SUMMARY OF HYDROLOGIC CONDITIONS

Hydrologic Setting

A distinctively varied climate characterizes Washington and results primarily from two features: (1) the Cascade Range, and (2) the prevailing marine influence of the Pacific Ocean (fig. 1). The north-south trending Cascade Range divides Washington into two areas: the wet western part and the dry eastern part. Average annual precipitation west of the Cascade Range is about 70 inches and ranges from about 30 to 40 inches in the Puget Sound Basin to about 150 to 200 inches on the western slopes of the Olympic Mountains, where temperate rain forests thrive. The Cascade Range acts as a barrier to air masses that move across the State, producing 100 to 150 inches of annual precipitation on the high western slopes of the Cascade Range and leaving much less moisture in the clouds for eastern Washington. Average annual precipitation in eastern Washington is only 7 to 40 inches, with the driest part being the Columbia Basin (fig. 1), where sagebrush and grasses grow and irrigation is required for most crops. About two-thirds of the precipitation in Washington occurs from October to March, either as rain in the lowlands or as snow at high elevations. Occasionally during winter, western Washington receives large amounts of rainfall from Pacific storms, accompanied by mild temperatures. The combination of melting snowpack at high elevations and rainfall during these storms can produce flooding in the lowlands. Snowpack and glaciers in the Olympic Mountains and Cascade Range are sources of water for many rivers in Washington and become the primary source of flow during the relatively dry summer.

Washington's varied climate and topography result in variable streamflow patterns throughout the State, as shown in the graphs of daily mean discharge for selected long-term gaging stations (figs. 1 and 2, table 1). Daily mean discharge at the Chehalis River near Grand Mound (fig. 2A) is representative of the streamflow patterns in the southwest lowlands of the State, where seasonal high flow occurs from November to March, coinciding with the typical winter rainfall. Flow normally decreases through the spring and summer months due to the generally dry weather and absence of snowpack. Daily mean discharge at the Quinault River at Quinault Lake (fig. 2B) is representative of the Olympic Peninsula. Two seasonal peak periods at this gaging station result from winter rainfall from November to January and late spring snowmelt from high altitudes in May and June. Winter rainfall and spring snowmelt in the East Fork Lewis River near Heisson in the southern Cascade Range overlap to produce a high-flow season that generally extends from November to May (fig. 2C). High flow in the Nooksack River at Deming (fig. 2D) is generated by rainfall in winter and again in May and June from a combination of spring rainfall and snowmelt. Daily mean discharge at Puyallup River near Orting (fig. 2E) is representative of the typical winter rainfall of the central Cascade Range and a late spring snowmelt sustained by the permanent snowfields and glaciers on the west slope of the Cascade Range.

Peak flows in rivers draining the east side of the Cascade Range, such as the Wenatchee River at Plain (fig. 2F), normally occur in April to July as a result of snowmelt. Streamflow during the winter generally stays low due to freezing weather that maintains or contributes to the snowpack; exceptions occur when mild weather and heavy rain combine to cause flooding. Daily mean discharge at Ahtanum Creek at Union Gap (fig. 2G) and the Walla Walla River near Touchet (fig. 2H) are representative of agricultural drainage basins in the lower Columbia Basin, where irrigation-return flows cause an increase in discharge from August to winter. During winter, high flows are sustained by a combination of precipitation and return flows. The daily mean discharge at Hangman Creek at Spokane (fig. 2I) is representative of rivers draining the eastern Washington highlands, where a combination of precipitation and melting snow produces maximum discharge in late winter and early spring.

Hydrologic Conditions for Water Year 2003

Annual mean streamflow in Washington during water year 2003 ranged from slightly above average in a few areas of the State to significantly below average in eastern Washington, as indicated by data collected at selected long-term streamflow-gaging stations (fig. 1, table 1). Annual mean streamflow was below or near average for river basins in western Washington (sites A-E, fig. 1, table 1). Annual mean streamflow was slightly above average in some eastern Washington river basins (sites G and H) but was only 75 percent of average in the Wenatchee River (site F) and 59 percent of average in Hangman Creek (site I). No stations had annual maximum discharges that exceeded period-of-record maximum discharges. Some stations had annual minimum discharges that were less than the period-of-record minimum discharges. Many rivers throughout the State had monthly mean streamflows in October and November near record lows.

