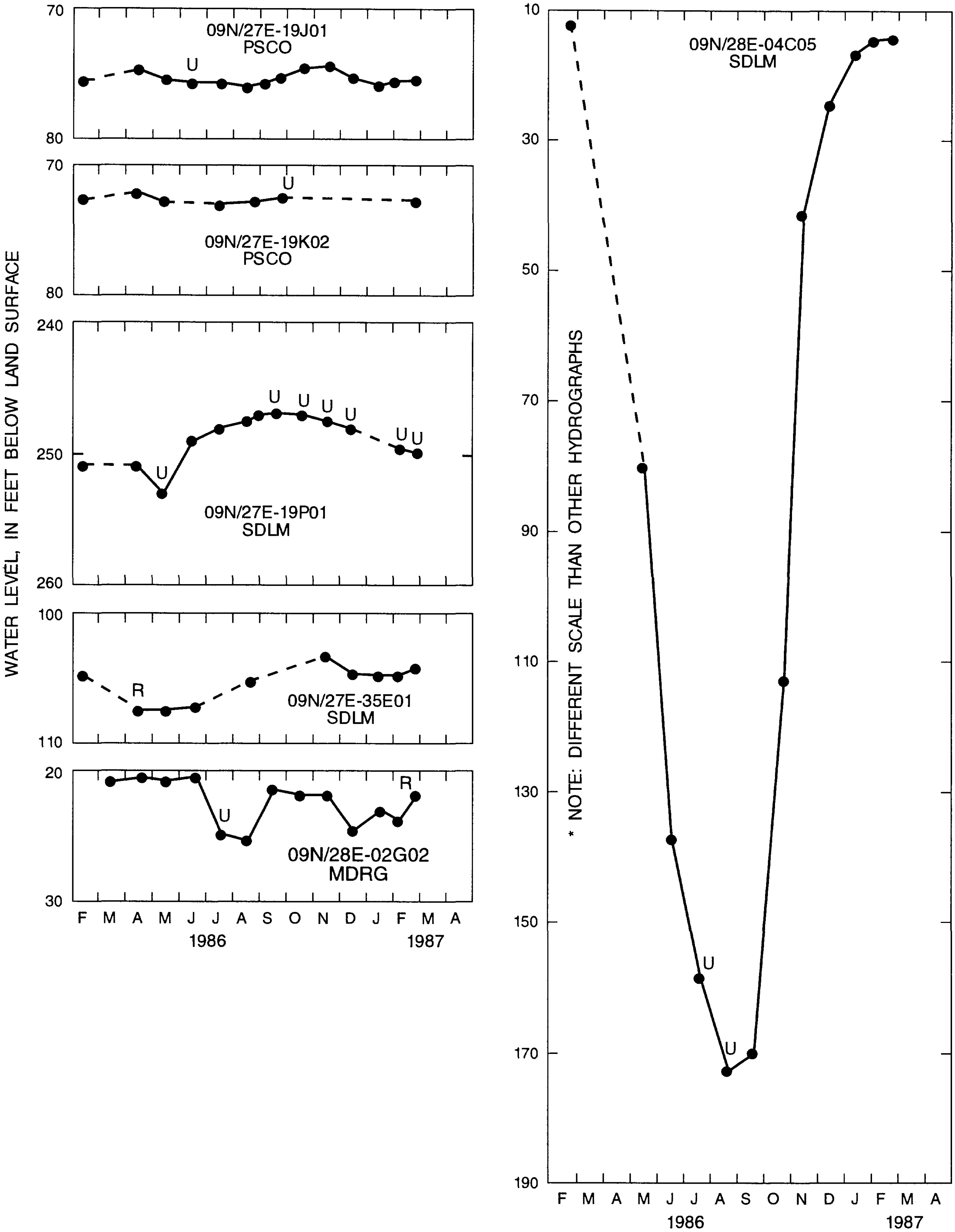
D	=	Dry
P	=	Pumping
R	=	Recovering
U	=	Unknown

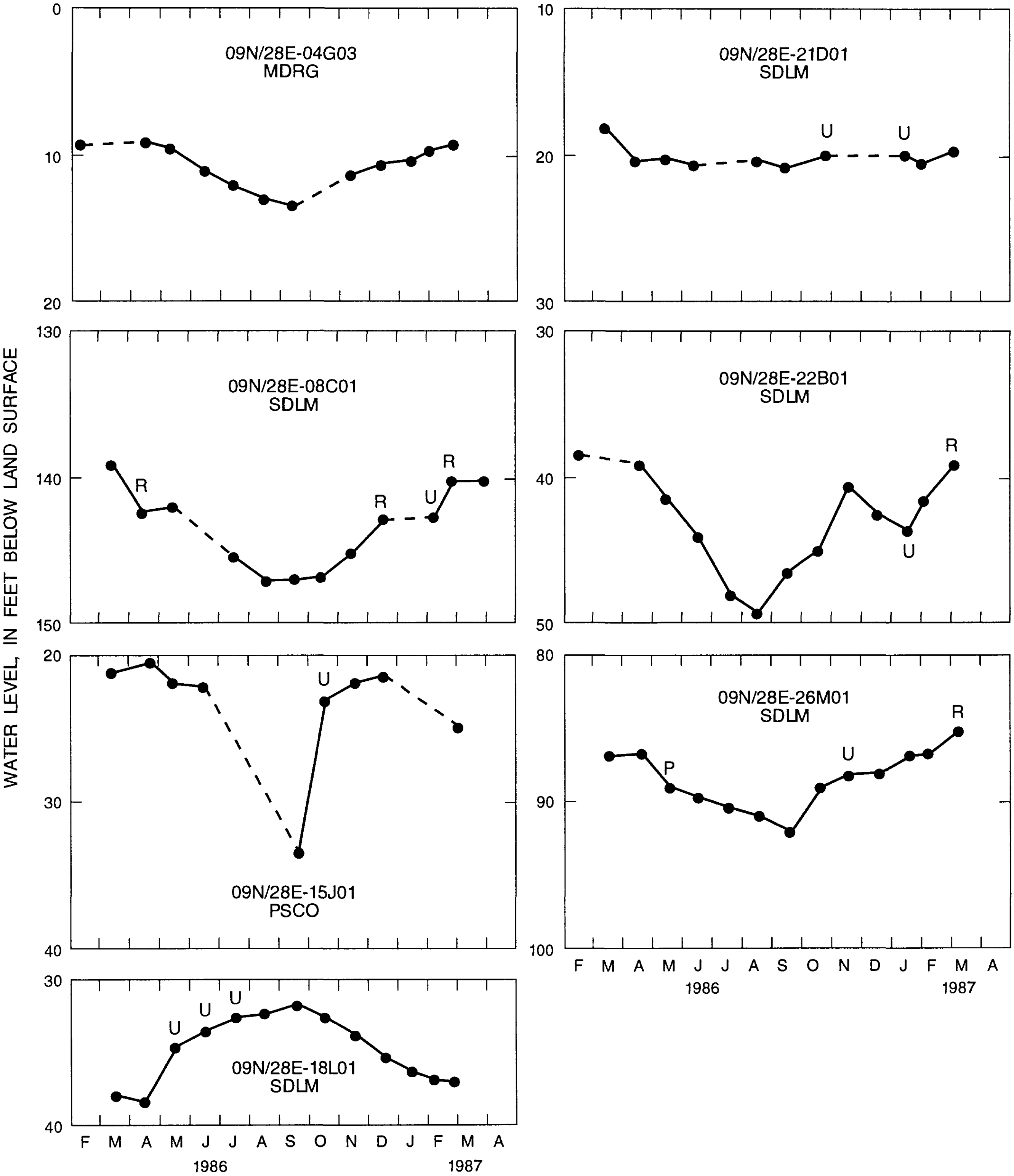

WATER LEVEL, IN FEET BELOW LAND SURFACE
07N/31E-07D01
SDLM
08N/28E-06G01
ELBG
08N/27E-01J02
SDLM
08N/28E-07A03
ELBG
08N/28E-06B01D2
SDLM
08N/28E-11Q01
SDLM
08N/28E-15P01
PSCO
F M A M J J A S O N D J F M A
1986
1987


WATER LEVEL, IN FEET BELOW (OR ABOVE, +) LAND SURFACE
08N/28E-17N02
PSCO
08N/28E-17P01
TCHT
08N/28E-21A01
PSCO
08N/28E-22D05
TCHT
08N/28E-22F02
PSCO
08N/28E-22G01
PSCO
08N/29E-05D01
PSCO
08N/29E-13A01
SDLM
08N/29E-17L01
SDLM
F M A M J J A S O N D J F M A
1986
1987

