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Hydrogeologic Framework and Ground-Water Budget of the Spokane Valley-Rathdrum Prairie Aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho

Scientific Investigations Report 2007–5041

U.S. Department of the Interior
U.S. Geological Survey

Cover: Photograph of the Spokane River looking downstream (west) from near the Sullivan Road bridge in the Spokane Valley, Washington. (Photograph taken by Sue Kahle, U.S. Geological Survey, November 9, 2005.)

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Contents

Contents—Continued

Ground-Water Budget—Continued

Plates

[in pocket]

Figures

Tables

Conversion Factors and Datums

Conversion Factors

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic mile (mi^3)	4.168	cubic kilometer (km^3)
foot (ft)	0.3048	meter (m)
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per minute per foot [(gal/min)/ft]	0.000206988834	meter squared per second (m^2/s)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
mile (mi)	1.609	kilometer (km)
million gallons (Mgal)	3,785	cubic meter (m^3)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
square mile (mi^2)	2.590	square kilometer (km^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32.$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8.$$

Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Hydrogeologic Framework and Ground-Water Budget of the Spokane Valley-Rathdrum Prairie Aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho

By Sue C. Kahle and James R. Bartolino

Abstract

The U.S. Geological Survey, in cooperation with the Idaho Department of Water Resources and Washington State Department of Ecology, investigated the hydrogeologic framework and ground-water budget of the Spokane Valley-Rathdrum Prairie (SVRP) aquifer located in northern Idaho and northeastern Washington. Descriptions of the hydrogeologic framework, water-budget components, and further data needs are provided. The SVRP aquifer, which covers about 370 square miles including the Rathdrum Prairie, Idaho, and the Spokane Valley and Hillyard Trough, Washington, is the sole source of drinking water for more than 500,000 residents. Continued growth, water-management issues, and potential effects on water availability and water quality in the aquifer and in the Spokane and Little Spokane Rivers have illustrated the need to better understand and manage the region's water resources.

The SVRP aquifer consists mostly of gravels, cobbles, and boulders — deposited during a series of outburst floods resulting from repeated collapse of the ice dam that impounded ancient Glacial Lake Missoula. In most places, the SVRP aquifer is bounded by bedrock of pre-Tertiary granite or metasedimentary rocks, or Miocene basalt and associated sedimentary deposits. Discontinuous fine-grained layers are scattered throughout the SVRP aquifer at considerably different altitudes and with considerably different thicknesses. In the Hillyard Trough and the Little Spokane River Arm of the aquifer, a massive fine-grained layer with a top altitude ranging from about 1,500 to 1,700 feet and thickness ranging from about 100 to 200 feet separates the aquifer into upper and lower units. Most of the Spokane Valley part of the aquifer is devoid of fine-grained layers except near the margins of the valley and near the mouths of lakes. In the Rathdrum Prairie, multiple fine-grained layers are scattered throughout the aquifer with top altitudes ranging from about 1,700 to 2,400 feet with thicknesses ranging from 1 to more than 135 feet.

The altitude of the base of the aquifer ranges from less than 1,800 feet near Lake Pend Oreille to less than 1,200 feet near the aquifer's outlet near Long Lake. The thickness of the aquifer is more than 800 feet in the northwestern part of the northern Rathdrum Prairie, through the West Channel area, and through the west-central part of the Rathdrum Prairie. In Washington, the areas of greatest thickness, more than 600 feet, are mapped in the central parts of the Spokane Valley, Spokane, and the Hillyard Trough.

Recharge or inflow to the SVRP aquifer occurs from six main sources: the Spokane River, lakes, infiltration from precipitation over the aquifer, tributaries, infiltration from landscape irrigation and septic systems, and subsurface inflow. Discharge or outflow from the SVRP aquifer occurs from five main sources: the Spokane River, the Little Spokane River, pumpage, subsurface discharge to Long Lake, and infiltration of ground water to sewers. Total estimated mean annual inflow to and outflow from the SVRP aquifer is about 1,470 cubic feet per second.

Several data needs were identified during this investigation that would improve the definition of the hydrogeologic framework and ground-water budget components for the SVRP aquifer study area. Deep drilling along the axis of the aquifer could determine the depth to the bottom of the aquifer where data are currently unavailable as well as identify the presence of fine-grained layers and their thickness. A more detailed analysis of the geologic and hydrologic setting near the southern ends of Spirit and Hoodoo Valleys could help determine the location of the ground-water divide between the two valleys and the Rathdrum Prairie. Better estimates of seepage into the aquifer from Coeur d'Alene Lake and Lake Pend Oreille and underflow from the aquifer to Long Lake would strengthen the recharge and discharge estimates of the aquifer. A hydrochemical study incorporating analyses of environmental tracers, isotopic ratios, and ground-water age dating could provide a means of quantifying recharge and discharge, and defining ground-water flow paths.

Introduction

The Spokane Valley-Rathdrum Prairie (SVRP) aquifer is the sole source of drinking water for more than 500,000 residents in Spokane County, Washington, and Bonner and Kootenai Counties, Idaho (fig. 1). Those counties include the rapidly growing cities of Spokane, Spokane Valley, and Liberty Lake, Washington, and Coeur d'Alene and Post Falls, Idaho. Concerns have been expressed about the potential effects of the recent growth and of projected urban, suburban, and commercial growth on water availability and water quality in the aquifer and in the Spokane and Little Spokane Rivers.

The SVRP aquifer consists primarily of thick layers of coarse-grained sediments — gravels, cobbles, and boulders — deposited during a series of outburst floods that resulted from repeated collapse of the ice dam that impounded ancient Glacial Lake Missoula (Bretz, 1930). Sources of recharge to the aquifer include infiltration from precipitation, return flow from water applied at land surface, leakage from the Spokane and Little Spokane Rivers and adjacent lakes, and surface-water inflow from tributary basins. The aquifer discharges primarily into the Spokane and Little Spokane Rivers and through withdrawals from wells. The aquifer was designated a "Sole Source Aquifer" by the U.S. Environmental Protection Agency (USEPA) in 1978 (under the provisions

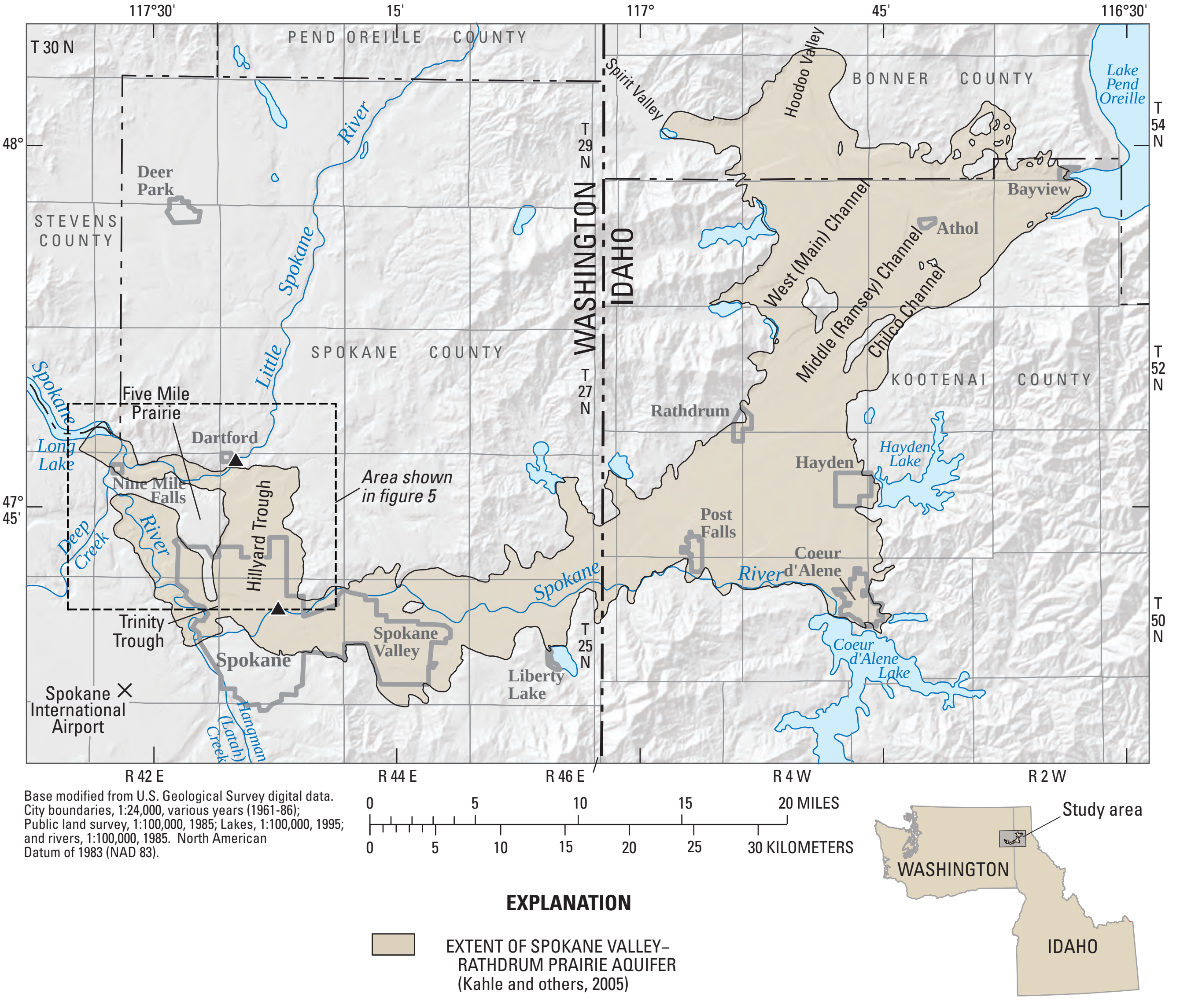


Figure 1. Location of the Spokane Valley-Rathdrum Prairie aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.

of the Federal Safe Drinking Water Act of 1974) in response to local concerns about aquifer vulnerability to water quality degradation. The U.S. Environmental Protection Agency (2000) defines such an aquifer as one that supplies at least 50 percent of the drinking water consumed in the area overlying the aquifer. Communities that depend on a sole-source aquifer generally do not have a viable alternate drinking-water source.

Water-management issues in this rapidly growing bi-State area have become increasingly regional in nature. Several groups have initiated a comprehensive, regional study of the SVRP aquifer to serve as a scientific basis for addressing regional water concerns. In 2004, the Washington State Department of Ecology (WDOE), the Idaho Department of Water Resources (IDWR), and the U.S. Geological Survey (USGS) in consultation with local stakeholders developed a comprehensive work plan for a study to gain a better understanding of ground-water and surface-water resources in the SVRP area. The first study objective is the development of a comprehensive knowledge base and accompanying data to provide an improved scientific basis for water management of the SVRP aquifer. This report, which describes the hydrogeologic framework and updates to the ground-water budget of the aquifer, along with six recently published reports (Campbell, 2005; Hortness and Covert, 2005; Kahle and others, 2005; Gregory and Covert, 2006; Oldow and Sprenke, 2006; Bartolino, 2007), provides comprehensive information based on historical and current investigations. The final and concurrent phase of the study uses this information to develop a numerical ground-water flow model to support the conjunctive management of ground water and surface water in the SVRP aquifer. The model is described in a separate report (Hsieh and others, 2007). The results of the overall investigation are intended to provide tools for the evaluation of alternate water-resource management strategies throughout the SVRP aquifer.

Purpose and Scope

The purpose of this report is to describe the current knowledge base for the hydrogeologic framework and ground-water budget of the SVRP aquifer. The description of the hydrogeologic framework is based on a review and interpretation of well logs, geologic maps, and geophysical studies available as of September 2006. The description of the hydrogeologic framework includes the approximate depth to the base of the aquifer, the approximate thickness of the aquifer, and the occurrence and thickness of fine-grained layers within the aquifer. Brief descriptions of the hydrogeologic units that bound the aquifer also are provided. The description of the ground-water budget is based on new information compiled during this investigation and updates to water-budget components developed by previous investigators.

The scope of this report includes the regional and local geologic history, the surficial and subsurface geology, selected physical characteristics of the SVRP aquifer and adjacent units, and an updated ground-water budget for the aquifer. Additional data needs that could improve understanding of the hydrogeologic framework and ground-water budget of the aquifer also are discussed.

Description of Study Area

The SVRP aquifer underlies about 370 mi^2 of a relatively flat, alluvial valley surrounded by bedrock highlands (Kahle and others, 2005). The aquifer extends south from Lake Pend Oreille to Coeur d’Alene Lake and west across the Washington-Idaho State line to near Nine Mile Falls northwest of Spokane. Land-surface altitudes in the area range from about 1,500 to nearly 2,600 ft. Several lakes, the largest of which are Coeur d’Alene Lake and Lake Pend Oreille in Idaho (pl. 1), are located along the margins of the aquifer. The area generally is devoid of surface drainage other than the Spokane and Little Spokane Rivers (pl. 1).

Ground water is the primary source for public-supply, domestic, irrigation, and industrial water use in the study area (Hutson and others, 2004). Estimated ground-water use in 2000 for Spokane, Bonner, and Kootenai Counties was more than 188 Mgal/d (Hutson and others, 2004). In Spokane County alone, estimated ground-water use in 2000 was about 110 Mgal/d for public supply, 12 Mgal/d for domestic use, 9 Mgal/d for irrigation, and 8 Mgal/d for industrial use (accessed September 13, 2004 at http://water.usgs.gov/watuse/data/2000/index.html). Peak summer daily ground-water withdrawals from the aquifer are estimated to be about 450 Mgal/d (MacInnis and others, 2000).

Primary land uses in the study area include urban and agriculture. Agricultural land is used predominantly for pasture or the production of hay, wheat, grass seed, barley, and oats (fig. 2). Urban areas supplied by the aquifer include the Spokane metropolitan area in Washington and Coeur d’Alene and Post Falls in Idaho. Residential and commercial development is increasing rapidly in the area as evidenced by a 16 percent population increase in Spokane County, Washington and nearly 56 percent increase in Kootenai County, Idaho, during the 1990s (U.S. Census Bureau, 2002).

The climate within the study area varies from subhumid to semiarid and is characterized by warm, dry summers and cool, moist winters (Molenaar, 1988). Mean annual (1971–2000) precipitation values for weather stations in the area were 16.7 in. at the Spokane International Airport, 25.9 in. near Bayview, Idaho, and 28.1 in. at Coeur d’Alene, Idaho (Western Regional Climate Center, 2005). Most of the precipitation falls as snow during the 5-month period from November through March (Molenaar, 1988). The distribution of average annual precipitation for 1961–90 in the study area is shown in figure 3.

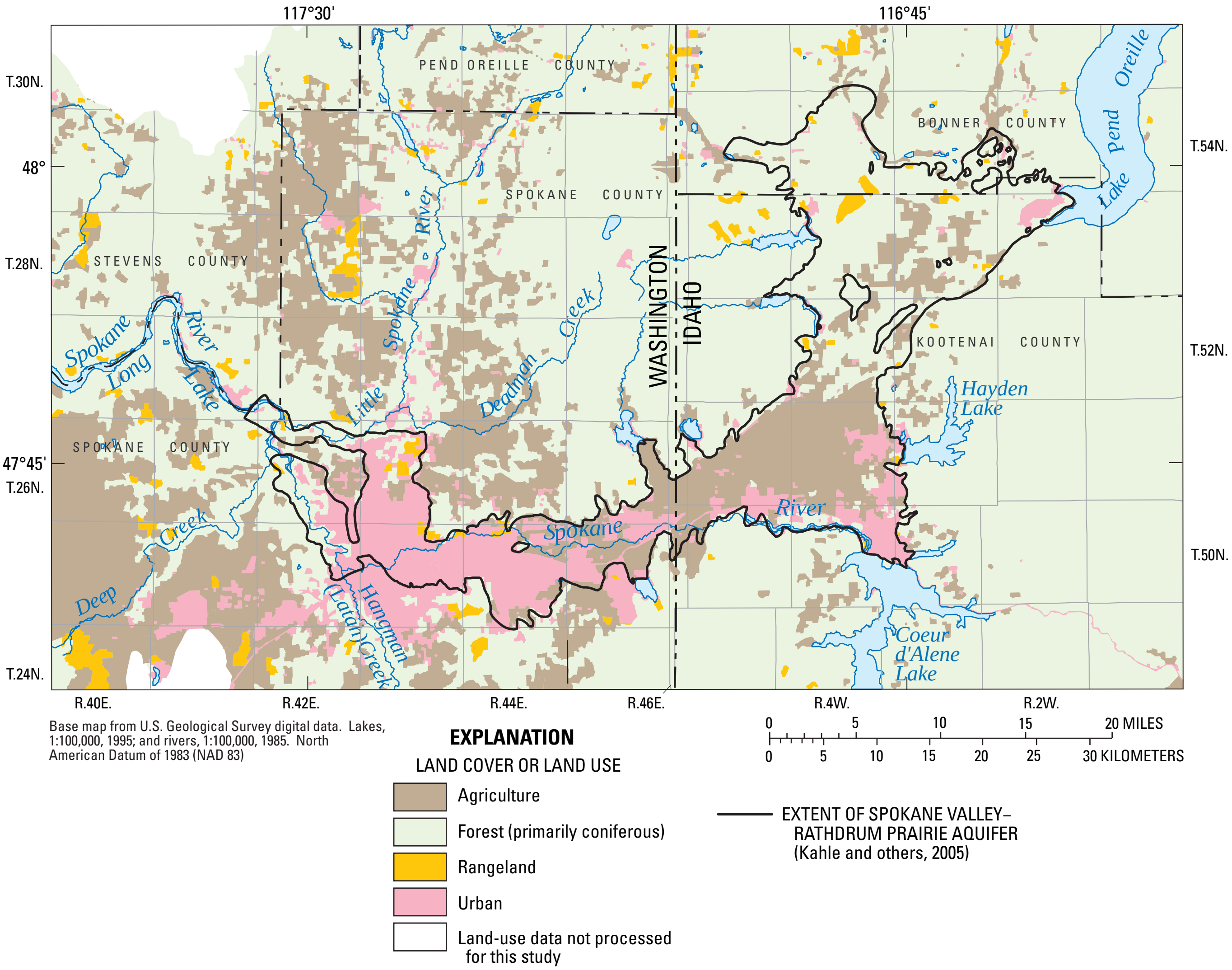


Figure 2. Generalized land cover and land use in the Spokane Valley-Rathdrum Prairie aquifer study area, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.

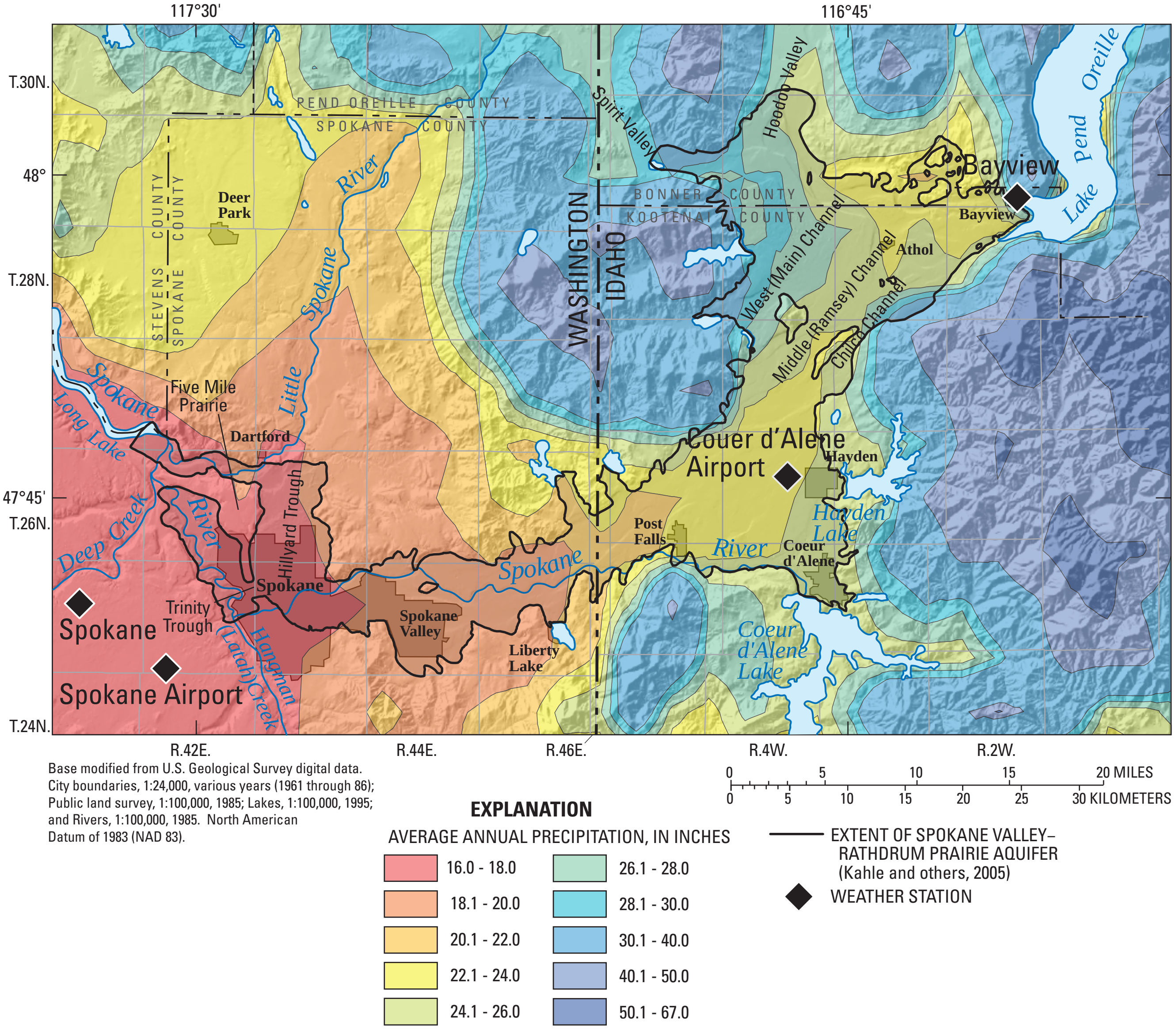
Methods of Investigation

Preparing the basic data required to characterize the hydrogeologic framework of the SVRP aquifer involved the review of existing hydrogeologic data as summarized in Kahle and others (2005) and the collection of more recently available drillers' logs. Methods used to compile the hydrogeologic data are presented in this section. Methods used to describe the ground-water budget of the aquifer are included in the section, "Ground-Water Budget."

Well Data

The first step in identifying available well data involved obtaining drillers' logs for previously inventoried (field verified) wells from records housed in USGS offices in Boise, Idaho, and Tacoma, Washington. These data were augmented by obtaining additional well records from the WDOE and IDWR on-line well logs databases and from other sources. In the well log selection process, preference was given to logs of deeper wells in order to characterize as much of the SVRP aquifer thickness as possible. Approximate locations (latitude and longitude coordinates) were assigned for the non-inventoried wells using public land survey locations (township, range, section, and quarter-quarter), well addresses, and (or) parcel number for each well included on drillers' logs. To the extent possible, paper maps (USGS 7 ½-minute quadrangles and City or County road maps) and on-line maps (Spokane County Assessor, Mapquest®, and Google™Earth) were used to verify drillers' locations and to estimate latitude, longitude, and land-surface altitude for the non-inventoried wells.

Data for 587 wells (table 3, at back of report) were used to characterize the hydrogeology of the study area. Information including site location, land-surface altitude,



Base modified from U.S. Geological Survey digital data. City boundaries, 1:24,000, various years (1961 through 86); Public land survey, 1:100,000, 1985; Lakes, 1:100,000, 1995; and Rivers, 1:100,000, 1985. North American Datum of 1983 (NAD 83).

Figure 3. Average annual precipitation based on 30 years of record, 1961–90, in the Spokane Valley-Rathdrum Prairie aquifer study area, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho. (Data obtained from Oregon State University, 2005.)

well-construction details, and available water levels for each well was entered into the USGS National Water Information System (NWIS) database (U.S. Geological Survey, 2007).

Hydrogeology

Lithologic data from drillers' logs for the 587 project wells were entered into the Rockworks 2002® software, a stratigraphic analysis package. A total of 26 hydrogeologic sections were constructed and plotted using Rockworks® to identify and correlate hydrogeologic units based primarily on lithology and stratigraphic position. Where data were sparse or unavailable, stratigraphic contacts between hydrogeologic units were inferred. The base of the aquifer was, in places, inferred from geophysical data and corresponding transects described in Kahle and others (2005). Of the original 26 sections, 15, which are representative of the 26, are published in this report (pl. 2). Three distinct hydrogeologic units were differentiated on the sections; the SVRP aquifer, the Basalt and fine-grained interbeds unit, and the Bedrock unit. Information from the hydrogeologic sections and data from additional wells were used to identify significant fine-grained layers within the aquifer and to describe the approximate altitude of the base of the aquifer and the thickness of the aquifer.

Well-Numbering System

The well-numbering system (fig. 4) used by the USGS differs slightly for the States of Washington and Idaho, but both systems are based on official rectangular subdivisions of the public land survey system. In both States, wells are assigned numbers that identify their location within a township, range, section, and 40-acre tract. Washington well number 25N/44E-14G01 (fig. 4) indicates the well is in Township 25 North and Range 44 East, north and east of the Willamette Base Line and Meridian, respectively. The numbers immediately following the hyphen indicate the section (14) within the township; the letter following the section indicates the 40-acre tract of the section. The two-digit sequence number (01) following the letter indicates the well was the first one inventoried in that 40-acre tract.

Idaho well number 54N 04W 31DDD1 (fig. 4) indicates the well is in Township 54 North and Range 4 West, north and west of the Boise Base Line and Meridian, respectively. The numbers immediately following the hyphen indicate the section (31) within the township; the letters following the section indicate the quarter section (160-acre tract), quarter-quarter section (40-acre tract), and quarter-quarter-quarter section (10-acre tract). In Idaho, quarter sections are designated by the letters A, B, C, and D in counterclockwise order from the northeast quarter of each section. Within the quarter sections, 40-acre and 10-acre tracts are lettered in the same manner. For example, well 54N 04W 31DDD1 is in the SE ¼ of the SE ¼ of the SE ¼ of section 31. The number following the letters (1) represents the serial number of the well within the tract.

