The Spokane Valley-Rathdrum Prairie Aquifer Atlas

2009 Update

Contents

Welcome!

The Spokane Valley-Rathdrum Prairie Aquifer Atlas presents a comprehensive summary of the region's most precious groundwater resource and is a basic reference of the geographic, geologic and hydrologic characteristics of this Aquifer. It is intended for broad community use in education, planning, and general technical information. The preparation and publication of the original Atlas were partially funded by a United States Environmental Protection Agency aquifer wellhead protection grant.

The Spokane Valley-Rathdrum Prairie Aquifer spans two states (Washington and Idaho) and lies within four counties (Kootenai, Bonner, Stevens and Spokane). Natural resources, such as the Aquifer, that cross political boundaries are often subject to different, and sometimes conflicting standards, protection and uses. This Atlas is a joint effort by agencies in both states to create a holistic representation of the Aquifer as both a geologic feature and a natural resource used daily by more than 500,000 people.

Political boundaries are absent on the front cover map. The authors intend the reader to first view the Aquifer as a continuous natural feature, then investigate the various aquifer elements presented in this Atlas. The authors believe that factual information about the Aquifer will generate greater public understanding of the region's groundwater and lead to continued protection and wise use of this precious and finite resource.

The original Aquifer Atlas was published in 2000, and an Update was issued in 2004. This document is an update of the 2004 publication that includes information from the 2007 USGS Bi-State Aquifer Study.

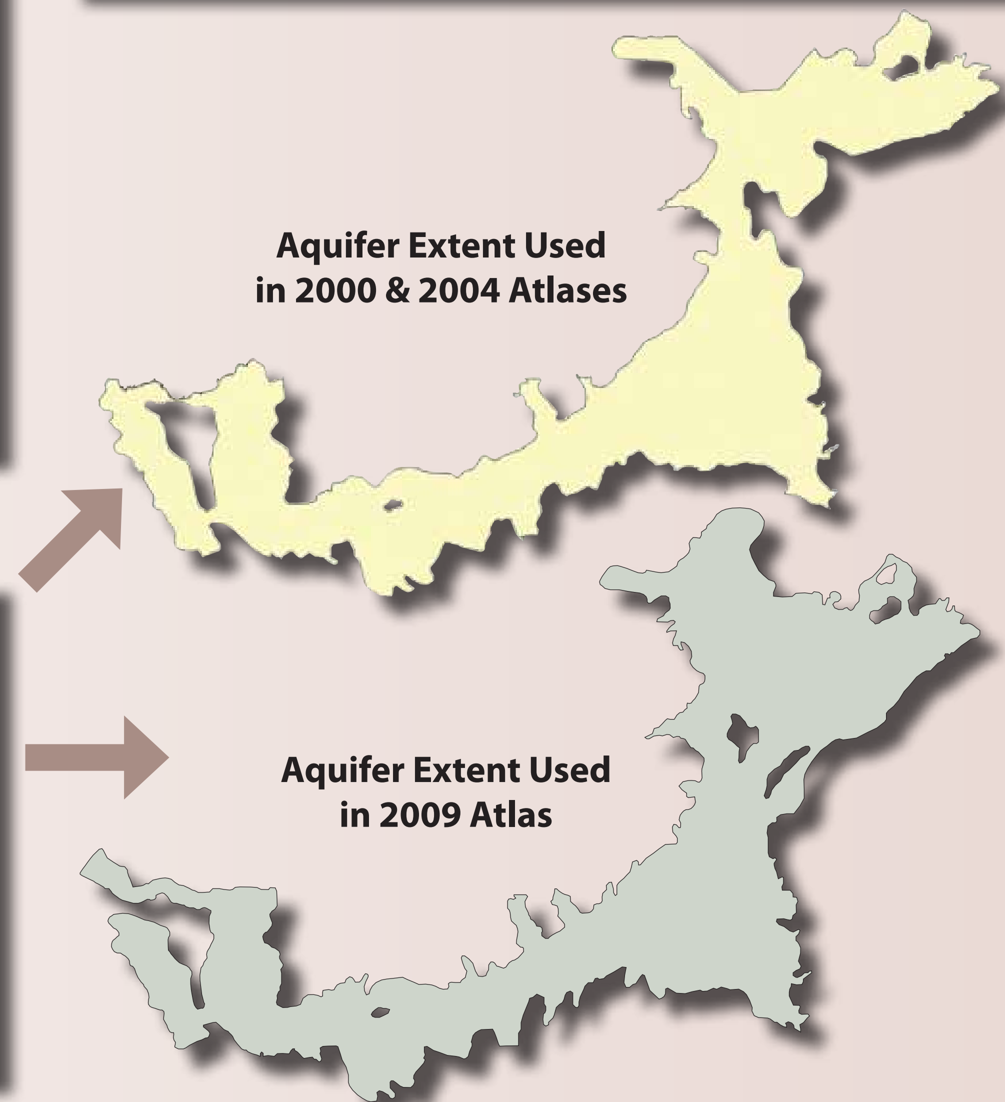
A Bi-State Aquifer Study

In response to concerns about continued growth, water management issues, and water availability, a bi-state aquifer study was initiated in 2004 by the Idaho Department of Water Resources, the Washington Department of Ecology, and the U.S. Geological Survey. The study was funded by: Congressional appropriations through the U.S. Environmental Protection Agency, state funding from both the Washington and Idaho legislatures and staff support from both state agencies. The total study cost was approximately $3.5 million.

Building upon previous studies and new data from a coordinated ground and surface water monitoring program conducted in 2004-2005, the study reassessed the hydrogeology and water budget of the Spokane Valley-Rathdrum Prairie Aquifer (Aquifer). The Aquifer boundary has been redrawn to reflect recently available geologic information (see below), and the result is a new, detailed estimate of the shape of the basin. A key objective of the study was to develop a ground-water flow model to serve as a tool for estimating Aquifer dynamics, and the model was completed in 2007. Results of this study were incorporated into this Atlas update.

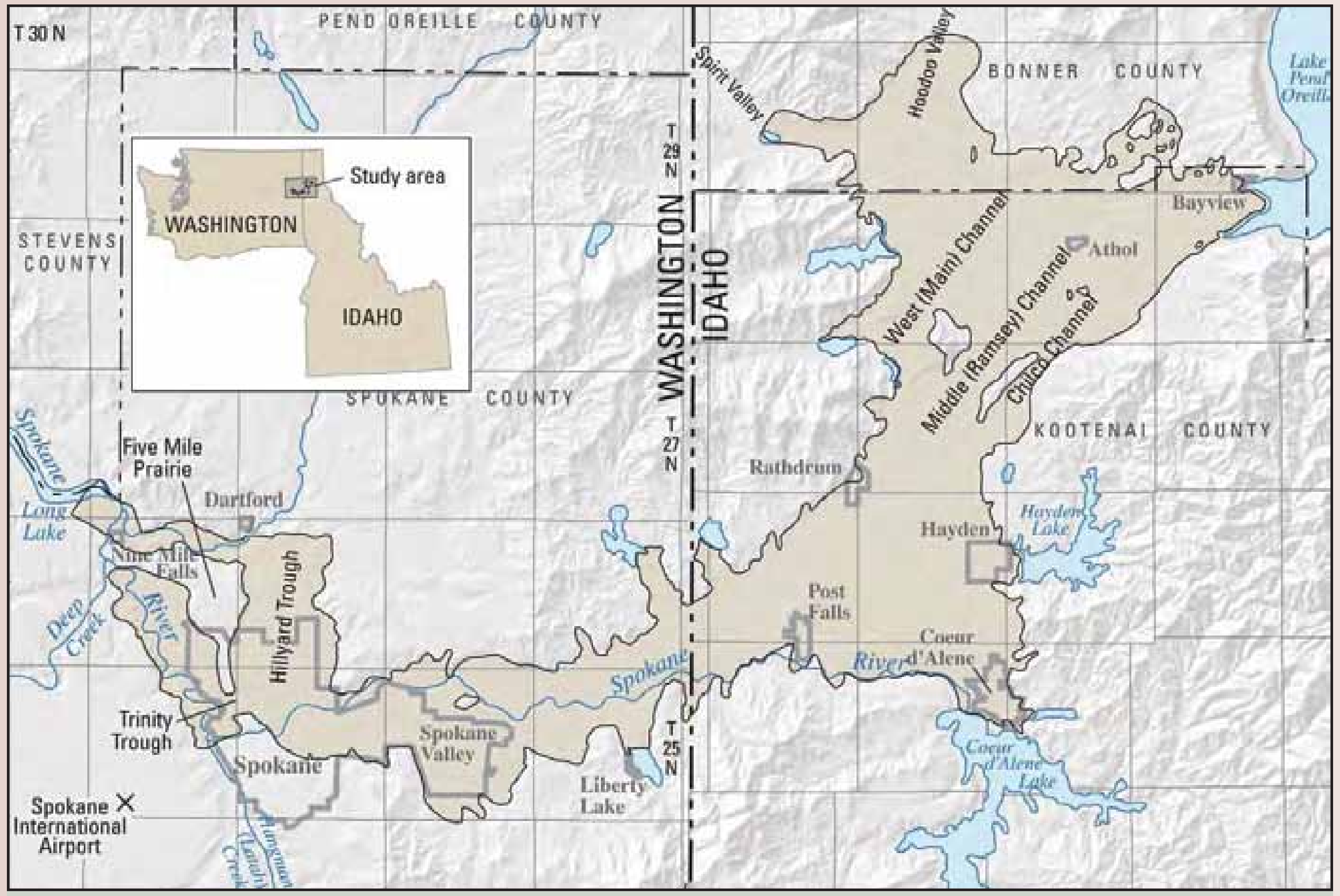
Aquifer Extent

The Aquifer extent designations differ somewhat between investigators and over time. The 2000 and 2004 Aquifer Atlases used a modified version of the original Sole Source Aquifer boundary designated by the USEPA in 1978, as shown at upper right. The extent used in this document is the same defined in 2005 by the USGS in their Scientific Investigations Report 2005-5227, as shown at right and on page 19. The Aquifer extent used in the 2007 groundwater modeling (see page 17) is a modified version of the 2005 USGS extent.



Navigating the Atlas

The pages are organized into four (4) theme categories with a unique color for each.



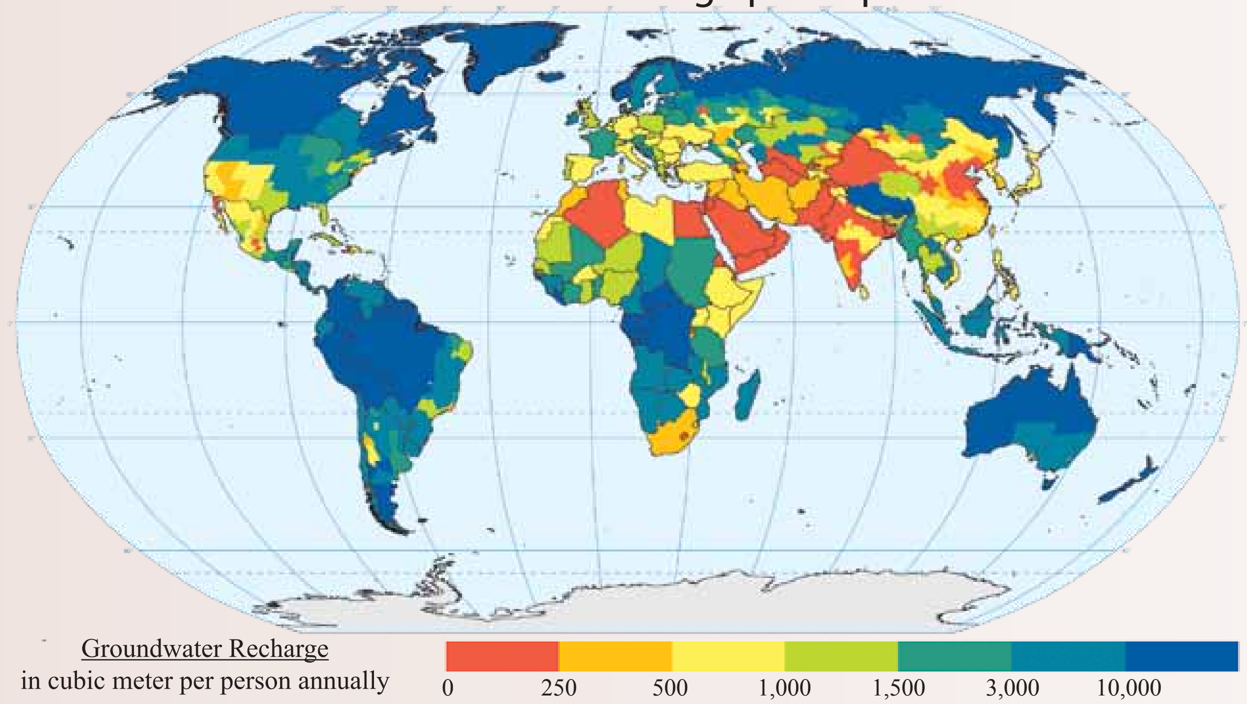
The Aquifer

The sole source of water for most people in Spokane County, Washington and Kootenai County, Idaho, is a large underground rocky formation containing high-quality water called the Spokane Valley-Rathdrum Prairie Aquifer (Aquifer), and it is also commonly known as the "Rathdrum-Spokane Aquifer." Discovered in 1895, this Aquifer has become one of the most important resources in the region, supplying drinking water to more than 500,000 people. The Aquifer has been studied in considerable detail since 1977, and the results of these investigations have produced programs and regulations designed to ensure this aquifer will remain a valued and protected resource for future generations.

The Spokane Valley and Rathdrum Prairie are ancient geologic features that have, over millions of years, been formed by water flowing from the western slopes of the Rocky Mountains to the Pacific Ocean. During the last Glacial Age (18,000 to 12,000 years ago), and possibly in multiple previous Ice Ages, cataclysmic floods inundated North Idaho and Washington as a result of the rapid draining of Glacial Lake Missoula when ice dams broke (see pages 7 and 8). These floods deposited thick layers of gravels, cobbles, and boulders. Water from adjacent lakes, mountain streams, the Spokane River, and precipitation flows through these flood deposits supplying the Aquifer.

In the 1970s area residents recognized that their unconfined aquifer could easily become contaminated. The highly permeable flood deposits, together with very thin topsoil layers in many locations, make the Aquifer highly susceptible to pollution. The Environmental Protection Agency (EPA) took the first important step to protect the Aquifer by designating the Spokane Valley-Rathdrum Prairie a "Sole Source Aquifer" in 1978. It was the second aquifer in the nation to receive this special designation. The sole source designation increased public awareness for Aquifer protection and supported the development of special management practices (such as eliminating septic tanks and pre-treating stormwater over the Aquifer) by local agencies. Presently, Aquifer protection efforts are managed cooperatively by Spokane County, local cities, agencies and utilities in Washington and by the Department of Environmental Quality and the Panhandle Health District, and local cities and counties in Idaho.

Groundwater Recharge per Capita



Earth's Water

Of all the Earth's water, only about 3% is fresh water. The majority of fresh water is found in icecaps and glaciers (68.7%) and groundwater (30.1%). A global view of groundwater is provided in the map above. The remaining 1.2% of freshwater is contained in lakes, rivers, swamps, the atmosphere and the soil. Our Aquifer with its ample quantity of fresh, potable groundwater is a rare feature in the world.

Climate Change

The Climate Impacts Group (CIG) located at the University of Washington (Seattle) is studying the impacts of natural climate variability and global climate change on the U.S. Pacific Northwest. The CIG used climate computer models to assess probable impacts associated with projected 21st century changes in climate that indicate three major changes for the Inland Northwest.

First, winter snow pack will be lower than normal. Second, while total annual precipitation will remain about the same, extreme high precipitation events will increase. Third, temperatures are projected to increase across all seasons with the largest temperature increases in summer.

As these changes occur, the Inland Northwest will likely experience peak stream flows earlier in the spring and with greater variability. How the impacts of climate change may affect Aquifer recharge deserves further study.

Aquifer Facts

Our Aquifer underlies about 370 square miles in two states. It has one of the fastest flow rates in the United States, flowing as much as 60 feet per day in some areas. In comparison, a typical aquifer has a flow rate between 1/4-inch and five feet per day. The volume of the entire Aquifer is about 10 trillion gallons, making it one of the most productive aquifers in the country.

SPOKANE'S WATER PUREST IN WORLD

City Bacteriologist Frank Rose Reports Results No Colon Bacilli Found

Showing the Spokane water supply purer than the average of American cities, Frank Rose, city bacteriologist, has made a report of tests from the city well made monthly since last October. The tests are simply counts of the number of bacteria found in a cubic centimeter of water.

The average count shows only seven or eight germs in that amount of water. The test was made from water taken from the drinking fountain at Howard street and Riverside avenue or from water from a faucet in the Rookery building. Speaking of his tests, Dr. Rose said:

"It can be said that there is no city in the world that has a better water supply than Spokane. Water which shows 100 germs in a cubic centimeter is considered comparatively pure and drinkable. I made from four to eight counts monthly since last October, and the counts in any one month was 17 bacteria, while the tests last month showed 15 bacteria in eight tests, less than two each.

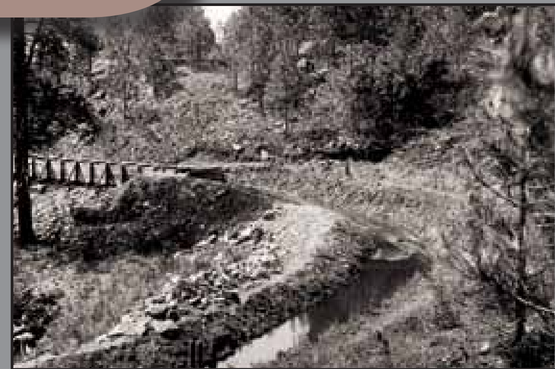
"In April, 1908, I made tests of the river water from which Spokane got its drinking supply at that time. I took water from the place where the Coeur d'Alene sewer emptied into it and another sample from a place about 500 feet below the outlet of the sewer. In both cases the number of bacteria was so great as to be practically uncountable.

"In contrast to this is the practical purity of the water since last October. Special care was taken to make tests for colon bacilli, which show the presence of sewage, and in no case was there a single trace."

Spokesman-Review
Thursday, May 6, 1909

Historic Aquifer

Modern Electric & Water, 3,000 GPM, 1908



Irrigation System, Post Falls, ID 1900

Pines Rd looking south to Broadway, 1908

Post Falls Lumber Co sawmill pre-1902

Apple orchard in Opportunity, WA 1908

Overview of Fort Sherman, ID 1890

Wood stave pipe, Rathdrum Prairie, ID 1961

Vera Water & Power, 1908

2004 photo with same view as watercolor

3

In 1860, James Madison Alden painted this watercolor of the Spokane Valley from near the present-day Arbor Crest Winery. In the foreground is Plante's Ferry.

Aquifer Timeline

Since 1977 cities, counties, health districts, and states over the SVRP Aquifer have adopted regulations and programs to protect the Aquifer from contamination. These include critical and hazardous materials regulations, storage tank regulations, septic system regulations, stormwater regulations, household hazardous waste collection programs, and wellhead protection plans.

1860
James Madison Alden paints "Plante's Crossing" shown on page 3.

1894
Aquifer accidently discovered by City of Spokane contractor during Upriver Dam construction.

1905
Aquifer rediscovered by City of Spokane contractor while excavating for a new pump station foundation at Upriver Dam site.

1908
The Aquifer replaces the Spokane River as the City of Spokane's primary source of drinking water.

1923
Dr. J Harlen Bretz discovers the geologic process (catastrophic floods) that created the Aquifer and the channeled scablands of eastern Washington.

1931
Washington Water Power Company (Avista) prepares the first comprehensive study of groundwater in the Spokane Valley and Rathdrum Prairie.

1938
A survey of all major Washington rivers and waterways found the Spokane River the foulest water body in the state.

1940
Joseph T. Pardee, a USGS geologist, proposes that an Ice Age glacial lake (Lake Missoula) had drained rapidly creating Bretz's catastrophic floods.

1952
USGS publishes an updated inventory of Aquifer wells in the Spokane Valley.

1972
Federal Clean Water Act provides authority and funding for Aquifer protection planning efforts.

1974
EXPO '74 opens in Spokane with the theme: "Celebrating Tomorrow's Fresh New Environment."

1976
Corp of Engineers publishes 14 volume Spokane Region Water Resources Study.

1976
Local citizens and environmental groups petition the EPA to designate the Aquifer as a "Sole Source Aquifer".

1977
Local "208" studies are completed, and the sources of Aquifer pollution are identified.

1977
Panhandle Health District promulgates rule that limits domestic septic systems to one per 5 acres.

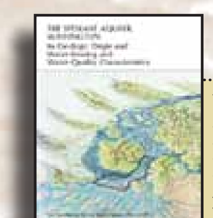
1978
EPA designates the Aquifer as a "Sole Source Aquifer" under Section 1424(e) of the Safe Drinking Water Act.

1980
IDEQ designates the Aquifer as a "special resource water" in Idaho, the highest level of state protection.

1980
Spokane County and Panhandle Health District initiate a Ground Water Monitoring Program for the Aquifer.

1985
Spokane County authorizes the Aquifer Protection Area for 20 years in a public vote.

1988
U.S. Congress provides Aquifer Protection Funding through the EPA.



1988
USGS publishes Molenaar's Aquifer Report, the first modern Aquifer study.

1995
IDEQ adopts guidelines for land applying wastewater over the Aquifer.

1997
IDEQ designates Aquifer as a "Sensitive Resource Aquifer" in the state Ground Water Quality Rule.

1998
City of Spokane and the Spokane Aquifer Joint Board publish a wellhead protection plan. Plan is updated in 2007.

1999
Local efforts to halt a new train refueling depot and other large water withdrawal projects evolve into grass roots Aquifer protection movements.

2004
Spokane County reauthorizes the Aquifer Protection Area.

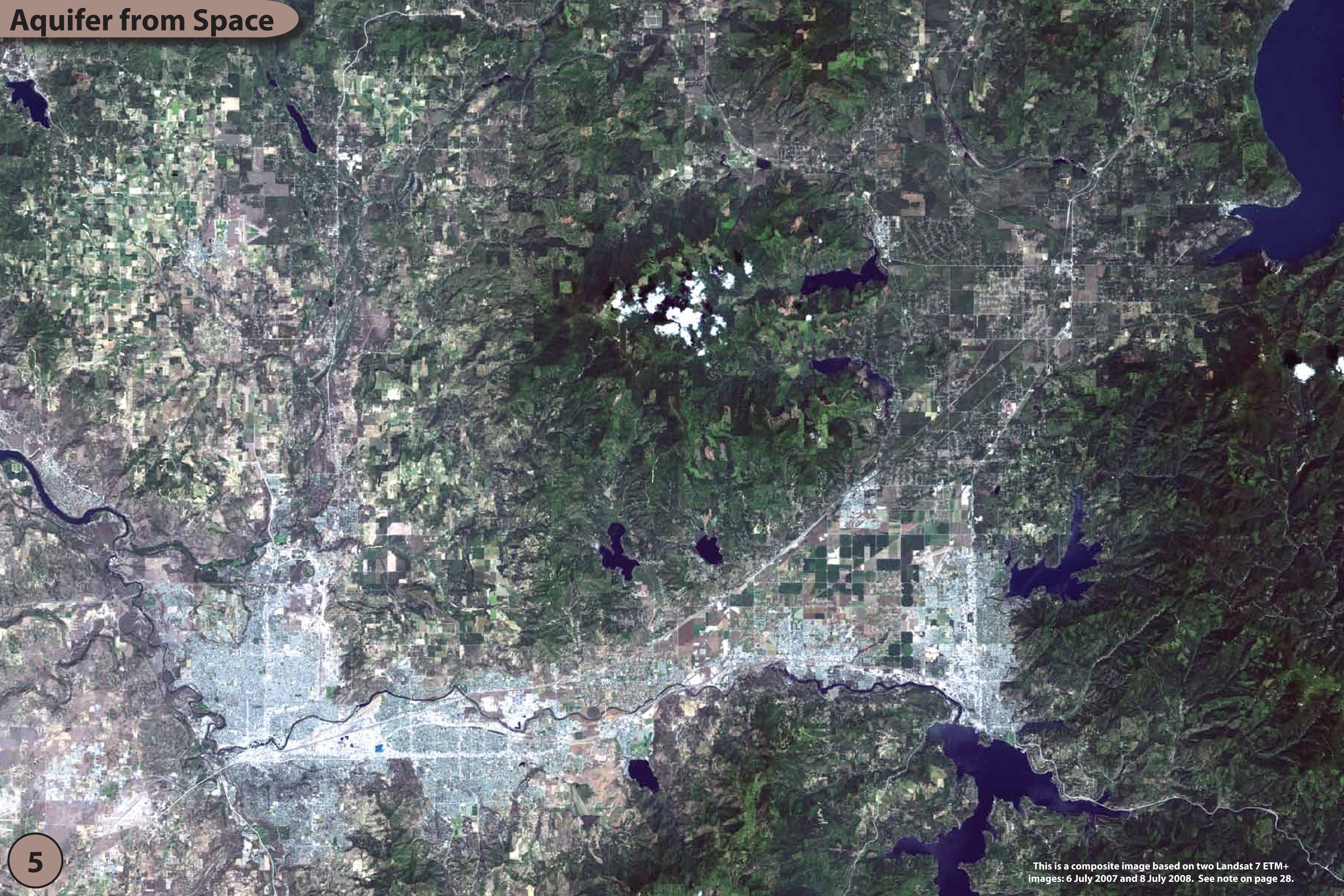
2007
Kootenai County residents vote to form and fund an Aquifer Protection District to fund Aquifer programs.

2007
The results of a four year USGS Bi-State Aquifer Study and monitoring program are presented to the Public.

1900 1910 1920 1930 1940 1950 1960 1970 1975 1980 1985 1990 1995 2000 2005 2010

Background is a photograph of the Upriver Dam constructed of timber on the Spokane River in 1895.

Aquifer from Space



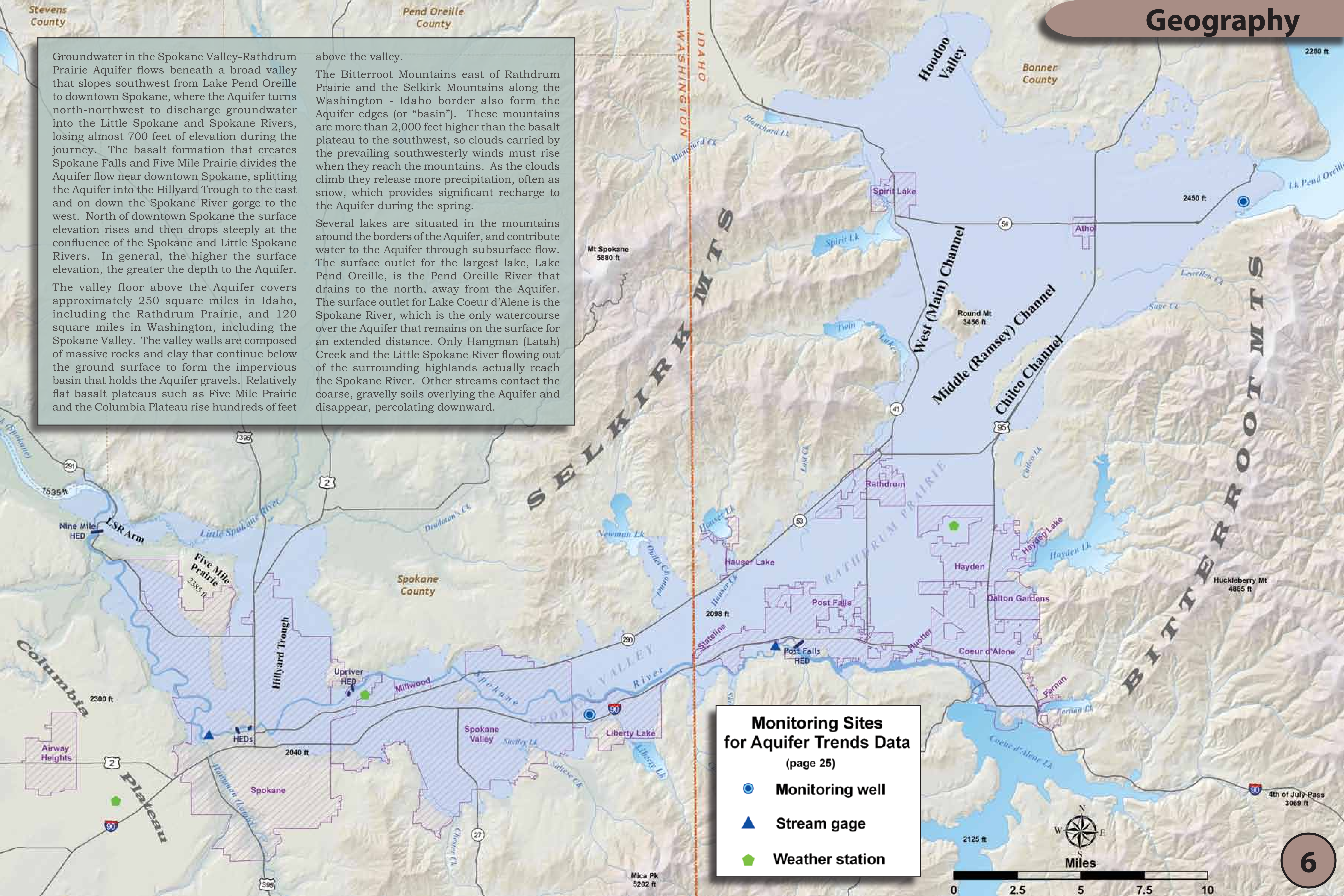
This is a composite image based on two Landsat 7 ETM+ images: 6 July 2007 and 8 July 2008. See note on page 28.

