Hydrologic and Water-Quality Conditions in the Horse Creek Basin, West-Central Florida, October 1992-February 1995

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Data within table 7 were modified after publication. This online version contains the revised values.

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Multiply inch-pound unit	By	To obtain
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot per mile (ft/mi)	1.89	meter per kilometer
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer
million gallons per day (Mgal/d)	0.4381	cubic meter per second

Equation for temperature conversion between degrees Celsius (^oC) and degrees Fahrenheit (^oF):

$$^oC = (^oF-32)/1.8$$

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)---a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called “Sea Level Datum of 1929.”

ABBREVIATED WATER-QUALITY UNITS

µg/L	micrograms per liter
µS/cm	microsiemens per centimeter at 25 degrees Celsius
mg/L	milligrams per liter

Hydrologic and Water-Quality Conditions in the Horse Creek Basin, West-Central Florida, October 1992-February 1995

By B.R. Lewelling

Abstract

A baseline study of the 241-square-mile Horse Creek basin was undertaken from October 1992 to February 1995 to assess the hydrologic and water-quality conditions of one of the last remaining undeveloped basins in west-central Florida. During the period of the study, much of the basin remained in a natural state, except for limited areas of cattle and citrus production and phosphate mining.

Rainfall in 1993 and 1994 in the Horse Creek basin was 8 and 31 percent, respectively, above the 30-year long-term average. The lowest and highest maximum instantaneous peak discharge of the six daily discharge stations occurred at the Buzzard Roost Branch and the Horse Creek near Arcadia stations with 185 to 4,180 cubic feet per second, respectively. The Horse Creek near Arcadia station had the lowest number of no-flow days with zero days and the Brushy Creek station had the highest number with 113 days. During the study, the West Fork Horse Creek subbasin had the highest daily mean discharge per square mile with 30.6 cubic feet per second per square mile, and the largest runoff coefficient of 43.7 percent. The Buzzard Roost Branch subbasin had the lowest daily mean discharge per square mile with 5.05 cubic feet per second per square mile, and Brushy Creek and Brandy Branch shared the lowest runoff coefficient of 0.6 percent. Brandy Branch had the highest monthly mean runoff in both 1993 and 1994 with 11.48 and 19.28 inches, respectively. During the high-baseflow seepage run, seepage gains were 8.87 cubic feet per second along the 43-mile Horse Creek channel. However, during the low-baseflow seepage run, seepage losses were 0.88 cubic foot per second.

Three methods were used to estimate average annual ground-water recharge in the Horse Creek basin: (1) well hydrograph, (2) chloride mass balance, and (3) streamflow hydrograph. Estimated average annual recharge using these three methods ranged from 3.6 to 8.7 inches.

The high percentage of carbonate plus bicarbonate analyzed at the Carlton surficial aquifer well could indicate an upward ground-water flow from the underlying intermediate aquifer system. Based on constituent concentrations in water samples from the six daily discharge stations, concentrations generally are lower in the upper three subbasins, West Fork Horse Creek, Upper Horse Creek, and Brushy Creek than in the lower three subbasins. Typically, concentrations were highest for major ions at Buzzard Roost Branch and nutrients at Brushy Creek.

INTRODUCTION

Horse Creek is a major tributary of the Peace River and drains the western part of the Peace River basin (fig. 1). The 241-mi^2 Horse Creek basin is predominantly within the western half of Hardee and De Soto Counties, with minor parts extending into Hillsborough, Polk, and Manatee Counties. A study of the Horse Creek basin was undertaken from October 1992 to February 1995 to assess the hydrologic and water-quality conditions of the basin, because it is one of the last remaining undeveloped basins in west-central Florida largely unaffected by agriculture and industry. The natural hydrologic conditions were defined by evaluating that part of the basin that drains above the daily discharge station at State Highway 72 (fig. 1, site 78) and the five major subbasins (fig. 1, sites 10, 11, 20, 55, and 61a). The study was performed in cooperation with the Southwest Florida Water Management District to provide a baseline of current hydrologic conditions which may later be compared to conditions resulting from continued development.

Potential future changes to the basin include an increase in residential and commercial development, an increase in acreage planted for citrus, and effects of widespread strip-mining for phosphate. Changes in land use could affect basin hydrology by increasing demand for both surface and ground water, in addition to altering surface drainage. Approximately one-half of the acreage within the Horse Creek basin is currently

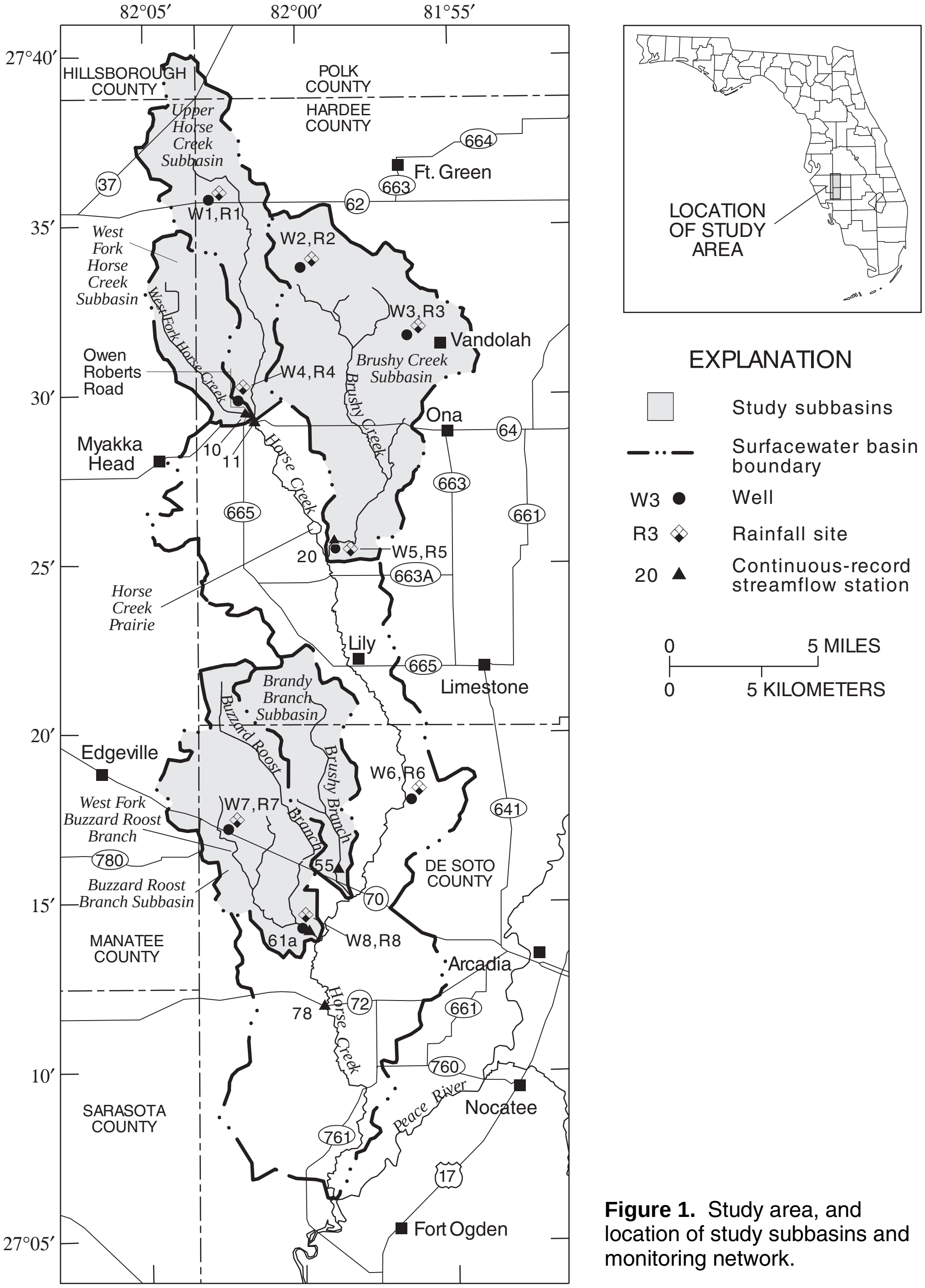


Figure 1. Study area, and location of study subbasins and monitoring network.

Base from SWFWMD digital data, 1:250,000, 1992
Albers Equal-Area Conic Projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

(1995) owned by chemical companies for the phosphate mining reserves. Large-scale strip-mining for phosphate, and the subsequent mine reclamation alters the natural topography, recharge, and drainage patterns of a basin. Because of a projected depletion of phosphate reserves in Polk and Hillsborough Counties, a southern migration by the phosphate industry into the Horse Creek basin is planned (Long and Orne, 1990).

Purpose and Scope

The purpose of this report is to describe the hydrologic and water-quality conditions in the Horse Creek basin from October 1992 to February 1995. The report examines rainfall, streamflow, and ground-water and water-quality data collected at six Horse Creek subbasins during the study and presents potentiometric maps, physical characteristics, horizontal hydraulic conductivity computations, streamflow and ground-water-level hydrographs, duration curves, recharge and seepage estimates, and trilinear diagrams showing major ion constituents in the ground and surface water.

Previous Investigations

Previous hydrologic, geologic, and water-quality investigations in the study area include an evaluation of the ground-water resources in Polk County (Stewart, 1966), an appraisal of the shallow ground-water resources of the upper Peace and Alafia River basins (Hutchinson, 1978), and a study of the geohydrology of the aquifer systems in southwest Florida (Duerr and others, 1988). Scott (1988) described the lithostratigraphy of the Hawthorn Group (Miocene) of Florida. Wilson (1977) described the hydrology and water quality of Hardee and De Soto Counties. Duerr and Enos (1991) evaluated the hydrogeology and water quality of Hardee and De Soto Counties. Buono and others (1979) presented the generalized thickness of the confining unit overlying the Upper Floridan aquifer throughout southwest Florida. Corral and Wolansky (1984) mapped the configuration of the top of the intermediate aquifer system in southwest Florida, but they did not include the confining unit below the surficial aquifer system as part of the intermediate aquifer system. Ryder (1985) described the hydrology of the Floridan aquifer system in west-central Florida. Miller (1986) presented a regional description of the Floridan aquifer system. Metz (1993) described the hydrogeology and effects of ground-water withdrawals in Hardee and De Soto Counties. Kaufman and Dion (1968) presented data on the ground-water resources of Charlotte, De Soto, and Hardee Counties. Additional references are listed in the "Selected References" section.

Acknowledgments

The author gratefully acknowledges the cooperation and assistance from the many organizations and individuals that were involved with the study. Special thanks is given to land owners, managers, and companies that permitted access to their property for gage installation and data collection. These individuals and companies included Harvey Keen, Roy Crews, Doyle Carlton Jr., Doyle Carlton III, Donald Smith, Jim Sampson, IMC-Agrico Company, and C.F. Industries.

DATA COLLECTION

Hydrologic and water-quality conditions within the Horse Creek basin were assessed by analyzing surface-water discharge data, ground-water level data, surface- and ground-water samples, and rainfall data collected from October 1992 through February 1995. The intent of this analysis was to provide a baseline of hydrologic conditions prior to possible future phosphate mining, which may alter hydrologic conditions. Streamflow stage was recorded hourly by electronic data-logging instrumentation that records stream fluctuations by the rising and falling of a float within a stilling well. Eight sites were established with associated pairs of continuous-record surficial aquifer monitor wells and tipping-bucket rainfall gages were installed throughout the Horse Creek basin (fig. 1). Site locations were selected to monitor the fluctuation of ground-water levels in response to rainfall for specific soil types, and to obtain optimal spatial coverage to determine rainfall distribution. Both rainfall volume and ground-water levels at each of the eight paired sites were recorded at 15-minute intervals using a single electronic data-logger. After rainfall passed through the tipping-bucket, it drained through a plastic hose to a carboy container that was buried below land surface. During each field trip, rainwater collected in the carboy was weighed to calculate the total rainfall in inches. This calculated rainfall was compared with that recorded by the tipping-bucket rainfall gage to determine if the raingage could have over or under registered the total rainfall. Rainwater and surficial aquifer water samples were collected for chloride analyses and used to estimate recharge to the water table using chloride ratio calculations.

Eight observation wells were drilled to continuously monitor water levels in the surficial aquifer. Three 2-in. diameter wells were installed using a solid-stem auger and five 4-in. diameter wells were drilled using a hollow-stem auger. All well casings and screens were polyvinylchloride (PVC). Well screen sections ranged from 5 to 10 ft in length, and total depth ranged from 7.2 to 15.7 ft below land surface. The five 4-in. monitor wells were instrumented with floats to record water-level fluctuations, and the three 2-in. wells were instrumented with pressure transducers. Well construction data are listed in table 1.

Five miniature well drive-points were installed just below the water table near each of the eight monitor wells for the purpose of collecting samples for water-quality analyses. The miniature well drive-points, designed with 0.01-in. slots, were driven using an electric hammer push-point system. The drive-points were installed at 1, 2, 3, 4, and 5 ft below land surface. One end of a length of 0.25-in. diameter polypropylene tubing was inserted into the well drive-point, and the other end extended to land surface for attachment to a peristaltic pump during sampling. Selection of the well-point sampling depth was determined from measuring depth to water below land surface in the adjacent 2- or 4-in. surficial aquifer well.

The horizontal hydraulic conductivity of the surficial aquifer was estimated by conducting slug-tests on each of the eight monitor wells. The rate of change

Table 1. Summary of surficial aquifer slug-test results

[ft, feet; ft/d, feet per day; analytical technique, Bouwer and Rice (1976)]

[1]Well	Well name	Well identification	Date of slug test	Total depth of well below land surface (ft)	Length of screen (ft)	Hydraulic conduc-tivity (ft/d)
W1	Watkins Road	273546082025201	March 30, 1993	14.2	5	0.83
W1	Watkins Road	273546082025201	March 30, 1993	14.2	5	0.63
W2	Mitchell Hammock	273345081595301	April 23, 1993	15.7	5	1.2
W2	Mitchell Hammock	273345081595301	April 23, 1993	15.7	5	1.6
W3	Lettis Creek	273144081562401	March 30, 1993	12.7	7	1.5
W4	West Fork Horse Creek	272950082015701	April 6, 1993	14.0	5	0.29
W4	West Fork Horse Creek	272950082015701	April 6, 1993	14.0	5	0.21
W5	Brushy Creek	272527081584901	April 23, 1993	7.2	5	0.11
W5	Brushy Creek	272527081584901	April 23, 1993	7.2	5	0.12
W6	Carlton Ranch	271802081562501	March 30, 1993	14.7	10	7.8
					10	
W6	Carlton Ranch	271802081562501	March 30, 1993	14.7	10	7.8
W7	West Fork Buzzard Roost	271711082022401	April 15, 1993	8.0	5	0.19
W7	West Fork Buzzard Roost	271711082022401	April 15, 1993	8.0	5	0.18
W8	Buzzard Roost	271414082000101	April 23, 1993	12	5	8.8
W8	Buzzard Roost	271414082000101	April 23, 1993	12	5	8.7

[1] Well locations are shown on figure 1.

in water levels was measured using a pressure transducer and was recorded by an electronic data-logger when a slug of known volume was either inserted into or removed from the water table. Estimates of the hydraulic conductivity were determined from calculations described by Bouwer and Rice (1976, p. 423-428).

Water samples from the six daily discharge stations and the eight surficial aquifer wells were analyzed for major dissolved ions and total nutrients (ammonia nitrogen, nitrite plus nitrate nitrogen, ammonia plus organic nitrogen, orthophosphorus, and phosphorus). On site measurements for pH, specific conductance, and temperature were also made. Streamflow samples were collected by depth integration near the centroid of the flow. All analyses were performed by the USGS laboratory in Ocala, Florida. The analytical methods are documented in Fishman and Friedman (1989) and Wershaw and others (1987).

DESCRIPTION OF STUDY AREA

The largest percentage of the 241-mi^2 Horse Creek basin area is within the western halves of Hardee and De Soto Counties, with a smaller percentage in eastern Manatee County. The extreme northern part of the basin (approximately 2 mi^2) lies in southeast Hillsborough and southwest Polk Counties (fig. 1), and has been largely strip-mined for phosphate.

Physiographic Setting

The Horse Creek basin lies entirely in the mid-peninsular physiographic zone described by White (1970); included are three subdivisions, the Polk Uplands, De Soto Plain, and Gulf Coast Lowlands. These subdivisions correspond approximately to several marine plains or terraces that were formed by rising sea level during the Pleistocene Epoch. The Polk Uplands is a broad, slightly dissected upland at the headwaters of the Horse Creek basin, usually at altitudes above 100 ft. The gently sloping, nearly undissected De Soto Plain lies at altitudes of between approximately 30 and 100 ft, and the Gulf Coastal Lowlands proper consists of poorly drained, low-lying land at altitudes below 30 to 40 ft, near the mouth of Horse Creek. The land in these lower two subdivisions is poorly drained and has numerous marshes, many in shallow, saucer-like sinkhole depressions (Wilson, 1977). The Horse Creek basin and most of its subbasins are elongated in shape and have a north-south drainage pattern. Subbasins along the steeper De Soto Plain have higher runoff extremes than either the Polk Uplands or the Gulf Coast Lowlands.

Climate

The climate in the study area is subtropical. The long-term weather station at Arcadia (fig. 1), approximately 3 mi east of the southeastern basin boundary, had a mean annual (normal) rainfall of 52.7 in., based on the National Oceanic and Atmospheric Administration (NOAA) 30-year period 1961-90 (National Oceanic and Atmospheric Administration, 1992). Intense rainfall generated by localized convective thunderstorm activity during the summer months (June through September) accounts for about 60 percent of the annual rainfall, and periodic cold fronts account for most of the rainfall during the winter months (December through March). The 30-year mean annual temperature at Arcadia is 71.6 ^{o}F, and the mean monthly temperatures range from 81.3 ^{o}F in August to 61.1 ^{o}F in January (National Oceanic and Atmospheric Administration, 1995).

Soils

Several dominant soil groups have been identified and described in the Horse Creek basin by the Soil Conservation Service (U.S. Department of Agriculture; 1984, 1989, and 1990). The Pomona-Floridana-Popash association occurs along the upper Horse Creek channel and includes much of the Brushy Creek drainage basin. This group consists of flat, poorly drained and very poorly drained soils. The Smyrna-Myakka-Ona and Smyrna-Myakka-Immokalee associations occur predominantly in Hardee and De Soto Counties, and are generally identical soil groups, except where the dark colored subsoil occurs (U.S. Department of Agriculture, 1990). These soils occur along the central and southern parts of the Horse Creek basin, and are characterized by flat, poorly-drained soils that are sandy throughout. The soil group Bradenton-Felda-Chobee, which occurs along the area immediately adjacent to the main channel of Horse Creek, from below State Road 64 (fig. 1) to just above the mouth, are flat, poorly to very poorly drained, and are sandy to a depth of 20 to 40 in.

Because the dominant soil groups in the Horse Creek basin generally are poorly drained, infiltration of rainwater to the water table in the surficial aquifer is reduced, limiting the amount of water available to support baseflow. Soil saturation is common throughout the basin in areas identified by standing water. The Arents-Hydraquents-Neilhurst soils group presently (1995) occurs in isolated areas of the extreme upper basin. This group is made up of soils that have been strip-mined for phosphate.

Hydrogeologic Framework and Hydraulic Properties

The three principal hydrogeologic units in the study area--the surficial aquifer, the intermediate aquifer system, and the Upper Floridan aquifer--generally occur throughout much of west-central Florida. These hydrogeologic units are presented in figure 2 by system, series, stratigraphic unit, lithology, and hydrogeologic unit.

<table>
<tr><th>System</th><th>Series</th><th colspan="2">Stratigraphic unit</th><th>General lithology</th><th colspan="2">Hydrogeologic unit</th></tr>
<tr><td rowspan="2">Quarternary</td><td rowspan="2">Holocene and Pleistocene</td><td colspan="2">Surficial sand, terrace sand, phosphorite</td><td>Predominantly fine sand; interbedded clay, marl, shell, and phosphorite</td><td colspan="2">Surficial aquifer</td></tr>
<tr><td colspan="2" rowspan="3">Undifferentiated deposits[1]
Tamiami Formation</td><td rowspan="3">Clayey and pebbly sand; clay, marl, shell, phosphatic</td><td rowspan="2">Upper confining unit</td><td rowspan="8">Intermediate aquifer system</td></tr>
<tr><td rowspan="13">Tertiary</td><td rowspan="3">Pliocene</td></tr>
<tr><td rowspan="5">Aquifer</td></tr>
<tr><td rowspan="5">Hawthorn Group</td><td rowspan="2">Peace River Formation</td><td rowspan="3">Dolomite, sand, clay, and limestone, silty, phosphatic</td></tr>
<tr><td rowspan="4">Miocene</td></tr>
<tr><td rowspan="3">Arcadia Formation
Tampa member
Nocatee member</td></tr>
<tr><td rowspan="2">Limestone, sandy, phosphatic, fossiliferous; sand and clay in lower part in some areas</td></tr>
<tr><td>Lower confining unit</td></tr>
<tr><td>Oligocene</td><td colspan="2">Suwannee Limestone</td><td>Limestone, sandy limestone, fossiliferous</td><td rowspan="3">Upper Floridan aquifer</td><td rowspan="5">Floridan aquifer system</td></tr>
<tr><td rowspan="3">Eocene</td><td colspan="2">Ocala Limestone</td><td>Limestone, chalky, foraminiferal, dolomitic, near bottom</td></tr>
<tr><td colspan="2">Avon Park Formation</td><td rowspan="2">Limestone and hard brown dolomite; intergranular evaporite in lower part in some areas</td></tr>
<tr><td colspan="2">Oldsmar Limestone</td><td>Middle confining unit</td></tr>
<tr><td rowspan="2">Paleocene</td><td colspan="2" rowspan="2">Cedar Keys Limestone</td><td rowspan="2">Dolomite and limestone with intergranular gypsum and anhydrite</td><td>Lower Floridan aquifer</td></tr>
<tr><td colspan="2">Sub-Floridan confining unit</td></tr>
</table>

[1] Includes all or parts of Caloosahatchee Marl and Bone Valley Member.

Figure 2. Correlation chart showing hydrogeologic framework (modified from Metz , 1995).

Surficial Aquifer

The unconfined surficial aquifer is a permeable hydrogeologic unit whose upper surface is contiguous with land surface. This aquifer is composed principally of unconsolidated to poorly indurated clastic deposits (Southeastern Geological Society, 1986). The sediments that comprise the surficial aquifer in the study area are predominantly fine to medium sand, becoming increasingly clayey and phosphatic with depth (Hutchinson, 1978). The hydraulic properties of the surficial aquifer vary due to the variability of the lithology and environment of deposition of sediments (Duerr and others, 1988). Sediment grain size and sorting is highly variable and influence porosity and permeability which, in turn, affect the transmitting characteristics of the aquifer. Thickness ranges from approximately 25 to 50 ft throughout most of the study area.

The transmissivity of the surficial aquifer, estimated from two aquifer tests in the study area, was reported to be 602 and 401 ft^2/d and the specific yields were 0.025 and 0.1, respectively (Southwest Florida Water Management District, 1988). These specific yields are within the range of 0.01 to 0.3 reported for unconfined aquifers by Freeze and Cherry (1979). Horizontal hydraulic conductivity of the surficial aquifer was calculated from the results of eight slug-tests performed during the study; conductivity values ranged from 0.11 to 8.8 ft/d (table 1). Slug-tests generally were performed in the upper 10 to 15 ft, and may not represent the full thickness of the surficial aquifer system. Surficial material is variable and some parts are more permeable than others. The highest horizontal hydraulic conductivity values recorded, 7.8 and 8.8 ft/d, were at the Carlton and Buzzard Roost wells (fig. 1, W6 and W8), respectively, thus it is likely that a better potential exists within the surficial aquifer for lateral movement of water to support baseflow in these areas than in other areas within the basin.

Intermediate Aquifer System

The intermediate aquifer system includes all water-bearing units (aquifers) and confining units between the overlying surficial aquifer and the underlying Floridan aquifer system (Duerr and others, 1988). The intermediate aquifer system consists of at least three hydrogeologic units: (1) a clayey and pebbly sand, clay, and marl upper confining unit that separates the uppermost water-bearing unit in the intermediate aquifer system from the surficial aquifer, (2) an aquifer consisting of one-to-three water-bearing units composed primarily of carbonate rocks, sand, and discontinuous beds of sand and clay, and (3) a sandy clay or clayey sand lower confining unit that lies directly over the Upper Floridan aquifer (fig. 2) (Ryder, 1985). The confining units retard vertical movement of ground water between the water-bearing units and the overlying surficial aquifer and the underlying Upper Floridan aquifer (Duerr and others, 1988). The intermediate aquifer system is recharged by downward leakage from the surficial aquifer and more directly through sinkholes and abandoned mine pits that breach the semiconfining units (Hutchinson, 1978). The intermediate aquifer system is a major source of water throughout much of De Soto, Hardee, Hillsborough, Manatee, and Polk Counties, although yields of individual wells and total withdrawals of water from the aquifer system generally are much less than from wells open to the deeper Upper Floridan aquifer (Duerr and others, 1988).

The potentiometric surfaces of the intermediate aquifer system in September 1993 and May 1994 are shown in figure 3. The potentiometric surface is an imaginary surface connecting points to which water would rise in tightly cased wells from a given point in an aquifer (Lohman, 1972). The September 1993 map (Mularoni, 1994a) shows the potentiometric surface at the end of the summer wet season (June-September) when ground-water withdrawals are reduced and water level heads usually are near their annual maximum. The May 1994 map (Metz and Brendle, 1994a) represents the potentiometric surface near the end of the dry season (February to May) when ground-water withdrawals are greatest and water levels generally are at their annual low. The extreme upper part of the Horse Creek basin lies within a recharge area, where the configuration of the potentiometric surface is generally constant throughout the year, ranging areally from 80 to 120 ft above sea level. Maps show large head differences between September 1993 and May 1994, exceeding 20 ft in places, largely due to the seasonal demand for ground water.

Floridan Aquifer System

The Floridan aquifer system is defined as a vertically continuous sequence of Tertiary age of carbonate rocks of generally high permeability that are hydraulically connected to each other in varying degrees, the permeability of which is several orders of magnitude greater than that of the rocks that bound the

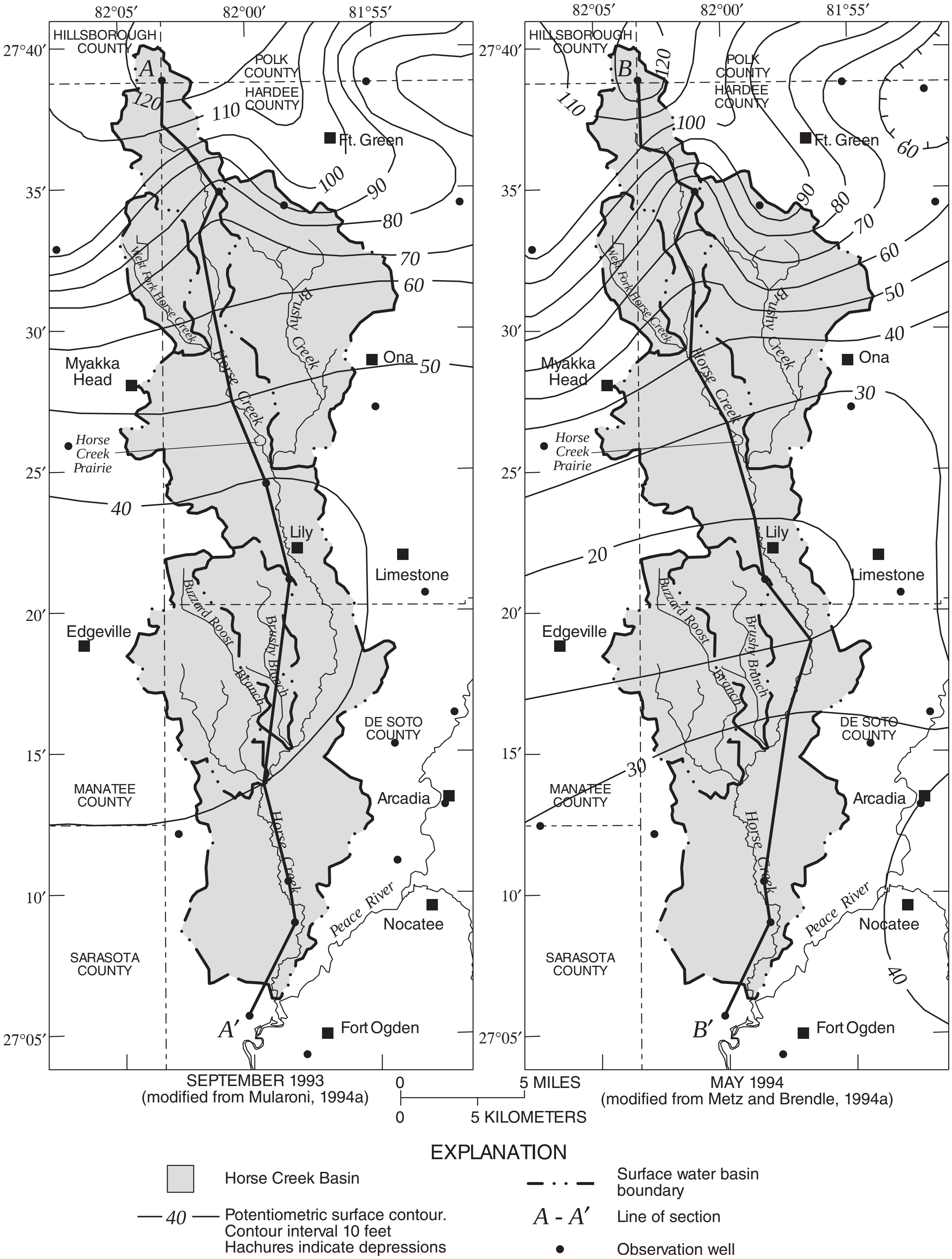


Figure 3. Potentiometric surface of the intermediate aquifer system, September 1993 and May 1994, and line of section A-A′ and B-B′.

system above and below (Ryder, 1985). The Floridan aquifer system consists of the Upper and Lower Floridan aquifers that are separated by a middle confining unit (Miller, 1986). The middle confining unit and Lower Floridan aquifer generally contain saltwater (Ryder, 1985). In most reports on the hydrology of southwest Florida, the term "Floridan Aquifer" has been applied to the water-bearing rocks herein referred to as the Upper Floridan aquifer (Duerr and Enos, 1991). The carbonate units of the Upper Floridan include the Suwannee and Ocala Limestones and the Avon Park Formation of Oligocene and Eocene age (fig 2). The base of the Upper Floridan aquifer, the middle confining unit, is characterized by limestone with a drastically reduced permeability due to the presence of intergranular evaporites (Southeastern Geological Society, 1986). The Upper Floridan aquifer is tapped by virtually all municipal, industrial, and agricultural production wells in the study area.

The potentiometric surface of the Upper Floridan aquifer in September 1993 and May 1994 are shown in figure 4. The September 1993 map (Mularoni, 1994b) shows that the seasonal high head in the Horse Creek basin ranged from about 40 to 60 ft above sea level. Comparison of the September 1993 to the May 1994 map (Metz and Brendle, 1994b) shows stresses have lowered the head approximately 20 to 25 ft in places. Seasonal fluctuations of the potentiometric surface in the southern part of the basin ranged from approximately 5 to 10 ft.

Horse Creek Subbasins

Daily discharge stations were established on four major tributaries to evaluate the surface-water conditions of the subbasins (fig. 1). These four subbasins include: West Fork Horse Creek (fig. 1, site 10); Brushy Creek (fig. 1, site 20); Brandy Branch (1, site 55,); and Buzzard Roost Branch (fig. 1, site 61a). The subbasins that drain to the two long-term main-channel Horse Creek daily discharge stations near Myakka Head and Arcadia (fig. 1, sites 11 and 78) were also characterized. For purposes of this report, the Myakka Head and Arcadia stations have been identified as the Upper Horse Creek subbasin and the Horse Creek subbasin, respectively. The Upper Horse Creek subbasin drains a 42-mi^2 area that also includes the drainage from the West Fork Horse Creek (site 10) subbasin. The Horse Creek subbasin includes drainage from the five subbasins and that ungaged part of the basin above State Highway 72 (fig. 1).

West Fork Horse Creek Subbasin

The West Fork Horse Creek subbasin is located in northeastern Manatee and northwestern Hardee Counties (fig. 1). The subbasin is irregularly shaped and is predominantly covered by pastureland. The creek flows in a southeasterly direction to its confluence with Horse Creek. The daily discharge station, West Fork Horse Creek near Myakka Head (site 10), was installed directly upstream of the Owen Roberts Road bridge, approximately 0.38 mi upstream from the confluence with Horse Creek. The drainage area of West Fork Horse Creek at the gage is approximately 13.5 mi^2.

The main channel is approximately 8.5 mi in length and the drainage pattern is dendritic. Drainage from the upper half of the basin occurs through a network of wetlands that have been connected by a series of ditches. The lower half of the basin has more relief and is drained by a number of first-order tributaries. Total relief in the basin is approximately 60 ft. The highest point in the basin is a mound on the northern drainage divide that is 135 ft above sea level. The elevation of the channel at the gage is 75 ft above sea level and the average channel slope is approximately 7 ft/mi.

The daily mean discharge at the West Fork Horse Creek station ranged from 0 to 413 ft^3/s during the period of October 1992 to October 1994 (fig. 5). Ground-water discharge (baseflow) in the West Fork Horse Creek subbasin sustained some streamflow during all low-flow periods, except for 1 day (May 29, 1994) when the flow was zero. Water levels in the surficial aquifer were monitored continuously at the 14-ft deep West Fork Horse Creek surficial well near Myakka Head (site W4), located approximately 0.6 mi north of the daily discharge station. Water levels ranged from land surface to 7.28 ft below land surface (fig. 5). Hydraulic conductivity of the surficial aquifer computed from two slug-tests using this well averaged 0.25 ft/d (table 1).