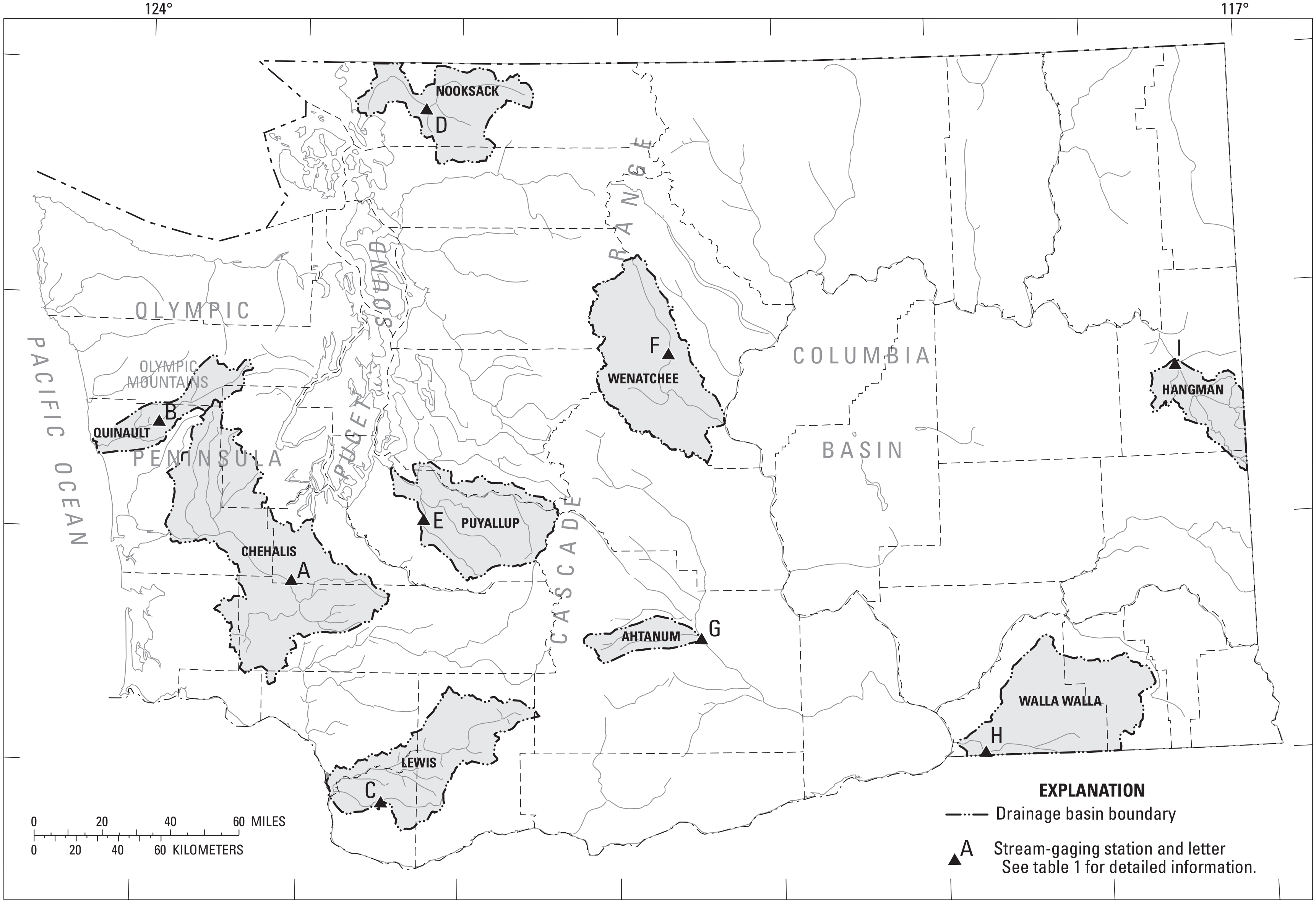

Figure 1. Selected stream-gaging stations and drainage basins in Washington.

Table 1. Selected stream-gaging stations in Washington

Letter in figure 2	Station number	Stream-gaging station	Period of record	Annual mean streamflow, 2003 water year: Streamflow, in cubic feet per second	Annual mean streamflow, 2003 water year: Percentage of long-term mean
A	12027500	Chehalis River near Grand Mound	1929-2003	2,371	84
B	12039500	Quinault River at Quinault Lake	1912-2003	2,799	98
C	14222500	East Fork Lewis River near Heisson	1930-2003	605	82
D	12210500	Nooksack River at Deming	1935-2003	2,783	83
E	12093500	Puyallup River near Orting	1932-2003	613	86
F	12457000	Wenatchee River at Plain	1911-1929, 1931-79, 1990-2003	1,689	75
G	12502500	Ahtanum Creek at Union Gap	1961-2003	82	105
H	14018500	Walla Walla River near Touchet	1952-2003	583	102
I	12424000	Hangman Creek at Spokane	1948-2003	139	59

Streamflow is largely influenced by variabilities in precipitation and snowpack. Precipitation in Washington during water year 2003 generally was below normal. Precipitation in October and November was below normal for most parts of the State. Precipitation in December and January was near normal throughout the State, except for the Puget Sound, which was below normal in December. Precipitation in February was below normal with many areas significantly below normal. Precipitation in March was variable with most areas above normal, and precipitation in the Central Columbia Plateau in east-central Washington and the Okanogan Mountains in north-central Washington was below normal. Precipitation in April was above normal throughout the State. Precipitation in May through July was below normal to significantly below normal throughout the State. Precipitation in August and September was below normal in most parts of the State; however, precipitation was above normal in August in some areas of southeastern Washington, and above normal in September in parts of south and northeastern Washington.

Snowpack for water year 2003, measured from January through June, was consistently below normal throughout the State. By April snowpack was 65-95 percent of normal in all areas. Snowpack reached the peak in late March to late April in all areas, with the exception of some upper elevation sites in the Cascade Range, where the snowpack reached a peak in May. The snowmelt ended before the normal date for most areas from late April to late June, with some areas near the normal ending date.

The normal range in streamflow is defined as flows between the 25 and 75 percentile which are computed using the entire record of daily mean streamflow for a particular gaging station. Daily mean streamflows were below normal from October to mid-December for rivers draining to the Pacific Ocean (figs. 2A and 2B); however, precipitation increased flows to normal and above normal for parts of November. Flow in the Chehalis River generally was normal from mid-December through the end of the water year (fig. 2A). In the Quinault River, streamflow generally was from normal mid-December through April, and below normal from May through September (fig. 2B). Streamflow in rivers draining the western Cascade Range varied from north to south. Streamflow in rivers in the southern Cascade Range (fig. 2C) was significantly below normal from October to mid-December. Streamflows from late December through May generally were normal and below normal June through September. Streamflows in rivers in the central Cascade Range (fig. 2E) were below normal for many days from October through mid-December, and were normal from January through September, except for several days in January and most of March, which were above normal. Streamflows in rivers in the northern Cascade Range (fig. 2D) were below normal in October, with the rest of the year near normal, except mid-March through mid-April, which had several days with above normal flow.