In the illustrations in this report, wells are identified individually by only the section and 40-acre tract, such as 14G01 or 31DDD1. Township and range are shown on the map borders.

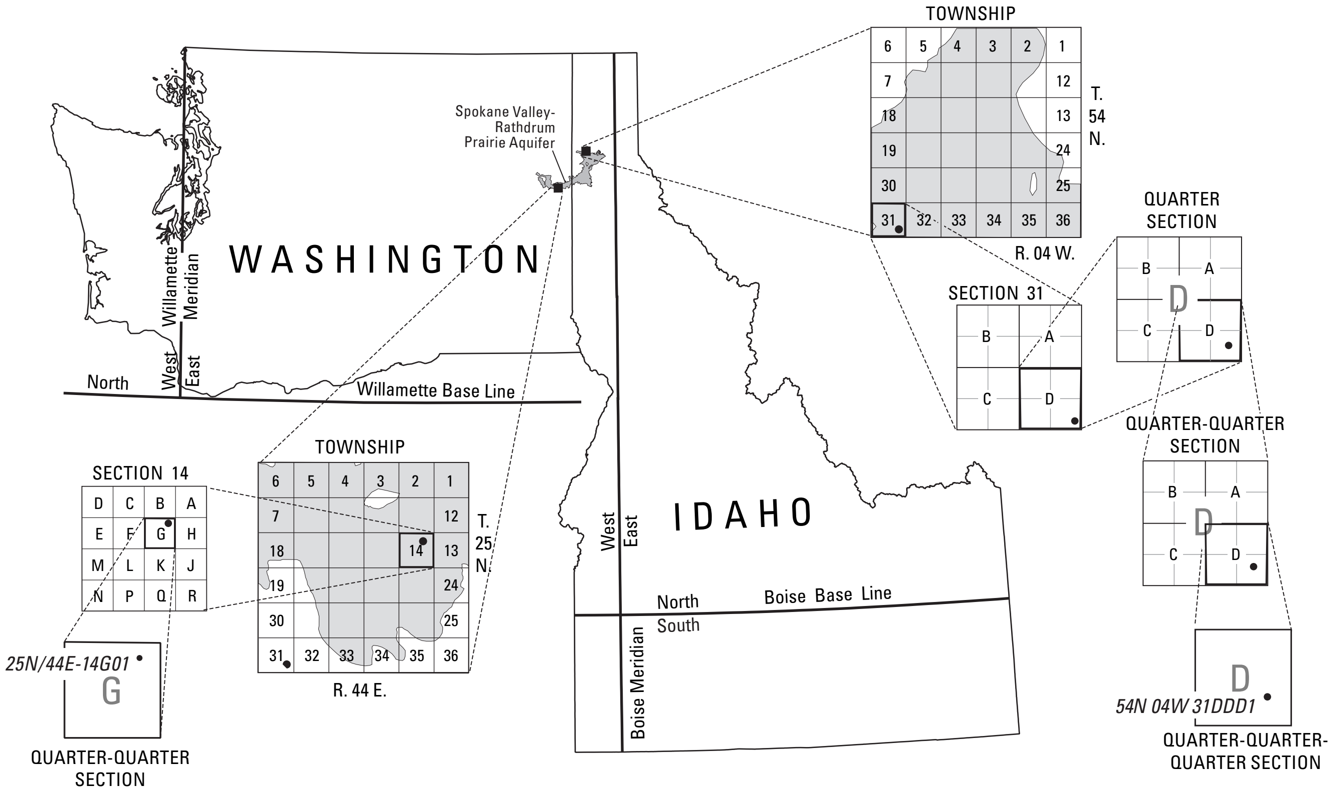


Figure 4. Well-numbering systems used in Washington and Idaho.

Hydrogeologic Framework

Geologic Setting

A series of geologic events has defined the surface and subsurface geologic framework in the study area. A basic description of these events was provided in Kahle and others (2005). That description has been modified slightly and repeated here to provide the reader with a comprehensive understanding of the geologic framework that affects the occurrence and movement of ground water in the study area. Although descriptions of the region’s geologic history are available at various levels of detail in numerous documents, the summary that follows is based in part on descriptions contained in Conners (1976), McKiness (1988), Molenaar (1988), Adema (1999), Breckenridge and Othberg (2001), Kiver and Stradling (2001), and Lewis and others (2002).

The simplified geologic history presented in this report describes three major time periods. The pre-Tertiary geology includes mostly Precambrian sedimentary rocks that have been metamorphosed and disrupted in places by igneous intrusions. The Tertiary geology includes the Columbia River basalts and interbedded lacustrine deposits of the Latah Formation. The Quaternary geology includes mostly glacial and catastrophic flood deposits of varying grain size that overlie the older rocks. A simplified geologic time scale (table 1) is provided to aid the reader in understanding the sequence of geologic events and the magnitude of geologic time during which they occurred. A map of the extent of late-glacial ice and glacial lakes in northern Washington, Idaho, and western Montana is shown in figure 5.

Pre-Tertiary Geology

The oldest rocks in the region surrounding and underlying the study area are metamorphosed, fine-grained sediments that originally were deposited in a large, shallow north-south-trending marine basin during the Precambrian. These rocks are present in outcrop today as low-grade metasedimentary rocks, including argillite, siltite, and quartzite, which grade locally into more highly metamorphosed schists and gneisses (p€m, pl. 2).

Following deposition and metamorphism, as much as 20,000 ft of the Precambrian rocks were eroded before the Paleozoic Era began (Conners, 1976). During the Cambrian, additional sedimentation occurred in shallow seas that resulted in shale, limestone, and sandstone being deposited over the Precambrian rocks. However, from the end of Cambrian time to the present, the region mostly has been emergent and much of the post-Cambrian sediments have been eroded from the area leaving few surface exposures (€s, near southern end of Lake Pend Oreille, pl. 2).

Emplacement of various igneous intrusive bodies, along with associated metamorphism and deformation, occurred during a long period of time between the Jurassic and Tertiary. During the Cretaceous, faulting and emplacement of large granitic bodies (TKg, pl. 2) resulted in the formation of the north-south-trending Purcell Trench, a geomorphically low feature that extends from north of the Canadian border south through the Cocolalla Valley and into the Rathdrum Prairie (pl. 1, fig. 5).

In pre-Tertiary time, the region’s surface-water drainage was from a vast area to the north and east of the study area. Streams flowed south from the Purcell Trench and Clark Fork Valley into presumably a large river that flowed through the Rathdrum Prairie and then west through the Spokane Valley to the ancient Columbia River. The pre-Tertiary landscape was characterized by ridge crests and valley bottoms that had considerable relief, probably 4,000 ft or more in places (Molenaar, 1988).

Tertiary Geology

During the Miocene, basalt flows of the Columbia River Group spread northeast from the Columbia Plateau and filled the deep canyons of the pre-Tertiary landscape. Drainage systems that previously had transported sediment out of the area now deposited sediment at the margins of the basalt flows. The Early Miocene basalt flows dammed drainages, including the ancient Rathdrum-Spokane River, and created lakes in which sand, silt, and clay of the Latah Formation were deposited. The earliest basalt flows apparently did not extend to the eastern and northern areas of the Rathdrum Prairie, and a relatively thick section of sediment accumulated in those areas. With the northeastward flow of basalt, Late Miocene basalt eventually overrode the entire Rathdrum Prairie region and created alternating layers of basalt and Latah Formation interbeds as recorded in drillers’ logs for wells located in the northeastern Rathdrum Prairie (Hammond, 1974).

During a period of slow downcutting from the Late Miocene to the Early Pleistocene, as much as 590 ft of Latah Formation sediments were removed from the region (Anderson, 1927). Streams in the developing drainages eroded much of the exposed Latah Formation beds and some of the younger basalt near the margins of the basin. Accurate estimates of the thickness and extent of the remaining Latah Formation sediments are difficult to determine because of the cover of Pleistocene drift and a scarcity of boreholes that penetrate below the water table. Anderson (1940) discovered a 980-ft-thick bed of Latah Formation beneath an exposed basalt flow when drilling a well west of Hayden Lake.

Table 1. Geologic time scale with simplified geologic units of the Spokane Valley-Rathdrum Prairie aquifer study area, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.

[Modified from http://pubs.usgs.gov/gip/geotime/divisions.html and http://www.geosociety.org/science/timescale/timescl.htm, accessed March 22, 2007. **Abbreviations:** ya, years ago; mya, million years ago; –, indicates a gap in the geologic record resulting from erosion and(or) nondeposition]

Geologic Time				Simplified geologic unit
Phanerozoic Eon (544 mya to present)	Cenozoic Era (65 mya to present)	Quaternary Period (1.8 mya to present)	Holocene Epoch (8,000 ya to present)	Recent non-glacial sediment
			Pleistocene Epoch (1.8 mya to 8,000 ya)	Glacial deposits and catastrophic flood deposits
		Tertiary Period (65 to 1.8 mya)	Pliocene Epoch (5.3 to 1.8 mya)	–
			Miocene Epoch (23.8 to 5.3 mya)	Basalt and older sediments
			Oligocene Epoch (33.7 to 23.8 mya)	–
			Eocene Epoch (55.5 to 33.7 mya)	Intrusive igneous rocks
			Paleocene Epoch (65 to 55.5 mya)	
	Mesozoic Era (248 to 65 mya)	Cretaceous Period (145 to 65 mya)		
		Jurassic Period (213 to 145 mya)		–
		Triassic Period (248 to 213 mya)		
	Paleozoic Era (544 to 248 mya)	Permian Period (286 to 248 mya)		
		Carboniferous Period (360 to 286 mya)		
		Devonian Period (410 to 360 mya)		
		Silurian Period (440 to 410 mya)		
		Ordovician Period (505 to 440 mya)		
		Cambrian Period (544 to 505 mya)		Sedimentary rocks
Precambrian Time (4,500 to 544 mya)	Proterozoic (2,500 to 544 mya)			Metamorphic rocks
	Archean (3,800 to 2,500 mya)			–
	Hadean (4,500 to 3,800 mya)			

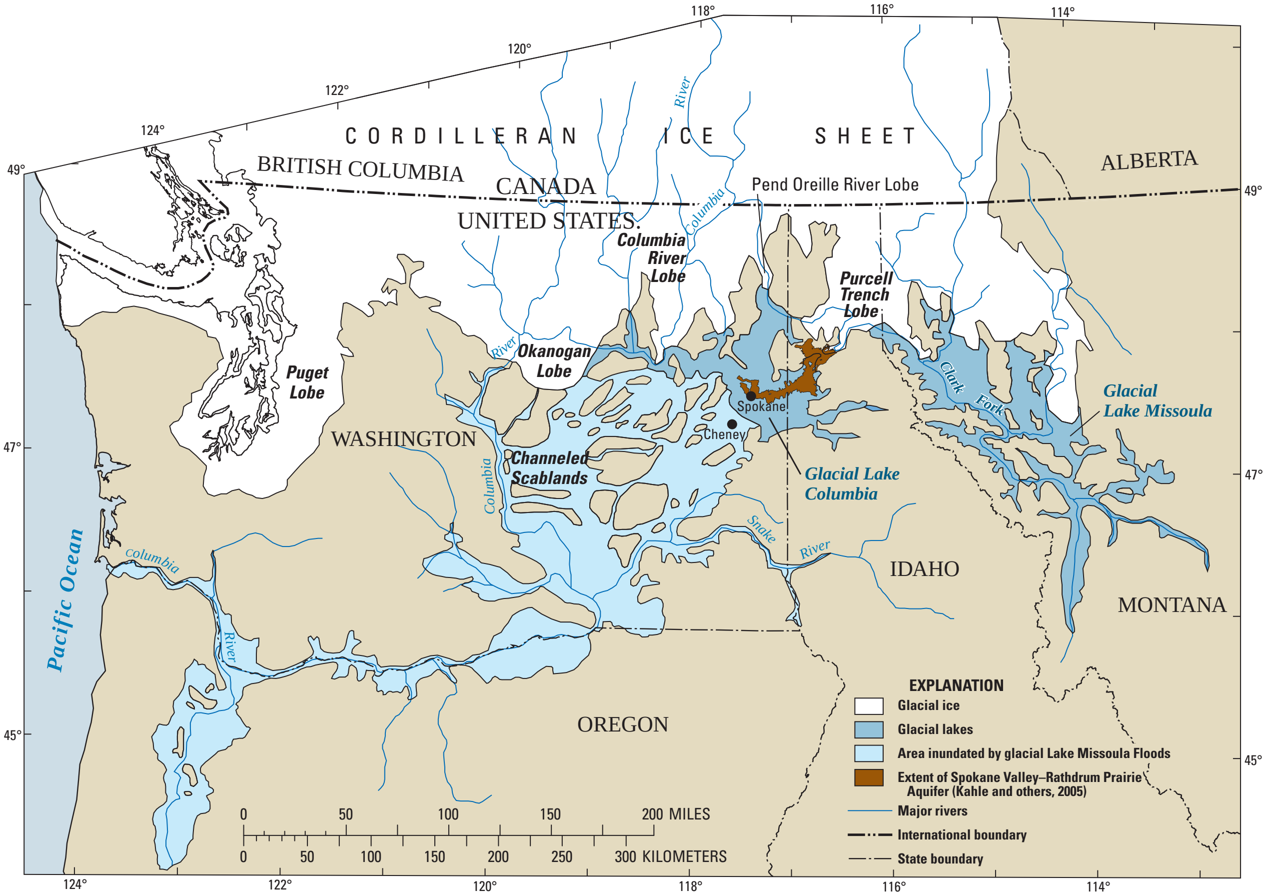


Figure 5. Extent of glacial ice and glacial lakes in northern Washington, Idaho, and parts of Montana. (Modified from Allen and Burns, 1986, and Atwater, 1986.)

The late Tertiary landscape likely was characterized by the ancestral Spokane River, which followed a course similar to that of today's Spokane River except in north Spokane where the ancestral river's course probably was through the Hillyard Trough on the east side of the basalt plateau of Five Mile Prairie (Newcomb and others, 1953). The river then flowed west along the present reach of the Little Spokane River Valley toward the present main valley near Long Lake. Tertiary sediments associated with the ancestral river may occur at depth along its historic course, now buried by Pleistocene drift.

Today, the Latah Formation has limited surface exposures near Hayden and Coeur d'Alene Lakes and near Spokane and occurs mostly as deeply weathered, yellow to orange silt and clay (older sediments, Ts, pl. 2). Surface exposures of the Columbia River basalt are common in the upland areas surrounding the SVRP aquifer in Washington. In Idaho, the largest exposures of basalt occur near Hayden and Coeur d'Alene Lakes (Tb, pl. 2).

Quaternary Geology

During the Pleistocene, the study area was subjected repeatedly to the erosional and depositional processes associated with glacial and interglacial periods. Although as many as six major glaciations affected the area, only the most recent can be described with any level of certainty. Sediments from earlier periods probably are encountered locally in some wells, but little surface evidence remains to reconstruct the depositional history of those sediments.

During the climax of the most recent Pleistocene glaciation (about 15,000 years before present), much of northern Washington, Idaho, and westernmost Montana was covered by lobes of the Cordilleran ice sheet (fig. 5). The large ice sheet formed in the mountains of British Columbia and flowed south, filling valleys and overriding low mountain ranges in the northern parts of Washington, Idaho, and Montana. The Pend Oreille River and Purcell Trench lobes contributed vast quantities of sediment to the study area via meltwater streams from the glacial lobes. The Okanogan and

Columbia River lobes affected the study area by occasionally blocking westward drainage of the ancestral Columbia and Spokane Rivers and creating large ice-age lakes. The Columbia River lobe created Glacial Lake Spokane; later, the Okanogan lobe created Glacial Lake Columbia (fig. 5), which inundated the smaller area covered by Glacial Lake Spokane. When the Purcell Trench lobe in northern Idaho blocked the drainage of the ancestral Clark Fork in northwestern Montana, Glacial Lake Missoula was created (fig. 5).

Glacial Lake Missoula had a maximum surface altitude of about 4,200 ft, a maximum depth of 2,000 ft, and a maximum surface area of 3,000 mi^2. Catastrophic failure of the Clark Fork ice dam released as much as 500 mi^3 of water at a rate 10 times the combined flow of all present-day rivers on Earth. The torrent of floodwater crossed parts of Montana, Idaho, Washington, and Oregon before reaching the Pacific Ocean. The continuous southward flow of ice repeatedly blocked the Clark Fork allowing Lake Missoula to refill multiple times. This cycle may have been repeated as many as 100 times (Atwater, 1986) before the end of the last glaciation. The largest of the Missoula floods, many of which probably occurred relatively early in the lake-filling and flooding cycle, overwhelmed local drainages and topped the 2,400-ft divide west of Spokane, spilling south towards Cheney and beyond and creating the Channeled Scablands (fig. 5). Smaller floods that spread through the Rathdrum Prairie and Spokane River Valley likely discharged through lower altitude drainages, including the present-day Little Spokane River, Long Lake, and Hangman (Latah) Creek (pl. 1).

The south end of Lake Pend Oreille at Farragut State Park marks the location of the outbreak of the Missoula floods (pl. 1). Most of the floodwaters flowed south through the Rathdrum Prairie and then west toward the Spokane area. The flood deposits consisted mostly of gravels of glaciofluvial origin derived from glacial outwash of the Purcell Trench lobe and reworked by the flood events. Near-surface deposits include coarser gravels located in the center of the valley and finer sands and gravels located along the margins. Flood bars of these deposits occur along the margins of the Rathdrum Prairie and Spokane Valley and dam the outlets of Spirit, Twin, Hayden, Coeur d’Alene, Hauser, Liberty, and Newman Lakes.

Glacial Lake Columbia, impounded by the Okanogan lobe, was the largest glacial lake in the path of the Missoula floods (fig. 5). This lake was long-lived (2,000–3,000 years) and had a typical surface altitude of 1,640 ft; however, the altitude reached 2,350 ft during maximum blockage by the Okanogan lobe and rose as high as 2,460 ft during the Missoula floods (Atwater, 1986). The higher level of Glacial Lake Columbia probably occurred early, whereas the lower and more typical level of the lake occurred in later glacial time (Richmond and others, 1965; Waitt and Thorson, 1983; Atwater, 1986). At the lower level (1,640 ft), Glacial Lake Columbia extended east to the Spokane area, where clayey lake sediment is intercalated with Missoula flood sediment (Waitt and Thorson, 1983). At the higher level of Glacial Lake Columbia (2,350 ft), the glacial lake would have flooded the Rathdrum Prairie to within a few miles of the Purcell Trench lobe that dammed Glacial Lake Missoula.

Sedimentation associated with Glacial Lake Columbia resulted in thick, fine-grained sediments throughout much of the region. Within the study area, clay and silt deposits, presumed to be Glacial Lake Columbia sediments, have been identified in deep boreholes in the Hillyard Trough and north Spokane areas and in the Hangman (Latah) Creek Valley. At least 16 beds of Glacial Lake Missoula flood deposits have been identified within Glacial Lake Columbia deposits in the Hangman (Latah) Creek Valley just south of Spokane (Waitt and Thorson, 1983). These fine-grained deposits generally occur at depth beneath late glacial deposits of the Missoula floods and likely occur elsewhere in the study area. Alternating beds of lake and flood deposits may occur at considerable depth (400–600 ft) throughout parts of the study area.

Although Glacial Lake Columbia apparently inundated most of the study area at least periodically, the last of the Missoula floods may have spilled through an area devoid of a glacial lake. A complex of flood bars that develop only when standing water is very shallow or absent is present from the Spokane River Valley to its confluence with the Columbia River 65 mi downstream (Kiver and Stradling, 2001). The present surface morphology of the Rathdrum Prairie and Spokane River Valley developed during the last outburst floods between 13,000 and 11, 000 years ago (Waitt, 1985). These late glacial-outburst-flood deposits constitute much of the upper part of the SVRP aquifer.

Surface exposures of Quaternary deposits within the study area include:

- *Undifferentiated glacial and alluvial deposits* (Qu, pl. 2) consisting of Pleistocene glacial or glaciofluvial deposits and Holocene alluvium in the northeast part of the study area where recent deposits have not been differentiated in Bonner County, Idaho.

- *Recent non-glacial sediment* (Qs, pl. 2) consisting mostly of Holocene sediment including alluvium in stream channels, lacustrine deposits associated with study area lakes, mass-wasting deposits most commonly detected along the base of basalt bluffs in Spokane County, peat associated with poorly drained and organic rich areas, and wind-blown deposits on the surface of prairies and the basalt plateaus.

- *Glacial outwash and till* (Qot, pl. 2) consisting of very coarse boulder gravels with sand deposited by meltwater streams from either overflow of the Lake Pend Oreille basin during Cordilleran deglaciation of the Purcell Trench or from noncatastrophic drainage of Glacial Lake Missoula. At the south end of Lake Pend Oreille, the unit consists of bouldery clay till and boulder outwash deposits that form a modified end moraine.

- *Glacial lake deposits* (Qgl, pl. 2) consisting of silt and fine sand, with clay interbeds, scattered boulders, and some sand and gravel lenses deposited in Glacial Lake Columbia and (or) Glacial Lake Spokane. These deposits are mapped along Deadman and Hangman (Latah) Creeks.

- *Catastrophic flood deposits, gravel* (Qfg, pl. 2) consisting of a mixture of boulders, cobbles, pebbles, and sand with lenses of sand and silt deposited by catastrophic draining of Glacial Lake Missoula. These deposits occur over much of the study area from near Lake Pend Oreille through the Rathdrum Prairie and the Spokane River Valley.

- *Catastrophic flood deposits, sand* (Qfs, pl. 2) consisting of sand with sparse pebbles, cobbles, and boulders deposited by catastrophic draining of Glacial Lake Missoula into backwater or lower energy environments along the margins of the main path of the floods. The unit is mapped in Washington in the Hillyard Trough and areas west of Five Mile Prairie. Smaller exposures are mapped along the boundaries of the SVRP aquifer near the Washington-Idaho State line where the unit consists of sand and silt with some gravel that was deposited mostly in waning floodwaters.

Hydrogeologic Units

Hydrogeologic data compiled from 587 wells (table 3) was used to describe the hydrogeologic units of the study area. Although characterization of the SVRP aquifer is the focus of this investigation, the Basalt and fine-grained interbeds unit, which includes Columbia River basalt and interbedded lacustrine deposits of the Latah Formation and the Bedrock unit, which includes metasedimentary and igneous intrusive rocks, also are described. A simplified conceptual model of the hydrologic conditions in the study area is shown in figure 6. Using the data described in the section “Methods”, hydrogeologic sections were constructed and used to describe the SVRP aquifer and the surrounding hydrogeologic units. Using these sections and additional wells, the approximate base and thickness of the aquifer were estimated and the significant fine-grained layers within the aquifer were described.

Fine-Grained Deposits in the Study Area

Although the SVRP aquifer is known for its extremely coarse-grained texture and high transmissivity, several recent investigators have described fine-grained or confining layers within the aquifer, specifically in the Hillyard Trough and Little Spokane River valley (CH2M HILL, 1998; Golder Associates, Inc., 2004). Identification of the location and thickness of significant fine-grained layers within the aquifer is important for appropriate representation in computer models being developed to simulate the movement and storage of ground water in the aquifer. As part of this investigation, an attempt was made to identify and map significant (more than 5 ft thick) fine-grained layers within the aquifer on the basis of available well data.

During the process of identifying fine-grained layers within the SVRP aquifer, it became apparent that some of the fine-grained material recorded in drillers’ logs probably was not glaciolacustrine but rather older lacustrine deposits of the Latah Formation at the base of the aquifer. In some cases, fine-grained layers were fully penetrated in boreholes, and the aquifer was easily identifiable and described as continuous below the fine-grained layer. For example, see wells 26N/43E-08E04 [hydrogeologic section *A-A’*]; 26N/45E-24C02 [hydrogeologic section *F-F’*]; and 51N 04W 35DDA1 [hydrogeologic section *I-I’*] on plate 2. In other cases, however, fine-grained layers were not fully penetrated and were encountered at or near the base of the well, making it difficult to determine whether the fine-grained layer was within the aquifer or was older lacustrine material below the aquifer. For example, see wells 51N 04W 35BBA1 [hydrogeologic section *I-I’*], 51N 05W 11ADB1 (hydrogeologic section *J-J’*), and 53N 04W 25DDC2 [hydrogeologic section *L-L’*] on plate 2.

Although these two types of fine-grained layers are nearly impossible to differentiate on the basis of lithology alone, a method was devised using stratigraphic position, color, and the occasional presence of organic matter to help differentiate glaciolacustrine fine-grained layers within the aquifer from older lacustrine fine-grained material below the aquifer. A description of the fine-grained deposits—clay and (or) silt with some sand and occasional gravel—that occur in the study area follows.

Deeply weathered or organic-rich clays commonly described in drillers’ logs as red, orange, yellow, brown, or green (with or without associated wood) were interpreted to be Miocene non-glacial lacustrine deposits of the Latah Formation. Within boreholes in the study area, the fine-grained deposits of the Latah Formation generally occur along the perimeter of the aquifer, especially near the three-channel area in Idaho, and commonly are associated with basalt. The top surface of the Latah Formation in this area represents the bottom extent of the SVRP aquifer. Latah Formation sediments undoubtedly exist throughout much of the aquifer area at greater depth than indicated by the well data. This unit is difficult to distinguish from glaciolacustrine deposits in drillers’ logs unless the driller recorded an “organic-rich” color, organic matter (such as wood), or basalt layers.