Upper Horse Creek Subbasin

The drainage area for the 42.0-mi^2 Upper Horse Creek subbasin includes drainage from both a 28.5-mi^2 area of the upper Horse Creek basin and the 13.5-mi^2 West Fork Horse Creek subbasin (fig. 1). The upper subbasin boundary is located in extreme southeastern Hillsborough County and southwestern Polk County, with approximately one-third of the subbasin in northeastern Manatee County and two-thirds in northwestern Hardee County. The Horse Creek generally flows in a southerly direction, and the channel is well defined throughout its

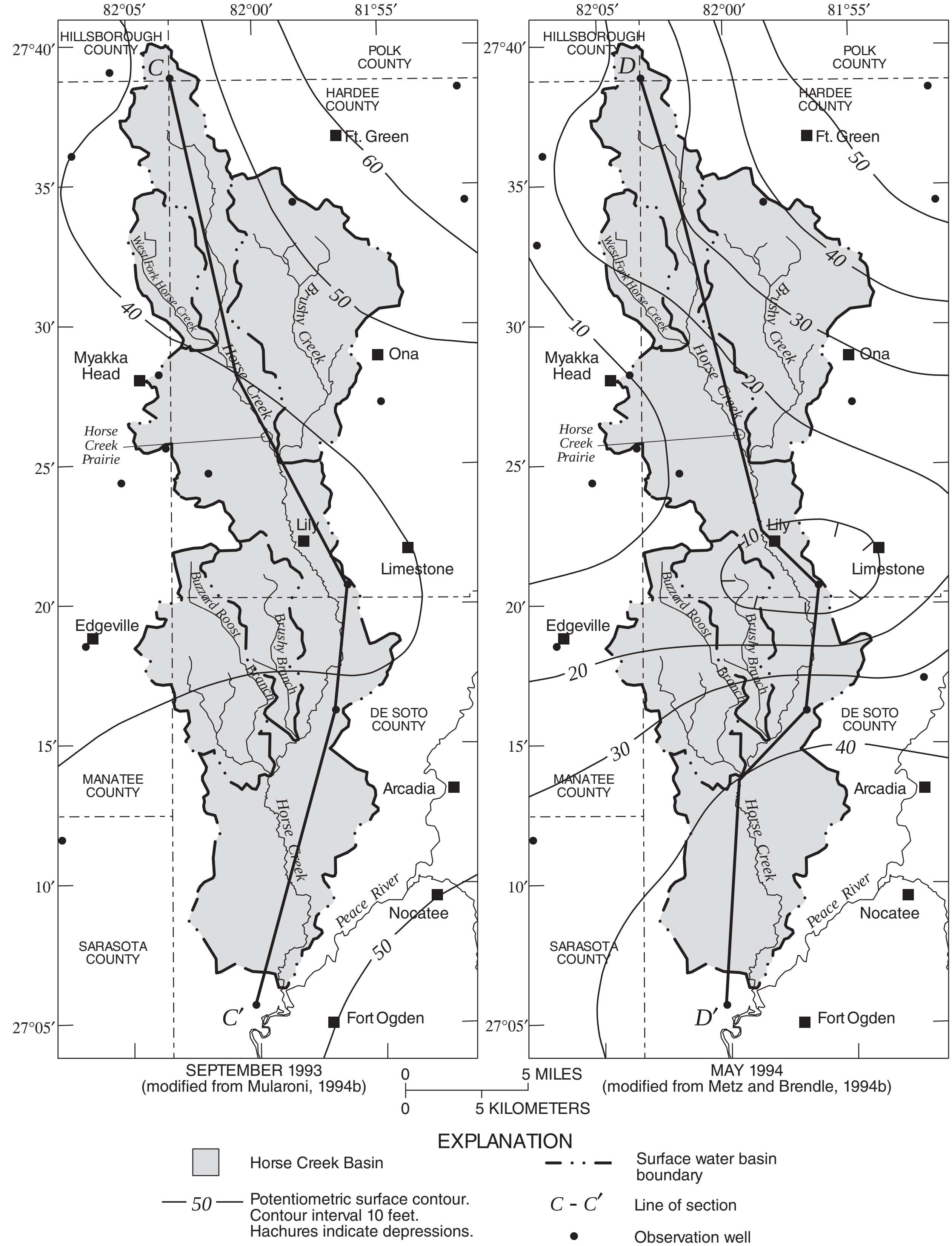


Figure 4. Potentiometric surface of the Upper Floridan aquifer, September 1993 and May 1994, and line of section C-C′ and D-D′.

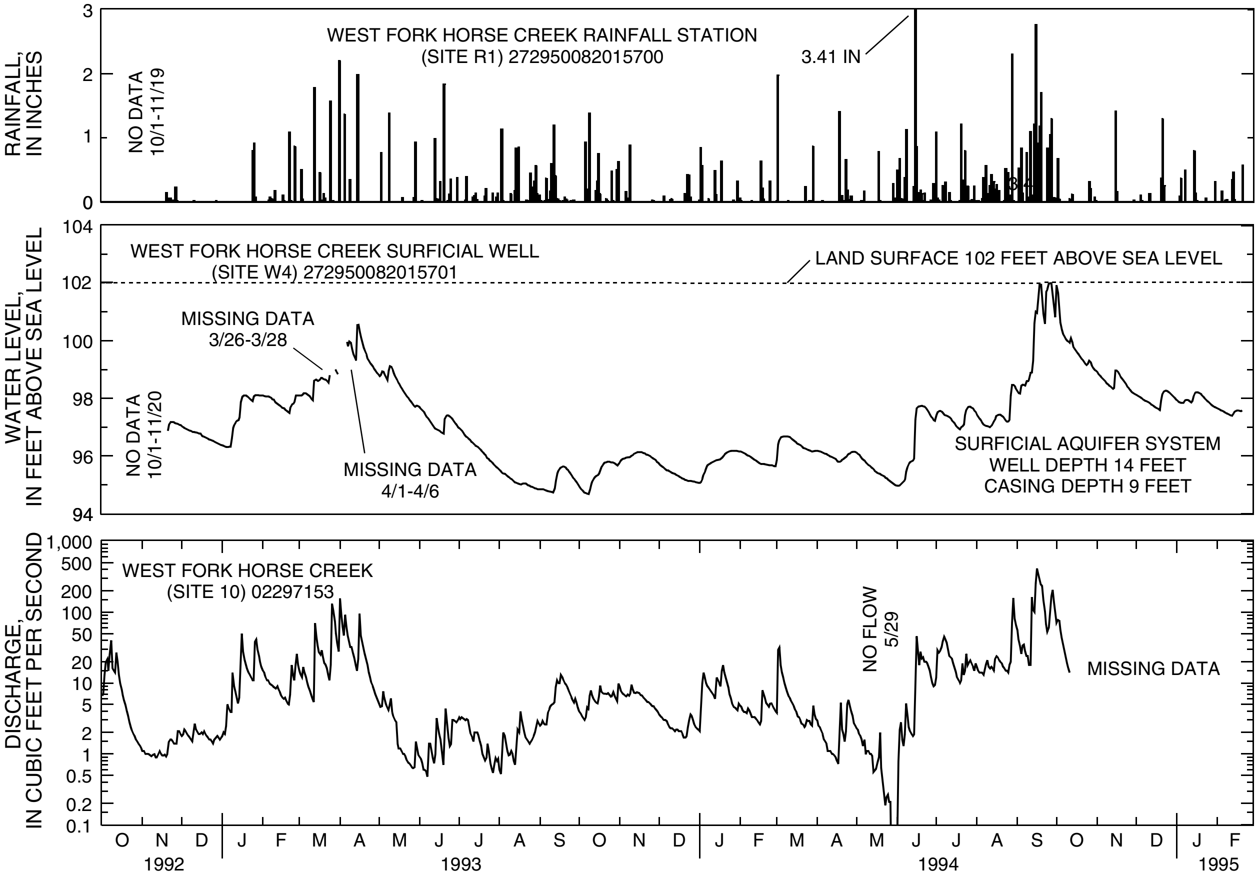


Figure 5. Daily rainfall and ground-water levels at the West Fork Horse Creek station and daily mean discharge at West Fork Horse Creek, 1992-95. (Location shown in fig. 1.)

length. The long-term (1977 to current year) daily discharge station, Horse Creek near Myakka Head (site 11), is located below the State Highway 64 bridge.

The upper one-third of the Upper Horse Creek subbasin has low relief and is dominated by low-lying marshlands. In the lower two-thirds of the basin, the gradient of the land adjacent to Horse Creek slopes gently towards the channel. Total relief in the subbasin is approximately 75 ft. The highest point in the subbasin is along the extreme northern boundary and is 140 ft above sea level. The elevation of the channel at the gage is approximately 65 ft above sea level and the average channel slope is approximately 5 ft/mi.

Daily mean discharge from the Upper Horse Creek subbasin, recorded at the Horse Creek near Myakka Head gaging station, ranged from 0 to 1,160 ft^3/s during the period of October 1992 to September 1994 (fig. 6). Water levels in the surficial aquifer were monitored continuously at two well locations in the subbasin, the previously discussed West Fork Horse Creek surficial well (site W4) and at the 14.2-ft-deep Watkins Road well near Duette (site W1), located approximately 0.2 mi north of State Highway 62. Water levels in the Watkins Road well fluctuated about 5 ft between wet and dry seasons (fig. 6). Horizontal hydraulic conductivity of the surficial aquifer computed from slug-tests using the Watkins Road well averaged about 0.73 ft/d (table 1).

Brushy Creek Subbasin

The Brushy Creek subbasin is located in western Hardee County (fig. 1). The basin generally exists in a natural state, covered predominantly with palmetto scrub and wetlands; however, some areas have been cleared and drained for pasture. Brushy Creek flows in a southerly direction to the daily discharge station, Brushy Creek near Lily (site 20), approximately 0.57 mi upstream from the confluence with Horse Creek. The drainage area of the Brushy Creek subbasin at the gage is 47.8 mi^2.

The Brushy Creek main channel is approximately 14.5 mi in length, and the densely

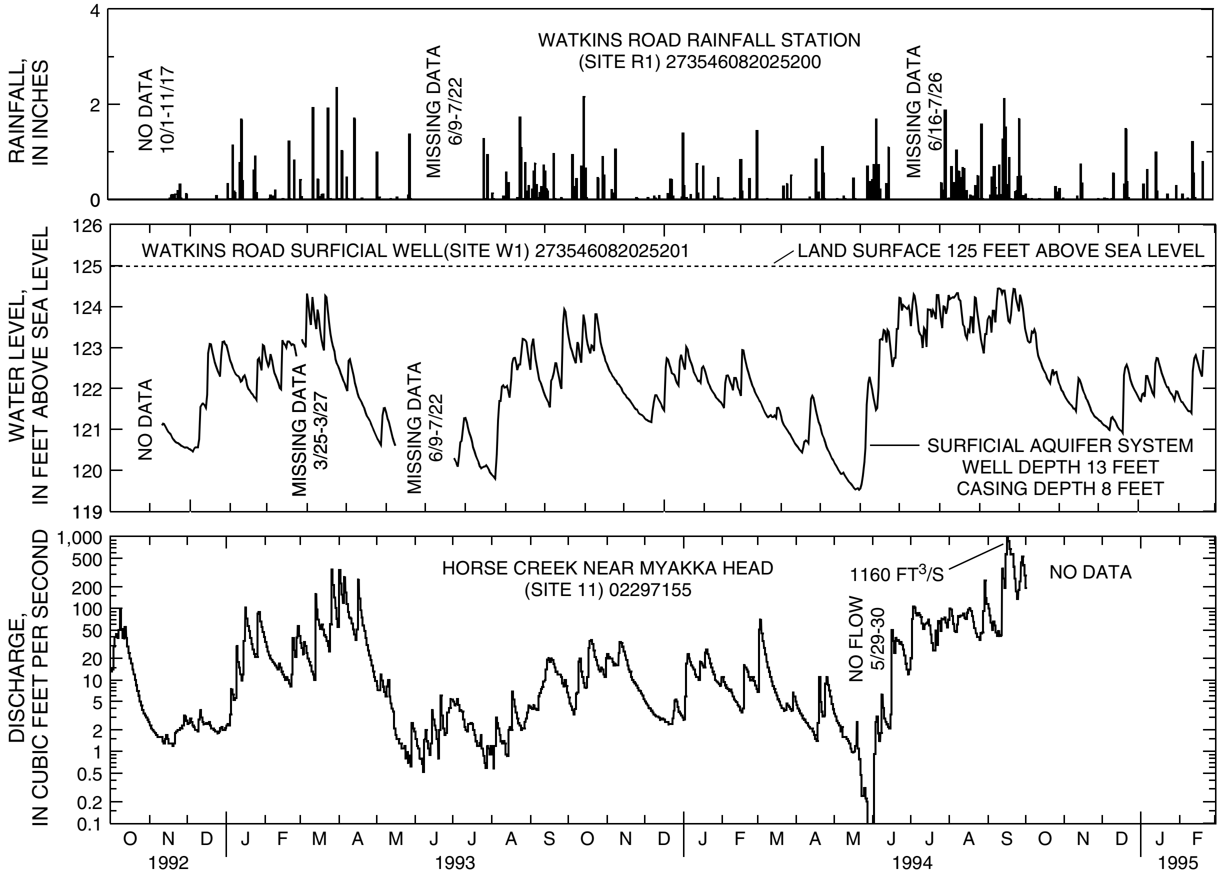


Figure 6. Daily rainfall and ground-water levels at the Watkins Road station and daily mean discharge at the Horse Creek station near Myakka Head, 1992-95. (Location shown in fig. 1.)

wooded floodplain ranges from approximately 200 to 3,000 ft in width. The drainage pattern of the subbasin is dendritic. The subbasin is generally flat and has a total relief of about 70 ft. The highest point in the subbasin is approximately 125 ft above sea level at the extreme northern drainage divide near State Highway 62. The elevation of the channel at the gage is approximately 55 ft above sea level, and the average channel slope is approximately 4.8 ft/mi. The daily mean discharge at the Brushy Creek gaging station ranged from 0 to 819 ft^3/s during October 1992 to February 1995 (fig. 7).

Water levels in the surficial aquifer in the Brushy Creek subbasin were monitored continuously at three sites, the Brushy Creek well, the Mitchell Hammock well, and the Lettis Creek well. The Brushy Creek surficial well near Ona (site W5) is located approximately 1.0 mi north of County Road 663A and approximately 1 mi east of Horse Creek (fig. 1). Water levels in the 7.2-ft-deep Brushy Creek well fluctuated about 6 ft between wet and dry seasons (fig. 7). Water levels in the well were above land surface during wet periods when the surficial aquifer was saturated. The Mitchell Hammock surficial well near Fort Green Springs (site W2) is located approximately 2.25 mi south of State Highway 62 and 2 mi east of Horse Creek (fig. 1). Water levels in the 15.7-ft-deep Mitchell Hammock well fluctuated about 5.5 ft between wet and dry seasons (fig. 8). The Lettis Creek surficial well near Vandolah (site W3) is located approximately 1.5 mi northwest of Vandolah (fig. 1). Water levels in the 12.7-ft-deep Lettis Creek well fluctuated about 8 ft between wet and dry seasons (fig. 9). Horizontal hydraulic conductivity of the surficial aquifer, computed from two slug-tests performed at the Brushy Creek and the Mitchell Hammock wells, averaged 0.12 ft/d and 1.4 ft/d, respectively. The hydraulic conductivity of the surficial aquifer at the Lettis Creek well was estimated to be 1.5 ft/d based on a single slug-test (table 1).

Brandy Branch Subbasin

The Brandy Branch subbasin is located in southwestern Hardee and northwestern De Soto Counties (fig. 1). The stream drains a predominantly agricultural area consisting of improved cattle pastures

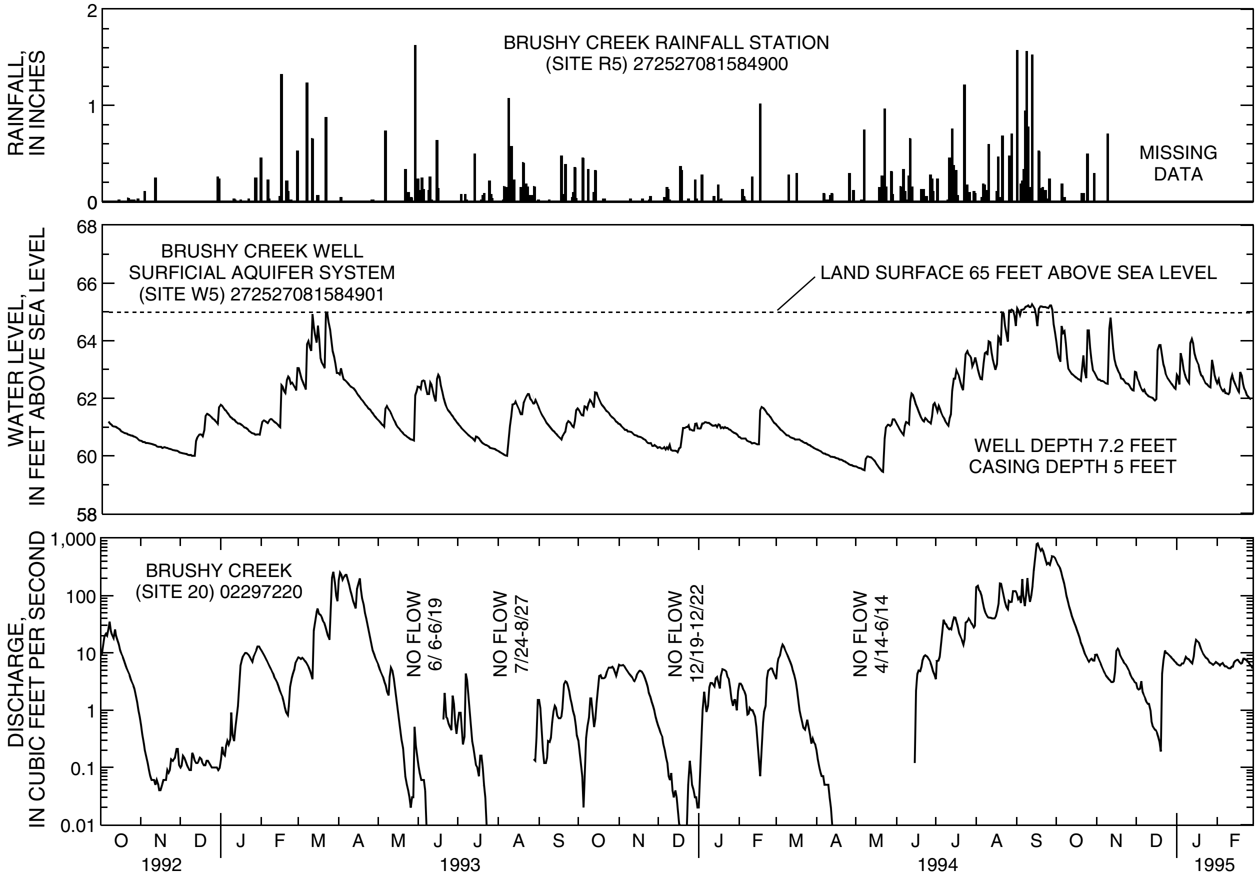


Figure 7. Daily rainfall and ground-water levels at the Brushy Creek station and daily mean discharge at Brushy Creek, 1992-95. (Location shown in fig. 1.)

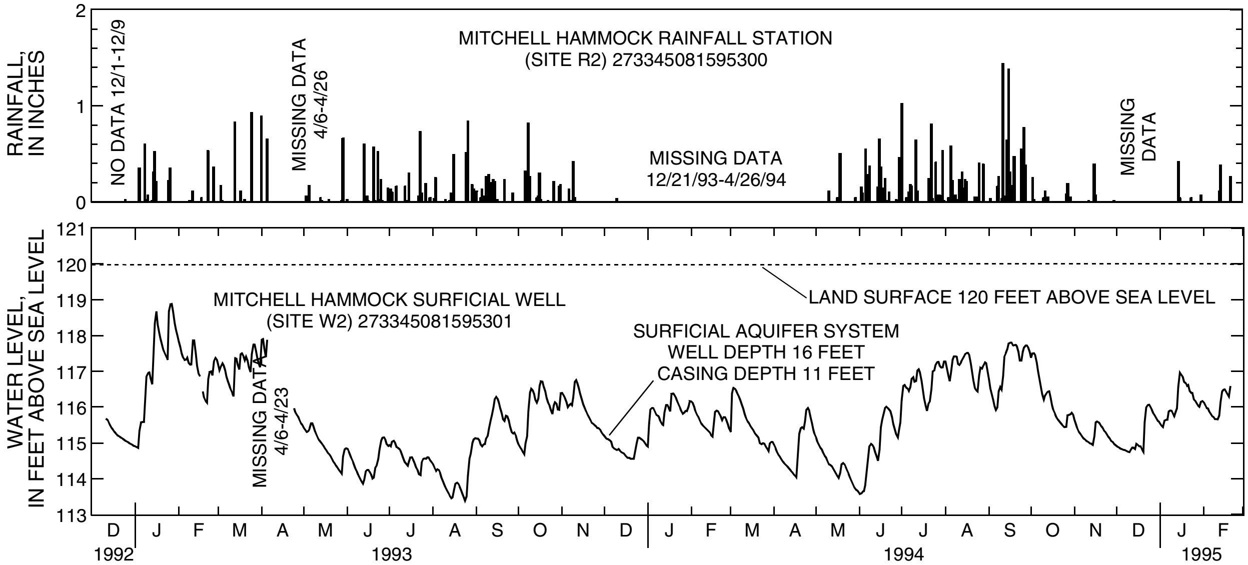


Figure 8. Daily rainfall and ground-water levels at the Mitchell Hammock station, 1992-95 (Location shown in fig. 1.)

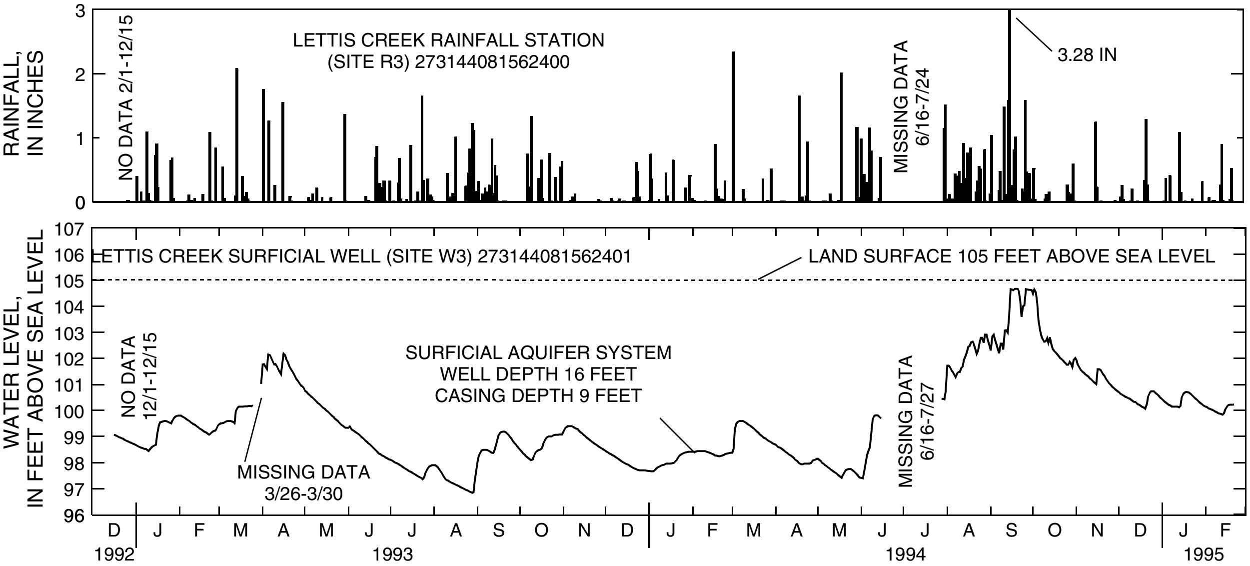


Figure 9. Daily rainfall and ground-water levels at the Lettis Creek station, 1992-95 (Location shown in fig. 1.)

and citrus groves. Brandy Branch flows south from its headwaters to the streamflow gaging station, Brandy Branch at Pine Level (site 55), directly upstream of the State Highway 70 bridge and 0.75 mi upstream of its confluence with Horse Creek. The drainage area of Brandy Branch is approximately 15.1 mi^2 at the gage. The Brandy Branch subbasin is elongated in shape with the main channel approximately 7.5 mi in length. The upper half of the stream channel, which is poorly defined within a broad flat floodplain, drains an area of low relief; the lower half is an incised channel within a narrow floodplain surrounded by higher relief. Total relief in the basin is 65 ft. The highest point in the subbasin is a mound on the northeastern drainage divide that is 100 ft above sea level. The elevation of the channel at the gage is approximately 35 ft above sea level and the average channel slope is approximately 8.7 ft/mi.

The daily mean discharge at the Brandy Branch station ranged from 0 to 225 ft^3/s during October 1992 to February 1995 (fig. 10). In the 1993 water year (October 1992 to September 1993) and the partial water year (October 1994 to February 1995), Brandy Branch had zero days of no flow. However, in the 1994 water year 32 days of no flow were recorded.

Buzzard Roost Branch Subbasin

The Buzzard Roost Branch drainage basin is irregularly shaped and is located in southwestern Hardee, De Soto, and eastern Manatee Counties (fig. 1). The stream drains predominantly agricultural areas consisting of improved cattle pastures, citrus groves, and turf farms. Buzzard Roost Branch flows southward to the daily discharge station, Buzzard Roost Branch near Pine Level (site 61a), above the multiple culvert at Pine Level Street, approximately

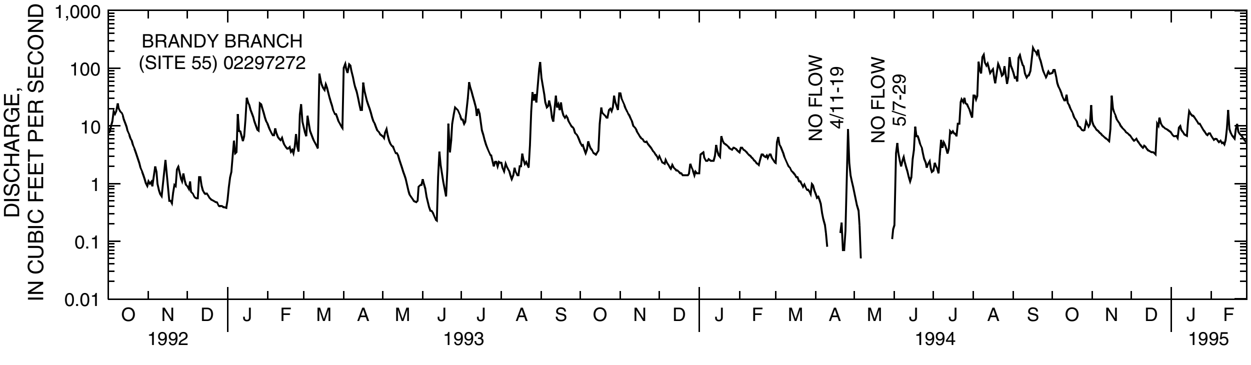


Figure 10. Daily mean discharge at Brandy Branch, 1992-95. (Location shown in fig. 1.)

0.57 mi upstream from the branch’s confluence with Horse Creek. The drainage area of Buzzard Roost Branch subbasin at the gage is 28.7 mi^2.

The main channel of Buzzard Roost Branch is approximately 13 mi in length and is drained by a series of first-order tributaries and ditches. The upper half of the stream has been channelized to improve drainage from wetlands in areas of low relief. West Fork Buzzard Roost Branch is a major tributary to Buzzard Roost Branch and drains the western half of the basin. The drainage pattern of the West Fork Buzzard Roost Branch is dendritic, and the stream empties into Buzzard Roost Branch approximately 3,000 ft upstream from the gage. Total relief in the Buzzard Roost Branch basin is 60 ft. The highest point in the basin is a slight mound in a citrus grove on the northern drainage divide that is 95 ft above sea level. The elevation of the channel at the gage is 35 ft above sea level and the average channel slope is approximately 5.4 ft/m.

Daily mean discharge at the Buzzard Roost Branch station ranged from 0 to 199 ft^3/s during October 1992 to February 1995 (fig. 10). Buzzard Roost Branch had no-flow periods during 7 days in 1993, 29 days in 1994, and no days during the partial 1995 water year (October-February).

Water levels in the surficial aquifer were monitored continuously at two well locations in the basin, the Buzzard Roost well and the West Fork Buzzard Roost well. The Buzzard Roost surficial well near Pine Level (site W8) is located approximately 200 ft north of N.W. Pine Level Road and 0.1 mi west of Buzzard Roost Branch (fig. 1). Water levels in the 12.0-ft-deep Buzzard Roost well fluctuated about 5.5 ft between wet and dry seasons (fig. 11). The West Fork Buzzard Roost surficial aquifer well near Edgeville (site W7) is located approximately 0.1 mi north of State Highway 70 and 1.1 mi east of the Manatee-De Soto County line (fig. 1). Water levels in the 8.0-ft-deep West Fork Buzzard Roost well fluctuated about 5 ft between

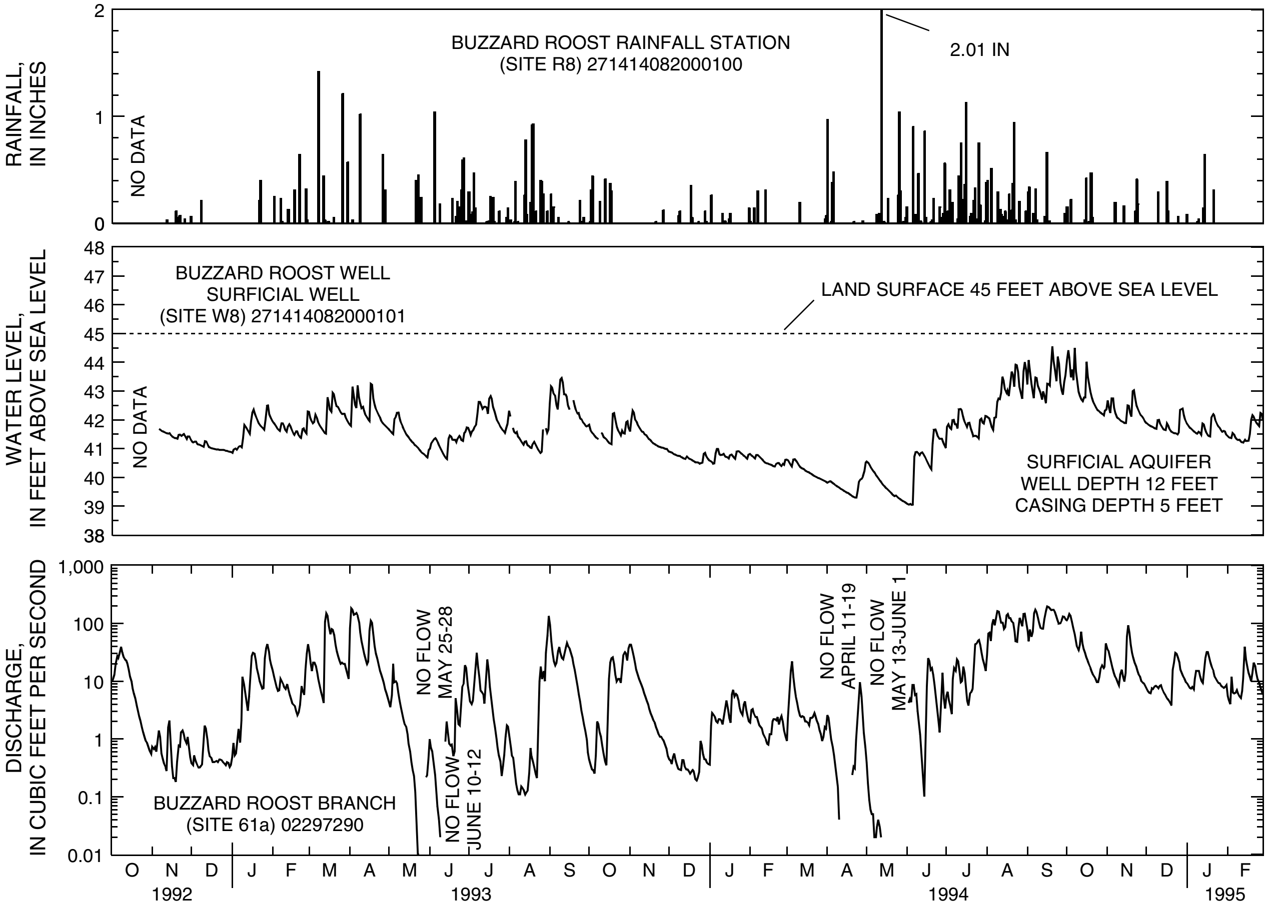


Figure 11. Daily rainfall and ground-water levels at the Buzzard Roost station and daily mean discharge at Buzzard Roost Branch, 1992-95. (Location shown in fig. 1.)

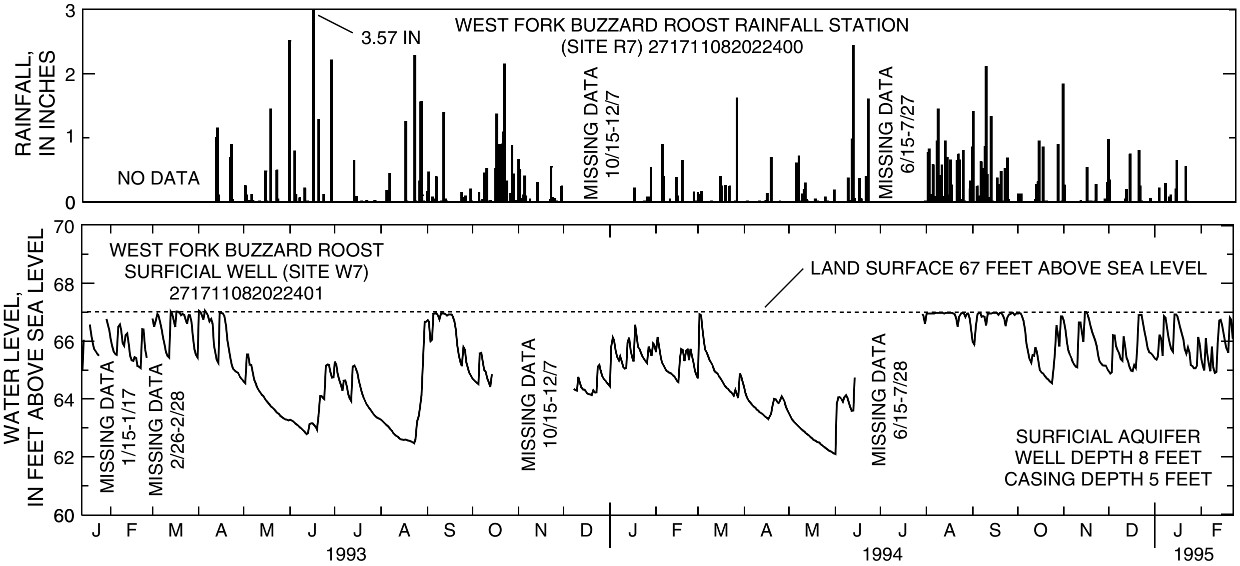


Figure 12. Daily rainfall and ground-water levels at the West Fork Buzzard Roost station, 1993-95. (Location shown in fig. 1.)

wet and dry seasons (fig. 12). Horizontal hydraulic conductivity in the surficial aquifer, computed from slug-tests using the Buzzard Roost and the West Fork Buzzard Roost wells, averaged 8.8 ft/d and 0.18 ft/d, respectively (table 1).

Horse Creek Subbasin

The 218-mi^2 Horse Creek subbasin includes the 133-mi^2 area monitored by the five previously discussed gaged subbasins and the 85-mi^2 of ungaged area (fig. 1). Horse Creek drains that part of the subbasin to the daily mean discharge station at the State Highway 72 bridge. The study area does not include the part of the Horse Creek basin downstream of the daily discharge station at State Highway 72 because of the tidally influenced backwater conditions that exist along much of the channel. The basin is elongated in shape (approximately 40 mi long and ranging from 4 to 10.5 mi in width), with a dendritic drainage pattern. The Horse Creek channel is approximately 43 mi long and has an average slope of 3.0 ft/mi. The shape of the channel along the upper reaches is relatively straight. However, in areas along middle and lower reaches where the gradient is low, channel meander is common. Altitudes in the Horse Creek subbasin range from approximately 10 ft at the gage to approximately 140 ft along the northern boundary.