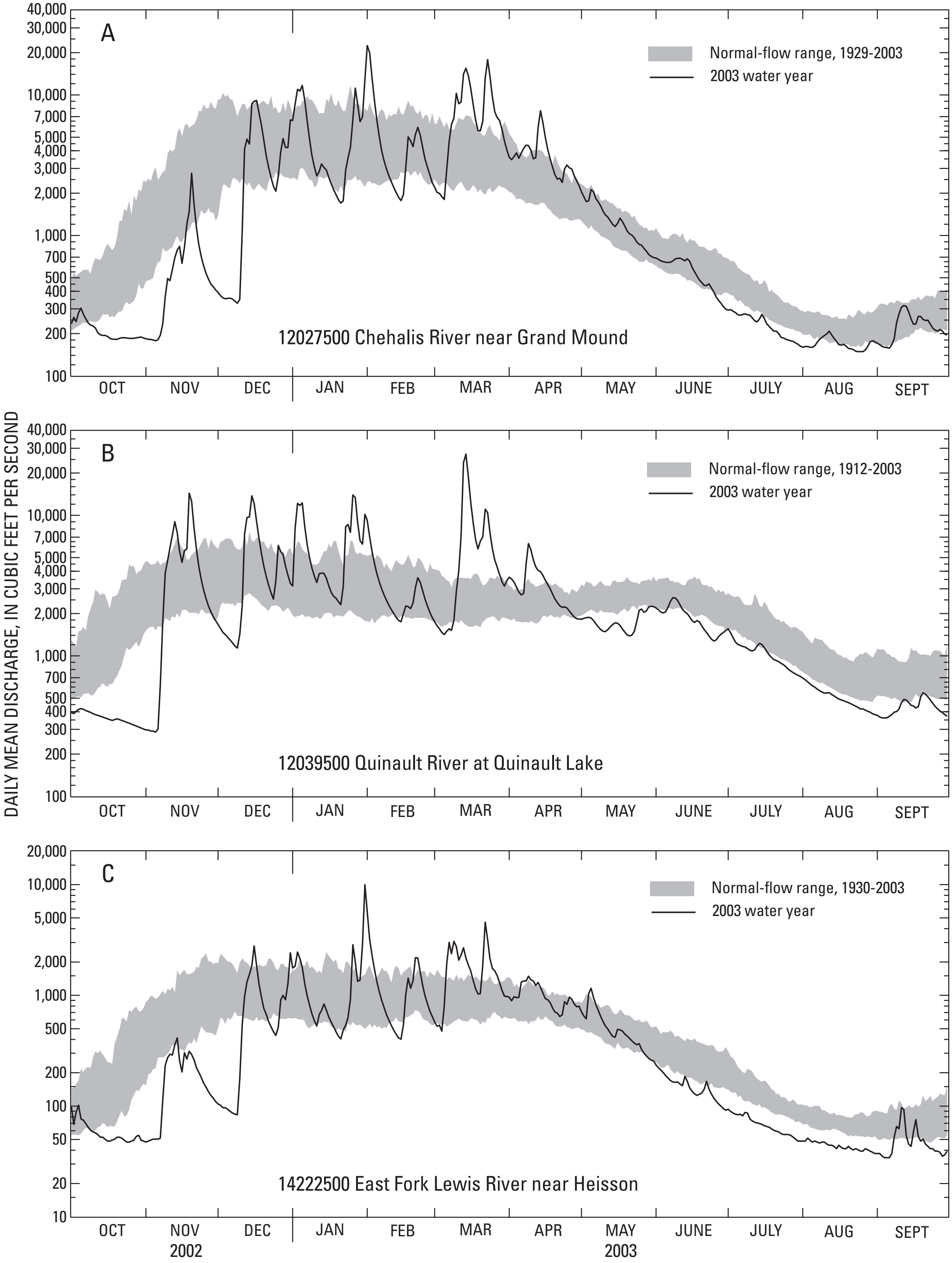

Figure 2. Daily mean discharge for water year 2003 compared with the percentile distribution of daily mean discharges for the period of record, for selected stream-gaging stations. Daily mean discharges equal to or greater than the 25th percentile and equal to or less than the 75th percentile are within the normal range of flow.

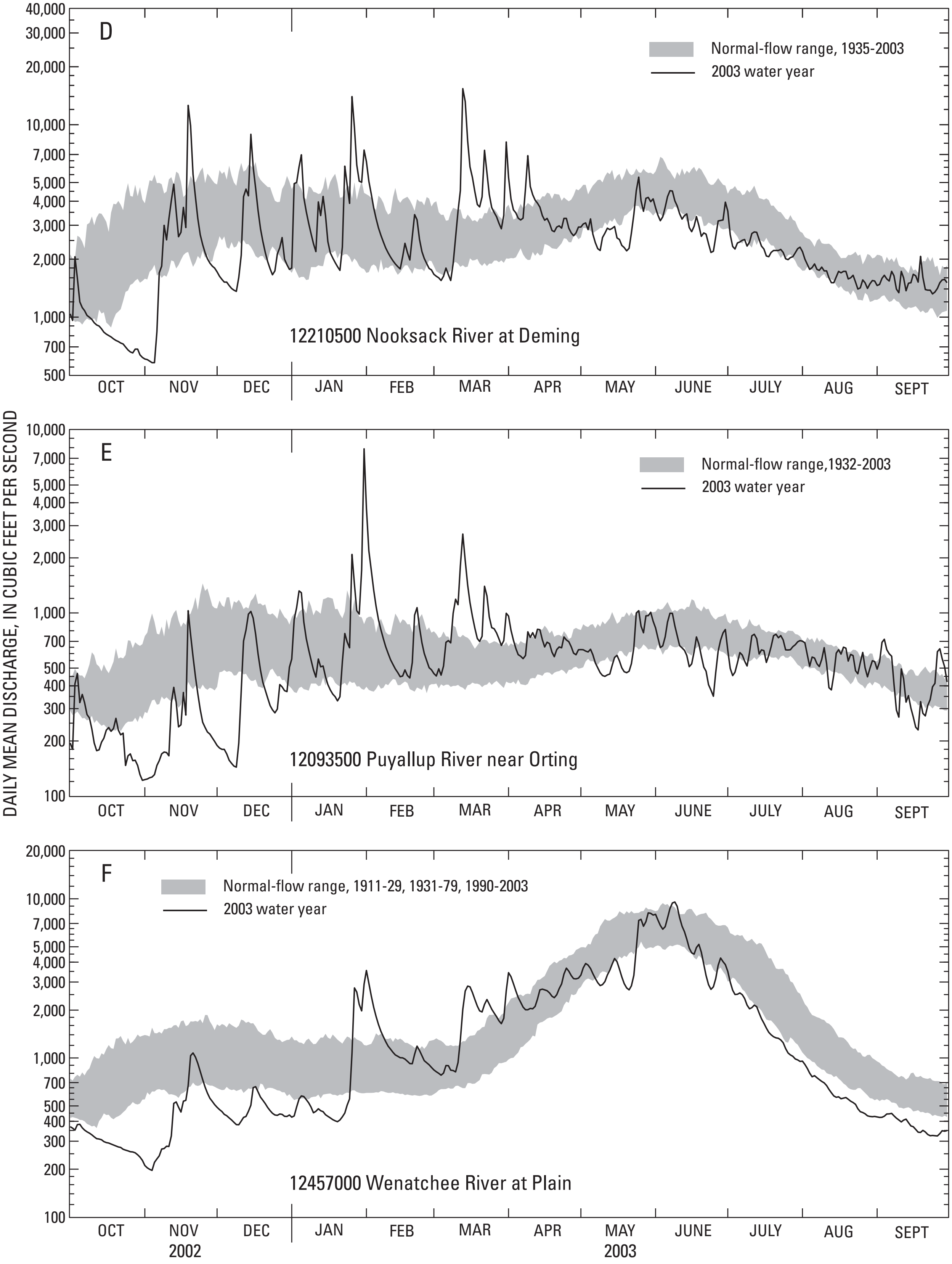

Figure 2. —*Continued*.