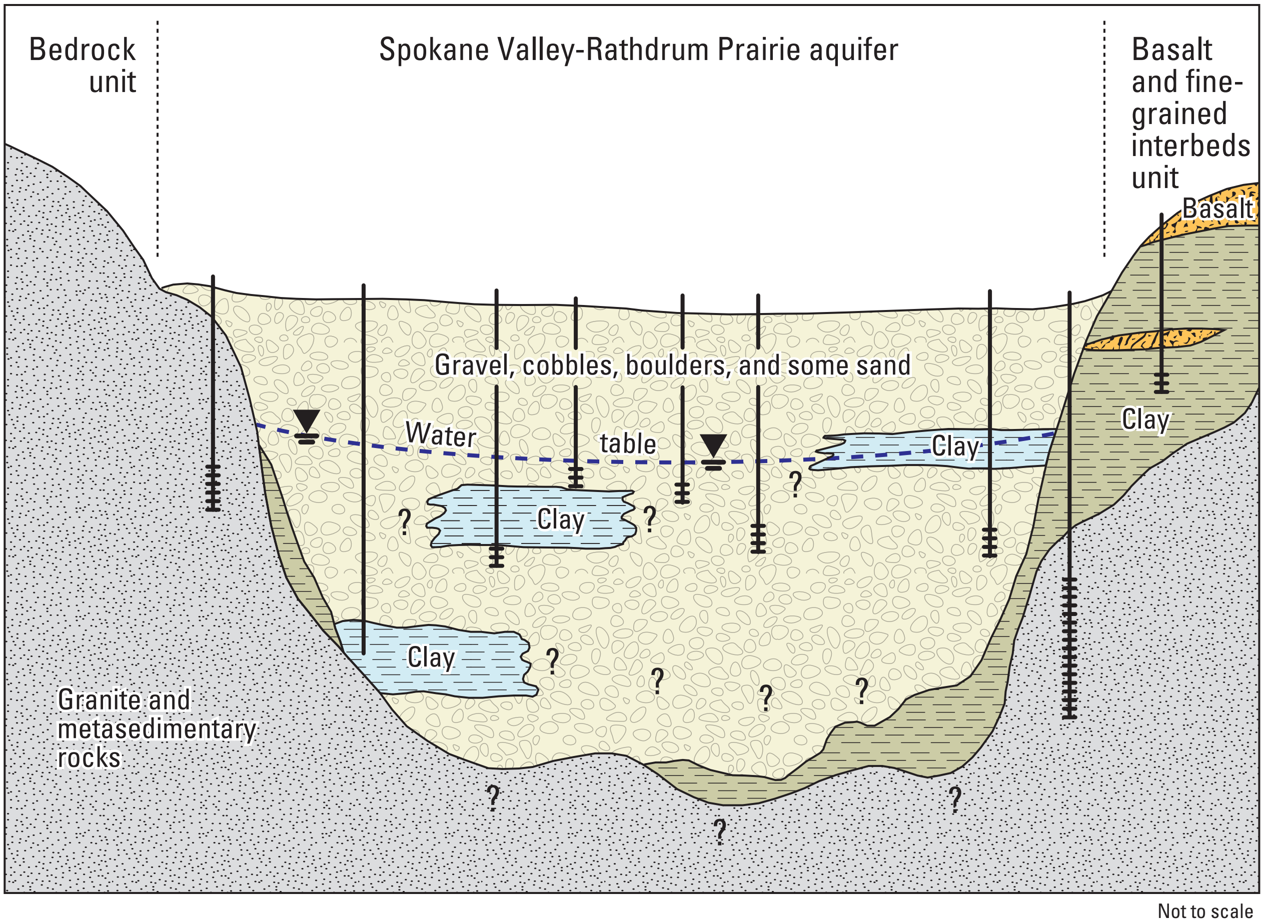


Figure 6. Simplified conceptual model of hydrologic conditions in the Spokane Valley-Rathdrum Prairie aquifer and surrounding hydrogeologic units, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.

Most of the deposits described in drillers' logs as blue or gray clay likely are glaciolacustrine deposits in the SVRP aquifer. These fine-grained layers were deposited in the previously described large proglacial lakes caused by damming of the ancient Rathdrum-Spokane and Columbia Rivers by ice lobes downstream of present-day Spokane. Long-lasting stands of glacial lakes would have resulted in great thicknesses of fine-grained material being deposited over large areas. In places, the immense floods from Glacial Lake Missoula could have deeply eroded these fine-grained layers. Outside the main path of the floodwaters, remnants of the fine-grained layers may occur. The repetition of the depositional and erosional processes for thousands of years would have caused multiple episodes of fine-grained sedimentation and then subsequent removal and scouring in places during the Missoula floods as well as deposition of coarse-grained material. This history has resulted in the variable nature of the fine-grained layers within the aquifer that have been recorded in drillers' logs. Additional uncertainty associated with well locations, and variability in the level of detail recorded by different drillers, also contributes to the difficulty of mapping the fine-grained layers. The cross sections on plate 2 illustrate the great variability of the altitude and thickness of the glaciolacustrine deposits within the aquifer and of the Latah Formation adjacent to or beneath the aquifer.

Spokane Valley-Rathdrum Prairie Aquifer

The SVRP aquifer consists of unconsolidated, coarse-grained gravel, cobbles, boulders, and some sand primarily deposited by a series of catastrophic glacial outburst floods. The material deposited in this high-energy depositional environment is coarser grained than is typical for most basin-fill deposits and forms one of the most productive aquifers in the United States (Molenaar, 1988). Fine-grained layers of clay and silt are scattered throughout the aquifer and likely were deposited in large proglacial lakes in the path of the Missoula floods. The aquifer extends from Lake Pend Oreille through the Rathdrum Prairie and Spokane Valley to near Spokane where it is divided by Five Mile Prairie (pl. 1). On the west side of Five Mile Prairie, the Western Arm of the aquifer follows the course of the present-day Spokane River from near downtown Spokane to the community of Seven Mile. On the east side of Five Mile Prairie, the main body of the aquifer extends through the Hillyard Trough and then west through the Little Spokane River Valley to Long Lake, an area referred to as the Little Spokane River Arm of the aquifer (pl. 1). To the south of Five Mile Prairie, the aquifer is separated by a buried basalt ridge that extends about 2 mi south to an area referred to as the Trinity Trough, a breach in the basalt ridge that connects the east and west parts of the aquifer in that vicinity.

Owing to the depositional history described previously, the aquifer generally has a greater percentage of finer material near the margins of the valley and becomes more coarse and bouldery near the center throughout the Rathdrum Prairie and Spokane Valley. In the Hillyard Trough, the deposits generally are finer grained and the aquifer consists of sand with some gravel, silt, and boulders.

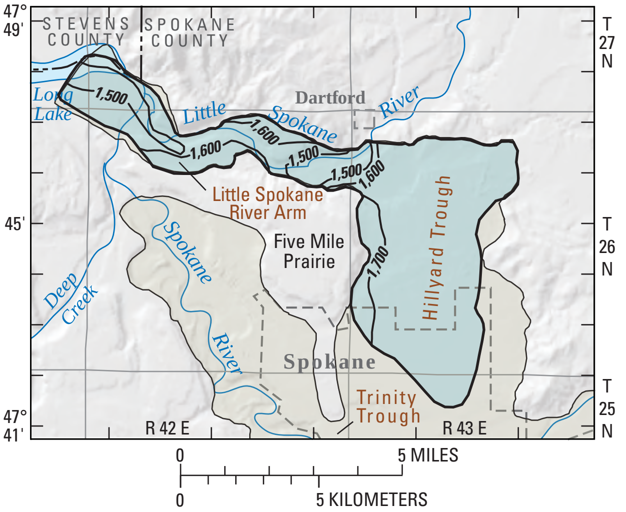
Approximate water levels within the aquifer, based on the September 2004 water-level map (Campbell, 2005), are shown in the hydrogeologic sections on plate 2. The greatest depths to water, about 500 ft, occur in the northwest part of the Rathdrum Prairie (hydrogeologic section *M-M'*, pl. 2). Depth to water in the downgradient part of the aquifer in Washington is about 200 ft or less (hydrogeologic section *D-D'*, pl. 2). The shallowest depths to water occur along the Spokane and Little Spokane Rivers; near the outlets of Lake Pend Oreille (hydrogeologic sections *L-L'* and *M-M'*, pl. 2) and Hayden and Coeur d'Alene Lakes (hydrogeologic sections *J-J'* and *I-I'*, respectively, pl. 2); and near Long Lake (hydrogeologic section *A-A'*, pl. 2). In the northern Rathdrum Prairie where bedrock "highs" protrude up into the aquifer, the aquifer may have very thin or seasonally saturated zones (hydrogeologic sections *K-K'*, *L-L'*, and *O-O'*, pl. 2). Although most of the SVRP aquifer is unconfined, the lower unit of the aquifer is confined in the Hillyard Trough and along the Little Spokane River Arm below the extensive fine-grained layer (hydrogeologic sections *A-A'* and *B-B'*, pl. 2). In the Little Spokane River Arm, the altitude of the fine-grained layer is sufficiently high that most of the upper unit of the aquifer is unsaturated.

Fine-Grained Layers within the Spokane Valley-Rathdrum Prairie Aquifer

Numerous fine-grained, low-permeability, interbedded deposits occur within the SVRP aquifer at considerably different altitudes (sections *A-A'* through *J-J'* and *M-M'* through *O-O'*, pl. 2). General observations about these fine-grained layers, each at least 5 ft thick, are presented by geographic area in the following sections.

Hillyard Trough and Little Spokane River Arm

As reported in CH2M HILL (2000), an extensive fine-grained layer separates the SVRP aquifer into upper and lower units in the Hillyard Trough (pl. 2, hydrogeologic sections *A-A'* through *D-D'*). Based on observations made during this investigation, altitudes of this layer range from about 1,660 to 1,720 ft. Most of this layer, however, occurs at an altitude of about 1,670 ft (fig. 7). The thickness of the layer ranges from 162 to 265 ft and averages 215 ft as indicated by logs for five wells that fully penetrated the layer. To the south, this layer is estimated to extend within about 2 mi of downtown Spokane (fig. 7). Based on drillers' logs used during this investigation, a local fine-grained layer occurs at higher altitudes within the Hillyard Trough; however, this layer is thinner and less continuous than the layer at the 1,670-ft altitude. Although the top of the upper fine-grained layer ranges from about 1,790 to 1,840 ft, it generally occurs at an altitude of about 1,820 ft and has a thickness of about 30 ft. Site-scale hydrogeologic characterization of the Kaiser Mead Plant in the north end of the Hillyard Trough (T 26 N, R 43 E, section 16) suggests the presence of numerous thin clay layers, some less than 5 ft thick, in the upper part of the aquifer (HartCrowser, 1988).



EXPLANATION

▨ APPROXIMATE EXTENT OF FINE-GRAINED LAYER IN HILLYARD TROUGH AND LITTLE SPOKANE RIVER ARM

— *1,700* — CONTOUR SHOWING ALTITUDE OF TOP OF FINE-GRAINED LAYER WITHIN THE HILLYARD TROUGH AND LITTLE SPOKANE RIVER ARM—
Contour interval is 100 feet. Datum is North American Vertical Datum of 1988

Figure 7. Approximate location and altitude of the top of the fine-grained layer in the Hillyard Trough and Little Spokane River Arm of the Spokane Valley–Rathdrum Prairie aquifer, Spokane County, Washington.

The extensive fine-grained layer in the Hillyard Trough also is present in the Little Spokane River Arm of the SVRP aquifer that extends into the Long Lake area. However, the top of the layer in this part of the aquifer is more variable than in the Hillyard Trough and occurs at an altitude of about 1,500–1,700 ft. The thickness of the layer ranges from 20 to 280 ft and averages 130 ft as indicated by logs for 30 wells that fully penetrated the layer.

Western Arm

Too few data are available for the Western Arm of the SVRP aquifer to identify the presence or absence of continuous fine-grained layers. The driller's log for well 26N/42E-35M01 indicates two clay layers within the aquifer were encountered; one 5-ft thick layer with an altitude of 1,744 ft and a lower 10-ft thick layer with an altitude of 1,644 ft. CH2M HILL (1988) reports that near the former City of Spokane North Landfill site (pl. 1), flood deposits of the aquifer are underlain by glacial lake deposits (silt and clay) except in lower altitude areas near the Spokane River where the aquifer is underlain by basalt (hydrogeologic section *C-C'*, pl. 2).

Spokane Valley

Based on available well-log data, the central axis of the Spokane Valley appears to be devoid of extensive fine-grained deposits (hydrogeologic section *E-E'*, pl. 2). Isolated fine-grained deposits occur locally but mostly are limited to the valley's margins and at the outlet of Liberty, Newman (hydrogeologic section *F-F'*, pl. 2), and Hauser Lakes.

Rathdrum Prairie

Multiple fine-grained deposits are scattered throughout the SVRP aquifer in the Rathdrum Prairie (hydrogeologic sections *G-G'* through *J-J'* and *M-M'* through *O-O'*, pl. 2). However, the extent of these deposits are difficult to map because of their discontinuity and variable altitudes and thickness. Of the 321 project wells located in Idaho, 52 fully penetrated a clay layer within the aquifer. The altitude of these clay layers range from 1,653 to 2,392 ft with thicknesses ranging from 5 to 98 ft (fig. 8). Another 22 project wells in Idaho partially penetrated 1–135 ft of fine-grained material at their completion depths (fig. 8). Nearly 77 percent of the project wells in Idaho did not penetrate fine-grained material, even though several were in close proximity and depth to wells that did penetrate the fine-grained material. The discontinuity of the fine-grained deposits probably is attributable to this area being along the principal path of repeated Missoula floods in contrast to the Hillyard Trough where more of a slack water environment would have allowed the preservation of more preexisting fine-grained deposits. The locations of wells that fully penetrate fine-grained deposits in the Rathdrum Prairie part of the aquifer are shown in figure 8.

More extensive fine-grained deposits at various altitudes appear to be somewhat common on the east margin of the Rathdrum Prairie between Coeur d'Alene Lake and the south end of the Middle (Ramsey) Channel than elsewhere in the area (fig. 8). A fine-grained deposit with an altitude ranging from about 1,860 to 1,980 ft occurs in the area just west of Hayden Lake (hydrogeologic section *I-I'*, pl. 2). Well 51N 04W 35DDA1 fully penetrated 90 ft of clay above the lower part of the aquifer; wells 51N 4W 14AAC1, 14DBB2, 23DCB1, 26ACC1, and 35BBA1 partially penetrated clay at the base of each well (hydrogeologic section *I-I'*, pl. 2). A higher and apparently thinner fine-grained deposit was penetrated in wells 50N 04W 12BCD1 and 51N 04W 11DDA1 and 23ABAC1 (hydrogeologic section *I-I'*, pl. 2).

On the west margin of the SVRP aquifer near Rathdrum, fine-grained deposits were noted in several wells. Altitudes of the fine-grained deposits in those wells range from about 1,963 to 2,234 ft (fig. 8). Well 51N 04W 06CCDD1 (pl. 1) fully penetrated 80 ft of clay above the lower part of the aquifer.

Southwest of Rathdrum, two deep grounding wells, 51N 05W 11ADA1 (620 ft) and 51N 05W 11ADB1 (650 ft), encountered clay at an altitude of 1,671 and 1,673 ft, respectively. The deeper of the two wells, 51N 05W 11ADB1, only partially penetrated 135 ft of the clay at the base of the borehole (hydrogeologic section *J-J'*, pl. 2). The altitude and thickness of this clay are similar to those of the extensive fine-grained layer in the Hillyard Trough. These two boreholes are the only ones in the central part of the Rathdrum Prairie that provide information on the lower part of the aquifer. Only coarse-grained material was recorded by the driller for the upper 515 ft of each of the boreholes, indicating the upper and thinner fine-grained deposits that occur elsewhere in the Rathdrum Prairie are absent at this location.

Immediately north of Round Mountain, wells 53N 04W 27DBD1 (hydrogeologic section *L-L'*, pl. 2), 53N 04W 22CBD1 (pl. 1), and 53N 04W 28CAB1 (hydrogeologic section *N-N'*, pl. 2) fully penetrated clay at altitudes of 2,271, 2,262, and 2,224 ft, respectively. Thicknesses of the clay layers are 16, 10, and 71 ft, respectively.

Near Athol, fine-grained deposits were penetrated in several wells between altitudes of 2,007 and 2,125 ft. The thickness of the deposits in well 53N 03W 08AC1 is 94 ft (hydrogeologic section *O-O'*, pl. 2). A 39-ft-thick clay layer at an altitude of 2,392 ft also was penetrated in this area in well 53N 03W 05DCC1 (section *O-O'*, pl. 2). Near the southern ends of Hoodoo and Spirit Valleys, numerous wells penetrated fine-grained deposits at altitudes that range from 1,983 to 2,258 ft. Thicknesses of the layers range from 12 to 80 ft (fig. 8).

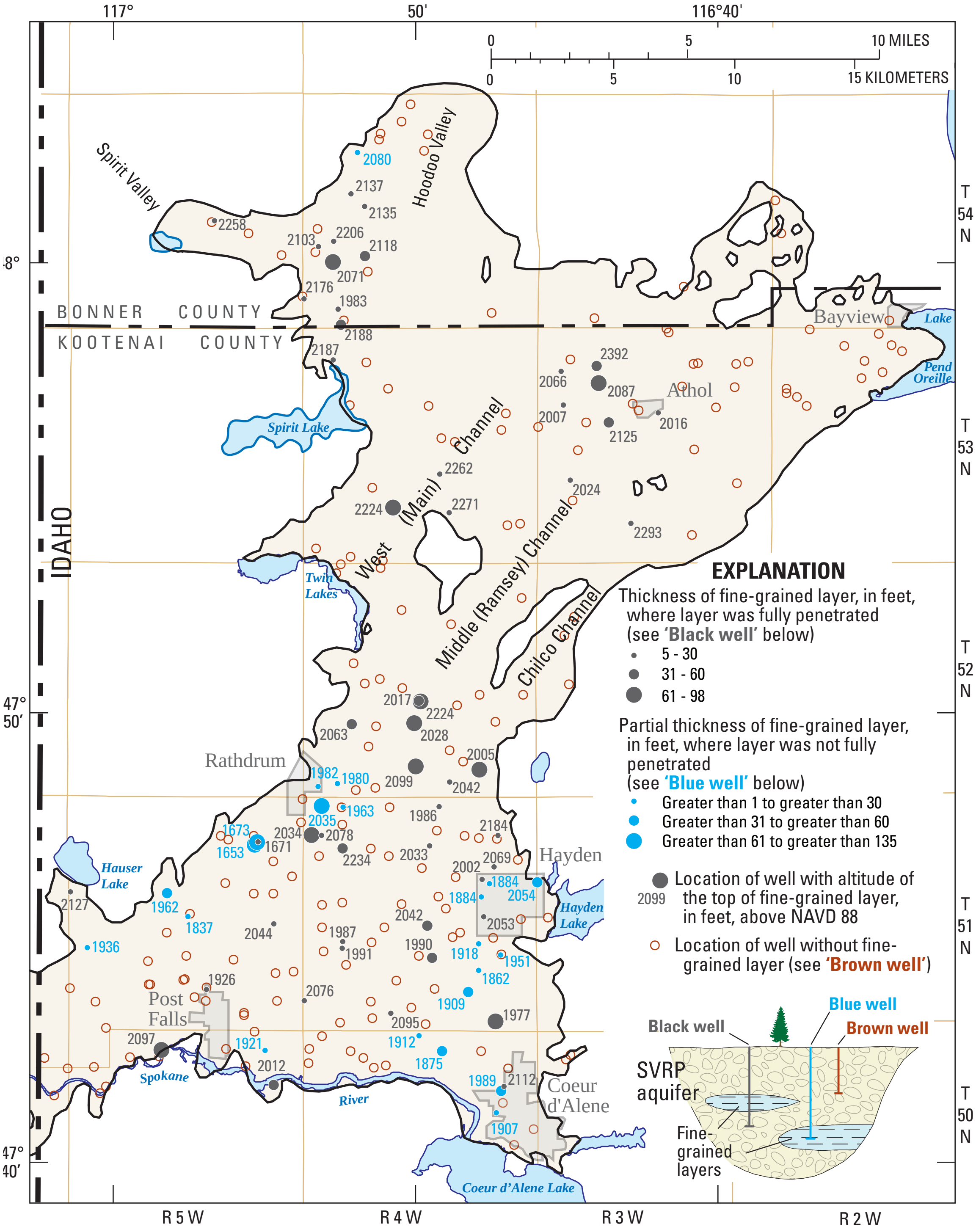


Figure 8. Locations of wells with and without fine-grained deposits within the Rathdrum Prairie part of the Spokane Valley-Rathdrum Prairie aquifer, Bonner and Kootenai Counties, Idaho.

Hydraulic Properties

A description of the hydraulic properties of the SVRP aquifer is included here in a generalized fashion in order to provide the reader with an understanding of the highly transmissive nature of the aquifer. Several previous studies including Drost and Seitz (1978), Bolke and Vaccaro (1981), and CH2M HILL (1998) estimated aquifer characteristics based on aquifer tests and ground-water model simulations. Although hydraulic properties of the aquifer were variable, most results indicated that hydraulic conductivity (a measure of the ability of the aquifer material to transmit water) and transmissivity (the rate at which water is transmitted through a unit width of the aquifer under a unit hydraulic gradient, equal to the hydraulic conductivity multiplied by the aquifer thickness) values were on the upper end of values measured in the natural environment (Kahle and others, 2005). Drost and Seitz (1978) reported transmissivity values that ranged from less than 130,000 ft^2/d in the western part of the aquifer to more than 13 million ft^2/d near the Washington−Idaho State line. Bolke and Vaccaro (1981) estimated hydraulic conductivity values of 2,600–6,000 ft/d for most of the aquifer on the Washington side and about 860 ft/d in the Hillyard Trough. CH2M HILL (1998) reported hydraulic conductivity values ranging from about 100 to 6,200 ft/d, with most values greater than 1,000 ft/d.

Boundary Conditions

In most places, the SVRP aquifer is bounded laterally by metamorphic or igneous intrusive rocks. In places, such as near Spokane and Coeur d'Alene, the aquifer is laterally bounded by basalt and fine-grained interbeds. The bottom boundary of the aquifer generally is unknown except along the margins or in shallower parts of the aquifer where wells have penetrated the entire aquifer thickness and reached bedrock (metamorphic or igneous intrusive rocks) or basalt and fine-grained interbeds. The upper boundary of the saturated portion of the aquifer is represented by the regional water table as described by Berenbrock and others (1995) and Campbell (2005). In the northern Rathdrum Prairie, the water table can be as deep as 500 ft below land surface; near the Washington-Idaho State line the water table is about 150 ft below land surface. Reported ground-water divides approximately represent the aquifer boundary in the Hoodoo and Spirit Valleys and near Careywood, Idaho (Kahle and others, 2005). Upgradient areas of the aquifer also are bounded by tributary lakes, including Pend Oreille, Spirit, Twin, Hayden, Coeur d'Alene, Hauser, Newman, and Liberty. Streams tributary to the aquifer include Lewellen, Sage, and Rathdrum Creeks in Idaho, and Chester and Saltese Creeks in Washington. Streams tributary to the Spokane River in the aquifer extent include Hangman (Latah) Creek near Spokane, Washington, and the Little Spokane River north of Spokane. The aquifer's lower discharge area is poorly defined, but is believed to be near Long Lake at the confluence of the Spokane and Little Spokane Rivers.

Base of Aquifer

A contour map of the approximate altitude of the base of the SVRP aquifer is shown in figure 9. The base of the aquifer is defined as where the aquifer lies on top of bedrock (granite or metamorphic rock), basalt, or fine-grained deposits that probably are the Latah Formation. Contours were manually drawn and lie within the 2005 revised extent of the aquifer (Kahle and others, 2005). Data used to construct the map include data for the 587 project wells. Of these wells, slightly more than 100 fully penetrate the base of the aquifer and generally are located along the aquifer's margin. For these wells, the altitude of the base of the aquifer was obtained by subtracting the depth to the base of the aquifer from the digital-elevation-model (DEM) derived land-surface altitude for the well. The inferred base of the aquifer drawn on the hydrogeologic sections also was used for contouring. Data from existing geophysical transects described in Kahle and others (2005) were used as a guide to estimate the base of the aquifer on the sections but not directly on the base-of-aquifer map. If well data appeared to contradict the geophysical transects, preference was given to the well data. Along the aquifer margin, subsurface contours were tied to DEM-derived land-surface contours, also in 200-ft intervals. The altitude of the base of the aquifer ranges from less than 1,800 ft near Lake Pend Oreille to less than 1,200 ft near the aquifer's outlet near Long Lake (fig. 9).

There is general agreement between the base of aquifer depicted on the map in this report and other more site specific maps (Graham and Buchanan, 1994; Boese and Buchanan, 1996; Golder Associates Inc., 2004; Baldwin and Owsley, 2005; Stevens, 2005). Similarly, there is general agreement between the map in this report and Buchanan's (2000) map, the first aquifer-wide map produced for the study area. Notable differences are related largely to the different aquifer boundaries used for the two maps. Buchanan used an aquifer boundary similar to the Sole Source boundary (shown in Kahle and others, 2005, fig. 5) that excludes the Middle and Chilco Channels, excludes the southern end of Hoodoo Valley, and connects the aquifer near Nine Mile Falls.