Discharge data at the Horse Creek near Arcadia long-term daily mean station (fig. 1, site 78) have been collected continuously since 1950. Daily mean discharge at the Horse Creek near Arcadia station ranged from 0.2 to 4,130 ft^3/s during December 1992 to February 1995 (fig. 13).

Water levels in the surficial aquifer in the Horse Creek subbasin were monitored continuously at eight wells; seven of these wells have been previously described. The Carlton well near Kinsey (site W6), is located approximately 3.0 mi west of County Road 661 and 4.0 mi north of State Highway 70. Water levels in the Carlton well fluctuated about 6 ft between wet and dry seasons (fig. 13). Horizontal hydraulic conductivity of the surficial aquifer was 7.8 ft/d, computed from two slug-tests at the Carlton well (table 1).

HYDROLOGIC CONDITIONS

Surface and ground-water conditions in the Horse Creek basin described in this report represent current conditions prior to future agricultural, industrial, and mining expansion. Surface water, ground-water/surface-water interaction and ground-water recharge are discussed in the following sections.

Surface Water

Streamflow conditions of the six Horse Creek study subbasins were evaluated and compared, based on data collected from October 1992 to February 1995 (fig. 1). These results define pre-development

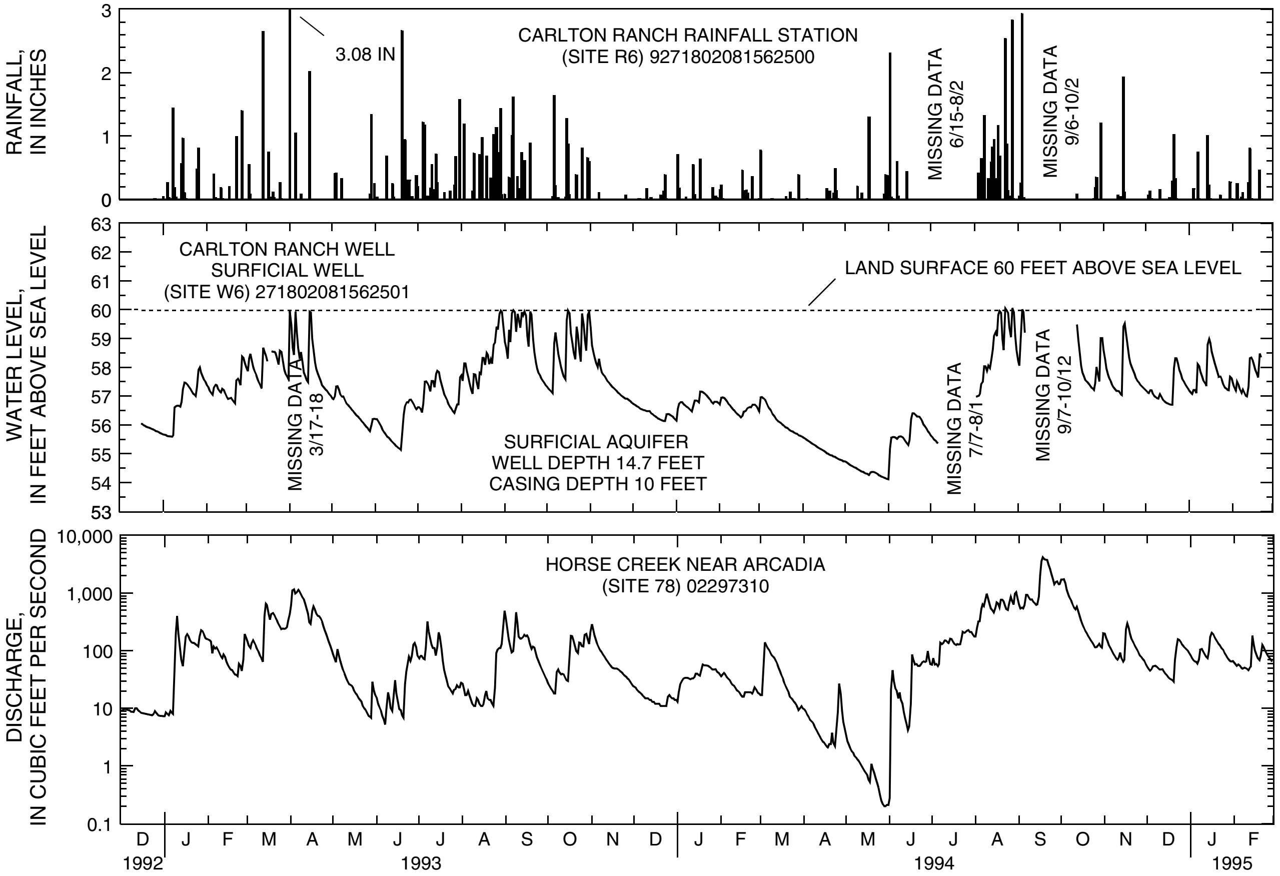


Figure 13. Daily rainfall and ground-water levels at the Carlton station and daily mean discharge at the Horse Creek station near Arcadia, 1992-95. (Location shown in fig. 1.)

conditions in the Horse Creek basin. Frequent and intense summer thunderstorms, which produce about 60 percent of the annual rainfall, commonly result in high peak discharges. Low-intensity, long-duration frontal storms that typically move through west-central Florida during the winter months generate moderate to large peak discharges. Physical characteristics, such as size, shape, slope, and topography of a basin, along with rainfall intensity, determine the frequency and magnitude of peak discharges.

Rainfall in 1993 was slightly above average and rainfall in 1994 was well above average in the Horse Creek basin. The National Weather Service long-term rainfall stations at Wauchula and Fort Green are located approximately 2 and 6 mi east of the Horse Creek basin, and had 30-year average annual totals of 49.99 (1951-80) and 50.19 in. (1961-90), respectively (fig. 1). The time period used to calculate the National Oceanic and Atmospheric Administration 30-year annual average changed between 1993 (1951-80) and 1994 (1961-90). Rainfall reported at the Wauchula station for 1993 was 54 in. (8 percent above the long-term annual average) (National Oceanic and Atmospheric Administration, 1993). Rainfall reported at the Fort Green station for 1994 was 66 in. (31 percent above the long-term annual average) (National Oceanic and Atmospheric Administration, 1994). The corresponding annual rainfall totals at Fort Green in 1993 and Wauchula in 1994 were not available because of missing monthly data at those stations.

Daily Mean Discharge

The magnitude of daily mean discharges varies between subbasins primarily because of temporal and spatial variations in precipitation and evaporation, as well as spatial variations in topography, soils, and geology.

Maximum daily mean discharge and discharge per square mile at the six subbasins during this study (October 1992 to February 1995) are listed in table 2. The maximum daily mean discharge and discharge per square mile at the two long-term Horse Creek stations, Myakka Head and Arcadia, are also listed for the period of record of 18 and 44 years, respectively. Maximum daily mean discharges for 1993 may represent somewhat normal conditions, because rainfall accumulations for the year were slightly above average. However, during 1994, a year with much greater than average rainfall, the maximum daily mean discharge was approximately three times greater at the West Fork Horse Creek, Horse Creek near Myakka Head, Brushy Creek, and Horse Creek near Arcadia stations. The maximum daily mean discharge during 1994 was approximately two times greater than during 1993 at Brandy Branch and the about the same at Buzzard Roost Branch.

The greatest number of days with no flow (113 days) during the study period occurred at the Brushy Creek subbasin, followed by Buzzard Roost Branch (36 days) and Brandy Branch (32 days) (table 2). The West Fork Horse Creek and the Upper Horse Creek subbasins had 1 and 2 days of no-flow, respectively. The Horse Creek subbasin had no periods without flow. A low number of no-flow days in a small basin indicates that ground-water levels are sufficiently high to support baseflow.

Table 2. Annual extremes of daily mean and instantaneous peak discharge at two Horse Creek and four tributary stations

[mi^2, square miles; ft^3/s, cubic feet per second; (ft^3/s)/mi^2, cubic feet per second per square mile]

Station	Drainage area (mi^2)	Period of record (water year[1])	Maximum daily mean discharge			Instantaneous peak discharge			Days of no flow	Number of days with record
			Date	(ft^3/s)	[(ft^3/s)/mi^2]	Date	(ft^3/s)	[ft^3/s)/mi^2]		
West Fork Horse-Creek (Site 10) 02297153	13.5	1993	4-01-93	156	11.6	4-01-93	237	17.6	0	365
		1994	9-16-94	413	30.6	9-15-94	475	35.2	1	365
Horse Creek[2] near Myakka Head (Site 11) 02297155 (Upper Horse Creek sub-basin)	42.0	1993	3-26-93	349	8.31	4-01-93	495	11.8	0	365
		1994	9-16-94	1,160	27.6	9-16-94	1,550	36.9	2	365
		1995	8-03-95	637	15.2	8-3-95	763	18.2	0	365
		1977-94	9-07-88	2,240	53	9-06-88	2,310	55	many	18 years
Brushy Creek (Site 20) 02297220	47.8	1993	3-28-93	262	5.48	3-28-93	278	5.82	47	365
		1994	9-17-94	819	17.1	9-16-94	900	18.8	66	365
		1995[3]	10-01-94	400	8.37	10-01-94	431	9.02	0	151
Brandy Branch (Site 55) 02297272	15.1	1993	8-31-93	130	8.61	4-01-93	207	13.7	0	365
		1994	9-16-94	225	14.9	9-16-94	299	19.8	32	365
		1995[2]	10-02-94	94	6.22	10-02-94	122	8.08	0	151
Buzzard Roost Branch (Site 61a) 02297290	28.7	1993	4-02-93	180	6.27	4-02-93	185	6.45	7	365
		1994	9-16-94	199	6.93	9-16-94	201	7.00	29	365
		1995[3]	10-03-94	145	5.05	10-03-94	146	5.09	0	151
Horse Creek near Arcadia (Site 78) 02297310 (Horse Creek sub-basin)	218	1993	4-03-93	1,170	5.37	4-02-93	1,250	5.73	0	365
		1994	9-18-94	4,130	18.9	9-18-94	4,180	19.2	0	365
		1995	7-30-95	2,230	10.2	6-23-95	2,270	10.4	0	365
		1950-94	8-01-60	10,700	49	8-01-60	11,700	54	many	44-years

[1] Water year is a 12-month period from October 1 through September 30.

[2] Includes the West Fork Horse Creek drainage basin.

[3] Extremes for the 1995 water year are based on a partial year of record for the period of October 1 to February 28.

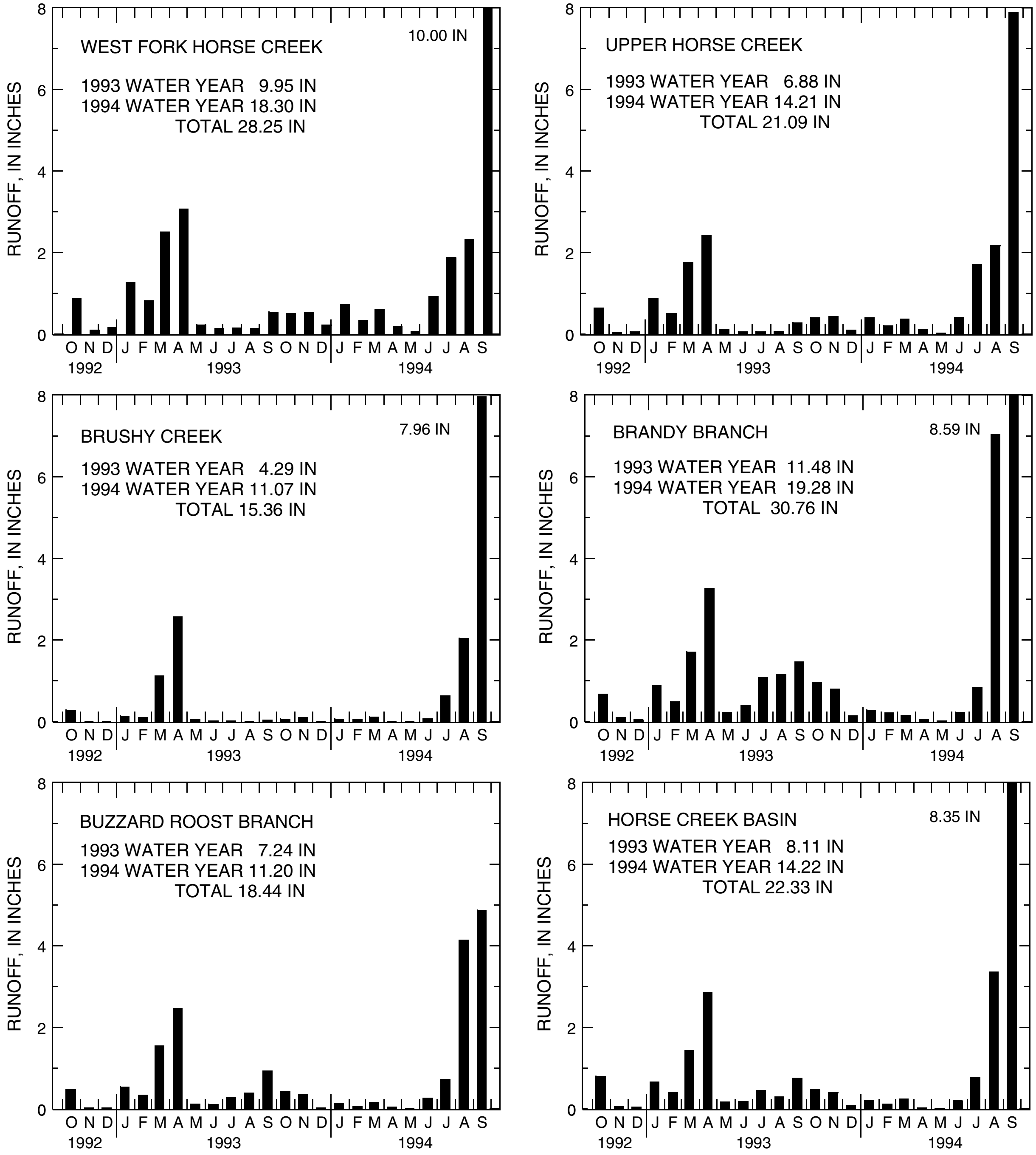


Figure 14. Monthly mean runoff at six Horse Creek subbasins, October 1992 though February 1995.

Monthly and Annual Mean Runoff

Monthly mean runoff at the six study subbasins are shown in figure 14. Monthly runoff is the depth in inches to which the drainage area would be covered if all the runoff for a given month were uniformly distributed on it. Typically, in west-central Florida the greatest distribution of rainfall occurs during the summer months. However, during 1993, the highest monthly runoff occurred in March and April at all subbasins. The highest monthly mean runoff at all sites during 1994 occurred in September, with the greatest runoff calculated at West Fork Horse Creek (10.0 in.).

The annual mean runoff for all subbasins in the 1994 water year was about two times that of 1993. Annual mean runoff at the two Horse Creek main-channel stations, Horse Creek near Myakka Head (site 11) and the Horse Creek near Arcadia (site 78), was nearly identical for the 1994 water year, with 14.21 and 14.22 in., respectively. Brandy Branch (site 55) had the highest annual mean runoff in the study area for both the 1993 and 1994 water years, with 11.48 and 19.28 in., respectively.

A comparison of the annual mean runoff between the 21-year long-term record and the 2-year period of study at the Horse Creek near Myakka Head station, was made to determine if conditions during the study represented average historical conditions. The average volumes for long-term and the period of study were similar with 9.56 and 10.54 in., respectively. The annual mean runoff at the Horse Creek near Arcadia station for the 44-year period of record and 2-year period of record were also similar with 11.56 and 11.16 in., respectively.

Maximum Instantaneous Peak Discharge

During the period of study, the maximum instantaneous peak discharge recorded at each of the six subbasins occurred during the thunderstorm of September 14-18, 1994 (table 2). The rainfall recorded at seven of the eight raingages (no data available at the Carlton gage) during the peak thunderstorm averaged 3.62 in., with the highest three rainfall amounts recorded in the upper Horse Creek basin at the Lettis Creek (5.21 in.), Watkins Road (4.89 in.), and West Fork Horse Creek (4.88 in.) rainfall stations. The greatest maximum instantaneous peak discharge occurred at the Horse Creek near Arcadia station (site 78), which receives runoff from the five gaged subbasins and the ungaged area in the subbasin above State Road 72, with 4,180 ft^3/s.

Discharge Duration

The discharge-duration curves presented in this report are cumulative frequency curves that show the percentage of time that daily mean discharge equaled or exceeded any given value during the period of study, October 1992 to February 1995. The shape of the duration curve indicates the flow characteristics throughout the range of discharge. The slope of the curve indicates the variability of flow. A steeply sloping curve indicates highly variable discharge from direct runoff, whereas, a moderately sloping curve indicates a more stable discharge from surface and ground-water storage. A flat slope at the lower end indicates a large amount of storage; and a steep slope indicates a negligible amount. A flat slope at the upper end indicates large floodplain storage (Searcy, 1959). Duration curves for daily mean discharge were calculated at the West Fork Horse Creek, Horse Creek near Myakka Head, and Horse Creek near Arcadia stations using a 730-day (October 1, 1992 to September 30, 1994) period of record. The duration curves for Brushy Creek, Brandy Branch, and Buzzard Roost stations were calculated using a 881-day (October 1, 1992 to February 28, 1995) period of record (figs. 15a-d and 16g and h). In addition, duration curves were also calculated at the two long-term Horse Creek stations, Myakka Head and Arcadia for a 17- (1978-94) and 44- (1951-94) year period of record, respectively (fig. 16e and f).

Long-term flows and flows recorded during the period of study at the Horse Creek near Arcadia station were similar at 50 percent of the time with approximately 50 ft^3/s. However, the duration curves indicate that long-term flows were approximately double the flows during the period of study 20 percent of the time, and half the long-term flows 80 percent of the time. During the approximate 2-year study, period of no-flow at the six subbasins ranged from zero at the Horse Creek near Arcadia station to 12.8 percent of the time at the Brushy Creek station. Periods of no-flow at the long-term Horse Creek near Myakka Head and Horse Creek near Arcadia stations were 1.7 and 0.01 percent of the time, respectively. Figure 16g and 16h shows that the two Horse Creek stations, Myakka Head and Arcadia, had the most stable flow during the period of study; however, the flow was somewhat more variable during the entire period of record (16e and f). The West Fork Horse Creek and Brandy Branch stations (fig. 15a and c) showed similar levels of stable flow, except for the number of no-flow days. The steep curve at both Brushy Creek and Buzzard Roost Branch stations (fig. 15b and d) indicate more variable flow.

During the study, maximum daily mean discharges that were equaled or exceeded 5 percent of the time are as follows: West Fork Horse Creek, 51.2 ft^3/s; Horse Creek near Myakka, 108 ft^3/s; Brushy Creek, 145 ft^3/s; Brandy Branch, 88.9 ft^3/s; Buzzard Roost Branch, 114 ft^3/s; and Horse Creek near Arcadia, 776 ft^3/s. Maximum daily mean discharges were equaled or exceeded 5 percent of the time at the long-term Horse Creek stations, Myakka Head and Arcadia, were 128 ft^3/s and 845 ft^3/s, respectively.

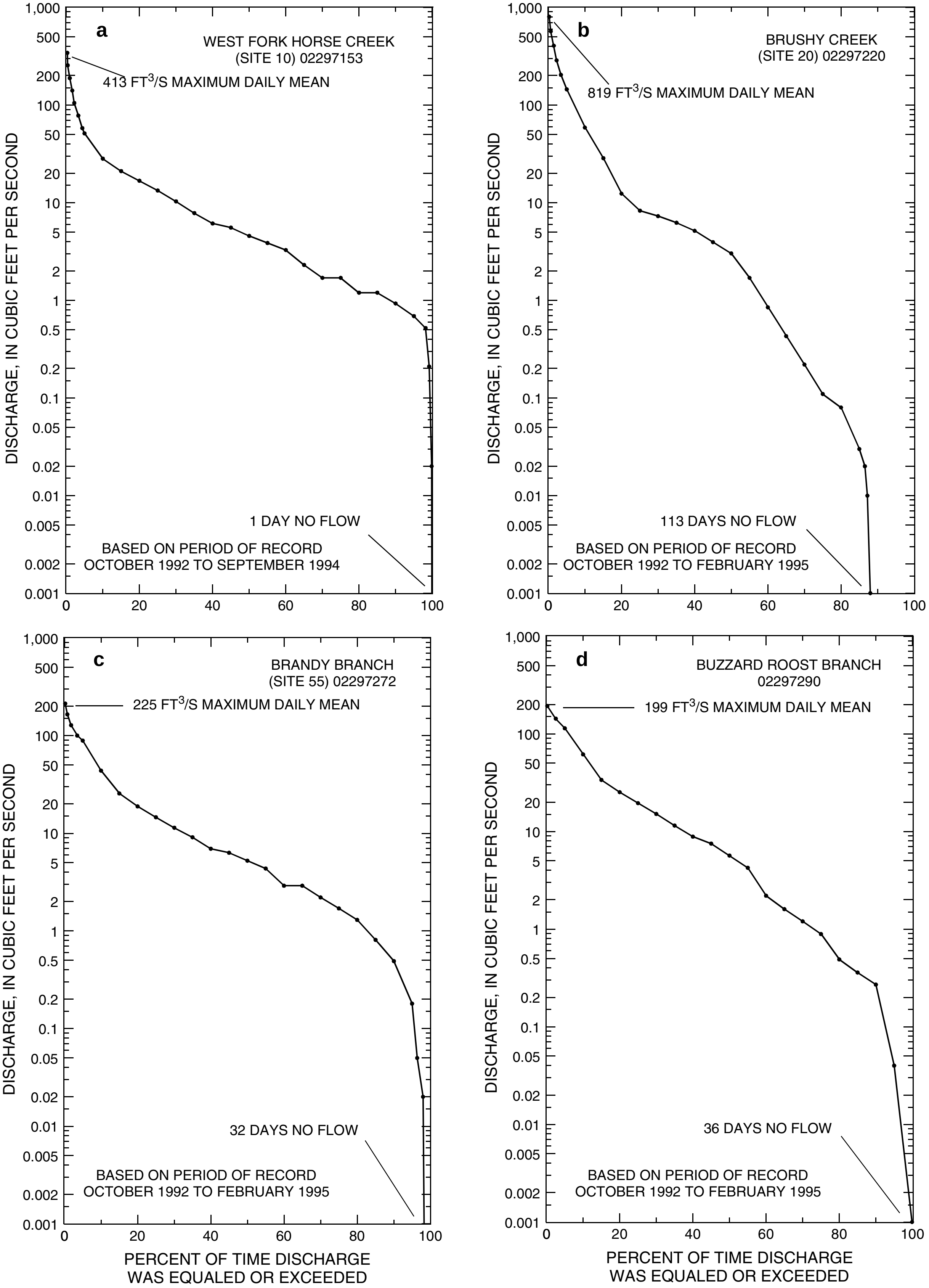


Figure 15. Duration curves of daily mean discharge at four Horse Creek tributary stations.

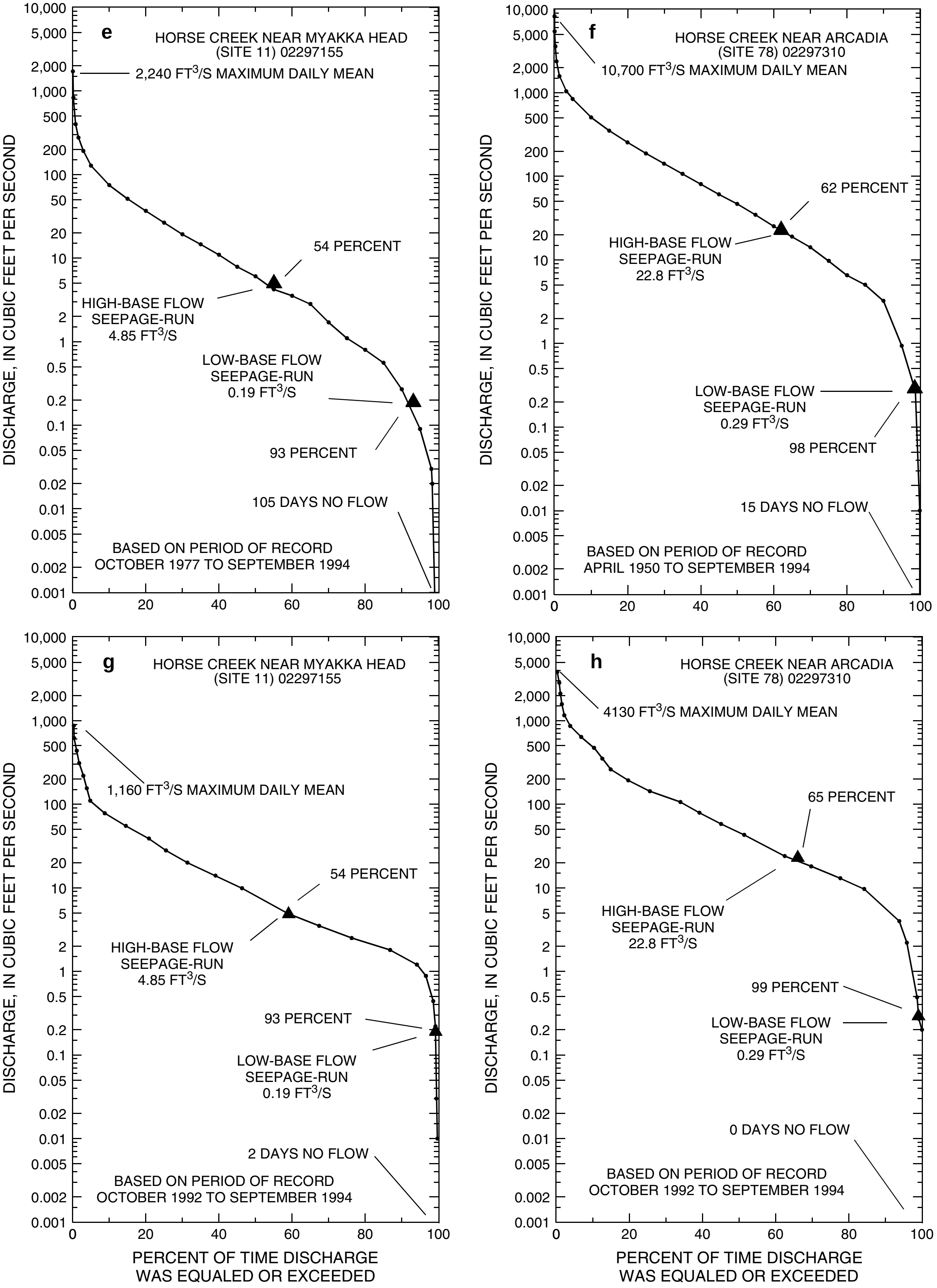


Figure 16. Duration curves of daily mean discharge at the Horse Creek near Myakka Head and Arcadia daily discharge stations for (g-h) water years 1993-94 and (e-f) period of record to 1994.

Consecutive days of low- and high-flow discharges at the six Horse Creek subbasins for the period of study (and for the period of record at the Horse Creek near Myakka Head and Arcadia daily discharge stations) are listed in tables 3 and 4, respectively. During the study, the minimum daily mean flow for 30 consecutive days at the Horse Creek near Arcadia discharge station was 0.86 ft^3/s, which occurred in 1994. However, during the 44-year period of record, it took approximately 60 days in 1956 to obtain a similar discharge (1.00 ft^3/s) at the station. The maximum mean discharge at the Horse Creek near Arcadia daily discharge station for 1 day during the period of record was 10,700 ft^3/s (1960), which was 259 percent higher than the highest mean discharge of 4,130 ft^3/s (1994) recorded during the 2-year study.

Table 3. Minimum daily mean discharge in cubic feet per second for number of consecutive days

Streamflow station	Period of record (years)	Water year	1 day	3 days	7 days	14 days	30 days	60 days	90 days	120 days	183 days
West Fork Horse Creek (Site 10) 02297153	1993-94	1994	0.0	0.013	0.073	0.24	0.71	1.47	1.88	3.41	4.20
Horse Creek near Myakka Head (Site 11) 02297155	[1]1993-94	1994	0.0	0.003	0.073	0.33	1.01	2.43	2.92	6.28	7.41
	1974-94	1985	0.0	0.0	0.0	0.0	0.02	0.087	0.085	0.12	0.22
Brushy Creek (Site 20) 02297220	1993-94	1994	0.0	0.0	0.0	0.0	0.0	0.0	0.10	1.47	1.50
Brandy Branch (Site 55) 02297272	1993-94	1994	0.0	0.0	0.0	0.0	0.05	0.36	0.76	1.30	1.86
Buzzard Roost Branch (Site 61a) 02297290	1993-94	1994	0.0	0.0	0.0	0.0	0.014	0.55	1.26	1.74	1.76
Horse Creek near Arcadia (Site 78) 02297310	[1]1993-94	1994	0.2	0.20	0.22	0.44	0.86	3.20	7.08	17.2	21.7
	1951-94	1956	0.0	0.0	0.014	0.071	0.097	1.00	1.26	1.50	2.65

[1] Water-year period concurrent with period of study.

Table 4. Maximum daily mean discharge in cubic feet per second for number of consecutive days

Streamflow station	Period of record (years)	Water year	1 day	3 days	7 days	15 days	30 days	60 days	90 days	120 days	183 days
West Fork Horse Creek (Site 10) 02297153	1993-94	1994	413	349	275	188	121	74.2	56.8	45.7	30.5
Horse Creek near Myakka Head (Site 11) 02297155	[1]1993-94	1994	1,160	903	687	478	297	188	146	114	76.0
	1974-94	1988	2,240	1,625	994	530	312	190	131	98	67.3
Brushy Creek (Site 20) 02297220	1993-94	1994	819	766	667	535	341	212	152	115	75.2
Brandy Branch (Site 55) 02297272	1993-94	1994	225	208	187	139	120	105	74.3	56.5	37.2
Buzzard Roost Branch (Site 61a) 02297290	1993-94	1994	199	191	179	149	126	115	83.3	64.2	42.3
Horse Creek near Arcadia (Site 78) 02297310	[1]1993-94	1994	41,301	3,920	3,554	2,554	1,632	1,140	811	619	407
	1951-94	1960	10,700	8,783	6,249	3,748	2,135	1,904	1,398	1,061	718

[1] Water-year period concurrent with period of study.

Hydrograph Separation

Six storms were selected to evaluate rainfall-runoff relations at each of the six subbasins (table 5). Rainfall and two example hydrographs for peak runoff and surficial aquifer ground-water levels from each of the six subbasins are shown in figure 17. Two typical storm classifications occur seasonally in west-central Florida, winter frontal storms and summer convective thunderstorms, each with unique precipitation patterns that produce different streamflow hydrograph shapes. In addition to the frontal storms and convective thunderstorms that occur in the area, severe storms periodically occur, such as tropical depressions and hurricanes, that produce locally heavy rainfall and flooding. Runoff hydrographs from thunderstorms usually have sharper peaks with faster rising and falling limbs of the curve than do hydrographs from frontal storms. Thunderstorms generally are intense within the narrow path of the storm, whereas, frontal storms produce similar rainfall amounts over a wide area. The majority of the storms selected for evaluation are classified as frontal storms. Hydrographs representing runoff from frontal storms typically have a single peak, followed by a smooth recession curve. Because frontal storms are isolated events that typically occur a week or more apart, the baseflow (ground water) component of the hydrograph is usually well defined, since it can begin and end at baseflow conditions. However, this is in contrast to thunderstorms that could occur daily, generating multiple peaks between baseflow conditions. The total volume of storm runoff for each of the 36 storms was calculated using a hydrograph separation method similar to that described by Rouse (1950). An analysis of the method used to calculate total runoff of the surface runoff, ground-water discharge, and baseflow components of the streamflow hydrograph for a selected frontal storm is shown in figure 18. Surface runoff is calculated as the difference between total runoff and the sum of ground-water discharge and residual baseflow. The ground-water hydrograph from a nearby surficial aquifer well was plotted for the concurrent period with the streamflow hydrograph to analyze the water-table response during the event. Generally, the ground-water hydrograph response at most of the wells was similar in shape of the peak and recession of the streamflow hydrograph. This indicates that ground-water discharge from the surficial aquifer in the Horse Creek subbasins supports streamflow.

The West Fork Horse Creek subbasin had the largest rainfall total (5.14 in.) used for runoff hydrograph analysis, resulting from the thunderstorm on June 13-29, 1994 (table 5). This thunderstorm also generated the greatest rainfall intensity, in which 2.77 in. fell during a 1-hour period. The smallest rainfall total used in the analyses was 0.33 in. which occurred during the thunderstorm on June 26-29, 1993, at the Brushy Creek subbasin.

The two largest runoff ratios (volume of runoff divided by volume of rainfall) of the 36 selected storms resulted from the March 24-31, 1993, storm at the West Fork Horse Creek and the Upper Horse Creek subbasins, with 43.7 and 27.3 percent, respectively (table 5). Although the rainfall amounts recorded in these two subbasins were moderate in intensity, they generated the highest calculated runoff with 0.69 and 0.53 in., respectively. Both the Brushy Creek and Brandy Branch subbasins had the smallest runoff ratio of 0.6 percent. Even though the rainfall amount at the Brushy Creek subbasin (0.33 in.) was small, a high degree of soil saturation could have occurred from a 2.10-in. antecedent rainfall recorded in the basin during the previous 7-day period that could have attributed to the runoff. In contrast, the 1.62- in. rainfall that fell in the Brandy Branch subbasin during the March 1-8, 1994, frontal storm was moderate in intensity, but resulted in a small runoff ratio because of a lack of significant antecedent rainfall (0.24 in.) during the previous 7-day period. The two smallest subbasins, West Fork Horse Creek (13.5 mi^2) and Brandy Branch (15.1 mi^2), generally exhibited the shortest response time from initial rise to peak discharge (table 5 and fig. 17).