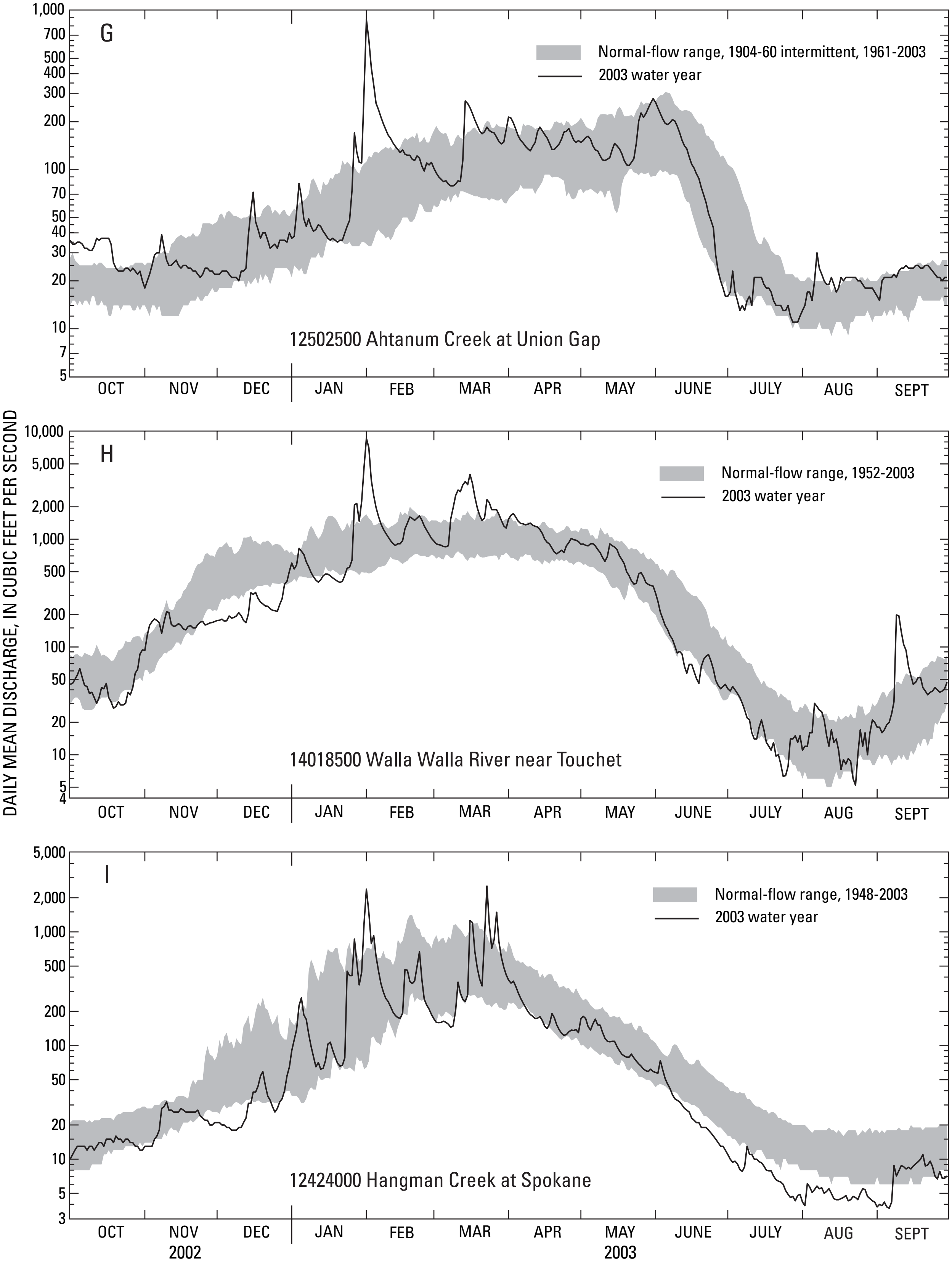

Figure 2. —*Continued*.

Streamflow in rivers draining the eastern side of the Cascade Range varied north to south. Daily mean streamflow in the Wenatchee River (fig. 2F), which is representative of rivers in the central and northern Cascade Range, was below normal from October through January and July through September, and generally normal from February through June. Daily mean streamflow in Ahtanum Creek in the Yakima River Basin (fig. 2G) was normal for most the year except for October and early February, which had several days above normal. Streamflow in eastern Washington varied by region. Streamflows in rivers in southeastern Washington (fig. 2H) were near normal except for December, which was below normal. Streamflows in rivers in central eastern Washington (fig. 2I) were near normal throughout the year except June through early September, which were below normal.

Surface-Water Quality

The National Water-Quality Assessment (NAWQA) program was established to assess the current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers and to describe how water quality is changing over time. In 2003, Washington operated nine surface-water-quality NAWQA stations throughout the State. Six of the stations are located in eastern Washington (Palouse River at Hooper, Crab Creek near Ritzville, Yakima River at Kiona, DR2 near Granger, Sunnyside Canal Diversion near Sunnyside, and Granger Drain at Granger) and are representative of agricultural land use; three are in western Washington, one representing urban land use (Thornton Creek near Seattle), one integrating mixed land use for which the samples are collected at a site locally influenced by urban land use (Duwamish River at Tukwila), and one representing relatively pristine conditions (North Fork Skokomish River near Hoodsport). In addition to these NAWQA stations, the Washington Water Science Center also continued operation of two long-term monitoring sites on the middle Columbia River (Columbia River at Richland and Columbia River near Priest Rapids Dam) and monitored irrigation return flow at four sites in the Columbia Basin Irrigation Project (CBIP, Crab Creek near Beverly, Lind Coulee Wasteway near Warden, Sand Hollow near Vantage, and Red Rock Coulee near Smyrna).