Groundwater in the Spokane Valley-Rathdrum Prairie Aquifer flows beneath a broad valley that slopes southwest from Lake Pend Oreille to downtown Spokane, where the Aquifer turns north-northwest to discharge groundwater into the Little Spokane and Spokane Rivers, losing almost 700 feet of elevation during the journey. The basalt formation that creates Spokane Falls and Five Mile Prairie divides the Aquifer flow near downtown Spokane, splitting the Aquifer into the Hillyard Trough to the east and on down the Spokane River gorge to the west. North of downtown Spokane the surface elevation rises and then drops steeply at the confluence of the Spokane and Little Spokane Rivers. In general, the higher the surface elevation, the greater the depth to the Aquifer.

The valley floor above the Aquifer covers approximately 250 square miles in Idaho, including the Rathdrum Prairie, and 120 square miles in Washington, including the Spokane Valley. The valley walls are composed of massive rocks and clay that continue below the ground surface to form the impervious basin that holds the Aquifer gravels. Relatively flat basalt plateaus such as Five Mile Prairie and the Columbia Plateau rise hundreds of feet above the valley.

The Bitterroot Mountains east of Rathdrum Prairie and the Selkirk Mountains along the Washington - Idaho border also form the Aquifer edges (or "basin"). These mountains are more than 2,000 feet higher than the basalt plateau to the southwest, so clouds carried by the prevailing southwesterly winds must rise when they reach the mountains. As the clouds climb they release more precipitation, often as snow, which provides significant recharge to the Aquifer during the spring.

Several lakes are situated in the mountains around the borders of the Aquifer, and contribute water to the Aquifer through subsurface flow. The surface outlet for the largest lake, Lake Pend Oreille, is the Pend Oreille River that drains to the north, away from the Aquifer. The surface outlet for Lake Coeur d'Alene is the Spokane River, which is the only watercourse over the Aquifer that remains on the surface for an extended distance. Only Hangman (Latah) Creek and the Little Spokane River flowing out of the surrounding highlands actually reach the Spokane River. Other streams contact the coarse, gravelly soils overlying the Aquifer and disappear, percolating downward.



Glacial Lake Missoula

Ice Age

During the Pleistocene Epoch, or Ice Age, between 10,000 and 1.6 million years ago, the Earth's climate underwent periods of alternate cooling and warming. During the periods of cooling, vast continental ice sheets grew in size and extended far beyond the polar regions. In southern Canada, the ice sheets periodically thickened and advanced southward, some reaching the northern parts of the United States. Evidence indicates that at least four, and perhaps six or more, major glaciations affected the Spokane–Coeur d'Alene area.

Ice Age Flood

As the water deepened behind the ice dam (see text box upper right), the glacial ice catastrophically failed, allowing the water in Glacial Lake Missoula to escape in an enormous "outburst" flood. The flood wave swept down the Rathdrum Prairie, through the Spokane Valley and eventually flowed across the Columbia plateau and through the Columbia Gorge to the Pacific Ocean. The Glacial Lake Missoula outburst floods had the largest velocity and flow rate of any documented floods, and they are described on the following page.

Bonneville Flood

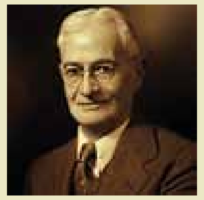
The Bonneville Flood occurred about 15,000 years ago when Lake Bonneville, which covered much of Utah, overtopped and flowed north to the Snake River in Idaho. The Bonneville flood released 1,000 cubic miles of water, about twice the volume of the largest Missoula flood. However, unlike the Missoula ice age floods, the Bonneville Flood occurred only once, and lasted over a period of several weeks.

Glacial Lake Columbia

Glacial Lake Columbia existed during the same period as Glacial lake Missoula. It was created when the Okanogan Ice Lobe advanced south and blocked the Columbia River. Glacial Lake Columbia was about 1,500 square miles at its greatest extent, and it was shallower than Glacial Lake Missoula, perhaps 500 to 700 feet deep. The Rathdrum Prairie and the Spokane Valley were covered at times by Glacial Lake Columbia. Some of the ice age floods from Glacial Lake Missoula flowed into and through Glacial Lake Columbia. Occasionally the Columbia River Ice Lobe would extend south and divide Glacial Lake Columbia, and the eastern portion of the divided lake is called Glacial Lake Spokane.

Ice Dam

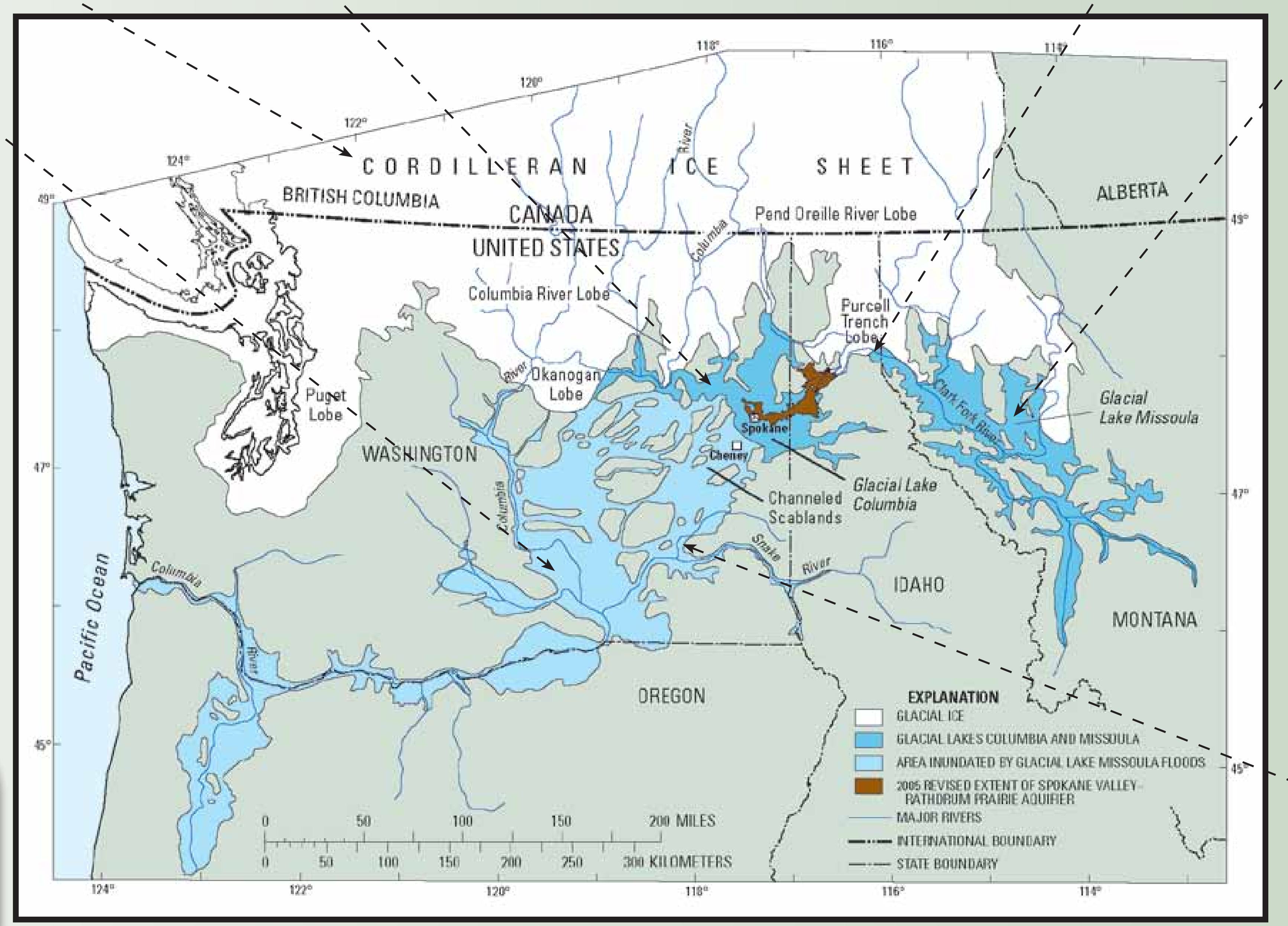
The last of the Ice Age glacial advances occurred between 10,000 and 22,000 years ago and had the most significant effect on the present landscape. Eventually, an ice lobe (a separate tongue of the glacier mass) moved into the valley of the north-flowing Clark Fork River near Sandpoint, Idaho and formed a massive ice dam across the valley, and the Purcell Trench Lobe completely covered the present-day Lake Pend Oreille. At the maximum glacial advance, the ice lobe dam was between 2,150 and 2,500 feet high, and melt water from other glaciers far up the Clark Fork River drainage became ponded behind the ice dam. Eventually the ponded melt water formed a vast lake, Glacial Lake Missoula, which occupied the intricate system of valleys in western Montana.



Joseph T. Pardee (1871-1960) was a U.S. Geological Survey geologist who built on the earlier J Harlen Bretz's theory of eastern Washington cataclysmic floods, tracing the floods' origin to Glacial Lake Missoula and publishing his work in 1942.

Glacial Lake Missoula

Glacial Lake Missoula existed during the period 13,000 to 15,000 years ago. At its highest level, the glacial lake covered an area of about 2,900 square miles and contained an estimated 500 cubic miles of water. At its maximum elevation, the lake was about 950 feet deep at present-day Missoula, more than 1,100 feet deep at the south end of Flathead Lake, and about 2,000 feet immediately behind the ice dam. At the same time, similar lakes, such as Glacial Lake Columbia, were formed by the melt water from local mountain glaciers and snow fields elsewhere in the valleys and basins of the Northwest interior.



Palouse Falls

The 200 foot high Palouse Falls is an artifact of the ice age floods originating with the draining of Glacial Lake Missoula. The Palouse River was captured and diverted to its present location by the floods.

Aquifer Facts

Glacial Lake Missoula Facts: The ice dam that created the lake was almost one half mile high and as much as 30 miles across. The deepest part of the lake was about 2,000 feet. The lake was approximately 200 miles long and roughly the size of Lake Erie and Lake Ontario combined. It drained and filled often with perhaps 40 to 140 years between floods.

J Harlen Bretz (1881-1981) was a University of Chicago professor who studied the channelled scablands of eastern Washington. His 1923 theory proposed the scablands resulted from a catastrophic ice age glacial flood, an idea that was not accepted until 1940.

What is a Jökulhlaup?

Jökulhlaup is an Icelandic term that has been adapted into the English language, and originally only referred to glacial outburst floods from Vatnajökull, which are triggered by volcanic eruptions, but now is accepted to describe any abrupt and large release of sub-glacial water.

Aquifer Formation

Passing through the Rathdrum Prairie and Spokane Valley, floodwaters carried great quantities of sediment. The heavier, larger materials (boulders, cobbles, and coarse gravel) were deposited along the main valley on top of the previously accumulated glacial outwash materials. These coarse materials today underlie the Rathdrum Prairie-Spokane Valley lowland and form the water-bearing formation we call the Spokane Valley-Rathdrum Prairie Aquifer. Above is a cross section of a Spokane Valley gravel pit that illustrates the ice age flood episodes: various layers of sands, gravels and cobbles.

Palouse River Cataract Canyon

Glacial Lake Missoula floodwaters cut the Palouse River cataract canyon after leaving the Cheney-Palouse Scabland. The canyon is a discontinuous collection of coulees, cataracts and buttes that extends for 11 miles between Washtucna Coulee and the Snake River.

Ice Age Floods

The rapid draining of over 500 cubic-miles of water in Glacial Lake Missoula, probably in only a few days, resulted in a maximum discharge across the Columbia Plateau 10 times the combined flow of all the rivers of the world today. The painting above is an artist's rendition of the "Purcell Plug", the glacial lobe that created the Glacial Lake Missoula dam. The painting at left illustrates the very beginning of the ice dam breach and the start of an ice age flood. The floods occurred repeatedly perhaps every 40 to 140 years. Paintings courtesy of Stev Ominski; used with permission.

Rathdrum Prairie-Spokane Valley

Within a few minutes of the Glacial Lake Missoula ice dam failure, flood waters on the Rathdrum Prairie were about 440 feet high traveling at 76 miles per hour. As the flood continued into the Spokane Valley, the flow was constricted and rose to 570 feet. During the 3-day draining of the lake, flood water velocities over the Rathdrum Prairie-Spokane Valley ranged from 56 to 100 miles per hour with an astounding minimum discharge of 4.5 billion gallons per second.

Lakes

The floods created a few small lakes perched in the lower parts of tributary mountain valleys. These lakes include Spirit, Twin, Hauser, and Newman Lakes on the flanks of the Spokane Mountain area, Hayden Lake at the base of the Coeur d'Alene Mountains, and Liberty Lake below Mica Peak. Discharges from the lakes percolate rapidly into the main valley gravels, and only a few short stream channels exist.

Aquifer Facts

Ice Age Flood Facts: The flood waters spilled into the Snake River causing the river water to backup past present-day Lewiston, Idaho. About 50 cubic miles of rich topsoil was stripped by the floods from the area we call "scablands" and was re-deposited in the Tualatin, Yamhill and Willamette valleys of western Oregon. The flood waters carved the fifty-mile-long Grand Coulee in central WA.

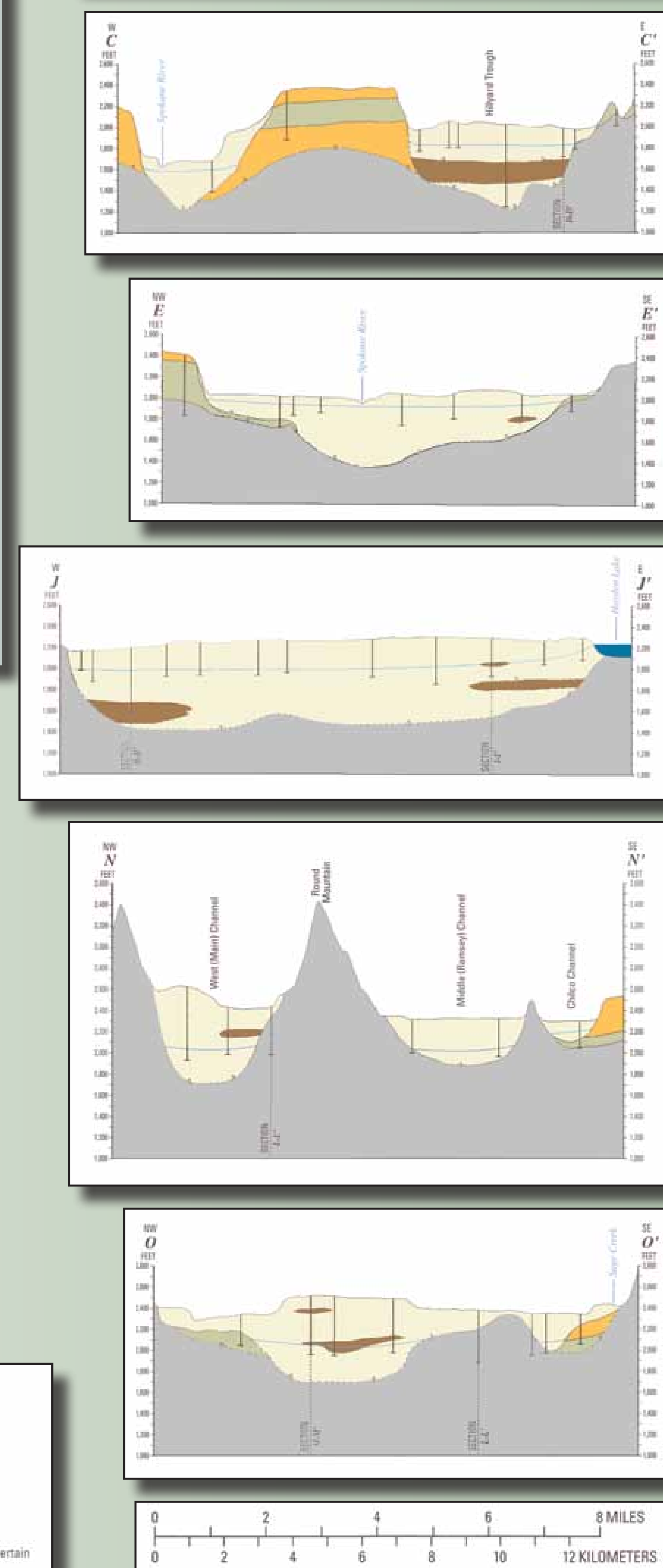
Geology

Several geologic regimes come together near and over the Spokane Valley-Rathdrum Prairie Aquifer, creating a richly varied and interesting geologic setting. The geologic history of this area includes ancient mountain building, spectacular basalt lava flows, and some of the largest known glacial outburst floods. The map on the opposite page provides a visual description of the surface geology of the Aquifer area.

Throughout the Idaho Panhandle and the mountains around the Spokane Valley of Washington, the Belt Formations of Proterozoic sedimentary rocks dominate the geologic landscape. These rock formations were named after the Belt Mountains of central Montana, where they were first studied. The Belt Formations of Idaho and Washington consist mostly of mudstones and sandstones in somber shades of gray and brown, along with some pale gray limestone. Ripple marks are preserved in many of the mudstone and sandstone layers of the Belt Formation rocks, indicating these rocks were likely deposited in a shallow marine environment. Throughout northern Idaho the Belt Formations contain intruded layers (or sills) composed of diabase, a black igneous rock with the composition of ordinary basalt. These sills were formed as molten magma squirted between layers of sedimentary Belt rock forming a layer of igneous rock. The Precambrian Belt Formation also contains metal minerals (of silver, lead, and gold) in hydrothermal vein deposits, a valuable resource for the region. The placement of these valuable mineral deposits is associated with the mountain building continental plate collisions that created the Rocky Mountains.

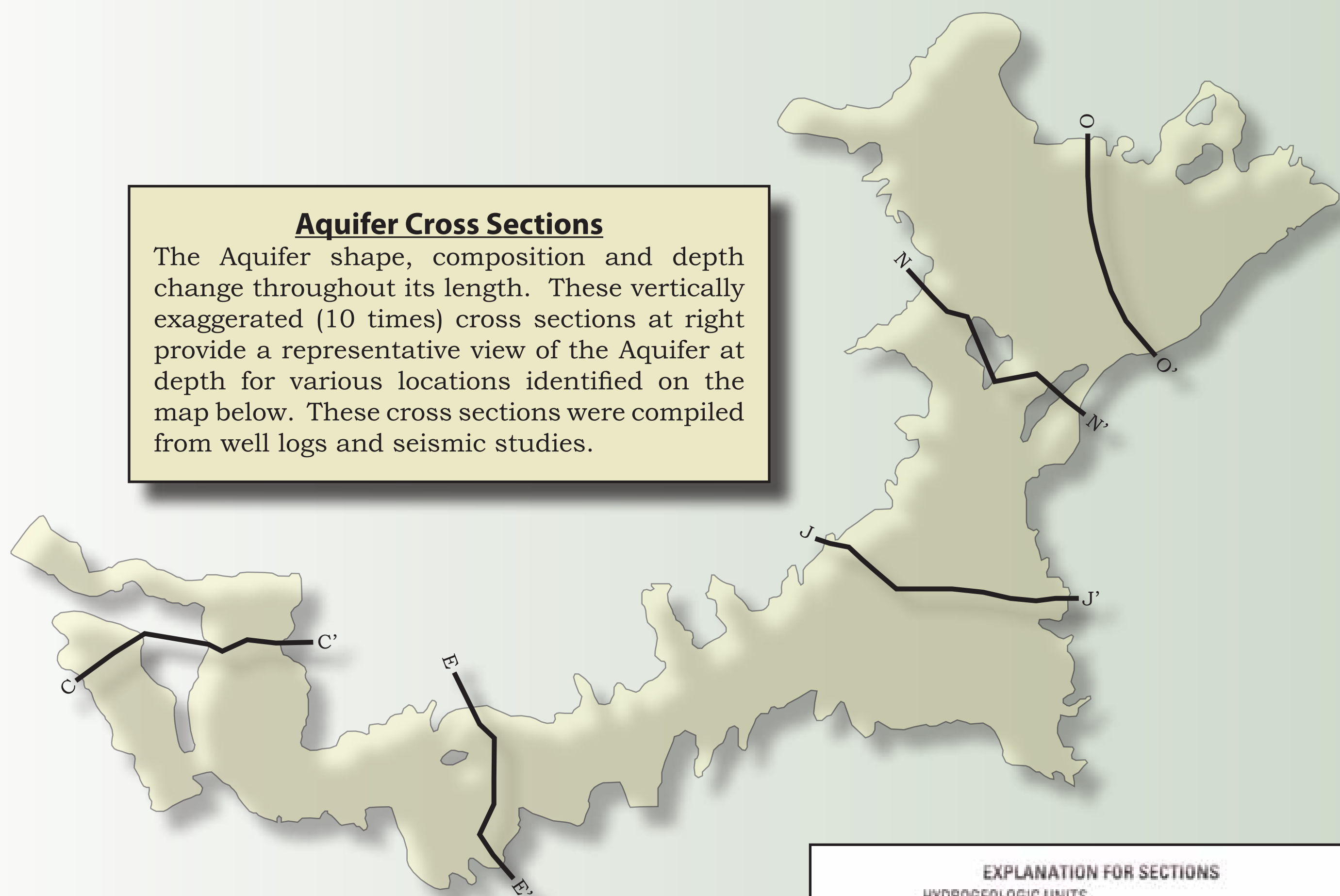
Spokane and Coeur d'Alene are situated on the eastern edge of the Columbia Plateau. Many of the largest basalt flows in the Columbia Plateau erupted about 135 miles southwest of the Aquifer. Extraordinarily fluid lava flows extended northward past the present location of Spokane and into Idaho. The remnants of these flows are found in and around the Spokane Valley. Basalt is a dense dark rock with very fine crystals, and it sometimes has a unique hexagonal (six-sided) column-like appearance. The Columbia basalts in the Spokane-Rathdrum valley were eroded prior to the formation of the Aquifer, and now only the western portion of the Aquifer lies on Columbia basalts.

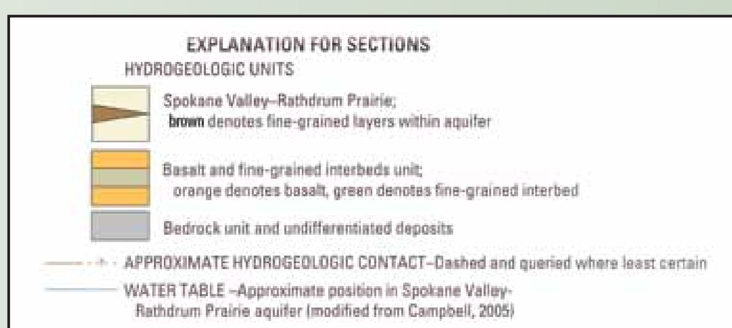
Cross-Section Vertical Exaggeration X 10



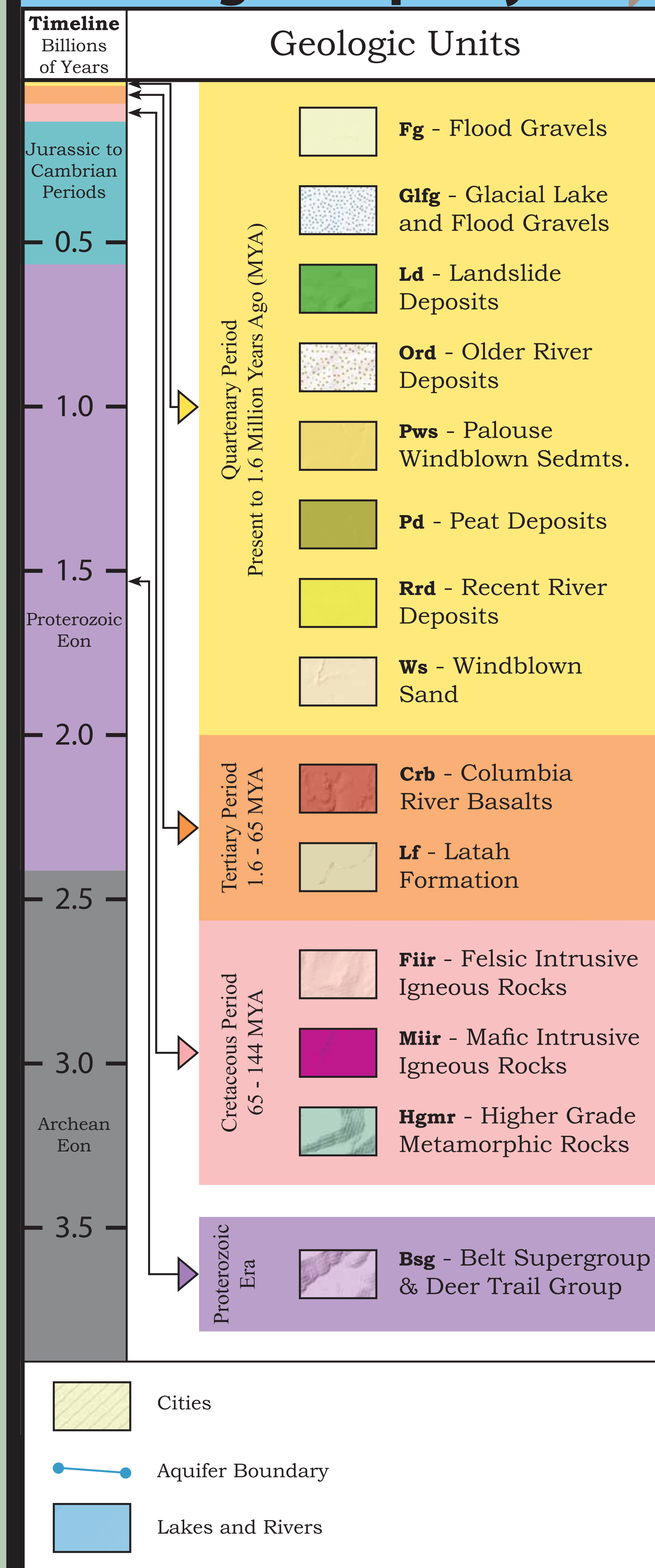
Aquifer Cross Sections

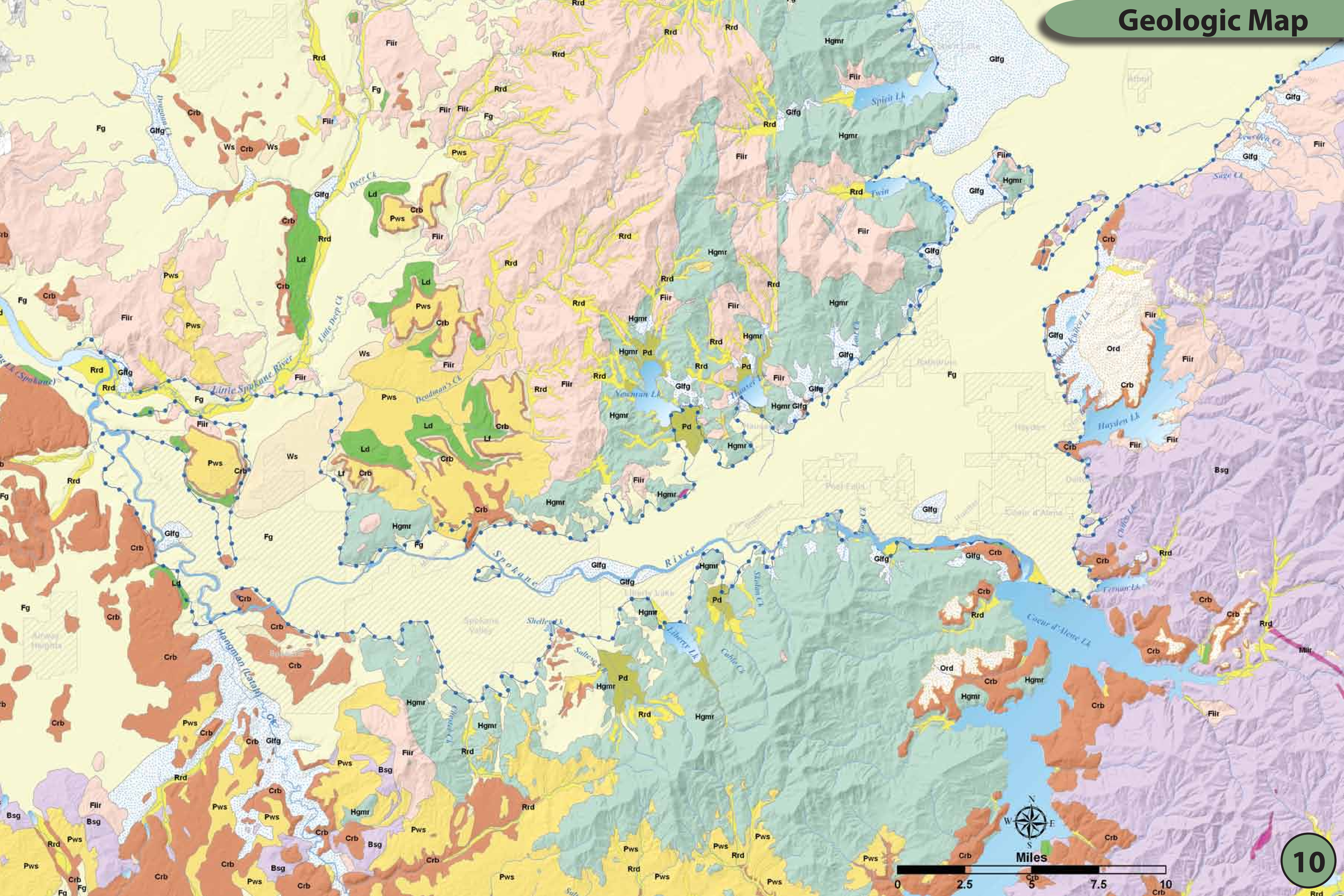
The Aquifer shape, composition and depth change throughout its length. These vertically exaggerated (10 times) cross sections at right provide a representative view of the Aquifer at depth for various locations identified on the map below. These cross sections were compiled from well logs and seismic studies.