Table 5. Peak discharge, rainfall, recharge, and runoff during selected storms, 1993-95

[ft^3/s, cubic feet per second]

Date	Peak discharge (ft^3/s)	Rainfall station	Rainfall (inches)	Recharge (inches)	Storm runoff[1] (inches)	Storm coefficient[2] (percent)	Time from rise to peak (hours)	Maximum rainfall intensity for indicated periods (inches)		Rainfall during indicated number of days previous to storm (inches)	
								15 minutes	1 hour	3 days	7 days
WEST FORK HORSE CREEK (SITE 10)											
Jan 13-22, 1993	63	Watkins	2.83	0.28	0.16	5.78	13	0.70	1.12	0.00	1.45
Mar 24-31, 1993	177	WFHC[3]	1.58	0.43	0.69	43.7	11	0.35	1.05	0.00	0.19
Mar 31-Apr 4, 1993	237	WFHC	2.20	0.44	0.41	18.5	10	0.56	0.99	0.00	1.58
April 14-24, 1993	136	WFHC	1.98	0.28	0.42	21.2	11	0.41	1.05	0.00	0.34
March 1-9, 1994	58	WFHC	1.98	0.15	0.17	8.64	18	0.35	0.90	0.01	0.33
June 13-29, 1994	63	WFHC	5.14	0.50	0.28	5.52	7	0.87	2.77	0.00	1.49
HORSE CREEK NEAR MYAKKA HEAD (SITE 11)											
Jan 13-24, 1993	119	Watkins	2.83	0.19	0.37	13.1	14	0.70	1.12	0.00	1.45
Mar 24-31, 1993	430	Watkins	1.94	0.27	0.53	27.3	13	0.65	1.79	0.00	0.24
April 14-23, 1993	305	Watkins	1.70	0.20	0.37	21.8	12	0.39	0.80	0.00	0.47
March 1-11, 1994	105	Watkins	1.45	0.09	0.15	10.3	19	0.42	0.78	0.01	0.44
Nov 14-24, 1994	35.6	Watkins	1.07	0.08	0.03	2.8	33	0.13	0.26	0.06	0.06
Jan 13-23, 1995	31.5	Watkins	1.15	0.11	0.04	3.5	39	0.30	0.46	0.00	0.62
BRUSHY CREEK (SITE 20)											
Jan 11-Feb 15, 1993	10	Lettis	3.22	0.05	0.13	4.0	192	0.20	0.50	0.01	1.25
Mar 12-25, 1993	63	Lettis	2.83	0.15	0.15	5.3	72	0.55	1.63	0.00	0.00
June 26-29, 1993	3	Lettis	0.33	0.001	0.002	0.6	13	0.08	0.20	0.54	2.10
July 5-12, 1993	5.3	Lettis	1.00	0.001	0.008	0.8	18	0.27	0.58	0.01	0.33
Nov 13-30, 1994	12.6	Lettis	1.47	0.04	0.02	1.4	60	0.31	0.51	0.00	0.00
Jan 13-29, 1995	17.8	Lettis	1.27	0.08	0.01	0.8	59	0.33	0.58	0.00	0.01
BRANDY BRANCH (SITE 55)											
Jan 13-25, 1993	35	WFBR[4]	2.15	0.21	0.17	7.9	12	0.46	0.88	--	--
Feb 25-Mar 3, 1993	42	WFBR	1.45	0.08	0.08	5.5	13	0.27	0.78	0.01	0.49
March 1-8, 1994	11	WFBR	1.62	0.04	0.01	0.6	13	0.45	0.97	0.00	0.24
June 15-25, 1994	16	BRB[5]	1.54	0.06	0.06	3.9	9	0.54	0.97	0.00	0.00
Nov 14-29, 1994	40.8	WFBR	2.11	0.26	0.11	5.2	29	0.41	0.84	0.01	0.90
Feb 12-17, 1995	38.3	WFBR	0.84	0.09	0.02	2.4	6	0.28	0.47	0.00	0.17
BUZZARD ROOST BRANCH (SITE 61a)											
Jan 23-Feb 5, 1993	46	WFBR	1.61	0.10	0.16	9.9	64	0.11	0.28	0.00	0.00
April 14-24, 1993	127	WFBR	2.21	0.17	0.38	17.2	54	0.63	1.20	0.00	0.11
Feb 28-Mar 12, 1994	25	WFBR	1.62	0.03	0.07	4.3	66	0.45	0.97	0.00	0.24
Apr 18-May 4, 1994	14	WFBR	2.06	0.01	0.03	1.5	6	0.39	0.60	0.00	0.00
Nov 14-30, 1994	97.3	WFBR	2.11	0.17	0.32	15.2	53	0.41	0.84	0.01	0.90
Feb 11-19, 1995	53.4	WFBR	0.80	0.08	0.06	7.5	6	0.28	0.47	0.00	0.17

Table 5. Peak discharge, rainfall, recharge, and runoff during selected storms, 1993-95 (Continued)

[ft^3/s, cubic feet per second]

Date	Peak discharge (ft^3/s)	Rainfall station	Rainfall (inches)	Recharge (inches)	Storm runoff[1] (inches)	Storm coefficient[2] (percent)	Time from rise to peak (hours)	Maximum rainfall intensity for indicated periods (inches)		Rainfall during indicated number of days previous to storm (inches)	
								15 minutes	1 hour	3 days	7 days
HORSE CREEK NEAR ARCADIA (SITE 78)											
Jan 14-24, 1993	203	WFBR	2.25	0.21	0.03	1.3	55	0.46	0.88	--	--
Oct 14-22, 1993	201	Carlton	2.17	0.10	0.02	0.9	45	0.34	0.71	0.00	0.23
Oct 30-Nov 10, 1993	303	Carlton	1.24	0.14	0.04	3.2	31	0.18	0.46	0.00	0.80
Apr 23-May 7, 1994	33	WFBR	0.64	<0.01	0.01	1.6	48	0.16	0.26	0.72	1.42
May 30-June 15,1994	66	Carlton	3.69	<0.01	0.03	0.8	13	0.65	1.81	0.45	0.45
Nov 14-30, 1994	307	WFBR	2.11	0.15	0.13	6.2	46	0.41	0.84	0.89	0.89

[1] Storm runoff is computed as the total runoff minus the base-flow, in inches.

[2] Runoff coeffiecient is storm runoff volume divided by rainfall volume multiplied by 100 percent.

[3] WFHC, West Fork Horse Creek rainfall gage.

[4] WFBR, West Fork Buzzard Roost rainfall gage.

[5] BRB, Buzzard Roost Branch.

Ground-Water/Surface-Water Interaction

Throughout much of the Horse Creek subbasin, ground-water discharge from the surficial aquifer contributes most of the baseflow. However, in places where the head of the intermediate aquifer system is generally higher than the water level in the surficial aquifer, ground water moves upwards from the intermediate aquifer system into the surficial aquifer and eventually discharges into the creek (Duerr and Enos, 1991). This condition occurs in the southern part of the Horse Creek subbasin where the head of the intermediate aquifer system and the Upper Floridan aquifer are higher than the water levels in the surficial aquifer (fig. 19).

Baseflow Conditions

A baseflow seepage run is used to identify flow gains and losses within selected reaches along the length of a river channel. A baseflow condition occurs when streamflow is derived exclusively from ground-water discharge, which usually occurs after an extended period of no rainfall. Surface-water or ground-water exchanges, if any, between the river and the underlying aquifers are determined from the differences between the discharge measured at the upper and the lower end of a reach, minus any tributary inflow. High- and low-baseflow seepage runs were performed along a 43-mi length of the Horse Creek channel and tributaries in December 1993 and May 1994, respectively (figs. 20 and 21). The seepage run included Horse Creek and tributary measurement sites from the headwaters above the State Highway 37 bridge near Duette to the Horse Creek daily discharge station near Arcadia at State Highway 72 (site 78). Because much of the lower 10-mi reach of the Horse Creek channel, between the Horse Creek daily discharge station near Arcadia to the mouth, is tidally influenced, this reach was not included in the seepage investigation.

Ideally, in conducting a seepage-run investigation, travel by boat along the length of a river channel is desirable for making discharge measurements at selected reaches and tributaries. Travel by boat along the channel improves the accuracy of the seepage run because (1) tributaries not identified on USGS topographic maps can be located and measured, and (2) boat travel provides a greater selection of potential discharge measurement cross-sections. However, a combination of physical limitations during both the low- and the high-baseflow seepage runs prevented the use of a boat, except for the

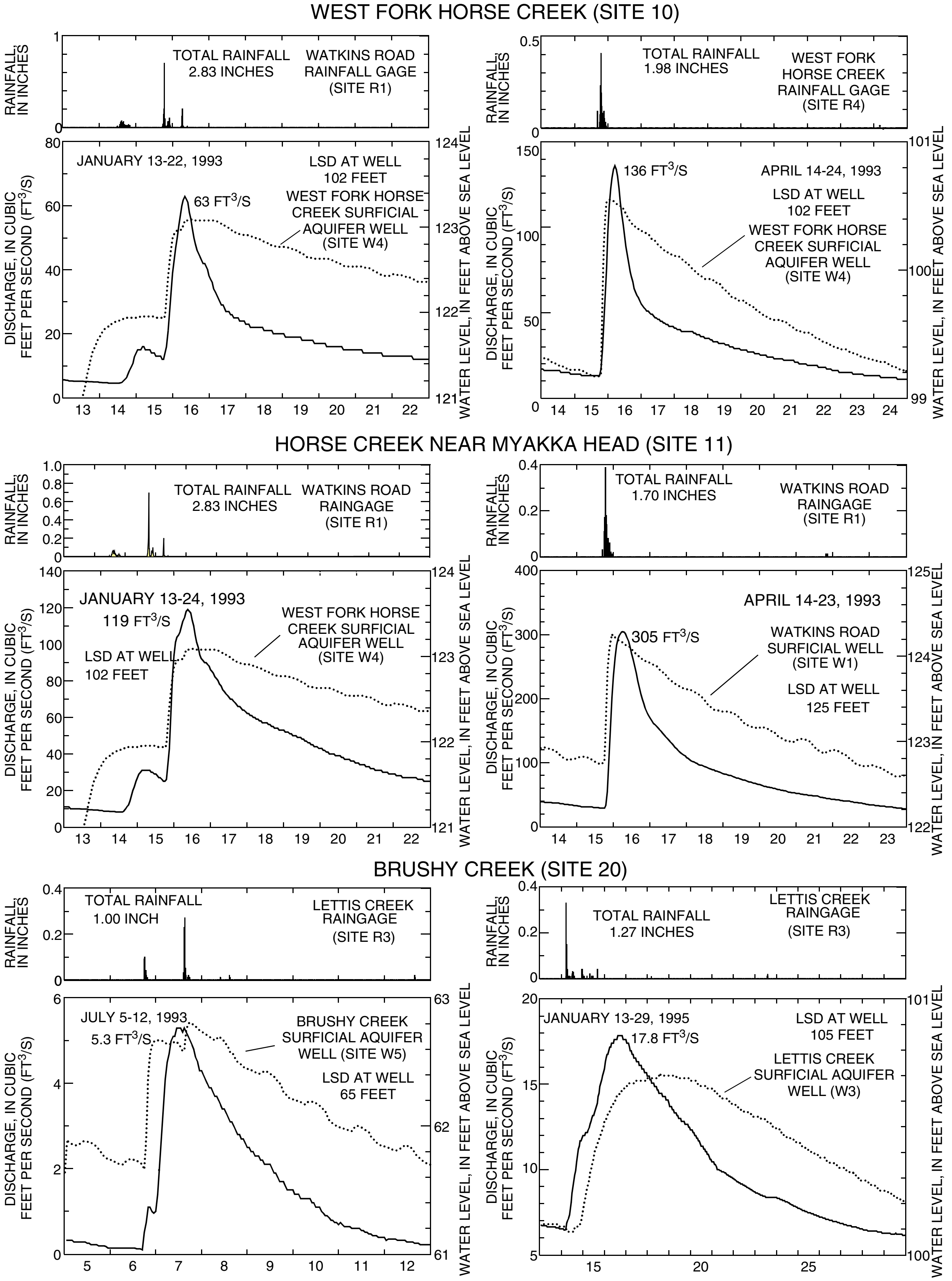


Figure 17. Rainfall, instantaneous discharge, and water levels for selected storms in the Horse Creek basin, January 1993 to February 1995. (Site locations are shown in fig. 1.)

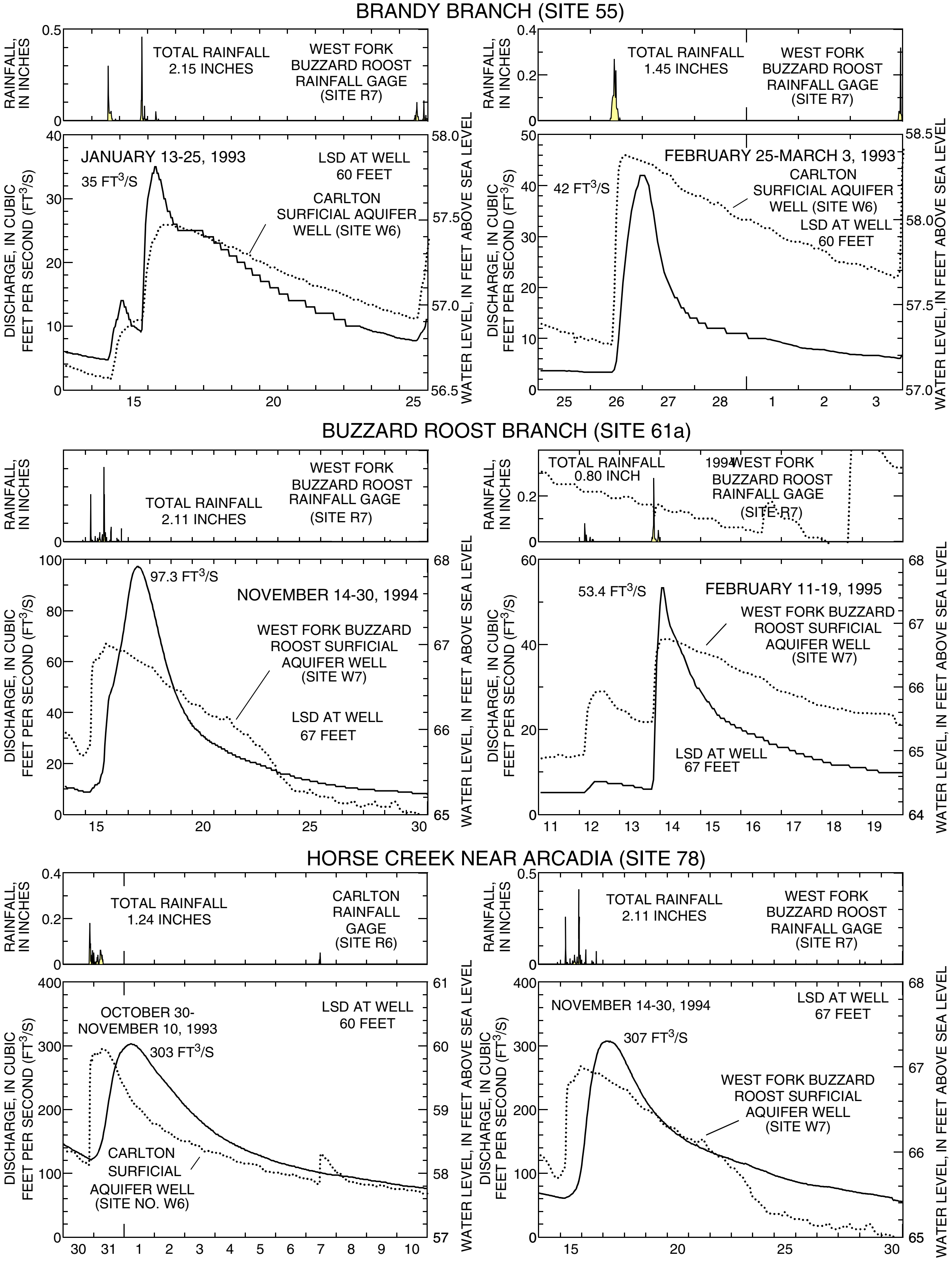
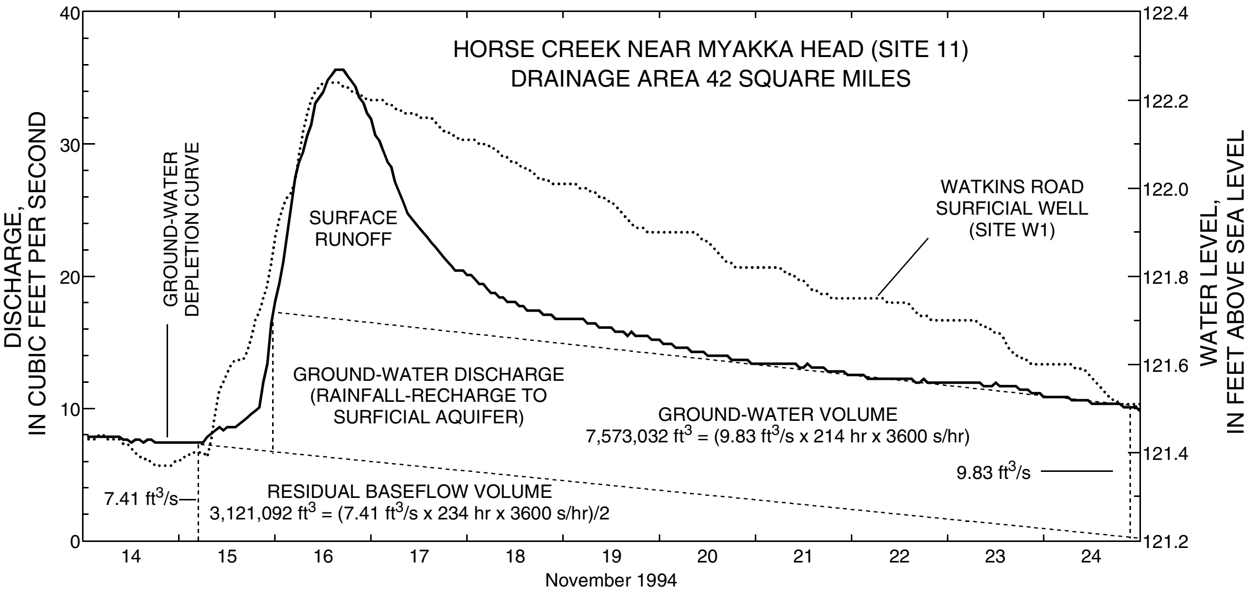


Figure 17. Rainfall, instantaneous discharge, and water levels for selected storms in the Horse Creek basin, January 1993 to February 1995. (Site locations are shown in fig. 1.) (Continued)



GROUND-WATER RUNOFF IN INCHES = 7,573,032 x C = 0.08 in

BASEFLOW RUNOFF IN INCHES = 3,121,092 x C = 0.03 in

NOTE: C = CONVERSION FACTOR = $\dfrac{12 \text{ in/ft}}{(\text{DA})\ \text{mi}^2 \times (5{,}280\text{ft})^2/\text{mi}^2} = 0.01 \times 10^{-6}$

Figure 18. Hydrograph separation example showing ground-water (baseflow) and residual baseflow discharge calculations for depth in inches over the subbasin, and the water-level response in the surficial aquifer.

lower 4-mi reach during only the high-flow seepage run. These limitations were the result of either no flow or very small discharges along most of the Horse Creek channel, complicated by restricted access to the channel and dense undergrowth. Because of these limitations, discharge measurements were made about a mile apart at locations along the Horse Creek channel where access was available. The longest reach without access to the channel was an approximately 5-mi section of low-lying swamp, between sites 11 and 15 (fig. 20), above the Horse Creek Prairie. Most tributary discharge measurements were made directly above the mouth. However, for those tributaries without access to the mouth, discharge measurements were made at the most downstream cross-section location, typically a highway crossing. Site description, discharge, and water-quality data are presented in the appendix.

High-Baseflow Conditions

The high-baseflow seepage run was conducted during December 1-2, 1993, when ground-water levels in the surficial aquifer were near a seasonal high and no measurable rainfall was recorded during the previous 3-week period. Hydrographs of the annual daily mean discharge at the Horse Creek near Myakka Head (site 11) and Arcadia (site 78) stations in figure 22 show that during the seepage run, streamflow conditions were at a high-baseflow condition. The shape of the receding limb of the two station hydrographs during the seepage run indicate that a baseflow condition existed in early December, and flow was derived from ground-water discharge. During the high-baseflow seepage run, the average flow recorded at the Horse Creek daily discharge stations near Myakka Head and Arcadia was approximately equal to flow that is exceeded 54 and 62 percent of the time for the period of record (18 and 44 years), respectively (fig. 16e and f).

Hydrographs from the eight Horse Creek surficial aquifer monitor wells show that during the period of the high-baseflow seepage run, water levels were near a seasonal high (figs. 5-9 and 11-13). Five of the eight monitor wells (fig. 1, W1, W4, W5, W6, and W8), located within 1 mi of the Horse Creek channel, could be used to approximate surficial ground-water levels near the channel. Based on the heads of the intermediate aquifer system (fig. 3) and the Upper

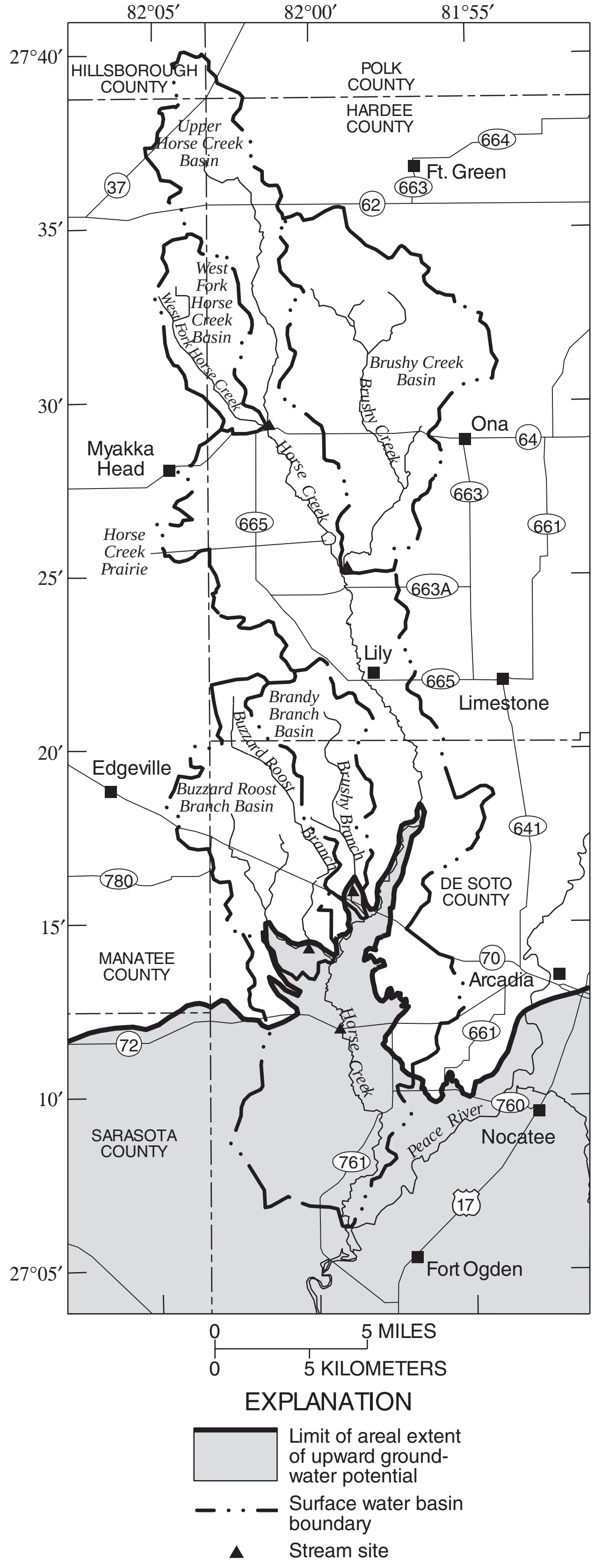


Figure 19. Areal extent of upward ground-water gradient in the intermediate aquifer system and the Upper Floridan aquifer.

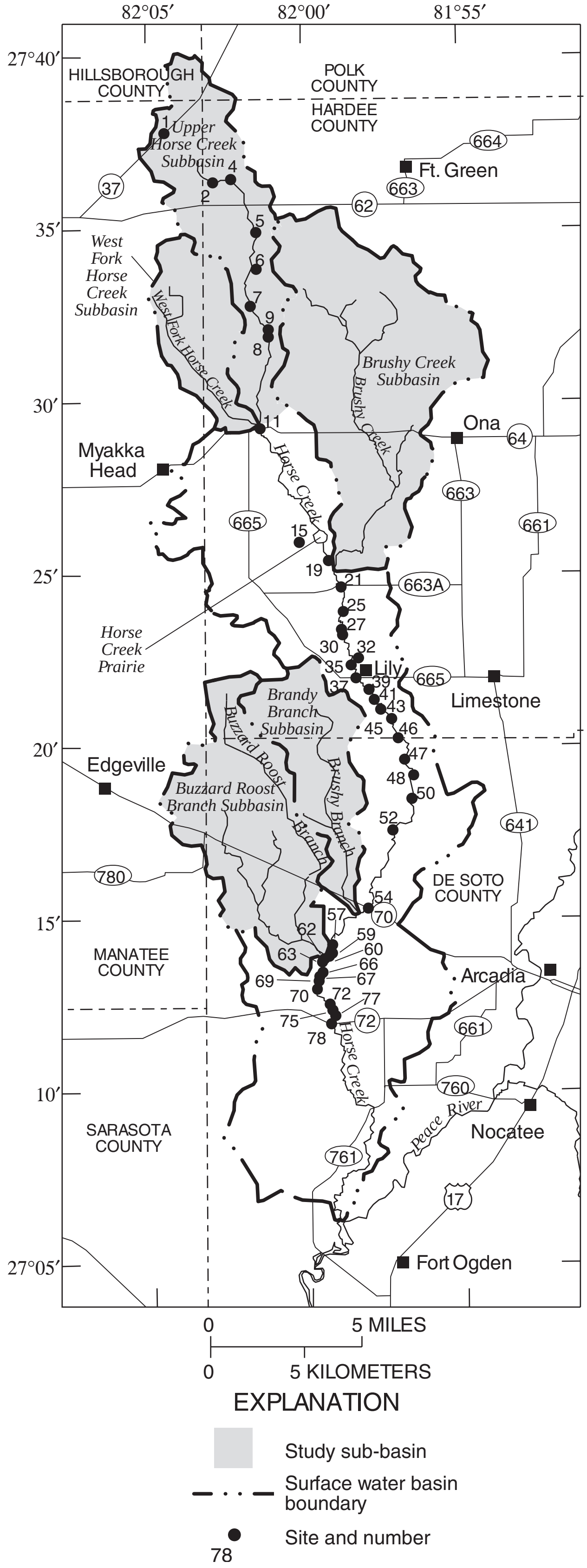


Figure 20. Location of Horse Creek discharge measurement sites.

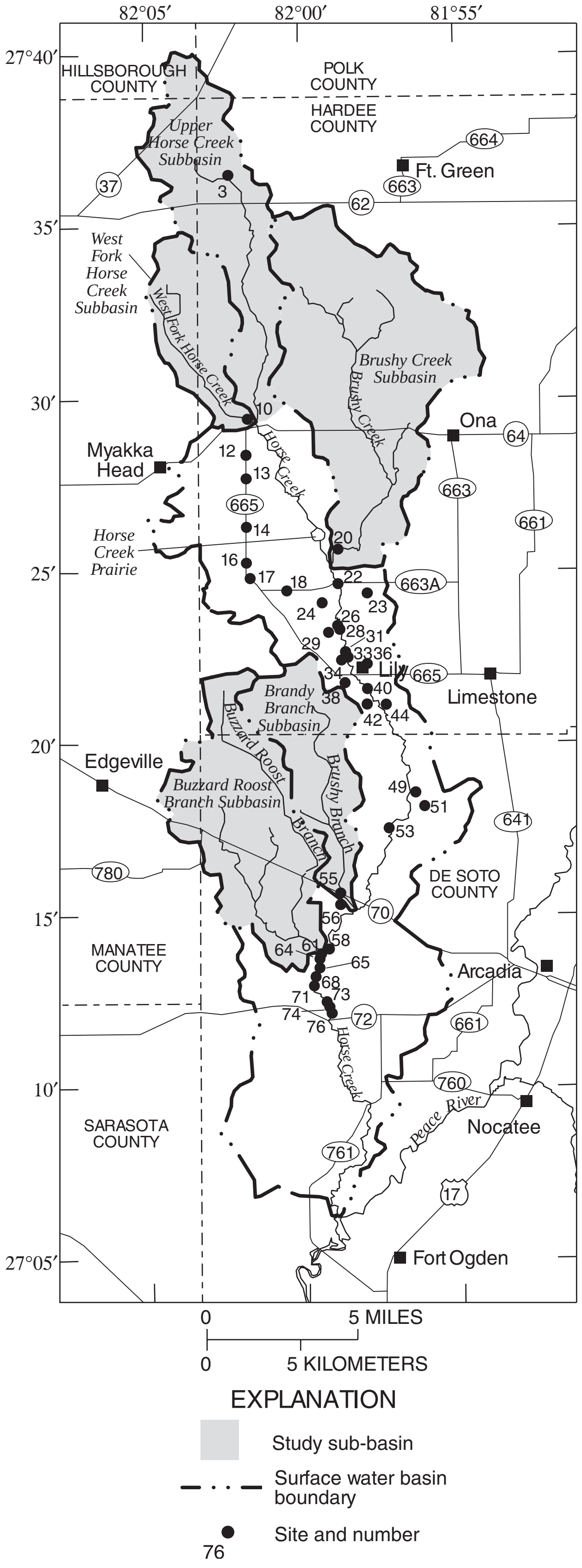


Figure 21. Location of Horse Creek tributary discharge measurement sites.

Floridan aquifer (fig. 4) in September 1993, an approximate relation to the Horse Creek stage during the period of the high-baseflow seepage run (December 1993) is shown in figure 23. Due to the 3-month delay between the water-level measurements in September and conducting the seepage run in December, the actual heads of the two aquifers were probably 5 to 8 ft lower. Because the heads of the two underlying aquifer systems only rose above the elevation of the channel from the Carlton Ranch (approximately 21 river miles above the mouth) to the mouth, ground-water discharge from the surficial aquifer to the channel was the only source of baseflow occurring between the headwaters and the Carlton Ranch. Potentially, ground-water seepage along the lower reach of the river could occur from the confined aquifers directly through springs or indirectly through the surficial aquifer.

Rainfall accumulations recorded at the eight rainfall gages, paired with surficial aquifer wells, and at a ninth rainfall gage located at the Horse Creek daily discharge station near Arcadia, ranged from zero to 0.06 in. during the 3-week period prior to the December 1-2 seepage run. During this dry antecedent period, the mean daily discharge at the Horse Creek near Arcadia station receded from a high of 79 to 22 ft^3/s (fig. 22).

A total of 41 Horse Creek (fig. 20) and 37 tributary (fig. 21) discharge measurements were made along a 43-mi length of the Horse Creek channel during the 2-day high-baseflow seepage run. Streamflow hydrographs in figure 24 show that the flow conditions at the Horse Creek near Myakka Head and Arcadia daily discharge stations (sites 11 and 78) were generally stable and gradually receding immediately prior to, during, and immediately after the seepage run. The Horse Creek discharge measurements ranged from zero, at the State Highway 37 bridge (fig. 20, site 1) to 23.8 ft^3/s at site 77, 0.2 mi above State Highway 72. Tributary flows ranged from zero at many sites to 3.85 ft^3/s at the West Fork Horse Creek site (fig. 21, site 10). The streamflow contribution from West Fork Horse Creek to Horse Creek comprised 75 percent of the total flow at the Horse Creek near Myakka Head (Upper Horse Creek) gaging station (fig. 20, site 11), 0.1 mi downstream.

Specific conductance samples were also collected at most discharge measurement sites. Specific conductance was used as a potential indicator of water source; a high value may indicate deep ground-water

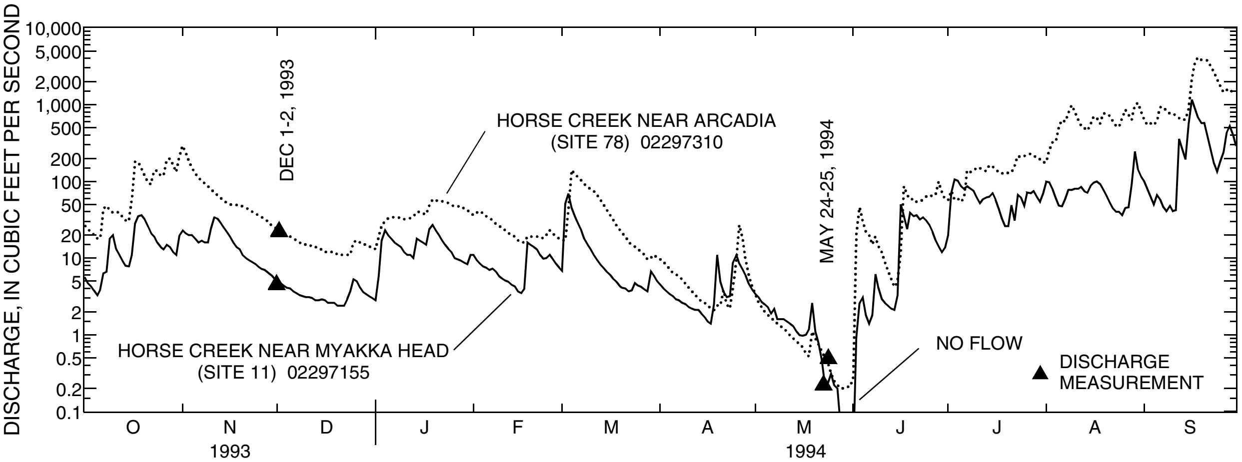


Figure 22. Annual daily mean discharge at the Horse Creek near Myakka Head and Arcadia stations, October 1993 to September 1994, and dates of high- and low-baseflow seepage runs.

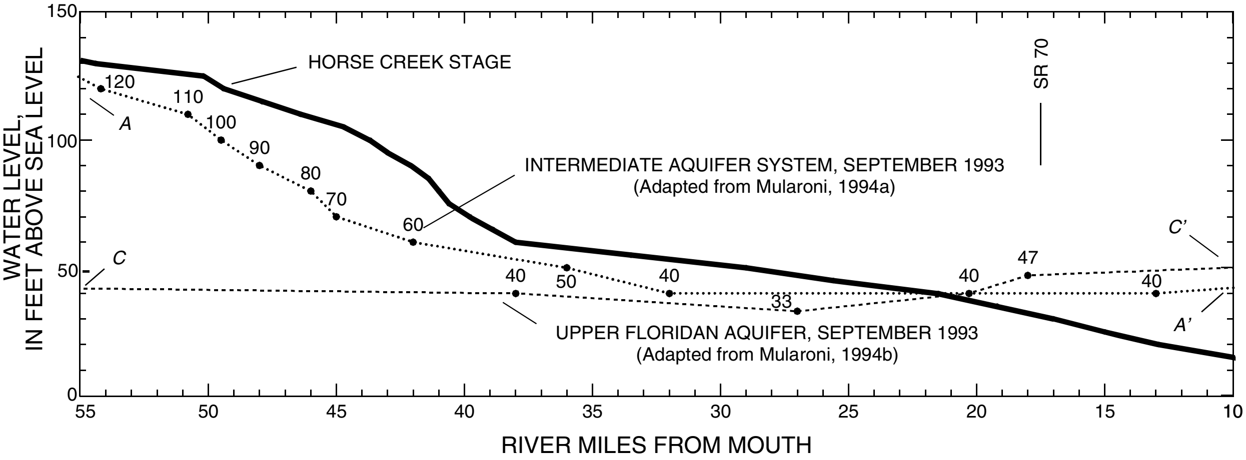


Figure 23. Water-level heads in the intermediate aquifer system and the Upper Floridan aquifer along sections A-A' and C-C,' September 1993. (Locations of sections are shown in figs. 3 and 4.)