There also is general agreement between the map in this report and a basement-altitude map produced using gravity data to constrain depth to basement modeling (Oldow and Sprenke, 2006). The difference between the two maps is related largely to the different assumptions used in the construction of each map and the uncertainties inherent to each method. An important difference in these maps is that the map in this report is a base-of-aquifer map, whereas the map constructed by Oldow and Sprenke (2006) is a basement

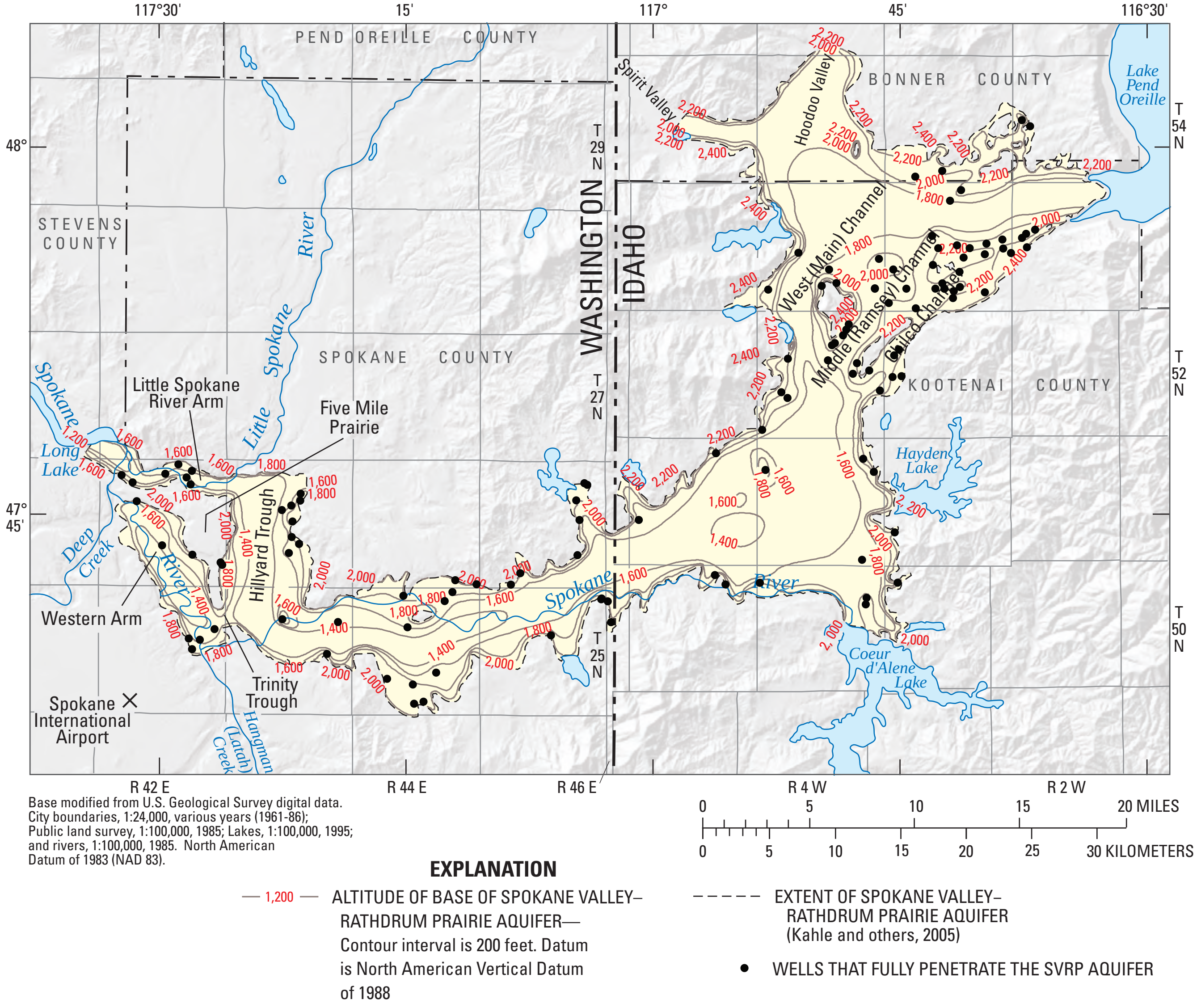


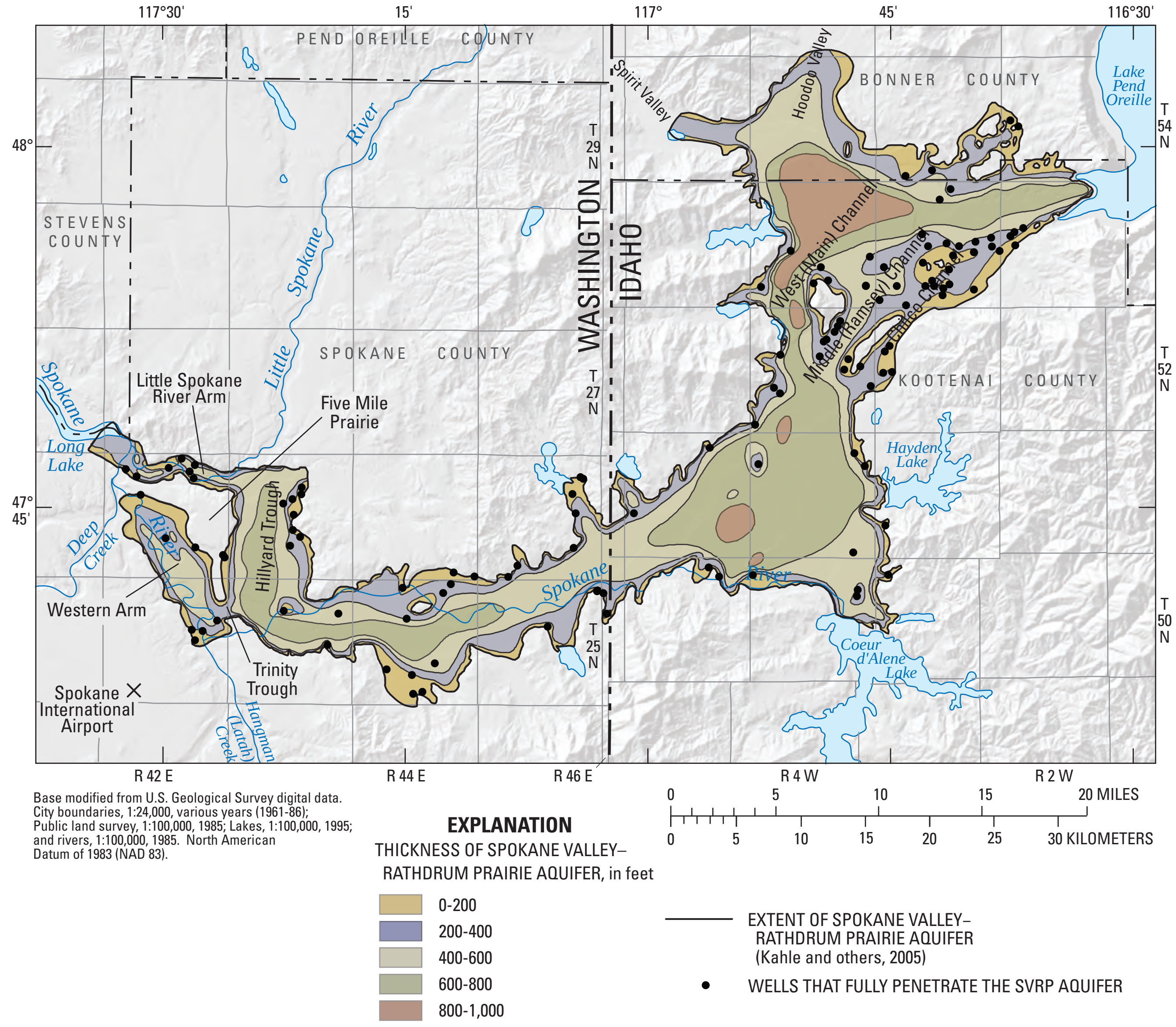
Figure 9. Approximate altitude of the base of the Spokane Valley–Rathdrum Prairie aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.

map based on a model of a pre-Tertiary basin filled with gravel. The pre-Tertiary basement surface would be expected to differ from the base-of-aquifer surface where the aquifer is underlain by Tertiary basalt and (or) associated fine-grained interbeds of the Latah Formation. The two maps may have better agreement where the basalt and Latah Formation interbeds have been eroded fully from the pre-Tertiary surface. This may be the case where the two maps appear very similar at the outlet of Lake Pend Oreille and throughout most of the Spokane Valley. In areas where the gravity-derived map (Oldow and Sprenke, 2006) indicates a lower surface, such as in the Hillyard Trough and central Rathdrum Prairie, the base-of-aquifer estimates shown in figure 9 infer a shallower base. Both maps and (or) methods would benefit from deep borehole information in these areas.

Aquifer Extent and Thickness

The extent of the SVRP aquifer used in this report remains the same as that used in Kahle and others (2005). Although much of the aquifer extent is fairly easily defined and well accepted, an exception to this is in southern Bonner County near the south end of Hoodoo and Spirit Valleys (pl. 1). Recent evaluation of water levels in wells in Township 54 N and Range 4 West indicates the ground-water divide near the southern end of Hoodoo Valley may be farther south than shown on plates 1 and 2 (Hsieh and others, 2007). Further analysis of water levels in existing wells and the possible addition of monitoring wells in this area are needed to better characterize the aquifer extent.

An aquifer thickness map was constructed using the same data set described in the previous section to illustrate the approximate thickness of the SVRP aquifer (fig. 10). In Idaho, areas of greatest thickness, more than 800 ft, occur in the northwest part of the northern Rathdrum Prairie, through the West Channel area, and through the west-central part of the Rathdrum Prairie. In Washington, the areas of greatest thickness, more than 600 ft, occur in the central part of the Spokane Valley, in Spokane, and in the Hillyard Trough. Near the Washington-Idaho State line, the thickness of the aquifer is about 400–600 ft. Aquifer thickness estimates are more reliable in areas where wells fully penetrate the aquifer than in areas where the thickness was inferred.



Base modified from U.S. Geological Survey digital data. City boundaries, 1:24,000, various years (1961-86); Public land survey, 1:100,000, 1985; Lakes, 1:100,000, 1995; and rivers, 1:100,000, 1985. North American Datum of 1983 (NAD 83).

Figure 10. Approximate thickness of the Spokane Valley-Rathdrum Prairie aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.

Basalt and Fine-Grained Interbeds Unit

Of the 587 project wells, 24 are completed in the Basalt and fine-grained interbeds unit. These wells are located near Spokane, northwest of Hayden Lake, and near Middle (Ramsey) and Chilco Channels (pl. 1). Although this unit can yield sufficient quantities of ground water for domestic use, it is discontinuous and not considered an important aquifer within the study area. As illustrated on plate 2, some wells completed in this unit are open to the Latah Formation interbeds (25N/43E-27B02 on hydrogeologic section *D-D'*, 26N/43E-15H02 on hydrogeologic section *A-A'*, and 52N 04W 24DDB1 on hydrogeologic section *K-K'*); others are open to the Columbia River basalt (26N/42E-23E01 on hydrogeologic section *C-C'*, 51N 04W 12ABA1 on hydrogeologic section *I-I'*, and 52N 04W 24DDB1 on hydrogeologic section *K-K'*). The total thickness of the Basalt and fine-grained interbeds unit is quite variable as are the individual layers of basalt and fine-grained material within the unit. The total thickness of the unit is shown on only two hydrogeologic cross sections (*E-E'* and *K-K'*, pl. 2) where wells 26N/44E-34B01 and 52N 03W-19DD1 penetrated 450 and 495 ft of this unit, respectively.

Bedrock Unit

Of the 587 project wells, 67 are completed in the Bedrock unit. Many of these wells are located along the perimeter of the SVRP aquifer near Nine Mile Dam, Hillyard Trough, and Spokane Valley (pl. 1). Others are located in the three-channel area of the Rathdrum Prairie and near Sage and Lewellen Creeks where the overlying aquifer is thin or has a thin saturated zone (pl. 1; hydrogeologic sections *K-K'*, *L-L'*, *N-N'*, and *O-O'*, pl. 2). The Bedrock unit includes the Precambrian to Tertiary metamorphic and intrusive igneous rocks that laterally bound and underlie the aquifer. The crystalline structure of these rocks generally inhibits their ability to store and transmit water. However, weathered or fractured zones within the rocks can transmit useable amounts of ground water to wells completed in the unit.

Yield

A summary of well yields, as reported on drillers' logs used during this investigation, is shown on the left side of the following table by hydrogeologic unit. Well-yield testing is done to determine if an adequate and sustainable yield is available from a well. Driller-reported well yields are not only dependent on the productivity of the unit to which the well is open, but also are a function of the design and purpose of the well. During well-yield testing, a well intended for municipal water supply likely would be pumped at a higher rate and have both a larger diameter casing and a longer open interval than one intended for single-family use, thereby having an apparent higher yield than that for the single-family well. Despite the fact that yields often are estimates, they are useful in comparing the general productivity of hydrogeologic units; they also illustrate the large amount of variability within a single unit. Based on the data set used for this study, the median yield for the SVRP aquifer, the Basalt and fine-grained interbeds unit, and the Bedrock unit are 100, 10, and 8 gal/min, respectively.

A summary of specific capacity information, derived from driller-reported yield divided by the drawdown measured in the well during pumping, is shown on the right side of the table below, by hydrogeologic unit. Specific capacity is often used to describe the productivity of a hydrogeologic unit. Based on the data set used for this study, the median specific capacity for the SVRP aquifer, the Basalt and fine-grained interbeds unit, and the Bedrock unit are 200, 8.3, and 0.66 gallons per minute per foot, respectively.

Hydrogeologic unit	Yield (gallons per minute)				Specific capacity (gallons per minute per foot)			
	Minimum	Median	Maximum	Number of values	Minimum	Median	Maximum	Number of values
SVRP aquifer	0.08	100	8,000	322	0.22	200	5,500	142
Basalt and fine-grained interbeds	0	10	2,280	19	0.43	8.3	510	4
Bedrock	0	8	1,905	60	0.01	0.66	3,810	16

Ground-Water Budget

A number of water budgets for all or part of the SVRP aquifer have been developed in previous studies: these are summarized in Kahle and others (2005). A ground-water budget using primarily new information compiled as part of this study is presented in table 2 and figure 11. Most components of this ground-water budget represent average conditions, 1990–2005, corresponding to the simulation period of the ground-water flow model of Hsieh and others (2007). Exceptions are estimates of ground-water and surface-water interaction, which are based on actual measurements made during one week; inflow from Coeur d’Alene Lake and Lake Pend Oreille and outflow to Long Lake are based on previously published estimates.

The estimated mean annual inflow and outflow to and from the aquifer is 1,471 and 1,468 ft^3/s, respectively. The 3 ft^3/s imbalance between estimated inflows and outflows of this ground-water budget (table 2, fig. 11) represents less than 1 percent of the total, and may be due to measurement error, uncertainty in the estimation of water-budget components, or the release of ground water from storage in the aquifer.

This brief summary of individual water-budget components draws upon a number of studies that are referenced in the text. The reader is encouraged to examine these sources directly for a complete understanding of the strengths and limitations of the respective components.

Inflows to the Aquifer

Recharge or inflow to the SVRP aquifer occurs from six main sources: the Spokane River, lakes, precipitation over the aquifer, tributaries, infiltration from landscape irrigation and septic systems, and subsurface inflow. Total estimated mean annual inflow to the aquifer is 1,471 ft^3/s.

Spokane River

Discharge measurements to determine seepage gains and losses on the Spokane River and some tributaries were made three times during this study: September 13–16, 2004; August 27–September 1, 2005; and April 24–28, 2006. Because a continuous streamflow record is lacking for most of these sites that would allow the calculation of a long-term annual mean, the current report uses the values measured during August 27–September 1, 2005 because they are the most comprehensive measurements and were made under favorable weather and flow conditions. During this period, discharge was measured at 31 sites in and near the study area: 11 on the Spokane River, 9 on the Little Spokane River, and 11 on various tributaries. Measured streamflow at these sites was compared to upstream and downstream measurements to define distinct gaining or losing reaches within the study area. Consequently, five contiguous gaining or losing reaches were defined: four on the Spokane River and one on the Little Spokane River below the “At Dartford” gaging station. Recharge to the aquifer from streamflow loss in the two losing reaches is shown in table 2. The cumulative recharge from both reaches is 718 ft^3/s (table 2, fig. 11) representing 49 percent of the total mean annual inflow of 1,471 ft^3/s, making this the largest source of recharge to the aquifer.

Lake Recharge

Nine lakes around the margin of the SVRP aquifer contribute recharge to ground water (pl. 1). These lakes are either perched or hydraulically connected to the aquifer. The magnitude of this recharge is important yet difficult to quantify—because inflow to the aquifer from lakes cannot be measured directly, several approaches have been used to estimate the volume of this inflow. The first approach requires the development of a water balance for the lake itself in which the residual is assumed to be recharge to the aquifer. (The primary component of such an analysis typically is surface-water inflow to the lake from its contributing basin, thus it is often referred to as the basin-yield method.) This approach works best for smaller lakes in which surface-water inflow and evaporation can be determined with more certainty as opposed to large lakes in which it is difficult to measure or estimate the increased number of inflows and outflows. For the SVRP aquifer study L. Murray (University of Idaho, written commun., March 3, 2006) used this approach for all lakes other than Coeur d’Alene and Pend Oreille. Another method of estimating inflow from lakes into the aquifer is to apply Darcy’s law; however this requires water-table gradient, cross-sectional area of the lake/aquifer interface, and hydraulic conductivity. The last two variables are poorly constrained for the aquifer in the area of Coeur d’Alene Lake and Lake Pend Oreille resulting in significant uncertainty in such an analysis. Finally, flow from the lakes into the aquifer can be estimated as a residual of a ground-water budget in which more certain estimates of other water-budget components are used to constrain and estimate less-certain components. All or some of these methods may be combined: a ground-water flow model can combine Darcian analysis with ground-water budget residual analysis.

L. Murray (University of Idaho, written commun., March 3, 2006) investigated a variety of techniques including water-level analysis and gradients, basin yield using StreamStats (U.S. Geological Survey, 2006), and water quality. For all but the two largest lakes, Coeur d’Alene and Pend Oreille, these basin-yield values are used in this report and are reported in table 2 and figure 11.

Table 2. Estimated ground-water budget for the Spokane Valley-Rathdrum Prairie aquifer for average conditions 1990–2005, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.

[**Abbreviations:** ft^3/s, cubic foot per second]

Component	Rate (ft^3/s)	Subcomponent or description	Rate (ft^3/s)	Source
Inflow to aquifer				
Spokane River	718	Spokane River near Coeur d'Alene Lake to Flora Road	606	Aug. 27–Sept. 1, 2005 streamflow measurements
		Spokane River below Greene Street at Spokane gage	112	
Lakes	287	Hayden	62	L. Murray (University of Idaho, written commun., March 3, 2006)
		Pend Oreille	50	Frink (1964), Pluhowski and Thomas (1968), McQueen and Nace (1970), Drost and Seitz (1978), Painter (1991)
		Spirit	48	L. Murray (University of Idaho, written commun., March 3, 2006)
		Coeur d'Alene	37	Sagstad (1977)
		Twin	35	L. Murray (University of Idaho, written commun., March 3, 2006)
		Newman	20	
		Hauser	17	
		Fernan	13	
		Liberty	5	
Areal recharge	233	Total	–	B.A. Contor (Idaho State University, written commun., April 20, 2006 and July 19, 2006); P.A. Hsieh (U.S. Geological Survey, written commun., December 6, 2006); Bartolino (2007)
Tributary recharge	112	Total	–	Hortness (this volume)
Infiltration of ground water applied at land surface	77	Landscape irrigation	54	B.A. Contor (Idaho State University, written commun., January 15, 2007)
		Septic systems	23	
Spirit Valley	44	Total	–	L. Murray (University of Idaho, written commun., March 3, 2006)
Total inflow:	1,471			
Outflow from aquifer				
Spokane River	861	Spokane River at Flora Road to below Greene Street	593	Aug. 27–Sept. 1, 2005 streamflow measurements
		Spokane River at Spokane gage to below Nine Mile Dam	268	
Pumpage	318	Public supply	205	M.A. Maupin (U.S.Geological Survey, written commun., January 4, 2006), B.A. Contor (Idaho State University, written commun., January 15, 2007)
		Self-supplied Industrial	34	
		Irrigation (outside purveyor service areas)	51	
		Domestic supply wells (outside purveyor service areas)	28	
Little Spokane River	232	Little Spokane R. below "At Dartford" gaging station		Aug. 27–Sept. 1, 2005 streamflow measurements
Subsurface outflow	55	Flow to Long Lake		Drost and Seitz (1978)
Infiltration of ground water into sewers	2.3	Total		L. Brewer (City of Spokane, written commun., February 8, 2006)
Total outflow:	1,468			
Totals				
Total inflow:	1,471			
Total outflow:	1,468			
Difference:	-2.7	0.2 percent		

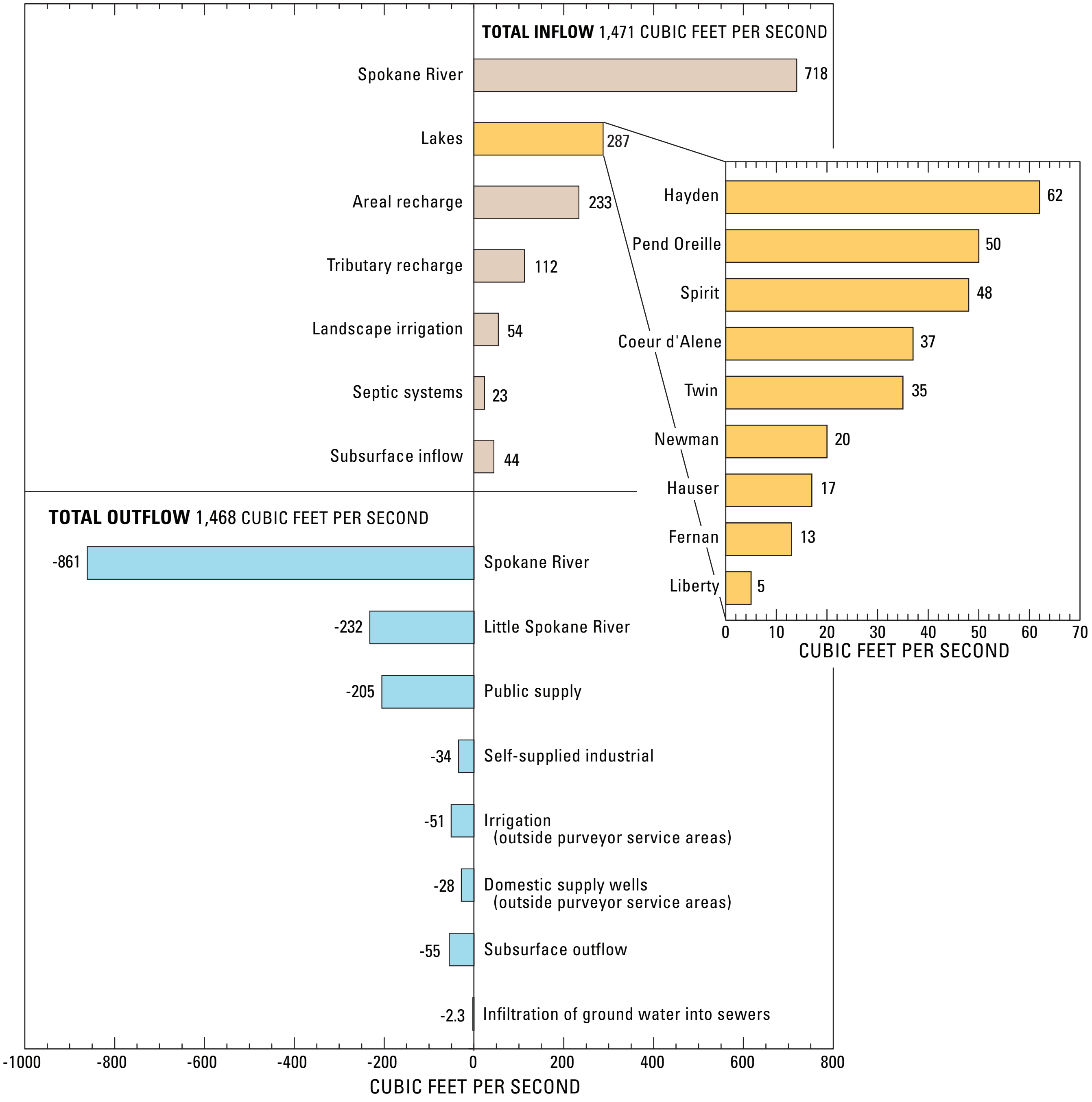


Figure 11. Estimated ground-water budget components for the Spokane Valley-Rathdrum Prairie aquifer for average conditions, 1990–2005, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho. An inset chart shows values for individual lakes.

Flow from Coeur d'Alene Lake and Lake Pend Oreille remains very uncertain. Previously published estimates of annual ground-water inflow to the SVRP aquifer from Coeur d'Alene Lake range from 35 to 300 ft^3/s; for Lake Pend Oreille they range from 20 ft^3/s to greater than 1,000 ft^3/s, though most estimates range from 20 to 61 ft^3/s (Kahle and others, 2005). As described in the section,"Ground-Water Budget Errors and Uncertainty", cumulatively the two lakes probably contribute less than 200 ft^3/s of inflow to the aquifer annually, which is in the lower range of previously published estimates. For this report, mean annual inflow from Coeur d'Alene Lake is taken as 37 ft^3/s: this is the value from Sagstad's (1977) Darcian analysis of a cross section across the approximate area which Coeur d'Alene Lake (and not the Spokane River) is in contact with the aquifer, which is similar to the 35 ft^3/s used in Buchanan's (2000) ground-water flow model. For Lake Pend Oreille, an estimate of 50 ft^3/s is used—this value was estimated in several previous studies using different methods (Kahle and others, 2005). Thus, the total contribution from lakes into the SVRP aquifer is shown in table 2 and figure 11 as 287 ft^3/s, of which Coeur d'Alene Lake and Lake Pend Oreille comprise 87 ft^3/s. This 287 ft^3/s represents 20 percent of the total mean annual inflow of 1,471 ft^3/s.

It seems counterintuitive that two of the largest lakes in the western United States contribute so little water to the SVRP aquifer (in addition, Lake Pend Oreille is one of the deepest lakes in the world). Frink (1964) noted that the sediments forming the natural dam of Lake Pend Oreille are glacial till and moraine and are thus of lower permeability—he confirmed this by citing lower specific capacities of wells on Farragut Naval Base as compared to the rest of the valley. Sagstad (1977) analyzed well logs and specific capacity data for four wells in the Coeur d'Alene area and concluded that the aquifer in this area generally was less permeable than in the Post Falls area. Therefore, there seems sufficient basis to support the premise that these two lakes contribute relatively little ground-water inflow to the SVRP aquifer.