Specific conductance and dissolved-solids concentration generally are inversely related to streamflow. Concentrations of dissolved solids usually are smallest during the high flows of late autumn and winter and early spring runoff, when rainfall and snowmelt are the major sources of water. Dissolved solids in western Washington are usually most concentrated during late summer and early autumn, when base flow from ground-water sources is the dominant component of flow; but in eastern Washington, dissolved solids may be more concentrated during the irrigation season due to irrigation return flows. Analysis of dissolved solids at seven of the sites was discontinued in 2001, but there is a good relation between dissolved solids and specific conductance. Specific conductance at the surface-water NAWQA, CBIP, and Columbia River surface-water stations during 2003 ranged from an average of 80 μS/cm (microsiemens per centimeter at 25 degrees Celsius) on the North Fork Skokomish near Hoodsport to an average of 471 μS/cm at Red Rock Coulee near Smyrna. The largest value of specific conductance measured during water year 2003 was 778 μS/cm, in a sample from Granger Drain at Granger during February, and the smallest value of specific conductance measured was 47 μS/cm, in a sample from the Duwamish River at Tukwila during February. The average specific conductance for all stations sampled was 323 μS/cm.

Surface waters in Washington generally are classified as clear and carry only small amounts of sediment, except where influenced by glaciers, unconsolidated volcanic deposits, or disturbed soils. Water flowing in the Columbia River is very low in sediment, usually less than 10 mg/L (milligrams per liter), and at times there is no measurable sediment. The streams east of the Cascades that characteristically carry sediment concentrations greater than 10 mg/L are those that carry return flow from heavily irrigated and farmed lands in the semiarid region. Concentrations of suspended sediment in samples from the Columbia River during 2003 ranged from 1 to 4 mg/L. Concentrations of suspended sediment in samples from NAWQA surface-water stations ranged from an average of 1.8 mg/L at North Fork Skokomish River near Hoodsport to an average of 94 mg/L at DR2 near Granger. Suspended-sediment concentrations generally were largest in samples from DR2 near Granger generally had the largest sediment concentrations, ranging from 26 to 304 mg/L. The largest suspended sediment concentration (495 mg/L in a sample during March) was measured at the Palouse River at Hooper.

Fifty-four different pesticides, metabolites (degradation products), or other trace organic compounds were detected in samples collected from the nine NAWQA surface-water stations and four irrigation return flow stations during water year 2003. The herbicides—atrazine, simazine, and trifluralin, as well as the pesticide degradates 2-chloro-4-isopropylamino-6-amino-s-triazine, referenced in this report as CIAT and commonly referred to as deethylatrazine, and alachlor ethanesulfonic acid (referenced in this report as alachlor ESA)—were the pesticides or degradates detected most frequently in samples from the stations in eastern and western Washington. Samples for the analysis of pesticides were not collected from the reference station at North Fork Skokomish during water year 2003. Samples collected from Thornton Creek near Seattle and the Duwamish River at Tukwila sites contained the insecticide carbaryl and the herbicides prometon and simazine; samples from Thornton Creek also contained the herbicide malathion, and samples from the Duwamish River contained the herbicides atrazine and tebuthiuron. Concentrations in samples from these urban sites ranged from at or near the limit of detection to a maximum of 0.219 µg/L (micrograms per liter) for the insecticide carbaryl at Thornton Creek.

Two herbicides, two insecticides and an herbicide degradate were detected in samples from Crab Creek near Ritzville, ranging in concentration from at or near the limit of detection to a maximum concentration of 0.025 µg/L for the insecticide azinphos methyl. Eight herbicides, four insecticides, and one herbicide degradate were detected in samples from Palouse River at Hooper, ranging in concentration from at or near the limit of detection to a maximum concentration of 0.092 µg/L for triallate. Eight herbicides, seven insecticides, two insecticide degradates, one herbicide degradate, and two fungicides were detected in samples from the Yakima River at Kiona, ranging in concentration from at or near the limit of detection to a maximum concentration of 0.092 µg/L for the insecticide azinphos methyl. Twelve herbicides, seven insecticides, ten pesticide degradates, and a fungicide were detected in samples from Granger Drain at Granger, with a maximum concentration of 0.9 µg/L for the herbicide glyphosate. Eight herbicides, seven insecticides, six pesticide degradates, and a fungicide were detected in samples from DR2 near Granger, ranging in concentration from at or near the limit of detection to a maximum concentration of 0.205 µg/L for the herbicide trifluralin. Three herbicides, five insecticides, two pesticide degradates, and a fungicide were detected in samples from the Sunnyside Canal Diversions near Sunnyside, ranging in concentration from at or near the limit of detection to a maximum of 0.037 µg/L for the insecticide azinphos methyl. Seventeen herbicides; four insecticides; four pesticide degradates, including 2-chloro-6-ethylamino-4-amino-s-triazine, referenced in this report as CEAT and commonly referred to a deisopropylatrazine, and 2-hydroxy-4-isopropylamino-6-ethylamino-s-triazine, referenced in this report as OIET and commonly referred to as hydroxyatrazine; and a trace organic stimulant (caffeine) were detected in four samples from Sand Hollow near Vantage, ranging in concentration from at or near the limit of detection to a maximum of 1.35 µg/L for the herbicide terbacil. Thirteen herbicides, three insecticides, two pesticide degradates, one fungicide, and a trace organic stimulant (caffeine) were detected in four samples from Lind Coulee Wasteway near Warden, ranging in concentration from near or at the limit of detection to a maximum of 0.17 µg/L for the herbicide 2,4-D. Fifteen herbicides, one insecticide, five pesticide degradates, and one trace organic stimulant (caffeine) were detected in four samples from Red Rock Coulee near Smyrna, ranging in concentration from at or near the limit of detection to a maximum of 0.169 µg/L for the herbicide DCPA. Eleven herbicides, one insecticide, and five pesticide degradates were detected in four samples from Crab Creek near Beverly, ranging in concentrations from at or near the limit of detection to a maximum of 0.29 µg/L for the herbicide 2,4-D.

Concentrations for pesticides detected in samples from NAWQA or CBIP surface-water stations during the water year 2003 exceeded the U.S. Environmental Protection Agency (USEPA) Maximum Contaminant Levels or Health Advisories for drinking water. The USEPA fresh-water chronic criteria for the protection of aquatic life for carbaryl, diazinon and azinphos methyl are 0.02, 0.009, and 0.01 µg/L, respectively. Concentrations of carbaryl in three samples from Thornton Creek (in November, January, and May); five samples from Granger Drain (in July, August, and September); three samples from DR2 near Granger (in August and September); one sample from Sunnyside Canal Diversions near Sunnyside (in May); and one sample from the Duwamish River (in January) exceeded the fresh-water chronic criteria for the protection of aquatic life. Concentrations of diazinon in two samples from Thornton Creek near Seattle during April and May, and one sample from Palouse River at Hooper during April exceeded the fresh-water chronic criteria for the protection of aquatic life. Concentrations of azinphos methyl in ten samples from Granger Drain at Granger from May through August; three samples from the Yakima River at Kiona during July, August and October; 12 samples from DR2 near Granger from May through August, two samples from Sunnyside Canal Diversions near Sunnyside during June and July, 1 sample from Sand Hollow near Vantage in July, and 2 samples from Crab Creek at Rocky Ford Road during June and August exceeded the fresh-water chronic criteria for the protection of aquatic life.

