Prepared in cooperation with the Fauquier County Board of Supervisors and the Virginia Department of Environmental Quality

Groundwater-Level Contour Map of Fauquier County, Virginia, October–November 2018

Scientific Investigations Report 2022–5014

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

Cover. U.S. Geological Survey continuous groundwater-level monitoring well 48U 32 installed in Fauquier County, Virginia, November 2016. Photograph by Kurt McCoy, U.S. Geological Survey.

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By Matthew R. Kearns and Kurt J. McCoy

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Conversion Factors

To convert U.S. customary units to International System (SI) of units

Multiply	By	To obtain
Length		
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
square mile (mi^2)	2.590	square kilometer (km^2)
Volume		
million gallons (Mgal)	3,785	cubic meter (m^3)
Flow rate		
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)

Datum

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

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

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

Abbreviations

blsd	below land surface datum (groundwater level and well depths)
DDMMSS	degrees, minutes, seconds (latitude and longitude)
DEM	digital elevation model
FCWSA	Fauquier County Water and Sanitation Authority
GIS	geographic information system
GPS	Global Positioning System
NHD	National Hydrography Dataset
NWIS	National Water Information System
RMSE	root-mean-squared error
USGS	U.S. Geological Survey
VADEQ	Virginia Department of Environmental Quality

Groundwater-Level Contour Map of Fauquier County, Virginia, October–November 2018

By Matthew R. Kearns and Kurt J. McCoy

Abstract

Groundwater withdrawals provide most public-water supplies and all private-domestic users in Fauquier County, Virginia, a fast-growing rural area southwest of Washington, D.C. Groundwater levels were measured in 129 wells during a county-wide synoptic survey from October 29 through November 2, 2018. Field measurements, combined with datapoints from the National Hydrography Dataset, were used to develop a county-wide groundwater-level contour map. Groundwater levels and withdrawals during the synoptic survey were near or slightly above long-term medians. Error analysis indicated that the estimated groundwater-level contours generally were lower than observed measurements, with a root-mean-squared error of 33.52 feet. Groundwater levels in Fauquier County are controlled largely by topography: low levels in the crystalline Blue Ridge aquifers in the northwestern part of the county contrast markedly with higher levels in the sedimentary Mesozoic Basin aquifers in the southeast. At current levels of groundwater withdrawal, and at the scale and scope of the synoptic survey, no cones of depression in the groundwater surface were detected. The Fauquier County groundwater-level contour map is available as a U.S. Geological Survey data release.

Introduction

Groundwater resources in Fauquier County, Virginia supply water to local communities, commercial and agricultural activity, and individual residences. The primary source of water for most rural households and the public-water systems that supply the majority of the county's residents is water withdrawn from fractured-rock aquifers (Dieter and others, 2018). Fauquier County is a growing suburban area within commuting distance of Washington, D.C., and the demand on groundwater resources is expected to increase on the basis of projections from the Fauquier County Water and Sanitation Authority (Fauquier County Water Resources, undated). Between 1985 and 2015, population grew 71 percent, with a corresponding 56 percent increase in groundwater withdrawals (Dieter and others, 2018). Greater knowledge of the area's groundwater is needed to understand how the resource can sustainably support the increasing population of Fauquier County.

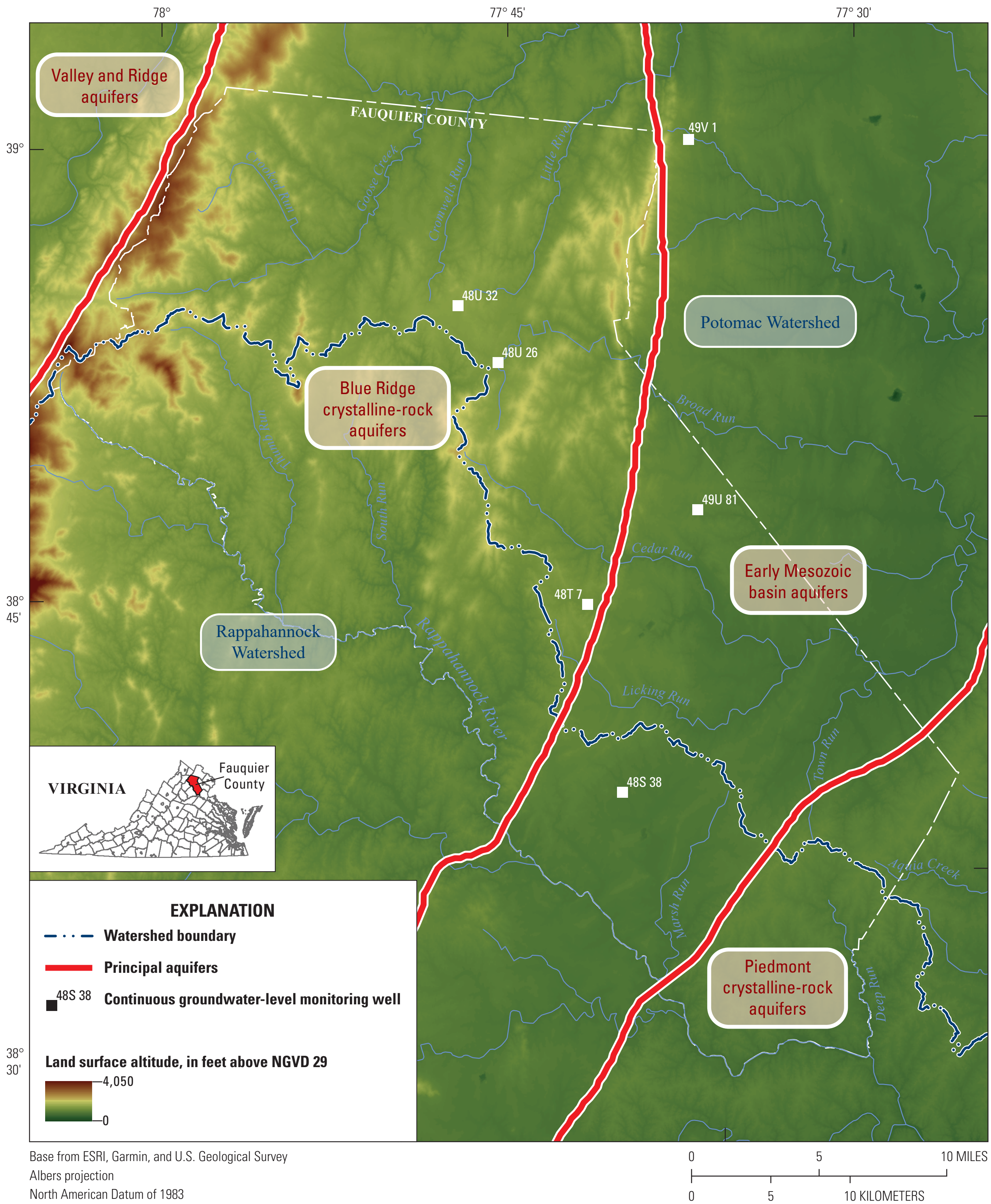
This report continues the multi-year collaboration of the U.S. Geological Survey (USGS), the Fauquier County Water and Sanitation Authority (FCWSA), and the Virginia Department of Environmental Quality (VADEQ) to collect data and assess county-wide groundwater conditions. Previous activities in this collaborative effort include geophysical well logging, the installation of additional continuous groundwater-level monitoring wells, and the development of a water budget using a Soil-Water-Balance (SWB) model (McCoy and Ladd, 2019). Collectively, these hydrogeologic investigations build a scientific foundation that can be used for management and future planning of Fauquier County water resources.

Purpose and Scope

This report documents the collection of synoptic groundwater level data in Fauquier County, Virginia in late October and early November 2018. These field measurements were used in a geographic information system (GIS) to develop a county-wide groundwater-level contour map. A basic error analysis was performed on the estimated groundwater-levels. Antecedent conditions that influenced the field measurements, and the limitations of the model, also are discussed.