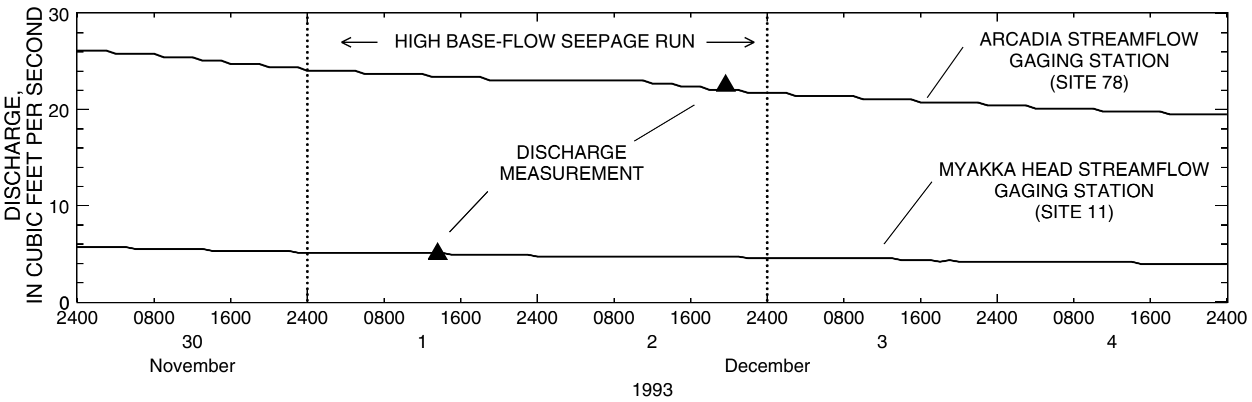


Figure 24. Instantaneous discharge at Horse Creek daily discharge stations near Myakka Head and Arcadia, November 30 to December 4, 1993, and period of the high-baseflow seepage run.

discharge. Specific conductance values along the Horse Creek channel during the high-baseflow seepage run ranged from 333 µS/cm at the Arcadia daily discharge station (site 78) to 123 µS/cm at site 15, 0.5 mi above Horse Creek Prairie (fig. 25). Tributary specific conductance values ranged from 558 µS/cm at site 64, 0.2 mi below Buzzards Roost Branch, to 47 µS/cm for a low flow of 0.02 ft^3/s at site 31, 1.4 mi above County Road 665 (fig. 26).

The high-baseflow seepage run was limited to a 2-day period to minimize potential changes in streamflow and climatic conditions. Discharge measurements were made at selected Horse Creek cross sections and above the mouth of all tributaries. The high-baseflow seepage run was conducted in a downstream order sequence. The sites from State Highway 37 (fig. 20, site 1) to the Horse Creek near Limestone partial record station (fig. 20, site 37) were measured on December 1. On December 2, the measurement sites included those sites from the Horse Creek near Limestone partial record station (site 37) to the Horse Creek daily discharge station near Arcadia (site 78). The instantaneous discharge measured at each of the 41 Horse Creek channel sites, calculated seepage-per-reach, and seepage-per-mile are shown in figure 27. The stream discharges are subject to errors of as much as 5 to 8 percent of the measured flow; thus the accuracy of each gain or loss is subject to an error of similar magnitude (Slade and Buszka, 1994).

The gains and losses of flow for reaches on the main channel of Horse Creek were calculated by the following equation:

$$Q_g = Q_d - Q_u - Q_t \qquad (1)$$

where

Q_g is gain (positive) or loss (negative) in streamflow between adjacent sites;
Q_d is streamflow at downstream site;
Q_u is streamflow at upstream site; and
Q_t is streamflow for all tributaries between upstream and downstream sites.

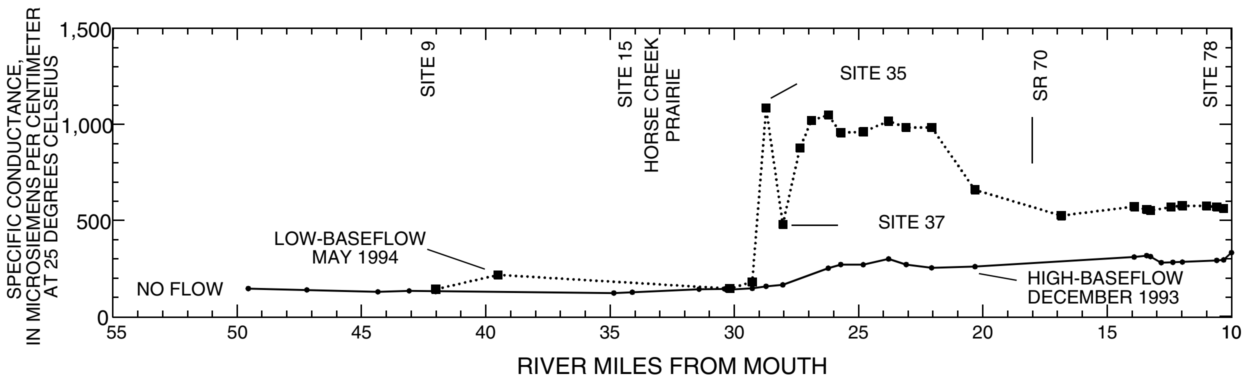


Figure 25. Comparison of Horse Creek specific conductance values during high- and low-baseflow seepage runs.

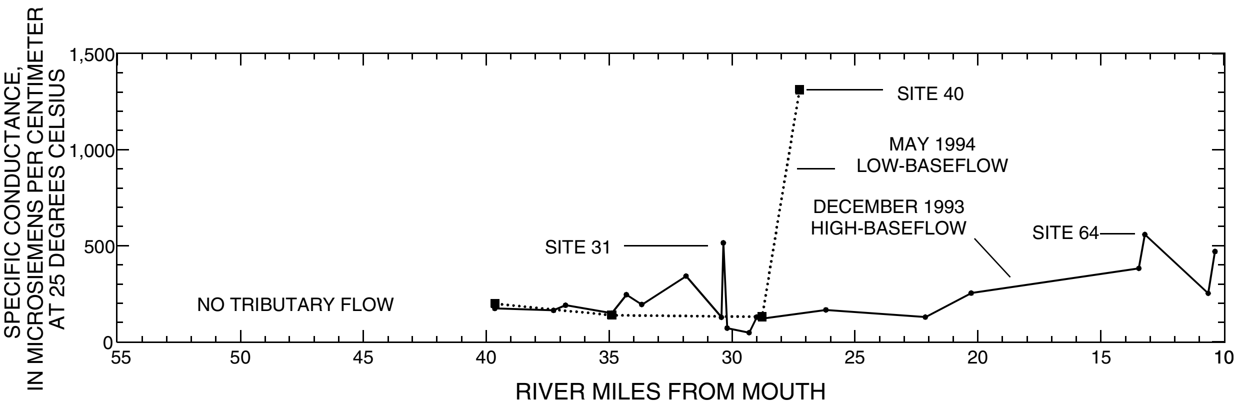


Figure 26. Comparison of tributary specific conductance values during high- and low-baseflow seepage runs.

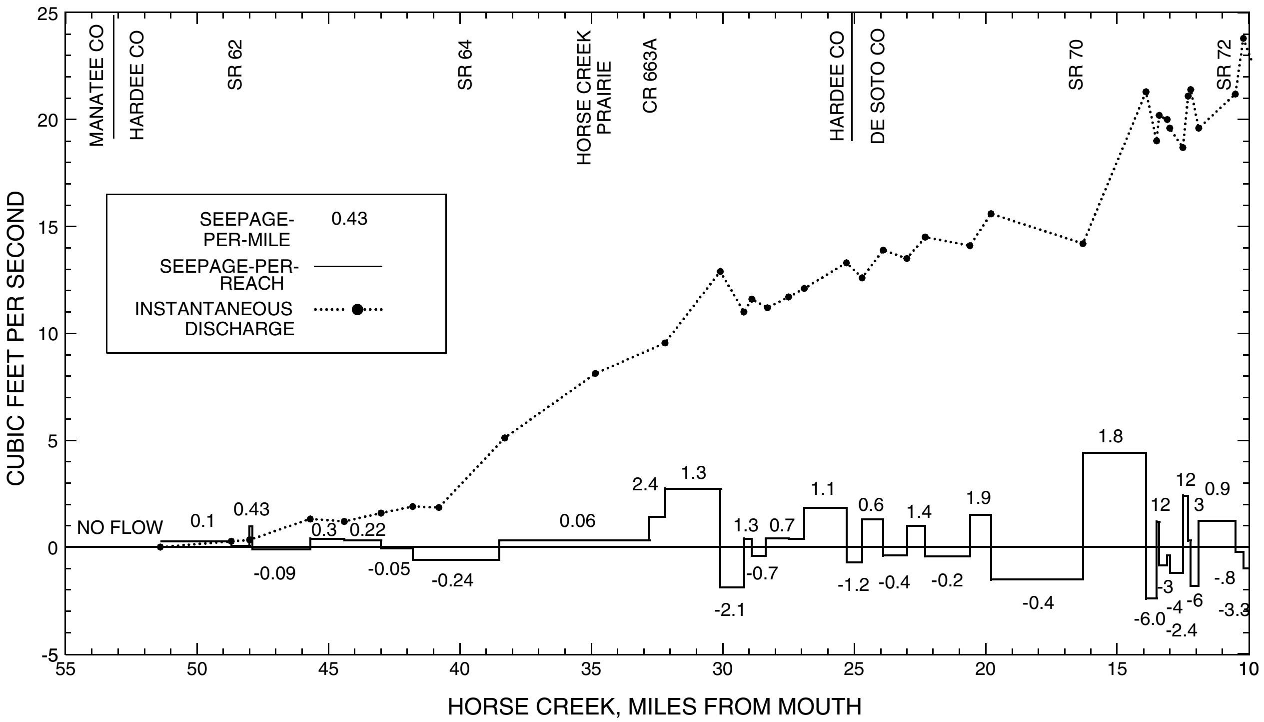


Figure 27. Horse Creek instantaneous discharge and calculated seepage-per-reach, and potential seepage-per-mile during the high-baseflow seepage run, December 1-2, 1993.

Results of the 25-mi long high-baseflow seepage run, conducted on the first day (December 1), were determined by examining two sections of the Horse Creek channel separately. These sections were determined by whether or not tributary flow discharged into the channel. The first section included the upper 11-mi reach (fig. 20, sites 1 through 9), in which no tributary flow was observed, and the second section included the lower 14-mi reach that had many tributary inflow sites.

Site 1, the uppermost Horse Creek discharge measurement site had no flow. The first Horse Creek measurement (0.27 ft^3/s) was made at site 2, located approximately 3 mi downstream of site 1. Sites 1 through site 9 of the first section had an average seepage of 0.17 (ft^3/s)/mi, with a cumulative total of 1.85 ft^3/s. The greatest seepage occurred along an approximate 2-mi reach, between sites 4 and 5, where the channel gained 0.98 ft^3/s. Along the approximate 14 mi of the second section, from site 9 to the Horse Creek gaging station near Limestone (fig. 20, site 37), ground-water seepage was similar to that of the first section, with an average ground-water discharge of 0.20 (ft^3/s)/mi, and a cumulative total of 2.78 ft^3/s.

Discharge measurements were made at the Horse Creek at Limestone partial record station (fig. 20, site 37) at the end of the first day and at the beginning of the second day of the seepage run evaluate continuity of flow. The discharge measured at site 37 on the evening of December 1 was 12.1 ft^3/s, and the discharge measured on the morning of December 2 was 11.4 ft^3/s. A decrease of 0.7 ft^3/s in flow occurred between the two discharge measurements. This decrease could be attributed to a combination of both a slowly falling stage and a diurnal streamflow fluctuation. A temporary daily discharge station was installed at the Horse Creek station near Limestone (site 37) to monitor continuous streamflow conditions, in addition to the permanent crest-stage-indicator gage. Data from the station indicated that no unusual fluctuations in stage occurred during the period of the study.

During the second day of the high-baseflow seepage run (December 2) along an 18-mi reach, travel by canoe was possible only along the lower 4-mi reach, between sites 57 and 78. Canoe access permitted measurement of all tributary inflow and additional measurement along the main channel. Evaluation of the second-day seepage-run results were done by examining discharge measurements along the two lower sections of Horse Creek, the upper 14-mi third section and the lower 4-mi fourth section.

The upper 14-mi third section, Horse Creek at Limestone partial record station (site 37) to site 57, had a cumulative seepage gain of 6.99 ft^3/s. The average ground-water seepage gain calculated along the third section was 0.51 (ft^3/s)/mi, or about twice that of the first and second sections measured during the first day of the seepage run. Seepage calculations from discharge measurements made along the lower 4-mi fourth section, which was accessed by canoe from site 57 to the Horse Creek daily discharge station near Arcadia (site 78), indicated a net loss of 2.75 ft^3/s. Streamflow losses along the fourth section, which is the only section that indicated a loss in flow, averaged approximately 0.68 (ft^3/s)/mi. An overall seepage gain of 8.87 ft^3/s was calculated along the 43-mi length of the Horse Creek channel during the 2-day high-baseflow seepage run, with an average seepage gain of approximately 0.20 (ft^3/s)/mi.

Low-Baseflow Conditions

The low-baseflow seepage run was conducted during the period of May 24-25, 1994, when water levels in the surficial aquifer were near a seasonal low (figs. 5-9 and 11-13). Streamflow hydrographs in figure 22 show that during the period of the seepage run, streamflow at the Horse Creek near Myakka Head and Arcadia daily discharge stations were at a low-baseflow condition. During the low-baseflow seepage run, the average flow recorded at the Myakka Head and Arcadia daily discharge stations was approximately equal to a flow that is exceeded 93 and 98 percent of the time, respectively, for the period of record at each gage (fig. 16e and f).

The potentiometric surfaces in the intermediate aquifer system (fig. 3) and the Upper Floridan aquifer (fig. 4) during May 1994 (Metz and Brendle, 1994a, 1994b) were at seasonally low levels. Figure 28 compares the heads of the two aquifers to the Horse Creek stage in May 1994. The potentiometric surface during May 1994 generally is lower than that measured in September 1993 (fig. 3); however, the potential for upward ground-water movement to the Horse Creek channel and tributaries along the extreme lower reach is similar for both periods.

Hydrographs in figure 29 show instantaneous discharge was low at both Horse Creek daily discharge

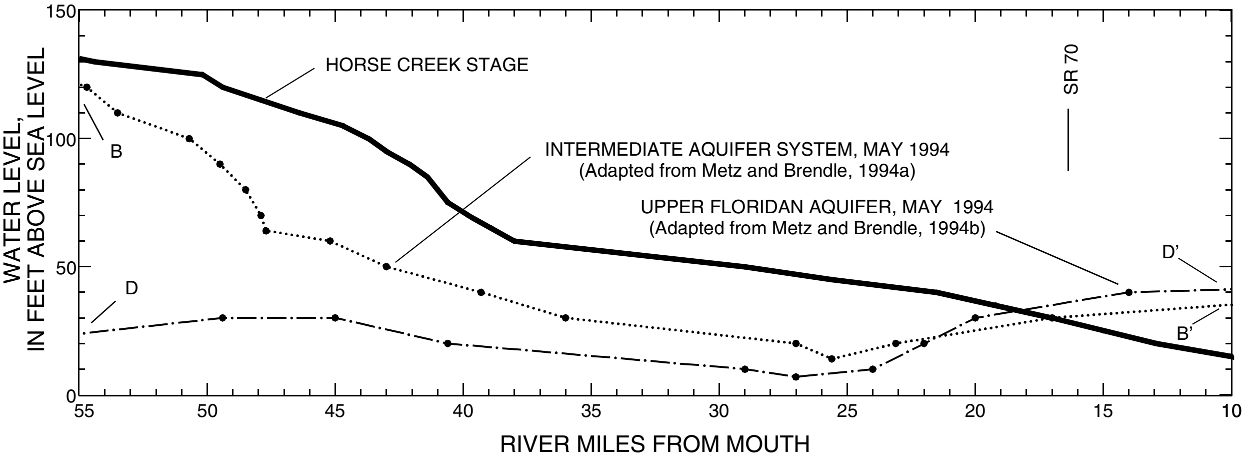


Figure 28. Water-level heads in the intermediate aquifer system and the Upper Floridan aquifer along sections B-B' and D-D,' May 1994. (Line of section shown in figs. 3. and 4.)

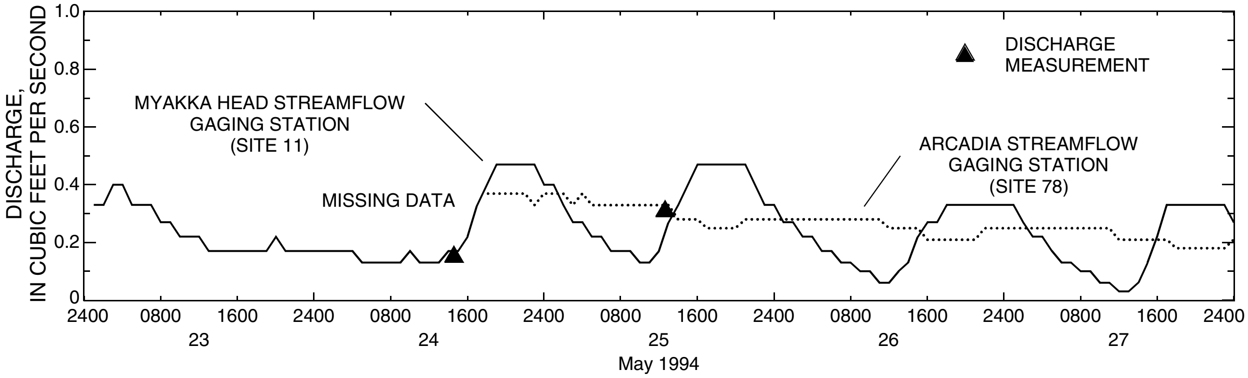


Figure 29. Instantaneous discharge at the Horse Creek near Myakka Head and Arcadia daily discharge stations during the low-baseflow seepage run, May 23-27, 1994.

stations near Myakka Head and Arcadia, during and after the seepage run. An oscillating diurnal discharge of approximately 0.4 ft^3/s was recorded at Myakka Head and approximately 0.05 ft^3/s at Arcadia stations. The uppermost 10-mi reach of the Horse Creek channel, from the head waters above site 1 to site 8 (fig. 20) was dry. In the approximate 7-mi reach, from site 9 to site 15, a cumulative seepage loss of 0.5 ft^3/s (0.14 (ft^3/s)/mi) was calculated from Horse Creek. This loss included the seepage increase of 0.03 ft^3/s to Horse Creek, between sites 8 and 9, and the contributions from two major tributaries, West Fork Horse Creek (site 10, 0.17 ft^3/s) and Elder Branch (site 14, 0.3 ft^3/s). Horse Creek and tributaries were dry along the approximate 4.5-mi reach from sites 15 to 27. A small baseflow seepage gain of 0.02 ft^3/s was measured along the 0.2-mi reach between sites 27 and 30. Within a distance of less than 0.1 mi downstream, the flow contribution of 0.32 ft^3/s from tributary site 34 to the Horse Creek channel was lost before reaching site 35. A seepage gain of 0.1 ft^3/s occurred along the approximate 0.7-mi reach between the last two Horse Creek sites, 35 and 37 (Horse Creek at Limestone partial record station), measured during the first day of the seepage run. The average seepage loss calculated along the upper 11-mi reach, from site 8 to site 37, during the first day (May 24) of the low-baseflow seepage run was approximately 0.08 (ft^3/s)/mi. Of the total 0.85 ft^3/s seepage loss, 0.06 ft^3/s was from the Horse Creek channel baseflow, and 0.79 ft^3/s was from tributary flow to the Horse Creek channel.

Results from the second day (May 25) of the low-baseflow seepage run indicate that the approximate 18-mi lower reach, from site 37 (Horse Creek at Limestone partial record station) to site 78 (Horse Creek daily discharge station near Arcadia), can be sub-divided into two gaining and one losing reach. The 2.3-mi upper reach from site 37 to site 45 had a net seepage increase of 0.41 ft^3/s (0.18 (ft^3/s)/mi). The 11.3-mi middle reach from site 45 to site 57 had a net loss of 0.68 ft^3/s (0.06 (ft^3/s)/mi). The 4.3-mi lower reach from site 57 to site 78 had a net increase of 0.24 ft^3/s (0.06 (ft^3/s)/mi). A net seepage loss of 0.03 ft^3/s was calculated over the 18-mi length that comprised the three reaches. Instantaneous discharge measured at the 41 Horse Creek sites, the calculated seepage-per-reach, and seepage-per-mile are shown in figure 30.

Specific conductance samples were also collected at most discharge measurement sites. Horse Creek specific conductance values during May 1994 ranged from 1,085 µS/cm at site 35, 0.4 mi north of County Road 665, to 142 µS/cm at site 9, 1.8 mi above State Highway 64 (fig. 25). Tributary specific conductance values during May 1994, ranged from 1,312 µS/cm at site 40, 0.8 mi below State Highway 64, to 130 µS/cm at site 34, 0.9 mi above County Road 665 (fig. 26).

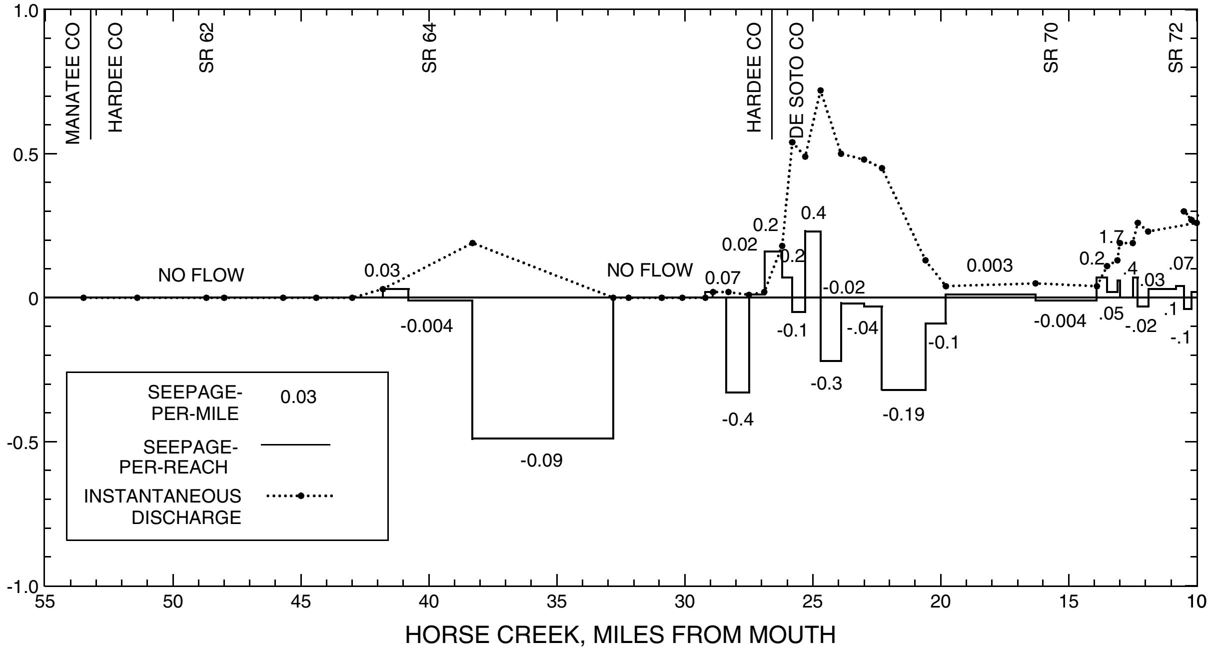


Figure 30. Comparison of Horse Creek instantaneous discharge and calculated seepage-per-reach and potential seepage-per-mile during the low-baseflow seepage run, May 24-25, 1994.

Ground-Water Recharge

Ground-water recharge is the replenishment of ground water by downward infiltration of water from rainfall, streams, and other sources. Many factors influence the amount of precipitation that becomes ground-water recharge under natural conditions. These factors include (1) texture and gradation of surface and near-surface deposits and their vertical permeability, (2) nature and water requirements of the vegetation, (3) frequency, intensity, and volume of rainfall, (4) topography, and (5) temperature (American Society of Civil Engineers, 1987). Ground-water recharge to the surficial aquifer represents accretions to the zone of saturation (ground-water reservoir), whose upper surface is the water table. Water from rainfall, streams, and other sources that infiltrates to the water table (surficial aquifer) generally flows from the higher recharge areas to discharge areas that are normally in topographically low places such as stream valleys, lakes and existing wetlands, and the sea (Vecchioli and others, 1990). The unconfined surficial aquifer is a major source of recharge to the underlying intermediate aquifer system in areas where a downward head gradient exists.

During the study, three methods were used to estimate recharge rates to the water table within the Horse Creek basin. Methods for estimating rates of recharge to the water table include: (1) water-level rises recorded on well hydrographs from rainfall infiltration; (2) chloride mass balance of rainwater and ground-water samples from the surficial aquifer; and (3) streamflow hydrograph separation for individual storms occurring in a subbasin.

Well Hydrograph Method

The well hydrograph method was used to estimate rates of recharge to the water table at the seven study wells located throughout the Horse Creek basin that tap the upper permeable zone of the surficial aquifer. These analyses utilize a method described by Rasmussen and Andreasen (1959, p. 94-95) and Phelps (1990, p. 44-45) in which recharge is estimated by summing the rises in ground-water levels and multiplying the results by the gravity yield (specific yield). This method can over estimate or under estimate actual recharge by (1) the amount of ground-water drainage occurring during the rise, and (2) the selection of the specific yield value. The specific yield (Sy) of a material is the ratio of the volume of water which, after being saturated, can be drained by gravity to its own volume. Reported specific yield values in the Horse Creek basin ranged from 0.005 to 0.2 at 7 wells having depths from 25 to 50 ft (Southwest Florida Water Management District, 1988). The shallowest well, having a depth of 25 ft and a specific yield value of 0.025, was used to calculate recharge rates in this study because the depth was most similar to the depth of the seven study wells. An example recharge calculation for sample water-level peak 16, selected from the 55 peaks used during the 1993 calendar year, is shown in figure 31 using this method. Rainfall-recharge rates were calculated for 1993 and/or 1994 at seven wells that had a continuous water-level record (table 6). Recharge calculations were performed for five wells that had a continuous record for either 1993 or 1994. However, Brushy Creek and Buzzard Roost wells had continuous water-level record for both years. Annual rainfall-recharge for the West Fork Buzzard Roost well (W7) was not calculated due to periods of missing record.

Calculated recharge estimates in 1993 at four wells, ranged from 3.26 to 16.06 in., with an average recharge of 8.66 in. The Lettis Creek well (W3) had the lowest rainfall (42 in.) and recharge (3.26 in.). The high

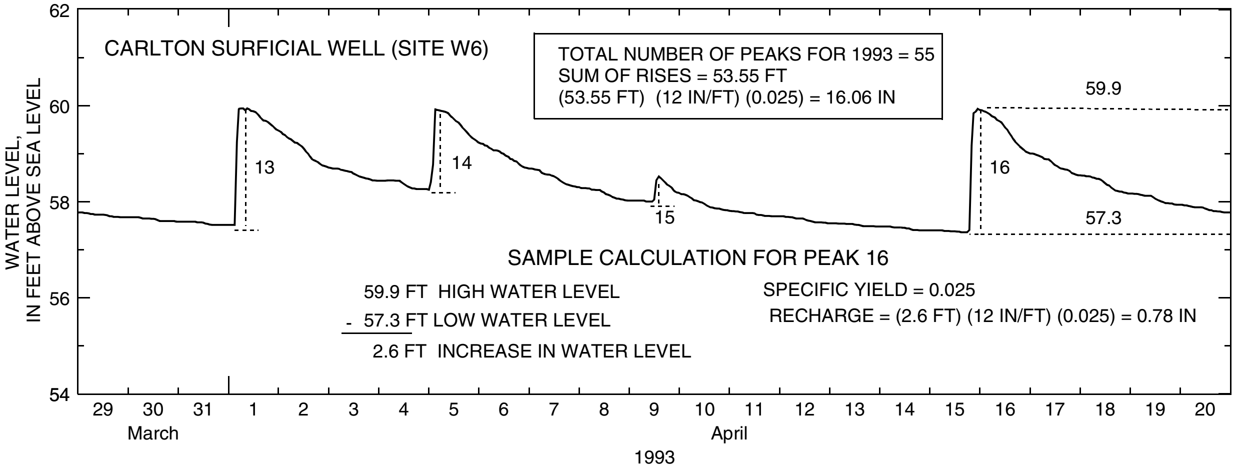


Figure 31. Sample rainfall-recharge calculation for peak 16 at the Carlton well on April 15, 1993 using the well hydrograph method.

calculated rainfall-recharge at the Carlton well (W1) in 1993 (16.06 in.) is the result of numerous large water-level rises in the surficial aquifer that totaled 53.55 ft, approximately double the rises of the other three wells in 1993. Recharges calculated at five wells in 1994, ranging from 5.90 to 12.50 in., had smaller estimates than in 1993. The average annual recharge for the five wells used in 1994 was 8.44 in. Brushy Creek and Buzzard Roost wells had similar annual recharge rates for both 1993 and 1994 (table 6). The average estimated recharge for the Horse Creek basin using the well hydrograph method for 1993-94 is 8.5 in/yr.

Table 6. Ground-water recharge estimates in the Horse Creek basin using the well hydrograph method

[1]Well	Well name	Sum of rises (feet)	Total rainfall (inches)	Recharge [5]Sy 0.025 (inches)	Recharge (inches/ year)
		[2]1993			
W3	Lettis Creek	10.88	42	3.3	
W5	Brushy Creek	24.06	[3]54	7.2	
W6	Carlton Ranch	53.55	57	16.1	
W8	Buzzard Roost	26.96	[3]54	8.1	
	Horse Creek basin average annual recharge for 1993				8.7
		[2]1994			
W1	Watkins Road	41.67	[4]66	12.5	
W2	Mitchell Hammock	23.06	[4]66	6.9	
W4	West Fork Horse Creek	19.68	51	5.9	
W5	Brushy Creek	28.25	[4]66	8.5	
W8	Buzzard Roost	27.92	[4]66	8.4	
	Horse Creek basin average annual recharge for 1994				8.4
	Horse Creek basin average annual recharge for 1993-94				8.6

[1]Well locations are shown on figure 1.

[2]Calendar year.

[3]Rainfall totals for 1993 at Wauchula (NOAA, 1993).

[4]Rainfall totals for 1994 at Ft. Green (NOAA, 1994).

[5]Specific yield.

Chloride Ratio Method

The chloride concentration in atmospheric deposition (rainfall plus dry deposition) was compared to the chloride concentration in water at the water table in the surficial aquifer. Chloride concentrations in the surficial aquifer should reflect the enrichment of chloride in wet (plus dry) deposition by evapoconcentration (Lee, 1996). The average recharge to the water table was calculated from chloride concentrations from composite rainfall samples collected at approximately 8-week intervals and water samples collected from the water table using the following equation:

$$R_{gw} = (Cl_p / Cl_{gw})P \qquad (2)$$

where

R_{gw} is recharge to the water table, in inches;
Cl_p is precipitation chloride concentration, in milligrams per liter;
Cl_{gw} is ground-water chloride concentration, in milligrams per liter; and
P is precipitation, in inches.

Chloride concentration from 53 ground-water samples collected from the eight surficial aquifer wells were used to estimate recharge in the Horse Creek basin. Chloride concentrations of ground-water ranged from 2.2 to 120 mg/L (table 7). A rainfall chloride concentration value of 1.0 mg/L was used in all chloride concentration analyses. Krulikas and Giese (1995) determined that a rainfall chloride concentration value of 1.0 mg/L represents long-term conditions adjusted for dryfall deposition in west-central Florida using the chloride ratio method. Using the reported long-term rainfall of 53 in/yr at Arcadia (NOAA, 1992), calculated annual recharge using equation 2 for the 54 samples ranged from 0.8 to 24.0 in/yr; and the average recharge for the eight well locations ranged from 0.14 to 17.89 in/yr. The average estimated recharge for the Horse Creek basin using the chloride ratio method for 1993-94 is 9.2 in/yr.

Table 7. Ground-water recharge estimates in the Horse Creek basin using the chloride ratio method

Sample no.	Sampling period		Well chloride (mg/L)	Recharge (inches/ year)	Average recharge 1993-94 (inches/ year)
	Begin date	End date			
		WATKINS ROAD WELL (W1)			
1	7-22-93	8-30-93	3.90	13.6	
2	8-30-93	10-13-93	4.40	12.0	
3	10-13-93	12-06-93	3.80	14.0	
4	12-06-93	1-26-94	2.70	19.6	
5	1-26-94	3-21-94	15.0	3.5	
6	10-12-94	12-14-94	2.30	23.0	
7	12-14-94	2-21-94	3.80	14.0	14.2
		MITCHELL HAMMOCK WELL (W2)			
8	7-22-93	8-30 93	11	4.8	
9	8-30-93	10-14-93	15	3.5	
10	10-14-93	12-06-93	34	1.6	
11	5-04-94	6-16-94	11	4.8	
12	6-16-94	7-27-94	18	2.9	
13	10-12-94	12-14-94	29	1.8	
14	12-14-94	[1]2-21-95	21	2.5	3.1

Table 7. Ground-water recharge estimates in the Horse Creek basin using the chloride ratio method (Continued)

Sample no.	Sampling period		Well chloride (mg/L)	Recharge (inches/ year)	Average recharge 1993-94 (inches/ year)
	Begin date	End date			
LETTIS CREEK WELL (W3)					
15	7-22-93	8-30 93	6.70	7.9	
16	8-30-93	10-14-93	7.00	7.6	
17	10-14-93	12-06-93	6.80	7.8	
18	12-06-93	1-26-94	8.90	6.0	
19	3-21-94	5-04-94	8.30	6.4	
20	5-04-94	6-16-94	15.0	3.5	6.5
WEST FORK HORSE CREEK WELL (W4)					
21	8-30-93	10-13-93	4.60	11.5	
22	10-13-93	12-08-93	4.30	12.3	
23	12-08-93	1-26-94	4.90	10.8	
24	1-26-94	3-21-94	4.20	12.6	
25	3-21-94	5-04-94	4.10	12.9	
26	5-04-94	6-16-94	2.90	18.3	
27	6-16-94	7-28-94	4.80	11.0	
28	7-28-94	10-12-94	1.60	33.0	
29	10-12-94	12-14-94	5.20	10.2	14.8
BRUSHY CREEK WELL (W5)					
30	8-30-93	10-21-93	21.0	2.5	
31	10-21-93	12-08-93	26.0	2.0	
32	12-08-93	1-27-94	28.0	1.9	
33	3-22-94	5-06-94	23.0	2.3	
34	6-15-94	7-27-94	26.0	2.0	2.2
CARLTON WELL (W6)					
35	9-01-93	10-14-93	2.4	22.1	
36	1-27-94	3-21-94	3.5	15.1	
37	3-21-94	5-04-94	3.4	15.6	
38	5-04-94	6-15-94	4.2	12.6	
39	10-13-94	[1]1-05-95	2.2	24.0	17.9
WEST FORK BUZZARD ROOST WELL (W7)					
40	8-31-93	10-15-93	98	0.5	
41	12-07-93	1-27-94	120	.4	
42	3-22-94	5-05-94	58	.9	
43	5-05-94	6-15-94	100	.5	
44	7-28-94	10-13-94	12	4.4	
45	10-13-94	12-13-94	11	4.8	
46	12-13-94	[1]2-23-95	110	.5	1.5
BUZZARD ROOST WELL (W8)					
48	8-31-93	10-15-93	2.80	18.9	
50	3-22-94	5-05-94	5.10	10.4	
51	5-05-94	6-15-94	6.70	7.9	
52	6-15-94	8-01-94	5.00	10.6	
53	10-13-94	[1]1-05-95	3.00	17.7	13.1
[2]54	1-05-95	2-23-95	5.10	10.4	
Annual average for all sites					9.2

[1] Partial month sampling period included in analysis.