Geologic Map Key




Spirit Lk
Twin Lakes
Deer Ck
Little Deep Ck
Little Spokane River
Deadman's Ck
Newman Lk
Hauser Lk
Hayden Lk
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Coeur d'Alene Lk
Spokane River
Shelley Lk
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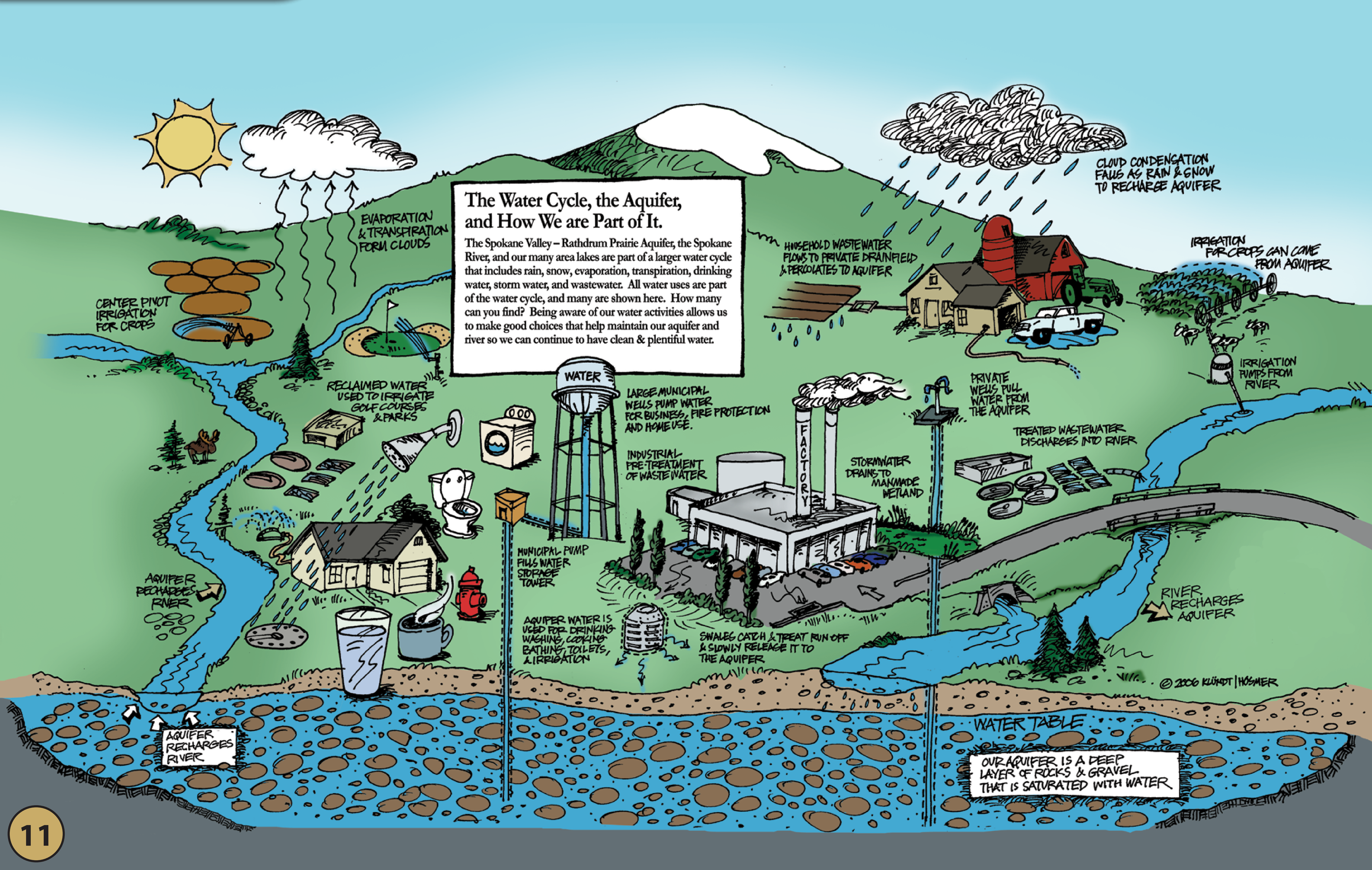
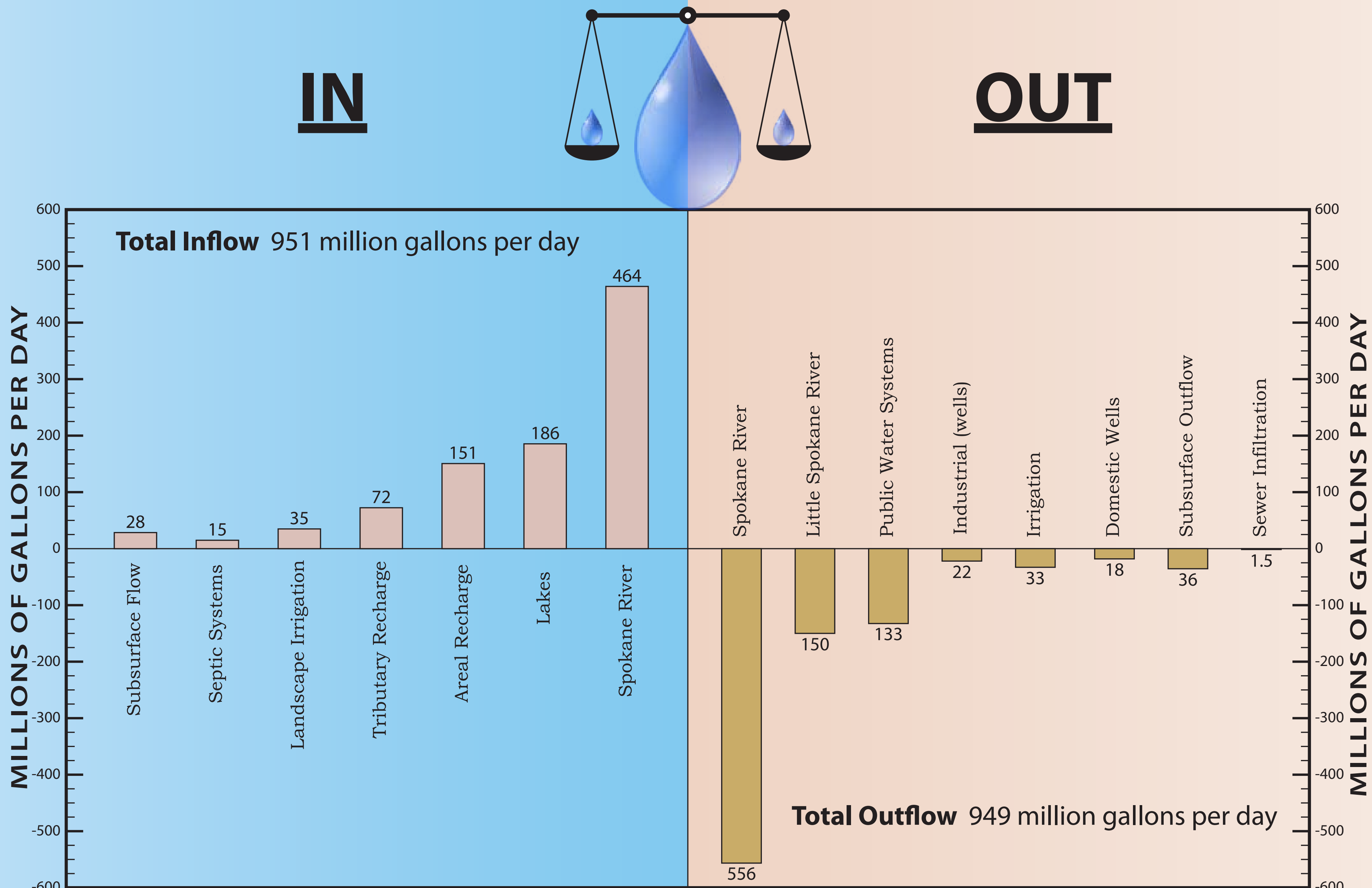


The Water Cycle, the Aquifer, and How We are Part of It.

The Spokane Valley – Rathdrum Prairie Aquifer, the Spokane River, and our many area lakes are part of a larger water cycle that includes rain, snow, evaporation, transpiration, drinking water, storm water, and wastewater. All water uses are part of the water cycle, and many are shown here. How many can you find? Being aware of our water activities allows us to make good choices that help maintain our aquifer and river so we can continue to have clean & plentiful water.

All Aquifer water originates as rainfall or snowfall.



The groundwater budget component values shown in this graph represent average conditions, 1990-2005.

Water exits the Aquifer at springs.
Waikiki Spring is shown above.

The Spokane River seeps water to the Aquifer.

Public water purveyors pump & store Aquifer water.

Water Budget

The Aquifer is dynamic with water flowing into and out of the system. Like a household budget, a **water budget** is an accounting of the amount and source of water recharging the Aquifer, and the amount and destination of water discharging from the Aquifer. This water budget is organized into two categories: inflow (water that **recharges** or flows **IN** to the Aquifer) and outflow (water that **discharges** or flows **OUT** of the Aquifer). As in any successful budget, the **IN** and **OUT** numbers should match!

The information on this page is adapted from the USGS Scientific Investigations Report 2007-5041. The report identified seven significant water recharge sources shown on the "**IN**" side of the graph above, and it identified eight recharge destinations shown on the "**OUT**" side of the graph.

Stormwater swales and drywells recharge the Aquifer.

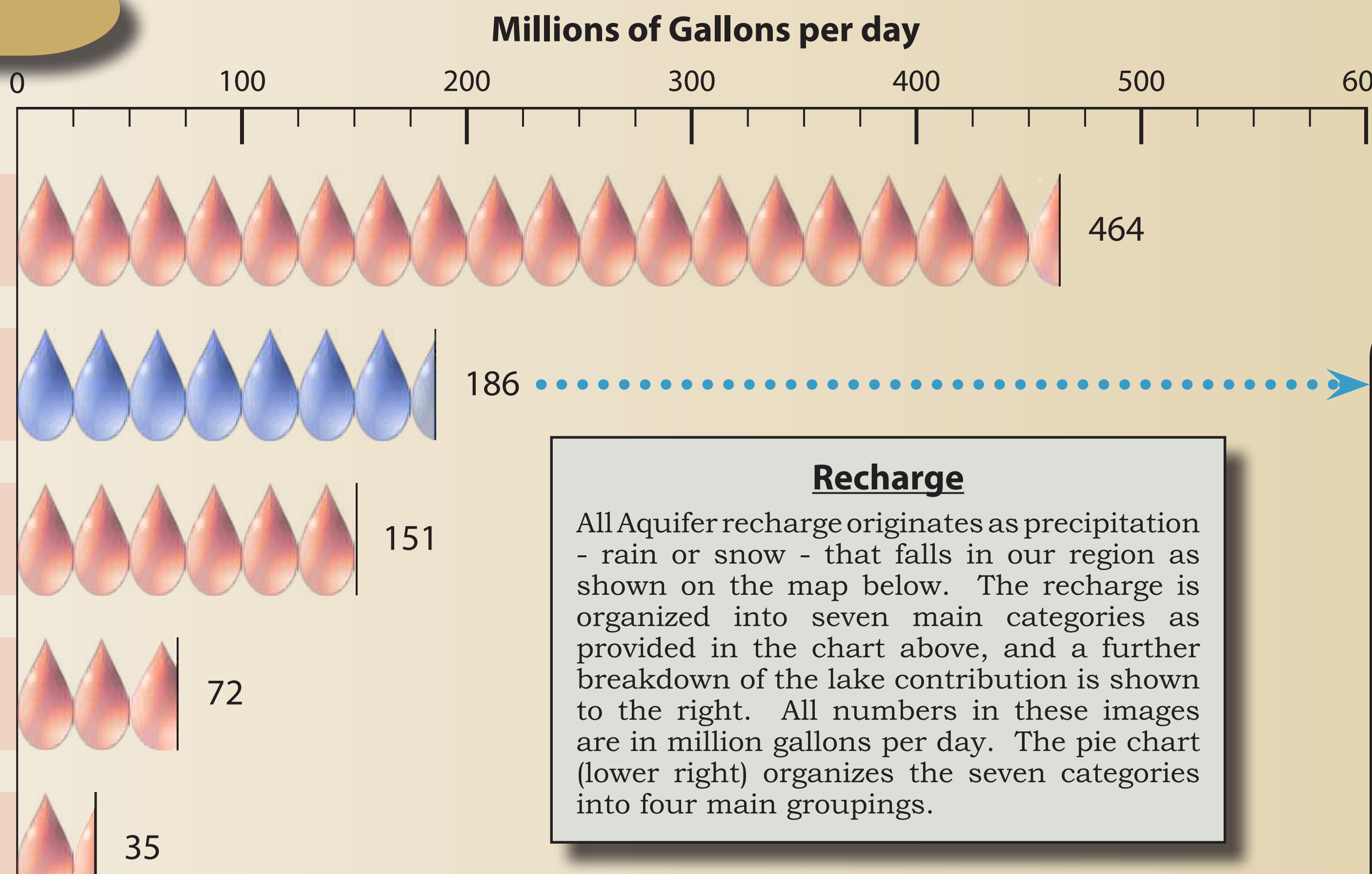
Aquifer Facts

Close to 1 billion gallons of water flows into and out of the Aquifer each day. The Spokane River plays a key role in the Aquifer water budget: the river provides about 49% of the Aquifer inflow, and it receives almost 59% of the Aquifer outflow. Human uses of Aquifer water comprise only about 22% of the Aquifer outflow. The lakes near the Aquifer contribute about 20% of the Aquifer inflow.

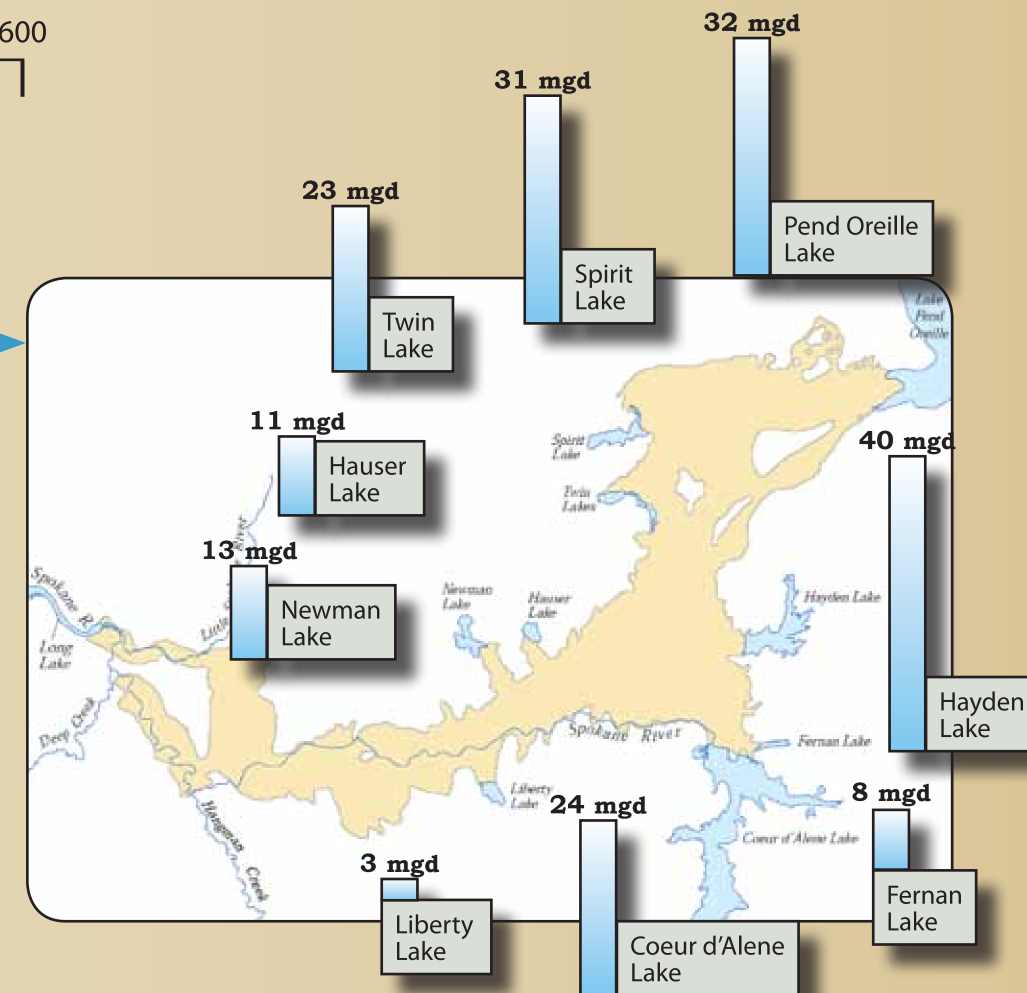
Aquifer water seeps into the Spokane River.

Aquifer Recharge

Recharge to the Aquifer from Spokane River streamflow loss occurs in two losing reaches.	**Spokane River**	464
The nine lakes around the margin of the Aquifer boundary contribute recharge to the groundwater.	**Lakes**	186
This recharge has two elements: direct soil infiltration of precipitation and urban stormwater runoff.	**Areal Recharge**	151
Runoff from the highland areas adjacent to the Aquifer contributes recharge to the groundwater.	**Tributary Recharge**	72
Water applied to the land surface for irrigation infiltrates through the soil and recharges the Aquifer.	**Landscape Irrigation**	35
Deep percolation of treated wastewater from septic system drainfields contributes recharge to the Aquifer.	**Septic Systems**	15
Groundwater from Hoodoo and Blanchard Valleys contributes a minor recharge to the Aquifer.	**Subsurface Inflow**	28



The recharge graphs on this page are adapted from Figure 11, page 22, USGS Scientific Investigations Report 2007-5041.



Recharge

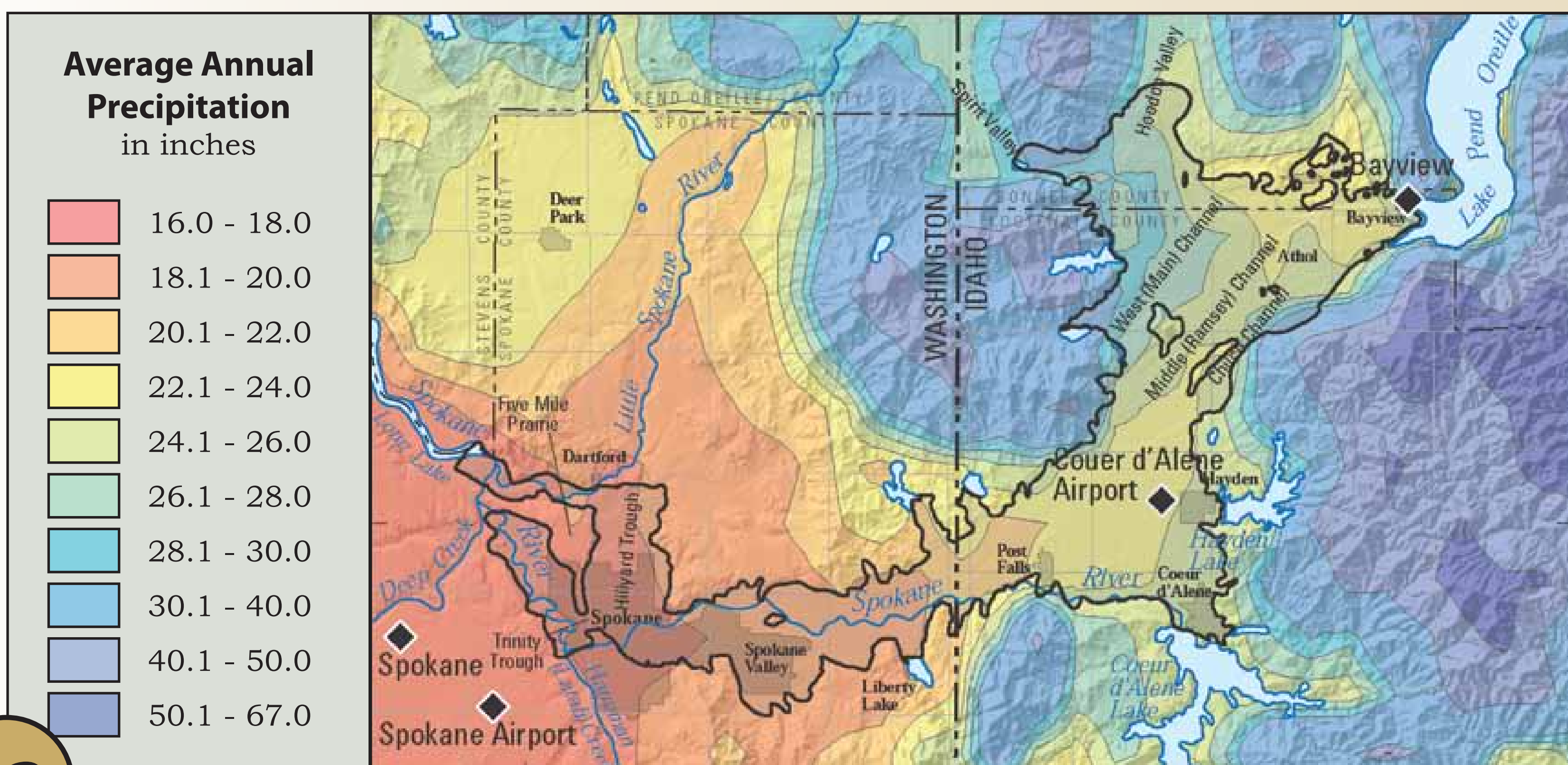
All Aquifer recharge originates as precipitation - rain or snow - that falls in our region as shown on the map below. The recharge is organized into seven main categories as provided in the chart above, and a further breakdown of the lake contribution is shown to the right. All numbers in these images are in million gallons per day. The pie chart (lower right) organizes the seven categories into four main groupings.

Hauser Lake recharges the Aquifer

Upland meadow that recharges our Aquifer

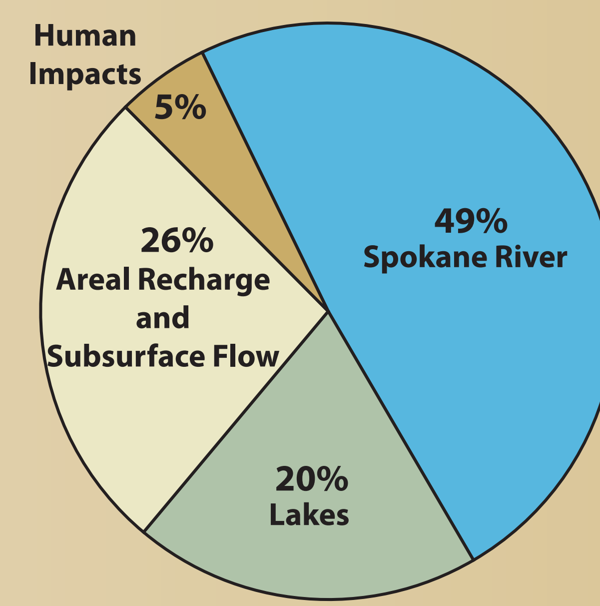
Spokane River Flows

In 2009 Avista agreed to release enough water from the Post Falls Dam to maintain a minimum instream flow in the Spokane River below the dam at 600 cubic feet per second (388 mgd). As a result, additional Aquifer recharge is anticipated during seasonal low river flow periods.



Aquifer Facts

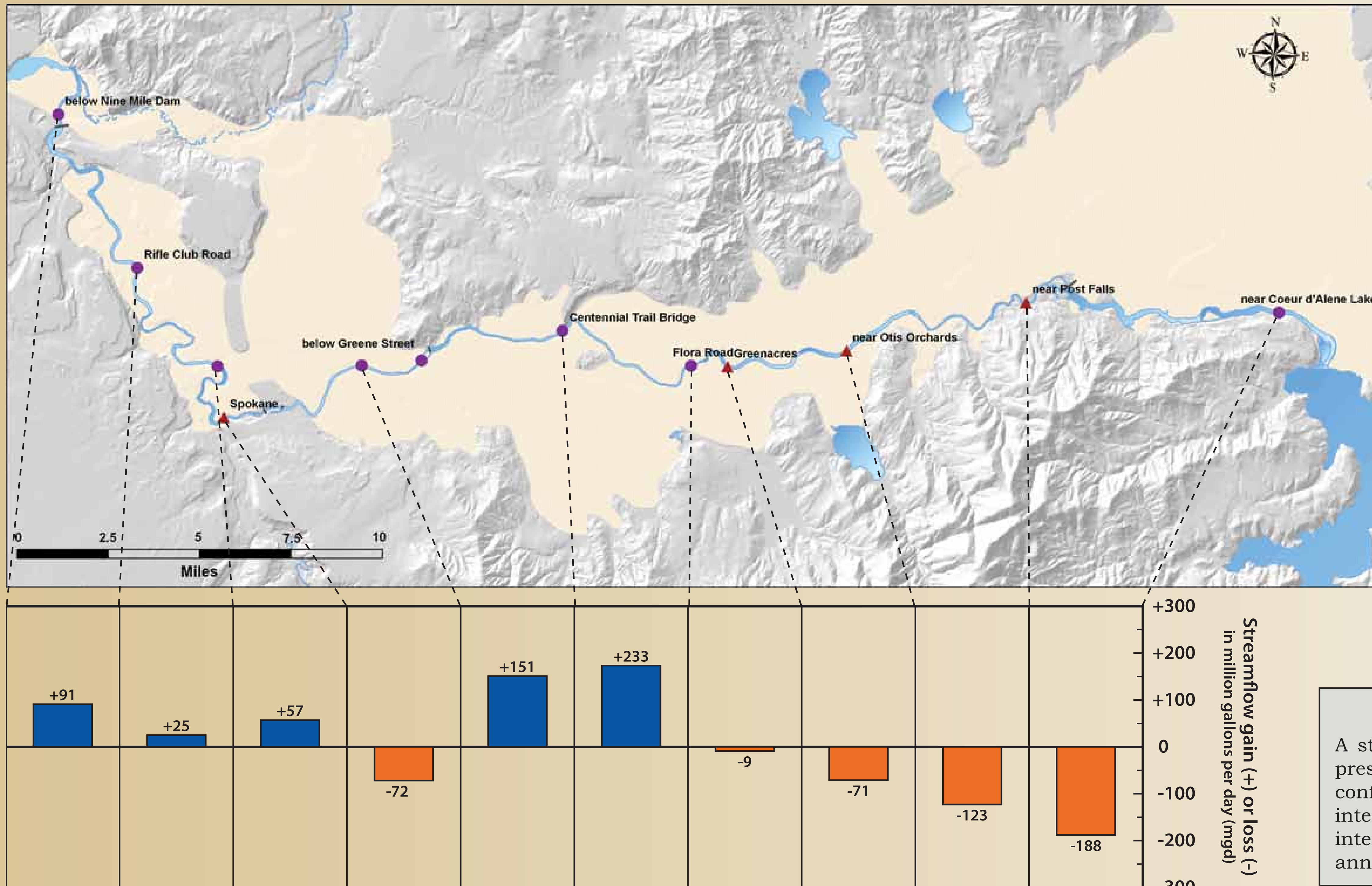
The Spokane River is the largest contributor to the Aquifer, providing an average of 464 million gallons daily, about 49% of the total Aquifer inflow. The Spokane River is also the largest destination for Aquifer water, receiving an average of 556 million gallons per day (mgd), about 58% of the total outflow. The Little Spokane River is the second largest Aquifer recipient with 150 mgd.