Description of Study Area

Fauquier County consists of 650 square miles (mi^2) in north-central Virginia. The county straddles the drainage divide between the north-flowing tributaries of the Potomac River and the south-flowing tributaries of the Rappahannock River (fig. 1). The county includes parts of the Piedmont and Blue Ridge Physiographic Provinces, two geographic regions with large topographic differences. In the northwestern part of Fauquier County, the Blue Ridge Physiographic Province has steep slopes with altitudes up to 2,400 feet. In the southeastern part of the county, the Piedmont Physiographic Province is characterized by rolling terrain and lower altitudes, from 160 to 800 feet. These altitude differences account for the



Base from ESRI, Garmin, and U.S. Geological Survey
Albers projection
North American Datum of 1983

Figure 1. General location and hydrogeologic overview of Fauquier County, Virginia. NGVD 29, National Geodetic Vertical Datum of 1929.

slight variation in mean annual precipitation, which averaged between 40 and 43 inches, across the county for the period from 1981 to 2010 (PRISM Climate Group, 2019).

Geologically, Fauquier County is underlain by crystalline rocks of the Blue Ridge Physiographic Province and the northwestern part of the Piedmont Physiographic Province. These rocks act as one principal aquifer and are referred to in this study as the Blue Ridge crystalline aquifer (fig. 1). The remainder of the Piedmont Physiographic Province is further divided by altitude and geologic structure. The central lowlands of the Piedmont Physiographic Province are underlain by Mesozoic sedimentary rocks deposited in a northeast-southwest trending rift basin, referred to as the Mesozoic basin aquifer for this study. The far southeastern corner of Fauquier County, part of the Piedmont Physiographic Province uplands, is underlain by rocks of multiple island-arc and volcanic origins and is referred to as the Piedmont crystalline aquifer in this study (Davis and others, 2001).

The City of Warrenton is the seat of local government in Fauquier County and the largest municipality. Nine service districts organized along major highways provide water and sewer utilities to low- and medium-intensity development areas (fig. 2). Most of the land area of Fauquier County, and 45 percent of its population, lie outside the nine service districts. Most of the county is rural, with major land cover consisting of deciduous forest or pasture (McCoy and Ladd, 2019).

As part of ongoing USGS investigations, groundwater levels are being continuously monitored at locations in and around Fauquier County. Continuous water-levels have been recorded in well 48U 26 since October 2007 and in well 49V 1 since September 2003. Continuous water-levels have been recorded in monitoring wells 48S 38, 48T 7, 48U 32, and 49U 81 since April 2018 (fig. 1). Water-levels are uploaded in near real time automatically by satellite telemetry to the USGS National Water Information System (NWIS) and verified with field measurements on a 6- to 8-week interval.

Study Methods

Groundwater levels were measured to develop a groundwater-level contour map of Fauquier County. Standard USGS protocols were followed for the collection, processing, review, and approval of the water-level measurements (Cunningham and Schalk, 2011). The groundwater-level contour map was developed by applying methods adapted from those used in previous USGS efforts by McCoy and others (2015), Nottmeier (2015), and Peck and Payne (2003).

Collection of Groundwater-Level Data

A synoptic survey of groundwater levels in 129 wells across Fauquier County was conducted from October 29 through November 2, 2018 (appendix 1; fig. 2). Field personnel requested access to the wells and any available well information from private-domestic well owners. Water levels were measured manually with a calibrated steel tape to the nearest one-hundredth of a foot. A calibrated electric tape was substituted for the steel tape in wells where the depth to water could not be determined with the steel tape, most often because of moisture inside the well casing. At each visit, multiple measurements were made, at least five minutes apart, until a pair of measurements were within two one-hundredths of a foot. This standard procedure reduces error from any short-term groundwater-level fluctuations attributed to recent well pumping (Cunningham and Schalk, 2011). The water-level measurements and pertinent well information were entered, reviewed, and approved, then stored in the USGS National Water Information System (NWIS) database.

Development of Groundwater-Level Contour Map

The synoptic groundwater-level data were used as one input in the development of a groundwater-level contour map for Fauquier County. Assuming that streams are a surficial expression of groundwater, the altitudes of key points in the stream network were selected to provide additional spatial coverage and help confine groundwater levels below land surface. These key stream points were defined as the intersections of streams from the National Hydrography Dataset (NHD) with a Strahler stream order of two or greater, with the intent to eliminate ephemeral headwaters that do not reliably indicate the presence of groundwater. Altitudes for the key stream points were obtained from a three-meter (9.84 ft) digital elevation model (DEM) of Fauquier County (U.S. Geological Survey, 2011). To avoid representing groundwater levels beyond the scope of field-verified measurements, key stream points were further restricted to those with an altitude less than the highest measured groundwater level. Stream points within 3 miles (mi) of the Fauquier County boundary were included in the analysis to avoid problematic interpolation along the county line.

Data from the synoptic groundwater-level survey and key stream points were merged into a geographic information system (GIS), which was used to create a spatially referenced raster surface of groundwater-level altitude using a natural-neighbor interpolation. A GIS contouring tool converted the interpolated raster surface into a line-based dataset. These contour lines represent an equal altitude of estimated groundwater levels above the NGVD 29 datum. To reduce errors where the interpolated groundwater levels were greater than three meters (9.84 feet) above the DEM land surface, contours were manually adjusted where steep hydraulic gradients are assumed to mimic the steep topography. Adjustments to groundwater-level contours also were required to depict groundwater discharge in stream bottoms. Gaining streams were an assumption

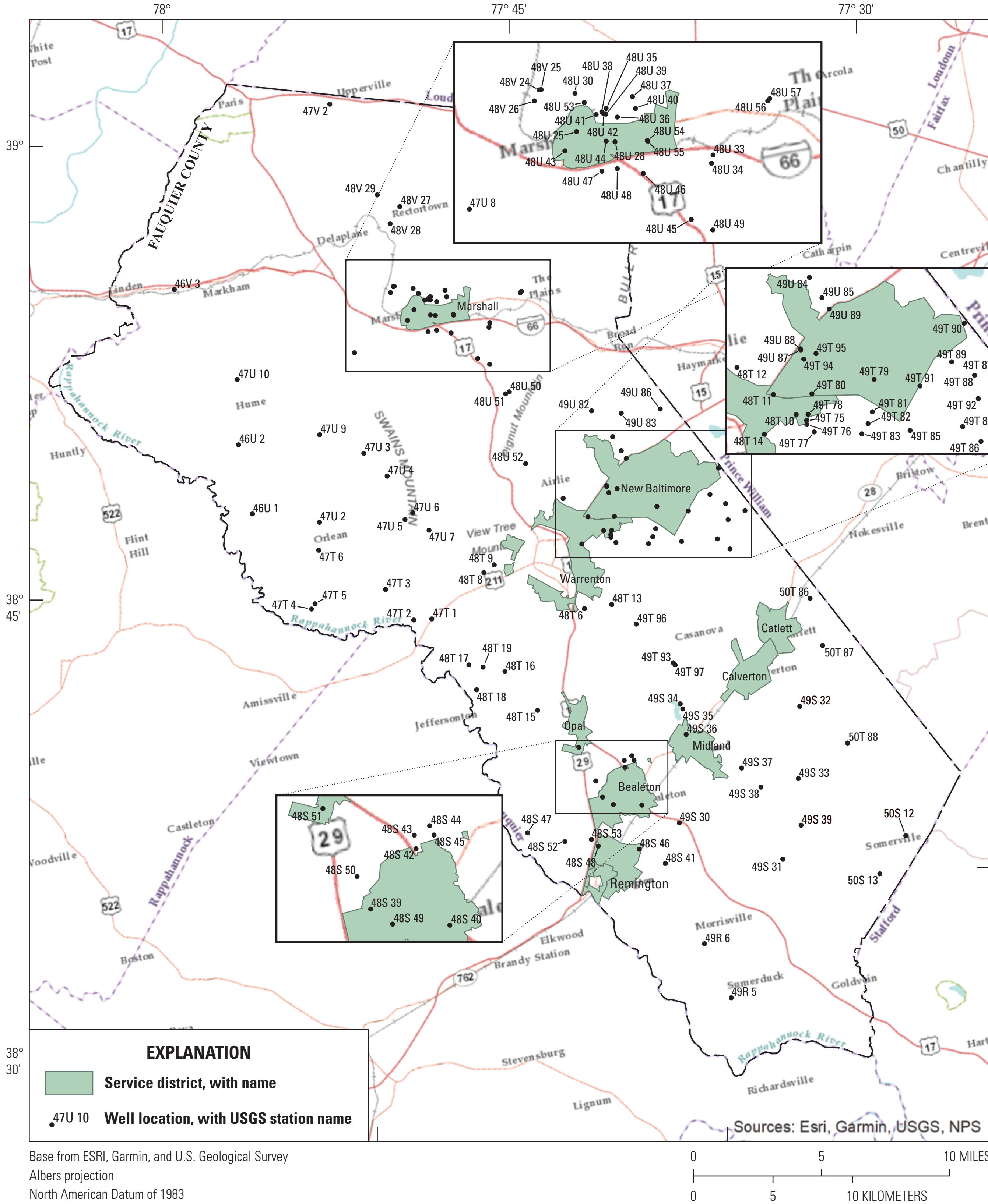


Figure 2. Location of service districts and wells used in groundwater-level survey of Fauquier County, Virginia, October 29–November 2, 2018.

embedded in this approach using stream altitude and are consistent with findings elsewhere in the Blue Ridge and Piedmont physiographic provinces (McCoy and others 2015).