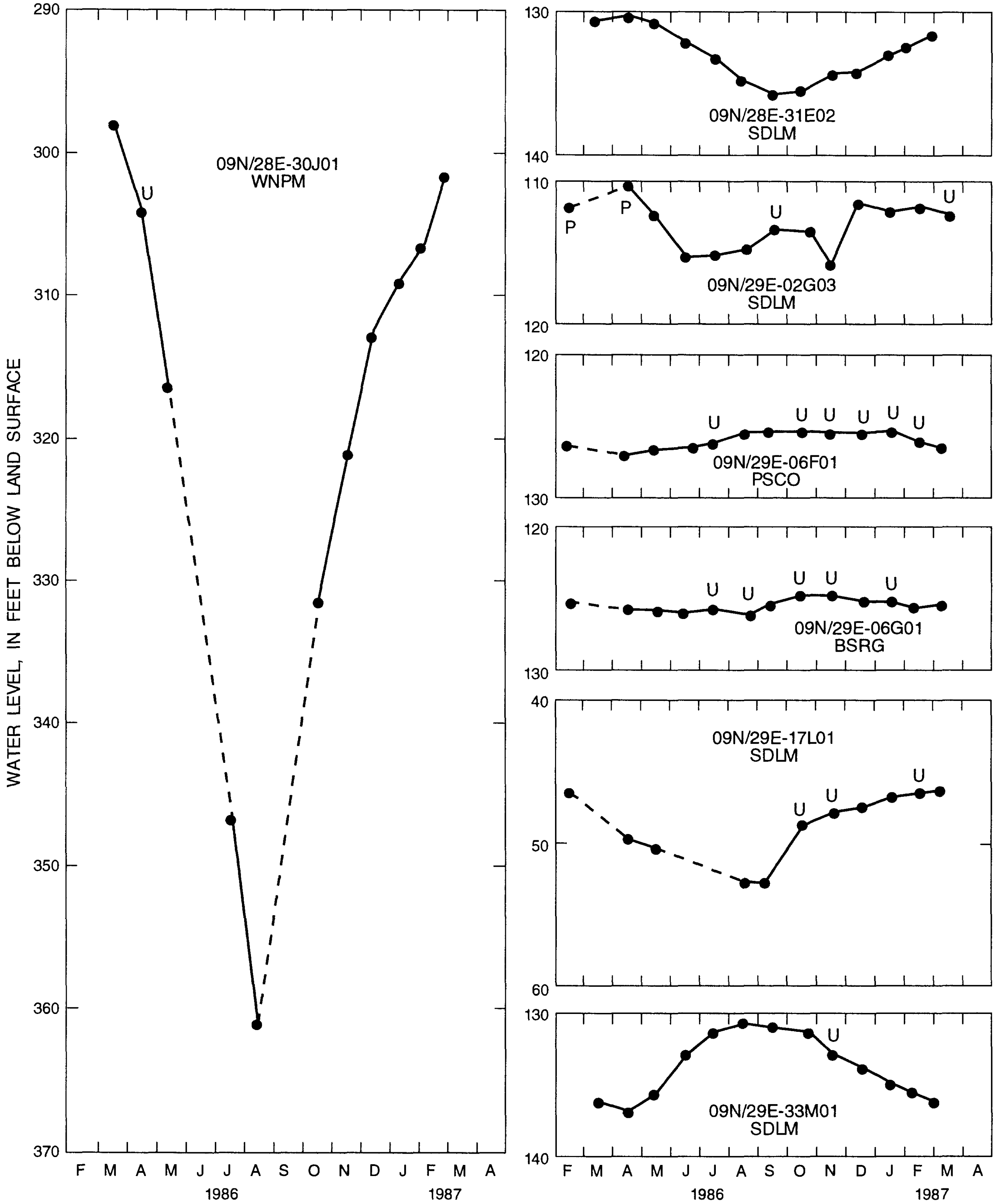

WATER LEVEL, IN FEET BELOW LAND SURFACE
08N/30E-05K01
PSCO
08N/30E-05K02
PSCO
08N/30E-07J02
PSCO
08N/30E-15K01
PSCO
08N/30E-22P01
PSCO
08N/30E-23A03
PSCO
08N/30E-25C01
SDLM
08N/30E-29A01
SDLM
08N/30E-29D01
PSCO
08N/30E-30N01
WNPM
08N/30E-34Q01
PSCO
F M A M J J A S O N D J F M A
1986
1987

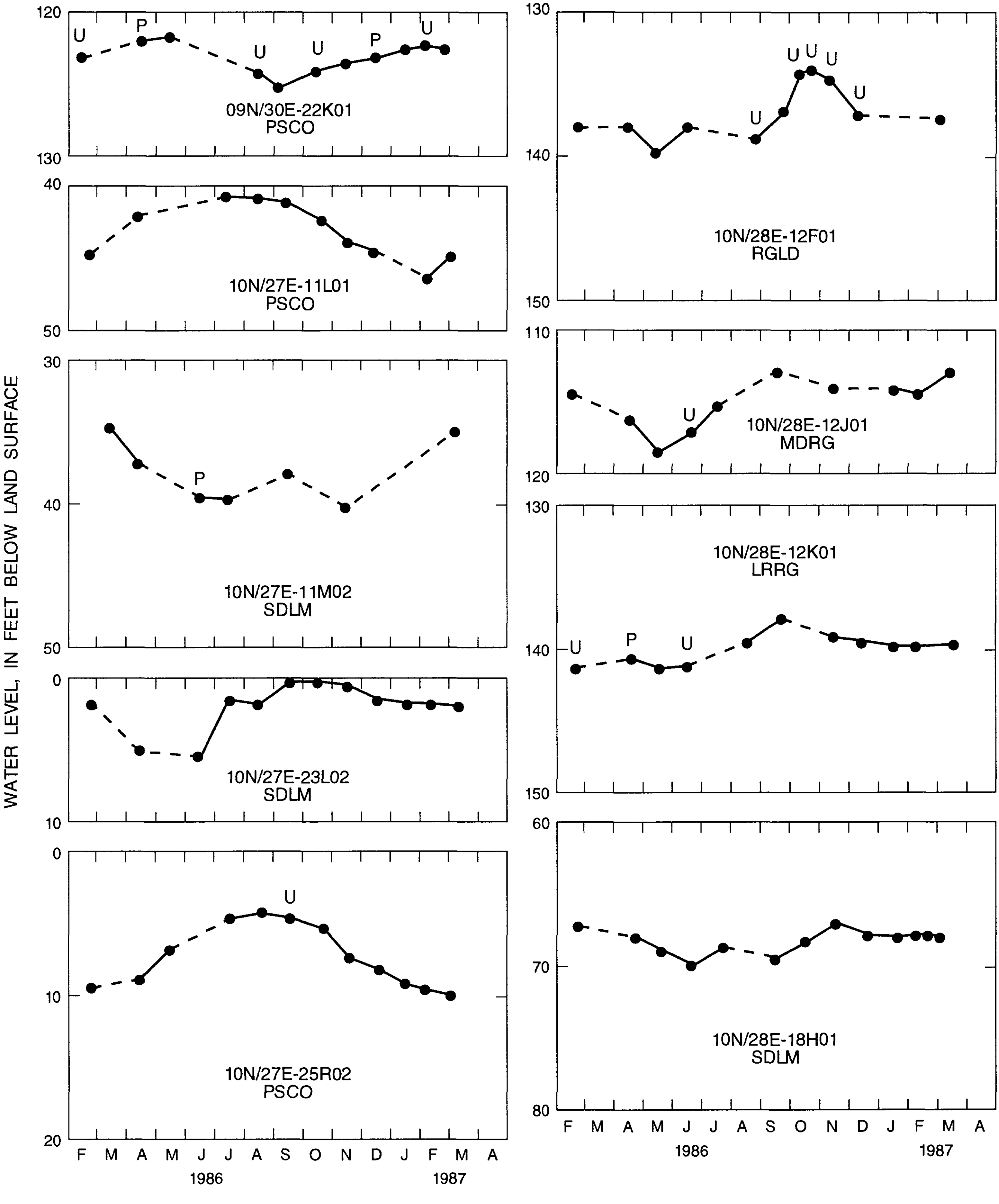

09N/27E-01D01
SDLM
09N/27E-08J02
SDLM
09N/27E-16B01
SDLM
09N/27E-16D01
SDLM+WNPM
WATER LEVEL, IN FEET BELOW LAND SURFACE
20
30
190
200
210
220
230
240
250
220
230
240
250
180
190
200
210
220
230
R
U
F M A M J J A S O N D J F M A
1986
1987