Percentage of Recharge to the Aquifer

Aquifer-River Interchange

The two maps on this page provide similar views of Aquifer-River interactions. The map at left shows the information collected during a 5-day investigation of streamflow in August 2005. The map below provides an estimate of the annual reach interactions from 2004 data, and it compares well to the map at left. Study of Aquifer-River interactions has generally occurred during late summer low streamflow conditions, and these interactions during other periods of the year are less well known.

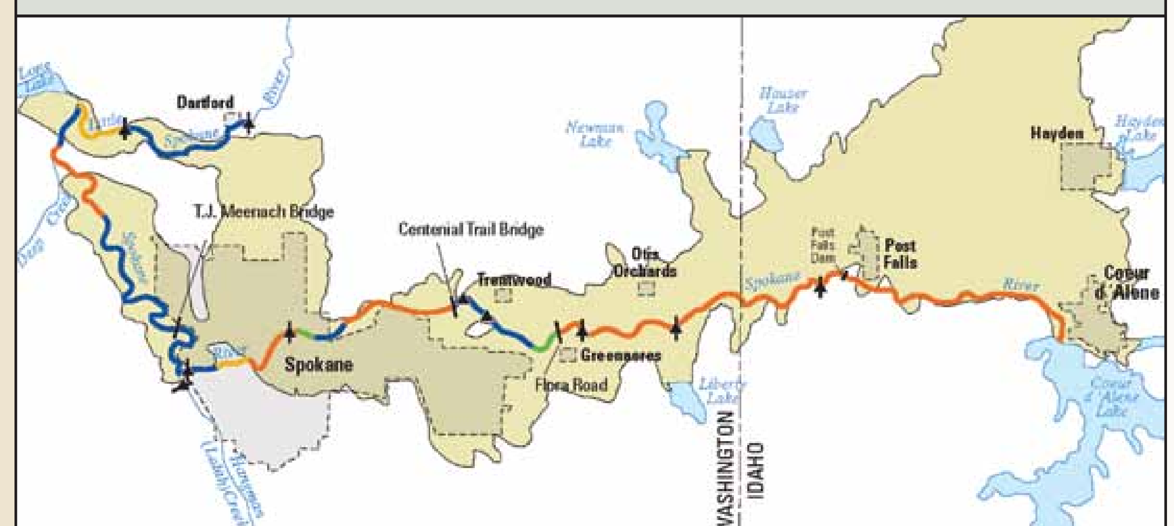


Low Flow Seepage Run: Spokane River Aquifer Interchange August 26-31, 2005

Losing reach of the Spokane River near Greenacres, August 1, 2003

River Reaches: Loss and Gain

A strong relationship between the Aquifer and the Spokane River is present throughout the river's length, from Lake Coeur d'Alene to the confluence with the Little Spokane River. Although the Aquifer-River interchange is complex, studies of the river have identified four types of interaction: **gaining, losing, transitional and minimal**. The average annual reach interactions based on 2004 data are shown below.

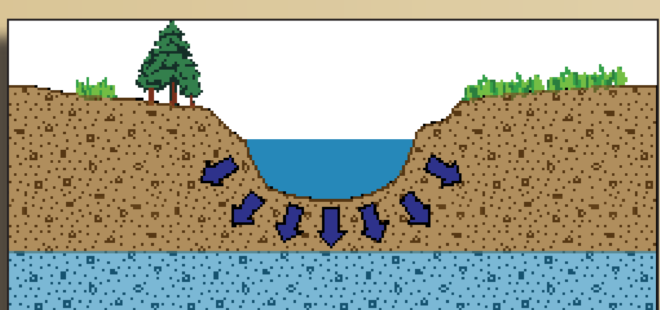


Losing Reach: the river loses water to the Aquifer

Gaining Reach: the river gains water from the Aquifer

Transitional Reach: changing condition between gain/lose

Minimal Interaction: the river neither gains nor loses



Losing Reach

Where the water table is below the bed of the river, water percolates through the gravelly bed and downward into the Aquifer. In these locations the river is losing water, the typical condition for the Spokane River in Idaho and into Washington to Flora Road.

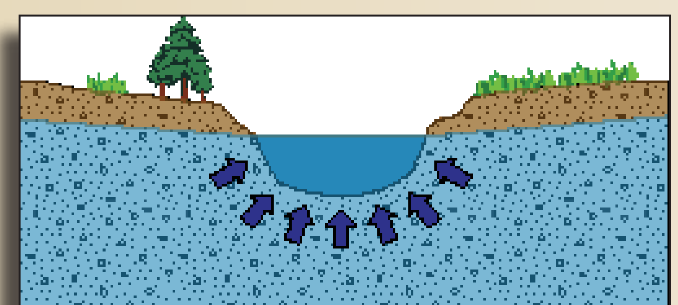
Aquifer Recharge and Discharge

River Streamflow Gain = Aquifer Discharge

River Streamflow Loss = Aquifer Recharge

Aquifer Facts

For almost its entire length, the Spokane River interacts dynamically with the Aquifer. Measurements of the River-Aquifer interactions have only been performed during low streamflow conditions in late summer. When the streamflow in the River is greater than 10,000 cubic feet per second, gaining and losing reach trends are hard to determine.



Gaining Reach

Where the water table is higher than the river bed, the Aquifer loses water through springs and seeps and adds volume to the river. In these areas the reach of the river is gaining. The reach between Sullivan Road and the Centennial Trail Bridge is a gaining reach.

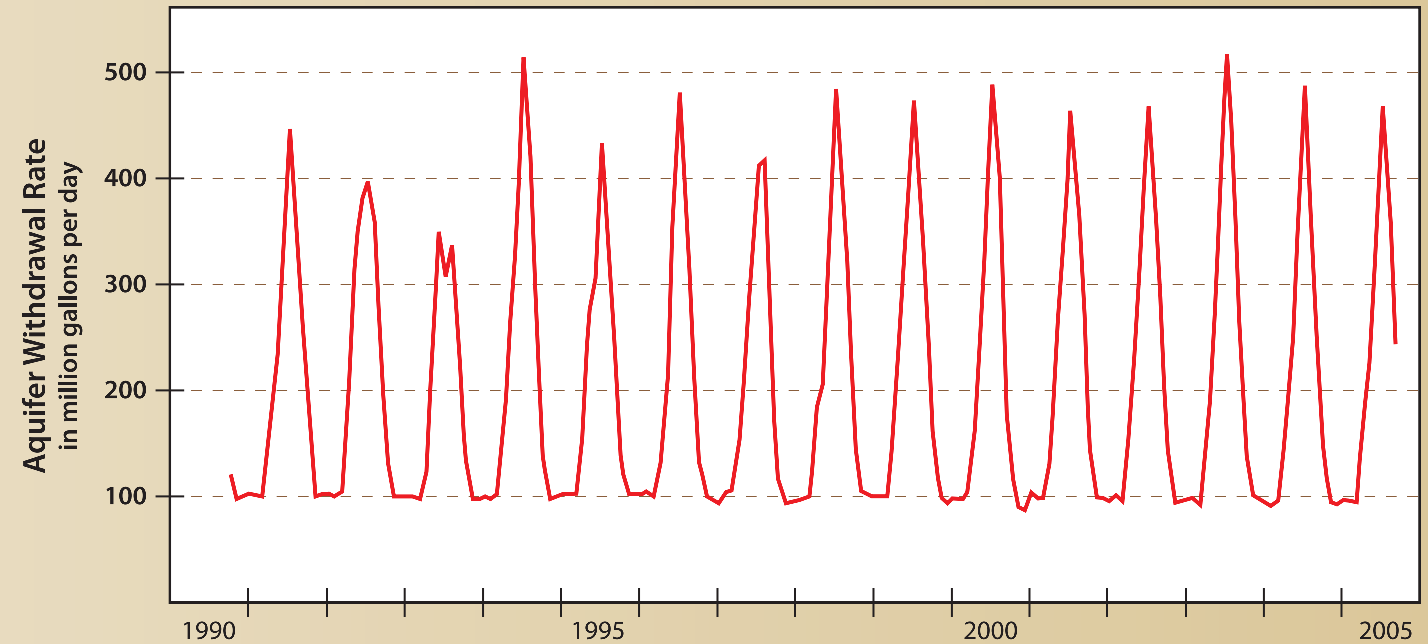
Aquifer Discharge

Millions of Gallons per day (average conditions)

Discharge from the Aquifer to the Spokane River (streamflow gain) occurs in two gaining reaches.	**Spokane River**	556
Discharge from the Aquifer to the Little Spokane River (streamflow gain) occurs in gaining reaches.	**Little Spokane R.**	150
Withdrawals from the Aquifer to provide water to all public water systems in the area.	**Public Supply**	133
Withdrawals from the Aquifer from private wells to provide water for industrial uses in the area.	**Industrial Use**	22
Water withdrawn from the Aquifer and applied to the land for crop & non-residential landscape irrigation.	**Irrigation**	33
Water withdrawn from the Aquifer by private wells for domestic uses including residential irrigation.	**Domestic Wells**	18
Groundwater discharge from the Aquifer as underflow including flow to Lake Spokane (Long Lake).	**Subsurface Outflow**	36
Groundwater infiltration into sewer pipes that is collected and discharged to the Spokane River.	**Sewer Infiltration**	1.5

Notes:

1. Residential landscape irrigation is included with the "Public Supply" category rather than the "Irrigation" category.
2. The information on this page is adapted from USGS Scientific Investigations Reports 2007-5041 and 2007-5044.



Total Aquifer Withdrawal Rates from All Wells

Discharge

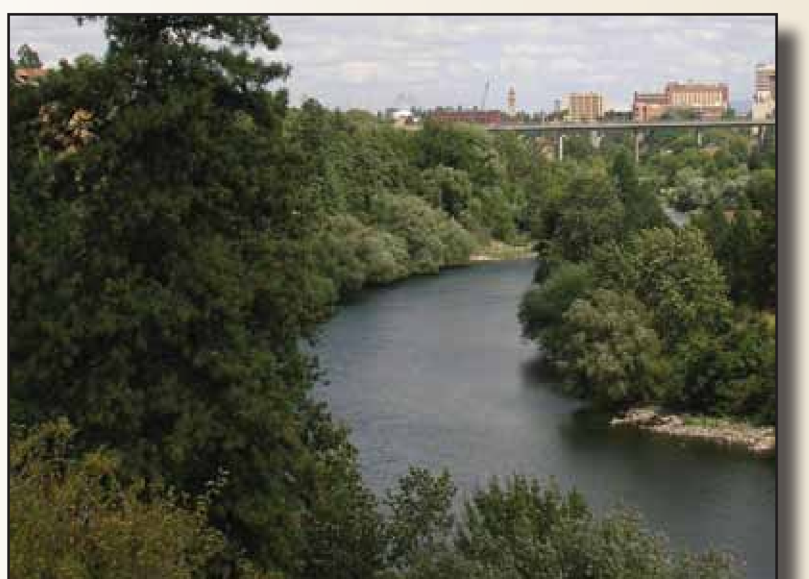
Groundwater leaves the Aquifer through natural means and human impacts. The discharge is organized into eight main categories as provided in the chart above. All numbers in these images are in million gallons per day. The pie chart below organizes the eight categories into four main groupings.

Aquifer withdrawals from wells vary considerably depending on the time of year. The graph at upper right combines values for Public Supply, Industrial Use, Irrigation and Domestic Wells, and it indicates that peak summer withdrawals can be three to four times the winter values.

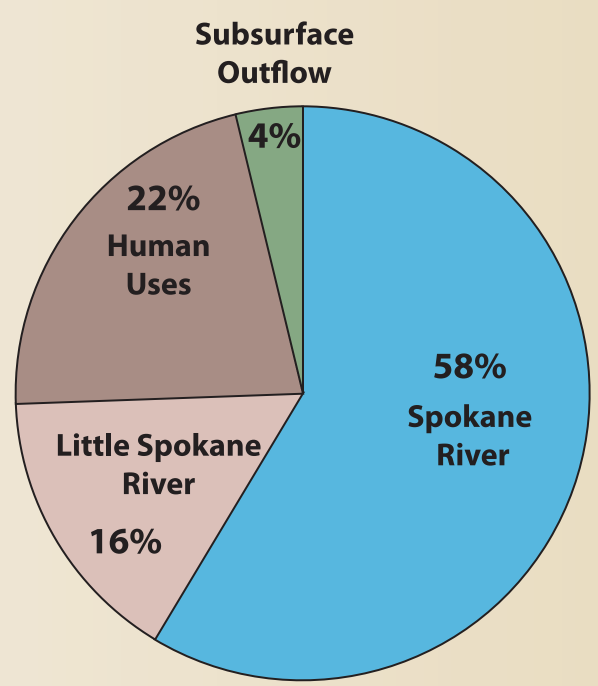
Modeling Human Uses

The computer model developed by the USGS Bi-State Study shows increased pumping of Aquifer water may decrease flow in the Spokane River. The following is an excerpt from a recent Spokane County Water Resources modeling report:

"Water usage from the aquifer is important to the Spokane River. Increases in pumping from the SVRP has the potential to decrease flow rates in the Spokane River since the aquifer and river are interconnected. A recent study indicates that the additional pumping due to a 57% projected increase in population in Kootenai County (1990 to 2025) would result in a decrease in Spokane River flows of about 1.8%. The study indicated that the additional pumping due to a 29% projected increase in population in Spokane County (1990 to 2025) would result in a decrease in Spokane River flows of about 7.0%."



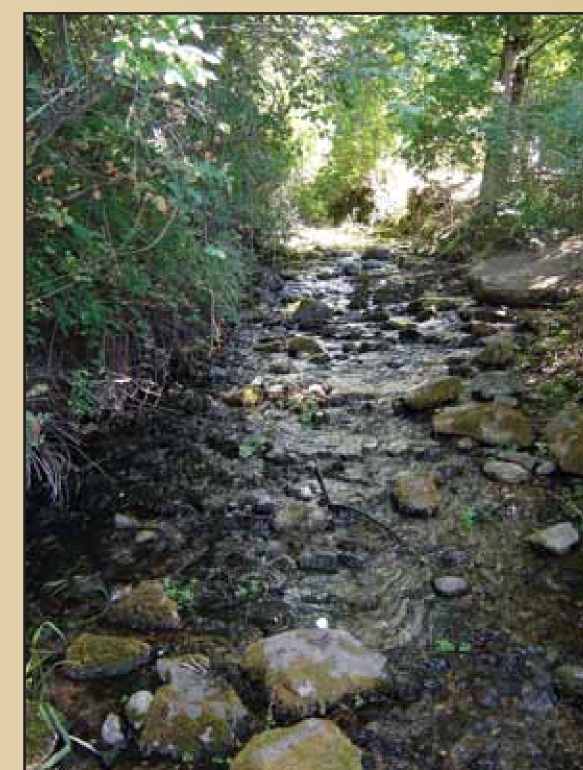
Gaining reach of the Spokane River



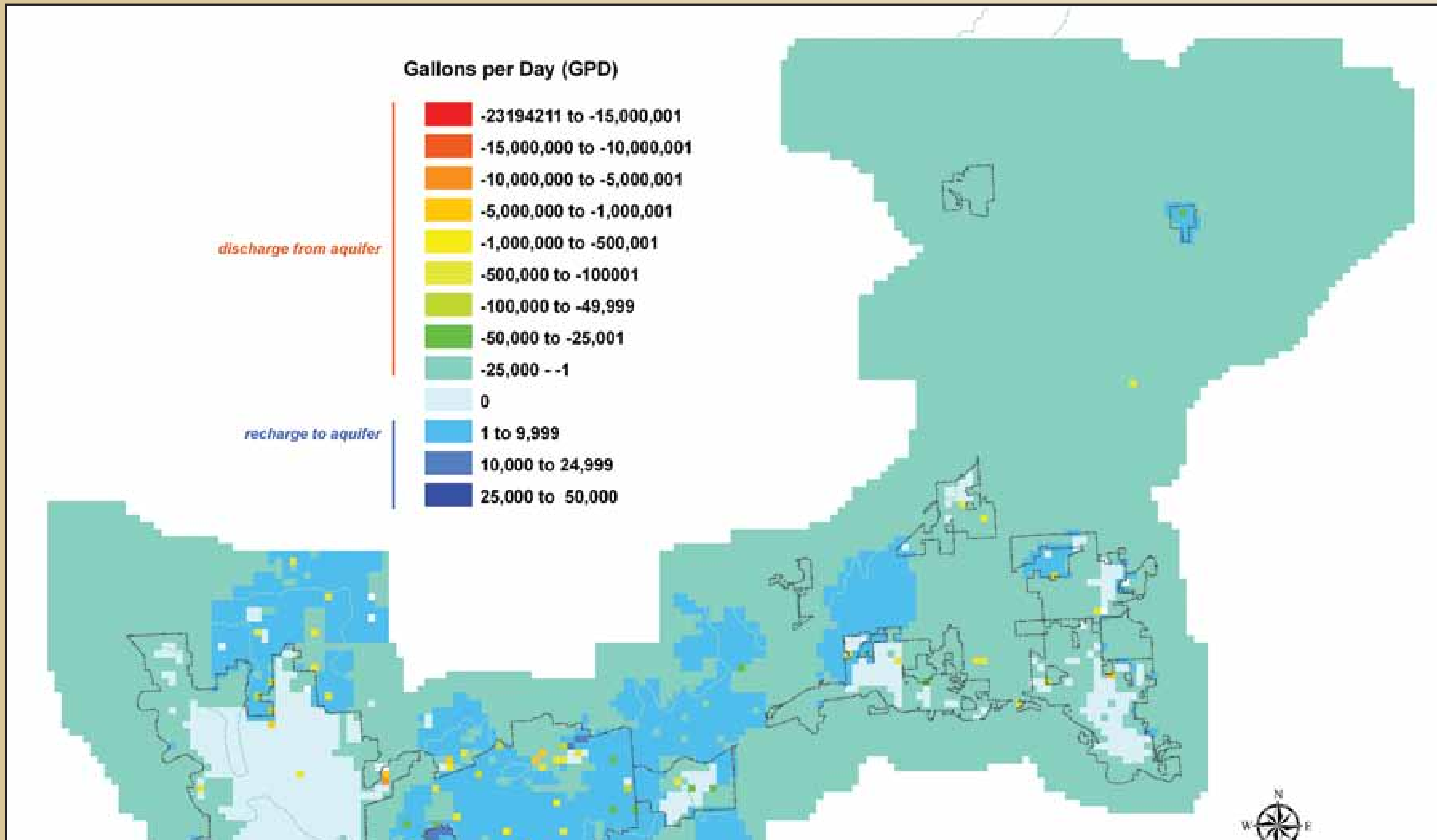
Percentage of Discharge from the Aquifer

Aquifer Facts

The Spokane River and the Little Spokane River receive 74% of the average annual Aquifer discharge. Human use of the Aquifer, groundwater withdrawal by wells, comprise 22% of the average Aquifer discharge; however peak summer water withdrawal can be three to four times the winter values.



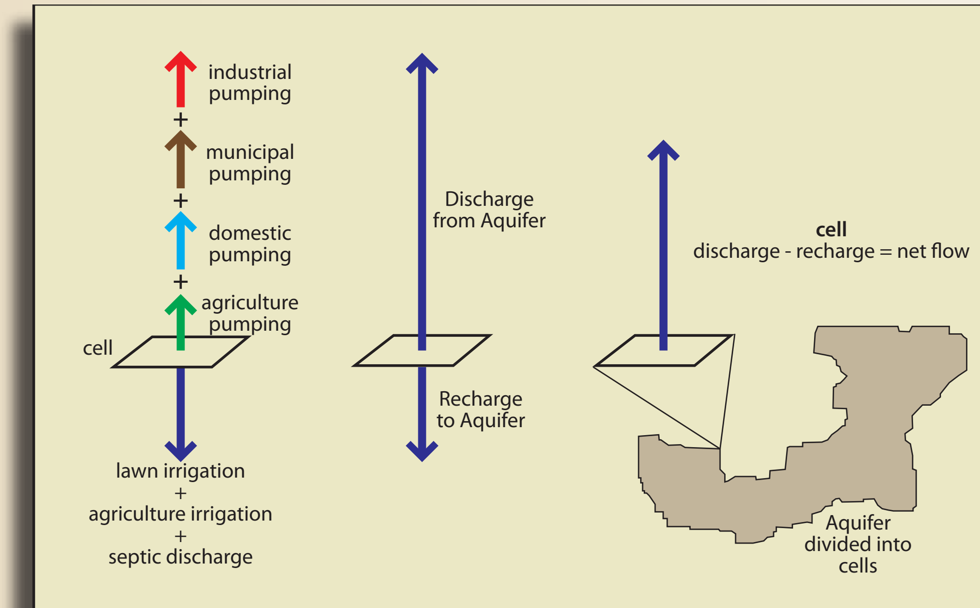
Griffith Spring near the Spokane Hatchery



Average Conditions During 2004 Non-irrigation Season
(November-February: 121 days)

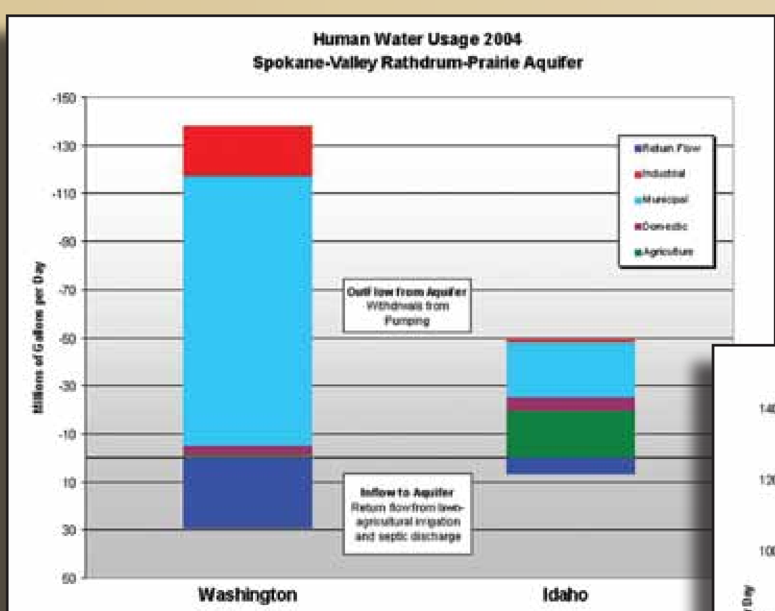
Human Use of the Aquifer

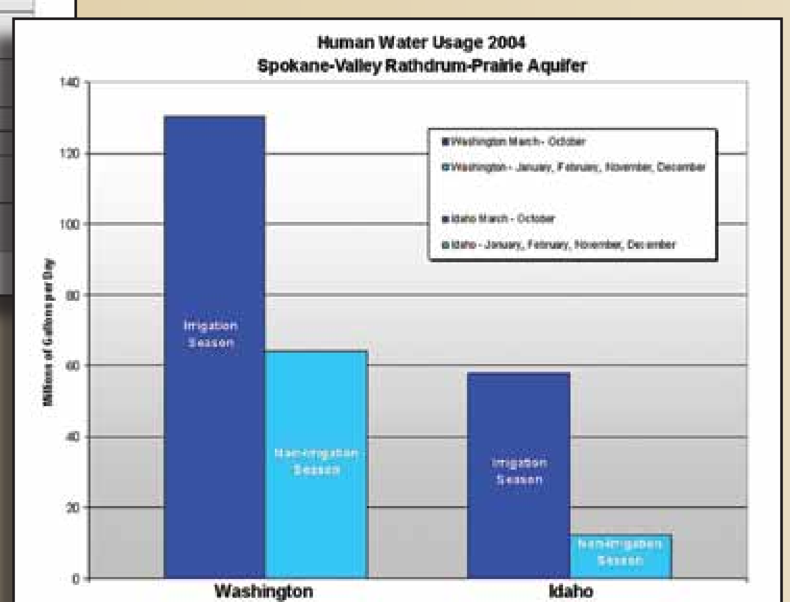
The two large maps on this page provide a visual representation of the spatial distribution of Aquifer discharge and recharge activities. The irrigation season and non-irrigation season are both represented, and the greater water withdrawals during the irrigation season are clearly shown.

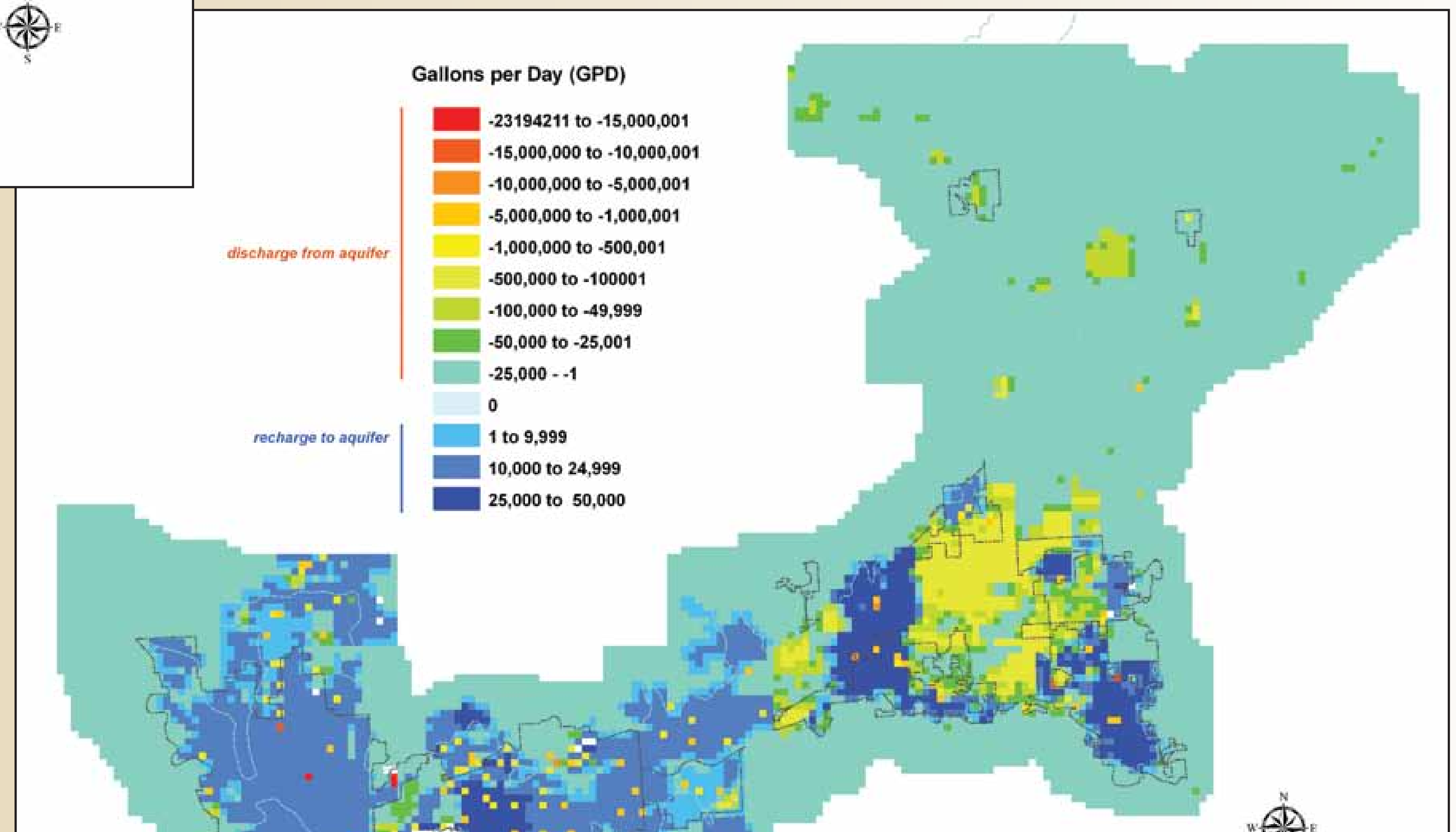


Creating Cell Values

The process used to create the two large color maps on this page is shown at left. First the Aquifer was divided into small squares, called "cells". Each cell has associated values for withdrawals (pumping) and for discharges to the Aquifer (such as irrigation). Discharge values are added together, and the recharge values are added. Recharge values are subtracted from discharge to create a net flow value for each cell. Each cell is assigned a color based on flow values in the map legends, and the cells are assembled as maps.