Areal Recharge

Areal recharge of the SVRP aquifer derives from two component sources—permeable and impermeable surfaces. The former is direct infiltration of precipitation through the soil zone, while the latter is precipitation runoff from impervious cover in urban areas that recharges to the aquifer. For the purposes of this ground-water budget, the two are combined into a total term for areal recharge.

Bartolino (2007) used data from six active weather stations in and near the study area to calculate direct areal recharge from precipitation using four different techniques. Bartolino (2007) concluded that the dual-coefficient FAO Penman-Monteith dual-crop evapotranspiration and deep percolation calculations (Allen and others, 1998) with 1990–2005 daily values best represented changes in soil moisture and thus temporal changes in recharge. Using GIS techniques, a triangular network was constructed of the six weather stations using summed daily recharge values (P.A. Hsieh, U.S. Geological Survey, written commun., December 6, 2006). Simple linear interpolation was used to establish recharge values within the triangle thus establishing recharge for the entire SVRP aquifer.

Using aerial photography and GIS coverages of precipitation and dry well locations, B.A. Contor (Idaho State University, written commun., April 20, 2006, and July 19, 2006) mapped changes in impervious cover between 1990 and 2005 and estimated recharge from impermeable surfaces to the SVRP aquifer. Precipitation on impervious cover that drained directly to the Spokane River or other water body was not included. The estimated mean annual areal recharge (inflow) for 1990–2005 to the aquifer from permeable and impermeable surfaces is 233 ft^3/s representing 16 percent of the total inflow of 1,471 ft^3/s.

Tributary Recharge

Runoff from highlands adjacent to the SVRP aquifer contributes recharge to the aquifer. Because the sediments of the valley floor are highly permeable, few distinct surface-drainage channels have developed other than the Spokane and Little Spokane Rivers, and it may be assumed that all streamflow from highlands and tributary basins infiltrates to the aquifer once drainage debouches onto the valley floor. As described in appendix A (at back of report), a GIS-based technique was used to estimate basin yield, which was then assumed to equal recharge to the aquifer.

Hortness (appendix A) calculated basin yield for 72 basins. Estimated total mean annual recharge to the aquifer from these 72 basins is 112 ft^3/s or 8 percent of the total inflow of 1,471 ft^3/s. Details of the calculation techniques, a table of the estimated recharge from each basin, and a map of the basins are in appendix A.

Irrigation and Septic System Recharge

Infiltration of water applied at the land surface for irrigation and deep percolation of water from septic systems contribute about 54 and 23 ft^3/s of recharge to the SVRP aquifer, respectively. These values were suggested by B.A. Contor (Idaho State University, written commun., March 28, 2006) who estimated that 60 percent of landscape-irrigation water and 5 percent of in-home domestic water use was consumptive, based on values found in the literature. The cumulative mean annual recharge from both sources is 77 ft^3/s (table 2, fig. 11) representing 5 percent of the total mean annual inflow of 1,471 ft^3/s.

Subsurface Inflow

Subsurface inflow into the SVRP aquifer through the Hoodoo and Blanchard Valleys is probably a minor component of recharge, however, because such underflow cannot be measured directly there is a high degree of uncertainty associated with any estimate. Previous work by Walker (1964) and Parliman and others (1980) note the presence of ground-water divides in both valleys that would limit the amount of subsurface inflow. Previous estimates for inflow from the two valleys are discussed in Kahle and others (2005) but because these estimates were often aggregates of recharge from various northern valleys of the Rathdrum Prairie, it is difficult to establish previous estimates for a specific valley. For the Hoodoo Valley, previous estimates range from 0 ft^3/s (Buchanan, 2000) to 90 ft^3/s (Drost and Seitz, 1978); for the Spirit Valley, previous estimates range from 3 ft^3/s (Buchanan, 2000) to 89 ft^3/s (Thomas, 1963). Using methodology discussed previously in section, “Lake Recharge,” L. Murray (University of Idaho, written commun., March 3, 2006) estimated that Blanchard Lake, near the south end of Spirit Valley, recharged 44 ft^3/s to ground water.

Ground-water levels were measured in only a few wells in this general area in September 2004 (Campbell, 2005). Four wells were measured in Hoodoo Valley: 260 and 261 in the northern end and 262 and 263 to the southwest (these well numbers are those used in Campbell [2005]). Whereas measured water-table altitudes in wells 260, 261, and 263 differ by less than 1.5 ft, the measured water-table altitude in well 262 is approximately 10 ft higher than in these three wells. Further uncertainty is introduced because the land-surface altitude accuracy of well 263 is ±5 ft, as opposed to ±0.1 ft for the other wells, and well 260 was pumped prior to the water-level measurement. However, if these water-table altitudes are accepted, and if well 262 is excluded because it is located on the margin of the Hoodoo Valley and thus probably affected by conditions in the Spirit Valley, the water-table gradient in the Hoodoo Valley is nearly flat. This, in conjunction with the ground-water divide noted in previous work, suggests that ground-water inflow to the SVRP aquifer from Hoodoo Valley is insignificant. Three wells were measured in September 2004 in the Spirit Valley: well 267 on the western end and wells 262 and 264 to the east. The altitude of the water-table declines about 130 ft in the nearly 3 mi between wells 267 and 264. Such a steep gradient could be the result of low-permeability sediments within the aquifer or may indicate a decreased saturated thickness through this area. The maps of wells with fine-grained layers within the Rathdrum Prairie (fig. 8) and of the approximate thickness of the aquifer (fig. 10) in this report could loosely support either interpretation.

Based on ground-water levels in the Hoodoo Valley, the ground-water budget in this report assumes that no subsurface inflow enters the SVRP aquifer through the Hoodoo Valley. L. Murray’s (University of Idaho, written commun., March 3, 2006) estimated value of 44 ft^3/s for mean annual recharge from Blanchard Lake is used as the value for subsurface inflow entering the SVRP aquifer through the Spirit Valley. Because Parliman and others’ (1980) small-scale map shows a ground-water divide near Blanchard Lake, this value could represent a maximum and the actual value could be considerably less. This estimate of 44 ft^3/s represents 3 percent of the total mean annual inflow to the aquifer.

Outflows from the Aquifer

Discharge or outflow from the SVRP aquifer occurs from five main sources: the Spokane River, the Little Spokane River, pumpage, subsurface discharge to Long Lake, and infiltration of ground water to sewers. Total estimated mean annual outflow from the aquifer is 1,468 ft^3/s.

Spokane and Little Spokane Rivers

Discharge measurements to determine seepage gains and losses on the Spokane River and some tributaries are described in section, “Spokane River.” Discharge from the aquifer was measured as streamflow gain in two reaches of the Spokane River and is shown in table 2. The measured flow of 1.5 ft^3/s from Hangman Creek and 56 ft^3/s of discharge from the Spokane Waste Water Treatment Plant were subtracted from the measured streamflow gain in the reach, Spokane River at Spokane to below Nine Mile Dam, to compute actual streamflow gain through this reach of the Spokane River. The cumulative discharge measured as streamflow gain from both reaches is 861 ft^3/s (table 2, fig. 11) representing 59 percent of the total mean annual outflow of 1,468 ft^3/s—the largest source of discharge from the SVRP aquifer.

Estimated outflow from the aquifer into the Little Spokane River includes measured flow in tributaries downstream of this gaging station because they were primarily ground-water fed during the measurement period (table 2). The measured streamflow gain or aquifer discharge is 232 ft^3/s (table 2, fig. 11), which represents 16 percent of the total mean annual outflow.

Pumpage

In developed areas, water-use and pumpage data are necessary in order to assemble a water budget or ground-water flow model. M.A. Maupin (U.S. Geological Survey, written commun., January 4, 2006) and B.A. Contor (Idaho State University, written commun., September 11, 2006) compiled data from public-supply, domestic, irrigation, and industrial wells and wastewater-treatment plants to estimate the amount of water pumped from the SVRP aquifer. Table 2 shows mean ground-water pumpage for 1990–2005 in four categories: public-supply, self-supplied industrial, irrigation (outside purveyor-service areas), and domestic (outside purveyor-service areas). The estimated total discharge from the aquifer for these five categories is 318 ft^3/s or 22 percent of the total mean annual outflow of 1,468 ft^3/s. Taken individually, percentages of the total outflow for each pumpage category are: 14 percent (public-supply), 2 percent (self-supplied industrial), 3 percent (irrigation), and 2 percent (domestic).

Subsurface Outflow

Previously published estimates of underflow from the aquifer range from 0 (CH2M Hill, 1998; Golder Associates, Inc., 2004) to 105 ft^3/s (Bolke and Vaccaro, 1981), and were computed as residuals to balance ground-water budgets or by calibration of ground-water flow models. Because such underflow cannot be measured directly, there is large uncertainty associated with this water-budget component. The hydrogeologic framework described in this report and anecdotal evidence suggest some outflow to Long Lake, accordingly, the lowest non-zero estimate is used: 55 ft^3/s (Drost and Seitz, 1978). This estimated value falls near the middle of the range of previously published estimates and represents 4 percent of the total mean annual outflow.

Other Outflow

The City of Spokane reports that approximately 2.3 ft^3/s of ground water infiltrates into sewer lines, is treated at the wastewater-treatment plant and discharged to the Spokane River (L. Brewer, City of Spokane, written commun.. February 8, 2006). This seepage is counted in the ground-water budget as a withdrawal and comprises less than 1 percent of the total mean annual outflow of 1,468 ft^3/s.

Changes in Ground-Water Storage

Under natural conditions, over the long term, recharge to an aquifer is approximately balanced by discharge from the aquifer—inflows approximate outflows and there is negligible change in the amount of ground water stored in the system. However, for developed aquifers, short-term climatic variations and subsequent land-use changes, and (or) changes in ground-water use, may tip this balance and water may be taken into or released from storage in the aquifer. The source of water for withdrawals (or pumpage) is either increased recharge, decreased discharge, removal of water from storage, or some combination of the three.

In the absence of artificial recharge, recharge can be increased over natural conditions by such mechanisms as increased infiltration of wastewater, infiltration of runoff from impervious surfaces such as roads or home sites (driveways, roofs, and so on), or infiltration from lakes or streams. Natural discharge is reduced by pumping or otherwise intercepting water that formerly discharged at springs and gaining stream reaches. A decrease in ground-water storage results in water-level declines. Thus, water levels decline if the rate of ground-water recharge is less than ground-water discharge from the aquifer.

If no water was used consumptively, all well pumpage eventually would be returned to the aquifer through direct infiltration resulting in no net water-level change after some sufficient period of time. However, because some pumpage is lost to consumptive use and a large percentage is treated and discharged to the Spokane River, any deficit must come from increased recharge, decreased discharge, or removal of water from storage. In the SVRP aquifer, no significant water-level declines have been observed in the study area; therefore major changes in storage probably have not occurred.

Ground-Water Budget Errors and Uncertainty

As with most ground-water budgets, there is some degree of uncertainty in the budget presented in this report because many of the components cannot be measured directly. Uncertainty may be associated with the estimation of such budget components because of incomplete data and (or) simplifying assumptions. However, even with components that can be measured directly, such as streamflow losses and gains, some uncertainty is introduced by measurement standard error and temporal variation. As with the measurement of any physical property, there is intrinsic uncertainty associated with the measurement of streamflow and computed discharge. The standard error of a discharge measurement can range from 2 percent under ideal conditions to 20 percent under poor conditions; most measurements fall in the range of 3 to 6 percent (Sauer and Myer, 1992). In addition, values shown in table 2 for streamflow gains and losses were measured over a week during a single season and single year; thus they do not represent a long-term mean.

Many of the components in previous budgets with large uncertainty have been addressed in the current SVRP study using technology and techniques unavailable to previous workers who also were limited by the generally smaller scale of their studies. Regardless, some components of the ground-water budget still cannot be quantified with a high degree of confidence: notably flow into the aquifer from Coeur d’Alene Lake and Lake Pend Oreille, subsurface inflow from the Spirit Valley, and subsurface outflow to Long Lake. Despite this, refinements to other aspects of the ground-water budget described here considerably narrow the range of possible values for these components.

A rough estimate can be made of the probable range of values for the most uncertain ground-water-budget components by making several simplifying assumptions. First, it is assumed that all water-budget component estimates are correct except Coeur d’Alene Lake, Lake Pend Oreille, subsurface inflow from the Spirit Valley, and subsurface outflow to Long Lake. Second, that the estimate of subsurface outflow to Long Lake is reasonably constrained by previously published values: 0 to 102 ft^3/s. Third, that the total inflows and outflows will continue to balance within 3 ft^3/s as shown in table 2. Using these assumptions, the only uncertain outflow component is subsurface outflow to Long Lake, thus total ground-water outflow is limited to a range of 1,413 to 1,515 ft^3/s. Thus to maintain the balance of the water budget, total ground-water inflow must range between 1,416 to 1,518 ft^3/s. Consequently the sum of inflows from Coeur d’Alene Lake, Lake Pend Oreille, and the Spirit Valley must vary between 76 and 178 ft^3/s; the ground-water budget in this report uses 131 ft^3/s representing 9 percent of the total mean annual inflows (table 2, fig. 11). Although this analysis cannot separate individual values for these three inflow components, it does indicate that cumulatively they probably represent between 5 and 12 percent of the total mean annual inflows.

The 3 ft^3/s imbalance between estimated inflows and outflows of this ground-water budget (table 2, fig. 11) represents less than 1 percent of the total, and may be due to measurement error, uncertainty in the estimation of water-budget components, or the release of ground water from storage in the aquifer.

Data Needs

The following data needs were identified during this investigation. The identified data could improve definitions of the hydrogeologic framework and ground-water budget of the SVRP aquifer.

Deep drilling at several locations along the axis of the SVRP aquifer from the south end of Lake Pend Oreille through the Rathdrum Prairie, Spokane Valley, Hillyard Trough, and Little Spokane River Valley would provide two important pieces of information. First, the presence or absence of fine-grained layers, and their thickness, in the deepest parts of the aquifer could be determined. Second, the depth to the bottom of the aquifer, represented by either the Basalt and fine-grained interbeds unit or the Bedrock unit, would allow for meaningful refinements to the approximate base of aquifer and aquifer thickness.

A more detailed analysis of the geologic and hydrologic setting near the southern ends of Spirit and Hoodoo Valleys would allow for a more complete understanding of aquifer characteristics and extent in those areas. The analysis likely would involve a field inventory of recently drilled wells and the drilling of new monitoring wells where coverage is poor. Analysis of the lithology encountered in those wells and the measurement of ground-water levels would allow for characterization of the aquifer as well as help determine the location of the ground-water divide between the two valleys and the Rathdrum Prairie.

Measurements or better estimates of seepage into the aquifer from Coeur d’Alene Lake and Lake Pend Oreille and subsurface outflow from the aquifer to Long Lake would strengthen the recharge and discharge estimates currently available for the aquifer. Among the data that would be useful in refining these estimates would be better definition of the cross-sectional area connecting the lakes to the aquifer and better characterization of the hydraulic properties of the sediments across this interface. A well-designed hydrochemical study incorporating analyses of environmental tracers, isotopic ratios, and ground-water age dating could potentially provide an independent means of quantifying recharge and discharge, and defining ground-water flow paths. An approach similar to that applied in the Middle Rio Grande Basin of New Mexico (Plummer and others, 2004) could improve understanding of the SVRP aquifer system.

Summary

The Spokane Valley-Rathdrum Prairie (SVRP) aquifer is the sole source of drinking water for more than 500,000 residents in Spokane County, Washington, and Bonner and Kootenai Counties, Idaho. Recent and projected urban, suburban, and industrial/commercial growth has raised concerns about potential impacts on water availability and water quality in the SVRP aquifer and the Spokane and Little Spokane Rivers. This report presents the hydrogeologic framework and water-budget components of the study area compiled and interpreted by the U.S. Geological Survey, in cooperation with the Idaho Department of Water Resources and Washington State Department of Ecology for the SVRP aquifer. Descriptions of the geologic history, hydrogeologic framework, water-budget components, and further data needs are provided in this document.

The SVRP aquifer consists primarily of thick layers of coarse-grained sediments—gravels, cobbles, and boulders—deposited during a series of outburst floods resulting from repeated collapse of the ice dam that impounded ancient Glacial Lake Missoula. Sources of recharge to the aquifer include infiltration from precipitation, return flow from water applied at land surface, seepage from the Spokane and Little Spokane Rivers and adjacent lakes, and surface-water and ground-water inflow from tributary basins. The aquifer primarily discharges into the Spokane and Little Spokane Rivers and through pumping wells.

A simplified geologic model of the Rathdrum Prairie and Spokane Valley includes filling of the ancient Rathdrum-Spokane River valley with generally unknown amounts of Miocene basalts and interbedded sediments followed by a period of downcutting, repeated cycles of glacial and interglacial sedimentation, and finally the repeated and catastrophic cycles of outburst flooding from Glacial Lake Missoula. In most places, the SVRP aquifer is bounded by bedrock of pre-Tertiary granite or metasedimentary rocks, or Miocene basalt and associated sedimentary deposits. The base or bottom boundary of the aquifer is uncertain except along the margins or in shallower parts of the aquifer where wells have penetrated the entire thickness of the aquifer and reached bedrock or silt and clay deposits.

Fine-grained layers are scattered throughout the SVRP aquifer at considerably different altitudes and with considerably different thicknesses. In the Hillyard Trough, a massive fine-grained layer with an altitude of about 1,670 feet and an average thickness of 215 feet separates the aquifer into upper and lower units. The southern extent of the layer is uncertain, but is believed to be within about 2 miles of downtown Spokane. The fine-grained layer that occurs in the Hillyard Trough also is present in the Little Spokane River Arm of the aquifer with a more variable altitude that ranges from about 1,500 to 1,700 feet and an average thickness of 130 feet. Most of the Spokane Valley part of the aquifer is void of fine-grained layers except near the margins of the valley and near the mouths of lakes. In the Rathdrum Prairie, multiple fine-grained layers are scattered throughout the aquifer with altitudes ranging from 1,653 to 2,392 feet with thicknesses ranging from 1 to more than 135 feet.

The altitude of the base of the aquifer ranges from less than 1,800 feet near Lake Pend Oreille to less than 1,200 feet near the aquifer's outlet near Long Lake. The thickness of the aquifer is more than 800 feet in the northwestern part of the northern Rathdrum Prairie, through the West Channel area, and through the west-central part of the Rathdrum Prairie. In Washington, the areas of greatest thickness, more than 600 feet, are mapped in the central parts of the Spokane Valley, the City of Spokane, and the Hillyard Trough.

Based on this study's data set, the median well yield for the SVRP aquifer, the Basalt and fine-grained interbeds unit, and the Bedrock unit are 100, 10, and 8 gallons per minute, respectively. The median specific capacity for wells completed in the SVRP aquifer, the Basalt and fine-grained interbeds unit, and the Bedrock unit are 200, 8.3, and 0.66 gallons per minute per foot, respectively.

Recharge or inflow to the SVRP aquifer occurs from six main sources: the Spokane River, lakes, precipitation over the aquifer, tributaries, infiltration from landscape irrigation and septic systems, and subsurface inflow. Total estimated mean annual inflow to the aquifer is 1,471 cubic feet per second. Discharge or outflow from the SVRP aquifer occurs from five main sources: the Spokane River, the Little Spokane River, pumpage, underflow to Long Lake, and infiltration of ground water to sewers. Total estimated mean annual outflow from the SVRP aquifer is 1,468 cubic feet per second.

Several data needs were identified during this investigation that would provide for a more refined characterization of the hydrogeologic framework and water-budget components for the SVRP aquifer study area. Deep drilling along the axis of the SVRP aquifer would identify the presence or absence of fine-grained layers, and their thickness in the deepest parts of the aquifer and determine the depth to the bottom of the aquifer where data are currently unavailable. A more detailed analysis of the geologic and hydrologic setting near the southern ends of Spirit and Hoodoo Valleys would help determine the location of the ground-water divide between the two valleys and the Rathdrum Prairie. Better estimates of seepage into the aquifer from Coeur d'Alene Lake and Lake Pend Oreille and underflow from the aquifer to Long Lake would strengthen the recharge and discharge estimates currently available for the aquifer. Well-designed hydrochemical studies using environmental tracers and ground-water age dating could reduce uncertainty in some ground-water budget estimates and improve definition of ground-water flow paths.

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Table 3. Physical data for wells used in the characterization of the hydrogeologic system of the Spokane Valley-Rathdrum Prairie aquifer study area, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.

[**USGS site No.** is based on the initial latitude and longitude determined for the site. The site No. does not change if more accurate latitude/longitude values are determined after the site is first created. **Data reliability:** C, field checked; U, not field checked but data considered reliable; M, minimal data available for site. **Hydrogeologic unit:** BASALT, Columbia River basalt and(or) Latah Formation interbeds; BR, bedrock; NA, not applicable; MULT, multiple units; SVRPA, Spokane Valley-Rathdrum Prairie Aquifer; and UNK; unknown. **Abbreviations:** USGS, U.S. Geological Survey; NAVD 88, North American Vertical Datum of 1988; NAD 83, North American Datum of 1983; ft, foot; gal/min, gallon per minute; (gal/min)/ft, gallon per minute per foot; –, no data]

Well No.	USGS site No.	Latitude (NAD 83)	Longitude (NAD 83)	Data reliability	Land-surface altitude (NAVD 88)	Hole depth (ft)	Yield (gal/min)	Specific capacity (gal/min)/ft)	Hydro-geologic unit
25N/42E-03K01	474126117290701	474126	1172907	C	1,764	220	100	–	SVRPA
25N/42E-10G03	474052117290101	474052	1172905	U	1,864	187	–	–	SVRPA
25N/42E-13B02	474018117263501	474018	1172635	M	1,882	500	–	–	NA
25N/42E-14C01	474009117275501	474009	1172759	C	1,864	200	–	–	SVRPA
25N/42E-14F01	473954117280501	473954	1172809	C	1,869	253	100	–	BASALT
25N/42E-14J01	473952117272501	473952	1172729	C	1,714	160	2,280	510	BASALT
25N/42E-14P03	473928117275001	473928	1172757	C	1,822	136	–	–	BASALT
25N/42E-23H01	473907117272001	473907	1172724	U	1,878	340	15	–	BASALT
25N/42E-24A01	473917117255301	473917	1172557	C	1,899	350	300	10	SVRPA
25N/43E-02Q03	474116117195601	474116	1172000	U	2,056	300	.25	–	BR
25N/43E-03C01	474155117213201	474155	1172129	C	2,036	231	250	100	SVRPA
25N/43E-04B02	474200117223901	474159	1172242	M	2,051	227	5,800	830	SVRPA
25N/43E-04G01	474143117223001	474142	1172235	U	2,044	380	–	–	NA
25N/43E-04G02	474143117222801	474143	1172228	C	2,043	203	–	–	SVRPA
25N/43E-04G03	474139117224301	474139	1172243	M	2,045	430	–	–	NA
25N/43E-04J01	474124117220401	474124	1172208	C	2,023	168	200	610	SVRPA
25N/43E-07M01	474045117255201	474045	1172552	C	1,900	258	–	–	SVRPA
25N/43E-09J01	474043117222401	474043	1172228	C	1,914	58	–	–	BASALT
25N/43E-09M02	474038117230901	474035	1172308	U	1,894	460	–	–	NA
25N/43E-11F01	474050117201501	474050	1172019	U	1,934	320	–	–	NA
25N/43E-12J06	474037117181501	474037	1171819	U	1,954	365	–	–	NA
25N/43E-12L04	474037117113401	474037	1171906	U	1,944	547	–	–	NA
25N/43E-14E01	473955117204201	473959	1172043	C	1,949	211	50	–	SVRPA
25N/43E-15F02	473959117213301	473959	1172133	M	1,956	405	–	–	NA
25N/43E-17N01	473933117243301	473933	1172433	M	1,910	442	–	–	NA
25N/43E-18H01	474001117244701	474001	1172447	M	1,906	406	–	–	NA
25N/43E-23A03	473918117194601	473918	1171946	C	1,940	164	3,000	1,154	SVRPA
25N/43E-24B01	473919117183901	473920	1171851	C	1,984	169	–	–	SVRPA
25N/43E-24B02	473919117183801	473920	1171850	C	1,984	180	4,500	882	SVRPA
25N/43E-24D01	473924117191401	473924	1171914	M	1,956	540	–	–	NA
25N/43E-24G01	473859117183201	473859	1171835	C	2,026	150	285	190	SVRPA
25N/43E-24J04	473857117185201	473857	1171816	C	2,030	158	–	–	SVRPA
25N/43E-24M01	473857117191801	473857	1171922	C	2,033	166	–	–	SVRPA
25N/43E-27B02	473827117211701	473827	1172118	U	2,159	620	–	–	NA
25N/44E-01D01	474150117114701	474150	1171148	C	2,055	159	–	–	SVRPA
25N/44E-01M01	474134117112901	474133	1171132	C	2,024	160	500	120	SVRPA
25N/44E-01Q01	474110117104701	474110	1171051	C	2,022	150	3,750	119	SVRPA
25N/44E-02B02	474155117121401	474151	1171209	C	2,042	236	3,000	405	SVRPA
25N/44E-02K03	474120117122301	474120	1171223	C	2,024	190	–	–	SVRPA
25N/44E-02L01	474129117123301	474129	1171237	U	2,014	295	–	–	NA
25N/44E-04F01	474142117150801	474142	1171508	M	2,014	405	–	–	NA
25N/44E-05D01	474155117164801	474156	1171650	C	1,999	202	2,700	101	SVRPA
25N/44E-05K01	474135117161401	474135	1171617	C	1,962	234	1,600	640	SVRPA
25N/44E-06A02	474346117154101	474149	1171707	C	1,986	160	–	–	SVRPA
25N/44E-06F01	474141117174101	474144	1171739	C	1,966	180	2,250	45	SVRPA
25N/44E-07Q01	474024117172201	474022	1171732	C	1,964	220	4,000	1,081	SVRPA