[2] 1995 data not included in analysis.

Streamflow Hydrograph Separation Method

The streamflow hydrograph separation method estimates recharge to the water table by defining what part of a storm hydrograph curve is ground-water discharge. This method is based on the assumptions that: (1) the rainfall volume generating the storm hydrograph is evenly distributed throughout the basin, (2) the ground-water discharge is uniformly contributed from each square mile of the drainage basin to the stream, and (3) there is no deep seepage flow into or out of the drainage basin. An example of how a typical storm hydrograph is subdivided for analysis into the three components: (1) surface runoff, (2) ground-water discharge, and (3) the ground-water depletion curve is shown in figure 18. A ground-water hydrograph for the surficial aquifer well, located nearest to each of the six daily discharge station, was also plotted for each concurrent hydrograph period to compare the surface and ground-water interaction. Both the ground-water depletion curve, which represents the depletion of residual ground-water discharge from the water table to the channel from an earlier storm, and ground-water discharge comprise total ground-water discharge (baseflow). Calculation of the ground-water discharge component of the storm hydrograph was used to estimate recharge to the water table in the subbasin. Rainfall and recharge for the 36 selected storms used in the study are summarized in table 5. Two typical storm hydrographs were selected from each of the six subbasins are shown in figure 17. Data for frontal storm hydrographs (storms which occur during the winter months) were selected more frequently for plotting because these storms typically are isolated events that produce a single peak discharge. Recharge estimates of the 36 storms using the hydrograph separation method generally were small, and ranged from 1.5 in/yr at the Brushy Creek subbasin to 9.0 in/yr at West Fork Horse Creek subbasin (table 8). Annual average recharge estimates in the Horse Creek basin using the hydrograph separation method were 4.8 in/yr in 1993 from 18 storms, and 3.8 in/yr in 1994 from 14 storms. Annual recharge was determined using proportionality. The ratio of total annual rainfall and the sum of rainfall for the selected storm events at each subbasin equaled the ratio of annual recharge and the sum of calculated recharge for each subbasin. Annual rainfall totals used for estimating recharge in the Horse Creek basin were the reported values of 54 in. at Wauchula in 1993 and 66 in. at Ft. Green in 1994 (NOAA, 1993 and 1994).

Annual average recharge for the Horse Creek basin for 1993 and 1994 was estimated at 4.3 in/yr. Annual recharge for each subbasin is determined by the following equation:

$$Rf_t / Rf_s = Rc_{yr} / Rc_s \qquad (3)$$

where

Rf_t is total annual rainfall, in inches per year;
Rf_s is sum of rainfall for selected storms, in inches;
Rc_{yr} is annual recharge, in inches per year; and
Rc_s is sum of recharge for selected storms, in inches.

Comparison of Recharge Estimation Methods

Rainfall-recharge estimates for individual occurrences for each of the three methods generally showed a wide range of recharge values (tables 6-8). However, the estimated average annual recharges were similar for the well hydrograph and chloride ratios methods, which used data for the same eight wells to estimate recharge through (1) rises in water-table levels or (2) chloride concentrations in ground water, respectively (table 9). Estimated recharge using the streamflow hydrograph separation method may have been less than estimated recharge from the other two methods because of riparian evapotranspiration.

WATER-QUALITY CONDITIONS

Surface and ground-water samples were collected in the Horse Creek basin and analyzed to establish a water-quality baseline to be used for assessing the effects of future development and proposed phosphate strip-mining. Water-quality sample collection was performed quarterly at the six daily discharge stations and bi-annually at the eight surficial aquifer wells. Water samples were analyzed for the following chemical constituents: major dissolved ions, alkalinity, dissolved solids, strontium, silica, nutrients (nitrogen and phosphorus species), and color. Field measurements of specific conductance and pH were also made. In addition, rainwater and ground-water samples were collected for chloride analysis from the mini drive-point wells and rainfall gages near the eight surficial aquifer well locations.

Table 8. Ground-water recharge in the Horse Creek basin using the streamflow hydrograph separation method

Site no.	Station	No. of storm hydro-graphs	Year	Total annual rainfall (inches)	Annual recharge (inches/ year)	Average recharge (inches/year)
10	West Fork Horse Creek	4	1993	54	9.0	8.2
		2	1994	66	7.5	
11	Horse Creek (Myakka Head)	3	1993	54	5.5	5.2
		3	1994	66	5.0	
20	Brushy Creek	4	1993	54	1.5	1.6
		1	1994	66	1.8	
55	Brandy Branch	2	1993	54	4.4	4.4
		3	1994	66	4.5	
61a	Buzzard Roost Branch	2	1993	54	3.8	3.1
		3	1994	66	2.4	
78	Horse Creek (Arcadia)	3	1993	54	4.3	3.0
		3	1994	66	1.7	
	Average annual recharge for all stations for 1993 and 1994					4.3

Table 9. Comparison of ground-water recharge methods in the Horse Creek basin

Site no.	Station/well	Well hydrograph (inches/year)	Chloride ratio (inches/year)	Streamflow hydrograph separation (inches/year)
10	West Fork Horse Creek			7.2
W4	West Fork Horse Creek surficial	5.9	2.4	
11	Horse Creek (Myakka Head)			5.2
W1	Watkins Road surficial	12.5	14.2	
20	Brushy Creek			1.6
W2	Mitchell Hammock surficial	6.9	3.1	
W3	Lettis Creek surficial	3.3	6.5	
W4	Brushy Creek surficial	[1]7.8	0.1	
55	Brandy Branch			4.4
61a	Buzzard Roost Branch			3.1
W7	West fork Buzzard Roost	--	1.5	
W8	Buzzard Roost surficial	[1]8.2	13.1	
78	Horse Creek (Arcadia)			3.0
W6	Carlton	16.1	17.9	
	Average recharge for 1993-94	8.7	7.4	3.6

[1] Average of 1993 and 1994 calculations.

At times, the concentration of a constituent was below analytical reporting limits (these data are called "censored data"). Calculations using censored data can only be done if a value is substituted for the censored data. However, simple substitution of a value for censored data introduces a bias in the results, because the actual concentration is unknown. Substituting a value of zero for all censored data will bias the results low, whereas substituting the reporting limit biases the results high (Helsel and Hirsch, 1995). For graphical display of such data, censored data were assigned a value of one half the analytical reporting limit. For example, the reporting limit for sulfate was 0.20 mg/L. Values for sulfate below the reporting limit were set to 0.10 mg/L.

Water in the Surficial Aquifer

A time-series plot of concentrations of selected constituents in water from the surficial aquifer at the eight wells in the Horse Creek basin is shown in figure 32 and a statistical summary is listed in table 10. Specific conductance of water samples ranged from 578 μS/cm at the West Fork Buzzard Roost well (site W7) to 21 μS/cm at the West Fork Horse Creek well (site W4). Dissolved solids concentrations, based on residue after evaporation, ranged from 451 mg/L at the West Fork Buzzard Roost well (site W7) to 8 mg/L at the Watkins Road well (site W1).

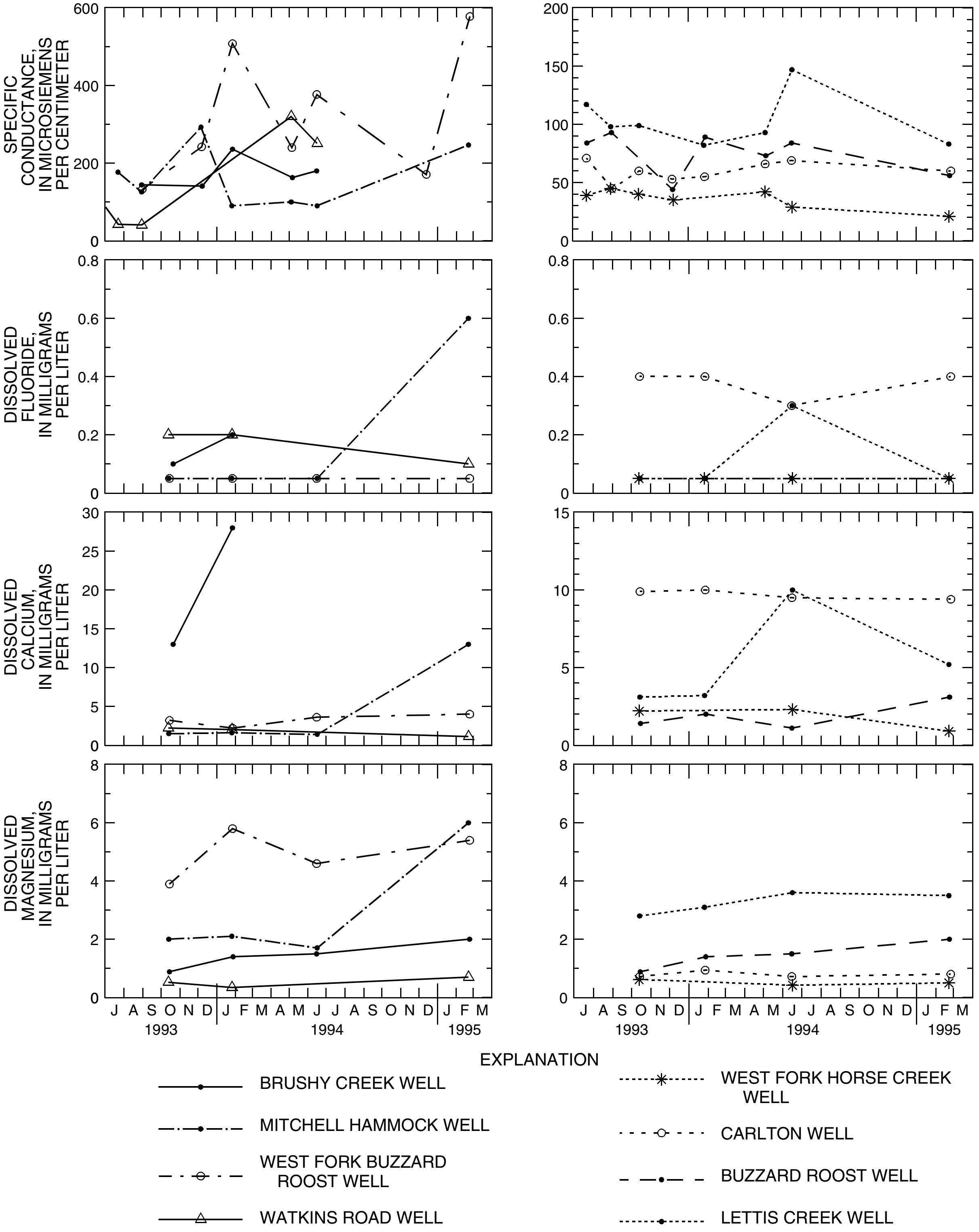


Figure 32. Concentrations of selected properties and constituents in water from eight surficial aquifer wells in the Horse Creek basin.

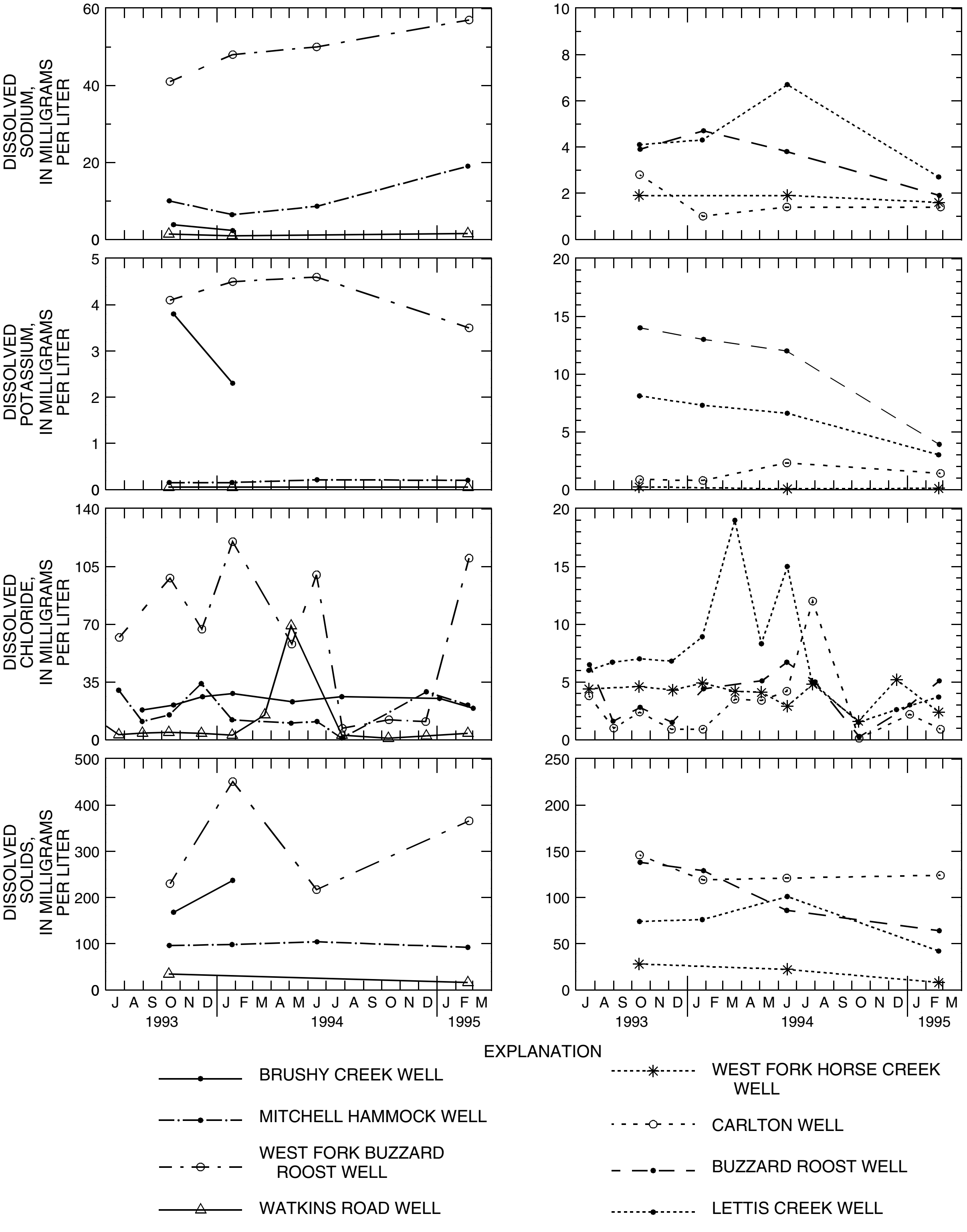


Figure 32. Concentrations of selected properties and constituents in water from eight surficial aquifer wells in the Horse Creek basin. (Continued)

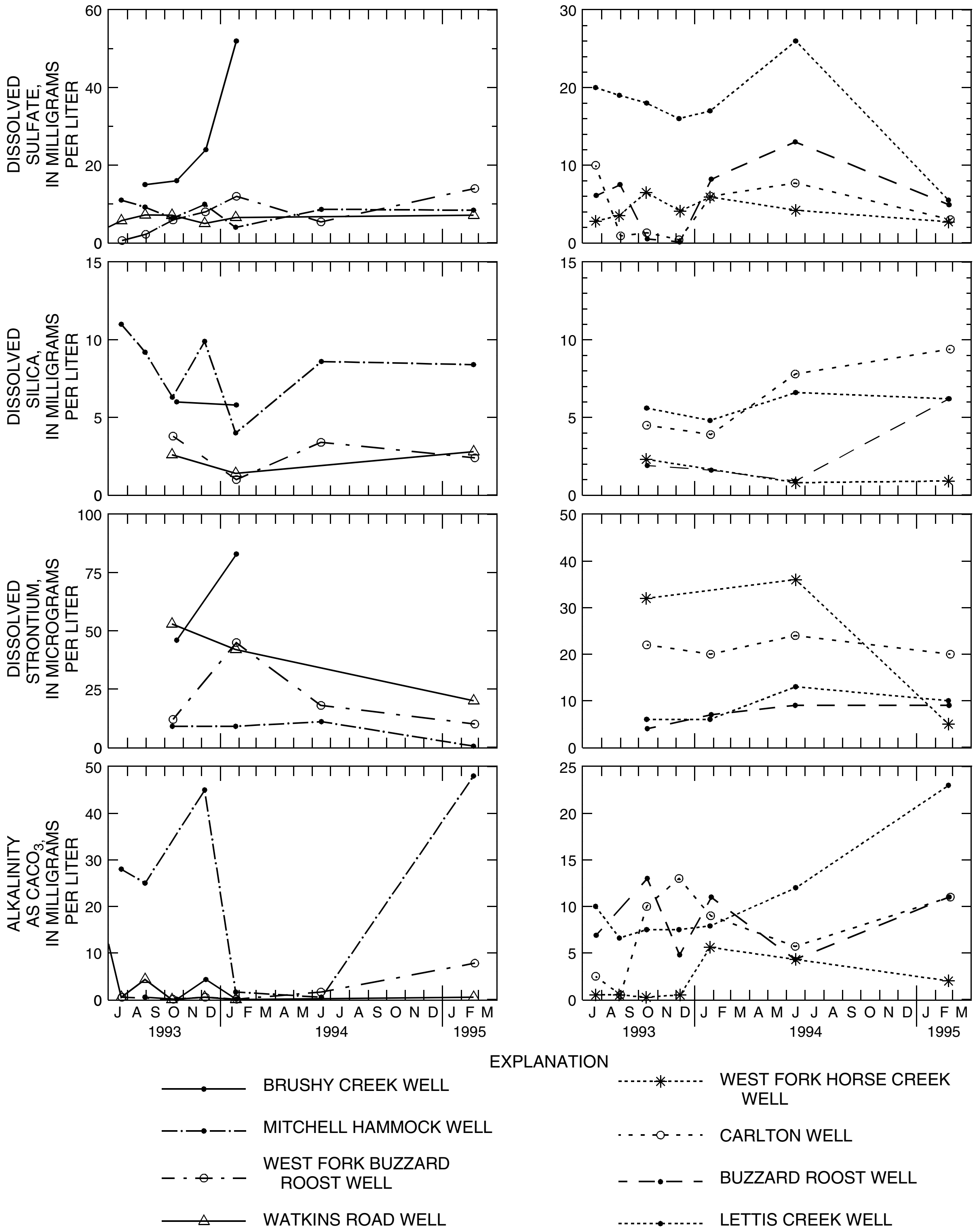


Figure 32. Concentrations of selected properties and constituents in water from eight surficial aquifer wells in the Horse Creek basin. (Continued)

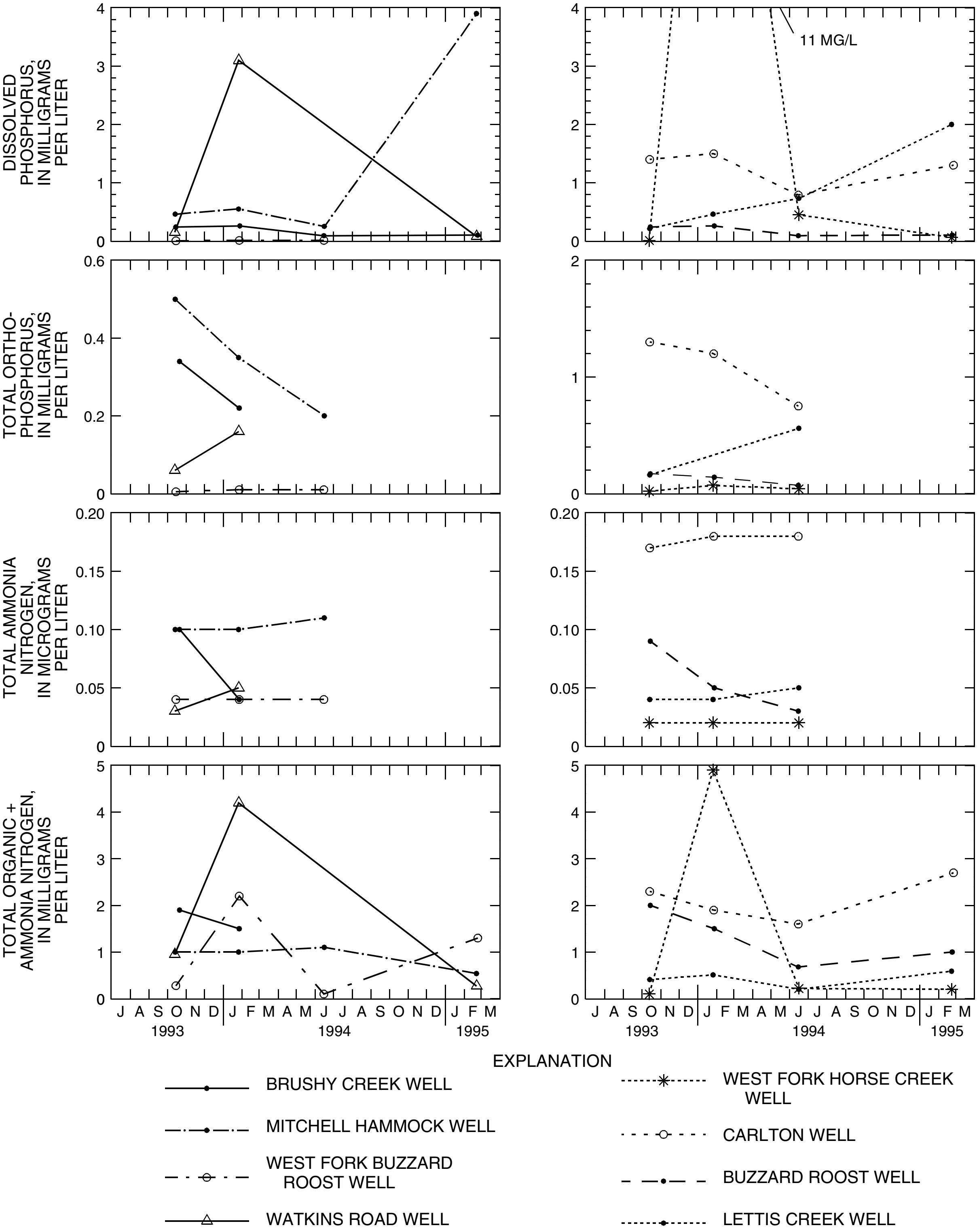


Figure 32. Concentrations of selected properties and constituents in water from eight surficial aquifer wells in the Horse Creek basin. (Continued)

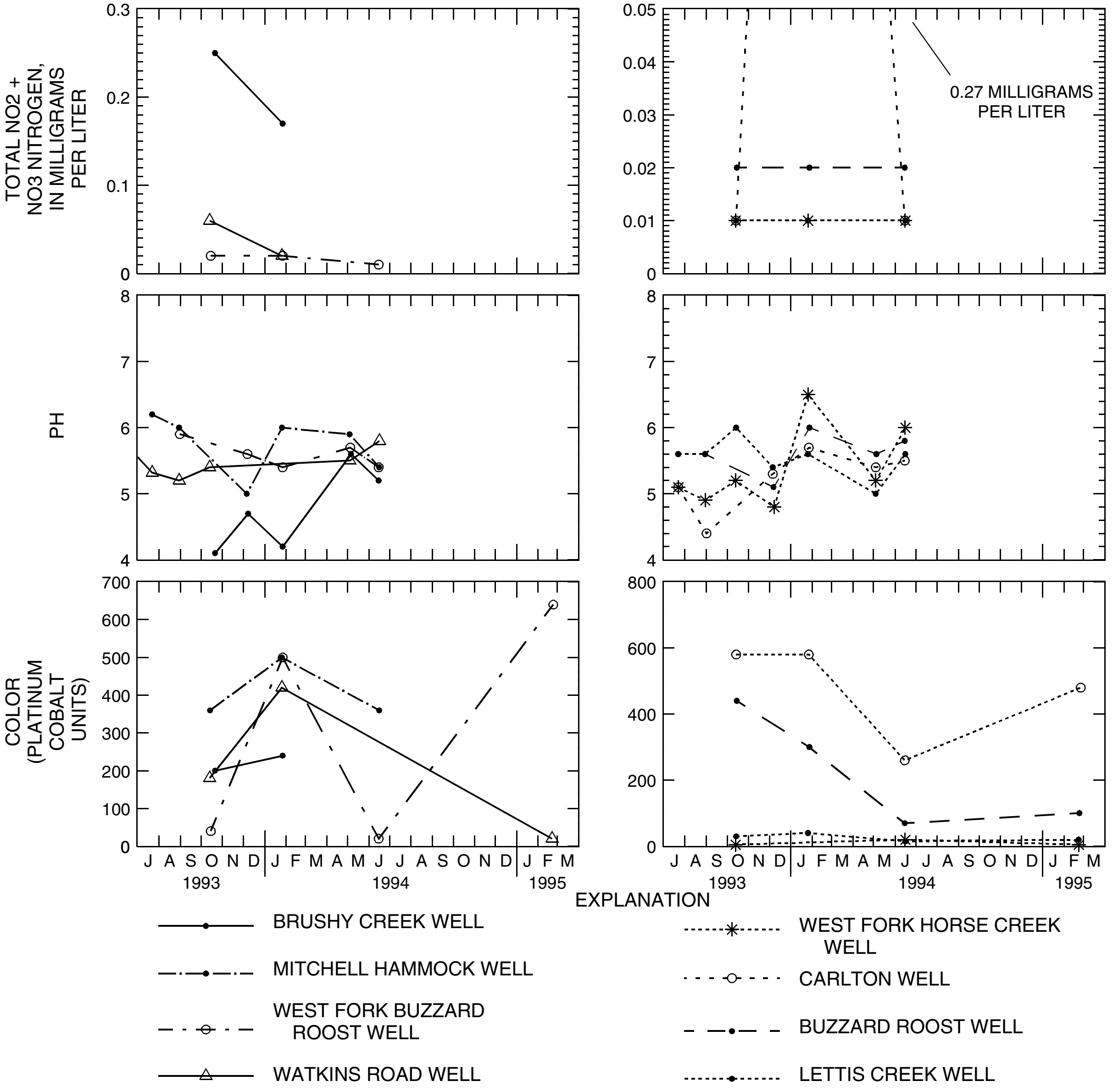


Figure 32. Concentrations of selected properties and constituents in water from eight surficial aquifer wells in the Horse Creek basin. (Continued)

Table 10. Statistical summary of physical and chemical constituents in surficial aquifer water in the Horse Creek basin, 1993-95

[Pt-Co, platinum-cobalt; --, no data; mS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; <, less than]

Property or constituent	No. samples	Watkins Road Well (Site W1)			No. samples	Mitchell Hammock Well (Site W2)			No. samples	Lettis Well (Site W3)		
		Max	Mean	Min		Max	Mean	Min		Max	Mean	Min
Color (Pt-Co units)	3	420	--	<5	4	500	--	5.0	4	40	--	15
Specific conductance (µS/cm)	6	320	--	41	7	293	160	90	7	147	103	82
pH (standard units)	6	5.8	--	4.7	6	6.2	5.75	5.0	7	6.0	5.5	5.0
Nitrogen, ammonia, total (mg/L as N)	3	0.05	--	0.03	3	0.11	--	0.10	3	0.05	--	0.04
Nitrogen, ammonia + organic, total (mg/L as N)	3	4.2	--	.27	4	1.1	--	.54	4	.59	--	.20
Nitrogen, NO_2 + NO_3, total (mg/L as N)	3	.06	--	.02	3	.05	--	.02	3	0.02	--	<0.02
Phosphorus, total (mg/L as P)	3	3.1	--	.08	4	3.9	--	0.25	4	2.0	--	0.21
Calcium, dissolved (mg/L as Ca)	3	2.2	--	1.1	4	13.0	--	1.4	4	10	--	3.1
Magnesium, dissolved (mg/L as Mg)	4	.70	--	.34	4	6.0	--	1.7	4	3.6	--	2.8
Sodium, dissolved (mg/L as Na)	3	1.5	--	.87	4	19.0	--	6.4	4	6.7	--	2.7
Potassium, dissolved (mg/L as K)	4	<.10	--	<.10	4	.21	--	.15	4	8.1	--	3.0
Chloride, dissolved (mg/L as Cl)	13	69.0		.15	10	34.0	17.4	.94	12	19	7.5	1.5
Sulfate, dissolved (mg/L as SO_4)	8	7.2		2.5	7	11.0	8.2	4.0	7	26	17.4	5.5
Fluoride, dissolved (mg/L as F)	2	.20	--	.20	4	.6	--	<.10	4	.30	--	<.10
Silica, dissolved (mg/L as SiO_2)	3	2.8	--	1.4	4	12.0	--	6.2	4	6.6	--	4.8
Strontium, dissolved (µg/L as Sr)	3	53	--	20	4	11	--	<1.0	4	13	--	6
Orthophosphorus, total (mg/L as P)	2	.16	--	.06	3	.50	--	.20	2	.56	--	.16
Alkalinity (mg/L as $CaCO_3$)	8	24	--	<1.0	7	48.0	21.4[1]	<1.0	7	23	10.6	6.6
Solids, sum of constituents, dissolved (mg/L)	3	34.0	--	2.0	4	104	--	92.0	4	101	--	42

[1] Mean value is estimated using a log-progability regression to predict the values below the detection limit.

Table 10. Statistical summary of physical and chemical constituents in surficial aquifer water in the Horse Creek basin, 1993-95 (Continued)

[Pt-Co, platinum-cobalt; --, no data; mS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; <, less than]

Property or constituent	No. samples	West Fork Horse Creek Well (Site W4)			No. samples	Brushy Creek Well (Site W5)			No. samples	Carlton Well (Site W6)		
		Max	Mean	Min		Max	Mean	Min		Max	Mean	Min
Color (Pt-Co units)	4	20	--	<5	2	240	--	200	4	580	--	260
Specific conductance (µS/cm)	7	45	35.8	21	5	236	--	141	9	71	60	45
pH (standard units)	7	6.5	5.4	4.8	5	5.6	--	4.1	7	5.7	5.2	4.4
Nitrogen, ammonia, total (mg/L as N)	3	0.02	--	0.02	2	0.10	--	0.04	3	0.18	--	0.17
Nitrogen, ammonia + organic, total (mg/L as N)	4	4.9	--	<.20	2	1.9	--	1.5	4	2.7	--	1.6
Nitrogen, $NO_2 + NO_3$, total (mg/L as N)	3	<.20	--	<.20	2	.25	--	.17	3	.27	--	<.02
Phosphorus, total (mg/L as P)	4	11	--	<.20	2	.37	--	.25	4	1.5	--	.79
Calcium, dissolved (mg/L as Ca)	3	2.3	--	0.9	2	28	--	13	4	10	--	9.4
Magnesium, dissolved (mg/L as Mg)	3	6.2	--	.42	2	1.2	--	.94	4	.94	--	.72
Sodium, dissolved (mg/L as Na)	3	1.9	--	1.6	2	6.4	--	5.0	4	2.8	--	1.0
	4	--										
Potassium, dissolved (mg/L as K)	3	.22	--	<.10	2	3.8	--	2.3	4	2.3	--	.78
Chloride, dissolved (mg/L as Cl)	11	5.2	3.9	1.6	8	28	23	18	13	12	2.96	.12
Sulfate, dissolved (mg/L as SO_4)	7	6.5	4.2	2.7	4	52	--	15	8	10	4.29	.40
Fluoride, dissolved (mg/L as F)	4	<.10	--	<.10	2	.20	--	.10	4	.40	--	.30
Silica, dissolved (mg/L as SiO_2)	3	2.3	--	.80	2	6.0	--	5.8	4	9.4	--	3.9
	3	1.9										
Strontium, dissolved (µg/L as Sr)	3	36	--	5	2	83	--	46	4	24	--	20
Orthophosphorus, total (mg/L as P)	3	.07	--	.02	2	.34	--	.22	3	1.3	--	.75
Alkalinity (mg/L as $CaCO_3$)	7	5.6	--	<.50	4	--	--	--	8	13	7.6[1]	<1.0
Solids, sum of constituents, dissolved (mg/L)	3	28	--	8	2	237	--	168	8	146	--	119

[1] Mean value is estimated using a log-probability regression to predict the values below the detection limit.

Table 10. Statistical summary of physical and chemical constituents in surficial aquifer water in the Horse Creek basin, 1993-95 (Continued)

[Pt-Co, platinum-cobalt; --, no data; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; <, less than]

Property or constituent	No. of samples	West Fork Buzzard Roost Well (Site W7)			No. of samples	Buzzard Roost Well (Site W8)		
		Max	Mean	Min		Max	Mean	Min
Color (Pt-Co units)	4	640	--	20	34	440	--	70
Specific conductance (µS/cm)	7	578	321	133	77	93	74.7	44
pH (standard units)	5	5.9	--	5.4	5	6.0	--	5.1
Nitrogen, ammonia, total (mg/L as N)	3	0.04	--	0.04	3	0.09	--	0.03
Nitrogen, ammonia + organic, total (mg/L as N)	4	2.2	--	<.2	4	2.0	--	.68
Nitrogen, NO_2 + NO_3, total (mg/L as N)	3	.02	--	<.02	.02	--	<.02	--
Phosphorus, total (mg/L as P)	4	0.07	--	0.02	4	.26	--	.09
Calcium, dissolved (mg/L as Ca)	4	22	--	3.2	4	3.1	--	1.1
Magnesium, dissolved (mg/L as Mg)	4	5.8	--	3.9	4	2.0	--	.88
Sodium, dissolved (mg/L as Na)	4	57	--	41	4	4.7	--	1.9
Potassium, dissolved (mg/L as K)	4	4.6	--	3.5	4	14.0	--	3.9
Chloride, dissolved (mg/L as Cl)	10	120	64.5	6.9	11	6.7	3.8	.25
Sulfate, dissolved (mg/L as SO_4)	7	14	6.87	.6	7	13.0	5.8[1]	.50
Fluoride, dissolved (mg/L as F)	4	<.10	--	<.10	4	--	--	--
Silica, dissolved (mg/L as SiO_2)	4	3.8	--	1.0	4	6.2	--	0.9
Strontium, dissolved (µg/L as Sr)	4	45	--	10	4	9.0	--	4.0
Orthophosphorus, total (mg/L as P)	3	--	--	--	3	.17	--	.07
Alkalinity (mg/L as $CaCO_3$)	6	7.8	--	<.1	6	13.0	--	4.3
Solids, sum of constituents, dissolved (mg/L)	4	451	--	217	4	138	--	64

[1] Mean value is estimated using a log-probability regression to predict the values below the detection limit.