The edited groundwater-level contours served as the primary dataset for the Fauquier County groundwater-level contour map, alongside the measured synoptic groundwater-level measurements and a background of land-surface altitude, also referenced to the NGVD 29 datum (fig. 3).

A final GIS contour to raster tool was used to convert the estimated groundwater-level contours to a continuous, thirty-meter (98.4 ft) resolution, estimated groundwater-level altitude raster surface for subsequent error analysis. Both the contour lines and raster surface are available as a USGS data release (Kearns, 2022).

Factors Affecting Groundwater Levels

Antecedent Conditions

Although a synoptic survey of groundwater levels is an attempt to provide a snapshot in time, it is important to recognize that groundwater is a dynamic resource, responsive to changes to inputs to, or demands on, the hydrologic system. Groundwater levels can fluctuate on a seasonal basis or deviate dramatically from average conditions during exceptionally wet periods or drought. Groundwater withdrawals also impact the water levels, particularly during drought conditions or anytime withdrawals exceed recharge.

Precipitation and Groundwater Levels

The synoptic survey period was selected to occur around the time of the usual seasonal minimum in the annual cycle of groundwater fluctuations, which – due to factors including precipitation, temperature, and growing season – typically includes a period of recharge in the winter and spring followed by a general decrease throughout the summer and fall (McCoy and others, 2015). Conditions prior to the October-November 2018 synoptic survey, however, were abnormally wet. Monthly mean PRISM precipitation data for Fauquier County from June to September (fig. 4*A*) were twice the 30-year monthly mean for the period 1981 to 2010 (PRISM Climate Group, 2019). This likely contributed to above-normal groundwater levels for most of the summer, as shown by data from the two USGS monitoring wells in the region with records long enough to compute a 10-year daily median from data published in NWIS for the period 2007 to 2017 (fig. 4*B,C*).

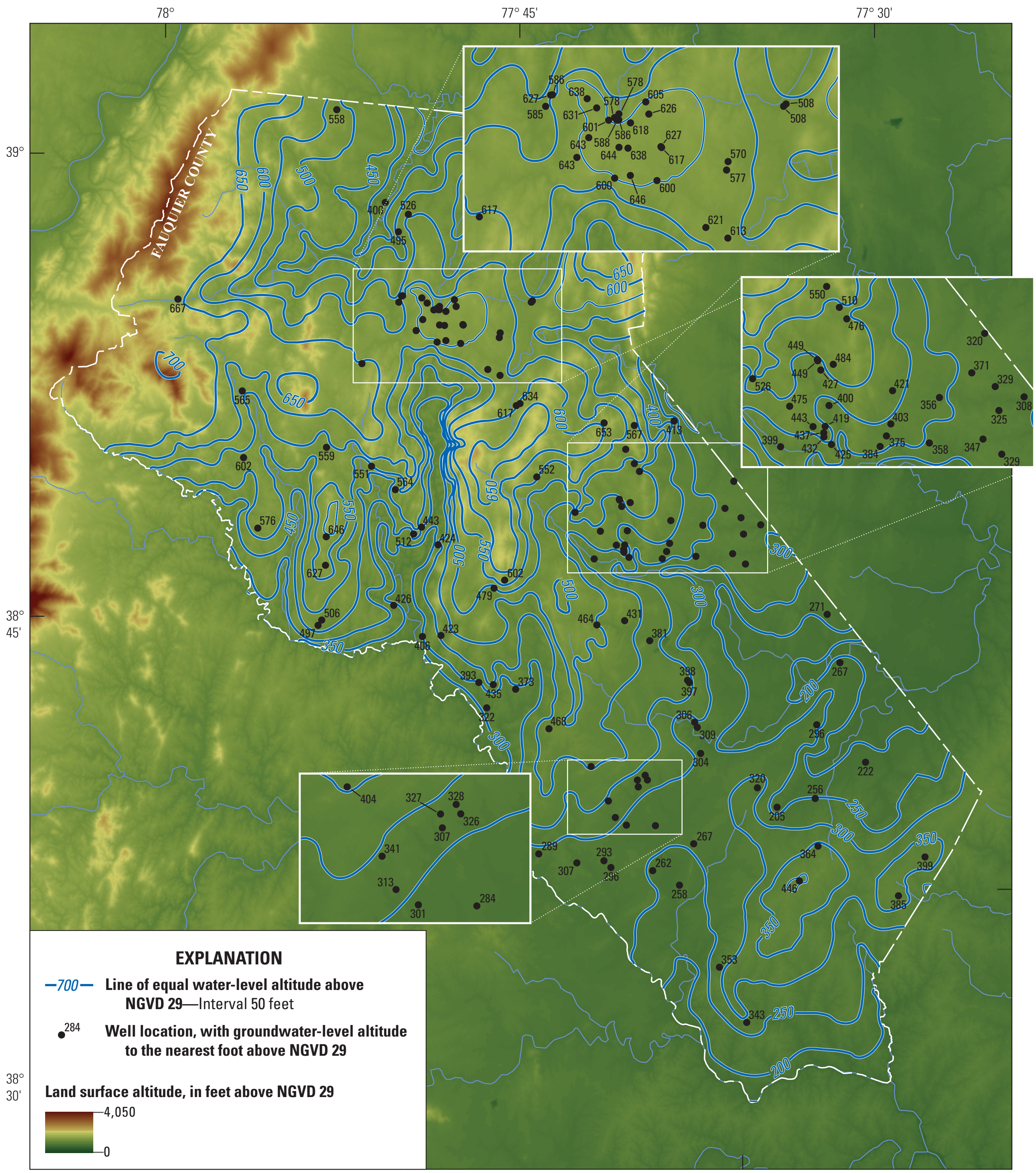
Monitoring well 48U 26 is in the Blue Ridge crystalline aquifer of northern Fauquier County. Water levels in 48U 26 were generally elevated during the summer, decreased throughout October 2018, and were nearing long-term median values during the period of the synoptic survey. Consistent with findings elsewhere in the crystalline aquifers of the Blue Ridge physiographic province (McCoy and others, 2015), well 48U 26 is highly sensitive to fluctuations in groundwater level; for wells less sensitive to short-term conditions, water levels that rose in response to the extreme summer precipitation would likely take even longer to return to normal. Monitoring well 49V 1 is completed in the Mesozoic basin aquifer approximately two kilometers east of Fauquier County. Water levels in well 49V 1 were consistently higher than 10-year daily median values for most of the summer of 2018. Although the groundwater level did decline throughout October, it rose again immediately before and during the period of the synoptic survey. Compared to well 48U 26, well 49V 1 appears less sensitive to fluctuations in water level and has a smaller range of median values throughout the year.

Evaluation of the combination of county-wide precipitation data and a monitoring well record in each of the two major aquifer systems indicates that it would be reasonable to conclude that groundwater levels in Fauquier County were likely at or above long-term median values during the October-November 2018 synoptic survey.

Groundwater Withdrawals and Use

The USGS, in cooperation with programs like the VADEQ's Virginia Water Use Data System, provides national water-use estimates summarized by county every five years. Data for 2015 (U.S. Geological Survey, 2020; the most recent available at time of publication) show that nearly 99 percent of the estimated 4.32 million gallons per day (Mgal/d) of groundwater withdrawn in Fauquier County was used for public- or private-water supply. Most (1.76 Mgal/d) of the public-water supply in Fauquier County and all (2.51 Mgal/d) private-domestic-water supply comes from groundwater wells (table 1). Private-domestic supply is the largest categorical use of groundwater in the county. The remaining 1 percent (0.05 Mgal/d) of the estimated groundwater withdrawal supports livestock and the irrigation of approximately 200 acres on golf courses. From 1985 to 2015, the estimated public-supply demand for groundwater in Fauquier County rose from 0.6 to 1.76 Mgal/d—a nearly threefold increase. During the same period, estimated withdrawal from private-domestic wells rose 18 percent, from 2.13 to 2.51 Mgal/d (Dieter and others, 2018).