Table 3. Physical data for wells used in the characterization of the hydrogeologic system of the Spokane Valley-Rathdrum Prairie aquifer study area, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.—Continued

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Well No.	USGS site No.	Latitude (NAD 83)	Longitude (NAD 83)	Data reliability	Land-surface altitude (NAVD 88)	Hole depth (ft)	Yield (gal/min)	Specific capacity (gal/min)/ft)	Hydro-geologic unit
25N/44E-08D02	474050117162401	474108	1171650	C	1,950	196	2,819	470	SVRPA
25N/44E-09C02	474117117142301	474109	1171504	C	2,002	150	40	–	SVRPA
25N/44E-09Q02	474024117145201	474024	1171452	M	2,004	390	–	–	NA
25N/44E-11A02	474103117130501	474103	1171155	C	2,013	150	3,511	662	SVRPA
25N/44E-11N02	474020117125902	474019	1171302	C	1,995	174	4,500	1,216	SVRPA
25N/44E-14G01	473954117120801	473954	1171212	C	2,053	152	150	–	SVRPA
25N/44E-14J01	473945117115301	473947	1171156	U	2,043	300	–	–	SVRPA
25N/44E-15E03	473953117141601	473953	1171416	C	2,052	280	–	–	SVRPA
25N/44E-18N01	473930117180001	473930	1171804	C	1,984	110	–	–	SVRPA
25N/44E-20G01	473913117155701	473910	1171612	U	1,994	200	–	–	NA
25N/44E-20G02	473913117155601	473910	1171612	U	1,994	200	–	–	NA
25N/44E-20J04	473850117155001	473850	1171554	C	2,043	175	280	–	SVRPA
25N/44E-21L01	473852117150501	473852	1171511	C	2,046	177	–	–	SVRPA
25N/44E-21N02	473839117152701	473835	1171524	C	2,084	240	–	–	SVRPA
25N/44E-22R03	473839117131001	473833	1171307	C	2,085	257	–	–	SVRPA
25N/44E-23J03	473852117115201	473857	1171156	C	2,049	240	4,500	2,368	SVRPA
25N/44E-26L02	473800117123201	473800	1171236	U	2,074	250	10	–	SVRPA
25N/44E-27E01	473813117141701	473813	1171422	C	2,066	220	4,000	870	SVRPA
25N/44E-27L01	473800117135801	473757	1171402	C	2,017	180	4,000	952	SVRPA
25N/44E-28C01	473832117151401	473832	1171518	C	2,084	205	80	–	SVRPA
25N/44E-28J01	473803117143201	473803	1171432	M	2,019	405	–	–	NA
25N/44E-28M02	473801117152301	473801	1171523	U	2,004	160	1,150	575	SVRPA
25N/44E-28P01	473747117151801	473747	1171521	C	2,034	167	–	–	SVRPA
25N/44E-29G01	473817117160201	473817	1171606	U	1,999	325	2	–	BR
25N/44E-29H02	473820117155201	473819	1171559	C	2,020	157	3,477	515	SVRPA
25N/44E-33A02	473728117143801	473736	1171436	C	2,034	185	3,000	429	SVRPA
25N/44E-33C01	473739117150801	473739	1171512	C	2,034	158	530	210	SVRPA
25N/44E-33H01	473716117142401	473716	1171428	C	2,024	173	600	17	SVRPA
25N/44E-34F01	473721117135001	473721	1171354	U	2,034	360	5	–	BR
25N/44E-34L01	473708117135001	473708	1171354	U	2,034	260	17	–	MULT
25N/44E-35H01	473721117115301	473721	1171157	U	2,054	165	40	–	BR
25N/45E-01D01	474159117034801	474159	1170348	C	2,082	150	15	–	SVRPA
25N/45E-01H03	474146117030501	474146	1170308	C	2,068	185	150	–	SVRPA
25N/45E-01J01	474133117030601	474133	1170306	C	2,074	500	7	–	BR
25N/45E-01J04	474128117031501	474135	1170305	C	2,059	360	4	–	BR
25N/45E-02G04	474136117043703	474136	1170439	C	2,070	270	4,490	3,207	SVRPA
25N/45E-03F01	474145117060501	474142	1170606	C	2,056	220	4,500	616	SVRPA
25N/45E-03N01	474109117064101	474109	1170641	M	2,042	470	–	–	NA
25N/45E-04C03	474156117072801	474156	1170726	C	2,063	225	4,500	2,647	SVRPA
25N/45E-06D02	474156117101801	474159	1171032	C	2,079	177	–	–	SVRPA
25N/45E-07A01	474109117091601	474109	1170918	C	2,025	195	4,500	1,000	SVRPA
25N/45E-08R02	474203117075301	474020	1170759	U	2,053	165	50	–	SVRPA
25N/45E-11K03	474032117044401	474033	1170443	C	2,113	186	700	–	SVRPA
25N/45E-11M01	474031117050401	474030	1170508	C	2,111	210	–	–	SVRPA
25N/45E-14F01	474004117044101	474004	1170453	C	2,147	238	–	–	SVRPA
25N/45E-14L01	473944117045001	473948	1170457	C	2,143	250	–	–	SVRPA
25N/45E-14M02	473938117050001	473938	1170504	C	2,134	220	–	–	SVRPA
25N/45E-14N01	473924117050201	473924	1170506	C	2,124	186	820	205	SVRPA

Table 3. Physical data for wells used in the characterization of the hydrogeologic system of the Spokane Valley-Rathdrum Prairie aquifer study area, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.—Continued

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Well No.	USGS site No.	Latitude (NAD 83)	Longitude (NAD 83)	Data reliability	Land-surface altitude (NAVD 88)	Hole depth (ft)	Yield (gal/min)	Specific capacity (gal/min)/ft)	Hydro-geologic unit
25N/45E-14P01	473933117045401	473936	1170502	C	2,134	236	50	–	SVRPA
25N/45E-14P02	473930117045001	473937	1170500	C	2,129	243	40	–	SVRPA
25N/45E-15C02	474010117060601	474005	1170610	C	2,086	173	500	–	MULT
25N/45E-15R01	473925117053201	473925	1170540	C	2,077	155	2,000	666	SVRPA
25N/45E-17D01	474016117085801	474015	1170900	C	2,039	230	4,500	2,812	SVRPA
25N/45E-17P03	473925117083603	473928	1170840	C	2,048	235	4,500	2,143	SVRPA
25N/45E-17Q01	473928117083001	473928	1170830	C	2,048	287	125	63	SVRPA
25N/45E-18R02	473929117092602	473930	1170930	C	2,043	231	4,500	2,500	SVRPA
25N/45E-23D02	473922117050102	473923	1170509	C	2,125	191	–	–	SVRPA
25N/46E-06E02	474135117023001	474135	1170230	C	2,085	180	100	–	SVRPA
25N/46E-06M01	474128117024201	474128	1170242	C	2,084	280	50	–	MULT
25N/46E-07E01	474049117023501	474049	1170235	C	2,178	248	10	–	SVRPA
25N/46E-07M01	474028117023601	474037	1170230	C	2,269	500	10	–	BR
26N/42E-02F01	474652117280701	474652	1172811	U	1,864	457	150	–	SVRPA
26N/42E-02L02	474636117280601	474647	1172801	U	1,844	398	150	–	SVRPA
26N/42E-02N05	474631117281601	474631	1172820	U	1,736	255	–	–	SVRPA
26N/42E-02N07	474636117281601	474636	1172816	U	1,764	350	37	12	MULT
26N/42E-02R01	474629117271901	474629	1172723	U	1,744	244	60	–	SVRPA
26N/42E-03B01	474703117285001	474703	1172850	U	1,894	485	–	–	MULT
26N/42E-03H01	474654117283901	474654	1172843	U	1,864	460	150	–	SVRPA
26N/42E-03H02	474710117284101	474701	1172845	U	1,864	460	–	–	SVRPA
26N/42E-03L03	474636117292201	474636	1172922	U	1,709	240	35	–	SVRPA
26N/42E-03M02	474640117293801	474640	1172938	U	1,694	160	18	–	MULT
26N/42E-03N02	474630117293501	474630	1172939	U	1,729	258	30	–	SVRPA
26N/42E-04N03	474629117305101	474627	1173055	C	1,729	321	40	–	SVRPA
26N/42E-04Q02	474629117301101	474634	1173016	U	1,709	360	100	–	SVRPA
26N/42E-04R01	474628117300001	474628	1173004	U	1,765	260	75	–	SVRPA
26N/42E-05M02	474636117321701	474636	1173217	U	1,744	205	5	.62	BR
26N/42E-05N03	474623117320301	474634	1173205	C	1,742	237	15	–	SVRPA
26N/42E-05Q01	474628117313001	474628	1173134	U	1,744	322	40	–	SVRPA
26N/42E-05R01	474628117311101	474628	1173115	U	1,630	280	–	–	SVRPA
26N/42E-07A03	474619117323601	474619	1173240	C	1,614	187	11	–	MULT
26N/42E-08A02	474616117311101	474622	1173117	U	1,739	260	–	–	SVRPA
26N/42E-08B01	474618117313301	474618	1173137	U	1,729	288	900	–	SVRPA
26N/42E-08D01	474615117320901	474620	1173215	U	1,739	440	3	–	BR
26N/42E-08Q01	474550117313001	474532	1173122	U	1,644	305	5	–	BR
26N/42E-09C01	474619117303601	474619	1173036	C	1,734	241	12	–	SVRPA
26N/42E-09D01	474611117304201	474616	1173046	C	1,736	405	–	–	SVRPA
26N/42E-10D01	474617117293401	474617	1172938	U	1,729	270	100	–	SVRPA
26N/42E-11C01	474620117275601	474615	1172753	U	1,749	340	50	–	SVRPA
26N/42E-11C02	474614117280501	474614	1172805	U	1,754	290	25	–	SVRPA
26N/42E-12P01	474537117264001	474537	1172644	U	1,767	182	12	–	BASALT
26N/42E-13K04	474458117262001	474458	1172624	U	2,414	250	0	–	BASALT
26N/42E-14F04	474512117275601	474512	1172800	U	2,434	160	0	–	BASALT
26N/42E-14G02	474512117273701	474512	1172741	U	2,394	200	2.5	–	MULT
26N/42E-23E01	474421117281701	474421	1172821	U	2,369	460	.25	–	BASALT
26N/42E-24B03	474433117262001	474433	1172624	U	2,404	165	5	–	BASALT
26N/42E-25P01	474256117265001	474256	1172654	C	2,049	355	50	–	BASALT

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Well No.	USGS site No.	Latitude (NAD 83)	Longitude (NAD 83)	Data reliability	Land-surface altitude (NAVD 88)	Hole depth (ft)	Yield (gal/min)	Specific capacity (gal/min)/ft)	Hydro-geologic unit
26N/42E-25R02	474256117260501	474256	1172609	C	2,029	230	360	14	BASALT
26N/42E-25R03	474302117261401	474302	1172614	M	2,018	396	–	–	NA
26N/42E-26L01	474321117275701	474321	1172757	M	2,040	403	–	–	NA
26N/42E-27D04	474334117284501	474343	1172948	C	1,682	294	–	–	BASALT
26N/42E-27N02	474307117293701	474307	1172941	C	1,714	150	60	–	SVRPA
26N/42E-35M01	474223117281801	474223	1172822	U	1,904	360	–	–	NA
26N/43E-02N09	474627117203501	474627	1172039	U	1,884	420	30	–	SVRPA
26N/43E-03F01	474654117213301	474654	1172137	U	1,884	214	–	–	SVRPA
26N/43E-03L01	474641117213301	474641	1172137	U	1,759	160	–	–	SVRPA
26N/43E-03N01	474623117220001	474623	1172203	C	1,867	180	1,510	68	SVRPA
26N/43E-03P01	474628117213201	474628	1172128	C	1,895	203	550	–	SVRPA
26N/43E-05K02	474642117234601	474628	1172401	U	1,749	345	150	–	SVRPA
26N/43E-07D02	474617117254501	474617	1172549	U	1,574	140	–	–	SVRPA
26N/43E-07G01	474607117244701	474607	1172451	C	1,819	160	40	–	SVRPA
26N/43E-07G02	474610117245401	474608	1172501	C	1,819	296	3,500	177	SVRPA
26N/43E-07K01	474549117250201	474545	1172507	C	1,794	164	3,000	149	SVRPA
26N/43E-08E04	474606117243001	474606	1172430	C	1,814	458	5,200	162	SVRPA
26N/43E-08G01	474601117234801	474609	1172357	C	1,784	84	300	43	SVRPA
26N/43E-09D01	474618117231501	474618	1172315	C	1,825	170	–	–	SVRPA
26N/43E-09D02	474618117231601	474618	1172316	C	1,825	165	1,000	58	SVRPA
26N/43E-10K02	474549117211401	474552	1172123	C	1,906	189	650	46	MULT
26N/43E-10P01	474534117213601	474534	1172140	U	1,924	247	25	.56	SVRPA
26N/43E-10Q02	474535117213001	474535	1172124	U	1,914	405	–	–	BR
26N/43E-14K01	474451117195701	474451	1172001	U	2,164	595	–	–	BASALT
26N/43E-15D02	474523117215301	474523	1172157	U	1,924	353	–	–	BR
26N/43E-15H02	474510117204901	474510	1172053	U	2,084	340	5	–	BASALT
26N/43E-15N01	474444117215301	474444	1172153	C	1,954	300	4	–	BR
26N/43E-16C01	474519117225901	474518	1172307	C	1,942	280	1,160	80	SVRPA
26N/43E-16C02	474518117223801	474512	1172252	C	1,943	283	230	115	SVRPA
26N/43E-16D02	474518117230501	474512	1172258	C	1,941	285	1,310	200	SVRPA
26N/43E-16D03	474526117231701	474526	1172321	C	1,942	286	2,750	138	SVRPA
26N/43E-16E01	474510117225101	474506	1172309	C	1,956	300	200	–	SVRPA
26N/43E-16F01	474515117225001	474515	1172254	C	1,942	277	1,460	150	SVRPA
26N/43E-16F02	474515117225002	474515	1172254	C	1,942	268	2,300	500	SVRPA
26N/43E-16F03	474515117225101	474515	1172255	C	1,942	284	5,000	500	SVRPA
26N/43E-16G01	474512117222701	474512	1172231	U	1,946	556	–	–	MULT
26N/43E-17B01	474525117234101	474525	1172345	C	1,941	221	50	–	SVRPA
26N/43E-17G01	474506117234901	474506	1172353	C	1,949	165	–	–	SVRPA
26N/43E-17J01	474503117233101	474503	1172335	C	1,970	248	55	11	SVRPA
26N/43E-17M01	474504117243501	474504	1172435	M	1,942	320	–	–	NA
26N/43E-17M02	474504117243901	474504	1172443	U	1,939	320	–	–	NA
26N/43E-18B01	474524117150501	474518	1172514	C	1,904	282	1,200	100	SVRPA
26N/43E-18G01	474516117250801	474515	1172504	C	1,919	197	550	5,500	SVRPA
26N/43E-18G02	474515117250401	474515	1172504	U	1,919	305	500	–	SVRPA
26N/43E-19A02	474432117244601	474436	1172459	C	1,938	240	4,000	250	SVRPA
26N/43E-19H04	474418117244101	474418	1172445	C	1,954	157	–	–	SVRPA
26N/43E-19P01	474358117251701	474359	1172521	C	1,982	210	1,560	92	SVRPA
26N/43E-19R01	474346117244001	474346	1172444	C	2,054	248	–	–	SVRPA

Table 3. Physical data for wells used in the characterization of the hydrogeologic system of the Spokane Valley-Rathdrum Prairie aquifer study area, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.—Continued

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Well No.	USGS site No.	Latitude (NAD 83)	Longitude (NAD 83)	Data reliability	Land-surface altitude (NAVD 88)	Hole depth (ft)	Yield (gal/min)	Specific capacity (gal/min)/ft)	Hydro-geologic unit
26N/43E-20D01	474437117243501	474437	1172440	C	1,950	286	1,800	200	SVRPA
26N/43E-20J01	474409117232701	474409	1172331	C	2,015	430	–	–	MULT
26N/43E-20J02	474409117232801	474409	1172332	C	2,015	761	–	–	SVRPA
26N/43E-20N01	474351117242901	474351	1172433	C	2,044	238	1,000	–	SVRPA
26N/43E-21E02	474418117231001	474418	1172312	C	1,995	246	2,200	550	SVRPA
26N/43E-21J01	474404117220901	474404	1172213	U	1,994	281	317	–	SVRPA
26N/43E-21R01	474355117221101	474358	1172211	C	2,002	260	–	–	SVRPA
26N/43E-22C01	474431117213301	474431	1172137	U	2,067	450	2	–	BR
26N/43E-22J01	474405117205401	474405	1172058	U	2,168	160	–	–	BR
26N/43E-22M01	474405117215201	474405	1172156	U	1,980	195	–	–	MULT
26N/43E-22N01	474346117214701	474346	1172151	C	2,009	216	958	140	SVRPA
26N/43E-22N04	474352117215101	474347	1172204	C	2,034	275	1,200	–	SVRPA
26N/43E-22P02	474348117212401	474348	1172128	U	1,999	191	30	–	MULT
26N/43E-22R01	474351117205401	474351	1172058	U	2,044	185	4	–	MULT
26N/43E-27F01	474324117213001	474324	1172134	C	2,014	200	210	35	SVRPA
26N/43E-27L02	474312117213202	474312	1172136	U	2,024	211	–	–	SVRPA
26N/43E-27N01	474303117215901	474304	1172159	C	2,019	225	.08	–	SVRPA
26N/43E-28H02	474325117220601	474326	1172206	C	2,030	275	–	–	MULT
26N/43E-28L01	474317117225301	474317	1172253	C	2,052	260	25	–	SVRPA
26N/43E-28Q01	474255117224801	474254	1172229	C	2,039	274	50	–	SVRPA
26N/43E-28R01	474301117220501	474301	1172209	M	2,034	405	–	–	NA
26N/43E-29G01	474327117235701	474327	1172401	C	2,060	303	50	–	SVRPA
26N/43E-29R01	474305117233701	474305	1172341	C	2,057	259	–	–	SVRPA
26N/43E-30F01	474325117251701	474326	1172521	C	2,049	312	900	41	SVRPA
26N/43E-30F02	474326117251701	474326	1172517	U	2,049	320	1,500	250	SVRPA
26N/43E-30G01	474322117251201	474322	1172516	C	2,051	220	150	5.7	SVRPA
26N/43E-30H01	474326117244901	474327	1172456	C	2,054	310	2,000	465	SVRPA
26N/43E-31A01	474242117244901	474242	1172454	C	2,068	272	4,200	1,400	SVRPA
26N/43E-31A03	474243117244802	474243	1172448	C	2,069	280	–	–	SVRPA
26N/43E-31A04	474247117253401	474242	1172459	U	2,064	405	–	–	NA
26N/43E-31J01	474216117244501	474216	1172445	C	2,063	223	1.15	–	SVRPA
26N/43E-33K02	474222117223401	474222	1172234	M	2,039	400	–	–	NA
26N/43E-34L01	474221117213201	474221	1172136	U	2,034	400	–	–	NA
26N/44E-34B01	474249117133201	474249	1171336	C	2,408	580	15	–	MULT
26N/44E-35J01	474234117121401	474220	1171159	U	2,084	600	–	–	BR
26N/44E-36DE1	474241117112601	474241	1171130	U	2,444	680	–	–	BR
26N/44E-36M01	474221117113501	474221	1171139	U	2,210	460	–	–	MULT
26N/44E-36R01	474210117103701	474210	1171041	C	2,104	158	–	–	BR
26N/45E-11A01	474619117040801	474619	1170408	C	2,160	117	6	–	BR
26N/45E-11Q01	474537117043401	474537	1170438	U	2,139	310	20	–	BR
26N/45E-12D02	474615117035301	474615	1170357	U	2,164	500	9	–	BR
26N/45E-13N02	474440117040702	474440	1170411	C	2,138	156	–	–	SVRPA
26N/45E-14G01	474508117043001	474508	1170434	U	2,144	178	15	–	SVRPA
26N/45E-14R01	474449117042201	474449	1170426	U	2,177	330	400	44	MULT
26N/45E-23A01	474428117041001	474428	1170414	C	2,144	170	–	–	SVRPA
26N/45E-24C01	474419117033901	474429	1170341	C	2,186	428	86	0.91	SVRPA
26N/45E-24C02	474417117034102	474429	1170341	C	2,186	465	116	2.2	SVRPA
26N/45E-24R01	474349117025201	474349	1170252	C	2,108	178	–	–	SVRPA

Table 3. Physical data for wells used in the characterization of the hydrogeologic system of the Spokane Valley-Rathdrum Prairie aquifer study area, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.—Continued

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Well No.	USGS site No.	Latitude (NAD 83)	Longitude (NAD 83)	Data reliability	Land-surface altitude (NAVD 88)	Hole depth (ft)	Yield (gal/min)	Specific capacity (gal/min)/ft)	Hydro-geologic unit
26N/45E-25B01	474333117034501	474335	1170325	C	2,099	213	150	–	SVRPA
26N/45E-25C03	474344117033501	474344	1170332	C	2,097	200	4,000	1,390	SVRPA
26N/45E-25E03	474321117040701	474321	1170407	C	2,081	169	35	–	SVRPA
26N/45E-25J01	474305117024901	474305	1170253	C	2,084	263	–	–	SVRPA
26N/45E-25N02	474302117035501	474302	1170355	C	2,091	150	20	–	SVRPA
26N/45E-26G01	474322117043301	474322	1170433	C	2,064	160	21.4	.71	BR
26N/45E-32H04	474247117080501	474238	1170802	C	2,110	190	15	–	SVRPA
26N/45E-32J02	474224117075901	474224	1170803	C	2,089	155	–	–	SVRPA
26N/45E-32K01	474222117082901	474219	1170820	C	2,079	158	160	6	SVRPA
26N/45E-32N02	474203117090601	474203	1170906	C	2,059	200	100	–	SVRPA
26N/45E-32Q01	474212117083301	474209	1170836	C	2,065	157	–	–	BR
26N/45E-33G01	474228117071901	474228	1170719	C	2,084	161	400	200	SVRPA
26N/45E-34L02	474218117060802	474219	1170612	C	2,071	238	4,490	3,454	SVRPA
26N/45E-35F03	474237117045803	474235	1170459	C	2,087	249	4,445	1,646	SVRPA
26N/46E-30D01	474344117024501	474344	1170249	C	2,107	190	50	–	SVRPA
26N/46E-31M03	474225117024601	474225	1170249	C	2,094	249	4,490	1,497	SVRPA
27N/41E-22R01	474906117362201	474902	1173631	U	1,621	254	1,500	–	SVRPA
27N/41E-26K01	474823117353201	474823	1173536	U	1,731	320	1,000	244	SVRPA
27N/41E-26L01	474821117354401	474821	1173544	U	1,619	198	–	–	SVRPA
27N/41E-27A01	474855117362001	474855	1173624	U	1,599	318	2,500	250	SVRPA
27N/41E-35A01	474802117350701	474802	1173515	U	1,636	181	270	90	SVRPA
27N/42E-31H03	474740117322501	474740	1173228	C	1,554	201	–	–	SVRPA
27N/42E-31H04	474740117362801	474740	1173228	C	1,554	200	500	–	SVRPA
27N/42E-32G01	474746117313001	474746	1173134	U	1,849	424	30	–	MULT
27N/43E-32J02	474726117233201	474726	1172332	C	1,614	208	330	7.7	BR
27N/43E-32J04	474723117233701	474740	1172337	C	1,647	220	3,500	129	SVRPA
27N/43E-32J05	474738117233401	474738	1172338	U	1,624	252	4,488	214	SVRPA
27N/43E-33M02	474734117230801	474734	1172308	C	1,629	236	5,000	199	SVRPA
27N/43E-35E01	474747117203501	474747	1172039	U	1,909	700	5	–	BR
50N 03W 06DAA1	474226116444101	474224	1164448	C	2,221	185	50	–	SVRPA
50N 03W 06DACC1	474218116445601	474218	1164457	C	2,224	215	60	–	SVRPA
50N 03W 06DCA1	474213116450601	474213	1164506	C	2,220	170	30	–	BR
50N 04W 01CCD1	474208116465001	474206	1164652	C	2,242	226	1,800	180	SVRPA
50N 04W 02ACC1	474229116474501	474229	1164745	C	2,224	440	–	–	SVRPA
50N 04W 03DBB1	474229116490301	474229	1164903	C	2,204	392	350	–	SVRPA
50N 04W 04AAD1	474309116494701	474250	1164949	C	2,252	350	5,000	256	SVRPA
50N 04W 04CCD1	474210116505001	474210	1165054	C	2,137	201	–	–	SVRPA
50N 04W 05CAB2	474230116520002	474230	1165204	C	2,254	350	160	40	SVRPA
50N 04W 05DBC1	474221116513801	474220	1165139	C	2,179	204	15	–	SVRPA
50N 04W 05DDC1	474207116511401	474207	1165118	C	2,154	163	30	–	SVRPA
50N 04W 06BAD1	473020116523001	474252	1165305	C	2,354	435	–	–	SVRPA
50N 04W 06BCA1	474233116532201	474233	1165326	C	2,367	426	–	–	SVRPA
50N 04W 06CCA2	474214116532402	474214	1165328	C	2,179	210	60	–	SVRPA
50N 04W 12BCD1	474142116470101	474141	1164701	C	2,227	400	60	–	SVRPA
50N 04W 12CBA1	474136116465501	474136	1164659	M	2,214	405	–	–	NA
50N 04W 12CBB1	474134116470001	474135	1164706	C	2,226	295	3,900	661	SVRPA
50N 04W 12CCB1	474115116470101	474120	1164703	C	2,224	270	3,100	290	SVRPA
50N 04W 13CDD1	474023116463701	474023	1164641	C	2,147	120	–	–	SVRPA