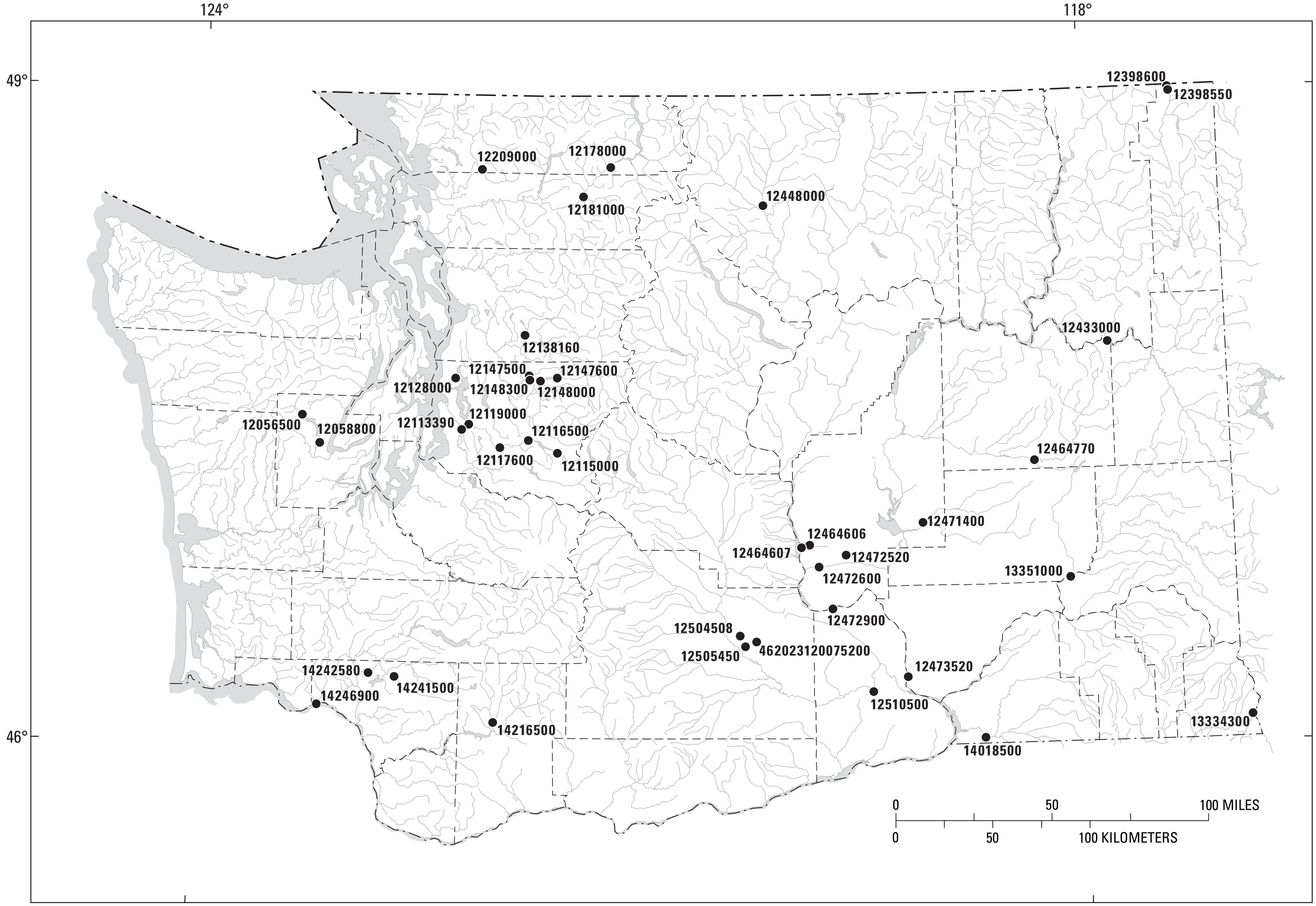

Figure 3. Surface-water stations with water-quality data collection in Washington.

Ground-Water Quality

Samples for analysis of bacteria were collected from 15 drinking-water wells in 7 counties in eastern Washington in 2003 (fig. 4). Sample results were less than (<) 1 colony per 100 milliliters (ml) except for the detection of 1 total coliform colony in a sample from 13N/18E-21N01. All samples were tested for presence (1) or absence (2) of F-specific coliphage and somatic coliphage and results were negative.

Ground Water

In eastern Washington, water levels in the water-table well in Spokane County (25N/45E-16C01) were above average from October through May (+0.2 foot to +4.6 feet), declined below average in June through August (-1.0 to -1.5 feet), and rose to above average in September (+0.8 feet). Water levels in the water-table well in Whitman County (18N/43E-35L01) were at or above average all year (0.0 to +3.0 feet). Water levels in the water-table well in Columbia County (10N/37E-23R01) were below average all year (-0.7 to -2.7 feet). Water levels in Lincoln County confined well 24N/36E-16A06 were above average (+0.2 to +2.7 feet) all year, and water levels in confined well 24N/36E-16A08 ranged from +5.9 feet above to -4.8 feet below average. Long-term water levels for well 25N/45E-16C01 are shown in figure 5.

In western Washington, water levels in confined well 16N/02W-29L02P2 in Thurston County started the year below average (-0.1 feet), reached a maximum negative deviation of -12.3 feet below average in December, remained below average through March, were above average from April through September reaching a maximum positive deviation of +2.8 feet above average in June and ended the year at +1.8 feet above average. Water levels in confined well 22N/01W-36H01D11 in Pierce County ranged from +2.9 feet in May to -3.0 feet in September. Long-term water levels for well 16N/02W-29L02P2 are shown in figure 6.