WATER LEVEL, IN FEET BELOW LAND SURFACE
09N/27E-19J01
PSCO
09N/27E-19K02
PSCO
09N/27E-19P01
SDLM
09N/27E-35E01
SDLM
09N/28E-02G02
MDRG
09N/28E-04C05
SDLM
* NOTE: DIFFERENT SCALE THAN OTHER HYDROGRAPHS
F M A M J J A S O N D J F M A
1986
1987

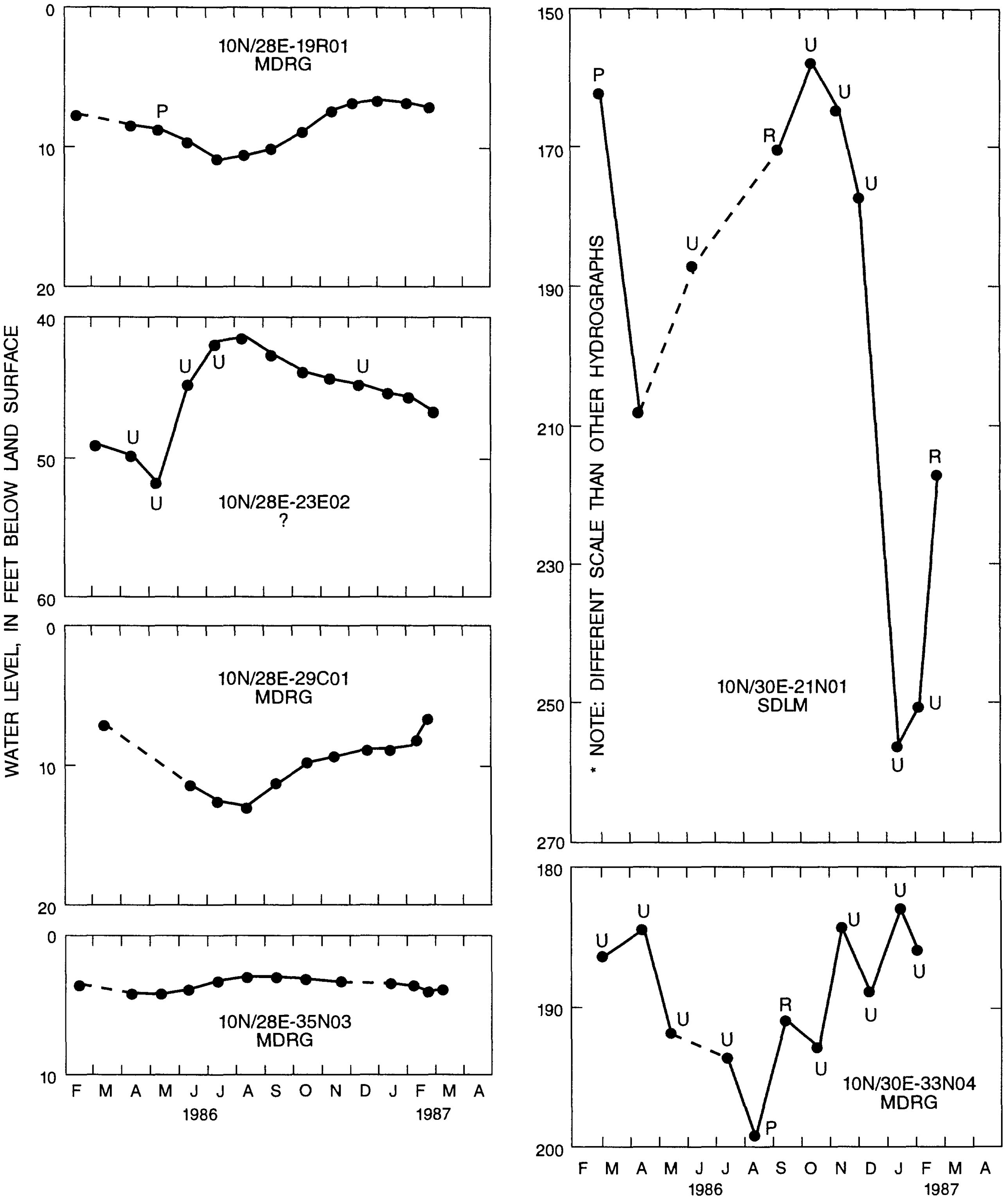


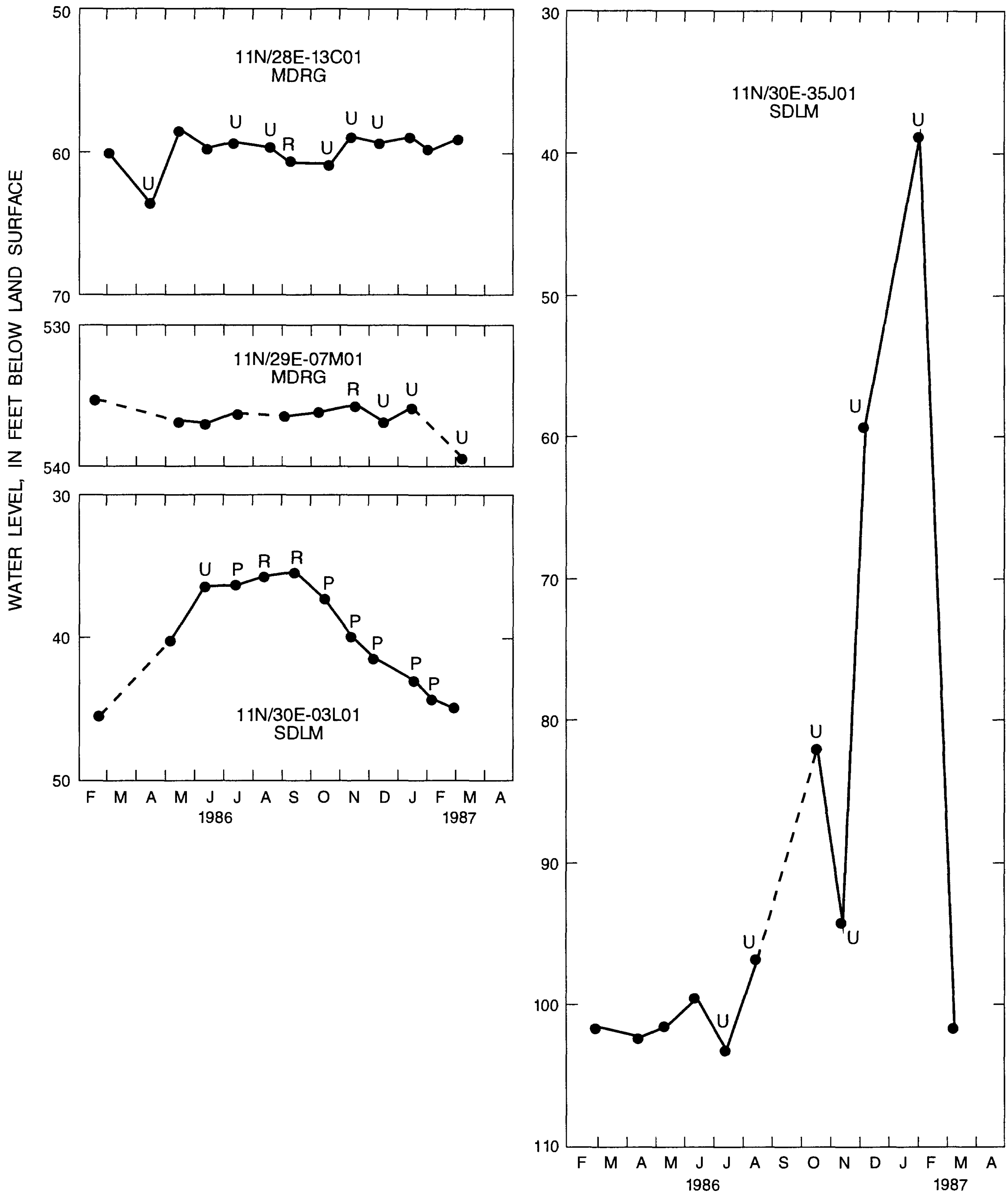
WATER LEVEL, IN FEET BELOW LAND SURFACE
09N/28E-04G03
MDRG
09N/28E-21D01
SDLM
09N/28E-08C01
SDLM
09N/28E-22B01
SDLM
09N/28E-15J01
PSCO
09N/28E-26M01
SDLM
09N/28E-18L01
SDLM
F M A M J J A S O N D J F M A
1986
1987