Water-use information is available on smaller and more recent spatio-temporal scales from VADEQ, but only for entities meeting reporting thresholds (withdrawing an average of 10,000 gal/day). This threshold would exclude private-domestic use but does capture public-water suppliers, golf course irrigation, and a small thermoelectric plant in Fauquier County. VADEQ data from 2015 to 2019 indicate an average annual reported groundwater withdrawal of 675 Mgal, or 1.85 Mgal/day—slightly greater than corresponding 2015 USGS estimates (Virginia Department of Environmental Quality, 2020). A monthly breakdown of VADEQ data for 2018 shows a clear seasonal fluctuation in groundwater withdrawals, with the highest demand from May to October, a peak in July, and



Base from ESRI, Garmin, and U.S. Geological Survey
Albers projection
North American Datum of 1983

0 5 10 MILES
0 5 10 KILOMETERS

Figure 3. Groundwater-level contour map of Fauquier County, Virginia. NGVD 29, National Geodetic Vertical Datum of 1929.

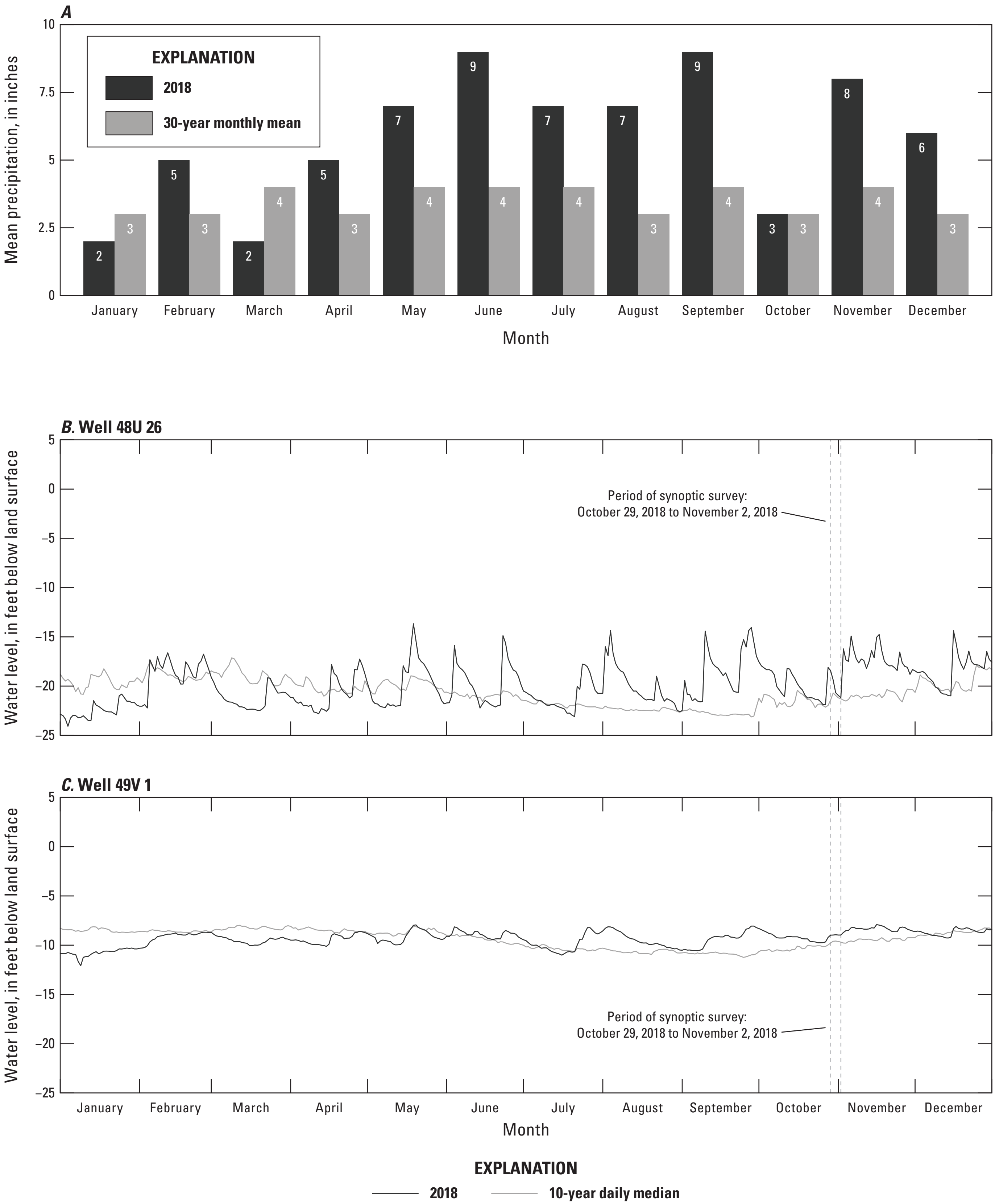


Figure 4. Antecedent conditions to October 29–November 2, 2018, groundwater survey in Fauquier County, Virginia: *A*, PRISM monthly precipitation in 2018 compared to 30-year monthly mean precipitation for 1981 to 2010, and *B* and *C*, 2018 daily groundwater levels in monitoring wells 48U 26 and 49V 1, respectively, compared to 10-year daily median for 2007 to 2017.

Table 1. Estimated groundwater withdrawals in Fauquier County, Virginia, 1985–2015. Water volumes in million gallons per day (Mgal/d). Data from Dieter and others (2018) and U.S. Geological Survey (2020).

[—, no data]

Year	Population, public supply groundwater	Public supply, groundwater	Population, domestic self-supplied	Domestic self-supplied	Industrial self-supplied	Thermoelectric power self-supplied	Livestock self-supplied	Irrigation, golf, self-supplied	Irrigation, crop, self-supplied
1985	4,750	0.6	28,350	2.13	0	0	—	—	—
1990	14,340	1.45	27,400	2.06	0	0	—	—	—
1995	11,300	1.69	32,170	2.41	0.02	0	—	—	—
2000	13,280	0.69	33,889	2.54	0	0	0.06	0	0.06
2005	22,418	1.77	31,472	2.36	0	0.01	0.05	0	0.16
2010	22,703	1.49	31,207	2.34	0	0.01	0.04	0.01	0
2015	26,229	1.76	31,328	2.51	0	0	0.04	0.01	0

the lowest demand in February (fig. 5). This seasonal demand contrasts with the annual pattern of groundwater availability in Fauquier County (as shown by the median conditions [water levels] in wells 48U 26 and 49V1 in figure 4*B*), in that demand is often highest when water levels typically are at their lowest. The groundwater withdrawal in October 2018 of 58.31 Mgal was 0.5 percent below the average October withdrawal and 3.6 percent above the average monthly withdrawal for 2015 to 2019 (Virginia Department of Environmental Quality, 2020). These values indicate that groundwater demand in Fauquier County was normal prior to the synoptic survey.

Precipitation and groundwater-levels prior to the synoptic survey suggest a slightly above-normal supply following a very wet summer. Estimated and reported groundwater withdrawals suggest normal seasonal demand. Determining the dominant force on groundwater levels from a single set of synoptic measurements is unlikely; however, the review of the data on antecedent precipitation, water levels, and withdrawals indicates the groundwater-level contour map was not developed from an extreme mismatch in groundwater conditions.

Error Analysis and Limitations of Estimated Groundwater Levels

Groundwater levels estimated from the contour map were compared to the levels measured during the synoptic survey. Root-mean-squared error (RMSE) of the estimated groundwater levels was 33.52 feet (eq. 1).