Departure from long-term average ground-water levels

[All values are in feet; —, no data, *, less than 10 years of record; **, less than 5 years of record, no departure calculated]

Well No.	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
10N/37E-23R01	-1.2	—	-1.3	—	-0.7	—	**	—	-2.1	—	—	-2.7
16N/02W-29L02P2	-0.1	-1.9	-12.3*	-6.4	-1.5	-2.0	+1.4	+1.0	+2.8*	+1.1	+0.6	+1.8
18N/43E-35L01	—	+2.0	—	+2.7	+2.2	—	+3.0	+1.2	+0.9	—	0.0	—
22N/01W-36H01D11	-0.7*	—	-1.0*	—	**	—	—	+2.9*	—	+0.8	—	-3.0
24N36E-16A01	-0.5	+1.4	-0.9	+0.1	+1.1	-1.7	-2.6	+0.1	-0.2	-1.8	0.0	-0.7
24N/36E-16A06	+2.7	—	—	+0.2	+1.2	—	—	+2.6	—	+1.8	+1.8	—
24N/36E-16A08	-1.2	—	—	-4.2	-4.8	—	—	-4.8	—	+5.9	+2.0	—
25N/45E-16C01	+3.7	+2.7	+1.6	+3.0	+4.6	+3.7	+3.7	+0.2	-1.5	-1.0	-1.0	+0.8

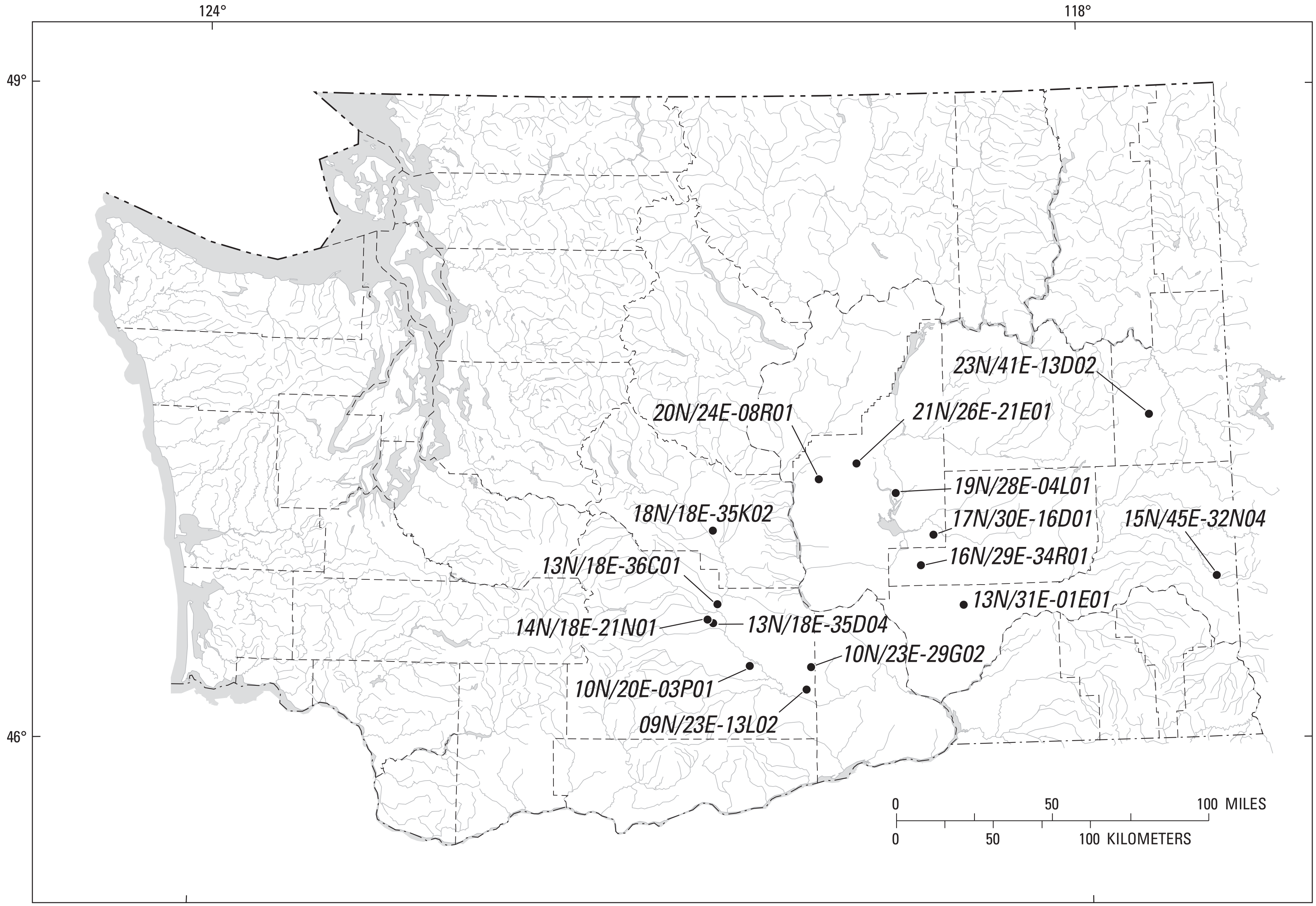

Figure 4. Ground-water wells with water-quality data.