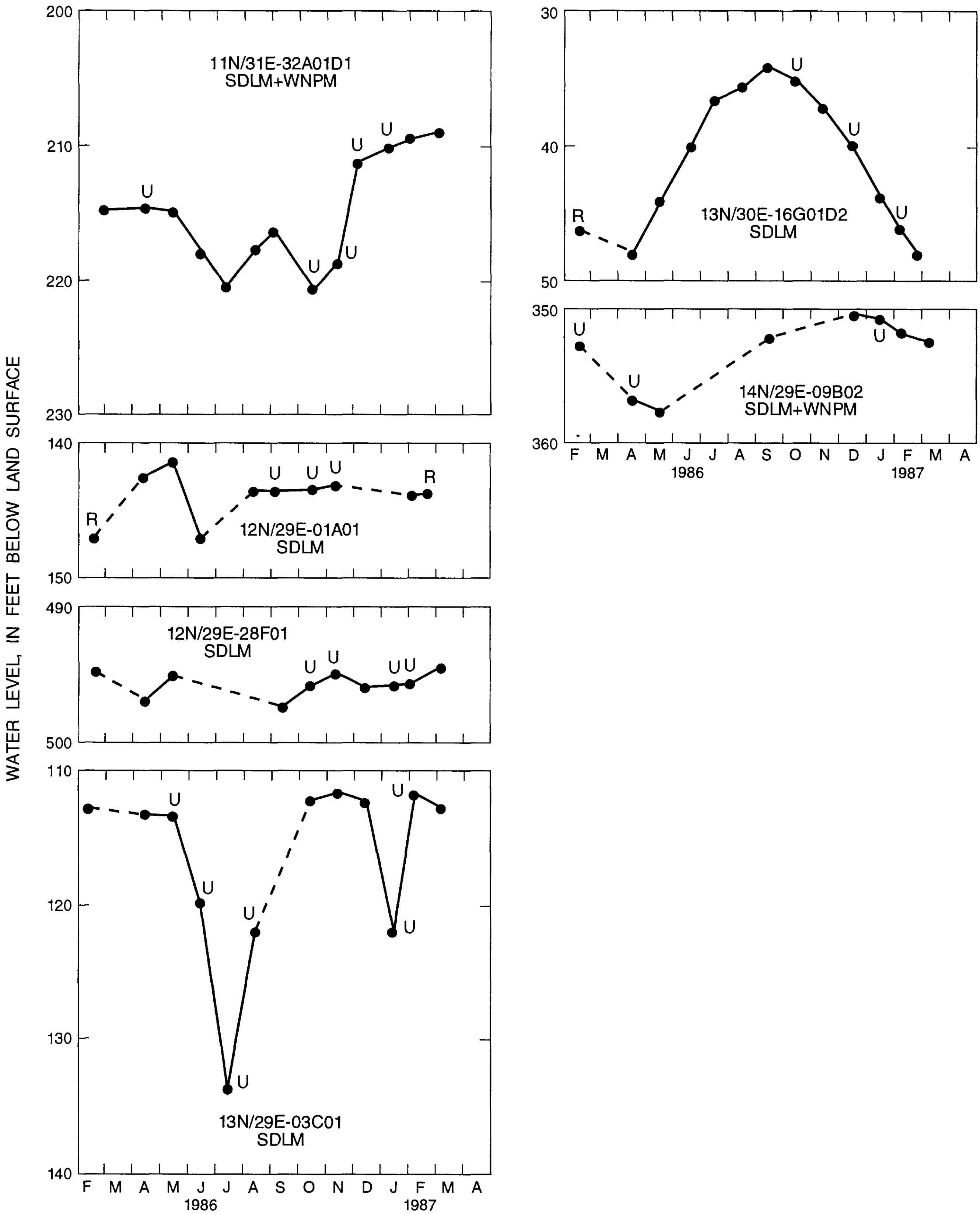

WATER LEVEL, IN FEET BELOW LAND SURFACE
09N/28E-30J01
WNPM
09N/28E-31E02
SDLM
09N/29E-02G03
SDLM
09N/29E-06F01
PSCO
09N/29E-06G01
BSRG
09N/29E-17L01
SDLM
09N/29E-33M01
SDLM
F M A M J J A S O N D J F M A
1986
1987



WATER LEVEL, IN FEET BELOW LAND SURFACE
09N/30E-22K01
PSCO
10N/27E-11L01
PSCO
10N/27E-11M02
SDLM
10N/27E-23L02
SDLM
10N/27E-25R02
PSCO
10N/28E-12F01
RGLD
10N/28E-12J01
MDRG
10N/28E-12K01
LRRG
10N/28E-18H01
SDLM
F M A M J J A S O N D J F M A
1986
1987


WATER LEVEL, IN FEET BELOW LAND SURFACE
10N/28E-19R01
MDRG
10N/28E-23E02
?
10N/28E-29C01
MDRG
10N/28E-35N03
MDRG
* NOTE: DIFFERENT SCALE THAN OTHER HYDROGRAPHS
10N/30E-21N01
SDLM
10N/30E-33N04
MDRG
F M A M J J A S O N D J F M A
1986
1987


WATER LEVEL, IN FEET BELOW LAND SURFACE
11N/28E-13C01
MDRG
11N/29E-07M01
MDRG
11N/30E-03L01
SDLM
11N/30E-35J01
SDLM
F M A M J J A S O N D J F M A
1986
1987



WATER LEVEL, IN FEET BELOW LAND SURFACE
11N/31E-32A01D1
SDLM+WNPM
12N/29E-01A01
SDLM
12N/29E-28F01
SDLM
13N/29E-03C01
SDLM
13N/30E-16G01D2
SDLM
14N/29E-09B02
SDLM+WNPM
200
210
220
230
140
150
490
500
110
120
130
140
30
40
50
350
360
U
R
F M A M J J A S O N D J F M A
1986
1987