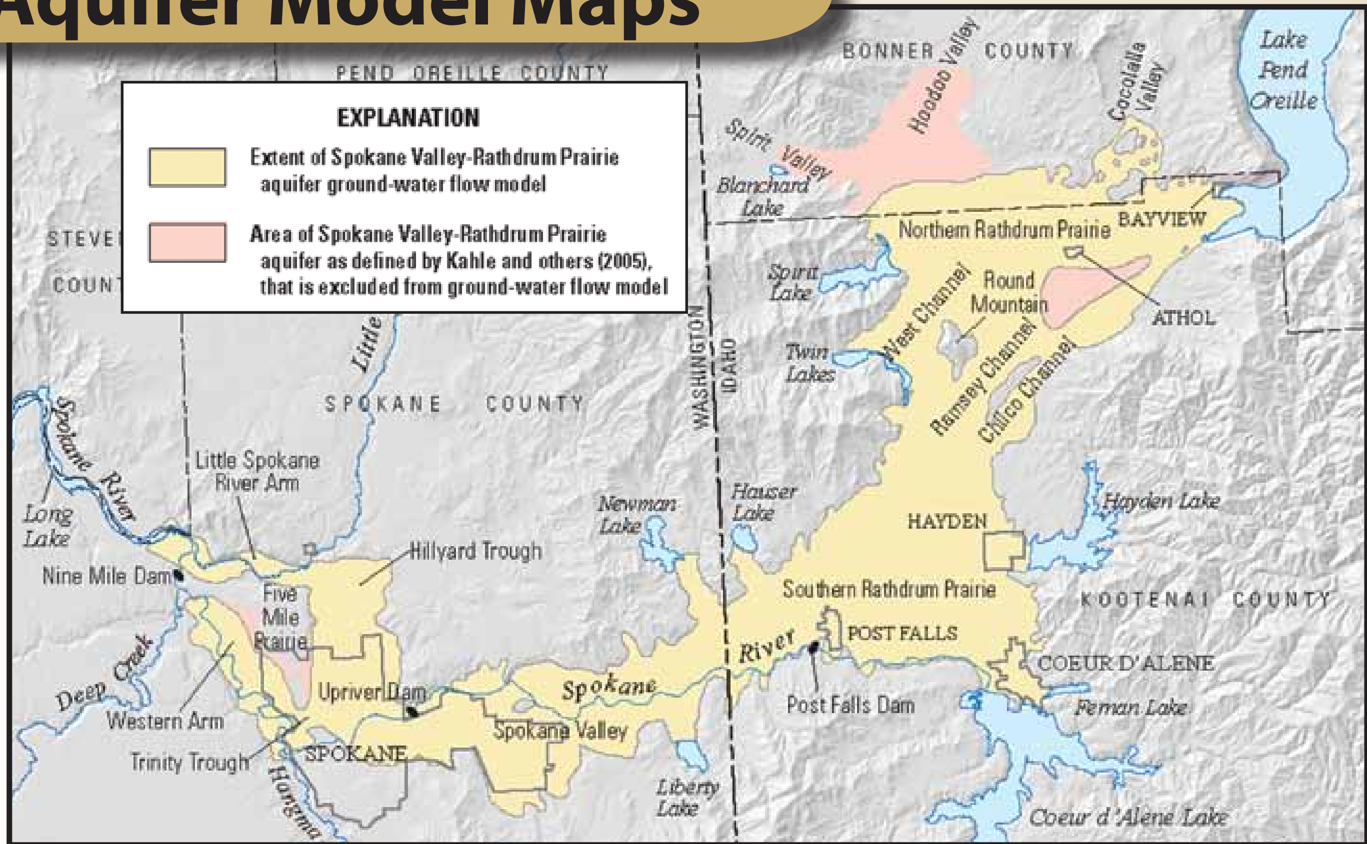






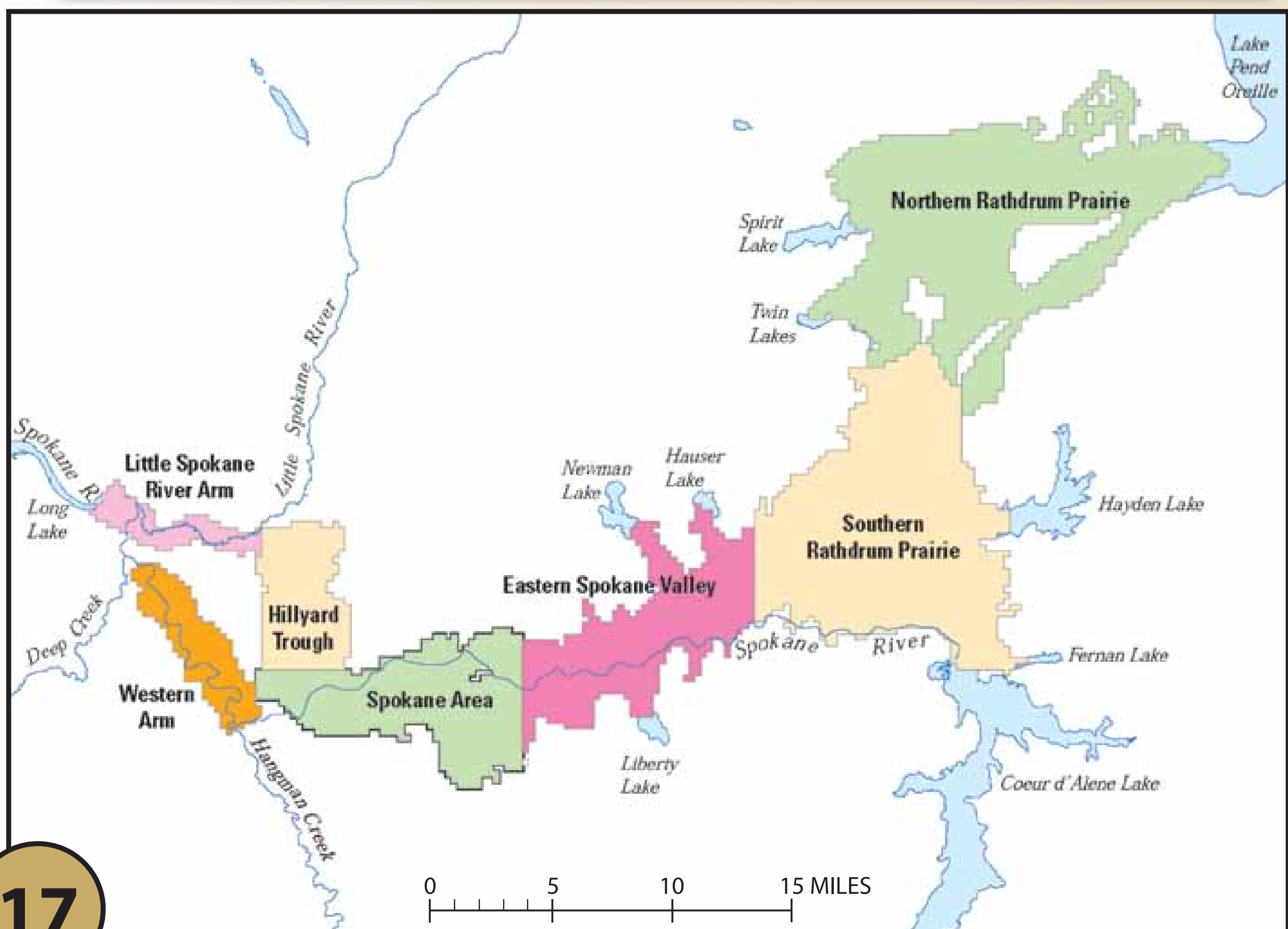
Average Conditions During 2004 Irrigation Season
(March-October: 245 days)

Aquifer Model Maps



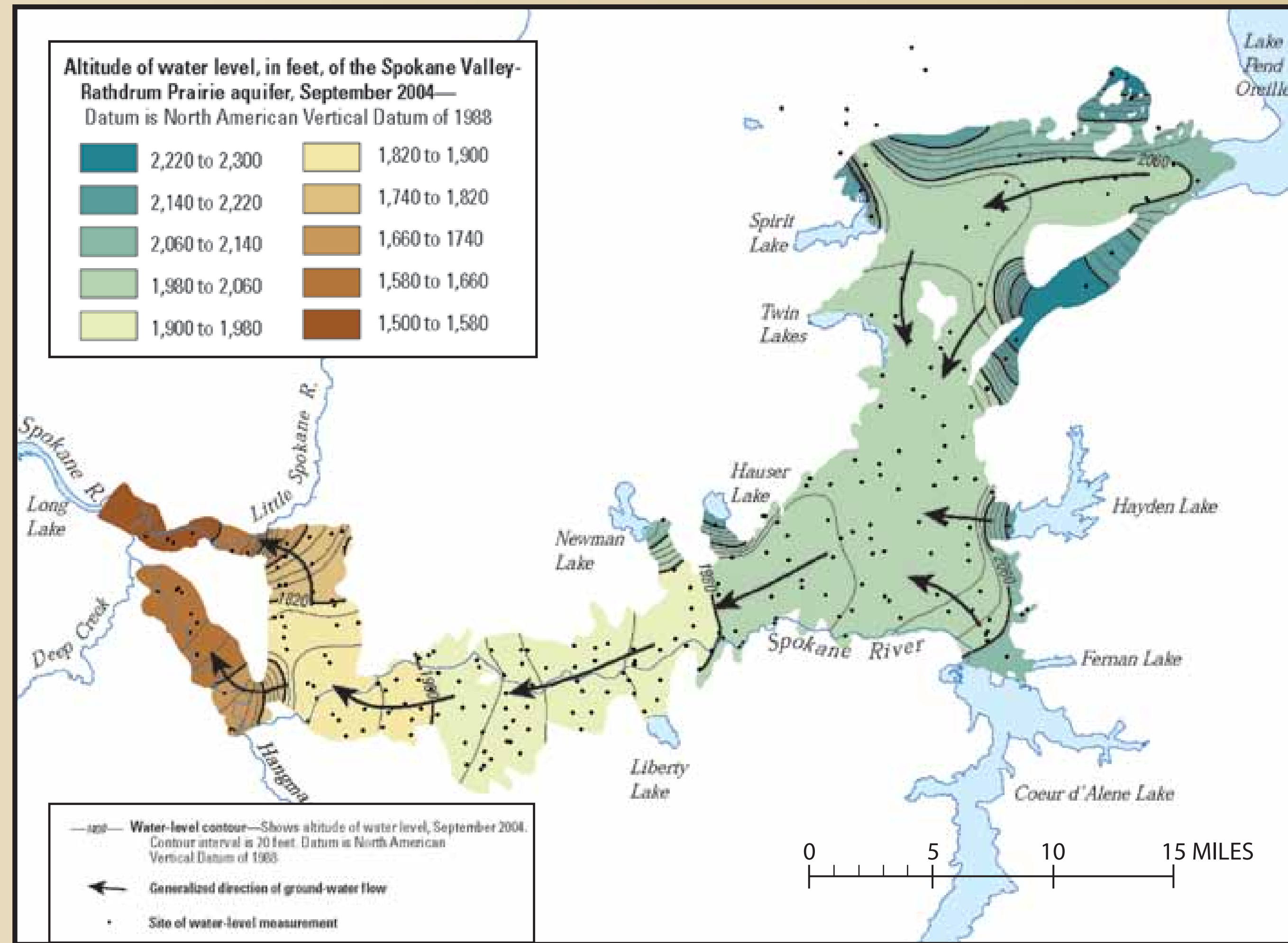
Aquifer Model Extent

Certain areas within the Aquifer extent were not included in the model because insufficient groundwater information was available in those areas. The map above shows the aquifer extent with areas (in pink) that are excluded from the groundwater flow model. The Aquifer was divided in the model (see map below) into areas called "subregions" in order to calculate the Aquifer water budget. The USGS MODFLOW computer model was adapted to simulate groundwater flow in the Aquifer.



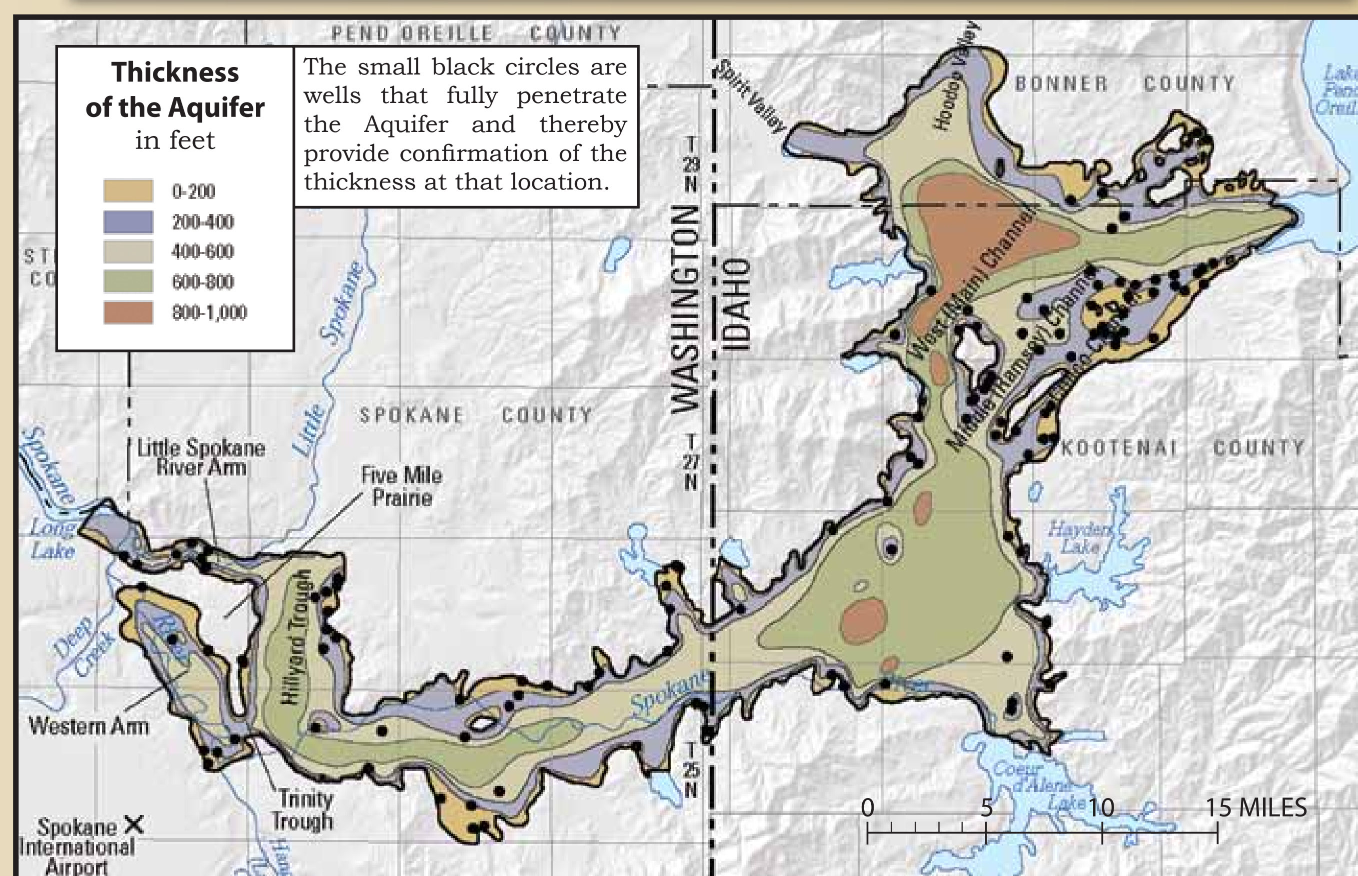
Aquifer Flow Model

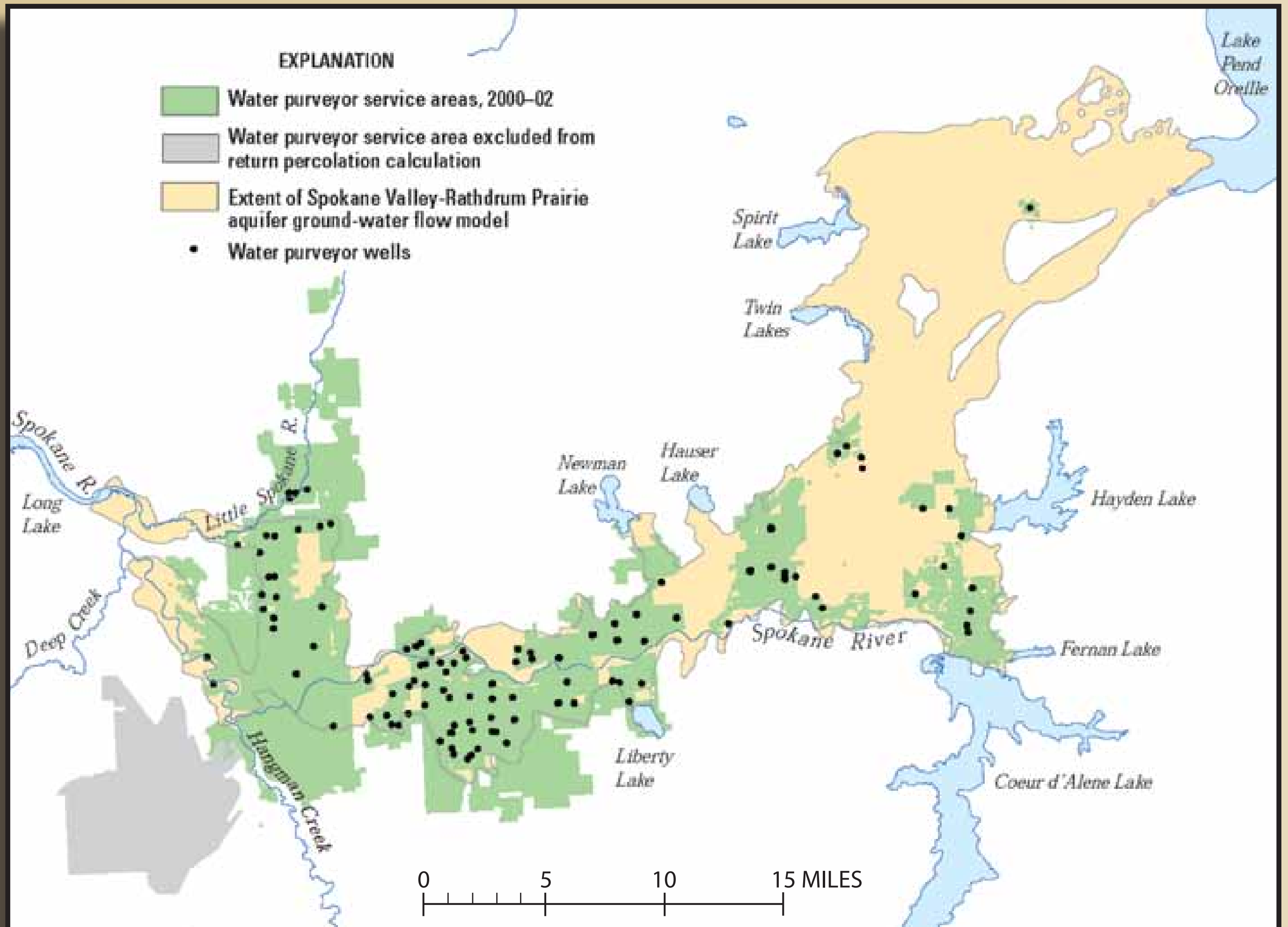
The maps on this page and the following page graphically represent the information used to construct a computer model for the Aquifer. The scale of the model and the level of detail were selected for analysis of aquifer-wide water supply. The MODFLOW-2000 computer model was adapted to simulate groundwater flow in the Aquifer.



Flow Model Input Data

The groundwater level - the top of the water table - is highest near Lake Pend Oreille and drops almost 800 feet to the low point at Long Lake (see map above). The flow of groundwater follows this drop in elevation from east to west. Aquifer thickness is deepest (over 800 feet) in the northwest part of the northern Rathdrum Prairie (see map below), and it is 400 to 600 feet thick at the Washington-Idaho border.



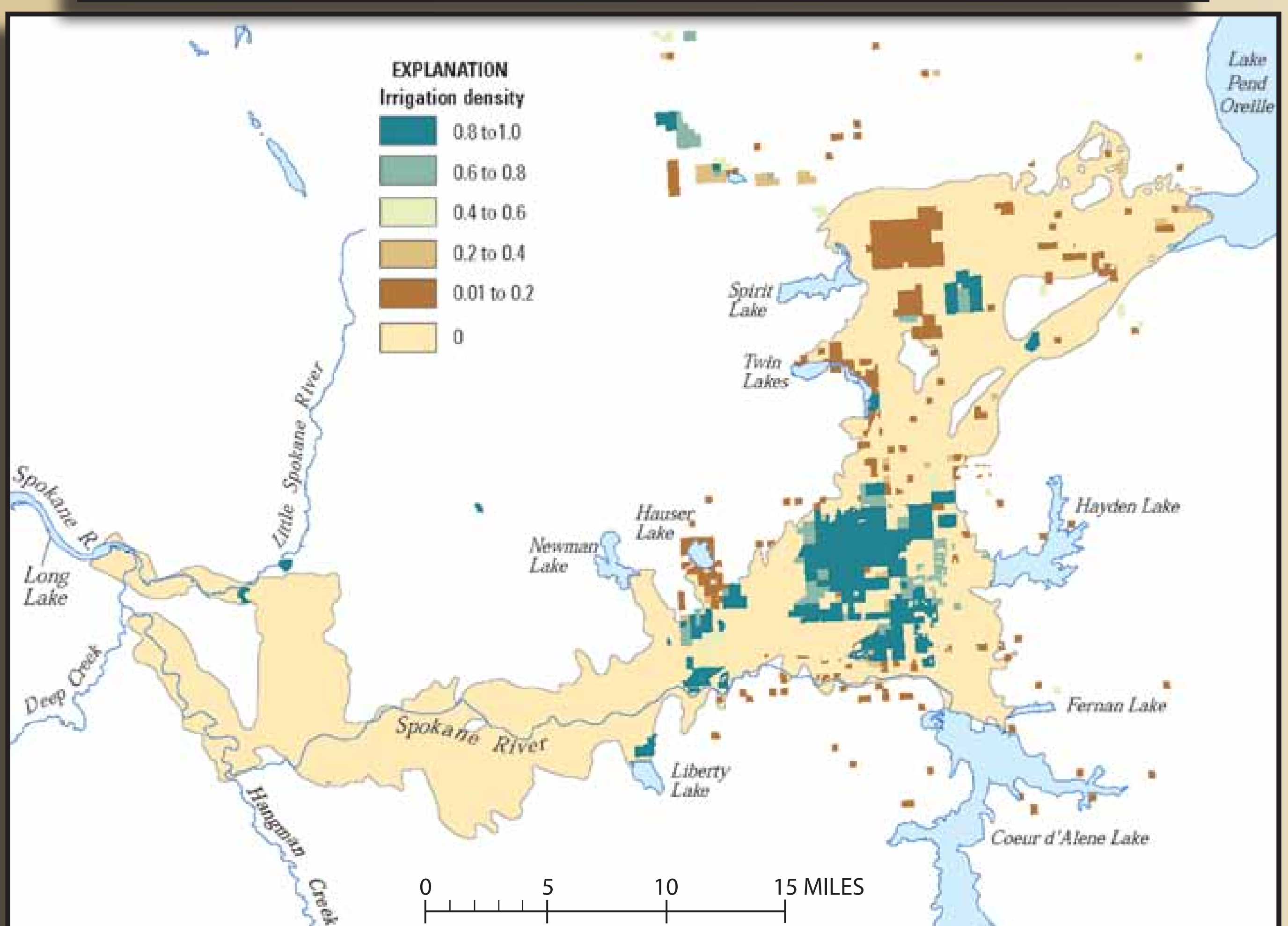


Water Purveyors (above)

Shown are water service areas and major wells that withdraw water from the Aquifer.

Irrigation Areas (below)

Shown are irrigation areas outside self-supplied golf courses and water purveyor service areas.



Developing a Flow Model

Developing a computer model to simulate groundwater flow in the Aquifer is a four step process.

Step 1

Define the extent of the model (upper left map, page 17) and the depth of the model (lower right map, page 17) based on the Aquifer boundary.

Step 2

Define the direction and flow rate of the groundwater in the Aquifer (upper right map, page 17).

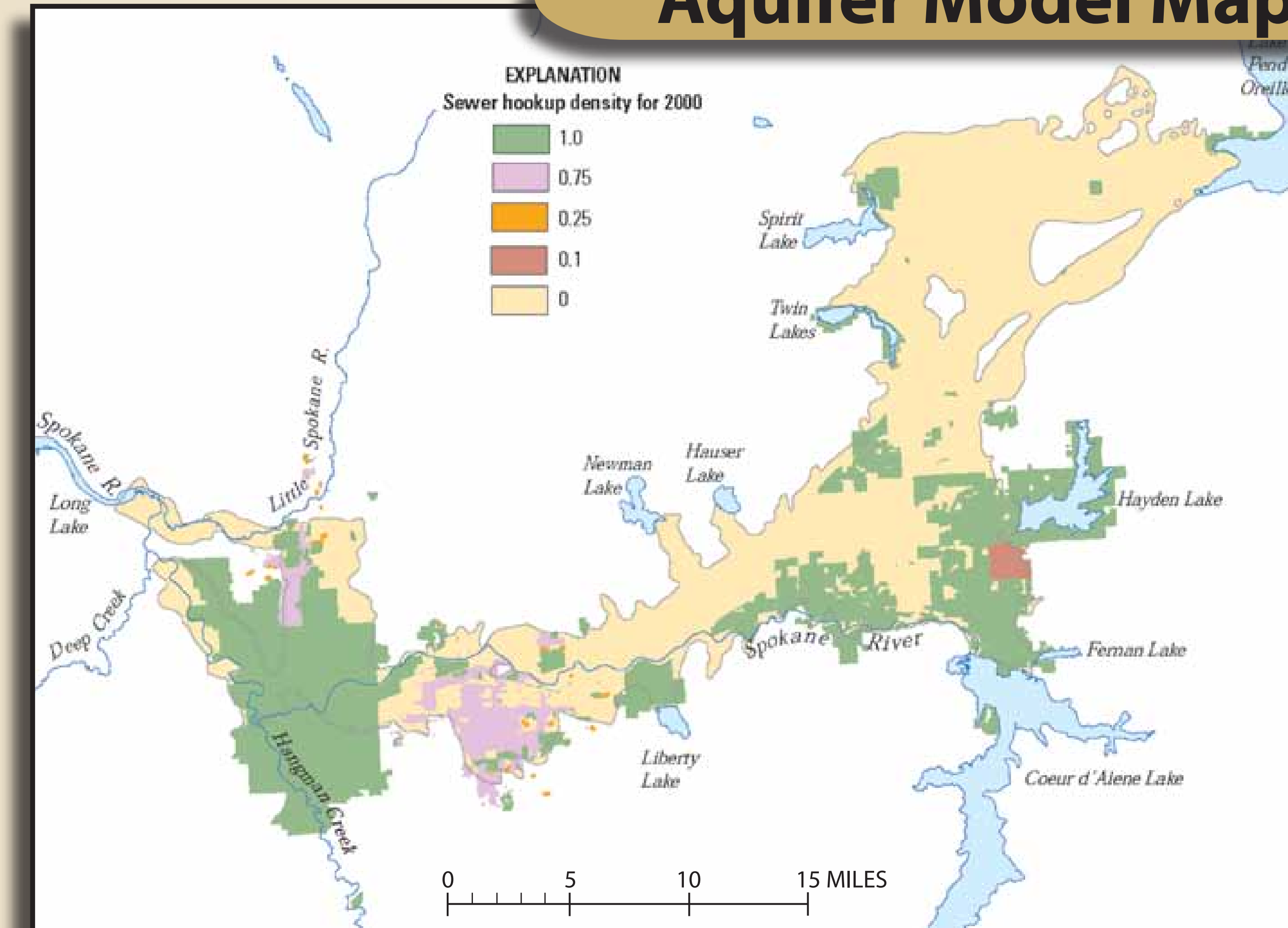
Step 3

Estimate the water entering and leaving the Aquifer (some of that information shown on the maps on this page).