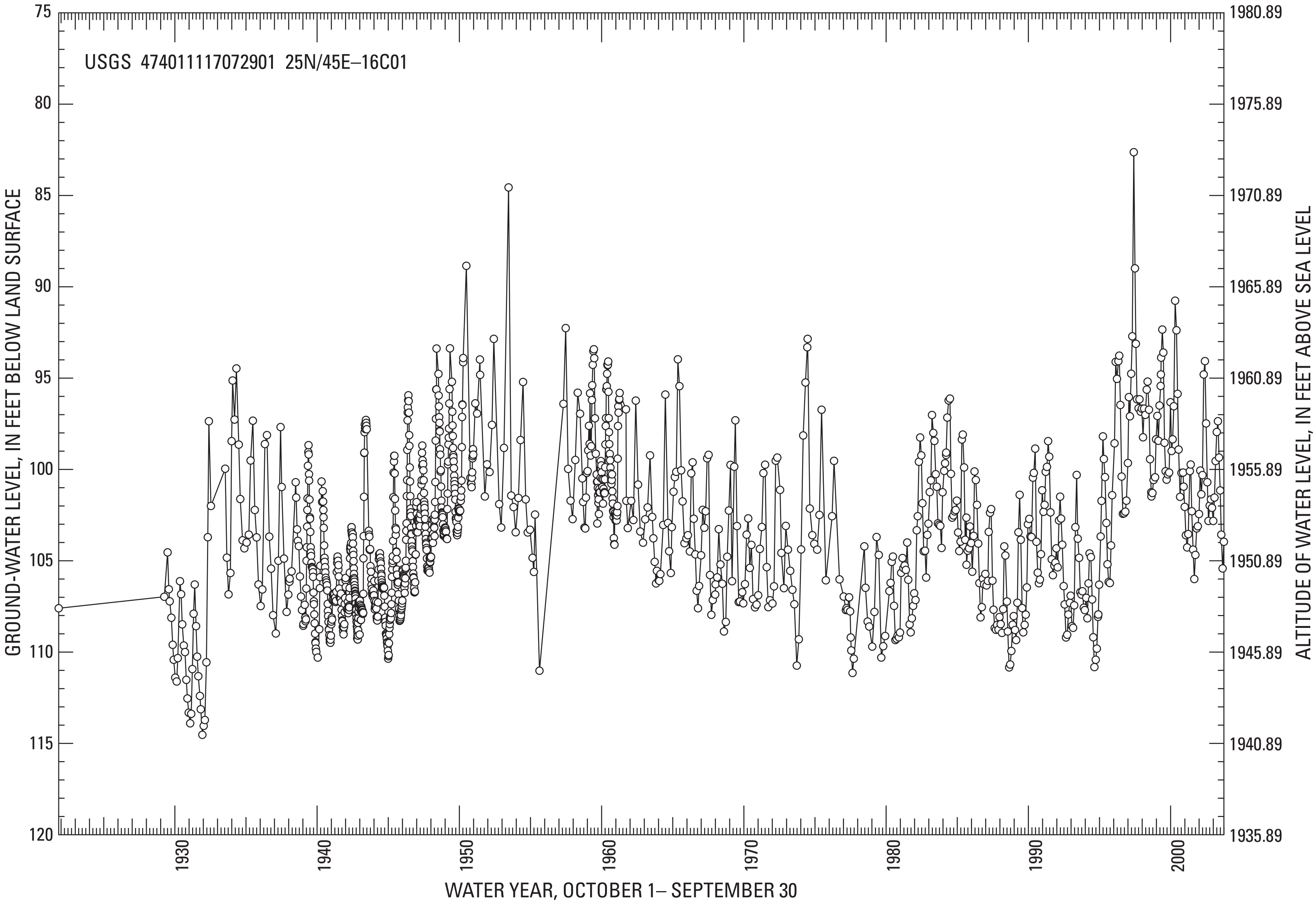

Figure 5. Long-term water levels for well 25N/45E-16C01.

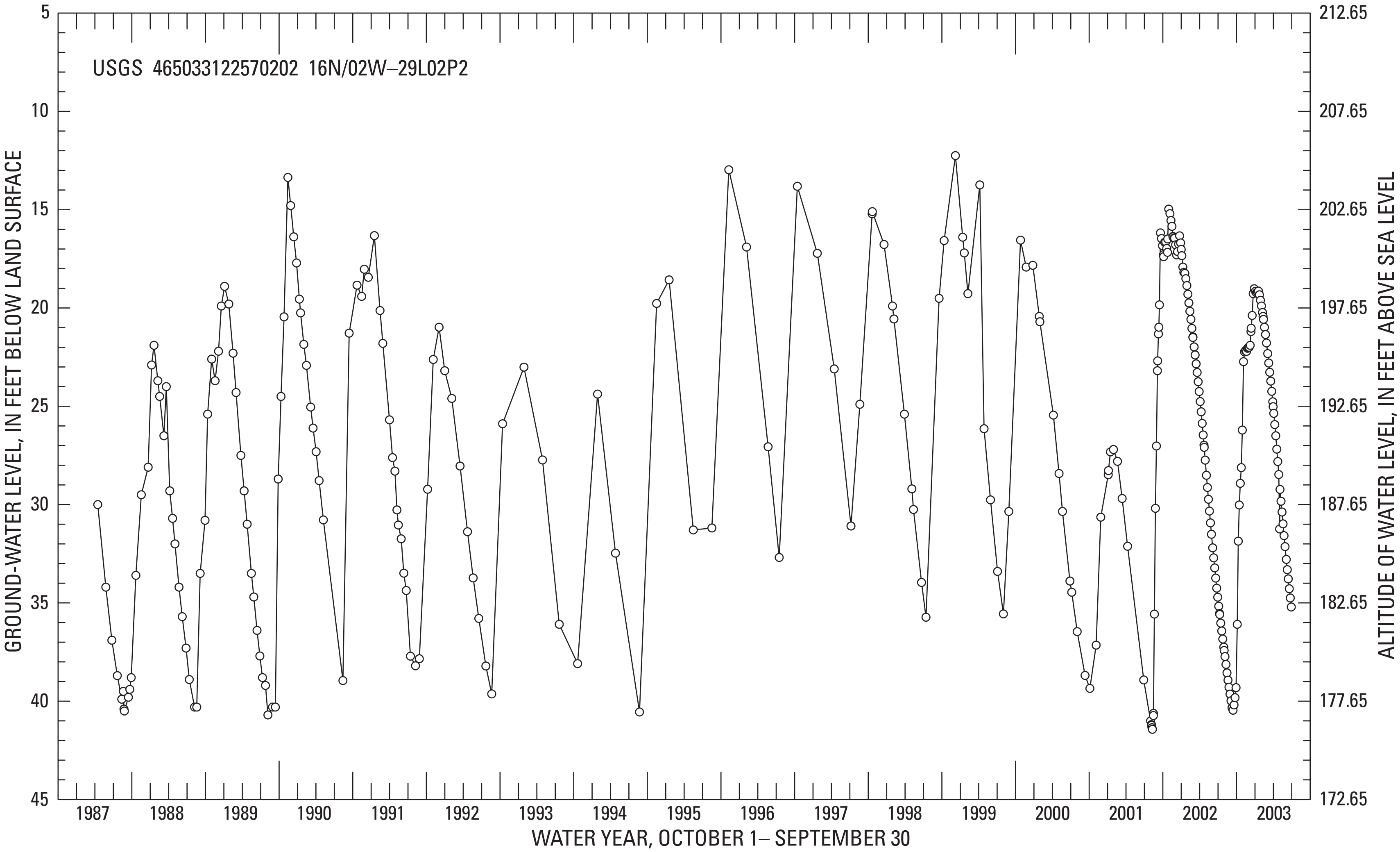

Figure 6. Long-term water levels for well 16N/02W-29L02P2.