Ground water in the Horse Creek basin is characterized by relatively low specific conductance, alkalinity, and dissolved solids concentrations. Differences in values or concentrations for the other properties and constituents between all sites are generally small. However, elevated concentrations of dissolved solids, magnesium, sodium, potassium, chloride, and specific conductance values analyzed from water at site West Fork Buzzard Roost well (site W7) may indicate an upward leakage of ground water from the lower confined aquifers.

Nitrogen and Phosphorus

Nitrogen compounds in water samples for the surficial aquifer system included nitrite and nitrate, ammonia, and organic nitrogen. Concentrations of dissolved nitrite and nitrate (NO_2+NO_3) were generally at or below detection limit (0.2 mg/L as N), except at the Brushy Creek (site W5) and the Carlton (site W6) wells, which had values of 0.25 and 0.27 mg/L, respectively (fig. 32). Concentrations of ammonia and organic nitrogen ranged from at or below detection limit (0.2 mg/L as N) at three wells to 4.9 mg/L at West Fork Horse Creek (site W4). Concentrations of ammonia ranged from 0.02 to 0.18 mg/L, with most values less than 0.1 mg/L.

Total phosphorous concentrations in water from the surficial aquifer system ranged from below the detection limit of 0.02 to 11 mg/L as P; both low and high values were analyzed in water collected from the West Fork Horse Creek well (site W4). The high total phosphorus concentration at the West Fork Horse Creek well may be related to a heavy application of treated sludge as an organic fertilizer in fields near the creek. Concentrations of orthophosphorus ranged from below the detection limit of 0.01 to 1.3 mg/L.

Major Constituents

Major constituents, as discussed in this section, include those cations and anions that constitute the bulk of the dissolved solids and commonly occur in concentrations exceeding 1.0 mg/L. The major dissolved cations generally are calcium, magnesium, sodium, and potassium; the major anions are sulfate, chloride, nitrate, and constituents contributing to alkalinity, primarily bicarbonate and carbonate (Hem, 1989).

At the eight study wells, pH values for water samples from the surficial aquifer system ranged from 4.1 to 6.5 standard units (fig. 32). Alkalinity concentrations in ground-water samples ranged from below the detection limit of 1.0 to 48 mg/L as $CaCO_3$. At times, alkalinity values varied widely from sample to sample, but most concentrations were less than 10 mg/L. Concentrations of calcium ranged from 0.9 to 28 mg/L at the Brushy Creek well (site W5). Most calcium values in water samples from the eight surficial aquifer wells were near or below 10 mg/L. Chloride concentrations generally were less than 35 mg/L in the study area, and ranged from 0.12 to 120 mg/L. Sulfate concentrations were relatively low, with most values below 25 mg/L; concentrations ranged from 0.5 to 52 mg/L. Sodium concentrations ranged from 0.87 to 57 mg/L. Magnesium concentrations ranged from 0.42 to 6.2 mg/L, of which both values were from the West Fork Horse Creek well (W4). Fluoride concentrations were relatively low, with many values at or below the detection limit of 0.1 mg/L; concentrations ranged from less than 0.1 to 0.6 mg/L. Strontium concentrations ranged from less than the detection limit of 0.1 to 83 µg/L. Silica ranged from 0.8 to 12 mg/L. Most water samples from the eight surficial aquifer wells were generally mixed and had no dominant cation or anion; however, calcium was the predominant cation in water from the Brushy Creek (site W5) and the Carlton (site W6) wells (fig. 33), and chloride was the dominant anion in water from the West Fork Buzzard Roost well (W7).

Surface Water

Surface-water samples were collected at the four Horse Creek tributary daily discharge stations (fig. 1, sites 10, 20, 55, and 61a) and at the two long-term Horse Creek daily discharge stations near Myakka Head and Arcadia (fig. 1, sites 11 and 78). Samples were collected during baseflow, moderate-, and high-flow conditions. Time-series plots of concentrations for selected constituents are shown in figure 34, and a statistical summary is listed in table 11.

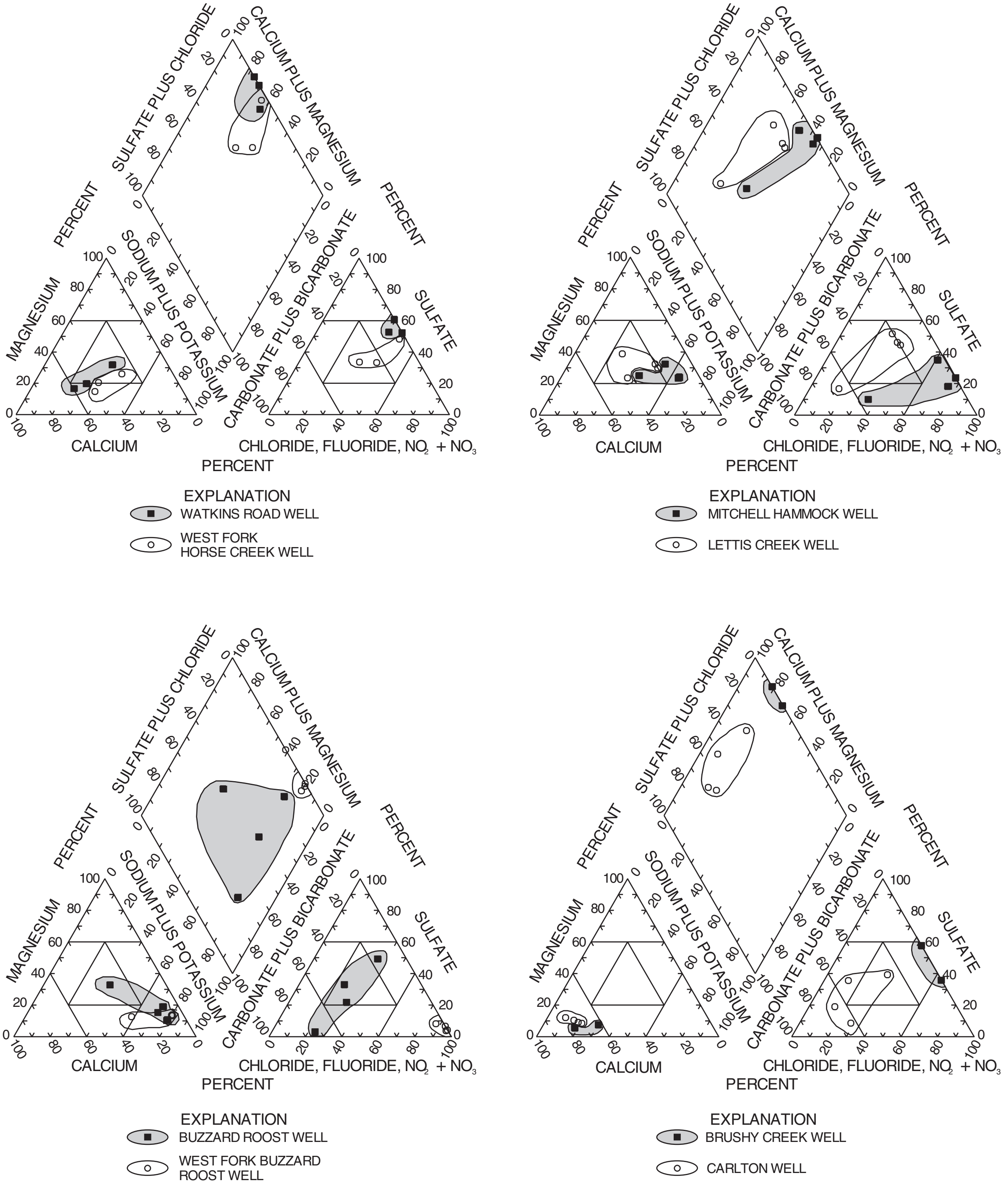


Figure 33. Trilinear diagrams showing major-ion composition of ground water in the surficial aquifer at eight wells in the Horse Creek basin, 1992-95.

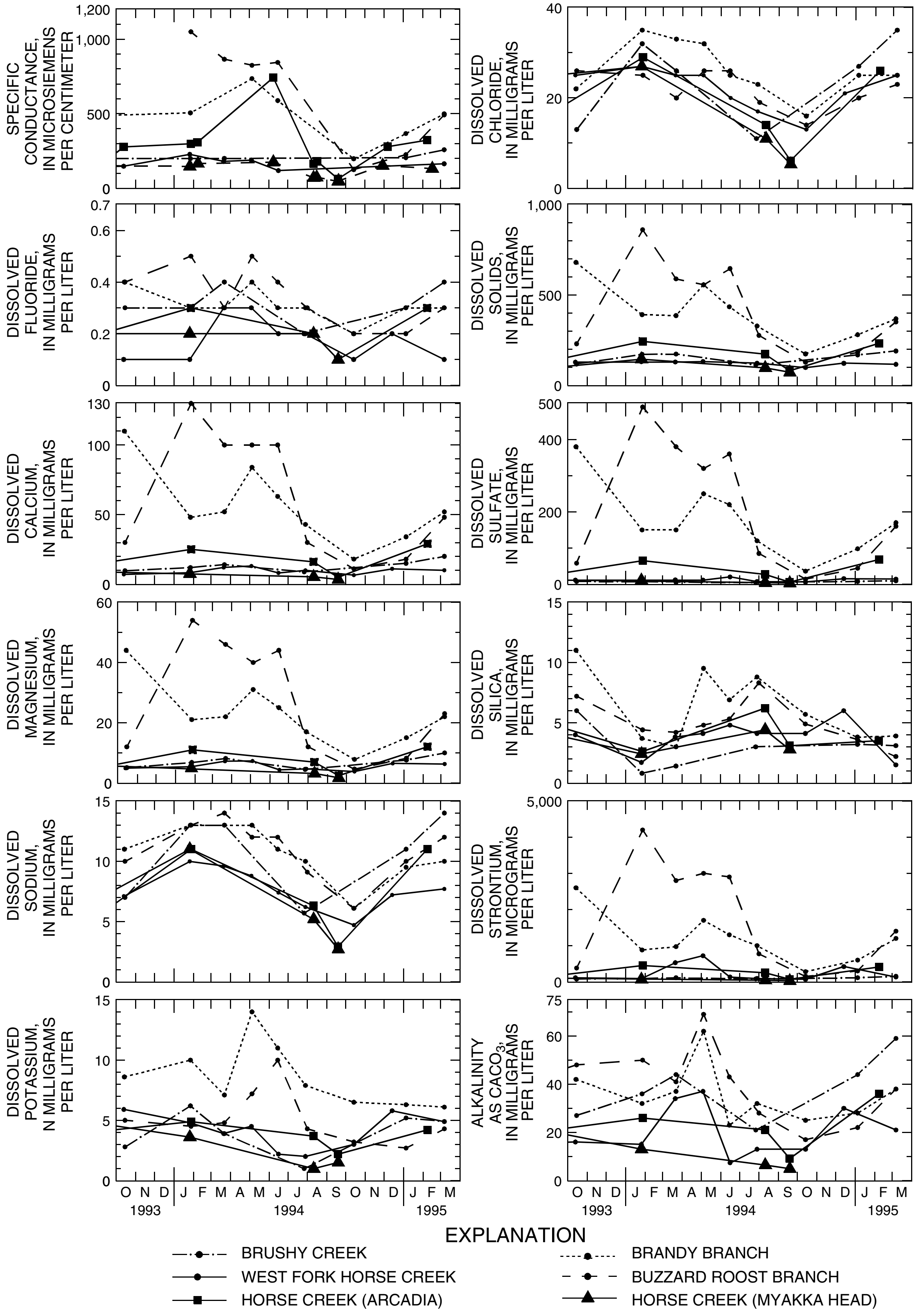


Figure 34. Concentrations of selected constituents in water samples from the Horse Creek near Myakka Head and Arcadia daily discharge stations and at four Horse Creek tributaries, October 1993 to March 1995.

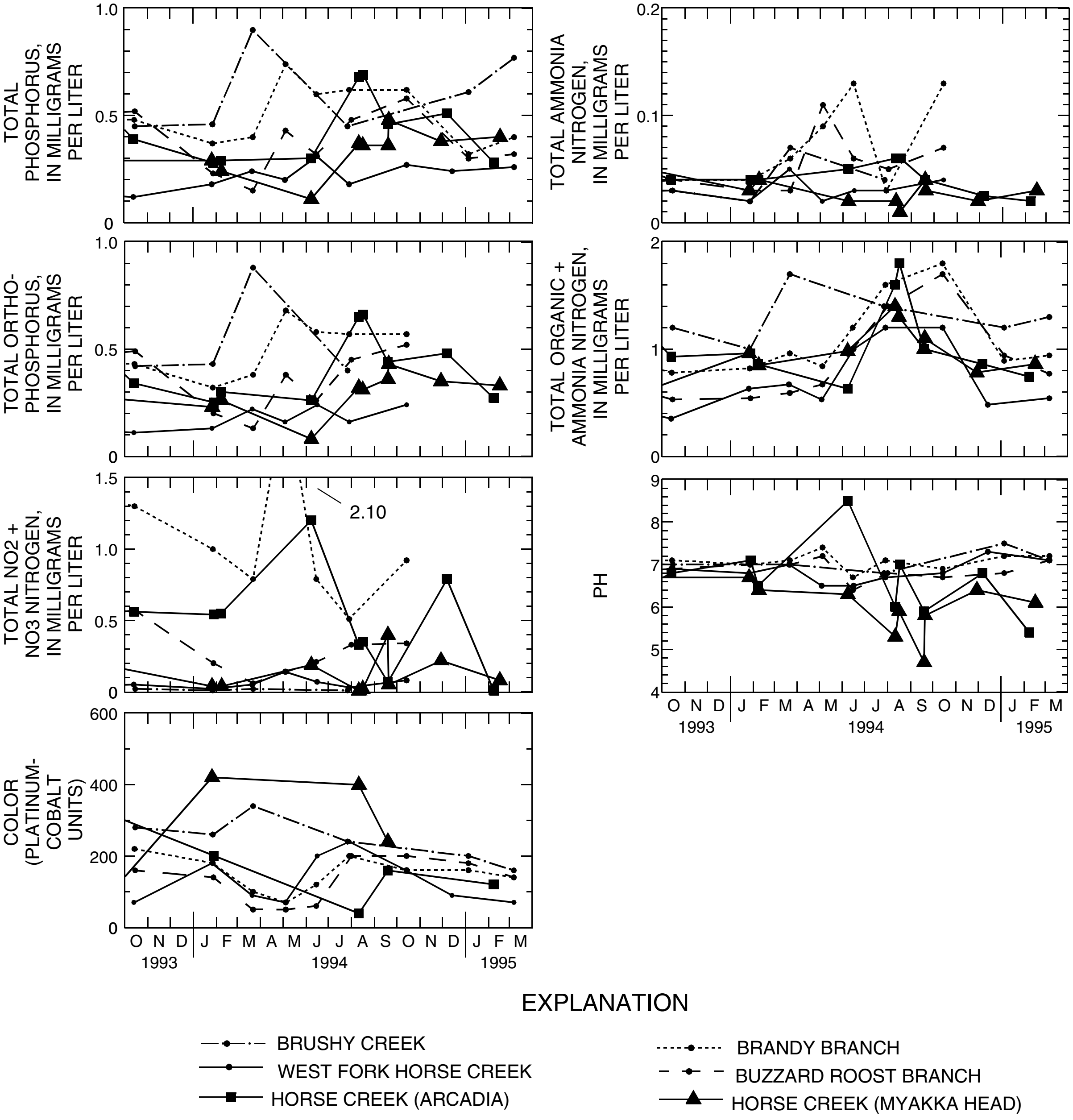


Figure 34. Concentrations of selected constituents in water samples from the Horse Creek near Myakka Head and Arcadia daily discharge stations and at four Horse Creek tributaries, October 1993 to March 1995. (Continued)

Table 11. Statistical summary of physical and chemical constituents in water from streams in the Horse Creek basin, 1993-95

[Pt-Co, platinum-cobalt; --, no data; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; <, less than]

Property or constituent	No. samples	West Fork Horse Creek (Site 10, 02297153)			No. samples	Horse Creek-Myakka Head (Site 11, 02297155)			No. samples	Brushy Creek (Site 20, 02297220)		
		Max	Mean	Min		Max	Mean	Min		Max	Mean	Min
Color (Pt-Co units)	8	240	138	70	5	420	--	90.0	5	340	--	200
Specific conductance (µS/cm)	6	227	165	119	12	175	120	46.0	4	205	--	199
pH (standard units)	5	6.9	--	6.5	12	7.6	6.23	4.7	2	7.1	--	7.0
Nitrogen, ammonia, total (mg/L as N)	7	0.06	0.03	0.02	12	0.05	0.95	0.03	4	0.07	--	0.02
Nitrogen, ammonia + organic, total (mg/L as N)	8	1.2	.76	.35	12	0.05	.03[1]	<.04	5	1.70	--	1.0
Nitrogen, NO_2 + NO_3, total (mg/L as N)	7	.14	.06	.02	12	.40	.13[1]	<.02	4	.02	--	<.02
Phosphorus, total (mg/L as P)	8	.31	.22	.12	12	.40	.34	.11	5	.90	--	.45
Calcium, dissolved (mg/L as Ca)	8	13	9.46	6.4	5	8.9	--	3.4	5	15.0	--	8.8
Magnesium, dissolved (mg/L as Mg)	8	7.3	5.51	3.8	5	5.7	--	1.7	5	8.1	--	4.5
Sodium, dissolved (mg/L as Na)	8	10.0	7.62	4.7	5	11.0	--	2.7	5	13.0	--	5.7
Potassium, dissolved (mg/L as K)	8	5.9	4.01	2.0	5	4.7	--	1.0	5	6.2	--	1.0
Chloride, dissolved (mg/L as Cl)	8	27.0	21.6	13.0	5	27.0	--	5.3	5	32.0	--	11.0
Sulfate, dissolved (mg/L as SO_4)	8	20.0	11.8	6.1	5	11.0	--	2.8	5	7.7	--	4.4
Fluoride, dissolved (mg/L as F)	8	.30	.19	.10	5	.30	--	.10	5	.40	--	.20
Silica, dissolved (mg/L as SiO_2)	8	6.0	4.08	1.7	5	4.7	--	2.4	5	6.0	--	.80
Strontium, dissolved (µg/L as Sr)	8	720	270	67.0	5	100	--	26.0	5	110	--	76.0
Orthophosphorus, total (mg/L as P)	7	.24	.18	.11	12	.43	.31	.08	4	.88	--	.40
Alkalinity (mg/L as $CaCO_3$)	8	37.0	20.7	7.4	5	24.0	--	4.9	5	44.0	--	21.0
Solids, sum of constituents, dissolved (mg/L)	8	131	123	98.0	5	144	--	72.0	5	173	--	113

[1] Mean value is estimated using a log-probability regression to predict the values below the detection limit.

Table 11. Statistical summary of physical and chemical constituents in water from streams in the Horse Creek basin, 1993-95 (Continued)

[Pt-Co, platinum-cobalt; --, no data; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; <, less than]

Property or constituent	No. samples	Brandy Branch (Site 55, 02297272)			No. samples	Buzzard Roost Branch (Site 61a, 02297290))			No. samples	Horse Creek-Arcadia (Site 78, 02297310)		
		Max	Mean	Min		Max	Mean	Min		Max	Mean	Min
Color (Pt-Co units)	8	220	151	70.0	8	200	130	50.0	6	320	167	40.0
Specific conductance (µS/cm)	6	736	476	198	6	1050	656	126	14	743	292	64.0
pH (standard units)	4	7.2	--	5.8	3	7.0	--	5.3	14	8.5	6.82	5.4
Nitrogen, ammonia, total (mg/L as N)	7	0.13	0.07	0.03	7	0.11	0.06	0.03	14	0.06	0.04[1]	<0.02
Nitrogen, ammonia + organic, total (mg/L as N)	8	1.8	1.11	0.78	8	1.7	.92	.53	14	1.8	1.02	.63
Nitrogen, NO_2 + NO_3, total (mg/L as N)	7	2.1	1.06	.51	7	.57	.26	.06	14	4.0	.817[1]	<0.02
Phosphorus, total (mg/L as P)	8	.74	.519	.32	8	.58	.38	.15	14	.69	.437	.28
Calcium, dissolved (mg/L as Ca)	8	110	56.5	18.0	8	130	64.9	11.0	6	29.0	19.2	5.0
Magnesium, dissolved (mg/L as Mg)	8	44.0	22.8	7.8	8	54.0	27.6	4.6	6	12	7.63	2.4
Sodium, dissolved (mg/L as Na)	8	13.0	10.8	6.1	8	14.0	10.8	6.1	6	11.0	7.68	2.9
Potassium, dissolved (mg/L as K)	8	14.0	8.93	6.3	8	10.0	5.21	2.7	6	4.9	3.85	2.2
Chloride, dissolved (mg/L as Cl)	8	35.0	26.4	16.0	8	26.0	22.0	14.0	6	29.0	19.0	6.1
Sulfate, dissolved (mg/L as SO_4)	8	380	176	36.0	8	490	219	14.0	6	68.0	38.3	5.6
Fluoride, dissolved (mg/L as F)	8	.40	.313	.20	8	.50	.35	.20	6	.30	.23	.10
Silica, dissolved (mg/L as SiO_2)	8	11.0	6.55	3.0	8	8.3	5.34	3.6	6	7.8	4.67	2.6
Strontium, dissolved (µg/L as Sr)	8	2600	1170	280	8	4200	1810	150	6	450	272	72.0
Orthophosphorus, total (mg/L as P)	7	.68	.50	.32	7	.52	.35	.13	14	.66	.41	.25
Alkalinity (mg/L as $CaCO_3$)	8	62.0	35.1	23.0	8	69.0	39.8	17.0	6	44.0	26.2	9.2
Solids, sum of constituents, dissolved (mg/L)	8	680	403	172	8	861	434	128	6	243	177	80.0

[1] Mean value is estimated using a log-probability regression to predict the values below the detection limit.

Measurements of specific conductance values at the six surface water sites ranged from 46 µS/cm at Horse Creek near Myakka Head (site 11) to 1,050 µS/cm at Buzzard Roost Branch (site 61a). High color from the leaching of organic debris is common in many natural streams in Florida. Color ranged from 40 platinum-cobalt units at Horse Creek near Arcadia (site 78) to 420 platinum-cobalt units at Horse Creek near Myakka Head (site 11).

Nitrogen and Phosphorus

A comparison of nitrogen and phosphorus species concentrations in water samples collected at the six daily discharge stations indicates that most concentrations generally were low and uniform over time. Total nitrite plus nitrate concentrations as N were less than 1.0 mg/L, except for concentrations of 2.1 mg/L at Brandy Branch (site 55) and 4.0 mg/L at Horse Creek near Arcadia (site 78). Concentrations of ammonia as N ranged from 0.02 at three daily discharge stations to 0.13 mg/L at Brandy Branch (site 55). Concentrations of total organic plus ammonia nitrogen in all streamflow samples ranged from 0.35 to 1.8 mg/L. Concentrations of total phosphorus and orthophosphorus were similar, ranging from 0.11 to 0.90 mg/L and from 0.08 to 88.0 mg/L, respectively.

Major Constituents

The major constituents in water from the streams in the six study subbasins are the cations calcium, magnesium, sodium, and potassium and the anions sulfate, chloride, fluoride, nitrate, and carbonate or bicarbonate. Alkalinity of surface water samples from the study subbasins ranged from 4.9 to 69 mg/L. Concentrations of dissolved solids were less than 300 mg/L in water samples from West Fork Horse Creek (site 10), Brushy Creek (site 20), and the two main channel daily discharge stations, the Horse Creek near Myakka Head (site 11) and Arcadia (site 78). However, dissolved solids concentrations at Brandy Branch (site 55) and Buzzard Roost Branch (site 61a) had maximum values of 680 and 861 mg/L, respectively. At the six surface water sites, the range of concentrations for fluoride (0.1-0.5 mg/L), sodium (2.7-14 mg/L), potassium (1.0-14 mg/L), chloride (5.3-35 mg/L), and silica (0.8-11 mg/L) were generally low and uniform. However, the range of concentrations for calcium (3.4-130 mg/L), magnesium (1.7-54 mg/L), sulfate (2.8-490 mg/L), and strontium (26-4,200 µg/L) had elevated levels at Buzzard Roost Branch (site 61a) and Brandy Branch (site 55) compared to concentrations at the other four sites sampled. A possible source related to the increased concentrations may be the result of an upward movement of ground water from the intermediate aquifer system into the surficial aquifer or irrigation within the subbasin with a higher mineralized water. A seasonal fluctuation in the concentration of surface water constituents during the wet and dry period occurs in the subbasin. An increase in constituent concentrations occurs during dry periods (winter-spring) when streamflow is largely derived from ground-water discharge.

The trilinear plots in figure 35 generally indicate samples had mixed ion types. No dominant cation was present in water from the samples from the six surface-water sites. Sulfate was the dominant anion at Brandy Branch and Buzzard Roost Branch (sites 55 and 61a). The sample collected at Horse Creek near Arcadia (site 78) was a composite of the water chemistry for water that drains from the entire 218-mi^2 area above the station. The higher sulfate concentrations from samples collected upstream at Brandy Branch and Buzzard Roost Branch are reflected in the sulfate concentrations at Horse Creek near Arcadia.

COMPARISON OF CONDITIONS IN THE HORSE CREEK BASIN DURING THIS STUDY TO LONG-TERM CONDITIONS

Rainfall

Rainfall in 1993 was slightly above average and rainfall in 1994 was well above average in the Horse Creek basin. The National Weather Service long-term rainfall stations at Wauchula and Fort Green are located approximately 2 and 6 mi east of the Horse Creek basin, and had 30-year average annual totals of 49.99 (1951-80) and 50.19 in. (1961-90), respectively (fig. 1). Rainfall reported at the Wauchula station for 1993 was 54 in. or 8 percent above the long-term annual average (National Oceanic and Atmospheric Administration, 1993). Rainfall reported at the Ft. Green station for 1994 was 66 in. or 31 percent above the long-term annual average (National Oceanic and Atmospheric Administration, 1994). The corresponding annual rainfall totals at Fort Green in 1993 and Wauchula in 1994 were not available because of missing monthly data at those stations.

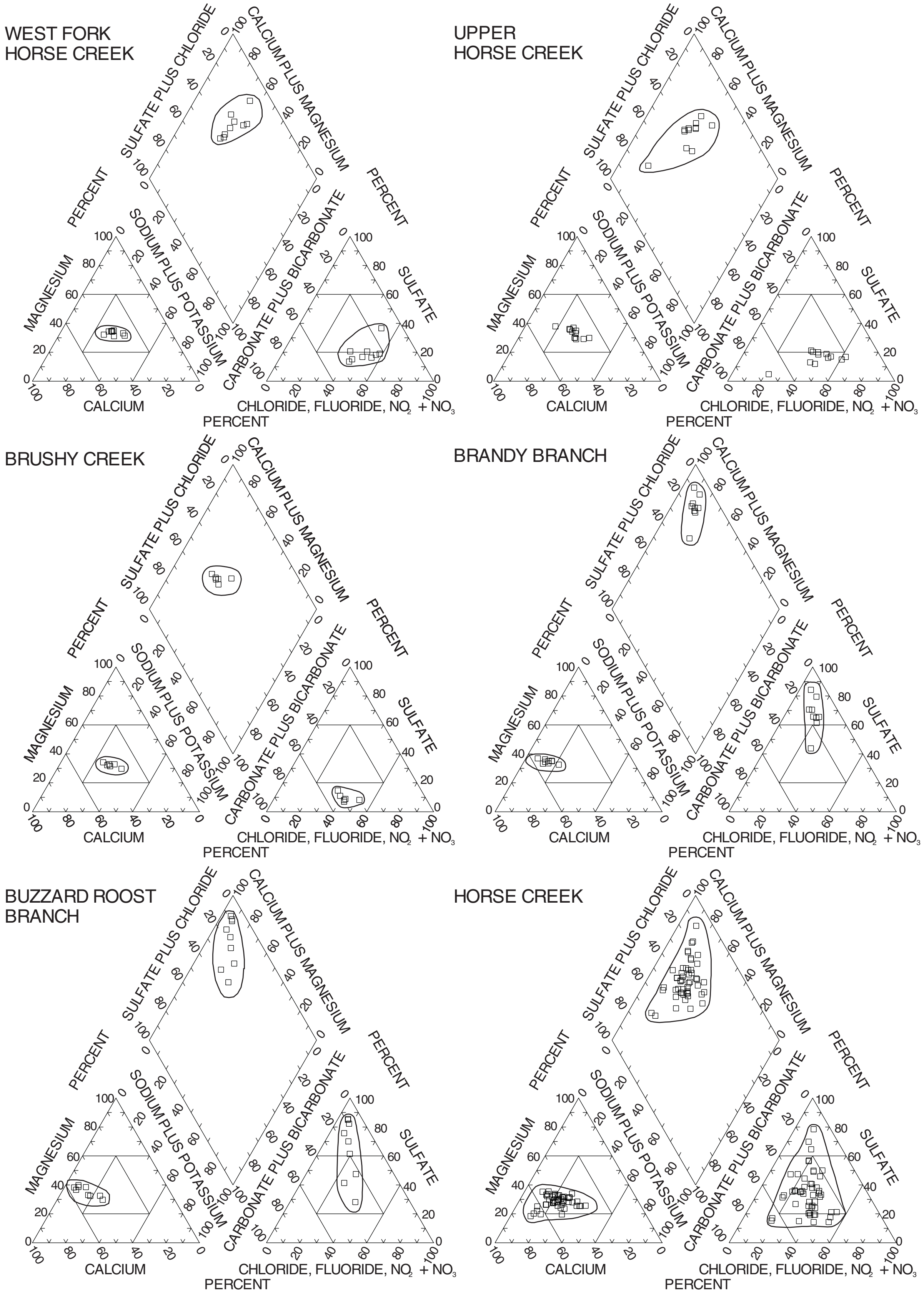


Figure 35. Trilinear diagrams showing major-ion composition of water from streams in the Horse Creek basin, 1993-95.

Surface Water

Long-term daily discharge has been collected at the Horse Creek near Myakka Head and Horse Creek near Arcadia stations since 1977 and 1950, respectively. During the study, a maximum daily mean discharge at the Horse Creek near Myakka Head station of 1,160 ft^3/s was 52 percent of the peak flow recorded in 1988 (2,240 ft^3/s); at the Horse Creek near Arcadia station, a maximum daily mean discharge of 4,130 ft^3/s in 1994 was 38 percent of the flow recorded in 1960 (10,700 ft^3/s) (table 2). The number of consecutive no-flow days at the Horse Creek near Myakka Head station during the study was 2 days in 1994 and 30 days during the period of record in 1985 (table 3). The Horse Creek near Arcadia station had zero no-flow days during the study, and 7 days in 1956. Duration curves in figure 16 (f and h) indicate that 50 percent of the time long-term and study-period discharges at the Horse Creek near Arcadia station were similar with approximately 50 and 45 ft^3/s, respectively.

Ground Water

Water-level fluctuation extremes at the eight study surficial aquifer wells ranged from 5 to 8 ft during the study, and are consistent with the 9-ft fluctuation extremes recorded at the 15-ft deep, long-term (1978 to current year) ROMP 26 surficial aquifer well near Gardner. Bush and Johnston (1988) estimated the pre-development potentiometric surface of the Upper Floridan aquifer (fig. 36). Heads in the Horse Creek basin were approximately 10 to 20 ft higher than present wet season (September) heads. The smooth shape of the parallel pre-development contour lines contrasts with the current orientation of the potentiometric lines in the Horse Creek area affected by localized ground-water withdrawal in figure 4.

SUMMARY AND CONCLUSIONS

A baseline study of the 241-square-mile Horse Creek basin was undertaken from October 1992 to February 1995 to assess the hydrologic and water-quality conditions of one of the last remaining undeveloped basins in west-central Florida. During the period of the study, much of the basin remained in a natural state, except for limited areas of cattle and citrus production and phosphate mining. Some potential future impacts to the hydrology of the basin include additional

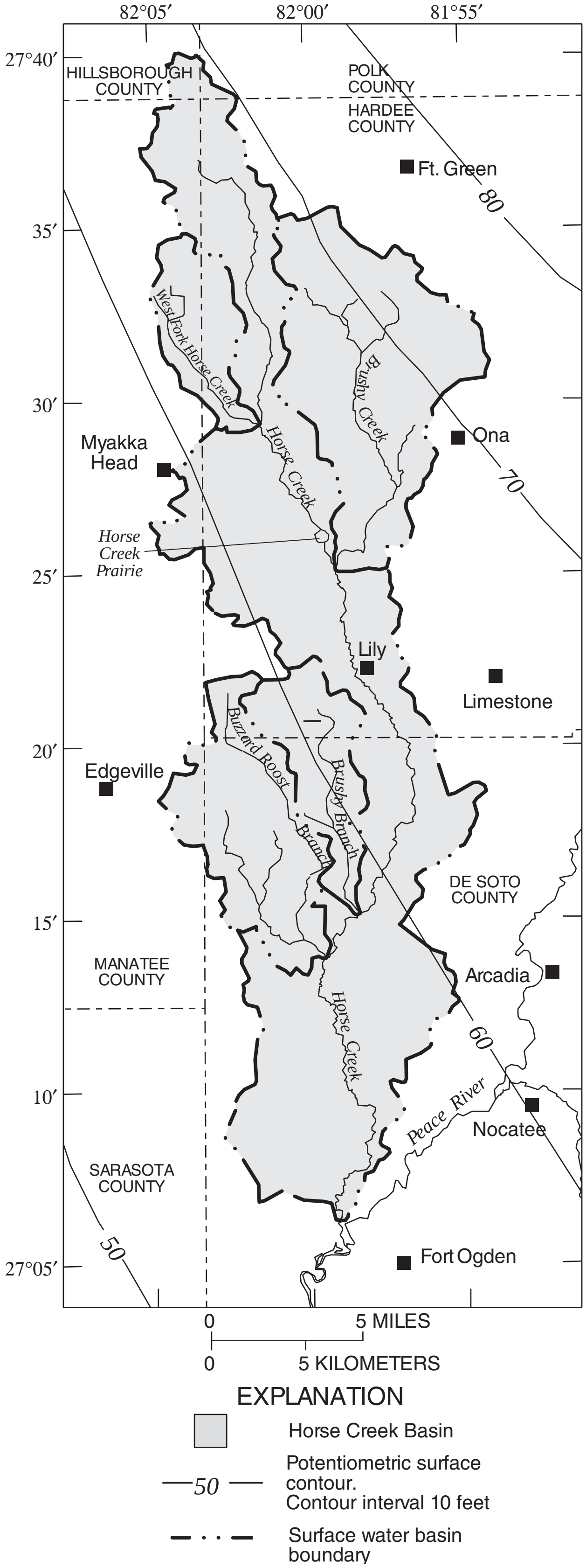


Figure 36. Estimated pre-development potentiometric surface of the Upper Floridan aquifer (modified from Bush and Johnston, 1988.).

residential and commercial development, increased acreages planted for citrus, and strip-mining for phosphate. Approximately one-half of the acreage within the Horse Creek basin is presently owned by various chemical companies for future phosphate mining. Surface mining of phosphate, and subsequent reclamation, alter the natural topography, recharge, and drainage patterns of a basin.