Table 3. Physical data for wells used in the characterization of the hydrogeologic system of the Spokane Valley-Rathdrum Prairie aquifer study area, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.—Continued

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Well No.	USGS site No.	Latitude (NAD 83)	Longitude (NAD 83)	Data reliability	Land-surface altitude (NAVD 88)	Hole depth (ft)	Yield (gal/min)	Specific capacity (gal/min)/ft)	Hydro-geologic unit
50N 04W 13DAA1	474043116460201	474044	1164602	C	2,185	458	200	–	SVRPA
50N 04W 14AA1	474106116471201	474106	1164716	U	2,204	315	10	–	SVRPA
50N 05W 01CBBB1	474230116544901	474230	1165455	C	2,198	279	–	–	SVRPA
50N 05W 02AAB1	474256116551501	474256	1165515	C	2,194	315	2,500	806	SVRPA
50N 05W 02BCC1	474233116560801	474233	1165612	C	2,172	210	350	–	SVRPA
50N 05W 02DCC1	474210116552901	474210	1165533	C	2,172	202	–	–	SVRPA
50N 05W 04CAB1	474232116582001	474232	1165820	C	2,130	180	30	1.2	SVRPA
50N 05W 04CACB1	474223116582501	474223	1165825	C	2,111	165	50	–	SVRPA
50N 05W 05DBC1	474222116591901	474222	1165923	C	2,127	170	–	–	SVRPA
50N 05W 06DCDC1	474209117003401	474209	1170034	C	2,114	190	–	–	SVRPA
50N 05W 07ADDD1	474145117000701	474143	1170010	C	2,069	110	10	2	SVRPA
50N 05W 07DABC1	474134117002201	474134	1170022	C	2,073	79.3	–	–	SVRPA
50N 05W 12BCDA1	474144116543801	474144	1165438	C	2,187	250	800	500	SVRPA
50N 06W 01CAC1	474221117020901	474221	1170213	C	2,104	200	600	–	SVRPA
50N 06W 01DDD1	474208117012301	474207	1170127	C	2,115	168	–	–	SVRPA
50N 06W 12DBCD1	474130117015401	474130	1170154	C	2,073	137	50	–	SVRPA
51N 03W 18BCB1	474615116454901	474615	1164553	C	2,299	300	1,320	40	SVRPA
51N 03W 19BAB1	474529116452601	474528	1164532	C	2,297	221	154	–	SVRPA
51N 03W 30BDD1	474417116451701	474417	1164516	C	2,272	275	15	–	BR
51N 04W 01CCC1	474718116471001	474718	1164710	C	2,314	430	300	2.6	BASALT
51N 04W 02CCD1	474718116481701	474718	1164817	C	2,321	400	–	–	SVRPA
51N 04W 03BAD1	474757116492701	474757	1164908	C	2,312	373	1,800	257	SVRPA
51N 04W 03CDA1	474725116490801	474725	1164912	C	2,289	351	1,800	138	SVRPA
51N 04W 04BCA1	474756116504201	474756	1165046	C	2,308	381	1,900	1,428	SVRPA
51N 04W 05BCB1	474756116521501	474756	1165219	C	2,249	290	100	–	SVRPA
51N 04W 05CBC1	474732116521701	474733	1165220	C	2,275	311	2,800	–	SVRPA
51N 04W 06ADA1	474755116521901	474757	1165222	C	2,247	277	3,000	3,000	SVRPA
51N 04W 06BAD1	474758116525701	474758	1165301	C	2,227	256	–	–	SVRPA
51N 04W 06CCDD1	474720116532101	474720	1165321	C	2,240	310	15	–	SVRPA
51N 04W 06CDDD1	474718116530201	474718	1165302	C	2,259	300	35	–	SVRPA
51N 04W 07BDD1	474651116530301	474651	1165307	C	2,273	312	50	–	SVRPA
51N 04W 08ADB1	474659116511901	474701	1165124	C	2,275	315	–	–	SVRPA
51N 04W 08BCB1	474701116521601	474701	1165220	C	2,266	304	–	–	SVRPA
51N 04W 09CBA1	474651116504401	474651	1165048	C	2,291	323	–	–	SVRPA
51N 04W 10BBD1	474704116495001	474704	1164927	C	2,300	361	–	–	SVRPA
51N 04W 10CCB1	474635116493901	474635	1164943	C	2,292	305	–	–	SVRPA
51N 04W 11AAA1	474714116471301	474714	1164713	C	2,314	377	250	2.9	SVRPA
51N 04W 11ABB1	474715116474301	474715	1164749	C	2,326	408	–	–	SVRPA
51N 04W 11DDA1	474636116471501	474636	1164719	C	2,312	354	100	–	SVRPA
51N 04W 12ABA1	474715116460701	474715	1164611	C	2,429	232	–	–	BASALT
51N 04W 12CBA1	474646116462701	474646	1164631	C	2,300	370	25	.68	SVRPA
51N 04W 14AAC1	474614116472901	474613	1164728	C	2,304	440	2,146	58	SVRPA
51N 04W 14ABA1	474620116473501	474619	1164742	C	2,309	380	30	–	SVRPA
51N 04W 14DBB2	474555116474102	474555	1164745	C	2,301	417	8,000	571	SVRPA
51N 04W 15AAA1	474623116483101	474623	1164835	C	2,304	348	200	–	SVRPA
51N 04W 15DBB1	474553116485701	474557	1164909	C	2,304	382	–	–	SVRPA
51N 04W 15DCD2	474542116485702	474540	1164855	C	2,304	450	4,000	252	SVRPA
51N 04W 16DBC1	474547116501701	474547	1165023	C	2,280	363	1,800	–	SVRPA

Table 3. Physical data for wells used in the characterization of the hydrogeologic system of the Spokane Valley-Rathdrum Prairie aquifer study area, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.—Continued

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Well No.	USGS site No.	Latitude (NAD 83)	Longitude (NAD 83)	Data reliability	Land-surface altitude (NAVD 88)	Hole depth (ft)	Yield (gal/min)	Specific capacity (gal/min)/ft)	Hydro-geologic unit
51N 04W 17CBC2	474549116521601	474549	1165220	C	2,262	305	25	–	SVRPA
51N 04W 18DBC1	474547116524801	474546	1165301	C	2,256	323	–	–	SVRPA
51N 04W 19BDD1	474512116525801	474516	1165301	C	2,238	295	–	–	SVRPA
51N 04W 19DCC3	474443116525701	474443	1165258	C	2,253	325	35	–	SVRPA
51N 04W 20CBCD1	474456116522001	474456	1165220	C	2,249	290	30	–	SVRPA
51N 04W 20CCCC1	474445116521601	474447	1165221	C	2,249	298	30	0.73	SVRPA
51N 04W 20DDA1	474455116511801	474455	1165122	C	2,265	325	500	–	SVRPA
51N 04W 21BC1	474515116505301	474515	1165057	U	2,274	322	200	–	SVRPA
51N 04W 22BCA1	474517116492801	474517	1164932	C	2,301	357	–	–	SVRPA
51N 04W 22DAB1	474502116483801	474502	1164842	C	2,296	351	15	–	SVRPA
51N 04W 23ABAC1	474529116474001	474529	1164740	C	2,290	363	100	–	SVRPA
51N 04W 23BCC1	474508116482301	474508	1164827	C	2,290	324	20	–	SVRPA
51N 04W 23DAA1	474501116471701	474501	1164721	C	2,279	330	30	–	SVRPA
51N 04W 23DCB1	474453116474501	474452	1164750	C	2,278	367	100	–	SVRPA
51N 04W 24ABB1	474526116462201	474526	1164626	C	2,253	217	30	–	SVRPA
51N 04W 25BBB1	474438116470201	474438	1164706	C	2,254	297	1,000	370	SVRPA
51N 04W 25BBB2	474439116470501	474439	1164705	C	2,254	309	–	–	SVRPA
51N 04W 26ACC1	474417116475001	474417	1164750	C	2,278	425	4,011	4,011	SVRPA
51N 04W 27BA1	474434116491801	474434	1164922	U	2,284	372	–	–	SVRPA
51N 04W 27CD1	474353116491401	474353	1164918	U	2,274	360	300	–	SVRPA
51N 04W 28AAA1	474437116494801	474437	1164948	C	2,284	410	3,400	243	SVRPA
51N 04W 28CAD1	474404116503001	474404	1165034	C	2,286	348	–	–	SVRPA
51N 04W 29BCB1	474425116521001	474425	1165214	C	2,234	296	25	–	SVRPA
51N 04W 31BBC1	474337116533201	474337	1165337	C	2,212	268	30	–	SVRPA
51N 04W 31DDA1	474308116522101	474308	1165226	C	2,347	420	–	–	SVRPA
51N 04W 32ACA1	474331116512201	474336	1165124	C	2,275	318	–	–	SVRPA
51N 04W 32DAC1	474314116511801	474314	1165122	C	2,266	343	–	–	SVRPA
51N 04W 33ADC1	474328116500001	474328	1165004	C	2,264	335	–	–	SVRPA
51N 04W 33CAB1	474320116504101	474320	1165045	C	2,273	332	–	–	SVRPA
51N 04W 34DDB1	474306116493601	474306	1164936	C	2,257	365	2,500	595	SVRPA
51N 04W 35BBA1	474346116480701	474348	1164811	C	2,271	400	6,000	24	SVRPA
51N 04W 35DDA1	474309116471601	474309	1164716	C	2,240	462	50	–	SVRPA
51N 05W 01AAA1	474808116534001	474808	1165340	C	2,203	265	1,018	127	SVRPA
51N 05W 01DAD1	474736116533801	474736	1165342	C	2,215	235	–	–	SVRPA
51N 05W 02CBC1	474733116560801	474733	1165608	C	2,184	480	4	.01	BR
51N 05W 10AAA1	474718116562201	474718	1165622	C	2,151	177	20	.74	SVRPA
51N 05W 11AAB1	474718116551201	474718	1165516	C	2,176	250	2,000	53	SVRPA
51N 05W 11AAD1	474710116550801	474710	1165508	U	2,194	602	–	–	NA
51N 05W 11ADA1	474706116551001	474706	1165510	U	2,194	620	–	–	NA
51N 05W 11ADB1	474706116551501	474706	1165515	U	2,194	650	–	–	NA
51N 05W 11BB1	474713116560301	474713	1165607	U	2,164	293	2,000	–	SVRPA
51N 05W 12CBC1	474644116543401	474644	1165438	C	2,223	305	–	–	SVRPA
51N 05W 13AAB1	474624116535101	474624	1165401	C	2,246	314	–	–	SVRPA
51N 05W 13BCD1	474601116543401	474601	1165438	C	2,238	299	–	–	SVRPA
51N 05W 14BBC1	474615116560901	474615	1165613	C	2,194	240	–	–	SVRPA
51N 05W 14DAB1	474601116551301	474601	1165517	C	2,222	244	–	–	SVRPA
51N 05W 16BBD1	474617116584101	474617	1165839	C	2,165	500	7	.02	BR
51N 05W 16DBA1	474559116574901	474602	1165800	C	2,145	220	–	–	SVRPA

Table 3. Physical data for wells used in the characterization of the hydrogeologic system of the Spokane Valley-Rathdrum Prairie aquifer study area, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.—Continued

[**USGS site No.** is based on the initial latitude and longitude determined for the site. The site No. does not change if more accurate latitude/longitude values are determined after the site is first created. **Data reliability:** C, field checked; U, not field checked but data considered reliable; M, minimal data available for site. **Hydrogeologic unit:** BASALT, Columbia River basalt and(or) Latah Formation interbeds; BR, bedrock; NA, not applicable; MULT, multiple units; SVRPA, Spokane Valley-Rathdrum Prairie Aquifer; and UNK; unknown. **Abbreviations:** USGS, U.S. Geological Survey; NAVD 88, North American Vertical Datum of 1988; NAD 83, North American Datum of 1983; ft, foot; gal/min, gallon per minute; (gal/min)/ft, gallon per minute per foot; –, no data]

Well No.	USGS site No.	Latitude (NAD 83)	Longitude (NAD 83)	Data reliability	Land-surface altitude (NAVD 88)	Hole depth (ft)	Yield (gal/min)	Specific capacity (gal/min)/ft)	Hydro-geologic unit
51N 05W 18BCC1	474603117010301	474603	1170122	C	2,215	140	60	0.75	SVRPA
51N 05W 19CDD1	474449117004501	474449	1170049	C	2,129	480	–	–	UNK
51N 05W 19DBC3	474458117004002	474458	1170044	C	2,132	212	–	–	SVRPA
51N 05W 21ACC1	474509116580601	474509	1165810	C	2,163	200	–	–	SVRPA
51N 05W 22BBB3	474532116572401	474531	1165728	C	2,167	326	4,000	220	SVRPA
51N 05W 22BBB5	474530116572401	474530	1165728	C	2,168	330	2,399	185	SVRPA
51N 05W 24BCA1	474520116543701	474520	1165437	C	2,221	298	–	–	SVRPA
51N 05W 25CAB1	474414116543001	474414	1165434	C	2,226	281	1,000	286	SVRPA
51N 05W 25DAB1	474416116535401	474416	1165358	C	2,211	290	–	–	SVRPA
51N 05W 26BCA1	474432116555301	474432	1165557	C	2,245	274	–	–	SVRPA
51N 05W 27BBB1	474439116572601	474438	1165731	C	2,147	184	20	–	SVRPA
51N 05W 27DCCC1	474353116565101	474352	1165651	C	2,241	328	–	–	SVRPA
51N 05W 27DCCC2	474352116565201	474352	1165651	C	2,241	350	3,000	1,000	SVRPA
51N 05W 28BBC1	474431116584301	474431	1165847	C	2,139	181	–	–	SVRPA
51N 05W 28CCB2	474359116584101	474359	1165845	C	2,151	257	3,768	1,603	SVRPA
51N 05W 28CCB3	474359116583901	474359	1165843	C	2,150	257	4,000	1,423	SVRPA
51N 05W 28DAD1	474407116573301	474405	1165737	C	2,157	276	3,806	835	SVRPA
51N 05W 28DAD2	474406116573001	474406	1165734	C	2,156	270	4,000	1,290	SVRPA
51N 05W 30CCC1	474355117012201	474354	1170122	C	2,114	188	300	–	SVRPA
51N 05W 31ACA1	474336117002701	474336	1170031	C	2,109	189	–	–	NA
51N 05W 31C1	474314117010501	474314	1170109	U	2,104	422	–	–	SVRPA
51N 05W 31DDD1	474301117000601	474301	1170010	C	2,128	180	30	–	SVRPA
51N 05W 34ABC1	474337116564801	474337	1165652	C	2,217	278	1,045	–	SVRPA
51N 05W 34BA1	474342116571001	474342	1165714	U	2,224	295	2,526	–	SVRPA
51N 05W 35CAA1	474318116553401	474318	1165537	C	2,193	273	1,500	–	SVRPA
51N 05W 35DB1	474321116553201	474321	1165536	U	2,204	321	25	–	SVRPA
51N 05W 36BAC1	474337116543101	474337	1165431	C	2,219	290	–	–	SVRPA
52N 03W 07ADDA1	475211116443801	475211	1164438	C	2,314	147	100	–	SVRPA
52N 03W 07DCA1	475146116445401	475146	1164458	C	2,312	270	1,300	433	SVRPA
52N 03W 18BAA1	475132116451501	475132	1164515	C	2,304	180	45	.75	BR
52N 03W 19AAB1	475041116444401	475041	1164448	C	2,364	335	5	–	SVRPA
52N 03W 19BAD1	475039116451701	475039	1164521	C	2,344	300	10	–	BASALT
52N 03W 19DD1	474959116444201	474959	1164446	U	2,504	1,000	2	–	BR
52N 04W 01DC1	475237116461801	475237	1164622	U	2,324	360	30	–	SVRPA
52N 04W 02CA1	475249116475701	475249	1164801	U	2,354	360	10	–	BASALT
52N 04W 02CDC1	475237116480601	475236	1164810	C	2,346	1,742		–	MULT
52N 04W 05AAA1	475317116510301	475317	1165103	C	2,444	500	20	–	SVRPA
52N 04W 06AAAA1	475322116522201	475322	1165222	C	2,412	445	15	–	SVRPA
52N 04W 06AAC1	475310116522801	475310	1165232	C	2,344	355		–	SVRPA
52N 04W 09BAD1	475221116502201	475221	1165022	C	2,364	400	15	–	SVRPA
52N 04W 10DAB1	475202116484301	475202	1164843	C	2,312	340	40	–	SVRPA
52N 04W 10DB2	475158116485901	475158	1164903	U	2,314	430	50	–	BR
52N 04W 10DBA3	475159116485101	475203	1164852	C	2,314	635	30	–	BR
52N 04W 11BBC1	475222116481801	475222	1164822	C	2,314	318	0	–	BR
52N 04W 13BD1	475121116465701	475121	1164644	U	2,314	700	1	–	BR
52N 04W 13CDB2	475055116464302	475055	1164647	C	2,274	500	8	1.3	BR
52N 04W 14DAB1	475110116474201	475113	1164731	C	2,296	422	20	–	BASALT
52N 04W 14DCC1	475047116474301	475047	1164747	C	2,304	328	6	.43	BASALT

Table 3. Physical data for wells used in the characterization of the hydrogeologic system of the Spokane Valley-Rathdrum Prairie aquifer study area, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.—Continued

[**USGS site No.** is based on the initial latitude and longitude determined for the site. The site No. does not change if more accurate latitude/longitude values are determined after the site is first created. **Data reliability:** C, field checked; U, not field checked but data considered reliable; M, minimal data available for site. **Hydrogeologic unit:** BASALT, Columbia River basalt and(or) Latah Formation interbeds; BR, bedrock; NA, not applicable; MULT, multiple units; SVRPA, Spokane Valley-Rathdrum Prairie Aquifer; and UNK; unknown. **Abbreviations:** USGS, U.S. Geological Survey; NAVD 88, North American Vertical Datum of 1988; NAD 83, North American Datum of 1983; ft, foot; gal/min, gallon per minute; (gal/min)/ft, gallon per minute per foot; –, no data]

Well No.	USGS site No.	Latitude (NAD 83)	Longitude (NAD 83)	Data reliability	Land-surface altitude (NAVD 88)	Hole depth (ft)	Yield (gal/min)	Specific capacity (gal/min)/ft)	Hydro-geologic unit
52N 04W 15BDB1	475121116491801	475121	1164918	C	2,322	365	50	2	BR
52N 04W 17BDA1	475125116514001	475125	1165144	C	2,374	390	5	.33	BR
52N 04W 17CAB1	475110116515701	475110	1165157	C	2,327	377	20	–	SVRPA
52N 04W 17DDD1	475048116510101	475048	1165105	C	2,302	350	150	–	SVRPA
52N 04W 20AB1	475042116513101	475042	1165135	U	2,304	343	20	–	SVRPA
52N 04W 20CCB1	475002116521101	475002	1165208	C	2,271	500	2	–	MULT
52N 04W 21ABC1	475036116502001	475036	1165020	C	2,297	362	30	–	SVRPA
52N 04W 21DAA1	475019116494701	475019	1164947	C	2,284	348	30	–	SVRPA
52N 04W 22CBB1	475018116494001	475018	1164944	C	2,287	320	13	–	SVRPA
52N 04W 22DAD1	475013116482801	475013	1164832	C	2,274	305	–	–	SVRPA
52N 04W 23AC1	475027116474301	475027	1164747	U	2,274	320	80	–	SVRPA
52N 04W 24ACD2	475025116462301	475027	1164620	C	2,305	335	100	1.4	SVRPA
52N 04W 24DDB1	475006116460401	475006	1164608	C	2,344	452	5	–	BASALT
52N 04W 26AAA1	474953116470801	474951	1164715	C	2,288	315	10	.56	SVRPA
52N 04W 27DCD1	474906116484801	474913	1164847	C	2,264	306	25	2.1	SVRPA
52N 04W 28AA1	474949116495301	474949	1164957	U	2,244	340	50	–	SVRPA
52N 04W 29AAC1	474945116510901	474945	1165113	C	2,244	279	20	–	SVRPA
52N 04W 29AB1	474948116514201	474948	1165146	U	2,264	320	5	–	MULT
52N 04W 29BBA1	474948116515701	474948	1165201	C	2,272	314	20	1.7	SVRPA
52N 04W 29DAD1	474918116512401	474918	1165128	C	2,235	265	20	–	SVRPA
52N 04W 31CAB1	474830116531501	474830	1165319	C	2,191	268	220	44	MULT
52N 04W 31CAD1	474824116530401	474824	1165309	C	2,192	250	1,047	–	SVRPA
52N 04W 31DAD1	474828116522601	474828	1165230	C	2,201	225	–	–	SVRPA
52N 04W 32CDB1	474820116515001	474820	1165154	C	2,231	300	–	–	SVRPA
52N 04W 32DDB1	474823116511601	474823	1165115	C	2,264	300	15	1.5	SVRPA
52N 04W 33AAD1	474851116495001	474851	1164954	C	2,252	277	60		SVRPA
52N 04W 34DAC1	474829116484801	474830	1164847	C	2,313	380	500	6.2	SVRPA
52N 04W 35ACB1	474847116474701	474847	1164747	C	2,315	457	50	.44	SVRPA
52N 04W 35BBD1	474858116481501	474858	1164819	C	2,314	339	20	6.7	SVRPA
53N 02W 03BCC1	475816116340401	475814	1163402	C	2,274	331	750	–	SVRPA
53N 02W 03CAA1	475804116333401	475805	1163341	C	2,275	322	–	–	SVRPA
53N 02W 04AAC1	475829116342301	475829	1163427	C	2,273	328	–	–	SVRPA
53N 02W 04CDA1	475753116345301	475753	1163457	C	2,302	357	1,250	1,250	SVRPA
53N 02W 05ADC1	475816116353301	475813	1163537	C	2,294	362	800	400	SVRPA
53N 02W 06AAA1	475835116364201	475835	1163646	C	2,299	293	100	–	SVRPA
53N 02W 07CA1	475710116372901	475710	1163733	U	2,434	492	20	–	SVRPA
53N 02W 07CAA1	475716116372901	475716	1163733	C	2,436	404	11	–	SVRPA
53N 02W 07DBD1	475705116371201	475705	1163712	C	2,442	442	20	–	SVRPA
53N 02W 07DDD1	475653116364801	475653	1163652	C	2,464	460	50	–	SVRPA
53N 02W 09AAC1	475736116341701	475737	1163421	C	2,295	351	–	–	SVRPA
53N 02W 09BDB1	475729116345801	475729	1163502	C	2,366	420	1,500	1,500	SVRPA
53N 02W 17BCC1	475640116363401	475640	1163638	C	2,465	450	380	380	MULT
53N 02W 18AC1	475621116371301	475630	1163714	U	2,464	777	3.5	–	BR
53N 02W 18CAA1	475607116375201	475620	1163729	U	2,464	600	3	–	BR
53N 02W 19ABA1	475556116370301	475556	1163707	C	2,464	281	3	–	BR
53N 02W 19ADD1	475534116364801	475534	1163652	C	2,524	401	8	1	BR
53N 03W 01CCC1	475749116391301	475749	1163913	C	2,429	430	11	–	SVRPA
53N 03W 01CDD1	475752116384801	475752	1163848	C	2,441	443	20	–	SVRPA

Table 3. Physical data for wells used in the characterization of the hydrogeologic system of the Spokane Valley-Rathdrum Prairie aquifer study area, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.—Continued