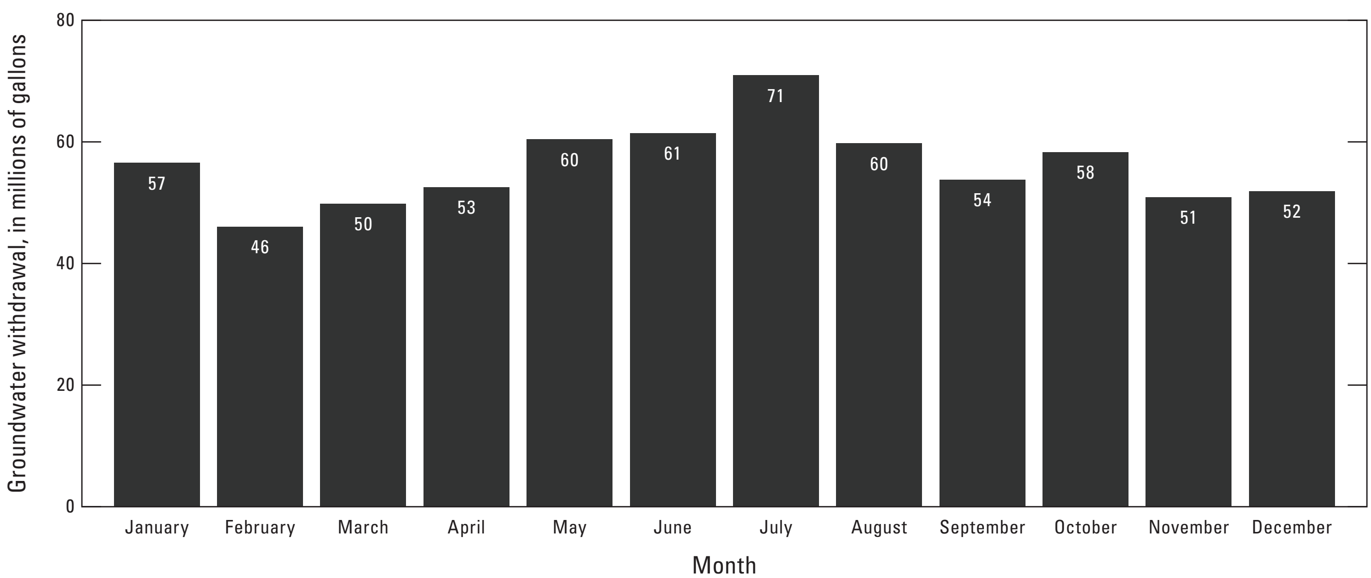


Figure 5. Monthly groundwater withdrawals in Fauquier County, Virginia, 2018, as reported by Virginia Department of Environmental Quality.

Root-mean-squared error

$$RMSE = \sqrt{(e - m)^2}\,, \tag{1}$$

where

e is the estimated value; and

m is the measured value.

A plot of estimated groundwater levels against measured levels (fig. 6*A*) and residual error (fig. 6*B*) indicated that the estimated groundwater-level altitudes generally were lower than the measured altitudes. This bias generally was consistent across all groundwater levels, with a slight increase at greater altitudes. A GIS comparison of the groundwater-level raster surface and the DEM of Fauquier County indicated that the greatest error in estimated altitude of the groundwater-level surface was on hillsides and in stream valleys in steep terrain. On hillsides in particular, the depth-to-water and residual error are sensitive to small shifts of groundwater-level contour lines. Additionally, the horizontal resolutions of the raster and DEM used to estimate groundwater-level and land-surface altitudes are less accurate in high-relief terrain.

As discussed in the study methods, the groundwater-level contours were adjusted in areas of steep topographic gradient. Adjustments to contours resulted in lowering of estimated groundwater-level altitudes in comparison to actual water-level observations, increasing error in these steep areas. Thus, the development of a county-wide groundwater-level contour map is a balance between reducing local error between estimated and measured water levels while maintaining large-scale topographic and hydrologic integrity.

The Fauquier County groundwater-level contour map was developed with the intent to represent steady-state groundwater conditions when recharge and groundwater levels were near their long-term averages. With only 129 observations across the 650-mi^2 county, it was necessary to interpolate groundwater-level contours from limited data. The interpolations assumes that the groundwater occurs and moves within a single, unconfined system; however, gradients and pressures within the system are regionally controlled by surface topography and geology. Therefore, estimated groundwater levels differed from those measured in wells, as indicated by the RMSE and residuals. Extrapolation of the results of this study to smaller-scale investigations would require more hydrogeologic data than were available at the time of publication. Documenting changes in groundwater levels due to seasonal variation, extreme conditions, climate change, or groundwater withdrawals also are outside the scope of this report. Despite these limitations, the groundwater-level map presented here represents the best-available science concerning county-wide groundwater levels and serves as a solid basis for future modeling of Fauquier County groundwater resources.

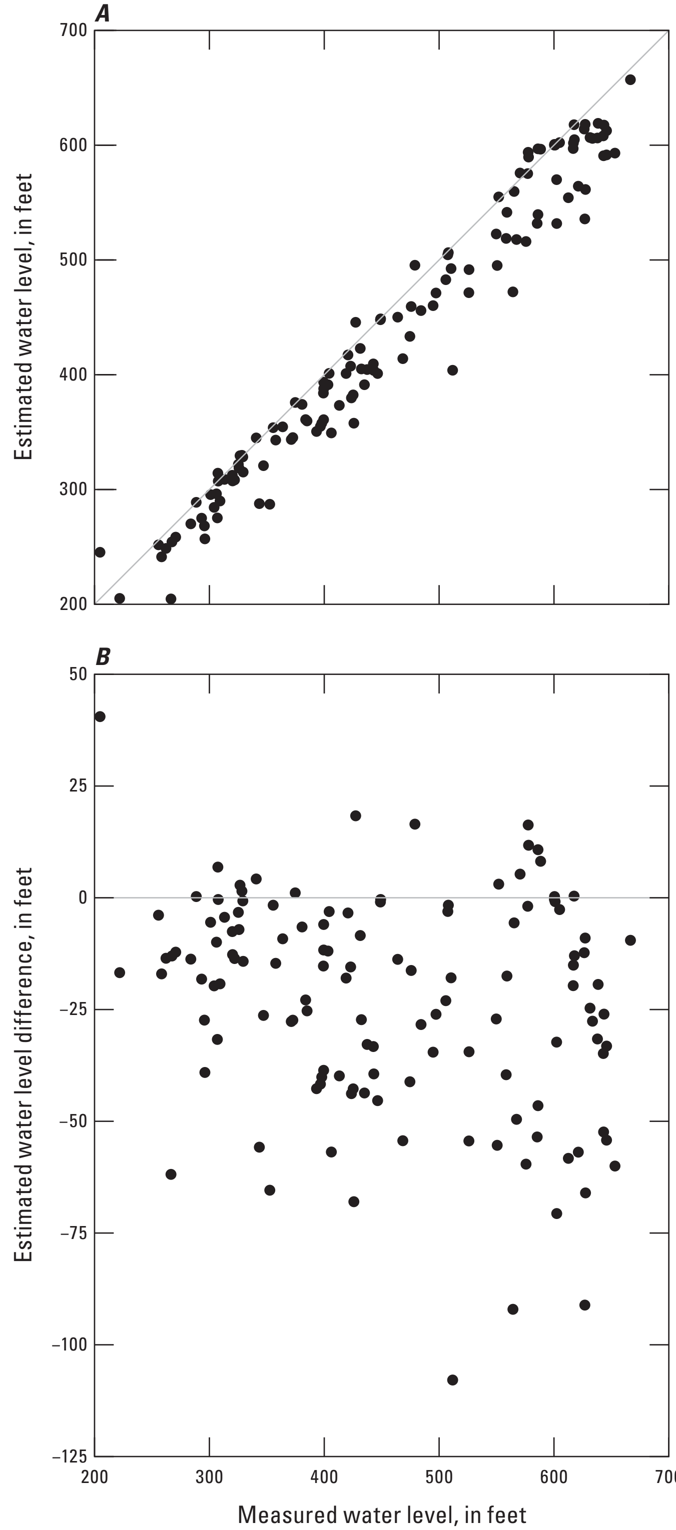


Figure 6. Estimated groundwater-level altitudes (National Geodetic Vertical Datum of 1929) from contour map plotted against measured groundwater levels in Fauquier County, Virginia: *A*, 1:1 plot, and *B*, residuals.