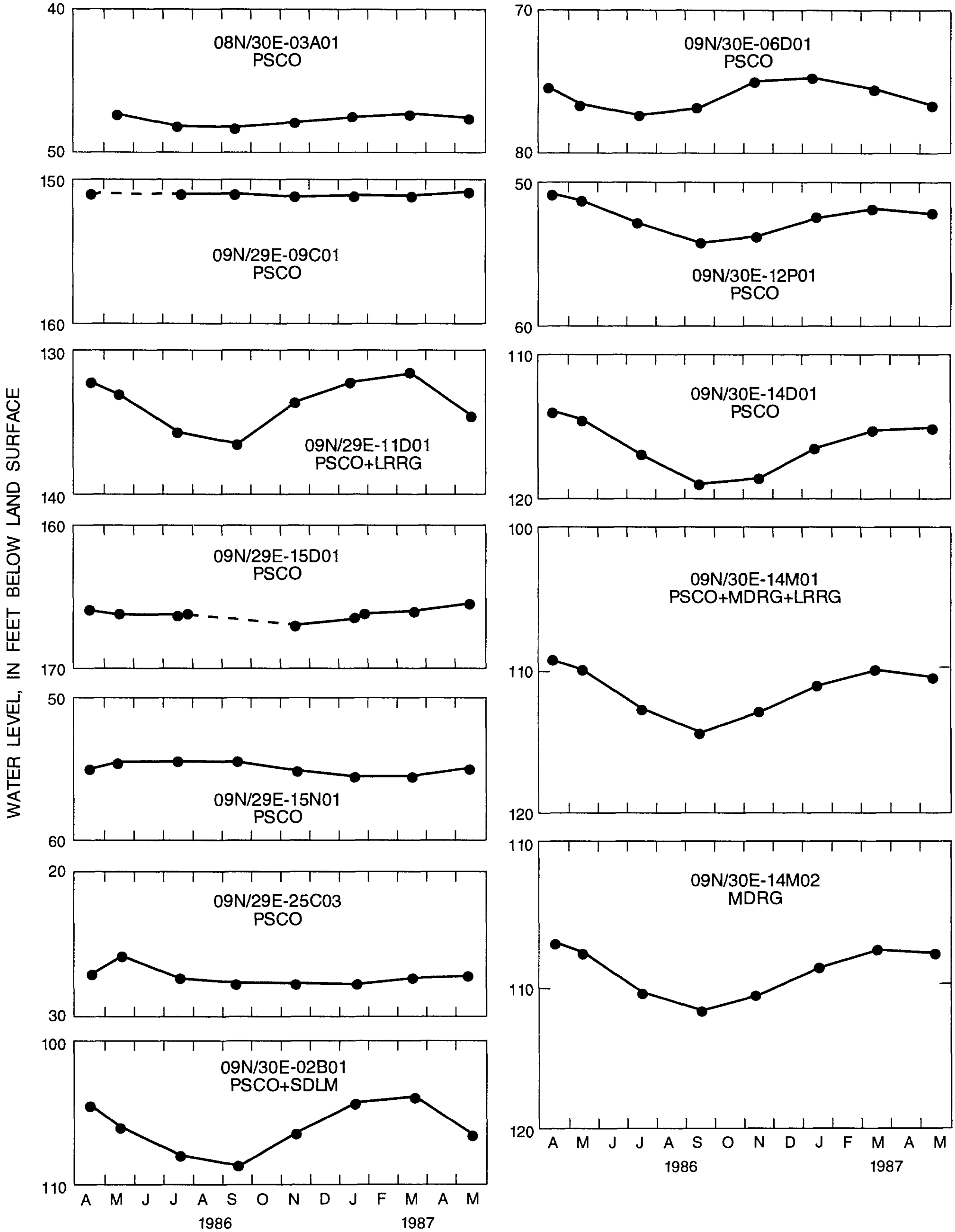
APPENDIX B

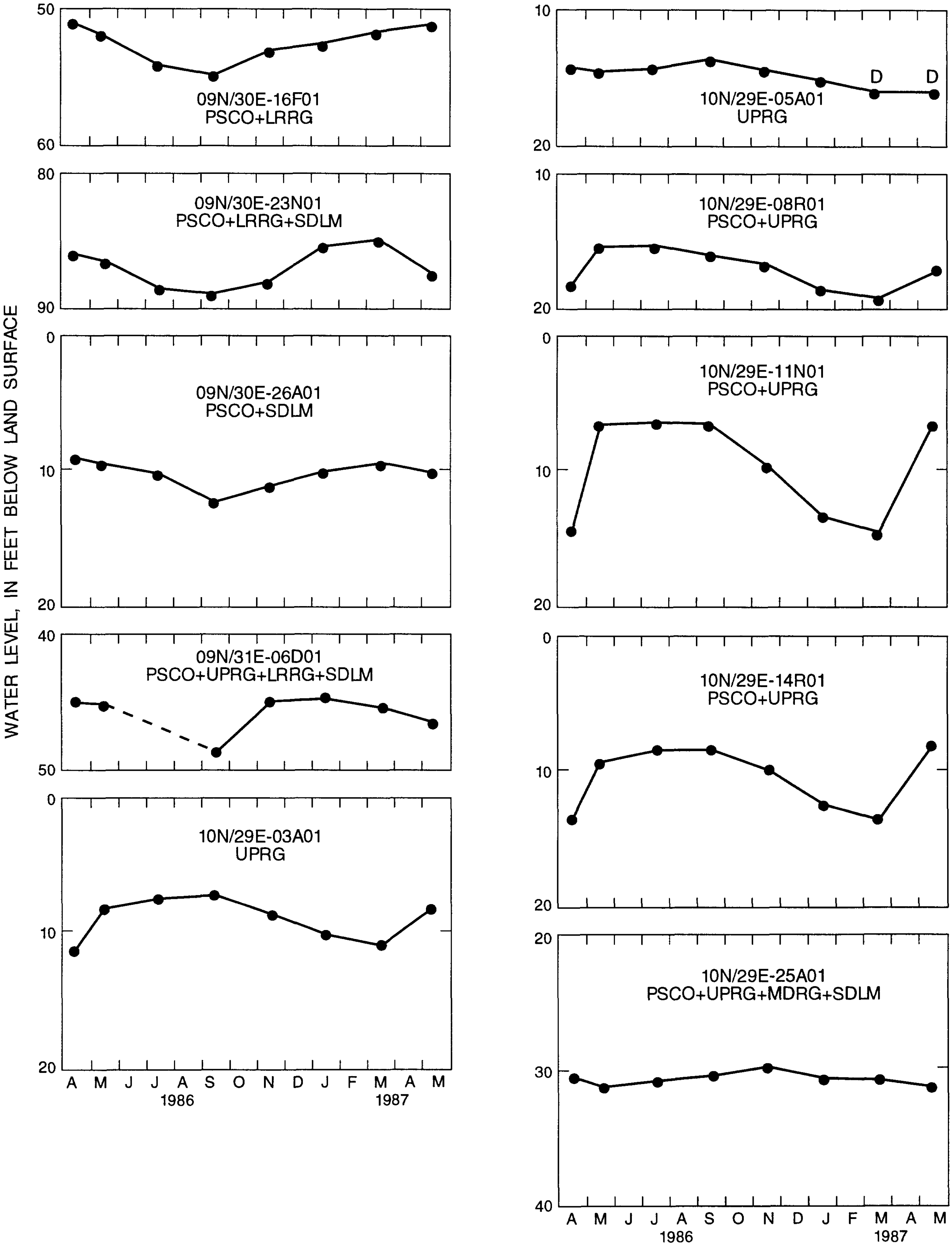
Hydrographs of wells measured bimonthly by the Bureau of Reclamation, April 1986 through May 1987