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Well No.	USGS site No.	Latitude (NAD 83)	Longitude (NAD 83)	Data reliability	Land-surface altitude (NAVD 88)	Hole depth (ft)	Yield (gal/min)	Specific capacity (gal/min)/ft)	Hydro-geologic unit
53N 03W 02CC1	475751116402501	475751	1164029	U	2,424	460	25	–	SVRPA
53N 03W 03AC1	475818116410401	475818	1164108	U	2,409	580	.25	–	MULT
53N 03W 03BA1D1	475832116412302	475832	1164127	U	2,394	458	45	–	SVRPA
53N 03W 03BAB1	475838116412101	475837	1164131	C	2,407	369	7.5	–	SVRPA
53N 03W 03CC1	475752116414401	475752	1164148	U	2,354	426	20	–	MULT
53N 03W 03DDDA1	475750116403801	475750	1164038	C	2,375	443	35	–	SVRPA
53N 03W 05DCC1	475747116435101	475747	1164351	C	2,516	563	30	–	SVRPA
53N 03W 06DDA1	475756116444101	475756	1164443	C	2,509	523	15	0.25	SVRPA
53N 03W 07AB1	475740116445801	475740	1164502	U	2,504	538	20	–	SVRPA
53N 03W 07DCD1	475655116445801	475655	1164458	C	2,491	518	20	.29	SVRPA
53N 03W 08AC1	475724116434301	475724	1164347	U	2,504	560	40	–	SVRPA
53N 03W 09CDD2	475657116424001	475657	1164240	C	2,389	410	1,000	278	SVRPA
53N 03W 10ACD1	475720116405601	475720	1164100	C	2,442	442	20	–	SVRPA
53N 03W 12CBB1	475717116391601	475718	1163916	C	2,454	458	20	.36	SVRPA
53N 03W 13DB1	475616116383301	475616	1163837	U	2,454	780	3	–	BR
53N 03W 14ABB1	475651116394901	475651	1163953	C	2,454	415	20	–	SVRPA
53N 03W 14DD1	475606116393101	475606	1163935	U	2,444	1,300	2	–	BR
53N 03W 15BB1	475644116414501	475644	1164149	U	2,404	421	20	–	SVRPA
53N 03W 15CD01	475602116411901	475602	1164123	U	2,409	560	10	–	BR
53N 03W 16ABB1	475649116422301	475648	1164227	C	2,394	440	700	1,400	SVRPA
53N 03W 16CA1	475626116425401	475626	1164254	C	2,376	359	–	–	NA
53N 03W 17AD1	475631116432301	475631	1164327	U	2,494	520	15	–	SVRPA
53N 03W 17BDA1	475632116440801	475632	1164412	U	2,494	525	60	–	SVRPA
53N 03W 18BCC1	475627116454501	475626	1164549	C	2,491	540	–	–	SVRPA
53N 03W 19DD1	475514116444101	475514	1164445	U	2,434	457	40	–	SVRPA
53N 03W 20BB1	475555116442501	475555	1164429	U	2,474	490	20	–	SVRPA
53N 03W 21AB1	475555116422801	475555	1164232	U	2,394	660	406	–	BR
53N 03W 21CDC1	475514116424801	475514	1164252	C	2,373	198	25	–	BR
53N 03W 22DAB1	475532116405501	475532	1164059	C	2,429	410	22	2.75	BR
53N 03W 23AC1	475540116393801	475540	1163942	U	2,464	380	18	–	BR
53N 03W 23BB1	475555116403301	475555	1164037	U	2,444	418	5	–	SVRPA
53N 03W 24ABD1	475554116383001	475554	1163834	C	2,454	500	14	–	BR
53N 03W 24CCCD1	475510116391201	475509	1163912	C	2,457	340	20	–	SVRPA
53N 03W 24DDA1	475542116380201	475542	1163806	C	2,476	435	40	.09	BR
53N 03W 27AB1	475457116411101	475457	1164115	U	2,434	800	1	–	BR
53N 03W 27DC1	475420116411001	475420	1164114	U	2,414	815	7	–	BR
53N 03W 28CDD1	475416116424001	475416	1164244	C	2,348	550	8	.4	BR
53N 03W 28DAB1	475429116421401	475429	1164218	C	2,347	400	6	–	BR
53N 03W 28DDC1	475416116421001	475416	1164210	C	2,344	910	30	.04	BR
53N 03W 28DDC3	475416116421003	475416	1164210	C	2,344	376	270	12	MULT
53N 03W 29CCC1	475416116442601	475416	1164429	C	2,394	470	50	.52	MULT
53N 03W 30AD1	475447116443601	475447	1164440	U	2,424	440	30	–	SVRPA
53N 03W 30BAA1	475055116451401	475503	1164518	C	2,445	446	20	–	BASALT
53N 03W 31CA1	475341116453001	475341	1164534	U	2,379	440	3	–	MULT
53N 03W 32DC1	475328116435101	475328	1164355	U	2,354	603	15	–	BR
53N 03W 34ADAA1	475400116404201	475400	1164042	C	2,460	237	15	.6	SVRPA
53N 03W 34BAB1	475410116413201	475410	1164136	C	2,351	525	20	–	BR
53N 03W 34BCD1	475352116413501	475352	1164139	C	2,349	300	1	–	BASALT

Table 3. Physical data for wells used in the characterization of the hydrogeologic system of the Spokane Valley-Rathdrum Prairie aquifer study area, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.—Continued

[**USGS site No.** is based on the initial latitude and longitude determined for the site. The site No. does not change if more accurate latitude/longitude values are determined after the site is first created. **Data reliability:** C, field checked; U, not field checked but data considered reliable; M, minimal data available for site. **Hydrogeologic unit:** BASALT, Columbia River basalt and(or) Latah Formation interbeds; BR, bedrock; NA, not applicable; MULT, multiple units; SVRPA, Spokane Valley-Rathdrum Prairie Aquifer; and UNK; unknown. **Abbreviations:** USGS, U.S. Geological Survey; NAVD 88, North American Vertical Datum of 1988; NAD 83, North American Datum of 1983; ft, foot; gal/min, gallon per minute; (gal/min)/ft, gallon per minute per foot; –, no data]

Well No.	USGS site No.	Latitude (NAD 83)	Longitude (NAD 83)	Data reliability	Land-surface altitude (NAVD 88)	Hole depth (ft)	Yield (gal/min)	Specific capacity (gal/min)/ft)	Hydro-geologic unit
53N 03W 35ABD1	475406116393901	475406	1163943	C	2,469	175	20	–	BR
53N 04W 05DCD1	475753116513101	475753	1165131	C	2,579	632	–	–	SVRPA
53N 04W 06DDB3	475754116523503	475756	1165237	C	2,458	362	50	–	SVRPA
53N 04W 08CCDA1	475656116520401	475656	1165204	C	2,548	503	20	–	SVRPA
53N 04W 09CBA1	475718116504401	475718	1165048	C	2,591	600	–	–	SVRPA
53N 04W 10CC1	475654116492301	475654	1164927	U	2,589	622	20	1	SVRPA
53N 04W 13BB1	475624116464801	475644	1164652	U	2,524	558	20	–	SVRPA
53N 04W 13CBBD1	475622116470101	475622	1164701	C	2,505	506	20	–	SVRPA
53N 04W 15DC1	475611116485701	475611	1164901	U	2,544	560	15	–	SVRPA
53N 04W 15DDB1	475611116483201	475606	1164835	C	2,519	563	15	–	SVRPA
53N 04W 20ADA1	475545116510401	475545	1165104	C	2,604	707	17	–	BR
53N 04W 22CBD1	475523116490101	475523	1164905	C	2,474	505	20	–	SVRPA
53N 04W 24DA1	475530116460501	475530	1164609	U	2,459	570	20	.95	NA
53N 04W 25DCC1	475416116462401	475416	1164625	C	2,416	428	40	–	SVRPA
53N 04W 25DDC2	475417116462501	475417	1164625	C	2,414	613	0	–	NA
53N 04W 27AAB1	475505116490801	475504	1164912	C	2,434	497	1,905	3,810	BR
53N 04W 27CCB1	475424116493601	475424	1164940	C	2,439	460	3	–	BR
53N 04W 27DBD1	475431116484201	475431	1164846	C	2,444	440	3.5	–	BR
53N 04W 28CAB1	475439116503401	475438	1165038	C	2,432	449	–	–	SVRPA
53N 04W 29AAB1	475505116511901	475505	1165119	C	2,624	700	20	–	SVRPA
53N 04W 31ABB1	475415116525201	475415	1165256	C	2,409	502	4	–	BR
53N 04W 31CA1	475344116530801	475344	1165312	U	2,374	430	10	–	SVRPA
53N 04W 32CDB1	475332116515901	475332	1165203	U	2,414	460	30	–	SVRPA
53N 04W 33CC1	475327116505501	475327	1165059	U	2,444	485	18	–	SVRPA
53N 04W 36BBA1	475414116464601	475414	1164650	C	2,423	426	25	–	SVRPA
54N 02W 18CBB1	480128116375301	480128	1163753	C	2,320	72	12	.34	SVRPA
54N 02W 19ADB1	480054116364901	480054	1163653	C	2,344	155	15	–	BR
54N 02W 19BAA1	480109116371901	480109	1163723	C	2,324	167	35	–	MULT
54N 02W 19CBA2	480046116373401	480044	1163741	C	2,341	210	20	–	SVRPA
54N 02W 29CCD1	475935116361901	475935	1163619	C	2,359	203	15	–	BR
54N 02W 34CCB1	475847116340201	475847	1163406	C	2,189	144	15	3	SVRPA
54N 03W 27DDC1	475935116405001	475933	1164057	C	2,178	90	55	61	SVRPA
54N 03W 32CDA1	475852116435501	475852	1164355	C	2,339	300	12	.24	MULT
54N 03W 33DBA1	475905116421701	475905	1164217	C	2,364	485	5.5	.02	BR
54N 04W 04AD1	480339116495801	480339	1165002	U	2,289	180	20	–	SVRPA
54N 04W 04DB1	480316116501601	480316	1165020	U	2,344	208	20	–	SVRPA
54N 04W 08AAD1	480249116510001	480252	1165104	C	2,326	198	15	–	SVRPA
54N 04W 08BD1	480234116514401	480234	1165148	U	2,344	261	15	–	SVRPA
54N 04W 09BBB1	480300116505801	480300	1165102	U	2,324	240	40	–	SVRPA
54N 04W 10BBA1	480300116492401	480259	1164927	C	2,234	133	30	.73	SVRPA
54N 04W 10BC1	480237116493001	480237	1164934	U	2,264	160	30	–	SVRPA
54N 04W 17CBA1	480139116515701	480139	1165201	C	2,315	207	10	.24	SVRPA
54N 04W 17DC1	480122116513001	480122	1165134	U	2,384	280	20	–	SVRPA
54N 04W 19BCD1	480051116532101	480052	1165308	C	2,304	200	20	–	SVRPA
54N 04W 19CD1	480028116530201	480028	1165306	U	2,381	304	15	–	SVRPA
54N 04W 19DD1	480035116523201	480035	1165236	U	2,384	282	15	–	SVRPA
54N 04W 29ABC1	480015116512901	480015	1165134	C	2,432	360	15	.22	SVRPA
54N 04W 29DBB1	475955116512301	475955	1165127	U	2,454	500	30	–	SVRPA

Table 3. Physical data for wells used in the characterization of the hydrogeologic system of the Spokane Valley-Rathdrum Prairie aquifer study area, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.—Continued

[**USGS site No.** is based on the initial latitude and longitude determined for the site. The site No. does not change if more accurate latitude/longitude values are determined after the site is first created. **Data reliability:** C, field checked; U, not field checked but data considered reliable; M, minimal data available for site. **Hydrogeologic unit:** BASALT, Columbia River basalt and(or) Latah Formation interbeds; BR, bedrock; NA, not applicable; MULT, multiple units; SVRPA, Spokane Valley-Rathdrum Prairie Aquifer; and UNK; unknown. **Abbreviations:** USGS, U.S. Geological Survey; NAVD 88, North American Vertical Datum of 1988; NAD 83, North American Datum of 1983; ft, foot; gal/min, gallon per minute; (gal/min)/ft, gallon per minute per foot; –, no data]

Well No.	USGS site No.	Latitude (NAD 83)	Longitude (NAD 83)	Data reliability	Land-surface altitude (NAVD 88)	Hole depth (ft)	Yield (gal/min)	Specific capacity (gal/min)/ft)	Hydro-geologic unit
54N 04W 30ADB1	480008116523301	480008	1165237	U	2,424	480	50	–	SVRPA
54N 04W 30BAB1	480021116531201	480021	1165312	C	2,401	423	30	–	SVRPA
54N 04W 31BBC1	475922116533801	475922	1165338	C	2,394	462	20	–	SVRPA
54N 04W 31BCB1	475913116531101	475918	1165336	C	2,347	390	–	–	SVRPA
54N 04W 31DA1	475904116522301	475904	1165227	U	2,564	602	50	–	SVRPA
54N 04W 31DDD1	475844116521801	475844	1165222	C	2,564	538	6	1.5	SVRPA
54N 04W 32CCB1	475849116521601	475849	1165216	C	2,577	582	10	–	SVRPA
54N 04W 35DAB1	475858116472201	475859	1164721	C	2,487	400	30	2	SVRPA
54N 05W 18AAA1	480207117001401	480205	1170018	C	2,284	146	42	–	SVRPA
54N 05W 22AA1	480103116563001	480103	1165634	U	2,314	203	30	–	SVRPA
54N 05W 22ACA1	480101116563601	480101	1165639	C	2,317	175	20	.8	SVRPA
54N 05W 23DBA1	480046116552201	480046	1165526	U	2,294	219	100		SVRPA
54N 05W 25BAD1	480017116541601	480017	1165420	C	2,293	139	120	–	SVRPA

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Appendix A. Highland and Side Valley Inflow Estimates, By Jon E. Hortness

Inflow from highlands and side valleys adjoining the Spokane Valley Rathdrum Prairie (SVRP) aquifer has been the least examined component of the SVRP ground-water budget. Published estimates are few and span a wide range. Drost and Seitz (1978) estimated the total inflow to the aquifer to be about 1,320 ft^3/s. Of this total inflow, 323 ft^3/s (about 25 percent) was estimated as ground-water inflow from adjoining highlands and side valleys that do not have a lake at the valley mouth. By contrast, Buchanan's (2000) model does not include ground-water inflow from adjoining highlands and side valleys. A model of the Spokane Valley completed by CH2M HILL (1998) was calibrated using values of 40 ft^3/s (autumn 1994 conditions) and 79 ft^3/s (spring 1995 conditions) for ground-water inflow from adjoining highlands and side valleys.

Estimates of the mean annual discharge from adjoining highlands and side valleys were obtained using existing regional regression equations developed by the USGS (Hortness and Berenbrock, 2001). These regression equations can be used to estimate the mean annual discharge at ungaged sites on streams in Idaho and in parts of adjacent states that are unaffected by regulations and (or) diversions. The equations were developed using mean-annual-discharge values from long-term gaging stations in the area. The equations relate the mean annual discharge to various physical and climatic characteristics (basin characteristics) of the upstream drainage basin.

Estimates of the mean annual discharge at ungaged locations on streams near the point where they flow onto the SVRP aquifer were obtained by determining the required basin characteristics for the upstream drainage basins and inserting those values into the appropriate regression equation. In the case of the SVRP aquifer, nearly all surface flows from adjoining highlands and side valleys quickly infiltrate into the highly permeable sediments overlying the aquifer. Therefore, estimates of surface flows at locations just prior to where the streams flow onto the SVRP aquifer are assumed to be reasonable estimates of inflow to the aquifer from those streams.

Methods

Both ArcGIS-ArcHydro tools (Environmental Systems Research Institute, Inc., 2005) and the USGS StreamStats web application (Ries and others, 2004) were used to obtain the estimates of mean annual discharge. The estimation approaches are identical except for the resolution of the digital elevation model (DEM) used. All highlands and side valleys in Idaho were analyzed using ArcGIS-ArcHydro tools where a 10-meter resolution DEM was available. Because the 10-meter DEM was not available for the Washington area of interest at the time of the analyses, the USGS StreamStats application was used to complete the analyses for the highlands and side valleys in Washington using a 30-meter DEM.

Results

Estimated discharges for 72 basins (fig. A1) adjacent to the SVRP aquifer are shown in table A1. Hortness and Berenbrock (2001) presented a standard error of estimate for each of the regression equations used. Depending on the location of the sites used in this analysis and their corresponding regression-equation region (fig. 2; Hortness and Berenbrock, 2001), the standard errors of estimate for the final results are as follow: Region 1, +57.4 to -36.5 percent; Region 2, +56.5 to -36.1 percent; and Region 3, +18.1 to -15.3 percent. It is important to note that because many of the mean annual discharge estimates are relatively small, even a large percentage of error will not necessarily result in a large-magnitude error range around the value.

Hortness and Berenbrock (2001) stated that the results might not be reliable for sites where the basin-characteristic values are outside of the range of values that were used to develop the equations. Because several of the locations where estimates were obtained had basin-characteristic values, most often drainage area, outside of this range, additional analyses and hydrologic judgment were used to determine whether the final estimates were reasonable. The analyses included a simple comparison with estimates of mean annual discharge per unit area obtained from long-term gaging station data from similar sites in the area.

The results are not reliable for sites where streamflow is affected by upstream diversions and (or) regulations, or by significant spring inflows (Hortness and Berenbrock, 2001). Because most of the highland and side valley areas are relatively undeveloped and produce relatively low amounts of streamflow, it is assumed that diversions and regulations are minimal or nonexistent. Inflow from springs is more likely to occur but is difficult to quantify. Thus, it is important to note that spring inflows in certain highland or side valley areas could result in larger discharge values than those estimated using the regression equations.

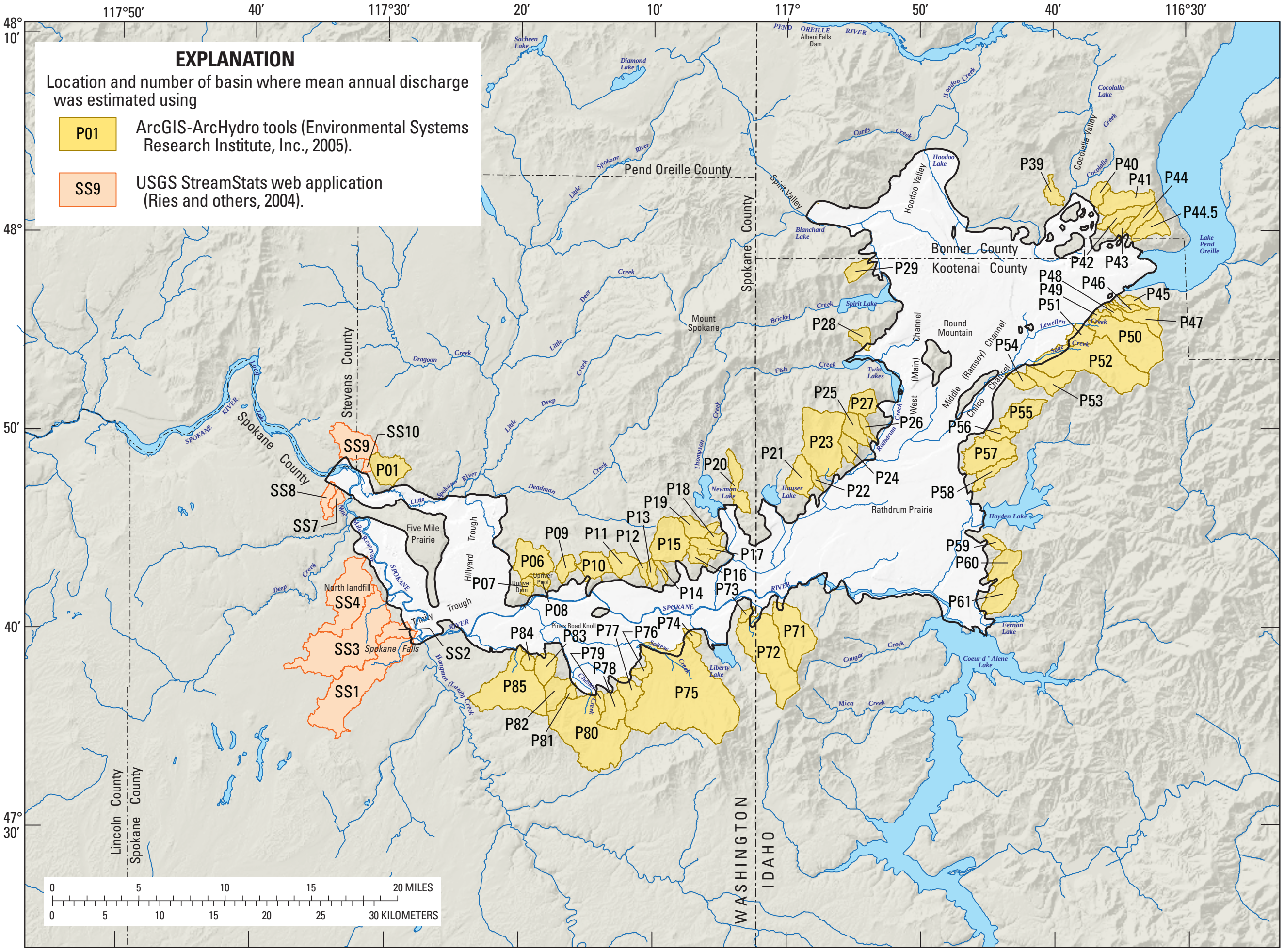

Figure A1. Location of selected basins adjacent to the Spokane Valley-Rathdrum Prairie aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho, for which mean annual discharge was estimated.

Table A1. Estimated mean annual discharge from selected basins adjacent to the Spokane Valley-Rathdrum Prairie aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.

[Basin locations are shown in figure A1. **Confidence limit** based on one standard error (67 percent confidence limit). **Abbreviations:** DMS, degree-minute-second; ft^3/s, cubic foot per second]

Basin No.	Location		Estimated discharge values (Hortness and Berenbrock, 2001)			
	Latitude (DMS)	Longitude (DMS)	Regression equation region	Mean annual discharge (ft^3/s)	Confidence limit (ft^3/s)	
					Upper	Lower
P01	47°47’07”N	117°29’39”W	1	2.03	3.20	1.29
P06	47°43’06”N	117°20’32”W	1	2.33	3.66	1.48
P07	47°41’35”N	117°19’10”W	2	.02	.04	.01
P08	47°41’53”N	117°17’55”W	2	.01	.02	.01
P09	47°42’13”N	117°16’50”W	2	.06	.10	.04
P10	47°42’24”N	117°13’52”W	2	.06	.10	.04
P11	47°42’29”N	117°12’30”W	2	.08	.12	.05
P12	47°42’09”N	117°10’31”W	2	.06	.09	.04
P13	47°42’04”N	117°10’07”W	2	.08	.13	.05
P14	47°42’16”N	117°09’05”W	2	.07	.12	.05
P15	47°43’22”N	117°08’11”W	2	1.51	2.36	.96
P16	47°43’06”N	117°06’04”W	2	.16	.25	.10
P17	47°44’00”N	117°04’33”W	2	.38	.59	.24
P18	47°44’54”N	117°04’42”W	2	.15	.24	.10
P19	47°45’18”N	117°05’01”W	2	.73	1.14	.47
P20	47°46’11”N	117°04’02”W	2	1.29	2.02	.83
P21	47°46’27”N	116°58’18”W	2	1.27	1.98	.81
P22	47°46’52”N	116°57’16”W	2	.13	.20	.08
P23	47°47’44”N	116°56’30”W	2	6.60	10.3	4.22
P24	47°48’14”N	116°54’57”W	2	.96	1.50	.61
P25	47°49’09”N	116°53’52”W	2	1.70	2.66	1.08
P26	47°49’21”N	116°53’16”W	2	.54	.84	.34
P27	47°51’14”N	116°53’13”W	2	1.80	2.82	1.15
P28	47°54’14”N	116°53’49”W	2	.93	1.45	.59
P29	47°58’29”N	116°53’34”W	1	1.93	3.04	1.23
P39	48°01’18”N	116°39’17”W	1	1.00	1.57	.63
P40	48°01’18”N	116°37’05”W	1	.95	1.49	.60
P41	48°00’53”N	116°36’42”W	1	3.33	5.24	2.11
P42	48°00’19”N	116°36’46”W	1	1.85	2.92	1.18
P43	47°59’42”N	116°35’07”W	1	.83	1.30	.53
P44	47°59’45”N	116°34’30”W	1	2.27	3.58	1.44
P44.5	47°59’25”N	116°34’04”W	1	3.22	5.06	2.04
P45	47°56’45”N	116°35’07”W	1	1.00	1.58	.64
P46	47°56’29”N	116°35’40”W	1	.66	1.03	.42
P47	47°56’24”N	116°35’54”W	1	4.32	6.80	2.74
P48	47°56’20”N	116°36’16”W	2	.32	.51	.21
P49	47°56’03”N	116°36’51”W	2	.32	.49	.20
P50	47°55’33”N	116°37’27”W	2	10.7	16.7	6.83
P51	47°54’33”N	116°39’08”W	2	.74	1.15	.47
P52	47°53’21”N	116°41’31”W	2	15.1	23.6	9.64
P53	47°53’16”N	116°41’60”W	2	3.14	4.91	2.00
P54	47°52’49”N	116°43’40”W	2	.57	.90	.37
P55	47°50’34”N	116°44’08”W	2	1.77	2.76	1.13
P56	47°49’58”N	116°45’14”W	2	.34	.54	.22
P57	47°47’49”N	116°46’37”W	2	1.21	1.90	.77
P58	47°46’55”N	116°46’09”W	2	.39	.61	.25
P59	47°44’21”N	116°45’10”W	2	.41	.64	.26
P60	47°42’20”N	116°44’48”W	2	1.42	2.22	.91

Table A1. Estimated mean annual discharge from selected basins adjacent to the Spokane Valley-Rathdrum Prairie aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho—contined.

[Basin locations are shown in figure A1. **Confidence limit** based on one standard error (67 percent confidence limit). **Abbreviations:** DMS, degree-minute-second; ft^3/s, cubic foot per second]

Basin No.	Location		Estimated discharge values (Hortness and Berenbrock, 2001)			
	Latitude (DMS)	Longitude (DMS)	Regression equation region	Mean annual discharge (ft^3/s)	Confidence limit (ft^3/s) Upper	Lower
P61	47°40’51”N	116°45’24”W	2	1.16	1.82	0.74
P71	47°41’16”N	117°00’34”W	2	2.48	3.88	1.58
P72	47°40’45”N	117°02’01”W	2	3.55	5.55	2.27
P73	47°41’06”N	117°02’39”W	2	.05	.07	.03
P74	47°39’56”N	117°07’25”W	2	.00	.01	.00
P75	47°38’59”N	117°10’55”W	2	3.61	5.65	2.31
P76	47°37’55”N	117°11’41”W	2	.03	.05	.02
P77	47°37’27”N	117°12’39”W	2	.23	.36	.15
P78	47°36’52”N	117°13’17”W	2	.52	.82	.34
P79	47°36’45”N	117°14’18”W	2	.07	.11	.05
P80	47°36’44”N	117°14’36”W	2	1.09	1.71	.70
P81	47°37’13”N	117°15’52”W	2	.01	.01	.01
P82	47°37’27”N	117°16’08”W	2	.20	.32	.13
P83	47°38’41”N	117°18’27”W	2	.16	.25	.10
P84	47°38’48”N	117°19’22”W	2	.09	.15	.06
P85	47°38’59”N	117°20’12”W	2	.57	.89	.36
SS1	47°39’24”N	117°28’02”W	3	1.57	1.86	1.33
SS2	47°39’45”N	117°27’44”W	1	1.03	1.62	.66
SS3	47°41’17”N	117°29’53”W	1	7.37	11.6	4.68
SS4	47°43’32”N	117°31’28”W	1	4.15	6.52	2.63
SS7	47°46’54”N	117°33’24”W	1	.30	.47	.19
SS8	47°47’12”N	117°33’52”W	1	.62	.98	.39
SS9	47°48’32”N	117°33’13”W	1	2.40	3.77	1.52
SS10	47°47’49”N	117°31’58”W	1	.29	.46	.19
Total				112		

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Kahle and Bartolino

Hydrogeologic Framework and Ground-Water Budget of the Spokane Valley-Rathdrum Prairie Aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho

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