Discussion of the Groundwater-Level Map

Groundwater levels measured in October-November 2018 in Fauquier County ranged from 667 ft NGVD 29 in the northwestern part of the county to 205 ft NGVD 29 in the southeast (fig. 3). Topography is the driving force for groundwater levels, in that the levels are generally a subdued reflection of the land surface configuration. This relation is similar to findings elsewhere in the Blue Ridge and Piedmont physiographic provinces (McCoy and others 2015). Streams in Fauquier County are assumed to be gaining streams, serving as discharge points for groundwater to enter the surface-water system. The topographic and geological differences between areas underlain by the crystalline aquifers in the Blue Ridge and Piedmont Uplands and by the sedimentary aquifer of the Mesozoic basin are readily apparent in the groundwater-level map. The crystalline system contains steep groundwater-level gradients and a much greater depth-to-water with distance away from streams. The Mesozoic basin is characterized by low groundwater gradients and shallow depth-to-water.

The spatial coverage of the wells in which water levels were measured as part of this study was limited, but groundwater divides indicated by the measured levels are coincident with major surface-water drainage divides. Groundwater in the northern and eastern parts of the county generally flows toward the Potomac River, whereas groundwater in the southern and western parts of the county drains toward the Rappahannock River. The Marshall service district (fig. 2) straddles this groundwater divide on a small hydrologic plateau. This plateau limits the source area for the Marshall service district, as groundwater likely flows away from, rather than toward, the source area for the service district.

At the county-wide scale of this investigation, and during the median to above-median groundwater conditions at the time of the synoptic survey, in none of the Fauquier County service districts did the water-level contours exhibit noticeable cones of depression that would indicate an unsustainable demand on groundwater resources at current withdrawal rates. Further monitoring would be needed to detect local decreases in groundwater storage or cones of depression of limited areal extent.

Estimated groundwater levels generally were lower than measured values during the synoptic survey; however, groundwater levels fluctuate seasonally with recharge and withdrawal. The five USGS continuous monitoring wells in Fauquier County (fig. 1) provide additional context for the representation of estimated groundwater levels over time. These wells were not visited during the synoptic survey, nor used for the interpolation of the groundwater-level contour map. Instead, these wells represent independent observations at surveyed locations where the groundwater-level altitudes are known to within ±0.01 ft. Groundwater-level altitudes at the 129 synoptic survey wells depend upon GPS and DEM accuracy at the measuring point, which increases the level of uncertainty, especially in steep terrain.

For each USGS continuous monitoring well, the estimated water level was plotted with the NWIS daily maximum value for all available data during the 3-year period from April 2018 through March 2021 (fig. 7). Well 48S 38 was the only well at which the daily maximum value was consistently below the estimated level. In wells 48T 7 and 48U 32, daily maximum values were above the estimated water level, with the level at well 48T 7 being particularly shallow. The estimated water level for well 49U 81 plotted between seasonal maximum and minimum values, whereas the estimated level for well 48U 26 coincided only with the lowest daily values during the three-year period. Although the synoptic survey was conducted following a period of abnormally high precipitation and above-median groundwater levels, the interpolation and edits to the groundwater-level contour map produced consistently lower estimated groundwater levels and resulted in a final product that best approximates seasonal or annual minimums in the groundwater resources at a county-wide scale.

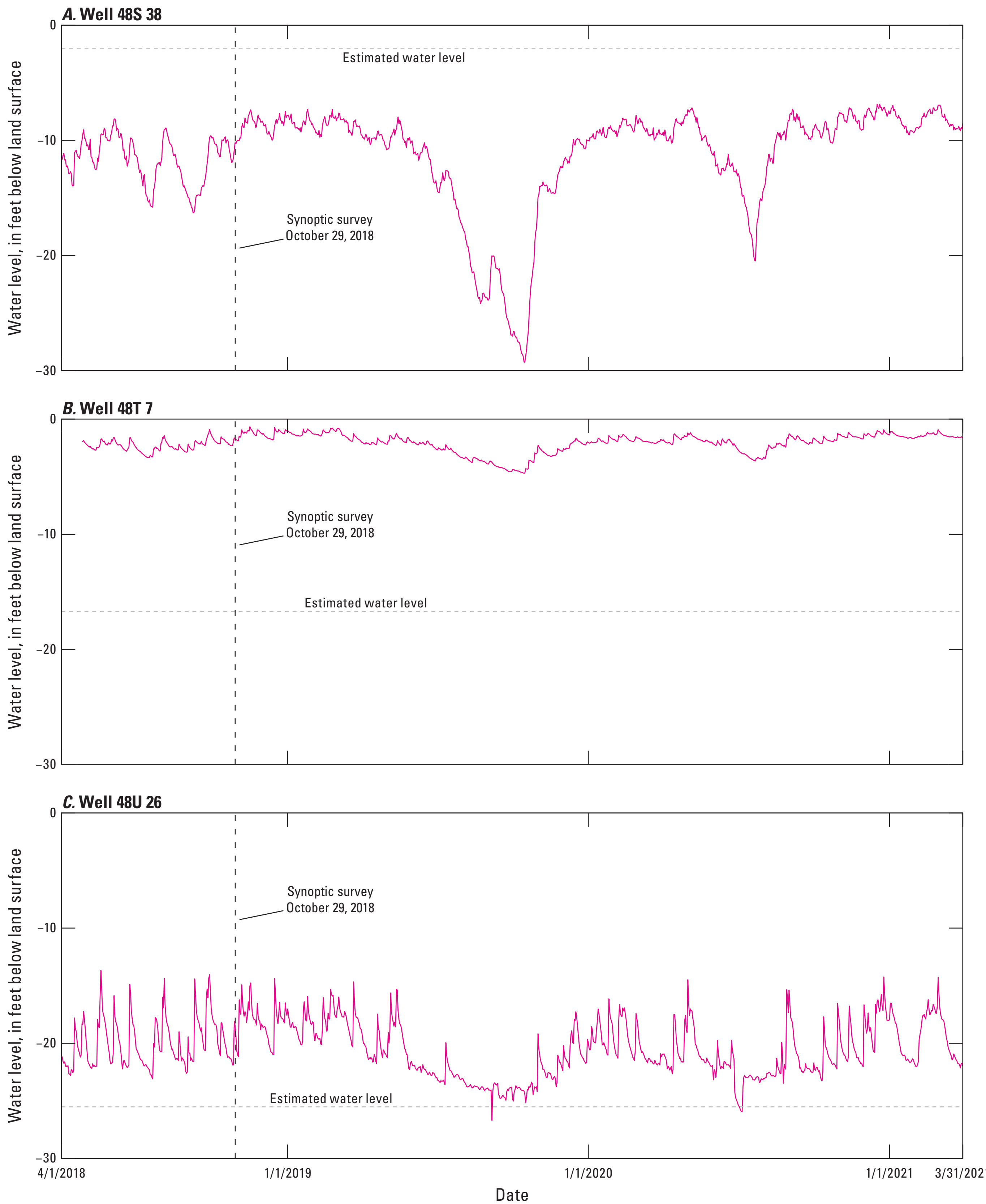


Figure 7. Daily-maximum values from U.S. Geological Survey continuous monitoring wells in Fauquier County, Virginia plotted with the estimated groundwater level from the contour map: *A*, Well 48S 38, *B*, Well 48T 7, *C*, Well 48U 26, *D*, Well 48U 32, and *E*, Well 49U 81.