Step 4

Calibrate the model by comparing model results with real-world data, then revising the model many times until the model results closely match the real world.

An aquifer groundwater flow model (when calibrated) can be used to predict the affect on water levels and flow rates from different uses and withdrawal rates. Some of the predicted affects on the Aquifer and the Spokane River from future pumping of the Aquifer are discussed on page 15.

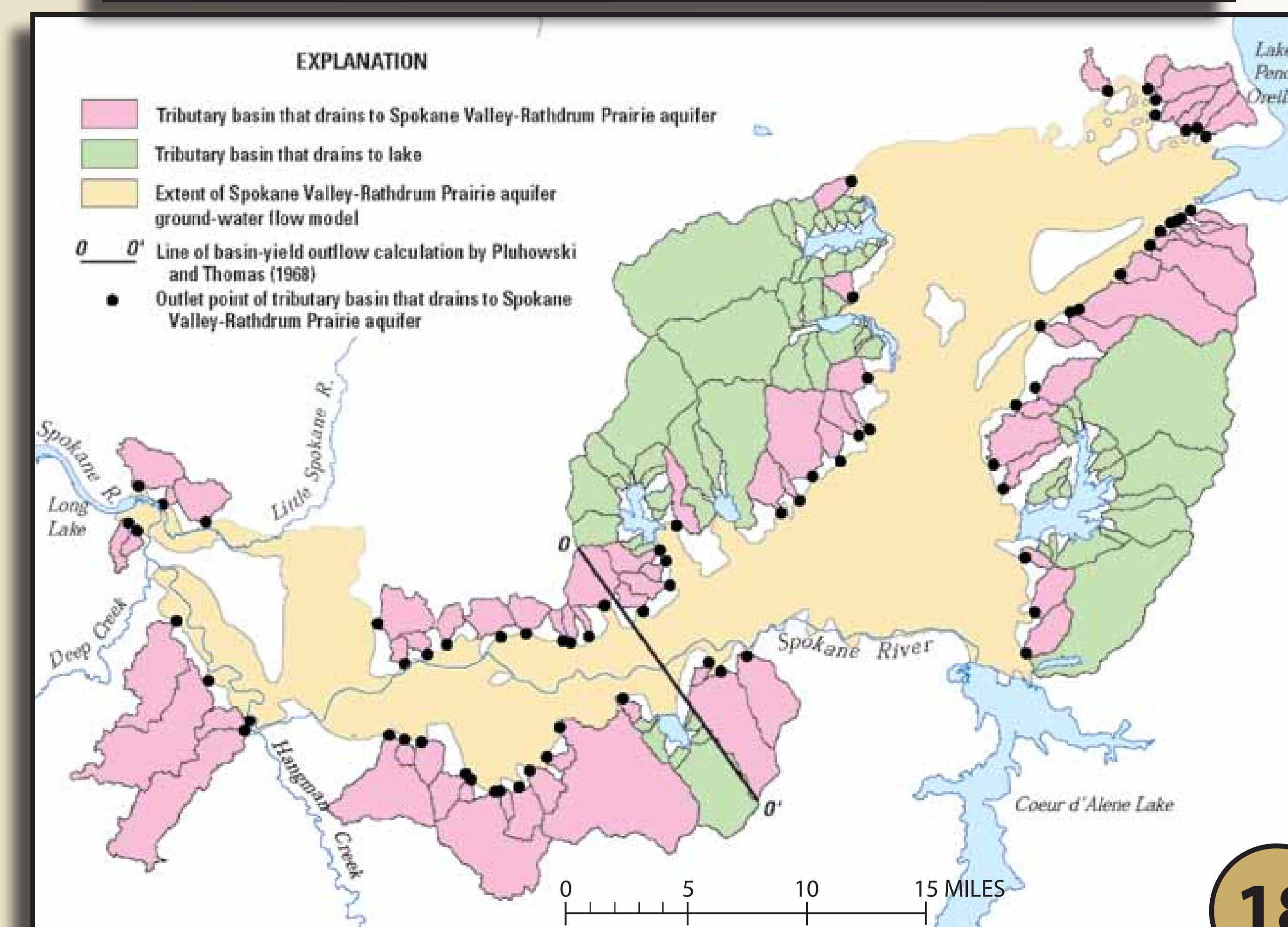


Pipe Sewer Areas (above)

These areas provide pipe sewer service that do not contribute septic drain field flow to the Aquifer.

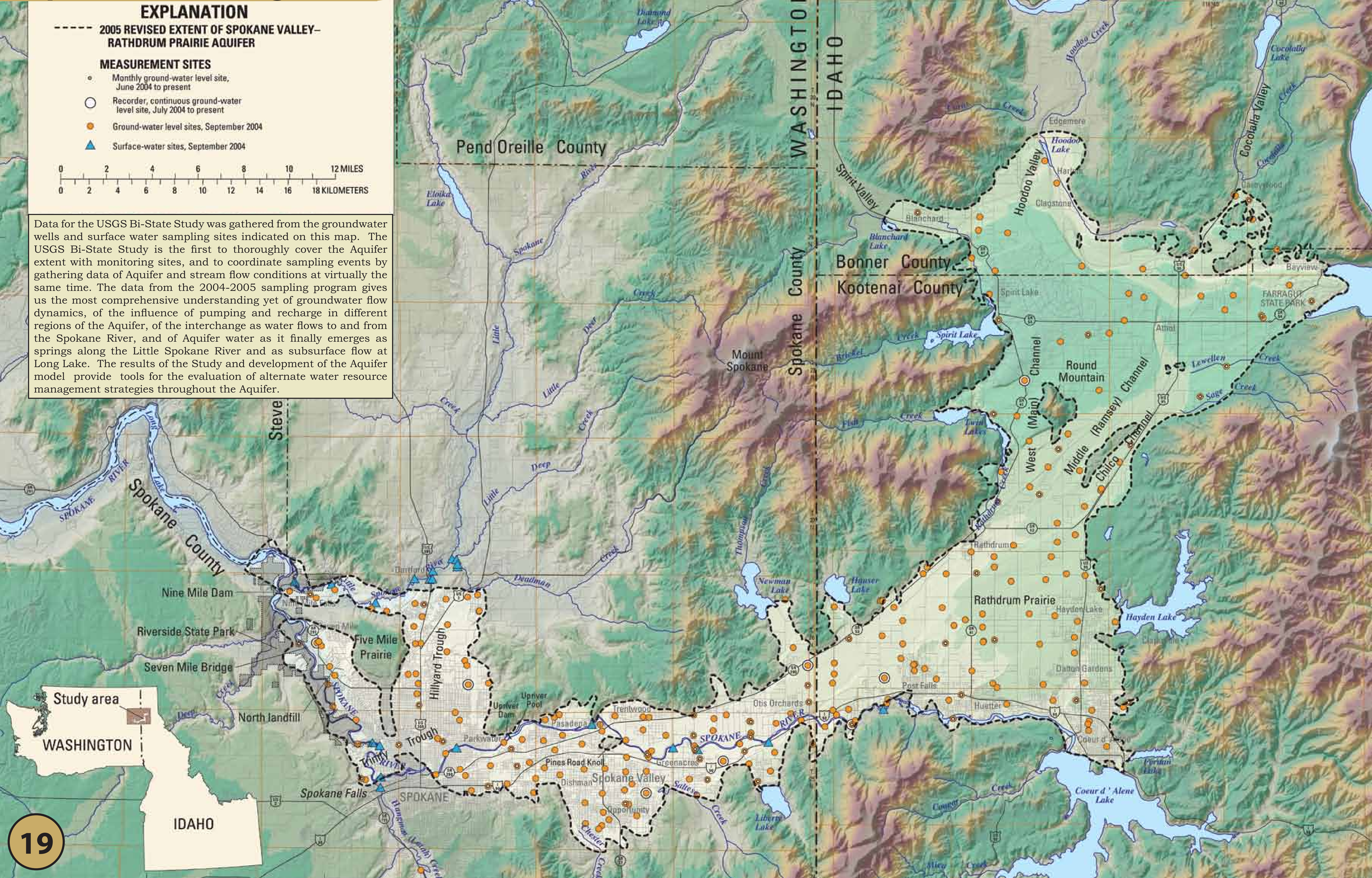
Aquifer Tributary Areas (below)

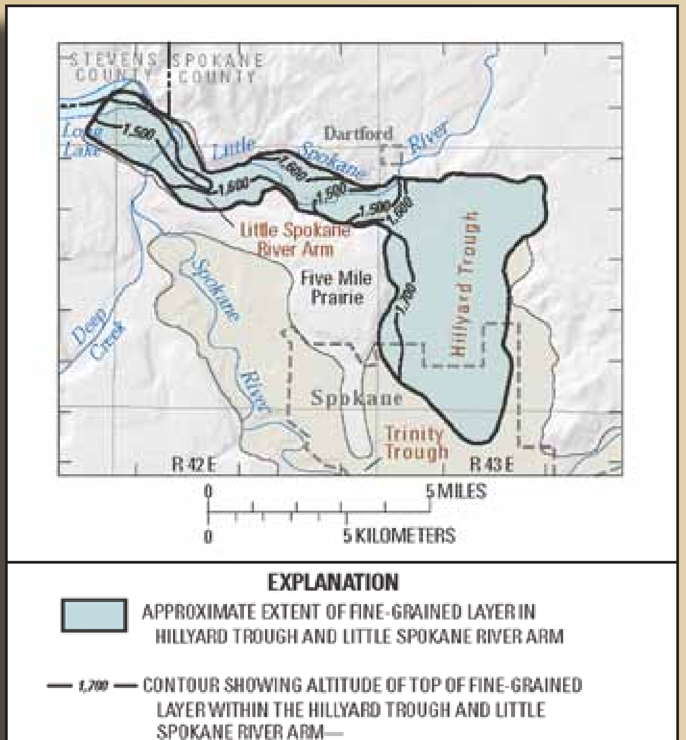
These areas either drain to the Aquifer (pink) or drain to lakes near the Aquifer (green).



Aquifer Monitoring Sites

Data for the USGS Bi-State Study was gathered from the groundwater wells and surface water sampling sites indicated on this map. The USGS Bi-State Study is the first to thoroughly cover the Aquifer extent with monitoring sites, and to coordinate sampling events by gathering data of Aquifer and stream flow conditions at virtually the same time. The data from the 2004-2005 sampling program gives us the most comprehensive understanding yet of groundwater flow dynamics, of the influence of pumping and recharge in different regions of the Aquifer, of the interchange as water flows to and from the Spokane River, and of Aquifer water as it finally emerges as springs along the Little Spokane River and as subsurface flow at Long Lake. The results of the Study and development of the Aquifer model provide tools for the evaluation of alternate water resource management strategies throughout the Aquifer.



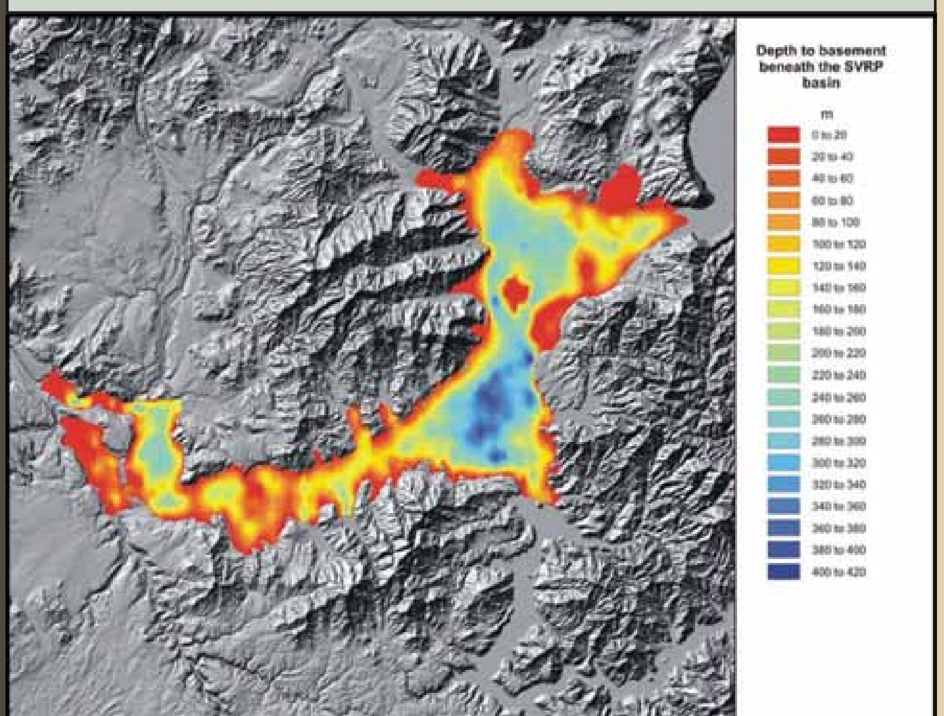


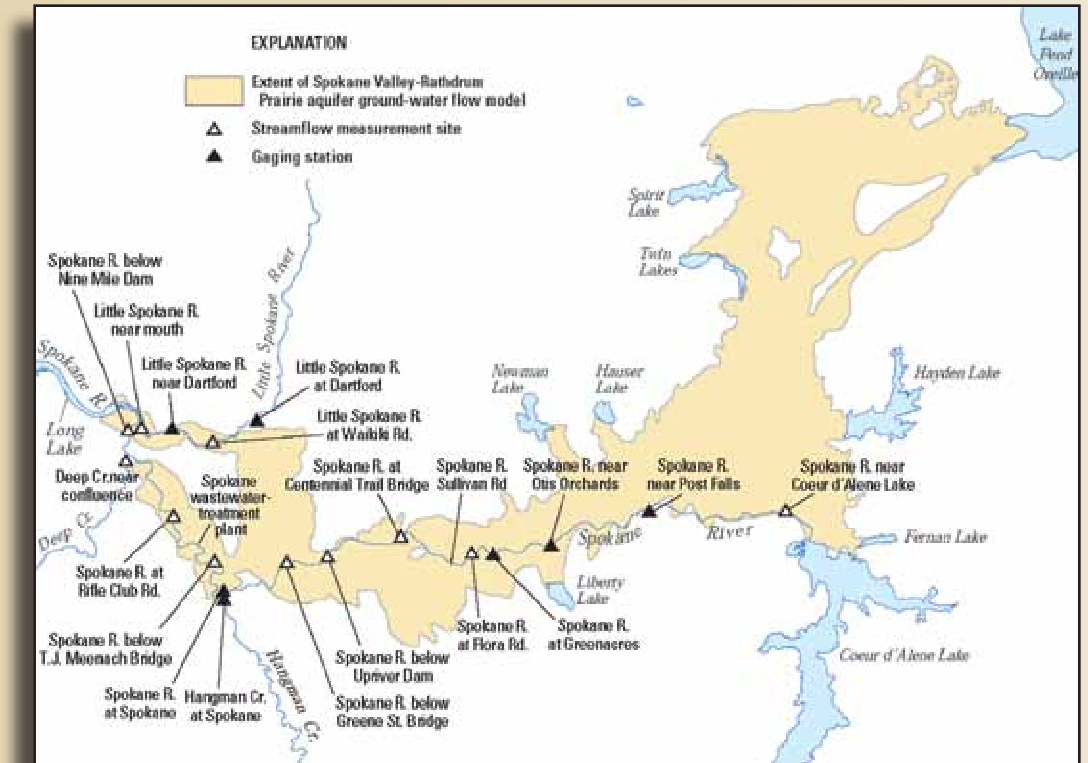
Hillyard Trough

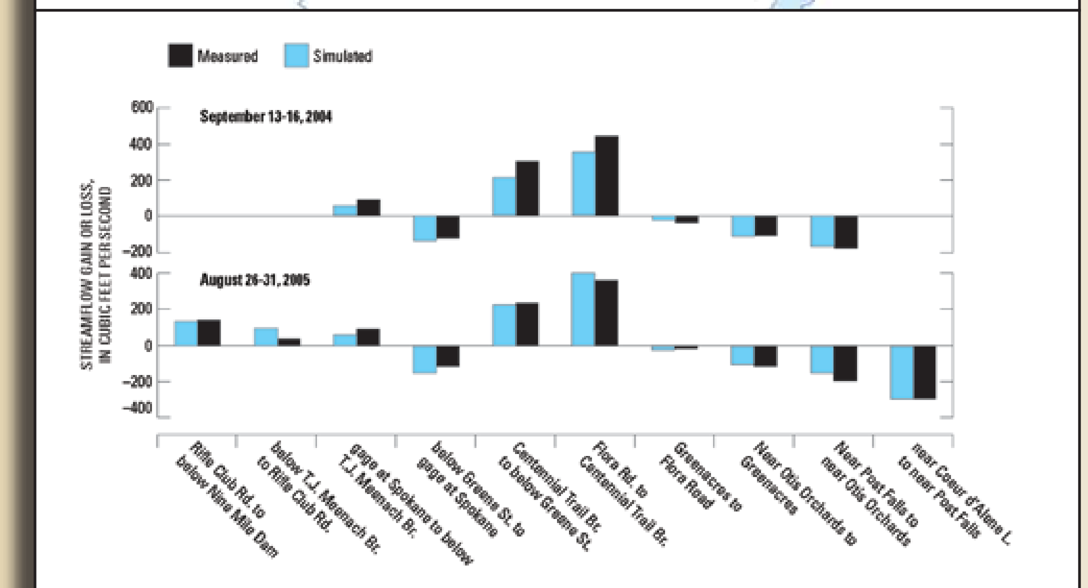
The USGS study confirmed an extensive impervious layer of fine-grained sediments (silts, clay) separates the Aquifer into two units in the Hillyard Trough: a confined aquifer below the fine-grained layer, and an unconfined, or water table aquifer, above it. This Hillyard Trough layer is 162 to 265 feet thick and averages 215 feet. The Little Spokane River arm averages only 130 feet thick. This is the only location where the Aquifer has a confined level. Except for this area, the entire Aquifer is unconfined without a protective impervious cap.

Depth to Bedrock

The map below indicates the depth from the surface to bedrock, the bottom of the Aquifer. The deepest portion is under the Rathdrum Prairie in Idaho.







Lake	2005 Estimates (million gallons per day)	2007 Model (million gallons per day)
Hayden	40	45
Pend Oreille	32	43
Spirit	31	36
Coeur d'Alene	24	89
Twin	23	26
Newman	13	21
Hauser	11	13
Fernan	8	10
Liberty	3	4

Area Lakes Discharge to the Aquifer

When comparing the 2005 estimated values for lake discharge to the Aquifer (page 13) with the 2007 model results, surprising differences can be found. While many values are similar, all the model values are larger, and two lakes, Newman and Coeur d'Alene, are much higher.

A Computer Model of the Aquifer

Two years of collecting comprehensive data about the Aquifer and the Spokane River produced not only thorough and comprehensive data about the Spokane River and the Aquifer, but also provided the data for hydrogeologists to construct a computer model of the Aquifer. This model can help us to better understand the complex interactive relationships of natural and human impacts upon the Aquifer. The computer model can be programmed to simulate "what if" situations, such as drought, heavy spring run-off, increased or reduced groundwater pumping, and the results of these simulations can help us understand how these events might impact water availability in the Spokane River and the Aquifer. The model is a tool to help us better understand and manage the region's water resources.

Calibrating the Groundwater Model

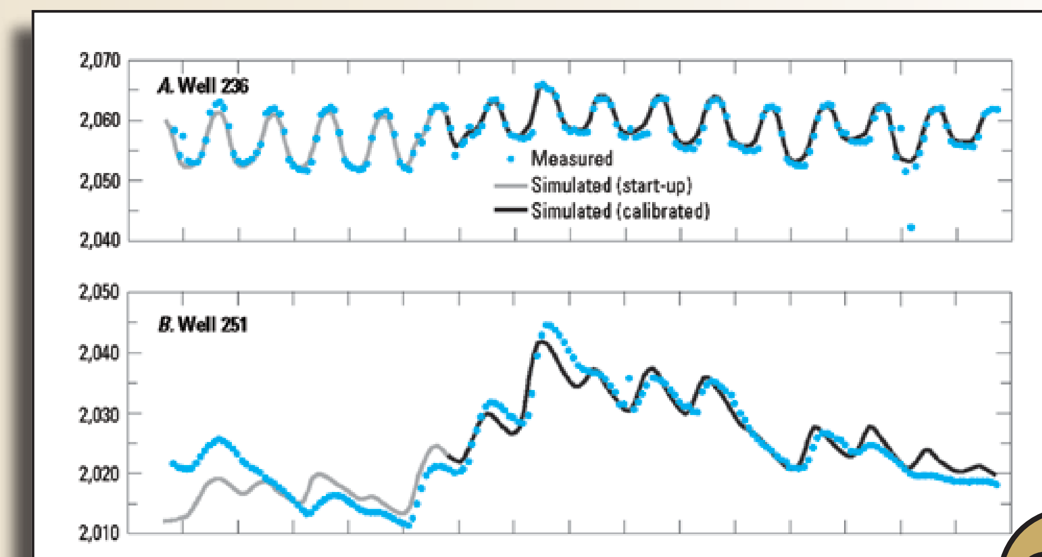
Model calibration is the adjustment of model parameters (such as groundwater flow and area lake contributions) so that the differences between the model values and the measured values in the real world are minimized. The model is calibrated to measured field values of water levels and river flows so that it accurately mimics the modeled period of study. Once the model is calibrated it can be used to evaluate water levels in the Aquifer and rivers in future "predictive scenarios."

The image at left presents a comparison between measured and simulated values for flow in the Spokane River at several locations for two dates. The differences between real world and model values are generally small.

The graphs below present a comparison between measured and simulated groundwater level values for two Aquifer wells. While most model values are close to the measured groundwater levels, they are not exact.

For more information on the Aquifer groundwater model, model calibration and other model results, please see USGS Scientific Investigations Reports 2007-5044.

The information on this page is adapted from USGS Scientific Investigations Reports 2007-5044 and 2007-5041.

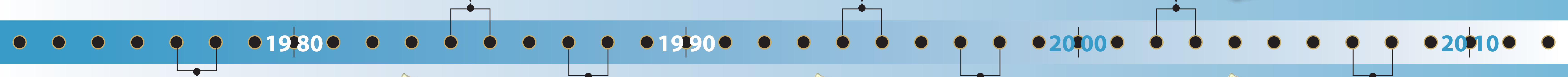


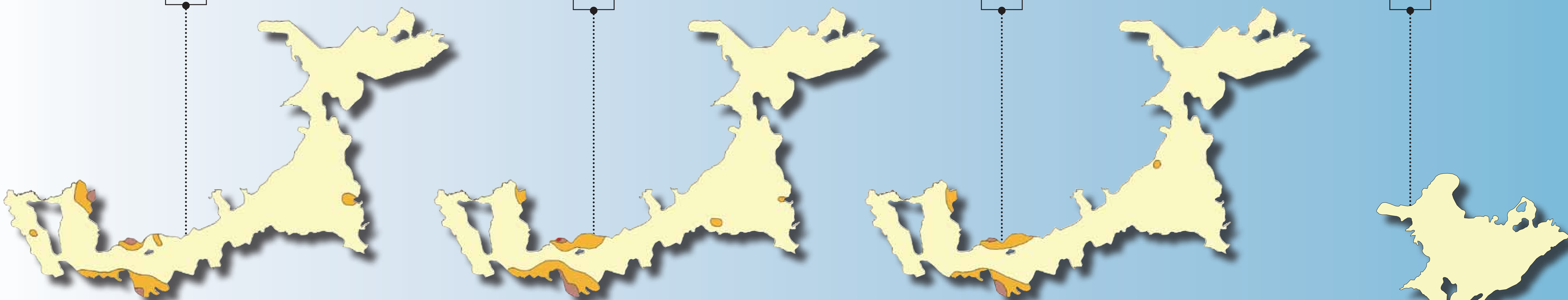
Water Quality

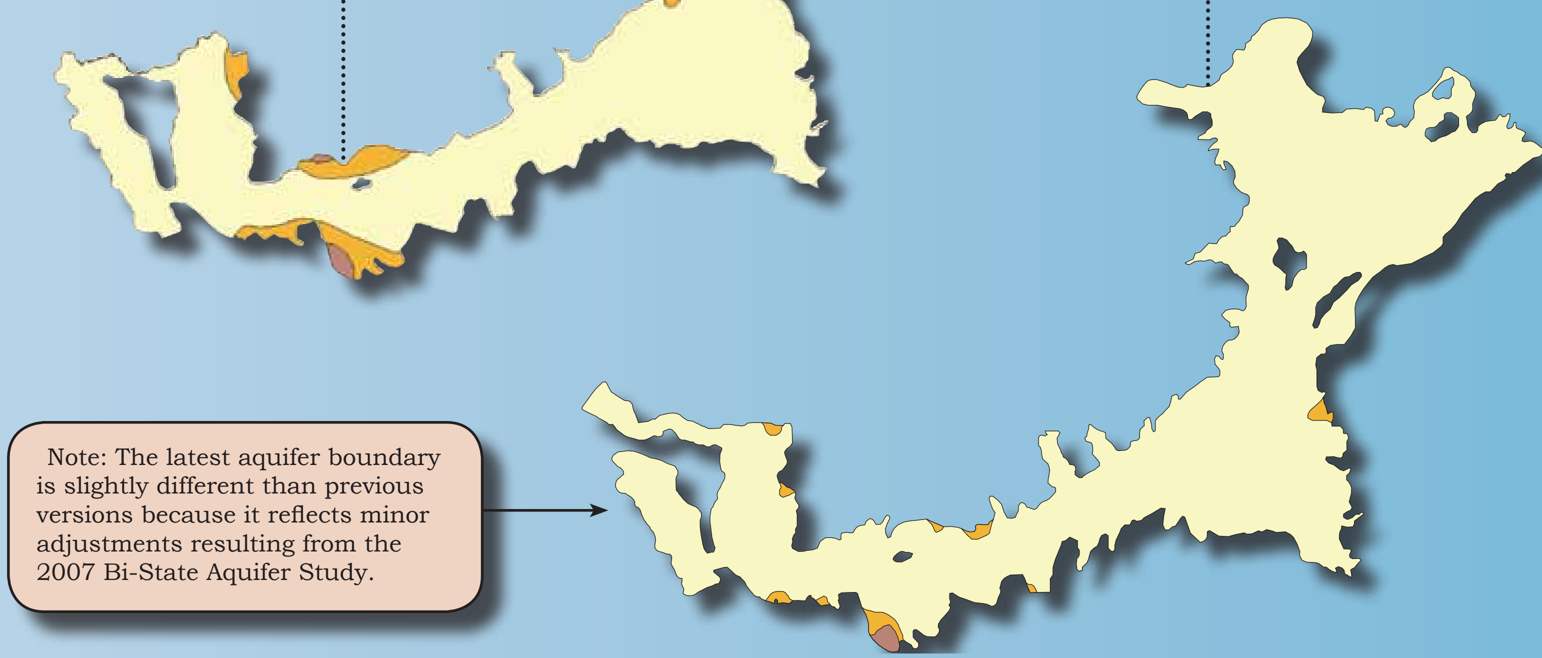
The illustrations on this page show concentrations of nitrate in the Aquifer through time. Nitrate is composed of nitrogen and oxygen and is highly stable in the water in soil and aquifer sediments. Under natural conditions in our Aquifer, nitrate occurs in low concentrations, typically 1 to 2 parts per million (ppm). Nitrate in drinking water above 10 ppm may cause illness. Septic systems, fertilizer, and stormwater are major causes of elevated nitrate levels in the Aquifer.