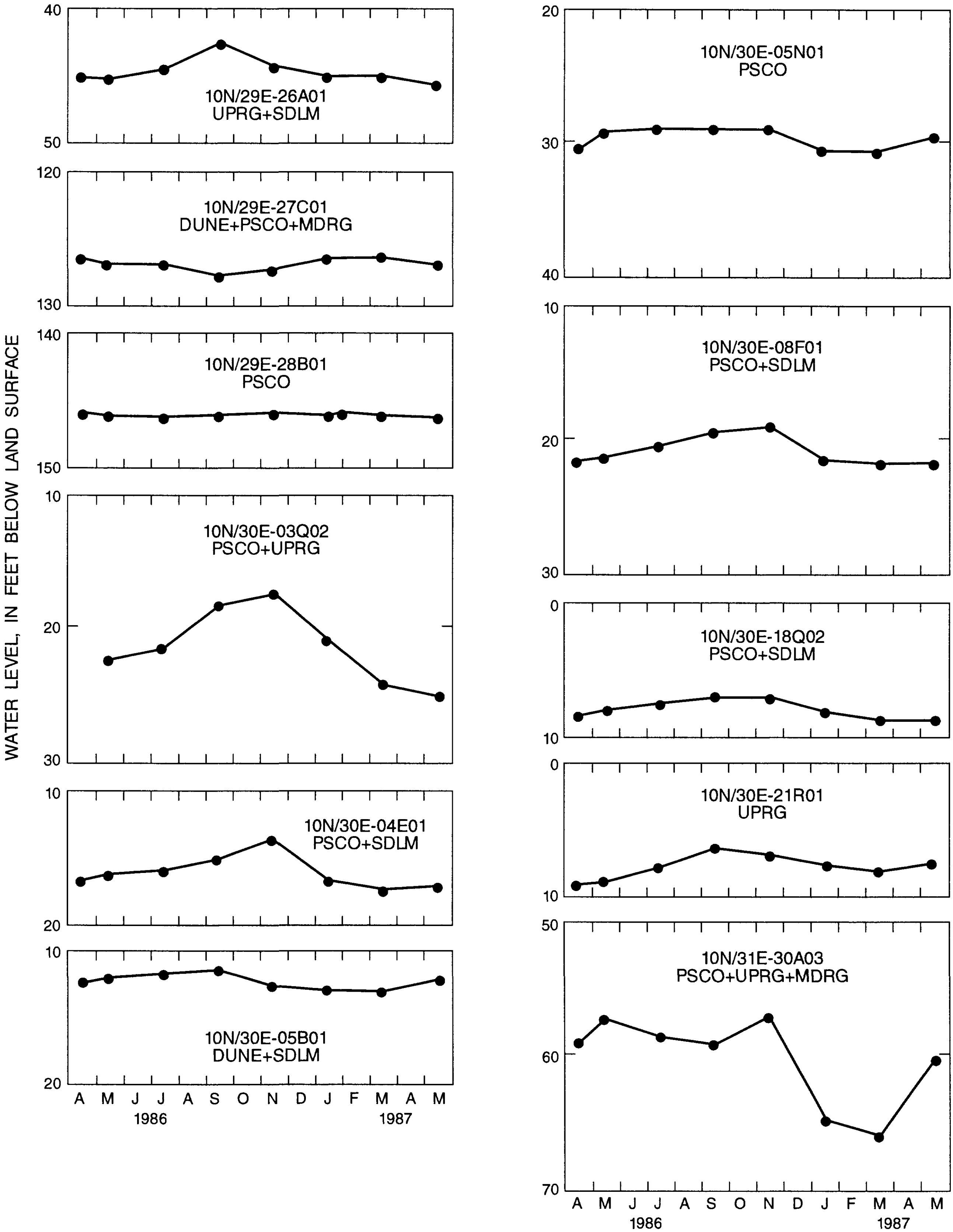
EXPLANATION

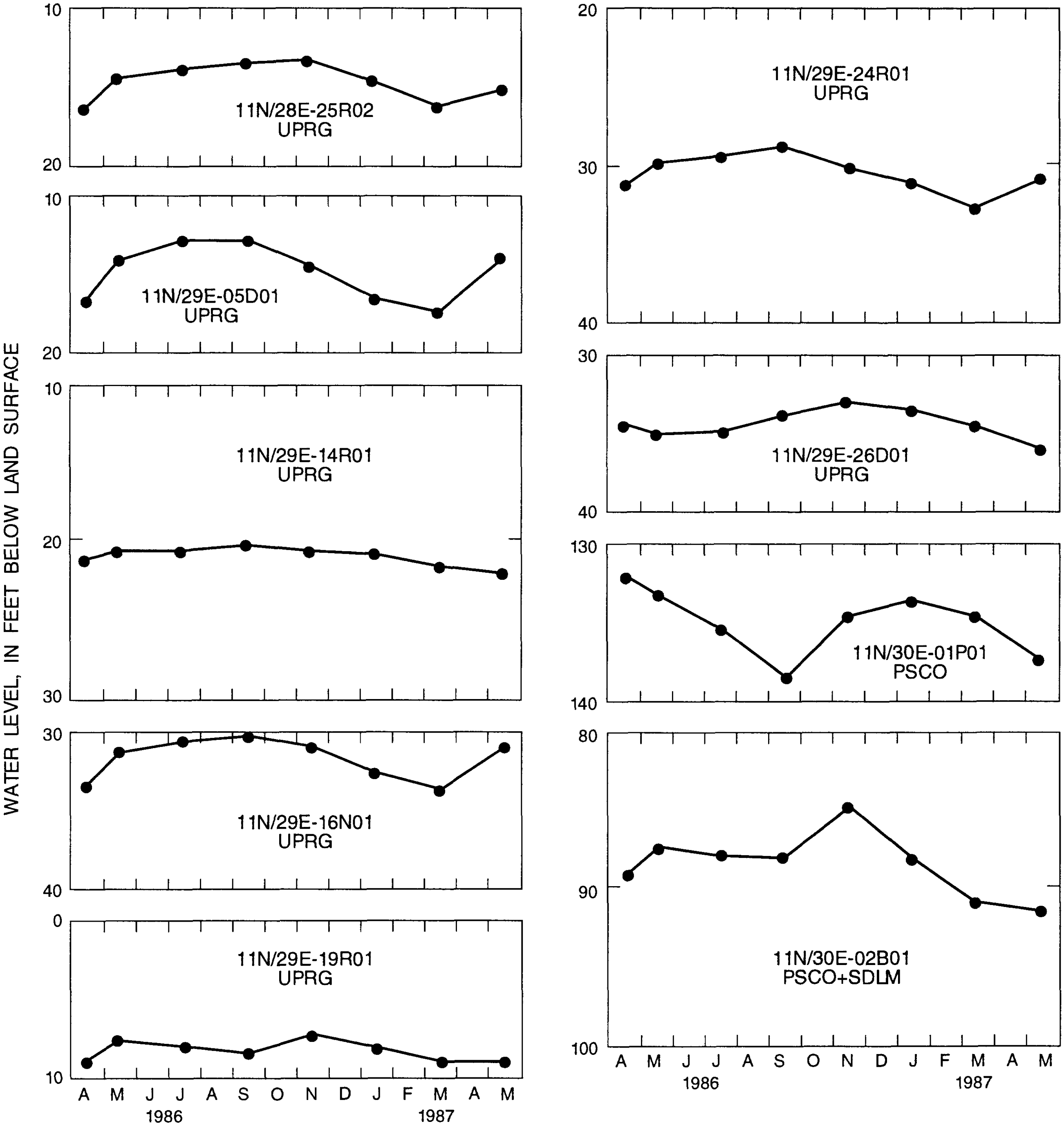
Aquifer: ALVM = alluvium
DUNE = dune sands
TCHT = Touchet Beds
PSCO = Pasco gravels
PLUS = Palouse Formation
UPRG = upper Ringold Formation
MDRG = middle Ringold Formation
LRRG = lower Ringold
SDLM = Saddle Mountains Basalt