During this study, a continuous data-collection network was established in the Horse Creek basin to monitor: (1) daily discharge from the four largest subbasins, in addition to the two existing long-term daily discharge stations located along the Horse Creek main channel near Myakka Head and Arcadia; (2) rainfall at eight sites; and (3) ground-water levels in the surficial aquifer at eight wells. Water-quality samples were collected from the surficial aquifer at each of the eight monitor wells and at the six daily discharge stations. All water-quality samples were analyzed for major dissolved ions and total nutrients (nitrogen and phosphorus). On site measurements were also made for pH, specific conductance, and temperature.

During the study, rainfall in the Horse Creek basin was 8 and 31 percent above the 30-year long-term average for 1993 and 1994, respectively. The lowest and highest maximum instantaneous peak discharge of the six daily discharge stations occurred at the Buzzard Roost Branch and the Horse Creek near Arcadia stations with 185 to 4,180 ft^3/s, respectively. The Horse Creek near Arcadia station had the lowest number of no-flow days with zero days and the Brushy Creek station had the highest number with 113 days. During the study, the West Fork Horse Creek subbasin had the highest daily mean discharge per square mile with 30.6 $(ft^3/s)/mi^2$, and the largest runoff coefficient of 43.7 percent. The Buzzard Roost Branch subbasin had the lowest daily mean discharge per square mile with 5.05 $(ft^3/s)/mi^2$, and Brushy Creek and Brandy Branch shared the lowest runoff coefficient of 0.6 percent. Brandy Branch had the highest monthly mean runoff in both 1993 and 1994 with 11.48 and 19.28 in., respectively. During the high-baseflow seepage run, seepage gains were 8.87 ft^3/s along the 43-mile Horse Creek channel. However, during the low-baseflow seepage run, seepage losses were 0.88 ft^3/s.

Three methods were used to estimate average annual ground-water recharge in the Horse Creek basin: (1) well hydrograph, (2) chloride mass balance, and (3) streamflow hydrograph. Estimated average annual recharge using these three methods ranged from 3.6 to 8.7 in/yr. Results from the well hydrograph and chloride ratio method, with used the same 8 surficial aquifer wells, were similar with 8.7 and 7.4 in/yr, respectively. The lower recharge estimation of 3.6 in/yr using the streamflow hydrograph method may be related to riparian evapotranspiration.

The highest constituent concentrations were commonly detected in water from the Buzzard Roost Branch well. The chemical composition of ground water in the surficial aquifer wells indicated that the anion and cations of most water types were well mixed. However, the high percentage of carbonate plus bicarbonate analyzed at the Carlton surficial aquifer well could indicate an upward ground-water flow from the underlying intermediate aquifer system. Based on constituent concentrations in water samples from the six daily discharge stations, concentrations generally are lower in the upper three subbasins, West Fork Horse Creek, Upper Horse Creek, and Brushy Creek, than in the lower three subbasins. Typically, concentrations were highest for major ions at Buzzard Roost Branch and nutrients at Brushy Creek.

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Appendix

APPENDIX. Horse Creek and Tributary Discharge Measurements

[Site no., site numbers are shown in figures 20 and 21; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ft^3/s, cubic feet per second; Lat., latitude; Long, longitude; ---, measurement not taken or unavailable]

Site no.	Station identication	Station name	Location	Date	Specific Conductance (µS/cm)	Discharge (ft^3/s)
1.	2737470820425	Horse Creek at State Highway 37 near Duette	Lat 27°37’47", long 82°04’25", Manatee County, Hydrologic Unit 03100101, at culvert on State Highway 37, 4.0 mi northeast of Duette, and 51.4 mi upstream from mouth.	12-01-93 05-24-94	--- ---	.00 .00
2.	2736210820252	Horse Creek at Watkins Road near Duette	Lat 27°36’21", long 82°02’52", Hardee County, Hydrologic Unit 03100101, 0.8 mi upstream from State Highway 62, 4.5 mi northeast of Duette, and 48.7 mi upstream from mouth.	12-01-93 05-24-94	--- ---	.27 .00
3.	2736310820217	Unnamed Tributary to Horse Creek near Duette	Lat 27°36’31", long 82°02’17", Hardee County, Hydrologic Unit 03100101, 1.0 mi upstream from State Highway 62, 5.1 mi northeast of Duette, and 48.0 mi upstream from mouth of Horse Creek.	12-01-93	---	.00
4.	2736260820217	Horse Creek above State Highway 62 near Duette	Lat 27°36’26", long 82°02’17", Hardee County, Hydrologic Unit 03100101, 1.0 mi upstream from State Highway 62, 5.1 mi northeast of Duette, and 48.0 mi upstream from mouth.	12-01-93 05-24-94	146 ---	.34 .00
5.	2734540820130	Horse Creek above Mitchell Hammock near Ft. Green Springs	Lat 27°34’54", long 82°01’30", Hardee County, Hydrologic Unit 03100101, 1.0 mi downstream from State Highway 62, 5.0 mi southwest of Ft. Green Springs, and 45.7 mi upstream from mouth.	12-01-93 05-24-94	139 ---	1.32 .00
6.	2733500820142	Horse Creek near Mitchell Hammock near Ft. Green Springs	Lat 27°33’50", long 82°01’42", Hardee County, Hydrologic Unit 03100101, 2.0 mi downstream from State Highway 62, 6.0 mi southwest of Ft. Green Springs, and 44.4 mi upstream from mouth.	12-01-93 05-24-94	--- ---	1.20 .00
7.	2732460820142	Horse Creek below Mitchell Hammock near Ft. Green Springs	Lat 27°32’46", long 82°01’42", Hardee County, Hydrologic Unit 03100101, 3.3 mi downstream from State Highway 62, 7.0 mi southwest of Ft. Green Springs, and 43.0 mi upstream from mouth.	12-01-93 05-24-94	129 ---	1.59 .00
8.	2731520820108	Horse Creek above New Zion Church near Myakka Head	Lat 27°31’52", long 82°01’08, Hardee County, Hydrologic Unit 03100101, 2.8 mi north of New Zion Church, 4.4 mi downstream from State Highway 62, 4.5 mi northeast of Myakka Head, and 41.8 mi upstream from mouth.	12-01-93 05-24-94	134 ---	1.90 .00
9.	2731050820108	Horse Creek near New Zion Church near Myakka Head	Lat 27°31’05", long 82°01’08", Hardee County, Hydrologic Unit 03100101, 1.7 mi north of New Zion Church, 1.8 mi above West Fork Horse Creek, 4.2 mi northeast of Myakka Head, and 40.8 mi upstream from mouth.	12-01-93 05-24-94	130 142	1.85 .03

APPENDIX. Horse Creek and Tributary Discharge Measurements--Continued

[Site no., site numbers are shown in figures 20 and 21; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ft^3/s, cubic feet per second; Lat., latitude; Long, longitude; ---, measurement not taken or unavailable]

Site no.	Station identification	Station name	Location	Date	Specific Conductance (µS/cm)	Discharge (ft^3/s)
10.	02297153	West Fork Horse Creek near Myakka Head	Lat 27°29’26", long 82°01’44", Hardee County, Hydrologic Unit 03100101, on right bank, 10 ft upstream from bridge on Owen Roberts Road, 0.3 mi upstream from mouth, 3.3 mi northeast of Myakka Head, 38.5 mi upstream from mouth of Horse Creek.	12-01-93 05-24-94	173 198	3.85 .17
11.	02297155	Horse Creek near Myakka Head	Lat 27°29’13", long 82°01’25", Hardee County, Hydrologic Unit 03100101, near left bank on downstream side of bridge on State Highway 64, 3.5 mi northeast of Myakka Head, and 38.3 mi upstream from mouth.	12-01-93 05-24-94	--- 217	5.11 .19
12.	2728230820148	Unnamed Tributary to Horse Creek on CR 665 near New Zion Church	Lat 27°28’23", long 82°01’48", Hardee County, Hydrologic Unit 03100101, on County Road 665, 0.9 mi south of State Highway 64, 1.2 mi southwest of New Zion Church, and 36.2 mi upstream from mouth of Horse Creek.	12-01-93 05-24-94	163 ---	.22 .00
13.	2727420820148	Unnamed Tributary to Horse Creek on CR 665 near Myakka Head	Lat 27°27’42", long 82°01’48", Hardee County, Hydrologic Unit 03100101, on County Road 665, 1.7 mi south of State Highway 64, 2.8 mi east of Myakka Head, and 34.7 mi upstream from mouth of Horse Creek.	12-01-93 05-24-94	190 ---	.42 .00
14.	2726180820148	Elder Branch on CR 665 near Myakka Head	Lat 27°26’18", long 82°01’48", Hardee County, Hydrologic Unit 03100101, on County Road 665, 3.2 mi south of State Highway 64, 3.5 mi southeast of Myakka Head, and 32.8 mi upstream from mouth of Horse Creek.	12-01-93 05-24-94	148 138	2.06 .30
15.	2726180815931	Horse Creek above Horse Creek Prairie near Myakka Head	Lat 27°26’18", long 81°59’31", Hardee County, Hydrologic Unit 03100101, 0.5 mi upstream from Horse Creek Prairie, 1.7 mi north of County Road 663A, 5.5 mi southeast of Myakka Head, and 32.8 mi upstream from mouth.	12-01-93 05-24-94	123 ---	8.12 .00
16.	2725150820149	Cypress Branch on CR 665 near Myakka Head	Lat 27°25’15", long 82°01’49", Hardee County, Hydrologic Unit 03100101, on County Road 665, 3.5 mi southeast of Myakka Head, and 32.3 mi upstream from mouth of Horse Creek.	12-01-93 05-24-94	245 ---	.01 .00
17.	2724480820142	Unnamed Tributary to Cypress Branch on CR 665 near Myakka Head	Lat 27°24’48", long 82°01’42", Hardee County, Hydrologic Unit 03100101, on County Road 665, at intersection Albritten Lane and CR 665, and 4.7 mi southeast of Myakka Head.	12-01-93 05-24-94	--- ---	.00 .00
18.	2724260820032	Unnamed Tributary to Cypress Branch on CR 663A near Myakka Head	Lat 27°24’26", long 82°00’32", Hardee County, Hydrologic Unit 03100101, on County Road 663A, 1.4 mi southeast of Horse Creek Prairie, and 5.8 mi southeast of Myakka Head.	12-01-93 05-24-94	--- ---	.00 .00

APPENDIX. Horse Creek and Tributary Discharge Measurements--Continued

[Site no., site numbers are shown in figures 20 and 21; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ft^3/s, cubic feet per second; Lat., latitude; Long, longitude; ---, measurement not taken or unavailable]

Site no.	Station identication	Station name	Location	Date	Specific Conductance (µS/cm)	Discharge (ft^3/s)
19.	2725230815916	Horse Creek below Horse Creek Prairie near Myakka Head	Lat 27°25’23", long 81°59’16", Hardee County, Hydrologic Unit 03100101, 0.1 mi downstream from Horse Creek Prairie, 1.0 mi north of County Road 663A, 6.2 mi southeast of Myakka Head, and 32.2 mi upstream from mouth.	12-01-93	127	9.55
				05-24-94	---	.00
20.	02297220	Brushy Creek near Lily	Lat 27°25’38", long 81°58’51", Hardee County, Hydrologic Unit 03100101, 0.5 mi upstream from mouth, 1.0 mi north of County Road 663A , 4.1 mi north of Lily, and 31.8 mi upstream from mouth of Horse Creek.	12-01-93	194	.55
				05-24-94	---	.00
21.	2724370815852	Horse Creek at CR 663A near Lily	Lat 27°24’37", long 81°58’52", Hardee County, Hydrologic Unit 03100101, 150 feet south of County Road 663A, 3.2 mi northwest of Lily, and 30.9 mi upstream from mouth.	12-01-93	---	--
				05-24-94	---	.00
22.	2724380815852	Unnamed Tributary to Horse Creek at CR 663A near Lily	Lat 27°24’38", long 81°58’52", Hardee County, Hydrologic Unit 03100101, 100 ft north of County Road 663A, 3.2 mi northwest of Lily, and 31.0 mi upstream from mouth of Horse Creek.	12-01-93	---	.00
				05-24-94	---	.00
23.	2724210815756	Unnamed Tributary to Horse Creek on Lily Road near Lily	Lat 27°24’21", long 81°57’56", Hardee County, Hydrologic Unit 03100101, on Lily Road, 0.3 mi south of County Road 663A, 0.9 mi upstream from mouth, 2.7 mi north of Lily, and 30.7 mi upstream from mouth of Horse Creek.	12-01-93	---	.00
				05-24-94	---	.00
24.	2724050815923	Unnamed Tributary to Horse Creek above Duck Pond near Lily	Lat 27°24’05", long 81°59’23’, Hardee County, Hydrologic Unit 03100101, 0.5 mi south of County Road 663A, 2.8 mi northwest of Lily, and 30.6 mi upstream from mouth of Horse Creek.	12-01-93	342	.07
				05-24-94	---	.00
25.	2723540815848	Horse Creek below Duck Pond near Lily	Lat 27°23’54", long 81°58’48", Hardee County, Hydrologic Unit 03100101, 0.8 mi south of County Road 663A, 2.4 mi northwest of Lily, and 30.1 mi upstream from mouth.	12-01-93	143	12.9
				05-24-94	---	.00
26.	2723250815853	Unnamed Tributary to Horse Creek below Duck Pond near Lily	Lat 27°23’25", long 81°58’53", Hardee County, Hydrologic Unit 03100101, 0.2 mi above Osborn Branch, 0.9 mi west of Lily Road, 1.9 mi northwest of Lily, and 29.3 mi upstream from mouth of Horse Creek.	12-01-93	127	.02
				05-24-94	---	.00
27.	2723230815852	Horse Creek above Osborn Branch near Lily	Lat 27°23’23", long 81°58’52", Hardee County, Hydrologic Unit 03100101, 0.2 mi above Osborn Branch, 0.9 mi west of Lily Road, 1.8 mi northwest of Lily, and 29.2 mi upstream from mouth.	12-01-93	144	11.0
				05-24-94	---	.00

APPENDIX. Horse Creek and Tributary Discharge Measurements--Continued

[Site no., site numbers are shown in figures 20 and 21; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ft^3/s, cubic feet per second; Lat., latitude; Long, longitude; ---, measurement not taken or unavailable]

Site no.	Station identication	Station name	Location	Date	Specific Conductance (µS/cm)	Discharge (ft^3/s)
28.	2723180815849	Unnamed Tributary to Horse Creek above Osborn Branch near Lily	Lat 27°23'18", long 81°58'49", Hardee County, Hydrologic Unit 03100101, 0.1 mi above Osborn Branch, 0.9 mi west of Lily Road, 1.7 mi northwest of Lily, and 29.1 mi upstream from mouth of Horse Creek.	12-01-93 05-24-94	515 ---	.06 .00
29.	2723130815911	Osborn Branch near Lily	Lat 27°23'13", long 81°59'11", Hardee County, Hydrologic Unit 03100101, 150 ft above mouth, 1.0 mi west of Lily Road, 1.7 mi northwest of Lily, and 29.0 mi upstream from mouth of Horse Creek.	12-01-93 05-24-94	71 ---	.14 .00
30.	2723140815850	Horse Creek below Osborn Branch near Lily	Lat 27°23'14", long 81°58'50", Hardee County, Hydrologic Unit 03100101, 1.4 mi north of State Highway 665, and 28.9 mi upstream from mouth.	12-01-93 05-24-94	141 146	11.6 .02
31.	2722390815839	Unnamed Tributary to Horse Creek near Lily	Lat 27°22'39", long 81°58'39", Hardee County, Hydrologic Unit 03100101, 250 ft upstream from mouth, 0.4 mi north of Solomons Castle, 1.4 mi northwest of Lily, and 28.3 mi upstream from mouth of Horse Creek.	12-01-93 05-24-94	47 ---	.02 --
32.	2722330815820	Horse Creek above Solomons Castle near Lily	Lat 27°22'33", long 81°58'20", Hardee County, Hydrologic Unit 03100101, 0.2 mi upstream from Solomons Castle, 1.2 mi northwest of Lily, and 28.3 mi upstream from mouth.	12-01-93 05-24-94	147 181	11.2 .02
33.	2722300815834	Unnamed Tributary to Horse Creek at Solomons Castle near Lily.	Lat 27°22'30", long 81°58'34", Hardee County, Hydrologic Unit 03100101, at Solomons Castle, 1.1 mi northwest of Lily, and 28.1 mi upstream from mouth of Horse Creek.	12-01-93 05-24-94	128 ---	<.01 00
34.	2722250815847	Unnamed Tributary to Horse Creek at Solomon Road near Lily	Lat 27°22'25", long 81°58'47", Hardee County, Hydrologic Unit 03100101, at Solomon Road, 1.1 mi northwest of Lily, and 27.8 mi upstream from mouth of Horse Creek.	12-01-93 05-24-94	121 130	.08 .32
35.	2722210815834	Horse Creek below Solomons Castle near Lily	Lat 27°22'21", long 81°58'34", Hardee County, Hydrologic Unit 03100101, 0.4 mi north of County Road 665, 0.8 mi northwest of Lily, and 27.5 mi upstream from mouth.	12-01-93 05-24-94	158 1085	11.7 .01
36.	2722180815757	Unnamed Tributary to Horse Creek at Lily Road at Lily	Lat 27°22'18", long 81°57'57", Hardee County, Hydrologic Unit 03100101, at Lily Road, 0.4 mi north of Lily, 0.5 mi upstream from mouth, and 27.2 mi upstream from mouth of Horse Creek.	12-01-93 05-24-94	--- ---	.00 .00

APPENDIX. Horse Creek and Tributary Discharge Measurements--Continued

[Site no., site numbers are shown in figures 20 and 21; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ft^3/s, cubic feet per second; Lat., latitude; Long, longitude; ---, measurement not taken or unavailable]

Site no.	Station identication	Station name	Location	Date	Specific Conductance (µS/cm)	Discharge (ft^3/s)
37.	02297251	Horse Creek near Limestone	Lat 27°21'58", long 81°58'25", Hardee County, Hydrologic Unit 03100101, at bridge on County Road 665, 4.5 mi west of Limestone, and 26.9 mi upstream from mouth.	12-01-93 12-02-93 05-24-94 05-25-94	165 --- 461 479	12.1 11.40 .02 .02
38.	2721450815840	Unnamed Tributary to Horse Creek at Cemetary Road at Lily	Lat 27°21'45", long 81°58'40", Hardee County, Hydrologic Unit 03100101, 0.1 mi south of Lily Church, 0.3 mi south of County Road 665, 0.8 mi southwest of Lily, and 26.8 mi upstream from mouth of Horse Creek.	12-02-93 05-25-94	--- ---	.02 .00
39.	2721380815800	Horse Creek at Lily	Lat 27°21'38", long 81°58'00", Hardee County, Hydrologic Unit 03100101, 0.75 mi east of Lily Church, 0.3 mi south of Lily, and 26.2 mi upstream from mouth.	05-27-94	877	.18
40.	2721340815757	Unnamed Tributary to Horse Creek above hunting camp at Lily	Lat 27°21'34", long 81°57'57", Hardee County, Hydrologic Unit 03100101, 0.9 mi east of Lily Church, 0.4 mi south of Lily, and 26.1 mi upstream from mouth of Horse Creek.	05-27-94	1312	.29
41.	2721200815750	Horse Creek at hunting camp at Lily	Lat 27°21'20", long 81°57'50", Hardee County, Hydrologic Unit 03100101, 0.6 mi south of Lily, 0.8 mi southeast of Lily Church, and 25.8 mi upstream from mouth.	05-25-94	1020	.54
42.	2721070815758	Unnamed Tributary to Horse Creek on Rainey Road near Lily	Lat 27°21'07", long 81°57'58", Hardee County, Hydrologic Unit 03100101, on Rainey Road, 1.0 mi east of Pine Level Road, 1.0 mi south of Lily, and 25.7 mi upstream from mouth of Horse Creek.	12-02-93 05-25-94	--- ---	.05e .00
43.	2721030815738	Horse Creek near Rainey Road near Lily	Lat 27°21'03", long 81°57'38", Hardee County, Hydrologic Unit 03100101, 0.1 mi east of Rainey Road, 1.1 mi southeast of Lily, and 25.3 mi upstream from mouth.	12-02-93 05-25-94	252 1050	13.3 .49
44.	2721060815721	Unnamed Tributary to Horse Creek below Rainey Road near Lily	Lat 27°21'06", long 81°57'21", Hardee County, Hydrologic Unit 03100101, 0.2 mi upstream from mouth, 0.4 mi east of Rainey Road, 1.2 mi southeast of Lily, and 25.3 mi upstream from mouth of Horse Creek.	12-02-93 05-25-94	166 ---	.01 .00
45.	2720470815717	Horse Creek above Hardee-De Soto County line near Kinsey	Lat 27°20'47", long 81°57'17", Hardee County, Hydrologic Unit 03100101, 0.3 mi east of Rainey Road, 3.7 mi west of Kinsey, and 24.7 mi upstream from mouth.	12-02-93 05-25-94	271 957	12.6 .72

APPENDIX. Horse Creek and Tributary Discharge Measurements--Continued

[Site no., site numbers are shown in figures 20 and 21; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ft^3/s, cubic feet per second; Lat., latitude; Long, longitude; ---, measurement not taken or unavailable]

Site no.	Station identication	Station name	Location	Date	Specific Conductance (µS/cm)	Discharge (ft^3/s)
46.	2720130815705	Horse Creek on Hardee-De Soto County line near Kinsey	Lat 27°20’13", long 81°57’05", Hardee County, Hydrologic Unit 03100101, on county line, 3.5 mi west of Kinsey, and 23.9 mi upstream from mouth.	12-02-93 05-25-94	270 963	13.9 .50
47.	2719360815653	Horse Creek below Hardee-De Soto County line near Kinsey	Lat 27°19’36", long 81°56’53", De Soto County, Hydrologic Unit 03100101, 0.7 mi below Hardee-De Soto county line, 3.3 mi southwest of Kinsey, and 23.0 mi upstream from mouth.	12-02-93 05-25-94	300 1018	13.5 .48
48.	2719080815636	Horse Creek near Kinsey	Lat 27°19’08", long 81°56’36", De Soto County, Hydrologic Unit 03100101, 1.2 mi below Hardee-De Soto county line, 3.2 mi southwest of Kinsey, and 22.3 mi upstream from mouth.	12-02-93 05-25-94	271 985	14.50 .45
49.	2718330815626	Unnamed Tributary to Horse Creek above Carlton Ranch near Kinsey	Lat 27°18’33", long 81°56’26", De Soto County, Hydrologic Unit 03100101, 0.2 mi upstream from mouth, 1.9 mi below Hardee-De Soto county line, 3.5 mi southwest of Kinsey, and 20.6 mi upstream from mouth of Horse Creek.	12-02-93 05-25-94	128 ---	.03 .00
50.	2718280815640	Horse Creek above Carlton Ranch bridge near Kinsey	Lat 27°18’28", long 81°56’40", De Soto County, Hydrologic Unit 03100101, 0.5 mi above Carlton Ranch bridge, 3.7 mi southwest of Kinsey, and 20.6 mi upstream from mouth.	12-02-93 05-25-94	254 985	14.1 .13
51.	2718090815609	Unnamed Tributary to Horse Creek below Carlton Ranch near Kinsey	Lat 27°18’09", long 81°56’09", De Soto County, Hydrologic Unit 03100101, 0.4 mi upstream from mouth, 0.5 mi northeast of Carlton Ranch bridge, 3.5 mi southwest of Kinsey, and 20.2 mi upstream from mouth of Horse Creek.	12-02-93 05-25-94	--- ---	.00 .00
52.	2717330815717	Horse Creek below Carlton Ranch bridge near Pine Level	Lat 27°17’33", long 81°57’17", De Soto County, Hydrologic Unit 03100101, 0.7 mi southwest of Carlton Ranch bridge, 3.0 mi northeast of Pine Level, and 19.8 mi upstream from mouth.	12-02-93 05-25-94	260 660	15.6 .04
53.	2717310815718	Unnamed Tributary to Horse Creek below Carlton Ranch near Pine Level	Lat 27°17’31", long 81°57’18", De Soto County, Hydrologic Unit 03100101, 100 ft upstream from mouth, 0.8 mi southwest of Carlton Ranch bridge, 2.9 mi northeast of Pine Level, and 19.8 mi upstream from mouth of Horse Creek.	12-02-93 05-24-94	253 ---	.12 .00
54.	02297266	Horse Creek near Pine Level	Lat 27°15’18", long 81°58’05", De Soto County, Hydrologic Unit 03100101, at bridge on State Highway 70, 1.6 mi southeast of Pine Level, and 16.3 mi upstream from mouth.	12-02-93 05-25-94	--- 526	14.2 .05

APPENDIX. Horse Creek and Tributary Discharge Measurements--Continued

[Site no., site numbers are shown in figures 20 and 21; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ft^3/s, cubic feet per second; Lat., latitude; Long, longitude; ---, measurement not taken or unavailable]

Site no.	Station identication	Station name	Location	Date	Specific Conductance (µS/cm)	Dis-charge (ft^3/s)
55.	02297272	Brandy Branch at Pine Level	Lat 27°15’38", long 81°58’53", De Soto County, Hydrologic Unit 03100101, at bridge on State Highway 70, 0.8 mi upstream from mouth, 0.7 mi southeast of Pine Level, and 15.8 mi upstream from mouth of Horse Creek.	12-02-93 05-25-94	--- ---	2.67 .00
56.	2715360815854	Unnamed Tributary to Brandy Branch at Pine Level	Lat 27°15’36", long 81°58’54", De Soto County, Hydrologic Unit 03100101, 10 ft upstream from mouth, 25 feet south of State Highway 70, and 0.7 mi southeast of Pine Level.	12-02-93 05-25-94	--- ---	.01 .00
57.	02297275	Horse Creek at NW Pine Level Road near Pine Level	Lat 27°14’15", long 81°59’15", De Soto County, Hydrologic Unit 03100101, at NW Pine Level, Road 0.6 mi east of Pine Level Church, 1.9 mi southeast of Pine Level, and 13.9 mi upstream from mouth.	12-02-93 05-25-94	--- ---	21.3 .04
58.	2714010815916	Unnamed Tributary to Horse Creek near Pine Level	Lat 27°14’01", long 81°59’16", De Soto County, Hydrologic Unit 03100101, at mouth, 0.2 mi south of NW Pine Level Road, 2.1 mi south of Pine Level, and 13.6 mi upstream from mouth of Horse Creek.	12-02-93 05-25-94	--- ---	<.01 .00
59.	2714000815916	Horse Creek below NW Pine Level Road near Pine Level	Lat 27°14’00", long 81°59’16", De Soto County, Hydrologic Unit 03100101, 0.2 mi south of NW Pine Level Road, 2.1 mi south of Pine Level, and 13.5 mi upstream from mouth.	12-02-93 05-25-94	310 573	19.0 .11
60.	2713550815922	Horse Creek above Buzzard Roost Branch near Pine Level	Lat 27°13’55", long 81°59’22", De Soto County, Hydrologic Unit 03100101, 0.1 mi upstream from Buzzard Roost Branch, 0.5 mi south of NW Pine Level Road, 2.2 mi south of Pine Level, and 13.4 mi upstream from mouth.	12-02-93 05-25-94	--- ---	20.2 ---
61.	2713530815931	Buzzard Roost Branch below NW Pine Level Road near Pine Level	Lat 27°13’53", long 81°59’31", De Soto County, Hydrologic Unit 03100101, at mouth, 0.4 mi south of NW Pine Level Road, 2.3 mi south of Pine Level, and 13.2 mi upstream from mouth of Horse Creek..	12-02-93 05-25-94	382 ---	.66 .00
62.	2713500815931	Horse Creek below Buzzard Roost Branch near Pine Level	Lat 27°13’50", long 81°59’31", De Soto County, Hydrologic Unit 03100101, 125 ft downstream from Buzzard Roost Branch, 0.4 mi south of NW Pine Level Road, 2.3 mi south of Pine Level, and 13.1 mi upstream from mouth.	12-02-93 05-25-94	318 557	20.0 .13
63.	2713450815935	Horse Creek near Pine Level Church near Pine Level	Lat 27°13’45", long 81°59’35", De Soto County, Hydrologic Unit 03100101, 0.5 mi south of NW Pine Level Road, 0.7 mi southeast of Pine Level Church, 2.4 mi south of Pine Level, and 13.0 mi upstream from mouth.	12-03-93 05-25-94	313 552	19.6 .19

APPENDIX. Horse Creek and Tributary Discharge Measurements--Continued

[Site no., site numbers are shown in figures 20 and 21; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ft^3/s, cubic feet per second; Lat., latitude; Long, longitude; ---, measurement not taken or unavailable]

Site no.	Station identication	Station name	Location	Date	Specific Conductance (µS/cm)	Discharge (ft^3/s)
64.	2713440815935	Unnamed Tributary to Horse Creek near Pine Level Church	Lat 27°13'44", long 81°59'35", De Soto County, Hydrologic Unit 03100101, 0.2 mi downstream from Buzzard Roost Branch, 0.8 mi southeast of Pine Level Church, and 12.9 mi upstream from mouth of Horse Creek.	12-02-93 05-25-94	558 ---	.30 .00
65.	2713280815935	Unnamed Tributary to Horse Creek below Pine Level Church	Lat 27°13'28", long 81°59'35", De Soto County, Hydrologic Unit 03100101, at mouth, 1.0 mi southeast of Pine Level Church, and 12.6 mi upstream from mouth of Horse Creek.	12-02-93 05-25-94	--- ---	.00 .00
66.	2713270815935	Horse Creek below Pine Level Church	Lat 27°13'27", long 81°59'35", De Soto County, Hydrologic Unit 03100101, 1.1 mi southeast of Pine Level Church, and 12.5 mi upstream from mouth.	12-02-93 05-25-94	281 ---	18.7 .19
67.	2713200815941	Horse Creek near Mizell Road below Pine Level Church	Lat 27°13'20", long 81°59'41", De Soto County, Hydrologic Unit 03100101, 0.6 mi east of Mizell Road, 1.2 mi southeast of Pine Level Church, and 12.3 mi upstream from mouth.	12-02-93 05-25-94	281 571	21.1 .26
68.	2713130815943	Unnamed Tributary to Horse Creek near Mizell Road below Pine Level Church	Lat 27°13'13", long 81°59'43", De Soto County, Hydrologic Unit 03100101, at mouth, 0.6 mi east of Mizell Road, 1.1 mi southeast of Pine Level Church, and 12.3 mi upstream from mouth of Horse Creek.	12-02-93 05-25-94	--- ---	.00 .00
69.	2713120815943	Horse Creek near Barrow Avenue below Pine Level Church near Pine Level	Lat 27°13'12", long 81°59'43", De Soto County, Hydrologic Unit 03100101, 0.7 mi west of Barrow Avenue, 1.3 mi southeast of Pine Level Church, and 12.2 mi upstream from mouth.	12-02-93 05-25-94	283 ---	21.4 ---
70.	2712580815946	Horse Creek near Barrow Avenue near Arcadia	Lat 27°12'58", long 81°59'46", De Soto County, Hydrologic Unit 03100101, 0.8 mi southwest of Barrow Avenue, 1.0 mi north of State Highway 72, 8.0 mi west of Arcadia, and 11.9 mi upstream from mouth.	12-02-93 05-25-94	284 577	19.6 .23
71.	2712570815946	Unnamed Tributary to Horse Creek near Barrow Avenue near Arcadia	Lat 27°12'57", long 81°59'46", De Soto County, Hydrologic Unit 03100101, at mouth, 0.8 mi southeast of Barrow Avenue, 1.0 mi north of State Highway 72, 8.0 mi west of Arcadia, and 11.8 mi upstream from mouth of Horse Creek.	12-02-93 05-24-94	--- ---	.06 .00
72.	2712310815921	Horse Creek near Mizell Road near Arcadia	Lat 27°12'31", long 81°59'21", De Soto County, Hydrologic Unit 03100101, 0.6 mi north of State Highway 72, 1.4 mi east of Mizell Road, 7.9 mi west of Arcadia, and 10.8 mi upstream from mouth.	12-02-93 05-25-94	--- 576	--- .26

APPENDIX. Horse Creek and Tributary Discharge Measurements--Continued

[Site no., site numbers are shown in figures 20 and 21; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ft^3/s, cubic feet per second; Lat., latitude; Long, longitude; ---, measurement not taken or unavailable]

Site no.	Station identication	Station name	Location	Date	Specific Conductance (µS/cm)	Discharge (ft^3/s)
73.	2712290815921	Unnamed Tributary to Horse Creek above State Highway 72 near Arcadia	Lat 27°12’29", long 81°59’21", De Soto County, Hydrologic Unit 03100101, at mouth, 0.6 mi north of State Highway 72, 0.9 mi west of Barrow Avenue, 7.9 mi west of Arcadia, and 10.7 mi upstream from mouth of Horse Creek.	12-02-93 05-25-94	-- ---	.28 .00
74.	2712200815916	Unnamed Tributary to Horse Creek near Mizell Road near Arcadia	Lat 27°12’20", long 81°59’16", De Soto County, Hydrologic Unit 03100101, at mouth, 0.4 mi north of State Highway 72, 1.5 mi east of Mizell Road, 7.9 mi east of Arcadia, and 10.5 mi upstream from mouth of Horse Creek.	12-02-93 05-25-94	252	.02 .00
75.	2712210815916	Horse Creek 0.4 mi north of State Highway 72 near Arcadia	Lat 27°12’21", long 81°59’16", De Soto County, Hydrologic Unit 03100101, 7.9 mi west of Arcadia, and 10.5 mi upstream from mouth.	12-02-93 05-25-94	293 570	21.2 .30
76.	2712090815912	Unnamed Tributary to Horse Creek near Arcadia	Lat 27°12’09", long 81°59’12", De Soto County, Hydrologic Unit 03100101, 40 ft upstream from mouth, 0.2 mi north of State Highway 72, 7.9 mi mi west of Arcadia, and 10.3 mi upstream from mouth of Horse Creek.	12-02-93 05-25-94	470 ---	2.37 <.01
77.	2712110815911	Horse Creek above State Highway 72 near Arcadia	Lat 27°12’11", long 81°59’11", De Soto County, Hydrologic Unit 03100101, 0.2 mi north of State Highway 72, 7.9 mi west of Arcadia, and 10.2 mi upstream from mouth.	12-02-93 05-25-94	295 562	23.8 .27
78.	02297310	Horse Creek near Arcadia	Lat 27°11’57", long 81°59’19", De Soto County, Hydrologic Unit 03100101, near center of span on downstream side of bridge on State Highway 72, and 9.9 mi upstream from mouth.	12-02-93 05-25-94	333 ---	22.8 .29