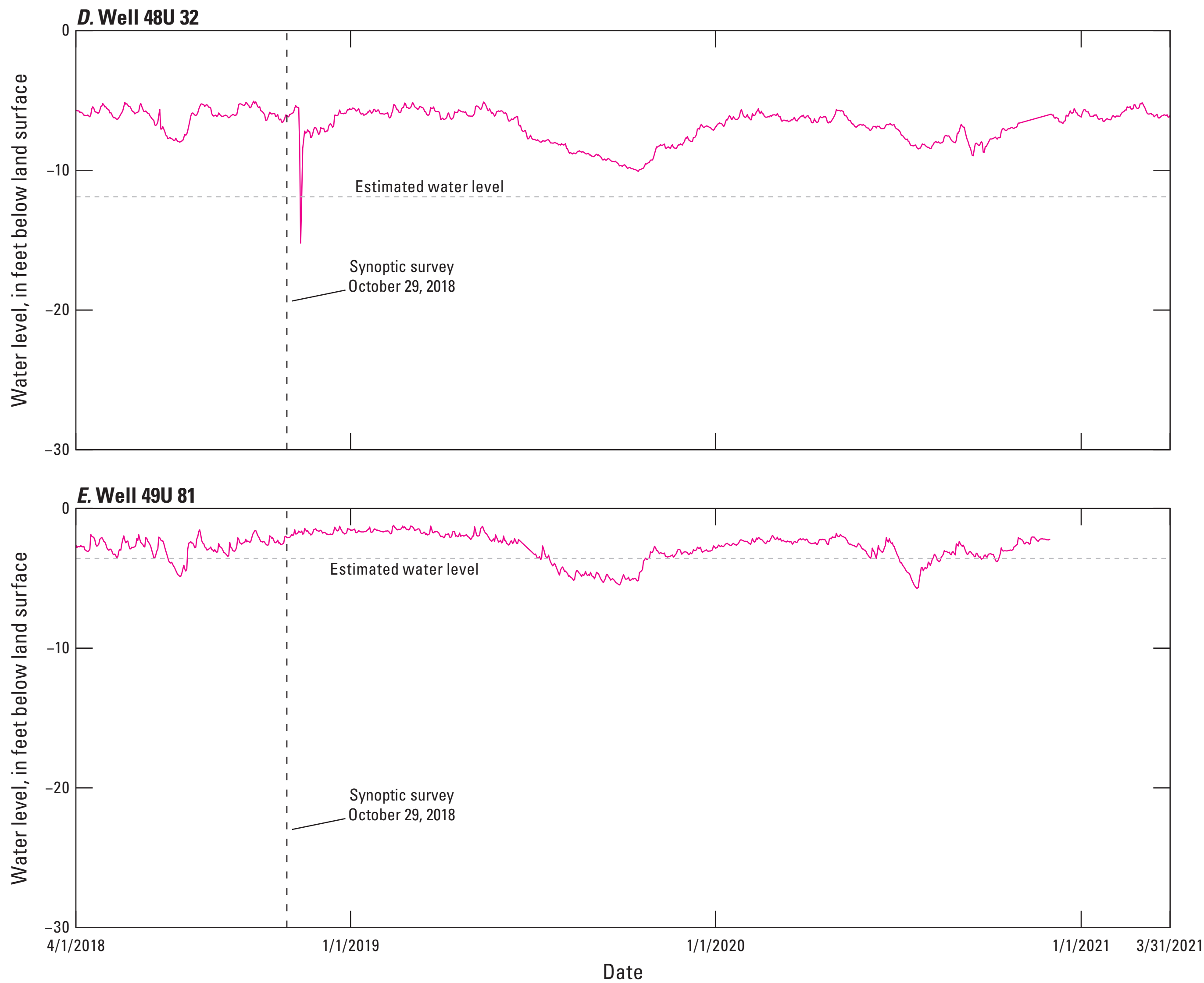


Figure 7.—Continued

Summary

Fauquier County, Virginia is a fast-growing rural area southwest of Washington, D.C. Groundwater provides most public water supplies and all private-domestic users in the county. Continuing U.S. Geological Survey (USGS) investigations of groundwater resources in Fauquier County support their management and planning. Groundwater levels were measured during a county-wide synoptic survey from October 29 through November 2, 2018. These field measurements were combined with data from the USGS National Hydrography Dataset and digital elevation models and used in the development of a county-wide groundwater-level contour map. The contour map was interpolated in a geographic information system (GIS) program and then manually edited to preserve major topographic features and reduce above-land-surface error of the groundwater levels.

Antecedent conditions suggest that groundwater levels and withdrawals during the synoptic survey were near or slightly above long-term median values. Error analysis indicated that estimated groundwater-level contours generally were lower than observed measurements, with root-mean-squared-error of 33.52 feet. A comparison of estimated groundwater levels to daily values in five USGS continuous monitoring wells over the 3-year period April 2018 through March 2021 suggests estimated groundwater levels coincide with seasonal or annual minimums.

Groundwater-levels in Fauquier County are primarily topographically driven, consistent with findings in other studies in the Blue Ridge and Piedmont Physiographic Provinces. Groundwater levels contrast markedly between those in the steep topography overlying the crystalline Blue Ridge aquifers in the northwestern part of the county and water levels in the rolling terrain of the sedimentary Mesozoic Basin in the

southeastern part. At current levels of groundwater withdrawal, and at the scale and scope of this synoptic survey, no cones of depression in the groundwater-level contours were detected. The Fauquier County groundwater-level contour map is available as a USGS data release (Kearns, 2022).

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Appendix 1. Site information for wells included in the groundwater-level survey of Fauquier County, Virginia, October–November 2018

Table 1.1. Site information for wells included in the groundwater-level survey of Fauquier County, Virginia, October–November 2018.

[Site locations shown in figure 2 and listed roughly from north to south. DDMMSS.S, degrees minutes, and seconds of latitude or longitude]

Well name	USGS site identification	Latitude, in DDMMSS.S	Longitude, in DDMMSS.S	Observed groundwater-level altitude, in feet	Estimated groundwater-level altitude, in feet
47V 2	385931077532701	38 59 30.64	77 53 27.42	558.37	518.79
48V 29	385612077521001	38 56 12.44	77 52 9.79	399.50	387.81
48V 27	385540077511701	38 55 40.61	77 51 17.2	526.04	491.60
48V 28	385510077515101	38 55 10.34	77 51 50.98	494.77	460.23
46V 3	385422078014201	38 54 21.94	78 01 42.3	666.59	657.07
48V 24	385305077521401	38 53 4.61	77 52 14.36	626.87	535.76
48V 25	385305077521101	38 53 4.54	77 52 11.5	586.08	539.58
48V 26	385253077522401	38 52 53.43	77 52 24.41	585.37	531.87
48U 30	385253077512401	38 52 53.09	77 51 23.96	637.86	606.28
48U 53	385241077511301	38 52 41.16	77 51 13.1	631.39	606.69
48U 37	385237077500201	38 52 37.43	77 50 2.35	604.89	602.26
48U 35	385230077504301	38 52 30.03	77 50 43.43	577.89	589.65
48U 38	385227077505001	38 52 27.01	77 50 50.4	577.54	593.83
48U 41	385225077505901	38 52 25.41	77 50 59.44	600.97	600.11
48U 42	385224077504801	38 52 24.28	77 50 48.29	588.38	596.55
48U 39	385224077504501	38 52 23.71	77 50 45.23	586.08	596.84
48U 40	385224077500101	38 52 23.65	77 50 1.34	626.35	614.06
48U 36	385218077503001	38 52 18.01	77 50 29.55	617.79	604.82
48U 25	385211077513301	38 52 10.69	77 51 32.26	642.96	608.12
48U 57	385206077464601	38 52 5.85	77 46 45.6	507.58	504.52
48U 56	385204077464901	38 52 3.71	77 46 49.01	508.04	506.39
48U 44	385154077505201	38 51 53.91	77 50 52.35	643.55	617.52
48U 43	385152077515401	38 51 51.86	77 51 54.4	643.21	590.81
48U 28	385151077504001	38 51 51.13	77 50 39.95	638.44	619.06
48U 54	385146077495301	38 51 45.97	77 49 53.16	627.17	618.16
48U 55	385142077495201	38 51 44.81	77 49 52.45	617.48	617.85
48U 47	385122077510701	38 51 21.57	77 51 6.89	600.38	600.03
48U 48	385121077504401	38 51 21.19	77 50 44.06	645.82	612.64
48U 33	385116077482301	38 51 15.78	77 48 22.82	570.48	575.77
48U 46	385110077500801	38 51 10.2	77 50 8.04	600.47	600.74
47U 8	385108077542801	38 51 8.02	77 54 27.71	616.93	601.86
48U 34	385107077482701	38 51 6.99	77 48 27.26	577.16	575.27
47U 10	385059077594401	38 50 59.56	77 59 44.05	565.30	559.69
48U 45	385009077491201	38 50 9.35	77 49 12.07	621.19	564.29
48U 49	384953077484401	38 49 53.27	77 48 44.05	612.53	554.24
48U 50	384851077480701	38 48 51.12	77 48 7.17	633.53	605.92
46U 2	384850078001301	38 48 49.51	78 00 13.04	602.40	531.76
48U 51	384848077481801	38 48 48.46	77 48 17.66	616.74	597.08

—Continued

[Site locations shown in figure 2 and listed roughly from north to south. DDMMSS.S, degrees minutes, and seconds of latitude or longitude]