The earliest nitrate concentration map is from the water year October 1977 to September 1978, which represents earlier stages of Aquifer protection activities in Washington and Idaho. The peak of observed nitrate degradation in the entire Aquifer was in the water year 1984-85. In 1985 a major effort on both sides of the state line was initiated to reduce septic system contamination of the Aquifer through installation of piped sewer collection systems. On all the maps, certain areas near the edge of the Aquifer show high levels of nitrate. These locations represent "eddy" areas where incoming contaminants from side hill development are not easily or quickly mixed with better quality water recharging from the east.

As the maps indicate, on-going Aquifer protection programs have decreased the nitrate contamination despite significant population increases. These programs include installation of sewers and stormwater management. The groundwater in the Aquifer remains some of the best quality water available anywhere.

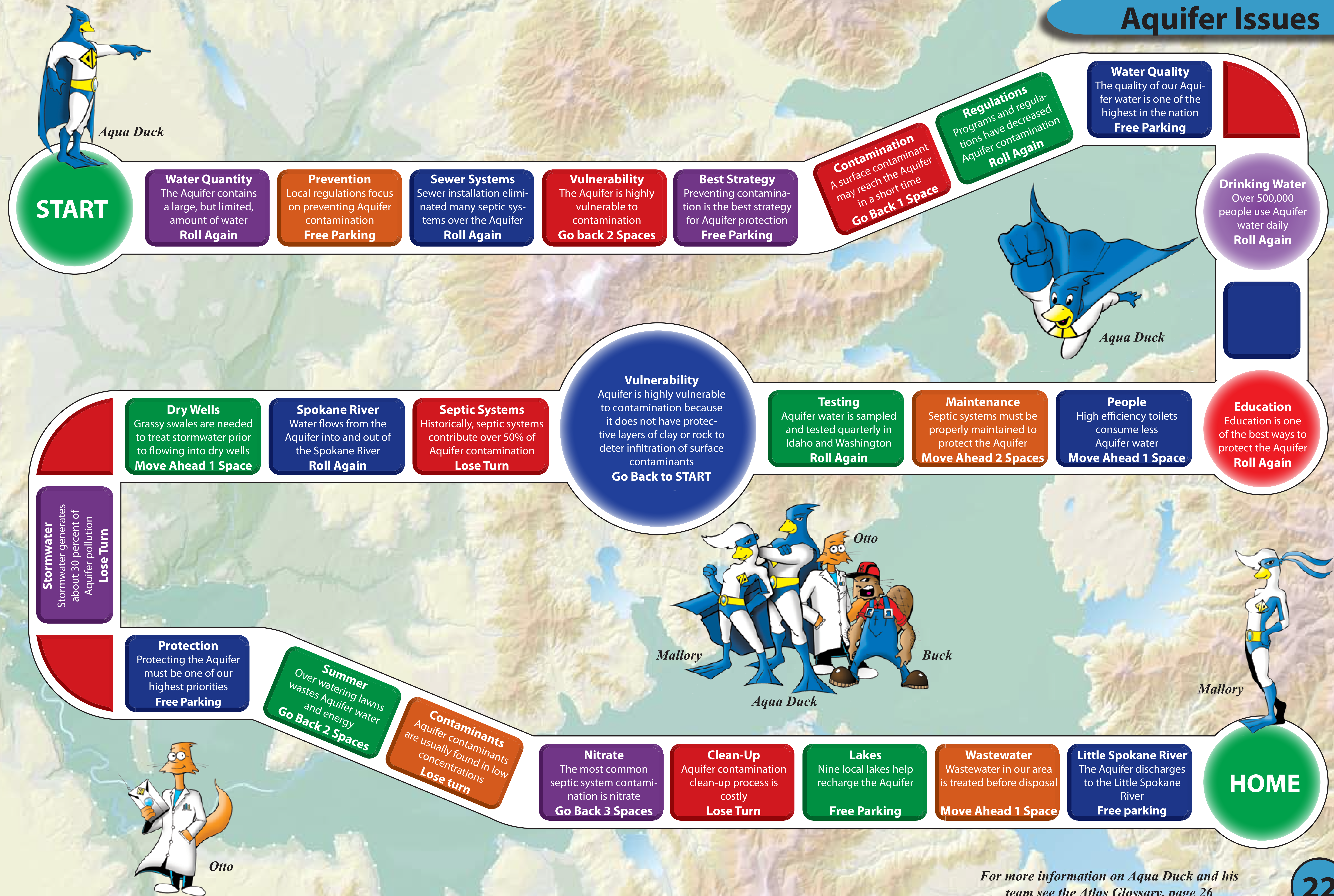






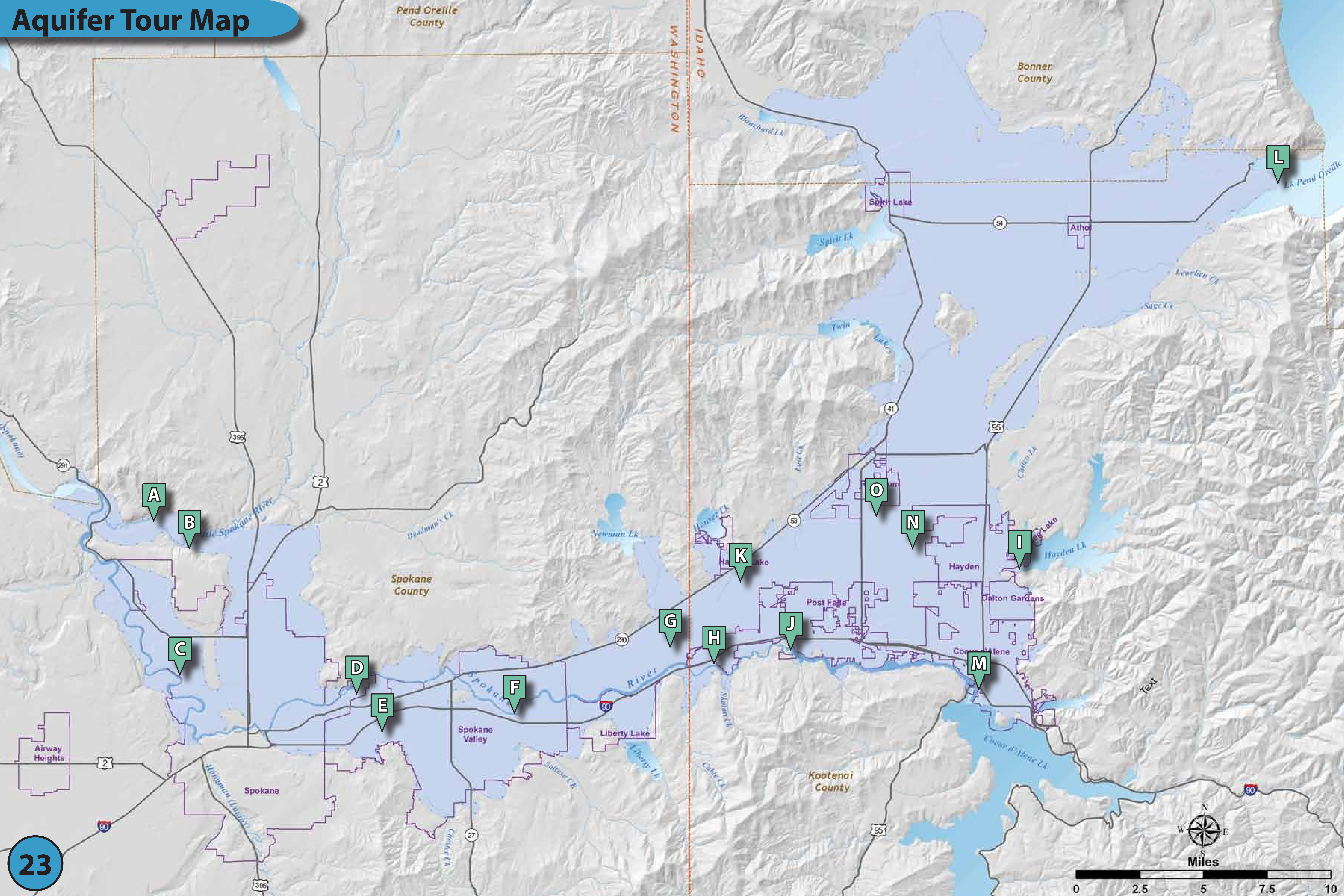
Contaminants

Nitrate is a by-product of human activities, and the presence of high levels of nitrate in groundwater is an indicator that other by-products of human activity may also be present. Other possible contaminants include phosphorous, petroleum products, heavy metals, and industrial chemicals. Traces of some of these other contaminants have occasionally been found in local Aquifer wells. On-going monitoring and protection programs are essential to protect the high quality of Aquifer water.



For more information on Aqua Duck and his team see the Atlas Glossary, page 26

Aquifer Tour Map



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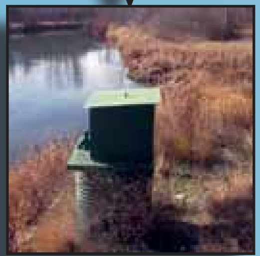
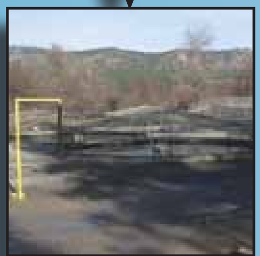


Painted Rocks Gauging Site

Park at the Painted Rocks parking lot and follow the path south to the Little Spokane River. Near the Rutter Parkway bridge is a circular corrugated metal stilling well with a locked box on top. This is the U. S. Geological Survey gauging station containing equipment which continuously measures the elevation of the surface of the river. This information and information from a similar gauging site near Dartford seven miles upstream is used to calculate how much water is flowing out of the Aquifer through springs between the two sites.

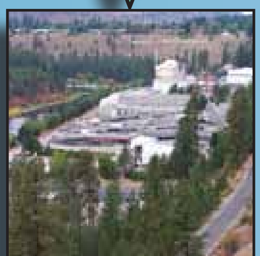
B



Spokane Hatchery

Griffith Spring, located at the Spokane Hatchery, is a place where water flows out of the Spokane Aquifer. Water from these springs, and other springs in the area, flow to the Little Spokane River. The Hatchery needs very clean water to grow its fish. To keep the water clean, the hatchery asks that people stay out of the springs area. Group tours can be arranged by calling (509) 892-1001.

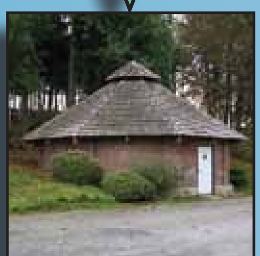
C



Water Reclamation Facility

4401 N. Aubrey L. White Parkway. If your home is connected to the City of Spokane-Spokane County sewer system, all the water that goes down your drain and into the sewer ends up at this facility. Spokane County is presently constructing a second water reclamation facility to serve this area. The wastewater is treated with solids removal, aeration, bacterial activity, and disinfection. Groups tours can be arranged (509)625-4600.

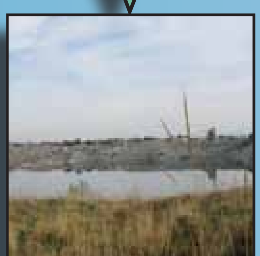
D



Original 1907 Well

Turn north onto Waterworks at the blinking yellow light near the 4600 block of Trent Avenue. Follow Waterworks to the Upriver Dam visitor parking lot. The first public water supply wells in the Aquifer were dug here in 1907. More water supply wells have been dug near the dam since 1907. The City of Spokane operates the dam and monitors its water distribution system from the facility at Upriver Dam. Group tours can be arranged by calling (509) 742-8156.

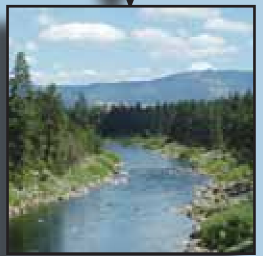
E



Gravel Pit

Drive along Thierman Street and Heacox Avenue between Sprague and Broadway. This gravel pit is another place to see the rock material of the Aquifer in the Spokane Valley. No vegetation hides the rock material because the pit is still being used. The pit extends below the water table and exposes the water of the Aquifer.

F



Sullivan Park

The park is just north of the river on the west side of Sullivan Road. You can see many big boulders like the kind in the Aquifer along the Spokane River at Sullivan Park. When the Spokane River is low, springs are visible around the Sullivan Road bridge pilings. This is water from the Aquifer flowing into the river.

G

Well Field

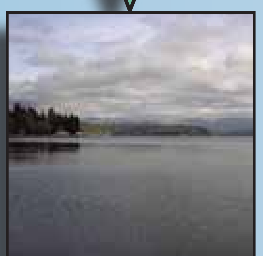
The Consolidated Irrigation District well field is at the corner of Idaho Road and Kildea. The objects that look like R2D2 robots are pumps that bring water from over 100 feet below ground up into the tower above you. From the tower water is distributed to where it is used: a house, a field, or a business. Not all pumps and water towers look like these. Many pumps are located inside small buildings.

H

Hand Pump

From Interstate 90 take exit 299 (last exit in Washington). Park in the Centennial Trail access parking lot just south of the interchange. Walk east about half a mile along the Trail and across the river to the hand pump and sign. Before electricity many people used hand powered pumps to get water from the ground.

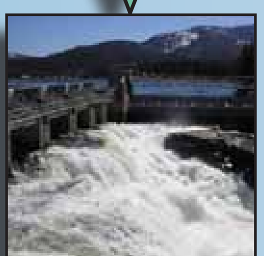
I



Recharge From Lateral Lakes

Hayden Lake and other lakes adjacent to the Rathdrum Prairie contribute water to the Aquifer through seepage from streams flowing out onto the aquifer or from the lake bottoms. Hayden Lake (image at left) is located on the east side of the Rathdrum Prairie. Take Highway 95 north from Coeur d'Alene to the City of Hayden, and turn right (east) on Honeysuckle Ave and then right on Hayden Lake Road. The spillway and canal that control lake levels can be seen on the left.

J



Post Falls Dam and Millrace Head Gate

From Interstate 90 take exit 5 (Spokane Street). Turn south on Spokane Street one block, turn right on 4th Street and drive ahead to the parking lot. The Post Falls Dam restricts the Spokane River during the summer months to produce 14.75 megawatts of electricity and to maintain a constant elevation in Lake Coeur d'Alene. Three dams constructed at Post Falls by the Washington Water Power Company (now called Avista Utilities) began operation in 1906. The Millrace Head Gate provided critical water for irrigation and commerce to lower elevations in the region.

K

Kootenai County Prairie Transfer Station

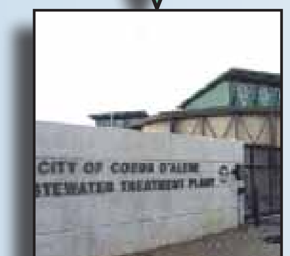
From I-90, take the Spokane St exit, turn north to W Seltice Way; turn left on W Seltice Way to McGuire Rd; turn right on McGuire and drive to Prairie Ave; turn left on Prairie and drive west; the station is on the right. Buildings are covered thereby preventing contaminated runoff, and the buildings' concrete floors are underlain with HDPE liners. Wash water is not used so wastewater is not generated, and the main facility has a 10,000 gallon collection system for incidental and accidental spills.

L

Ice Dam Site - Farragut State Park

Head north on US Highway 95 from Coeur d'Alene approximately 18-miles to Highway 54 Junction. Turn right heading east on Highway 54 to Farragut State Park. Approximately 5 miles turn right at Visitor's Center to obtain permit. Proceed east on Highway 54 approximately 0.5 miles to South Road junction. Turn right and follow South Road to viewpoint at end of road. This is the southern-most edge of the ice dam that created Glacial Lake Missoula. This area is also an important part of northern Aquifer recharge. Enjoy the view and the interpretative signs.

M



Coeur d'Alene Wastewater Treatment Plant

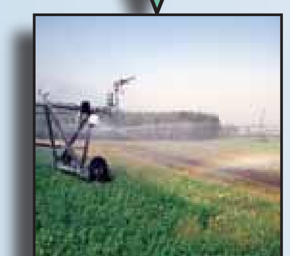
From I-90, take the Northwest Blvd exit, and drive south on Northwest Blvd; turn right on West Hubbard street, drive west for about 750 feet; the plant is located between the road and the river. Coeur d'Alene constructed a secondary-level municipal treatment plant in 1939 as one of the first such municipal plants in the world. The plant's staff performs over 700 laboratory tests per month, and they sample the river weekly and record weather observations.

N

Panhandle Health District Building

Panhandle Health District's (PHD) building is located at 8500 N Atlas Road in Hayden. Stormwater is managed on the site using examples of low impact development to prevent untreated stormwater disposal into the Aquifer. These examples range from sidewalk surfaces to planter placement and choice of plants. A 37,000-gallon cistern stores rainwater for irrigation of the lawns and drought-resistant native plants on the site. PHD added interpretive panels throughout the site and conducts tours upon request.

O

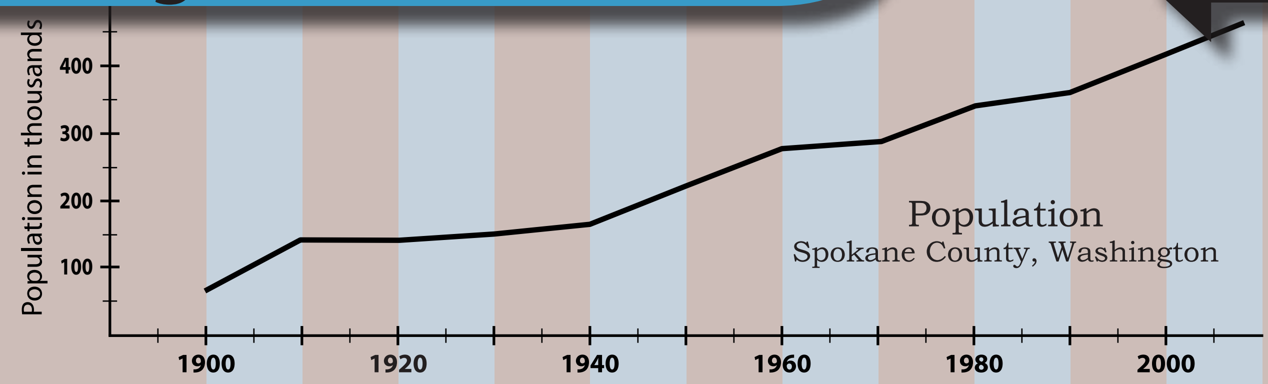


HARSB Land Application Site

The Hayden Area Regional Sewer Board (HARSB) manages sewer service to the residents of the City of Hayden as well as to the Coeur d'Alene (Kootenai County) Airport and the Hayden Lake Recreational Water and Sewer District. HARSB operates a wastewater reuse facility during the growing season that consists of 400 acres (south east corner of W Boekel Road and N Huetter Rd in Hayden) that are irrigated with 1.2 million gallons of reuse water daily. The reuse water is applied at rates that are completely consumed by alfalfa and hybrid poplar trees.

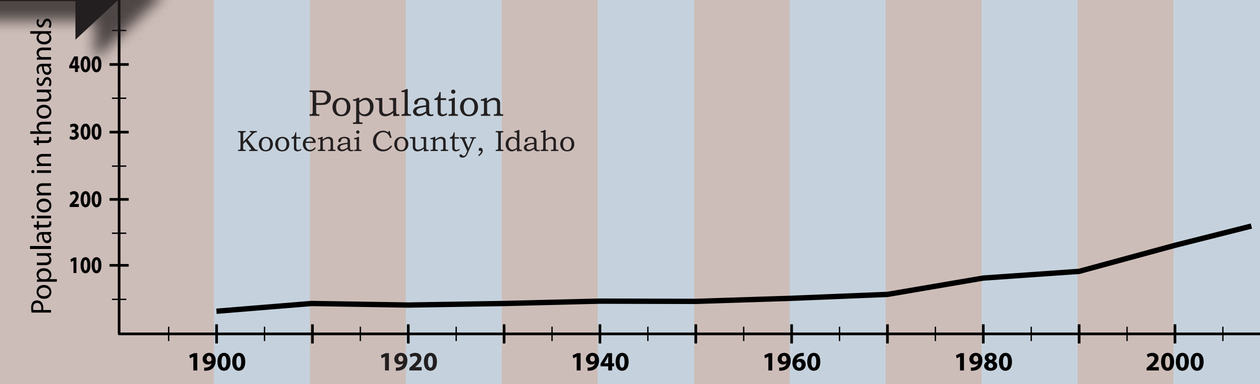
Regional Trends

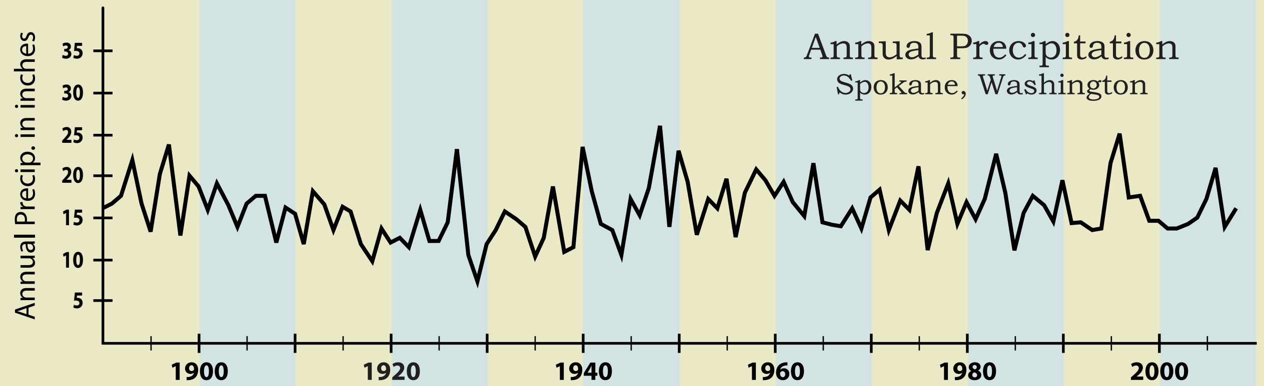
Washington | Idaho



Population

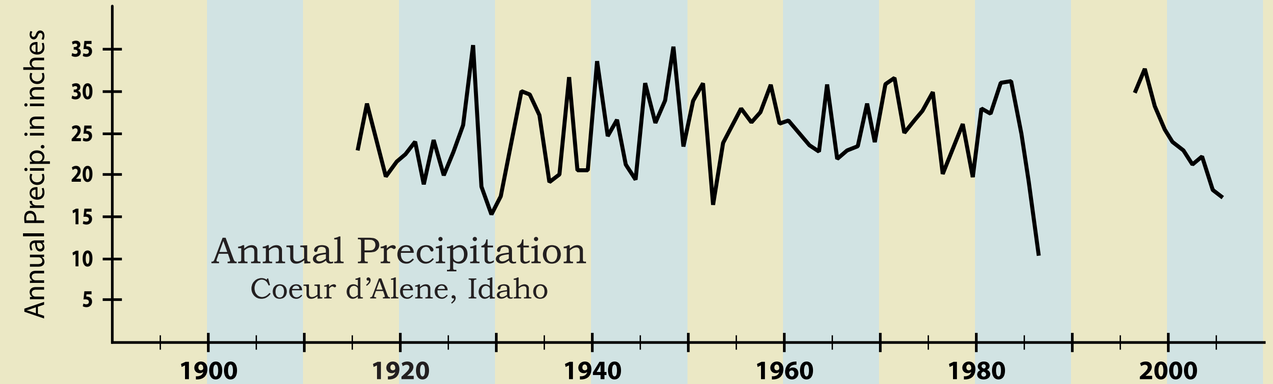
The region's population has grown in the past 100 years with the exception of a dip in 1920-1930. While the growth rate in Spokane County has remained stable since 1930, Kootenai County experienced a sharp population increase in 1990. A growing population requires an increasing amount of potable water, and the demand for Aquifer water continues to grow.

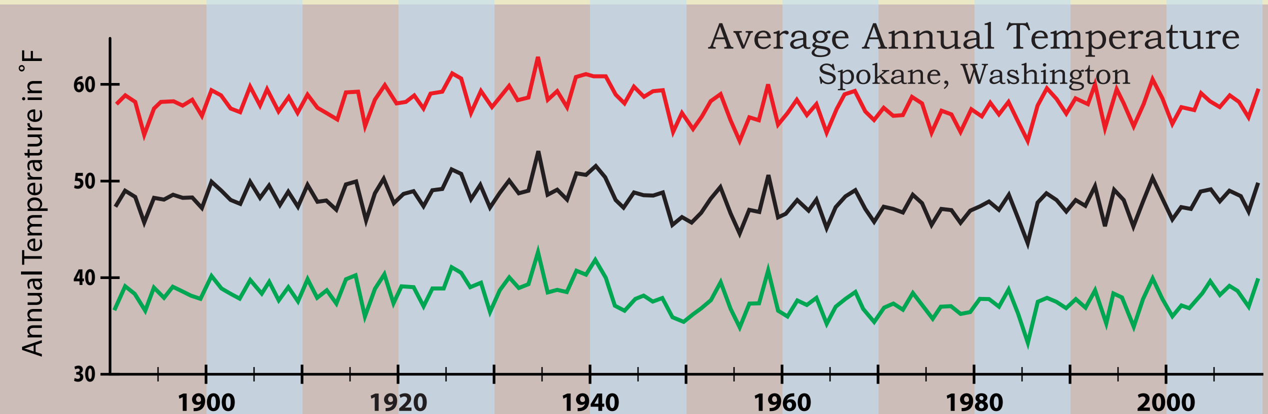




Annual Precipitation

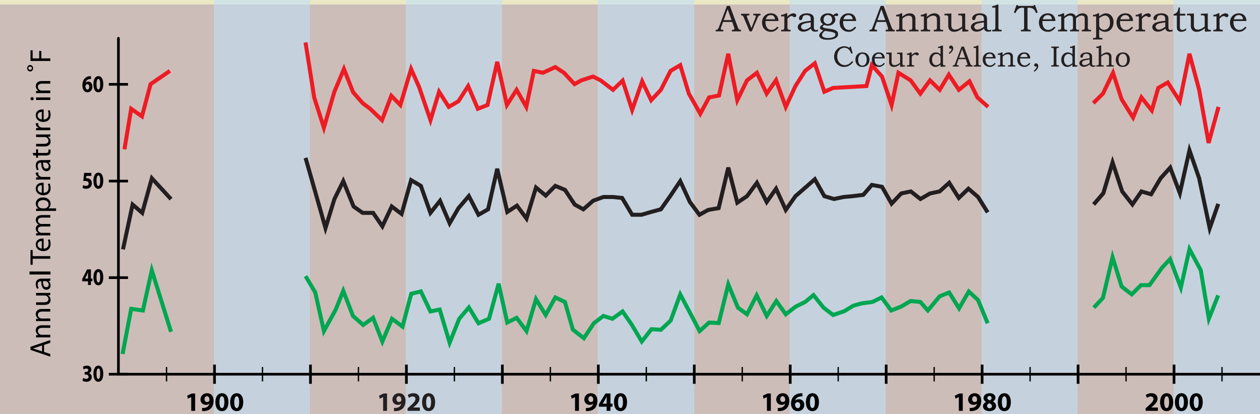
The annual precipitation varies across the Aquifer, increasing from west to east. The average annual precipitation in Spokane is about 16 inches, while it is over 25 inches in Coeur d'Alene. Precipitation is the primary Aquifer recharge source. Weather station locations are provided on the Geography map, page 6.