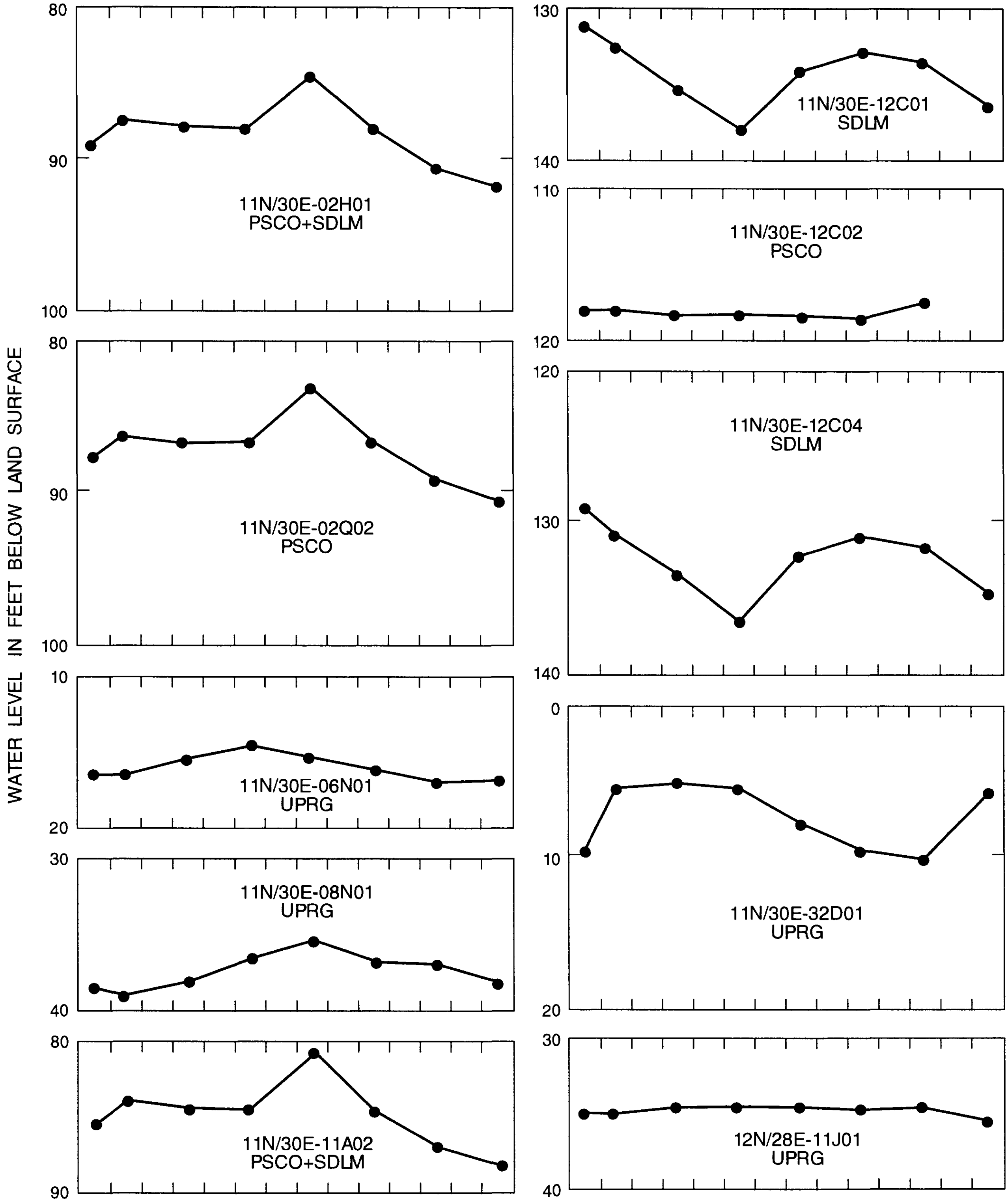
Water-level status: D = Dry

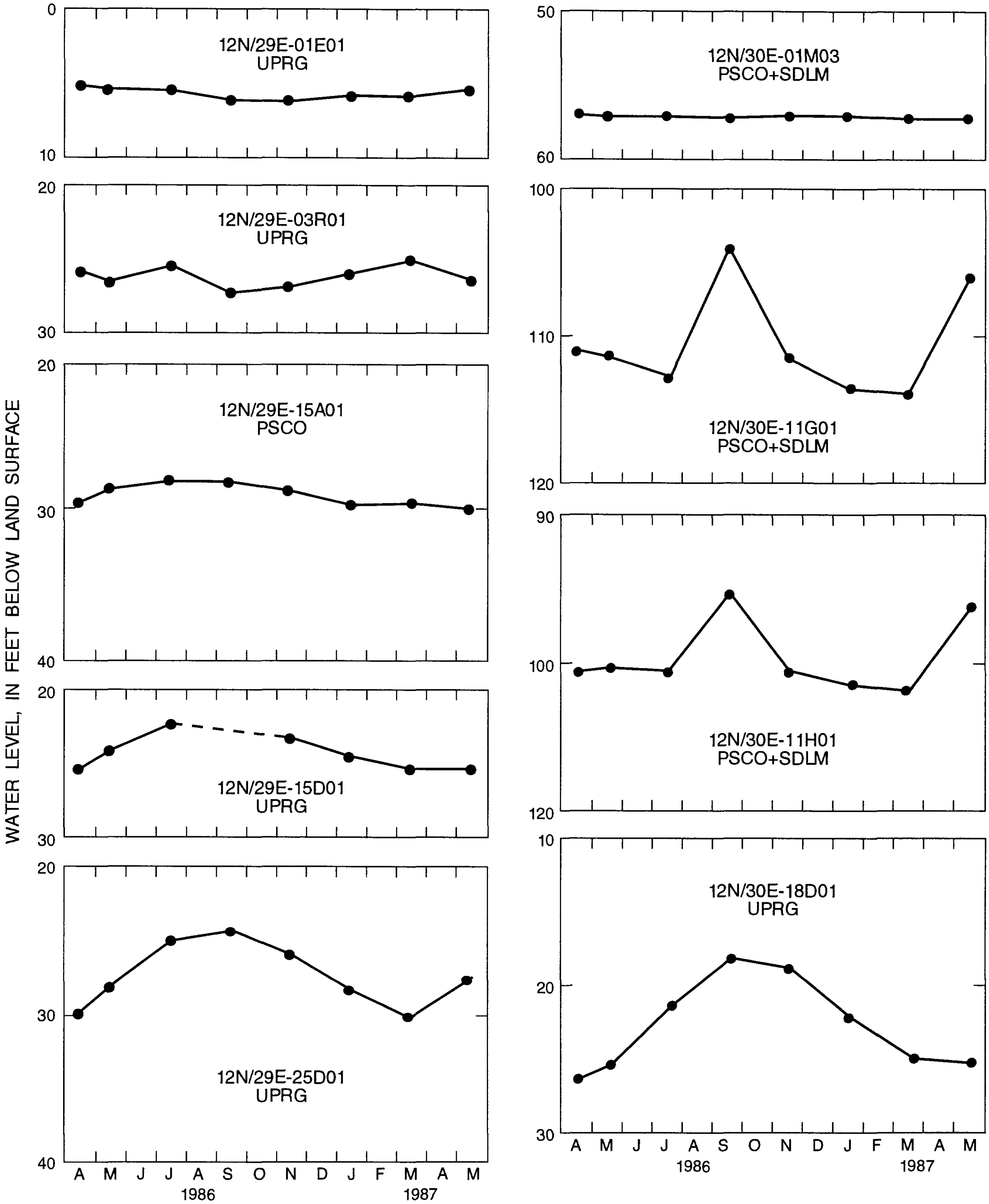

WATER LEVEL, IN FEET BELOW LAND SURFACE
08N/30E-03A01
PSCO
09N/29E-09C01
PSCO
09N/29E-11D01
PSCO+LRRG
09N/29E-15D01
PSCO
09N/29E-15N01
PSCO
09N/29E-25C03
PSCO
09N/30E-02B01
PSCO+SDLM
09N/30E-06D01
PSCO
09N/30E-12P01
PSCO
09N/30E-14D01
PSCO
09N/30E-14M01
PSCO+MDRG+LRRG
09N/30E-14M02
MDRG
A M J J A S O N D J F M A M
1986
1987

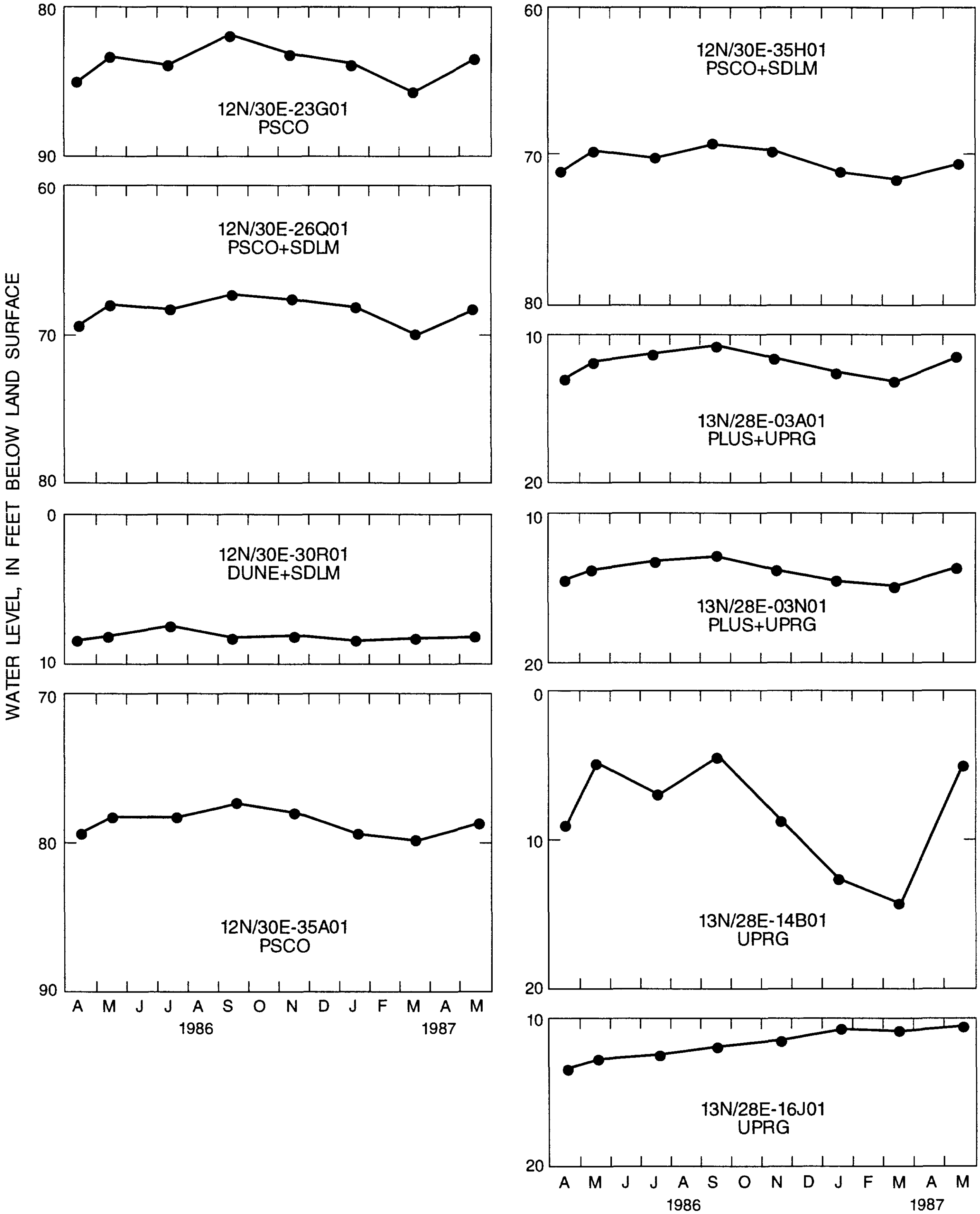

WATER LEVEL, IN FEET BELOW LAND SURFACE
09N/30E-16F01
PSCO+LRRG
09N/30E-23N01
PSCO+LRRG+SDLM
09N/30E-26A01
PSCO+SDLM
09N/31E-06D01
PSCO+UPRG+LRRG+SDLM
10N/29E-03A01
UPRG
10N/29E-05A01
UPRG
D
D
10N/29E-08R01
PSCO+UPRG
10N/29E-11N01
PSCO+UPRG
10N/29E-14R01
PSCO+UPRG
10N/29E-25A01
PSCO+UPRG+MDRG+SDLM
A M J J A S O N D J F M A M
1986
1987