Well name	USGS site identification	Latitude, in DDMMSS.S	Longitude, in DDMMSS.S	Observed groundwater-level altitude, in feet	Estimated groundwater-level altitude, in feet
47U 9	384839077563801	38 48 38.59	77 56 38.2	559.04	541.53
47U 3	384745077545401	38 47 45.03	77 54 53.55	550.56	495.19
49U 82	384742077444401	38 47 41.73	77 44 44.12	653.11	593.10
49U 83	384725077432901	38 47 25.37	77 43 28.93	567.38	517.82
49U 86	384719077414601	38 47 18.95	77 41 46.19	413.14	373.29
47U 4	384651077540501	38 46 50.72	77 54 4.74	564.27	472.21
49U 84	384642077440301	38 46 42.37	77 44 2.61	549.74	522.64
46U 1	384627078001101	38 46 27.19	78 00 11.24	575.67	516.09
48U 52	384622077480101	38 46 22.2	77 48 0.85	551.90	554.95
49U 85	384611077434801	38 46 11.35	77 43 47.62	510.42	492.51
49U 89	384554077433901	38 45 54.19	77 43 38.54	475.70	459.43
47U 2	384545077572201	38 45 44.97	77 57 22.41	645.77	591.55
47U 6	384528077531701	38 45 28.02	77 53 16.83	442.74	409.46
47U 5	384518077534001	38 45 17.61	77 53 40.23	511.78	403.91
49U 88	384508077444301	38 45 7.72	77 44 43.18	449.09	448.70
49U 87	384506077444301	38 45 6.1	77 44 42.92	448.91	447.96
48T 12	384459077464201	38 44 58.97	77 46 41.54	525.92	471.52
49T 90	384459077394501	38 44 59.2	77 39 45.16	319.96	312.41
49T 95	384457077441701	38 44 57.25	77 44 17.29	484.26	455.90
49T 94	384453077444101	38 44 52.88	77 44 40.75	427.35	445.69
47T 6	384450077573801	38 44 49.86	77 57 38.15	627.45	561.43
47U 7	384448077524301	38 44 47.51	77 52 43.39	423.65	379.84
48T 11	384413077454701	38 44 12.81	77 45 46.75	474.58	433.42
49T 89	384410077402101	38 44 10.16	77 40 20.78	371.28	343.60
49T 79	384407077424401	38 44 6.95	77 42 43.66	420.66	417.27
49T 80	384404077443801	38 44 3.65	77 44 38.41	399.50	393.53
49T 91	384346077412501	38 43 45.75	77 41 25	355.54	353.88
49T 88	384346077394501	38 43 45.85	77 39 44.91	329.10	328.41
48T 10	384340077451301	38 43 39.71	77 45 13.23	443.14	403.74
49T 78	384337077445201	38 43 37	77 44 52.2	419.03	401.07
49T 75	384329077445701	38 43 28.7	77 44 56.74	437.33	404.52
49T 87	384325077385901	38 43 24.62	77 38 58.53	307.69	307.31
49T 76	384323077445801	38 43 23.32	77 44 57.93	432.33	405.06
49T 81	384323077425801	38 43 23.23	77 42 57.87	403.25	391.33
48T 14	384321077461601	38 43 21.38	77 46 16.06	399.28	384.01
48T 9	384314077501301	38 43 13.73	77 50 12.61	602.30	570.01
49T 92	384313077394701	38 43 13.13	77 39 46.6	325.22	321.96
49T 77	384311077444701	38 43 11.33	77 44 47.35	425.19	382.44
49T 82	384308077431001	38 43 8.41	77 43 9.51	374.75	375.85
47T 3	384307077550501	38 43 6.6	77 55 5.19	425.78	357.79
47T 5	384305077581401	38 43 4.9	77 58 14.27	505.85	482.83
48T 8	384302077504301	38 43 2.22	77 50 43.2	478.94	495.41

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[Site locations shown in figure 2 and listed roughly from north to south. DDMMSS.S, degrees minutes, and seconds of latitude or longitude]

Well name	USGS site identification	Latitude, in DDMMSS.S	Longitude, in DDMMSS.S	Observed groundwater-level altitude, in feet	Estimated groundwater-level altitude, in feet
47T 4	384257077582501	38 42 55.86	77 58 26.01	497.30	471.23
49T 83	384256077432401	38 42 56.13	77 43 23.94	383.78	360.93
49T 85	384248077415801	38 42 47.99	77 41 57.73	357.74	343.08
49T 84	384239077402401	38 42 39.21	77 40 23.73	347.10	320.79
49T 86	384214077395601	38 42 14.3	77 39 56.47	329.42	315.20
47T 2	384155077540801	38 41 55.17	77 54 7.75	406.19	349.32
47T 1	384150077532101	38 41 50.34	77 53 20.56	422.97	407.49
48T 6	384112077464201	38 41 12.28	77 46 41.66	463.94	450.16
48T 13	384110077452001	38 41 10.02	77 45 29.36	431.36	422.92
49T 96	384022077443601	38 40 21.62	77 44 35.89	380.68	374.15
50T 86	384006077365501	38 40 5.51	77 36 55.03	270.69	258.52
48T 17	384005077520801	38 40 4.8	77 52 7.83	393.28	350.58
48T 19	383955077513201	38 39 55.24	77 51 32.43	435.00	391.33
48T 16	383938077503801	38 39 37.96	77 50 38.15	372.64	345.26
48T 18	383913077520001	38 39 12.52	77 52 0.25	321.92	308.33
49T 93	383850077432001	38 38 50.44	77 43 19.9	397.82	357.72
49T 97	383845077431601	38 38 45.3	77 43 16.39	396.66	354.97
50T 87	383827077364701	38 38 26.98	77 36 46.76	266.57	204.69
48T 15	383809077493301	38 38 8.62	77 49 33.28	468.40	414.05
49S 34	383726077432301	38 37 26.38	77 43 22.74	306.18	296.25
49S 35	383715077431901	38 37 15.36	77 43 18.54	309.25	289.99
48S 51	383639077480601	38 36 39.31	77 48 5.6	404.28	401.20
49S 32	383635077381601	38 36 35.16	77 38 16.02	296.08	257.00
49S 36	383624077432301	38 36 23.52	77 43 22.8	304.14	284.43
48S 44	383602077455301	38 36 2.01	77 45 53.49	328.30	329.80
48S 43	383556077461501	38 35 55.67	77 46 15.38	326.65	329.47
48S 45	383552077455001	38 35 52.06	77 45 50.05	325.78	318.68
48S 42	383542077461601	38 35 41.99	77 46 16.46	307.38	314.25
48S 50	383526077473901	38 35 25.88	77 47 38.78	340.77	344.98
50T 88	383504077363101	38 35 3.85	77 36 31.45	221.89	205.14
49S 37	383455077411701	38 34 55.33	77 41 16.73	320.18	307.47
48S 39	383451077472901	38 34 51.22	77 47 29.44	313.16	308.80
48S 49	383432077470501	38 34 32.25	77 47 5.2	301.05	295.56
48S 40	383420077455201	38 34 20.28	77 45 52.32	283.83	270.10
49S 33	383413077385601	38 34 12.65	77 38 56.14	255.70	251.80
49S 38	383410077403701	38 34 10.06	77 40 36.66	204.79	245.32
48S 47	383409077510001	38 34 9.33	77 51 0.17	288.58	288.85
48S 52	383338077492901	38 33 37.59	77 49 28.51	306.94	275.26
48S 53	383332077481901	38 33 31.5	77 48 19.28	293.24	275.04
49S 30	383331077442501	38 33 30.61	77 44 24.66	267.39	254.36
48S 48	383316077480501	38 33 15.76	77 48 4.93	295.66	268.29
48S 46	383254077462101	38 32 53.9	77 46 21.21	262.22	248.69

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Well name	USGS site identification	Latitude, in DDMMSS.S	Longitude, in DDMMSS.S	Observed groundwater-level altitude, in feet	Estimated groundwater-level altitude, in feet
49S 39	383239077391301	38 32 38.98	77 39 12.62	363.80	354.63
48S 41	383216077452101	38 32 15.66	77 45 20.87	258.38	241.35
49S 31	383139077401701	38 31 38.62	77 40 16.67	446.46	401.08
50S 12	383137077344901	38 31 37.36	77 34 48.52	399.46	360.86
50S 13	383032077361401	38 30 32.1	77 36 14.43	385.03	359.73
49R 6	382921077442001	38 29 21.24	77 44 20.42	352.58	287.16
49R 5	382724077433901	38 27 23.71	77 43 38.81	343.49	287.70

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