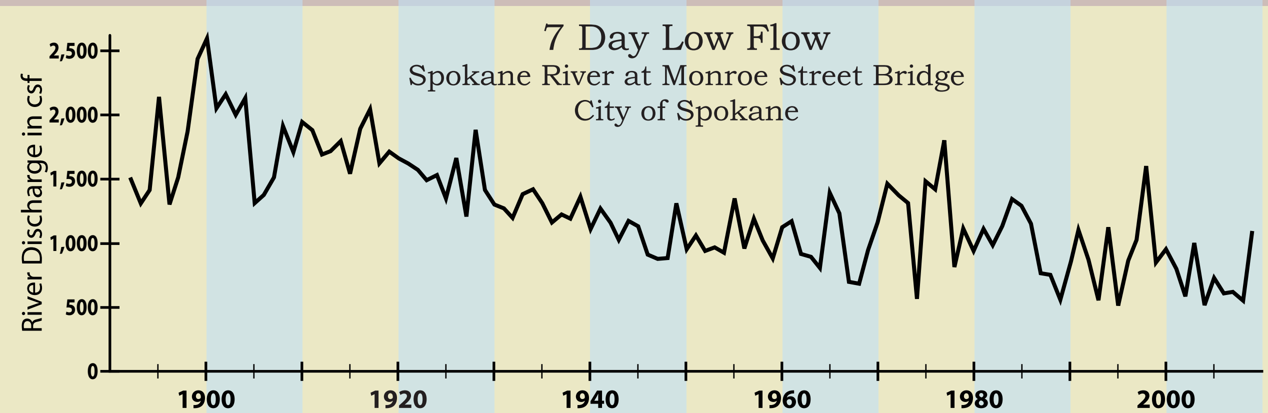




Average Annual Temperature

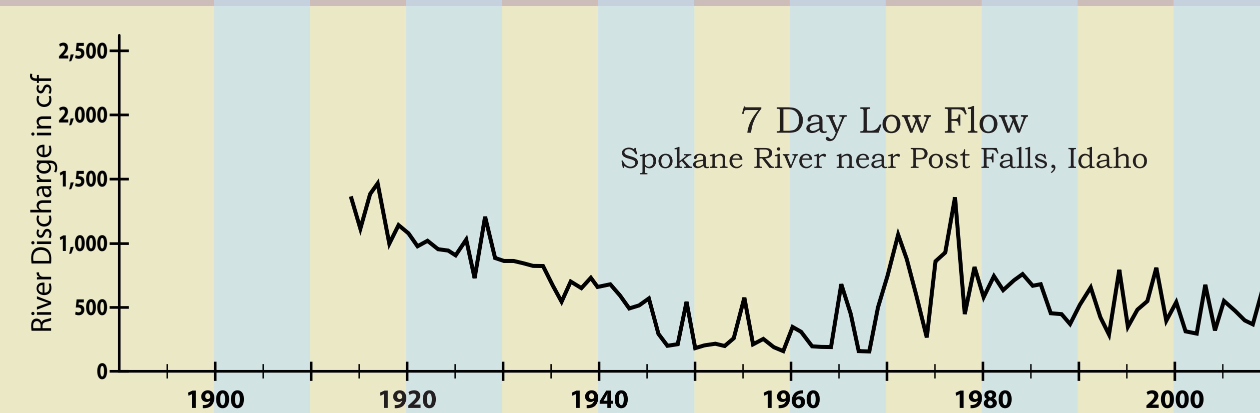
The annual temperatures shown in these two graphs were derived from monthly averages for each year. The red line is average annual maximum temperature; the black line is average annual temperature; and the green line is average annual minimum temperature. Weather station locations are provided on the Geography map, page 6.

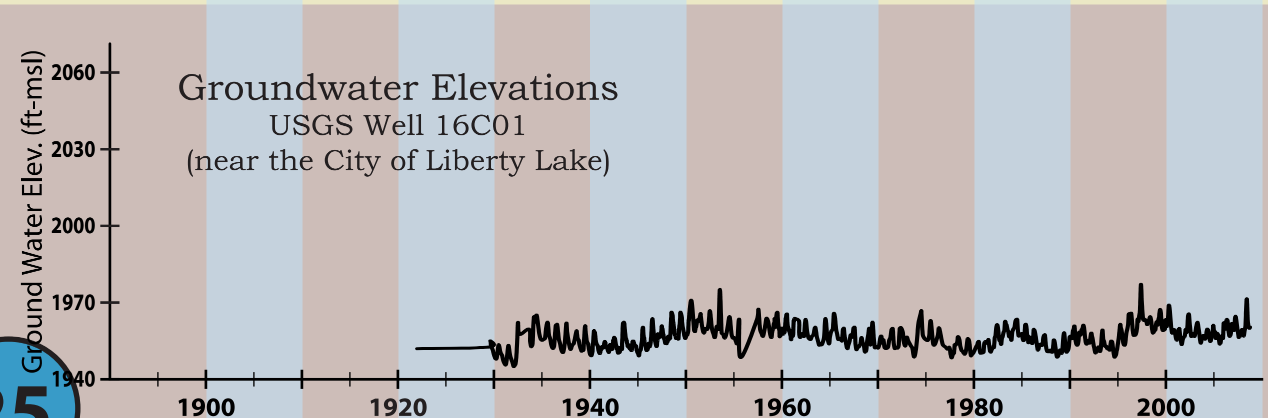




7 Day Low Flow

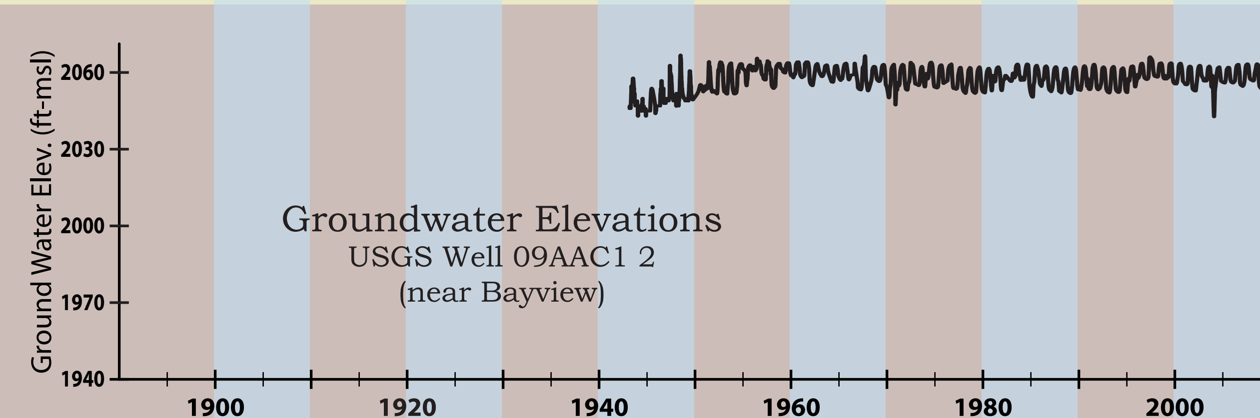
The 7 day low flow is the lowest average flow of seven consecutive days in the year. For the Spokane River two graphs are provided: one near Post Falls and the other in Spokane near the Monroe Street Bridge. River gage station locations are provided on the Geography map, page 6.





Groundwater Elevations

Variations in groundwater elevations are related to several factors, including precipitation, water withdrawals, and river flow. Compare the Spokane River 7 day low flow and precipitation graphs with the groundwater elevation graphs, and you may see similarities in general fluctuations and trends. Well locations are provided on the Geography map, page 6.



A

Aquifer: Rock or sediment in a formation, group of formations, or part of a formation which is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.

Anaerobic: Literally - without air. Generally means without oxygen.

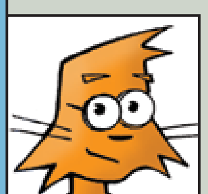
Aquifer Defense Force Team

Aqua Duck: Commander
Height : 6'2" Weight : 250 lbs.
Favorite Movie: "The Mighty Ducks"
Hobbies: Baseball, Kung Fu & Chess

Defending the Aquifer is a full-time job, and Aqua Duck adeptly commands his team through countless thrilling adventures. He faces numerous daunting challenges with a most talented team.

Mallory: Lt. Commander
Height : 5'6" Weight : 113 lbs.
Favorite Movie: "The Big Blue"
Hobbies: Martial Arts, Interior Design & 80's Music

Mallory is second in command. Her swift decision making and adept problem solving skills make her a strong leader. In the arena of combat she is seldom matched.



Otto: Chief Science Officer
Height : 4'10" Weight : 110 lbs.
Fav. Movie: "A River Runs Through It"
Hobbies: Chess, Gourmet Cuisine & Billiards

Otto's duties include hydrological research, advanced water purification technology and developing new hardware. With a vast intellect and mechanical skills, he is a valuable team member.

Buck: Chief Systems Operator
Height : 4'6" Weight : 112 lbs.
Favorite Movie: "Waterworld"
Hobbies: Hockey, Karaoke & Pinball

The fun loving Buck is responsible for the vast Aquifer Hydro-Distribution Waterway System. His hard working spirit is an inspiration to the entire team.

For more information about Aqua Duck and his team visit www.spokaneaquifer.org

B

Basalt: A fine-grained and usually dark-colored mafic igneous rock that originates as surface flow of lava.

C

Chlorination: The addition of chlorine to water for the purpose of disinfection.

Cobbles: Rocks that are larger than pebbles and smaller than boulders, usually rounded while being carried by water, wind, or glaciers.

Coliform Bacteria: A type of bacteria that live in the digestive tracts of animals and humans but are also found in soils and water. The presence of coliform bacteria in certain quantities in water is used as an indicator of pollution.

Confined Aquifer: An aquifer that is overlain by a confining bed. The confining bed has a significantly lower hydraulic conductivity than the aquifer.

Consumptive Use (of water): The water used for any purpose that does not return to its source, such as irrigation water lost to the atmosphere by evapotranspiration.

Coulee: A steep-sided gulch or water channel.

Cubic Feet Per Second (cfs): A unit of measurement for expressing the flow rate (discharge) of a moving body of water. One cubic foot per second is equal to a stream one foot deep, one foot wide and flowing at a velocity of one foot per second. One cubic foot of water is equal to 7.48 U.S. gallons.

D

Discharge: The volume of water that passes through a given cross section of a stream, pipe, or even an entire drainage basin.

Domestic Consumption (use): The quantity of water used for household use including drinking, washing, bathing and cooking.

Drainfield: Perforated pipes buried in trenches filled with gravel that allows water from the septic tank to be absorbed into the ground.

E

Effluent: Something that flows out, such as a liquid discharged as a waste; for example, the liquid waste that comes out of a sewage treatment plant.

Evaporation: The process by which water is changed from a liquid to a vapor. In hydrology, evaporation is vaporization that occurs at a temperature below the boiling point.

Evapotranspiration: Evaporation plus transpiration.

F

Fluvial: Of or pertaining to rivers; produced by a river's action, such as a fluvial plain.

G

Gaining Reach: A portion of a stream that receives all or part of its water from groundwater.

Gallons Per Minute (GPM): A unit for expressing the rate of discharge, typically for the discharge of a well.

Glacier: A mass of ice that is moving on land in a definite direction, originating from accumulated snow.

Glacial Outwash: Layers of clay, sand, and gravel deposited by glacial meltwater streams.

Grassy Swale: An area covered with grass or other vegetation used to catch and treat stormwater runoff by allowing the water to slowly percolate through the grass and soils.

Groundwater: Subsurface water found in the zone of saturation.

Groundwater Level: Usually found by measuring the level of water in non-pumping or non-flowing wells – also known as the static water level.

H

Hardness: A measure of the amount of calcium, magnesium, and iron dissolved in the water.

HDPE: High-density polyethylene plastic.

Hydraulic Conductivity: A measurement of permeability.

Hydrogeology: The science of the interaction between geologic materials and water, especially groundwater.

Hydrologic Cycle: The endless interchange of water between sea, air, and land: includes evaporation from oceans, movement of water vapor, condensation, precipitation, surface runoff, and groundwater flow.

Hydrology: The science of the behavior of water in the atmosphere, on the earth's surface, and underground.

Hydrothermal Vein Deposits: A mineral deposit formed in cracks in rocks by the injection and cooling of hot liquid containing dissolved minerals.

I

Ice Age: A geological period of widespread glacial activity when ice sheets covered large parts of the continents.

Ice Dam: A blockage of a river by ice.

Igneous Rock: A rock formed by the cooling of molten magma; for example, granite or basalt. Light colored igneous rocks tend to be felsic and dark tend to be mafic.

Impervious: Incapable of being penetrated by water.

Infiltration: In hydrology it is the movement of water into soil or porous rock.

Influent Stream: A stream contributing water to the zone of saturation thereby sustaining or increasing the water table; also called a "losing stream".

J-K

No Entries.

L

Lava: Molten rock erupted on the surface of the earth by volcanic processes.

Losing Reach: A portion of a stream contributing water to groundwater.

M

Metamorphic Rock: Rock derived from pre-existing sedimentary or igneous rock that has been transformed by heat and/or pressure.

Monitoring Site or Well: A surface water site or a well used to monitor water quality and/or changes in water levels.

N

Nonpoint Source Pollution: Pollution discharged over a wide area of land, not from one specific location.

O

No Entries.

P

Parts Per Million (ppm): The number of "parts" of a substance by weight per million parts. A commonly used unit used to express a pollutant's concentration in water. Equivalent to milligrams per liter (mg/L).

Percolation: The downward movement of water through the pores or spaces of a rock or soil.

Permeability: The ability of rock or sediment to permit water to pass through it. It is dependent on the volume of the pores and openings and their interconnectedness.

Point Source Pollution: Pollution discharged from a single source or point such as a pipe, ditch or sewers.

Porosity: In rock or soil, it is the ratio of the volume of openings in the material to the total volume of the material. In hydrology it is used to express the capacity of rock or soil to contain water and is expressed as a percentage.

Precipitation: In hydrology, any form of water that falls to the ground from the atmosphere, including rain, snow, ice, hail, drizzle, etc.

Proterozoic: Geological time unit before the first abundant complex life on Earth.

Purveyor: Someone who supplies provisions, in this case water.

Q

No Entries.

R

Recharge, Groundwater: In hydrology, the addition of water to the zone of saturation. Precipitation and its movement to the water table is an example.

Recharge Area: An area in which an aquifer receives water by the force of gravity moving water down from the surface.

Runoff: That portion of precipitation or irrigation water that drains from an area as surface flow.

S

Sewer: A system of pipes that carries domestic waste water and/or stormwater.

Saturated: In hydrology, the condition in which all the pore spaces in a rock or soil layer are filled with water.

Saturated Zone: A subsurface zone below which all rock pore space is filled with water (also known as the zone of saturation). The top of the saturated zone is the water table.

Sediment: 1) Any material carried in suspension by flowing water that ultimately will settle to the bottom of a body of water; 2) waterborne material deposited or accumulated on the bottom of waterways.

Sedimentary Rock: A layered rock resulting from the consolidation of sediments.

Seepage: Water that passes slowly through porous material.

Seismic Energy: Energy similar in character to that produced by an earthquake.

Septic Tank: Underground tanks that receive household wastewater. Anaerobic bacterial action breaks down the organic matter in the tank. The effluent then flows out of the tank into the ground through drains.

Septic System: The complete wastewater treatment system that includes a septic tank and a drainfield.

Seven Day Low Flow: The lowest average flow of seven consecutive days in the year.

Sewage: The total of organic waste and wastewater generated by residential and commercial establishments.

Sewer System: A system of pipes that carries wastewater and/or stormwater to a treatment facility. When the pipes carry both wastewater and stormwater it is called a Combined Sewer.

Sole Source Aquifer: An aquifer which is the sole or principal drinking water source for the area and which, if contaminated, would create a significant hazard to public health. Requires designation by EPA.

Storm Drain (Storm Sewer): A drain (sewer) that carries storm waters and drainage, but excludes domestic and industrial wastewater.

Stormwater: Runoff water from urban areas that originates during precipitation events.

Surface Water: All water on the land surface exposed to the atmosphere, includes oceans, lakes, streams, glaciers and snow.

T

Transmissivity (groundwater): The capacity of an aquifer to transmit water through its entire saturated thickness.

Transpiration: The process by which water from a plant is evaporated to the atmosphere, usually through the leaf surface.

U

Unconfined Aquifer: An aquifer in which there are no confining beds between the zone of saturation and the surface. There will be a water table in an unconfined aquifer.

Underground Storage Tanks: Tanks used to store fuels and other liquids underground. There are usually two or more such tanks at every gas station.

V

No Entries.

W

Wastewater: Water discarded after use by human activities so that it must be treated before being returned to the environment.

Water Budget: A numeric evaluation of all sources of supply to and discharge from an aquifer or a drainage basin.

Water Cycle: Water's journey through various phases including evaporation from surface water, movement through the atmosphere as clouds, and falling back to earth as precipitation. On earth the water may be used by plants or animals, become frozen, or flow as groundwater, subsurface flow or surface water, until repeating the cycle as evaporation.

Water Pollution: The addition of sewage, industrial waste, or other harmful or objectionable material to water in concentrations or in sufficient quantities to result in measurable decline of water quality.

Water Quality: A term used to describe the characteristics of water with respect to its suitability for certain uses. This can include chemical, biological, and physical characteristics.

Watershed: An area of land from which water drains to a single point; in a natural basin, the area contributing flow to a given point on a stream.

Water Table: The upper limit of the part of soil or underlying rock material that is completely saturated with water; the top of the zone of saturation.

Water Year: The 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1992, is called the "1992 water year."

Well: A connection to an underground source of water made accessible by drilling or digging to below the water table.

X-Y

No Entries.

Z

Zone of Saturation: A subsurface zone in which all pore spaces are filled with ground water; below the groundwater table.

2009 Atlas Update Acknowledgements

This document is an update of the 2004 Atlas; the Atlas team acknowledges the previous efforts.

Special Acknowledgements: Bea Lackaff (SC) created or revised Atlas maps and provided other graphics. Jim MacInnis (CoS) was responsible for project management, text writing, editing and layout. Gary Stevens (IDEQ) provided the data and source images for Human Uses (page 16) and contributed in many ways to the success of this Atlas. Special thanks to Spokane County, the City of Spokane and Idaho Department of Environmental Quality for generously supporting staff who worked on this Update. Much of the new information in this Atlas Update was published in USGS Scientific Investigations Reports 2005-5227, 2007-5041, and 2007-5044, and we gratefully acknowledge USGS and their partners: Idaho Department of Water Resources, Washington Department of Ecology, University of Idaho, and Washington State University.

2009 Aquifer Atlas Update Team: James D. MacInnis, P.E. (CoS), Beatrice B. Lackaff (SC), Reanette Boese (SC), Susan King (CoS), Gary Stevens (IDEQ), and Rob Lindsay (SC).

Special thanks to people who assisted with review and comments on the Atlas draft: John Covert, Sue Kahle, Paul Klatt, Kerry Brooks, Rick Eichstaedt, Stan Miller, Lloyd Brewer, Geoff Harvey, the SAJB and others.

2004 Atlas Update Acknowledgements

In early fall 2000 seven thousand Aquifer Atlases were printed and allocated to the participating agencies in Washington and Idaho. The Atlases were very popular, and within eighteen months most of the Atlases had been distributed to the public and to local schools. In 2003 Julia McHugh, working for the Spokane Aquifer Joint Board began efforts to reprint the Atlas. Although the original printing plates were not available, the computer files had been archived, and four of the original six Aquifer Atlas team members were available to contribute to an Atlas update. Beginning in fall 2003, a new Aquifer Atlas team, comprised of original and new members, began work on updating the 2000 Atlas with current information in preparation for a new printing.

Special Acknowledgements: Bea Lackaff (SC) created or revised Atlas maps and provided other graphics. Jim MacInnis (CoS) was responsible for project management, text writing, editing and layout. Special thanks to Spokane County and the City of Spokane for generously supporting Bea's and Jim's efforts on the Atlas Update.

2004 Aquifer Atlas Update Team: James D. MacInnis, P.E. (CoS), Beatrice B. Lackaff (SC), John P. Buchanan, Ph.D. (EWU), Reanette Boese (SC), Julia McHugh (SAJB), Geoff Harvey (IDEQ), Robert Higdem (IDEQ), and Gary Stevens (IDEQ).

Original 2000 Atlas Acknowledgements

Creation and publication of this Atlas was the result of faith, hard work and sweat by a small number of people, the Aquifer Atlas Team, whose names appear in the Preface (see below). However, many other people assisted the Team's efforts, and everyone's contribution added measurably to the quality and content of this document. The Aquifer Atlas Team acknowledges the following people for their contributions: Calvin Terada (EPA), Stan Miller (SC), Connie Grove (SC), Ken Lustig (PHD), John Sutherland (IDEQ), and Glen Pettit (IDEQ).

Original 2000 Aquifer Atlas Team: James D. MacInnis, P.E. (IDEQ), Jim Blake (SC), Brian Painter, P.G. (IDEQ), John P. Buchanan, Ph.D. (EWU), Beatrice B. Lackaff (SC), Reanette Boese (SC).

EWU	Eastern Washington University
SC	Spokane County
CoS	City of Spokane
IDEQ	Idaho Depart. of Environmental Quality
EPA	U.S. Environmental Protection Agency
PHD	Panhandle Health District
SAJB	Spokane Aquifer Joint Board
USGS	United States Geologic Survey

MacInnis, J.D., Jr., Lackaff, B.B., Boese, R.M., Stevens, G., King, S., Lindsay, R.C., 2009, *The Spokane Valley-Rathdrum Prairie Aquifer Atlas 2009 Update*: Spokane, Washington, City of Spokane, 30p.

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Front Cover: Spokane County Water Resources Program GIS, 2009.

Page 1: Atlas Team.

Page 2: Aquifer map = USGS SIR 2007-5041, Figure 1; earth photo = "The Blue Marble", NASA Visible Earth catalog; global groundwater map = United Nations Educational, Scientific and Cultural Organization and BGR (German Federal Institute for Geosciences and Natural Resources); climate change text = adapted by the Atlas Team and Stanley Miller from the *Washington Climate Change Impacts Assessment Study* Executive Summary (June 3, 2009) prepared by the University of Washington's Climate Impacts Group; Sidebar article = Spokesman-Review, May 6, 1909; text = Atlas Team.

Page 3: "Plante's Ferry" painting by James Madison Alden, International Boundary Survey, 1860. Courtesy of the National Archives, College Park, Maryland (thanks to Jack Nisbet.) 2004 photo = Jim MacInnis from Arbor Crest Winery; Vera photo = Vera Water and Power; Modern Electric, Broadway, and apple orchard photos = Modern Electric Water Company archives; irrigation system, wood stave, sawmill, Fort Sherman photos = Museum of North Idaho, Coeur d'Alene, ID.

Page 4: Background photo = Upriver Timber Dam, 1895, City of Spokane Water Department; J Harlen Bretz photo = IDEQ web site; Pardee photo = Public Broadcasting System web site; Timeline data = Archives of the Spokesman Review, the Spokane Chronicle and Atlas Team.

Page 5 : Landsat Data: National Aeronautic & Space Administration (NASA), Washington Remote Sensing Consortium (WARSC). This image is a composite image based on two Landsat 7 ETM+ images – 6 July 2007 and 8 July 2008. The image is a 'composite' because Landsat 7 had a hardware failure, the result of which is that 22% of data is missing from each scene. A second image was used to fill in the missing areas via computer processing techniques. The spatial resolution of the image is 30 meters. By Dr. Kerry Brooks, GIS & Simulation Laboratory, Washington State University Interdisciplinary Design Institute.

Page 6: Map data = Spokane County GIS, Kootenai County GIS; text = Aquifer Team.

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Page 23: Tour map = Spokane County Water Resources GIS

Page 24: Tour information and text: Reanette Boese (SC) and Gary Stevens (IDEQ); photo credits: (A) and (B) = Bea Lackaff; (C) = Jim MacInnis; (D) = Bill Rickard; (E) = Bea Lackaff; (F) = Stan Miller; (G) = Bea Lackaff; (H), (I), (J), (K), (O) and (L) = courtesy of IDEQ; (M) = courtesy of City of Coeur d'Alene; (N) = courtesy of Panhandle Health District.

Page 25: Population data = U.S. Census Bureau; climate data = National Weather Service; hydrologic data = USGS; collected and compiled by Gary Stevens (IDEQ); text = Atlas Team.

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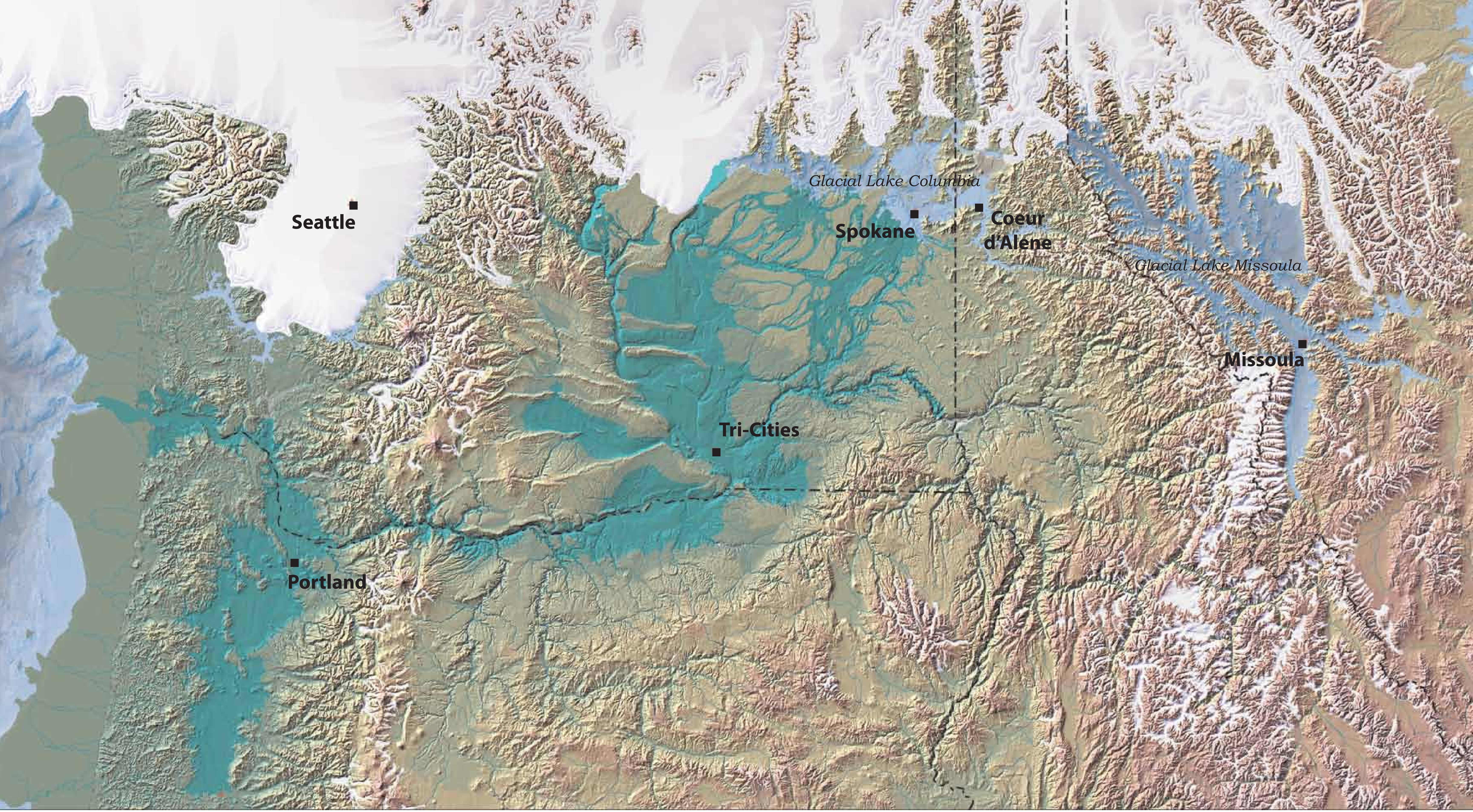
Back Cover: Image Jeff Silkwood's U.S. Forest Service poster, "Glacial Lake Missoula and the Channeled Scabland" Adapted for Atlas by Spokane County GIS.

Much of the information included in this Atlas Update was published in USGS Scientific Investigations Reports 2005-5227, 2007-5041, and 2007-5044. A central repository for Aquifer data and interpretation has been established by the Idaho Department of Water Resources on line at http://www.idwr.idaho.gov/Water Information/projects/svrp/, and links to obtain electronic copies of the USGS report may be found at this internet site.



The Pacific Northwest During the Last Ice Age: 15,000 to 12,000 Years Ago

This map depicts the Pacific Northwest during the late Pleistocene Epoch based on available scientific evidence. Several interesting conditions relative to modern times are evident. The present city of Missoula, Montana was under Glacial Lake Missoula, the lake responsible for generating the floods that created the Aquifer sediments. The flood paths are shown in green. Present day Spokane and Coeur d'Alene were also under water from Glacial Lake Columbia that was created when glacial ice blocked the Columbia River. The present location of Seattle, Washington was under a lobe of the glacial ice sheet. The vast amounts of water trapped in the ice sheet caused the Pacific Ocean level to drop about 300 feet, and the ocean shore retreated several miles from its present location. A full-size map developed by Jeff Silkwood, "Glacial Lake Missoula and the Channeled Scabland" is available from the United States Forest Service.