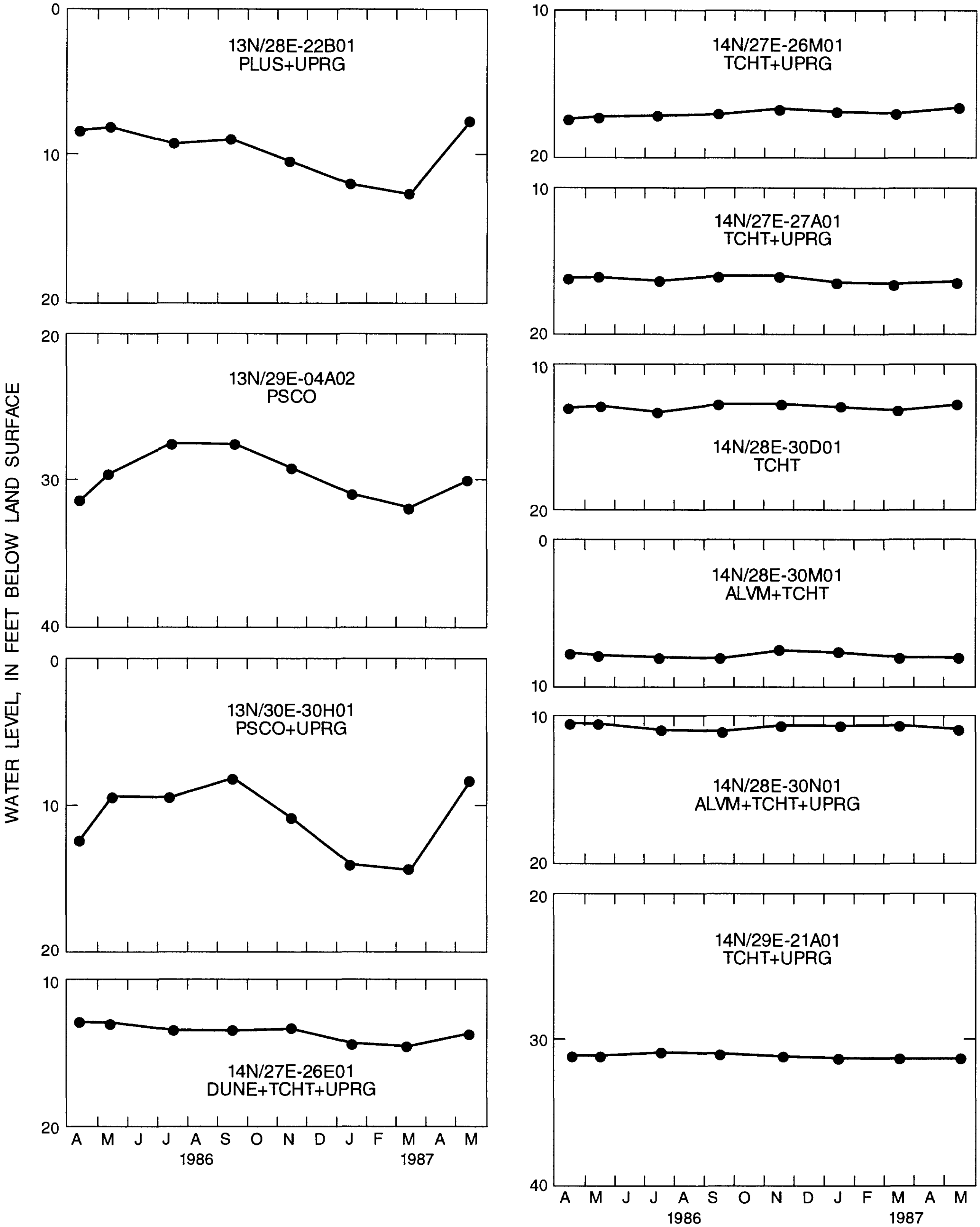

WATER LEVEL, IN FEET BELOW LAND SURFACE
10N/29E-26A01
UPRG+SDLM
10N/29E-27C01
DUNE+PSCO+MDRG
10N/29E-28B01
PSCO
10N/30E-03Q02
PSCO+UPRG
10N/30E-04E01
PSCO+SDLM
10N/30E-05B01
DUNE+SDLM
10N/30E-05N01
PSCO
10N/30E-08F01
PSCO+SDLM
10N/30E-18Q02
PSCO+SDLM
10N/30E-21R01
UPRG
10N/31E-30A03
PSCO+UPRG+MDRG
A M J J A S O N D J F M A M
1986
1987


WATER LEVEL, IN FEET BELOW LAND SURFACE
11N/28E-25R02
UPRG
11N/29E-05D01
UPRG
11N/29E-14R01
UPRG
11N/29E-16N01
UPRG
11N/29E-19R01
UPRG
11N/29E-24R01
UPRG
11N/29E-26D01
UPRG
11N/30E-01P01
PSCO
11N/30E-02B01
PSCO+SDLM
A M J J A S O N D J F M A M
1986
1987

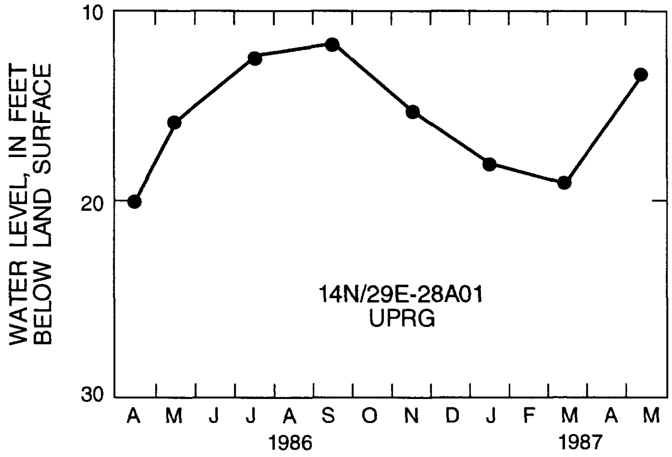

WATER LEVEL IN FEET BELOW LAND SURFACE
11N/30E-02H01
PSCO+SDLM
11N/30E-02Q02
PSCO
11N/30E-06N01
UPRG
11N/30E-08N01
UPRG
11N/30E-11A02
PSCO+SDLM
11N/30E-12C01
SDLM
11N/30E-12C02
PSCO
11N/30E-12C04
SDLM
11N/30E-32D01
UPRG
12N/28E-11J01
UPRG
80
90
100
10
20
30
40
130
140
110
120
0


WATER LEVEL, IN FEET BELOW LAND SURFACE
12N/29E-01E01
UPRG
12N/29E-03R01
UPRG
12N/29E-15A01
PSCO
12N/29E-15D01
UPRG
12N/29E-25D01
UPRG
12N/30E-01M03
PSCO+SDLM
12N/30E-11G01
PSCO+SDLM
12N/30E-11H01
PSCO+SDLM
12N/30E-18D01
UPRG
A M J J A S O N D J F M A M
1986
1987
0
10
20
30
40
50
60
90
100
110
120


WATER LEVEL, IN FEET BELOW LAND SURFACE
12N/30E-23G01
PSCO
12N/30E-26Q01
PSCO+SDLM
12N/30E-30R01
DUNE+SDLM
12N/30E-35A01
PSCO
12N/30E-35H01
PSCO+SDLM
13N/28E-03A01
PLUS+UPRG
13N/28E-03N01
PLUS+UPRG
13N/28E-14B01
UPRG
13N/28E-16J01
UPRG
A M J J A S O N D J F M A M
1986
1987



WATER LEVEL, IN FEET BELOW LAND SURFACE
13N/28E-22B01
PLUS+UPRG
13N/29E-04A02
PSCO
13N/30E-30H01
PSCO+UPRG
14N/27E-26E01
DUNE+TCHT+UPRG
14N/27E-26M01
TCHT+UPRG
14N/27E-27A01
TCHT+UPRG
14N/28E-30D01
TCHT
14N/28E-30M01
ALVM+TCHT
14N/28E-30N01
ALVM+TCHT+UPRG
14N/29E-21A01
TCHT+UPRG
0
10
20
30
40
A M J J A S O N D J F M A M
1986
1987



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